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

Advisory Circular

Subject: INSTRUCTIONS FOR CONTINUED AIRWORTHINESS; MAINTENANCE TASKS FOR HIGH INTENSITY RADIO FREQUENCY (HIRF)/ELECTROMAGNETIC INTERFERENCE (EMI)/LIGHTNING PROTECTION FEATURES

Date: xx/xx/xx
Initiated By: ANE-110

AC No: 33.4-3[DRAFT]
Change:

1. PURPOSE. This advisory circular (AC) provides guidance and methods, but not the only methods, that may be used to demonstrate compliance with §33.4 of Title 14 of the Code of Federal Regulations (14 CFR §33.4), Instructions for Continued Airworthiness. This AC provides maintenance tasks to ensure the integrity of HIRF/lightning protection features.

2. APPLICABILITY.

a. The guidance provided in this document is directed to engine manufacturers, modifiers, foreign regulatory authorities, and FAA engine 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 FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as “should,” “shall,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if the FAA becomes aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation as the basis for finding compliance.

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

3. RELATED REGULATIONS.

a. Part 33: Sections 33.4, 33.28, and Appendix A.

b. Part 121, Subpart L.

c. Part 135, Subpart L.

4. RELATED READING MATERIAL.

a. Flight Standards Information Bulletin for Airworthiness FSAW 97-16A-Amended, Lightning/High Intensity Radio Frequency (HIRF) (L/HIRF) Protection Maintenance, dated August 4, 1997.

b. Airworthiness Inspectors Handbook 8300.10, Volume 3, Chapter 36, (change 14, dated January 30, 2002) Section 1, Paragraph 7, Subparagraph E, Special Maintenance/Safety Considerations.

c. AC 25.1309-1A, System Design Analysis, dated June 21, 1988.

5. BACKGROUND.

a. Advances in electronic control technology associated with flight critical systems have increased concern for the vulnerability of these systems to exposure to HIRF or lightning (HIRF/L) threats. The lack of experience with the in-service effects of environmental factors such as corrosion, mechanical vibration, thermal cycling, mechanical damage and repair, and modification on the associated protection features of the type design has also raised concern. To address some of these concerns, the FAA issued FSAW 97-16A-Amended on August 4, 1997. This bulletin explains the need to include these systems in the maintenance plan of each operator to assure that the HIRF/L protection features of the type design are maintained in an airworthy condition.

b. The FAA has an on-going initiative to ensure that the Instructions for Continued Airworthiness (ICA) include appropriate maintenance plans for engine components that rely on maintenance activities for continued airworthiness. This initiative and the Flight Standards bulletin have revealed that the effectiveness of HIRF/L protection features depends on maintenance activities. The Airworthiness Inspectors Handbook 8300.10 and the Flight Standards FSAW 97-16A both rely heavily on the identification of critical systems, the protection elements employed in their designs, and the original equipment manufacturer's (OEM) recommendations regarding the inspection, maintenance, and possible replacement of all of those elements. The appropriate place for these recommendations is in the ICA (specifically, the maintenance and overhaul manuals). Operators use this OEM information when establishing and implementing their Continuous Airworthiness Maintenance Programs (CAMP). There have not been any problems reported that are attributable to the lack or incompletion of maintenance plans; however, some research has confirmed that without maintenance the HIRF/L protective features do become ineffective.

c. The rationale for this approach is that although there have not been any maintenance plans that specifically address the HIRF/L protection features of these flight critical systems for the FAA to review, existing overall engine maintenance programs are in place that ensure the integrity of the HIRF/L protection components. These general maintenance practices have been effective in maintaining the HIRF/L protective functions in designs that are currently used by industry. This is demonstrated by the 200+ million hours of in-service experience on engines with Electronic Engine Control (EEC) systems that have not had any known HIRF/L incidents attributable to in-service environmental degradation effects.

d. The following are examples of current maintenance practices that have played a role in providing good service experience:

(1) Inspection and associated procedures linked to troubleshooting and Line Replaceable Unit (LRU) removals;

(2) Fault detection or annunciation of electrical system faults through Built-In-Test;

(3) General Visual Inspection (GVI) associated with scheduled aircraft Zonal Inspection Programs; and

(4) Normal scheduled engine shop visits and specific component shop maintenance associated with on-condition maintenance, modification, or upgrade, and soft-time component refurbishment, when applicable.

