

**ELECTROMAGNETIC COMPATIBILITY ON GAS TURBINE ENGINES
FOR AIRCRAFT PROPULSION****1. SCOPE**

The purpose of this AIR is to acquaint the aerospace industry with problems in attaining electromagnetic compatibility on gas turbine engines, particularly as used in aircraft. It is also the purpose of this AIR to present guidelines for the application of EMC controls to the engine, to its components which of necessity must operate in very hostile environments and to its interface with the aircraft.

2. INTRODUCTION

- 2.1 The modern gas turbine engine used for aircraft propulsion is equipped with an ever increasing variety of electrical and electronic systems which provide for engine control, instrumentation and auxiliary functions.
- 2.2 Typical flight gas turbine equipment includes an ignition system, solenoid operated valves to control anti-icing air, compressor bleeds, enrichment/derichment and various auxiliary functions; position indicating and pressure operated switches, an oil quantity transmitter, and thermocouple arrays to indicate engine gas path temperature. The ignition system, which may also provide for after-burner ignition on engines so equipped, is frequently self-powered by a dedicated, engine mounted, permanent magnet generator which operates at an unregulated frequency directly proportional to engine rotor speed.
- 2.3 Many engines are also equipped with electronic limiters, electronic fine trim controls or limited authority electronic engine controls backed up by "traditional" control systems. Some of the more advanced engines utilize a completely electronic engine control system which receives its command inputs entirely by wire rather than by mechanical means. In their simplest form, these controls may be analog devices, although the more complex ones usually employ digital techniques. While these units may be powered directly from aircraft power busses, the more complex systems are usually powered from a dedicated, engine mounted, permanent magnet generator.
- 2.4 Flight gas turbine power plants may also be equipped with a full time condition monitoring system which transmits various engine functional parameters to a remote receiver. The receiver either records the data for future use or performs actual comparisons with established norms in order to arrive at a continuous, immediate analysis of engine health. Figure 1 depicts in block diagram form, a realistic assortment of components typifying the electrical and electronic complexity that exists on gas turbine engines. This multiplicity of equipment, which may be either engine or airframe mounted, brings with it the potential for severe EMC problems in both emission and susceptibility areas.
- 2.5 Signal control and power levels range from a small fraction of a milliwatt in the case of thermocouple signals, to several hundred thousand watts during ignition discharges. The customer should identify, whenever possible, any unique electromagnetic environment which results from "on board" equipment.
- 2.6 The electrical and electronics systems of the aircraft gas turbine engine are usually required to operate in a hostile environment involving severe vibration and very high temperatures.

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- 2.7 Many components are subjected to ambient temperatures in excess of 150° C. Arbitrarily applying stringent EMC requirements to engine components and subsystems can result in unnecessary size, weight and cost penalties, particularly in terms of conducted EMI and conducted susceptibility. The structures required to house components in the hostile environment are, in most cases, satisfactory shields for both radiated emission and radiated susceptibility. The capacitor discharge type ignition system consisting of exciter, ignition leads, and igniters, because of very high peak currents, is an exception in the case of radiated emission. Radiated susceptibility may present problems in the area of interconnecting cables, particularly if a premium is placed on cable size, weight and flexibility.

3. RECOMMENDATIONS

3.1 General:

- 3.1.1 EMC problems can be avoided only by carefully considering the design and testing of system components and their interconnecting wiring. The emphasis, however, must be placed on overall SYSTEM design and SYSTEM testing rather than concentrating exclusively on the EMI characteristics of components alone. However, component testing may be used in many cases to predict problem areas early in the engine program.
- 3.1.2 Table 1, which lists typical engine electrical and electronic components, should be used as a guide in selection of appropriate test methods to be applied on a component and/or system basis. Table 2 defines the test methods of Table 1.
- 3.1.3 It is incumbent on the purchaser to specify detailed EMC test method requirements in procurement/test requirement documents for system or components. The statement "Shall be designed to meet the requirements of MIL-STD-etc." is insufficient to ensure cost effective EMC designs. The component/subsystem designer is not in a position to determine either maximum permissible emission levels or ambient susceptibility levels.
- 3.1.4 It is extremely important to give due consideration to EMC during the proposal stage for an aircraft and its propulsion system. Consideration should also be given to applying the least stringent specification limits that will provide adequate compatibility in order to minimize system weight, cost and complexity.
- 3.1.5 Critical areas where design requirements must be carefully applied are discussed below:

