

Methods of Achieving Electromagnetic Compatibility of Gas Turbine Engine Accessories, for Self-Propelled Vehicles

FOREWORD

Changes in this revision are format/editorial only.

1. SCOPE:

This SAE Aerospace Information Report (AIR) is a description of methods to be employed to achieve Electromagnetic Compatibility (EMC) of gas turbine engine accessories. Its primary objectives are to aid those system designers of gas turbine assemblies who are employing commercial accessories, which are not always EMC designed, and to outline methods of achieving EMC employing readily available test instrumentation.

- 1.1 Electromagnetic Compatibility (EMC) as defined for this AIR is the ability of all engine accessories to perform within their specified capabilities when subjected to an electromagnetic environment generated by adjacent engine accessories.

2. REFERENCES:

The following references, which by no means can be considered all inclusive, does give information that is easily understood and of a practical nature. Most items listed below may be obtained from their source or from State and University Library Systems.

Charts Simplify Prediction of Noise from Periodic Pulses, by Robert B. Cowdell; Electronics, Sept. 2, 1968.

Simplified Interference Analysis of Waveshapes, by A. W. DeMarzio, Part I Frequency, May 1968, Part II June 1968.

Graphical Analysis of Signals, by Vernon R. Rizzino, Electro-Technology, February, 1966.

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2. (Continued):

Simplified Prediction of Conducted and Radiated Interference Levels for Pulses and Step Functions, by L. F. Babcock and P. J. Lagasta, IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-8, No. 2, June, 1966.

Designers Guide to EMI Shielding, by Willem F. Bakker, Machine Design, March 23, 1972.

Modeling of Fields Produced by Currents on Power Supply Wiring, Ralph M. Showers, IEEE Transactions on Electromagnetic Compatibility, November 1971.

Oscillatory Effects of EMI Power Line Filters, by Neal Orkin, IEEE EMC Symposium, July, 1971.

Grounding and Shielding Techniques in Instrumentation, by Ralph Morrison, John Wiley & Sons, Inc., Copyright 1967, 144 Pages.

Filters - a Handbook on Theory and Practice, by The Staff of White Electromagnetics Inc., Rockville, MD, Copyright 1963, 279 Pages.

Electrical Interference, by Rocco F. Ficchi, Hayden Book Company, Inc., New York, Copyright 1967, 262 Pages.

EMC Handbook, Volumes 1 - 5, by Donald R. J. White, Don White Consultants, German Town, Maryland, Copyright 1971-1974.

Electromagnetic Field Theory, by Robert D. Stuart, Addison-Wesley Publishing Company, Inc., Copyright 1965, 214 Pages.

Interference Control Techniques, Sprague Technical Paper, #62-1, by The Staff of the Interference Control Field Service Department Sprague Electric Company, North Adams, Massachusetts.

Electromagnetic Interference Sources and Suppression Techniques, A Compendium of Principles and Practices, EPA HI-693-1540-04-410-000, December 1964, Prepared by N. J. Sladek, Amphenol Connector Division, Amphenol Borg Electronics Corp., Chicago, Illinois.

Interference Reduction Guide, Volumes 1 and 2, A.D. 619666 and A.D. 619667, Prepared by Filtron Company Inc., New York, for U.S.-Army Electronics Laboratory, Fort Monmouth, NJ, Copyright 1965.

AFSC Design Handbook, DH1-4, Electromagnetic Compatibility, First Edition, January 10, 1969.

### 3. EMC CLASSIFICATION OF ACCESSORIES:

#### 3.1 Classification of Emission Accessories:

- 3.1.1 An emission accessory is one which will either conduct or radiate electromagnetic energy to an external medium. The conducted emission may be present on the accessories power lines or on its interconnecting control and signal lines. If levels of conducted emission are present, these lines can become radiators to nearby lines and accessories by either magnetic or electrostatic coupling.
- 3.1.2 Any accessory, where energy is released in the form of a rate of change of current or voltage with respect to time into its input and output impedances, should be considered a probable emission accessory.
- 3.1.3 Example of such engine accessories are switches (both mechanical and solid state), relays, solenoids, ignition systems and power control circuits.

