SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

AS8023	REV. A
Issued 1985-09 Revised 2006-08 Superseding AS8023	

(R) Minimum Performance Standards for Static Electric Power Inverters

RATIONALE

This revision to SAE Aerospace Standard AS8023 was created to update both the electrical performance requirements and environmental test requirements contained within the base document.

1. SCOPE

This SAE Aerospace Standard (AS) establishes the minimum performance standards for equipment used as secondary alternating current (AC) electrical power sources in aerospace electric power systems.

1.1 Purpose

The purpose of this document is to define the guidelines and minimum performance test standards to be met by static electric power inverters designed to operate from primary or emergency electric power systems. The tests specified herein provide a laboratory means to determine the performance and reliability characteristics of electric power inverters under electrical and environmental conditions representative of those encountered in actual aerospace applications.

1.2 Field of Application

Static electric power inverter equipment whose initial application is to provide three phase or single phase AC power by converting nominal DC power for aerospace utilization systems and equipment, but not limited to aerospace use.

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 shall apply. The applicable issue of other documents shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this specification and references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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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.

AS1212 Electrical Power, Aircraft, Characteristics and Utilization of

AS1831 Electrical Power, High Voltage Direct Current, Aircraft, Characteristics and Utilization of

AS4361 Minimum Performance Standards for Aerospace Electric Power Converters

2.1.2 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-HDBK-217 Reliability Prediction of Electronic Equipment

MIL-HDBK-263 Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) Metric

2.1.3 RTCA Publications

Available from Radio Technical Commission for Aeronautics Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA/DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

2.1.4 Federal Aviation Administration Publications

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

TSO-C73 Static Electrical Power Inverter

2.2 Definitions

2.2.1 AEROSPACE ELECTRIC POWER INVERTER

Equipment, or a combination of equipment, used to convert nominal DC aircraft power to three-phase or single phase AC power at 60 or 400 Hertz, typically.

2.2.2 DEFINITION OF TERMS

Unless otherwise specified herein, the terms used are those defined in RTCA Document Number DO-160.

2.2.3 STATIC

Equipment that does not utilize mechanical devices as active components of the power conversion technology.

2.2.4 FAILURE

Any test condition where the equipment/unit under test is unable to meet minimum performance requirements or as is otherwise specified for each test and or equipment.

2.2.5 VARIABLE COMPONENT

Electrically or mechanically adjustable component.

2.2.6 SWITCHING FREQUENCY RANGE

Primary or central frequency range within which the active power switching devices operate.

2.2.7 TRIPLENS

The 3rd harmonic and every whole integer multiple of the 3rd harmonic.

2.2.8 ONE-THIRD UNBALANCED LOAD

In a three-phase system, where two phases are carrying equal load and the third phase is carrying 1/3 phase rated load (1/9 of the product's total rated load) more. For example, A-Phase: 1/3 phase rated load, B-Phase: 1/3 phase rated load, C-Phase: 2/3 phase rated load.

2.2.9 TWO-THIRDS UNBALANCED LOAD

In a three-phase system, where two phases are carrying equal load and the third phase is carrying 2/3 phase rated load (2/9 of the product's total rated load) more. For example, A-Phase: 1/3 phase rated load, B-Phase: 1/3 phase rated load, C-Phase: full phase rated load.

3. TECHNICAL REQUIREMENTS

3.1 General

3.1.1 Design and Construction

The design, construction, finishes, and marking shall be consistent with the standards of aerospace industry good aircraft practice. Terminals, connections, components and conductors shall be designed to preclude accidental shorting, polarity reversal, improper installation, and contact with personnel or foreign conductive materials.

3.1.2 Adjustments and Controls

Controls and/or variable components that are not normally adjusted in flight shall not be readily accessible to flight personnel.

3.1.3 Flammable Materials

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

3.1.4 Reliability

As a minimum requirement, reliability predictions shall be made available. The statistical analysis shall be based on field usage and/or reliability analysis that is completed and documented. Reference tools for this process include but may not be limited to MIL-HDBK-217.

3.1.5 Handling of Product

Any special handling requirements during testing or installation of the product shall be identified. General guidelines for ESD handling of products should be referenced to MIL-HDBK-263.

3.2 Minimum Performance Requirements Under Standard Test Conditions

Unless otherwise stated herein, the conditions of test shall be those defined in Section 3 of RTCA Document Number DO-160 and, unless otherwise specified, after temperature stabilization of the equipment, reference DO-160 Section 2.

3.2.1 Qualification Test Conditions and Procedures

3.2.1.1 General

Unless otherwise specified herein, the test procedures and the environmental test conditions and procedures shall be those defined in DO-160 for the equipment and category as declared by the manufacturer.

3.2.1.1.1 FAA Certification

For applications where FAA Certification is required or desired, the appropriate FAA Standard Order, TSO-C73, may be used as a guideline.