3.2 CE/CS Methods:

- 3.2.1 Specify conducted emission power circuit requirements (CE-01, CE-03) on aircraft-engine interface leads only where power is actually supplied by the aircraft power source.
- 3.2.2 Specify signal and control requirements (CE-02, CE-04) with limits tailored to practical, necessary levels, at the aircraft-engine interface.
- Example A - If it is known that X-number of DB relaxation can be tolerated for a given CE method, it should be included in the procurement document.
- Example B - If it is known that for CS-01 at a given frequency, the signal level will be high but at all other frequencies, the level will be quite low; these levels should be specified in lieu of blanket CS-01 limits.
- 3.2.3 Indicate that conducted EMI Susceptibility on the engine controls and accessories must be considered in circuit design by vendors of potential emitters or highly susceptible equipments where engine accessory power is supplied by a dedicated engine mounted generator. Require that all proposals state approximate CE and CS levels so that analysis can show potential trouble areas at an early state.
- 3.2.4 Require clamping the current probe over both leads of a twisted control pair (not power) between any engine mounted accessory and a remote (cockpit) control point. The data so obtained, must be supplied to the aircraft contractor for his use in decision making relative to shielding these leads for cross talk or radiation control. Do not arbitrarily apply CE limits to these leads.

3.2.4 (continued)

Example - Cockpit ignition control leads where ignition power is supplied by the engine mounted dedicated generator. The wild frequency concept (up to several kilohertz) makes filtering of these circuits very impractical to CE-01 and lower frequency CE-03 requirements.

- 3.2.5 Take data on CE and CS levels (as discussed in paragraph 3 above) to support or modify earlier predictions. These data should be forwarded to the engine EMC coordinator for dissemination to cognizant EMC engineers for action in updating affected designs as early as possible where significant changes are indicated.
- 3.2.6 The use of special conducted susceptibility testing is recommended for Control and Signal Leads to meet special environments (i.e. near field or cavity effect) and to simulate high level E fields where these fields are difficult to generate. Test levels must be specified as early as possible in the program and applicable test plans should detail the nature of the test. This type of test may be used as a culling test to ensure a high probability of compatibility when the component is installed on the engine.

3.3 RE/RS Methods:

- 3.3.1 The radiated emission characteristics of a typical ignition system consists of a low frequency magnetic field generated by a low repetition rate pulse which may be either unidirectional or oscillatory. The energy is usually concentrated at frequencies between 20 kHz and 150 kHz. The ignition leads are a primary source of radiation as a result of the high current pulse. Excessively tight RE limits below 100 kHz can cause weight and size penalties. The limits in this frequency range can determine the choice of aluminum vs magnetic materials for the ignition exciter case. Spacing between sensitive electronic equipments and components of the ignition system should be carefully considered in the layout of the engine component locations.
- 3.3.2 Following implementation of good EMC design practices*, engineering test data should be taken for use in establishing or revising required limits. Consider the specific use of the proposed equipment and its exact function. Suggest limits that are practical and necessary.

Example A - If certain of the engines' electrical/electronics components are within a shroud, 10 DB relaxation of standard limits for RE-02 is suggested at frequencies below 150 kHz.

Example B - Exempt obviously unsusceptible components from any or all of the RS methods. This will reduce test time and costs.

Example C - For extreme RF environments MIL-HDBK-235 should be consulted as a guide in tailoring levels for Method RS-03.

*The bibliography lists sources of good EMC design practices.