#### 3.2 Classification of Susceptible Accessories:

- 3.2.1 A susceptible accessory is one which will deviate from its accepted performance parameters when exposed to a level of either conducted or radiated electromagnetic energy. This deviation in performance is of such a nature as to adversely affect the function of the accessory.
- 3.2.2 Examples of such susceptible engine accessories are low level circuits employed in temperature and vibration monitoring, amplifiers, especially if their input or output impedance is high and circuits employing solid state and integrated circuit components. These circuits can encompass such items as fuel control and injection components, speed sensors, governors, and automatic sequencing and multiplexing components.

#### 3.3 Dual Classifications:

- 3.3.1 The above classifications of accessories are, at times, not always clearly delineated as either emission or susceptible accessories, as some can be classed as both.
- 3.3.2 For example, a converter circuit may emit electromagnetic energy and in turn be caused to deviate from its performance specifications by induced electromagnetic energy.

### 4. ANALYTICAL APPROACH TO SYSTEM EMC:

#### 4.1 Charting:

- 4.1.1 The complete turbine engine accessory system should be charted similar to that shown in Figure 1.

<u>Emission Components</u>	<u>Emission/Susceptible Components</u>	<u>Susceptible Components</u>
Electro-mechanical portions of hydro-mech fuel control	Electronic control	Resistive temperature devices
Magneto power supply	Electrical harnesses	Thermocouples
Relay box	Differential transformers	T/C leads, harness, terminals
Ignition exciter	Oil quantity indicator	Gas gen. and turbine, speed pickups
Ignition leads	Oil quality indicator	Speed pickups, variable reluctance types
Ignition igniters	Tach generators	Condition monitor harnesses
Solenoid and motor operated valves	Magnetic speed pickups	Vibration pickups
Running time counter		Pressure transducers

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FIGURE 1 - Typical Turbine Engine Accessories and Their Predominant EMC Classification

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- 4.1.2 Separating the more clearly defined emission and susceptible accessories in this chart form assists the system designer in the following areas with respect to electromagnetic interference (EMI):
- a. Define those interconnecting power and/or control signal lines that are either emitters or receivers of EMI.
  - b. Define those accessory housings that, if not properly shielded, may emit or receive EMI.
  - c. Serve as a guide as to future wiring layouts to achieve maximum separation of accessories and wiring to reduce EMI influences on the overall system.
  - d. Serve as a guide as to the application of a minimum number of filters to achieve system EMC at a minimum cost.
- 4.2 Mathematical:
- 4.2.1 A study of both current and voltage waveforms from those items classified as emission accessories, with respect to level, risetime, falltime and duty cycle, can be performed with rough estimates of EMI levels derived. The frequency spectrum of any pulse can be defined in sinusoidal waveforms by employing Fourier analysis.
- 4.2.2 A knowledge of the frequency spectrum and levels from the emission accessories when applied to a study of the susceptible accessories will allow the designer to develop reasonable test methods and limits to apply to suspected susceptible accessories.
- 4.3 Empirical:
- 4.3.1 This AIR takes into account the possibility that EMI measuring equipment may not be readily available to the designer. It does assume that items such as oscilloscopes, voltage and current probes, magnetic pickup loops, and signal generators capable of a frequency response of at least 30 MHz are available. EMC problems above 30 MHz can exist, but if adequate suppression below 30 MHz is accomplished, high frequency problems in many cases will also be minimized.
- 4.4 Emission Studies:
- 4.4.1 Photographs of voltage and current waveforms employing oscillographic techniques should be performed on all lines entering or leaving a suspected emission accessory.
- 4.4.2 In order to perform a mathematical study of these waveforms, care in obtaining rise and fall times of pulses should be exercised. The complete risetime of the measuring system, including probes and oscilloscope plug-ins, should be calculated to prevent errors in risetime measurements. (The total risetime capability of any measuring system is equal to the square root of the sum of the squares of each measuring component's risetime). Figure 2 shows typical engine accessory waveforms and a simplified method of calculation to determine EMI magnitudes in the frequency domain.