e. However, typical maintenance on aircraft and engines has not always been adequate to ensure the maintenance of HIRF/L protection features. Depending upon the complexity of the protection design used, more specific and validated maintenance tasks may be necessary to ensure the effectiveness of protection features in service.

f. Although there have been no known HIRF/L incidents attributable to in-service environmental degradation effects (as noted in paragraph 5c of this AC), there has been one known case of an engine flameout attributed to lightning for which an airworthiness directive (AD) was issued. Investigation revealed that the engine flameout occurred because several shields for the cable harness of the EEC were not properly grounded to the airframe. This was probably due to a previous maintenance action. This condition, if not corrected, could result in insufficient protection of the EEC and could lead to an engine flameout following a lightning strike. The service bulletin associated with the AD describes procedures for a visual inspection to verify the integrity of the shield grounds for the cable harness of the EEC and correct any discrepancy. The service bulletin also describes procedures for measurement of the electrical resistance of certain shield grounds, and repair, if necessary. The repair procedures ensure that the metal overbraid (which provides lightning protection for the EEC cable harness) is electrically bonded to the connector, and that the electrical receptacles are electrically bonded to the airframe. This incident emphasizes the importance of assuring that the effectiveness of HIRF/L protection features are maintained in service.

6. GENERAL.

a. The first step in developing ICA for HIRF/L protection features is to identify the critical systems and equipment, their associated wiring, and all the critical design aspects used by the type design to meet its original certificated HIRF/L threat. Next, the ICA should address the associated inspection method(s) and acceptance criteria, as well as the current maintenance practices, intervals, etc. that apply to these HIRF/L protection features. The purpose of these HIRF/L maintenance instructions is to detect the degradation of protection features so that the features can be restored to their original condition. The scope of these maintenance instructions depends on the detailed HIRF/L protection design approach of a particular engine model and the level of criticality of the systems being protected.

b. Although this AC addresses the maintenance of HIRF/L protection features, it also applies to the general category of EMI protection. During engine certification, the engine control system is tested to demonstrate the system capability regarding HIRF/L and other aspects of EMI. For example, radio frequency (RF) susceptibility tests, both radiated and conducted, are performed to demonstrate system capability. Generally, the EMI capability of the engine control system depends on the same protection features as that of the HIRF/L. However, the applicant should ensure that the ICA maintenance tasks address all aspects of EMI for which the system has been tested and accepted during the certification program.

7. ICA MAINTENANCE TASKS; HIRF/L PROTECTION FEATURES.

a. Maintenance tasks for the HIRF/L protection features are an essential factor in the continued airworthiness of the protection features and devices. These ICA maintenance tasks verify the effectiveness of protection features of systems.

b. The engine and equipment HIRF/L protection features are typically designed to be effective over the life of the aircraft or equipment. Laboratory environmental tests for vibration, humidity, temperature, and salt exposure are often conducted on protection elements and equipment, and previous service experience on other aircraft models or configurations is typically considered when designing these features.

c. In addition, certain maintenance actions may not directly evaluate the effectiveness of HIRF/L protection features, but may provide indirect indications that might represent degradation in capability. For example, visual inspections may discover connector corrosion that would indicate the potential for increased shield bonding resistance. But the shielding effectiveness itself can only be determined by direct measurement.

d. Therefore, the ICA should specify those maintenance tasks necessary to provide a high degree of reliability for HIRF/L protection features and devices. These maintenance tasks should be validated as to their effectiveness in continuing the product's compliance with the type design in service.

8. TYPICAL MAINTENANCE TASK ELEMENTS. The following are some of the common elements of the protection maintenance tasks:

a. Full aircraft/engine tests are one method of determining the overall HIRF/L protection effectiveness. Full aircraft/engine tests include high-level RF tests, low-level swept frequency tests, and low level direct drive tests. The results of these tests can be directly compared to the original HIRF/L certification data. This approach can be very successful in demonstrating the effectiveness of the maintenance program. The disadvantage of full aircraft/engine tests is that these tests do not provide information on the location or extent of individual protection element degradation, if that degradation results in compromising the system's overall integrity. For example, a full aircraft/engine test could indicate unacceptable degradation, but could not determine that the cause is an individual connector or shield termination. Another disadvantage is that full aircraft/engine tests require dedicated access to the aircraft/engine, generally at a specific test site.

