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400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

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MINIMUM PERFORMANCE STANDARDS FOR AIRBORNE STATIC ELECTRIC POWER INVERTERS

1. PURPOSE: The purpose of this document is to define the minimum performance requirements to be met by static electric power inverters designed for use in civil aircraft.

2. SCOPE AND DEFINITIONS:

2.1 Scope: The tests specified herein provide a laboratory means to determine the performance characteristics of static electric power inverters under electrical and environmental conditions representative of those encountered in actual aeronautical operation.

2.2 Definitions:

2.2.1 Airborne Static Electric Power Inverter: Equipment, or a combination of equipment, used in aircraft to convert direct current (DC) electric power to 400 Hz alternating current (AC) electric power.

2.2.2 Definition of Terms: Unless otherwise specified herein, the terms used are those defined in Radio Technical Commission for Aeronautics (RTCA) Document Number DO-160.

2.2.3 Test Conditions and Procedures: Unless otherwise specified herein, the test procedures and the environmental test conditions and procedures shall be those defined in RTCA Document Number DO-160 for the equipment category declared by the manufacturer.

2.2.4 Test Samples: The tests under Sections 4.0 and 5.0 herein shall be performed using no more than two (2) inverters. The optional Section 6.0 test(s) may be conducted on these same inverters or an additional test sample.

2.2.5 Effect of Tests: As a minimum performance requirement, the equipment shall satisfactorily complete all tests herein without maintenance or failure.

2.2.5.1 Repair and Retest: If the equipment fails a test, the manufacturer may at his option repair and retest it or test a new unit in place of the failed unit. The manufacturer shall furnish a detailed report on the investigation of the failure and the corrective action. At the discretion of the inspecting authority, the repaired or replacement unit may be subjected to any applicable test herein in addition to those which the unit previously failed.

2.2.6 Manufacturer's Declarations: The manufacturer shall declare (1) the equipment category applicable to the inverter, and (2) the applicable environmental categories. Unless otherwise declared by the manufacturer, the environmental conditions and test procedures herein will apply.

(1)	Rated Input Voltage	22 to 29.5 VDC (Category Z) (27.5V Nominal)
(2)	Rated Input Current (AT 22 VDC Input)	To be declared by the manufacturer.
(3)	Rated Output Voltage	115 VAC r.m.s. + 5V (proportional regulation for inverters with 26 VAC tap).
(4)	Output Frequency	400 + 4 Hertz.
(5)	No. of Phases	To be declared by the manufacturer.
(6)	Output Power (VA)	To be declared by the manufacturer.
(7)	Power Factor Range	.80 Lagging to .95 Leading
(8)	Harmonic Distortion	5% total, 4% maximum individual harmonic.
(9)	Efficiency	To be declared by the manufacturer.
(10)	Weight (Maximum)	To be declared by the manufacturer.
(11)	Acoustic Noise Level	To be declared by the manufacturer.

3. GENERAL REQUIREMENTS:

3.1 Design and Construction: The design, construction, finish, marking shall be consistent with good aircraft practice. Terminals, connections, components and conductors shall be designed to preclude accidental shorting, contact with personnel or foreign conductive materials. Components should not be stressed beyond their manufacturer's ratings.

3.2 Voltage and Frequency Controls: Voltage and frequency controls or adjustments that are not normally adjusted in flight shall not be readily accessible to flight personnel.

3.3 Flammable Materials: Except for small parts (i.e. seals, grommets, fasteners and other small electrical parts) which would not contribute significantly to the propagation of a fire, all materials used in the equipment shall be non-burning or self-extinguishing.

4. MINIMUM PERFORMANCE REQUIREMENTS UNDER STANDARD TEST CONDITIONS: Unless otherwise stated herein, the conditions of test shall be those defined in Section 3.0 of RTCA Document Number DO-160 and, unless otherwise specified, after temperature stabilization of the equipment reference DO-160 Section 2.

4.1 AC Voltage and Frequency Regulation: Unless otherwise declared by the manufacturer, the inverter output limits shall remain within 400 Hz ± 4 and 115 VAC r.m.s. ± 5V when tested for five (5) minutes under each of the following conditions:

(1) Input Voltage	Load Conditions (Unity PF)
22 VDC	No Load, 25%, 50%, 75% and Full Load
27.5 VDC	Repeat
29.5 VDC	Repeat

(2) Repeat above tests at .80 Lagging PF Loads.