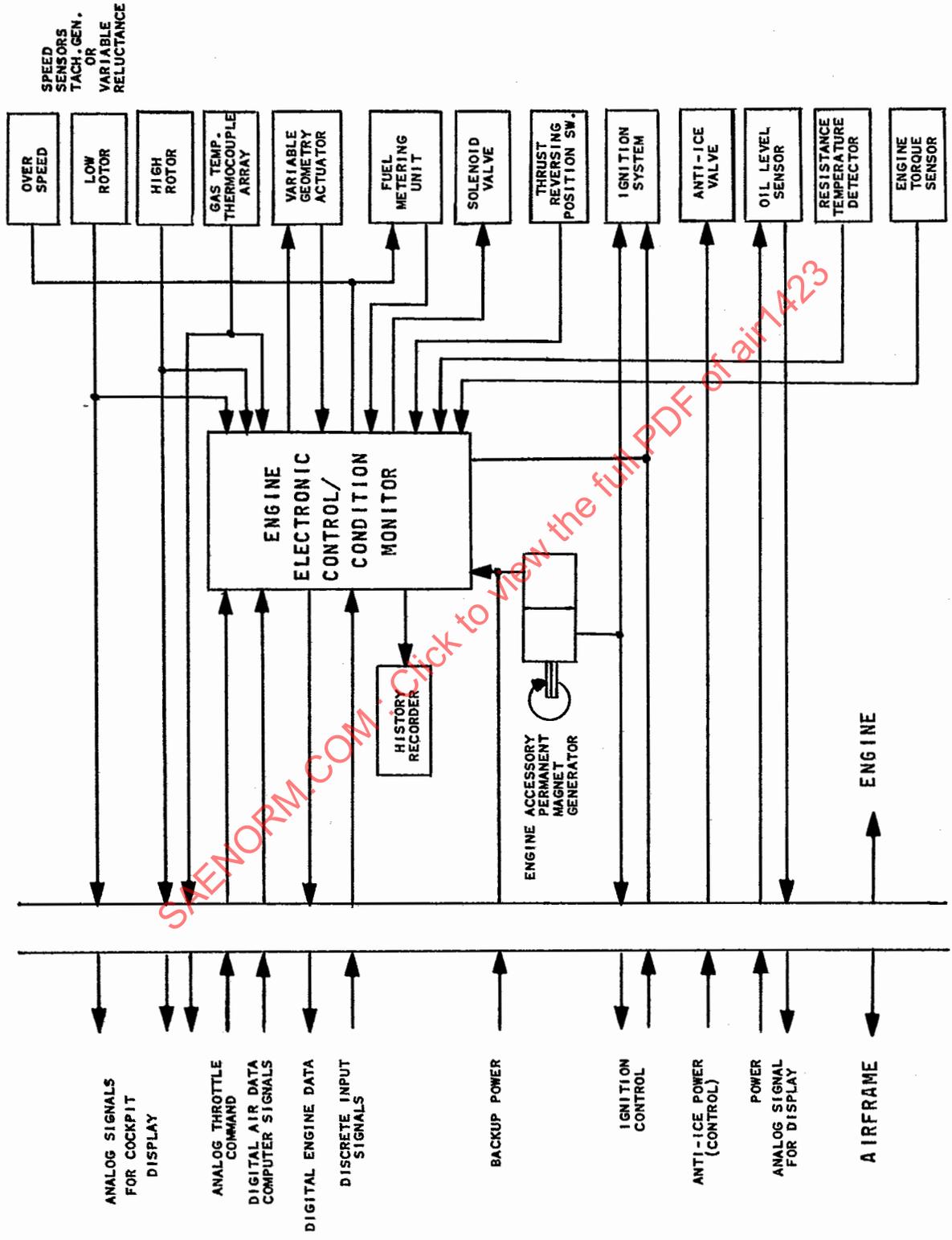
3.4 RECOMMENDED EMC CONTROL DOCUMENTS

The text of this AIR suggests several additional control and design approaches necessary for cost effective EMC achievement on the gas turbine engine. When these approaches are used in conjunction with MIL-STD-461A, Notice 3, EMC will, in most cases, be achieved between electrical and electronics systems on the engine and between the engine and the electrical/electronics systems on the aircraft. Class A-1 is suggested for advanced engines and aircraft, and Class F-1 is suggested for aircraft and engines operating in less stringent requirements. MIL-STD-462, Notice 2, is suggested for delineating standard test methods.