b. Detailed bonding resistance measurements are effective in determining changes to connector bonding resistance, panel bonding, or bonding jumper performance. The disadvantage is that additional evaluation is required to assess if bonding resistance changes are affecting the overall system HIRF/L protection. Bonding resistance on certain components may have more effect on the HIRF/L protection than bonding resistance on other components. Also, traditional bonding resistance measurements are not effective for detecting wire shield degradation, particularly for complex wire bundles with many branches and terminations. Bonding resistance measurements, however, can often be taken during other aircraft/engine maintenance activities and do not require that the aircraft/engine be located at a specific test site.

c. Loop resistance or impedance measurements are effective in determining changes to wire bundle shields and connectors. The loop measurements are particularly good for complex wire bundles. As with bonding resistance measurements, additional evaluation is required to assess if loop resistance or impedance changes have any real effect on the overall system HIRF/L protection margin. High loop resistance on certain wire bundles may have more effect on the HIRF/L protection than high loop resistance on other wire bundles. Loop resistance or impedance measurements can often be taken during other aircraft/engine maintenance activities and do not require that the aircraft/engine be located at a specific test site.

d. Tear-down inspections may be part of the required maintenance tasks. For example, disassembly of selected connectors to detect corrosion or shield termination failure that would not be visible during the maintenance inspections may be desirable.

9. VALIDATION OF MAINTENANCE TASK EFFECTIVENESS.

a. The extent of the validation activity depends on the scope of the engine maintenance program. If the maintenance tasks do not directly determine the effectiveness of the HIRF/L protection features, then validation is necessary. For example, maintenance may rely upon visual inspections to determine if wire shielding or raceways continue to provide effective protection. In that case, the validation activity should include direct measurements on appropriate protection features to show acceptable capability.

b. If the maintenance tasks are direct measurement of protection elements, then validation may not be required for these elements. When an applicant has determined that validation is not required, the applicant should document the rationale for this determination and present it to the FAA for concurrence. For example, the applicant may have relevant operating experience gained in the past with the same or similar installations. If the effect of this design experience has already been included in the applicant's design, the applicant may show that a validation activity is not necessary.

c. The validation activity typically uses a sample of in-service engines. When selecting engines for the sample, the applicant should:

(1) Focus on high operating time and high flight cycle aircraft.

(2) Consider the operating environment for the selected engines, such as extreme temperatures, corrosive environments like salt spray, or other harsh environments.

(3) Use more than one engine in the sampling activity. For example, when dealing with engine models with expected fleet sizes that exceed 500 aircraft, an initial sample size of five to ten aircraft and their associated engines is considered adequate.

d. During normal engine maintenance actions, the HIRF/L protection features may be affected; this may affect the validation activity. For example, during an engine shop visit for maintenance it may be determined that a harness should be replaced. This would alter the data for establishing the deterioration of the shielding effectiveness of the harness with time. The validation activities in the ICA should consider how to account for such engine maintenance actions that may affect the HIRF/L protection features.

e. The sampling activities are normally scheduled as close to the beginning of heavy maintenance activities as possible to ensure an evaluation of in-service conditions. Sampling typically requires suitable engine accessibility to gain access to HIRF/L protection features, which can be scheduled along with the heavy maintenance activities. Sampling activities scheduled every four to five years for the selected aircraft/engine are adequate.

10. IN-SERVICE DEGRADATION.

a. If the applicant observes deterioration of the protection features beyond the established acceptance criteria identified in the ICA, then the applicant should evaluate the ability of the system design to meet its type design certification levels. This evaluation will be used to revise the acceptance criteria or establish the need for additional maintenance actions to address the unacceptable in-service condition.

b. For example, HIRF/L tests for certification have been accepted based on a grounding configuration that meets the production specifications. However, the grounding system may deteriorate in service. The level of acceptable deterioration needs to be established for each system. It is recognized that this is a complex problem involving transmission line lumped constants or DC approaches depending on the cables, as well as multiple degradation points. However, it should be possible, using laboratory testing and engineering judgment, to determine the most critical path that can be inspected and measured in the field. In one system, the critical ground path was defined as the path from connector flange to EEC housing through a ground strap to engine ground.