(3) Repeat above tests at .95 Leading PF Loads.

Output transient voltages shall be measured during load application and removal. Duration and levels of voltage excursions shall not exceed limits shown in Fig. 1.

4.2 Efficiency: With nominal input voltage and at full rated load (Unity PF), the calculated efficiency shall not be less than that declared by the manufacturer.

4.3 Waveform:

4.3.1 Linear Load: Unless otherwise declared, the inverter waveform shall have a crest factor of 1.41 ± 0.1, a total harmonic content not exceeding 5% of the fundamental and an individual harmonic content not exceeding 4% of the fundamental over the normal input voltage range and output load range.

4.3.2 Non-Linear Load: The total harmonic and extraneous frequency content of the waveform shall not exceed 8% of the fundamental over the normal input voltage range when tested in accordance with paragraph 4.3.3.

4.3.3 Non-Linear Load Test: The load tests specified below shall be conducted at minimum, nominal and maximum normal input voltages. Tests on three-phase units may be conducted one phase at a time.

a. With an initial linear load of 50% rated current, an additional load of 50% rated current shall be added for approximately 1/2 of each positive and negative half cycle.

b. Part (a) shall be repeated except that the load during the positive cycle shall be linear and 100% rated current.

4.3.3 (Continued):

c. With no initial load, a load of 50% rated current shall be applied for approximately 1/2 of each positive and negative half cycle.

d. Part (c) shall be repeated except that the load during the positive half cycle shall be linear and 50% rated current.

4.4 Low Voltage Input Operation: The inverter shall demonstrate its ability to start under rated load and to operate continuously for 30 minutes at 18 VDC input. The output voltage shall not be less than 100 VAC and the frequency shall be 400 ± 20 Hertz. The inverter shall operate within normal regulation limits when the input voltage is increased to 27.5 VDC.

4.5 High Voltage Input Operation: The inverter shall be operated for 5 minutes at full load output with 32.2 VDC input applied. The inverter output shall not exceed 122 VAC and the frequency shall be 400 ± 20 Hertz. The inverter shall operate within normal regulation limits when the input voltage is reduced to 27.5 VDC.

4.6 Momentary Low Voltage Inputs: The inverter shall not be damaged, if when operating at full load and 22 VDC input, the input voltage is rapidly reduced to 0 volts for 5 msec. and then increased back to 22 VDC. The inverter shall operate within rated output voltage and frequency regulation limits upon reaching 22 VDC. This test shall be repeated five (5) times within a five-minute period using 0 voltage periods of 10, 25, 50, 100 and 150 msec. for each interruption.

4.7 Overload Capacity: Unless otherwise declared, with an initial load of 10% and nominal input voltage applied, the inverter shall, without damage, be capable of providing at least 150% load current for five (5) minutes when operating into a unity power factor load. For three (3) phase inverters, this test may be run on each phase individually or on all three phases simultaneously. Output transient voltages shall be measured during the load application and removal. Duration and levels of voltage excursions shall not exceed the limits of Figure 1.

4.8 Fault Clearing: Unless otherwise declared, the inverter, with rated input voltage applied, shall without damage be capable of delivering at least 200% rated load current for 5 seconds.

4.9 Surge Voltage (Category 2): Unless otherwise declared, the inverter shall be tested in accordance with DO-160, para. 16.3.5. Upon test completion, the inverter shall meet the requirements of para. 4.1(1) herein.

4.10 Voltage Spike Conducted Test (Category A): Unless otherwise declared, the inverter shall be tested in accordance with DO-160, para. 17.0, requirement category A.

4.11 Phase Voltage Displacement (3-Phase Inverters):

4.11.1 Balanced Load: Unless otherwise declared, the maximum spread in phase voltage shall not exceed 3V between the phase with the highest voltage and the phase with the lowest voltage when operating into a balanced load.