E. M. I. EMISSION PREDICTION - TIME TO FREQUENCY DOMAIN			
INTERFERENCE SOURCE	TIME DOMAIN	FREQUENCY DOMAIN	SPECTRUM EQUATIONS
TRAPEZOIDIAL (Convertors and Multivibrators)			$F_n < F_1 < \frac{1}{\pi(T_1 + T_2)}$ $A_n = 126 + 20 \log A(T_1 + T_2)$ $F_n > F_1 > \frac{1}{\pi(T_1 + T_2)}$ $A_n = 116 + 20 \log A - 20 \log F_n$ $F_n > F_2 > \frac{1}{\pi T_2}$ $A_n = 106 + 20 \log \frac{A}{T_2} - 40 \log F_n$
CLIPPED SAWTOOTH (Chopper & Transistor Convertors)			$F_n < F_1 < \frac{1}{\pi T_1}$ $A_n = 120 + 20 \log A T_1$ $F_n > F_1 > \frac{1}{\pi T_1}$ $A_n = 110 + 20 \log A - 20 \log F_n$ $F_n > F_2 > \frac{1}{\pi T_2}$ $A_n = 100 + 20 \log \frac{A}{T_2} - 40 \log F_n$
FULL WAVE RECTIFIED SINE WAVE (D.C. Regulators)			$F_n < F_1 < \frac{1}{\pi T_1}$ $A_n = 122 + 20 \log A T_1$ $F_n > F_1 > \frac{1}{\pi T_1}$ $A_n = 110 + 20 \log \frac{A}{T_1} - 40 \log F_n$
DAMPED OSCILLATORY (Ignition Discharge and Filter Switching Transient)			$F_n < 0.5 F_1 < \frac{1}{\pi T_1}$ $A_n = 126 + 20 \log A T_1$ $F_n = F_1 = \frac{1}{\pi T_1}$ $A_n = 126 + 20 \log A T_1 - 10 \log (46^2 (1 - \delta)^2)$ $F_n > 2 F_1 > \frac{2}{\pi T_1}$ $A_n = 96 + 20 \log \frac{A}{T_1} - 40 \log F_n$
OVER DAMPED UNIDIRECTIONAL (Ignition Discharge and Relay Switching Transient)			$F_n < F_1 < \frac{1}{\pi T_1}$ $A_n = 120 + 20 \log A T_1$ $F_n > F_1 > \frac{1}{\pi T_1}$ $A_n = 110 + 20 \log A - 20 \log F_n$ $F_n > F_2 > \frac{1}{\pi T_2}$ $A_n = 100 + 20 \log \frac{A}{T_2} - 40 \log F_n$

LEGEND AND NOTES

A = Volts or Amperes (peak)  
T = Time in Microseconds  
AN = dBμV/MHz or dBμA/MHz  
F = Frequency in Megahertz  
π = 3.1416

R = Resistance in ohms  
L = Inductance in Microhenries  
B.B. = Broad Band  
N.B. = Narrow Band  
dec. = Decade  
C = Capacitance in microfarads

NOTE: 1.0 the narrow band envelope in dBμV or dBμA can be calculated by subtracting the pulse repetition rate To in microseconds from any broadband frequency spectrum.

\*Damping Ratio (δ) =  $\frac{L \eta A_1 \cdot L \eta A_2}{2 \pi} = \frac{R}{2} \sqrt{\frac{C}{L}}$

NOTE: Te is Time for A to drop to a Value of 1/e A

FIGURE 2