11. SAMPLING OF INDIVIDUAL SYSTEMS, EQUIPMENT, OR COMPONENTS. The applicant may set up a separate maintenance validation activity for individual systems, electrical equipment, or EEC for HIRF/L protection features within the equipment that cannot be effectively verified by aircraft/engine tests or equipment acceptance tests. Electrical equipment or engine control inspections or tests may be required to determine the effectiveness of the HIRF/L and lightning protection features.

a. For example, if the ICA does not specify tests to assure functionality of HIRF/L filters based on an assumed reliability of the filters, then the validation activity could include tests to validate the assumed reliability, unless this could be done by other means, such as failure mode substantiation or field experience.

b. For example, inspection of protection features within the EEC has been acceptable at intervals when the EEC has been opened for some other reason. However, for this to be a valid method, it must be established that this interval is appropriate even though it may be an end of life 60,000-hour interval (that is, if the EEC is never returned for repair). This approach depends on two factors that must be shown to be valid, as follows:

(1) Common mode HIRF/L failures between engines that would invalidate the original system certification are not introduced; and

(2) Protection features are not degraded unacceptably when subjected to the HIRF environment and number of lightning strikes anticipated.

c. Figure 11-1 provides a conservative calculation to estimate if it is possible for the protection features to be inspected at such convenient intervals.

Figure 11-1

Assumptions:

- 20,000 hour mean time between failures (MTBF) per channel reliability.
- 10 percent of the channel failures are due to protection features.
- 10 percent of the protection feature failures (PFF) are not detected.
- An aircraft is struck by lightning on average once per 2500 hours.
- Life of the EEC is 60, 000 hours.
- Each EEC channel is designed to be independent of common mode failures due to lightning.
- Any lightning strike to an EEC channel with undetected PFF will fail the channel.

So:

20,000 hour MTBF = 50 failures per million hours, i.e., 50λ.

And:

$\lambda_{LF} = (50\lambda)(0.1)(0.1) = 0.5\lambda$ where λ_{LF} is the failure rate of a channel having undetected PFF that will lead to channel failure when struck by lightning.

And:

$\lambda t = (0.5\lambda)(2500) = 1.25 \times 10E\text{-}3$ where λt is the probability of a lightning strike on one channel causing failure of channel in the 2500 hour period between lightning strikes.

And:

Probability of lightning strikes causing failure of two channels in 2500 hour period = $(1.25 \times 10E\text{-}3)^2 = 1.5625 \times 10E\text{-}6$

There is a one in six possibility that the two channels with failures will be the controlling channels on each engine. Therefore, the probability of lightning strikes causing failure in both engines during the period is equal to:

$$1/6 \times 1.5625 \times 10E\text{-}6 = 0.2604 \times 10E\text{-}6 \text{ or } 2.6 \times 10E\text{-}7$$

So:

When converted to the probability per hour of flight, this becomes:

Probability of dual engine failure per hour of flight = 2.6 x 10E-7 ÷ 2500 =

1.04 x 10E-10

Conclusion:

This meets the desired safety objective defined in AC 25.1309-1A, which states that the probability of a single system failure leading to a catastrophic aircraft failure should be less than 1 x 10E-9.

12. DESIGN CHANGES AFFECTING HIRF/L PROTECTION FEATURES.

a. The applicant should consider the effect of field modifications and repairs to the original overall system HIRF/L protection. When possible, the engine maintenance manual should identify wiring, connectors, and components that should not be modified without additional HIRF/L protection validation. The engine maintenance manual should also provide guidance to assure repairs are made appropriately to maintain the desired HIRF/L protection performance.

b. During the design phase of a modification, the applicant should assess the impact on the system HIRF/L protection to ensure that the overall electromagnetic hardness will not be compromised. The applicant should evaluate:

(1) Those modifications and repairs that may introduce discontinuities in areas of the aircraft or nacelle skin or cause a decrease in the aircraft or nacelle structural shielding. This evaluation should ensure that the structural shielding of equipment or wiring has not been compromised.

(2) Changes in wiring type, connectors, bonding, shielding, and LRU modifications to ensure that they do not compromise the protection of systems. When equipment performs a function that has a high level of criticality, the routing of the wiring should not be modified without re-assessing the impact on the protection that is already provided. The methods used for assessing the protection levels should be equivalent to the methods used by the engine manufacturer or OEM for the design certification of the aircraft or equipment.

c. For systems that perform a function that has a low level of criticality, the applicant should verify that the overall system HIRF/L protection is not adversely affected by the modification.

d. Any modification should ensure that the segregation provided for wiring associated with systems of differing criticality is not compromised by the modification.

e. If a modification is proposed that requires an interface to a critical system, the applicant must verify that the HIRF/L protection of that Level A, B or C system is not degraded or compromised. The applicant may need to introduce additional HIRF/L protection measures to support the certification of the modification. If the appropriate information is not available from the aircraft manufacturer or OEM, additional HIRF/L tests or analysis may be required to support the modification certification.