4.11.2 Unbalanced Load: Unless otherwise declared, the voltage displacement between phases (highest to lowest) shall not exceed 3 volts when operating into a one-third unbalanced load. Maximum output voltage between phases shall not exceed 4 volts when operating into a two-thirds unbalanced load.

4.11.3 Unbalanced Load Test: The effects of single-phase and unbalanced three-phase loads on the balance of the three-phase voltage output of the unit shall be determined as follows at minimum, nominal, and maximum normal input voltages.

a. When the unit is carrying no three-phase load, a single phase line-to-neutral unity power factor load requiring 1/3 and then 2/3 of rated full load output current (a load of approximately 1/9 and 2/9 of the full three-phase rating of the unit) shall be connected successively to each phase.

b. When the unit is carrying a unit power factor balanced three-phase load requiring 1/3 of the rated full load output current, a single-phase line-to-neutral unity power factor load requiring 1/3 and then 2/3 of the rated full load output current (a load of approximately 1/9 and 2/9 of the full three-phase rating of the unit) shall be connected successively to each phase.

c. When the unit is carrying a unity power factor balanced three-phase load requiring 2/3 of the rated full load output current, a single-phase line-to-neutral unity power factor load requiring 1/3 of the rated full load output current (a load of approximately 1/9 of the full three-phase rating of the unit) shall be connected successively to each phase.

The maximum value of the output voltage unbalance and the phase voltage occurring during parts (a) through (c) above shall not exceed the limits specified in 4.11.2.

4.12 Phase Displacement (3-Phase Inverters): Unless otherwise declared, the displacement between corresponding zero points on the wave form shall be between the limits of 118 and 122° when operating into a balanced load.

4.13 Phase Rotation (3-Phase Inverters): The inverter shall have phase rotation ABC and this will be verified by test.

4.14 Reverse Polarity: Means shall be provided for protecting the inverter from the application of reverse polarity input voltage.

4.15 Starting: The inverter shall be capable of starting under all specified conditions. During starting, the output voltage shall not exceed the limits in Figure 1.

4.16 Influence on Electrical System: The inverter shall not unduly influence an aircraft D.C. power supply system. Peak to mean input ripple currents shall not exceed the values specified below, when the inverter is operated from a low impedence, low ripple source.

INVERTER RATING VA	PEAK TO MEAN INPUT RIPPLE CURRENT MAX - AMP.
Under 30	0.5
30 - 90	1
91 - 200	2
201 - 500	5
501 - 1000	10
1001 - 2500	20
OVER 2500	25

4.17 Insulation Resistance: The insulation resistance of the inverter shall be measured between:

-d.c. inuts and frame with a.c. outputs connected to frame. Test voltage 50 VDC.

-a.c. outputs and frame with d.c. inputs connected to frame. Test voltage 200 VDC.

At maximum operating temperature, the insulation resistance shall not be less than 10 MΩ.

5. MINIMUM PERFORMANCE UNDER ENVIRONMENTAL TEST CONDITIONS: Inverters shall meet the requirements of the following paragraphs by actual test, similarity proof or by analysis. Unless otherwise specified, the applicable terms, environmental and test conditions and procedures referenced are in accordance with RTCA Document DO-160.

5.1 Low Temperature Test: The inverter shall be tested in accordance with para. 4.4 of DO-160. Upon completion of the test, the inverter shall meet the requirements of para. 4.1 (1) herein.

5.2 High Temperature Test: The inverter shall be tested in accordance with para. 4.5 of DO-160. The unit shall be tested without a heat sink and in still air. Unless otherwise declared, the high temperatures shall be those defined for Category D2 equipment. If a fan is used in the temperature chamber, the moving air shall not impinge directly on the inverter. Upon completion of the test, the inverter shall meet the requirements of para. 4.1 (1) herein.

5.3 Altitude Test (High Temperature): The inverter shall be tested at the maximum temperature/altitude condition for the equipment declared by the manufacturer. Unless otherwise declared, applicable maximum temperatures shall be: (reference para. 4.2 of DO-160), (B-2) +70°C, (C-2) +45°C, (D-2) +20°C, and (E-1) +20°C. Upon completion of the test, the inverter shall meet the requirements of para. 4.1 (1) herein.