4. BIBLIOGRAPHY

- 4.1 The following Standards, Handbooks, Guides, etc. may be consulted for further guidance in specifying tests, test levels and control practices for achieving electromagnetic compatibility.
- a) Electromagnetic Compatibility Principles and Practices, National Aeronautics and Space Administration, Washington, D.C.; N66-16595 (NHB 5320.3)
 - b) Design Handbook Series 1-0, AFSC DH 1-4, Electromagnetic Compatibility, Third Edition; 5 January 1975; Department of The Air Force, Headquarters, Aeronautical Systems Division (AFSC), Wright Patterson Air Force Base, Ohio 45433
 - c) Interference Reduction Guide For Design Engineers, Volume 1; U. S. Army Electronics Laboratories, Fort Monmouth, New Jersey
 - d) Interference Reduction Guide For Design Engineers, Volume 2; U. S. Army Electronics Laboratories, Fort Monmouth, New Jersey
 - e) Prediction Of Coupling, Shielding, And Grounds For Low Frequency Fields; NUSC Report No. 4051; Naval Underwater Systems Center, Newport, Rhode Island 02840
 - f) Electromagnetic Compatibility Design Guide For Avionics And Related Ground Support Equipment; Navair AD1115
 - g) Military Handbook, Electromagnetic Environment Considerations For Design And Procurement Of Electrical And Electronic Equipment, Subsystem And Systems, MIL-HDBK-235
 - h) MIL-STD-461A, Notice 3; MIL-STD-462, Notice 2
 - i) MIL-B-5087 (ASG), Military Specification; Bonding, Electrical, And Lightning Protection, For Aerospace Systems
 - j) AIR 1425, Methods Of Achieving Electromagnetic Compatibility On Gas Turbine Engines For Self-Propelled Land Vehicles

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TEST METHOD (SEE TABLE 2)

SYSTEM/COMPONENT	INDIVIDUAL COMPONENT TEST	SYSTEMS* TEST	CE01	CE02	CE03	CE04	CS01	CS02	CS06	RE02	RS01	RS02	RS03	RS04
CONDITION MONITOR	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0
DIFFERENTIAL TRANSFORMER (POSITION MONITOR)	N	Y												
ELECTRICAL HARNESS	N	Y												
ENGINE ELECTRONIC CONTROL/ POWER MANAGEMENT CONTROL	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0
ENGINE ACCESSORY P.M. GENERATOR	Y	Y	N	T	N	T	N	N	T	Y	N	T	T	0
FUEL FLOWMETER, PASSIVE	N	Y												
FUEL FLOWMETER, ACTIVE	Y	Y	T	T	T	T	T	T	T	Y	Y	Y	Y	0
FUEL CONTROL, HYDROMECHANICAL, ELECTRICAL INTERFACES	N	Y												
IGNITION SYSTEM, AIRFRAME POWERED	Y	Y	T	T	Y	T	T	T	Y	Y	T	T	T	0
IGNITION SYSTEM, SELF-CONTAINED (USING ENGINE ACC. P.M. GEN.)	Y	Y	N	T	T	T	N	N	N	Y	T	T	T	0
IGNITION COMPONENTS, EXCITER, LEADS, IGNITERS	N	Y												
JUNCTION BOX	N	Y												
MAGNETIC CHIP DETECTOR	E	E												
OIL QUANTITY/QUALITY DETECTOR	N	Y												
PRESSURE TRANSDUCER	N	Y												
RELAY BOX	N	Y												

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TABLE 1 RECOMMENDED PFRT AND/OR DEVELOPMENTAL EMC TESTS