5.4 Humidity Test: The inverter shall be tested in accordance with para. 6.3.1 of DO-160. The inverter shall meet the requirements of para. 4.1 (1) and para. 4.5 herein.

5.5 Shock Test: The inverter shall be tested in accordance with para. 7.1 of DO-160. The inverter shall meet the requirements of para. 4.1 (1) herein.

5.6 Crash Safety: The inverter shall meet the requirements of para. 7.2 of DO-160.

5.7 Vibration: The inverter shall be tested in accordance with para. 8.2.1 of DO-160. Unless otherwise declared, the requirements for Figure 2 herein shall apply. The inverter shall be operated at nominal input voltage and at no load. Unless otherwise declared, the inverter output shall be in accordance with para. 2.2.6 (3) and (4) herein.

5.8 Audio Frequency Conducted Susceptibility: The inverter shall be tested in accordance with para. 18.0 of DO-160, for category Z. Unless otherwise declared, the inverter output shall be in accordance with para. 2.2.6 (3) and (4) herein when tested at nominal input voltage and at half load. Voltage modulation should be monitored during this test and shall not exceed limits of DO-160 para. 16.3.1.2.

5.9 Induced Signal Susceptibility: Unless otherwise declared, the inverter shall be tested in accordance with the test requirements of para. 19.0 of DO-160 for Category Z equipment. During the testing determine compliance with Section 4.

5.10 RF Susceptibility (Radiated and Conducted): Unless otherwise declared, the inverter shall be tested in accordance with para. 20 of DO-160 for category Z equipment. During the testing determine compliance with Section 4.

5.11 Emission of RF Energy (Conducted and Radiated): Unless otherwise declared, the inverter shall be tested in accordance with para. 21.0 of DO-160 for Category Z equipment.

5.12 Acoustical Noise: The manufacturer shall establish the maximum sound level allowable when measured in planes one (1) foot from each of the six (6) sides. The calibration devices or standards used shall be directly traceable to the National Bureau of Standards. Measurements shall be made under anechoic conditions with the inverter supported in a manner to minimize acoustic transmission and reflection by the support structure.

6. SPECIAL PURPOSE ENVIRONMENTAL TEST CONDITIONS AND PROCEDURES: Where any of the following requirements apply, the applicable portions of RTCA Document DO-160 shall be met.

6.1 Explosion Test (Category E): The inverter shall be tested in accordance with para. 9.0 of DO-160. Unless otherwise declared, Procedure I shall be used.

6.2 Waterproofness (Drip Proof) Test (Category W): The inverter shall be tested in accordance with para. 10.2 of DO-160. The inverter shall meet the requirements of para. 4.1 (1) herein.

6.3 Hydraulic Fluid Test (Category H): The inverter shall be tested in accordance with para. 11.0 of DO-160. The inverter shall meet the requirements of para. 4.1 (1) herein.

6.4 Sand and Dust Test (Category D): The inverter shall be tested in accordance with para. 12.0 of DO-160. Upon completion of the test, the inverter shall meet the requirements of para. 4.1 (1) herein.

6.5 Fungus Resistance (Category F): The inverter shall be tested in accordance with para. 13.0 of DO-160. Upon completion of the test the inverter shall meet the requirements of para. 4.1 (1) herein.

6.6 Salt Spray (Category S): The inverter shall be tested in accordance with para. 14.0 of DO-160. Upon completion of the test the inverter shall meet the requirements of para. 4.1 (1) herein.

6.7 Magnetic Effect: The inverter shall be tested in accordance with para. 15.0 of DO-160.

7. PRODUCTION ACCEPTANCE TESTS:

7.1 As a minimum requirement, each production inverter shall meet the requirements of the following paragraphs. These tests must be as defined by the manufacturer's quality control system, as approved by FAA.

7.2 Examination of Product: Each inverter, subassembly, and parts shall be examined, as determined by the manufacturer's quality control department, to determine compliance with acceptance test procedures and applicable drawings with respect to materials, electrical connector(s), wiring, threaded parts, finish, interchangeability, markings, instructions, weight, dimensions, and workmanship.

7.3 Burn-In: Each production inverter shall be subjected to a minimum burn-in period of 6 hours with nominal input voltage applied and at full rated load, unity PF.