3.2.1.2 Effects of Tests

As a minimum performance requirement, the equipment shall satisfactorily complete all tests herein without maintenance or failure.

3.2.1.3 Repair and Retest

If the equipment fails a test, the manufacturer may, with option, repair and retest the equipment 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 needed to return the equipment to specified condition. At the discretion of the inspecting authority, the repaired or replacement unit may be subjected to any or all applicable tests herein in addition to those, which the unit previously failed.

3.2.1.4 Manufacturer Declaration

Unless otherwise stated in the customer's detailed requirements document, the manufacturer prior to testing shall declare the applicable environmental categories per DO-160. The manufacturer shall also declare as a minimum the following:

a. Rated Input Voltage.

b. Rated Input Current.

c. Rated Output Frequency(s).

d. Rated Output Voltage(s).

e. Rated Output Maximum Load Current(s).

f. Rated Output Minimum Load Current(s).

g. Minimum Efficiency within the range of half to full rated load.

h. True Power Factor Range.

i. Switching Frequency.

j. Audible Noise.

k. Output Voltage Regulation (with tolerance values).

l. Line and Load Regulation.

m. Type and Limits of Input/Output Overload Protection.

n. Cooling Method (User requirements when applicable).

o. Dimensions (Maximum).

p. Weight (Maximum).

3.2.1.5 Line and Load Regulation Tests

Unless otherwise specified by the procurement organization, the inverter output voltage(s) and frequency(s) shall remain within the manufacturer's declared tolerances, when each of the following input voltage conditions of Table 1 are tested for a minimum of 5 minutes. As a minimum, for each input voltage condition the inverter shall be operated at all load and power factor combinations of minimum rated load, half rated load, full rated load, minimum rated leading power factor, and minimum rated lagging power factor.

The values within Table 1 are typical, specific applications may require modification of these typical test conditions and shall be declared.

TABLE 1 - LINE AND LOAD REGULATION TEST VOLTAGES

	DC Input Voltage (VDC)	
Voltage Limit	28 VDC Range	270 VDC Range
Minimum	22	250
Nominal	28	270
Maximum	29	280

3.2.1.6 Output Voltage Transients

Output transient voltages shall be measured during specified worst-case load changes. Voltage excursions shall not deviate by more than ±10% of the specified voltage regulation limits and shall return to steady state in less than 5 milliseconds.

3.2.2 Efficiency

Efficiency will be measured at nominal input voltage, full rated load, unity power factor and nominal environmental conditions. The calculated efficiency shall not be less than that declared by the manufacturer.

3.2.3 Waveform

3.2.3.1 Linear Resistive 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.

3.2.3.2 Non-Linear Load Test

The load tests specified below shall be conducted at minimum, nominal, and maximum normal input voltages. 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 this paragraph. 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.

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.

3.2.4 Low Voltage Input Operation

Unless otherwise declared, the inverter shall demonstrate its ability to start and to operate continuously for 30 minutes at minimum input voltage per 3.2.1.5 under full load and unity power factor as applicable. The output voltage shall remain within specified limits. The inverter shall continue to operate within normal regulation limits when the input voltage is increased to nominal.

3.2.5 High Voltage Input Operation

The inverter shall demonstrate its ability to start and operate for 30 minutes at minimum load output and unity power factor with maximum input voltage per 3.2.1.5 as applicable. The inverter output shall remain within normal limits. The inverter shall operate within normal regulation limits when the input voltage is reduced to nominal.

3.2.6 Momentary Low Voltage Inputs

The inverter shall not be damaged, while operating at full load and minimum input voltage, when the input voltage is rapidly reduced to 0 volts for 5 milliseconds and then increased back to minimum input voltage. The inverter shall operate within rated output voltage regulation limits upon reaching minimum input voltage. Each test condition shall be repeated five times, within a 5-minute period, using 0 voltage interruption periods of 5, 10, 25, 50, 100 and 150 milliseconds for each interruption.

3.2.7 Short/Overload Circuit Protection

Unless otherwise declared, with an initial minimum load and nominal input voltage applied, the inverter shall not be damaged or exhibit failure when a short circuit is applied across each output or when operated at 120% of nominal load for a duration agreed upon between the manufacturer and procuring organization. The output voltage shall return to within normal limits after the short or overload is removed and equipment is operated as specified.

3.2.8 Surge Voltage

Unless otherwise specified, the inverter shall be tested in accordance with section 16 of DO-160. Upon test completion, the inverter shall meet the requirements of 5.2 and 5.4 herein.

3.2.9 Conducted Voltage Spike Test

Unless otherwise specified, the inverter shall be tested in accordance with Section 17 of DO-160.

3.2.10 Phase Voltage Displacement (3-Phase Inverters)

3.2.10.1 Balanced Load

Unless otherwise specified, the maximum spread in phase voltage shall not exceed 3 VRMS between the phase with the highest voltage and the phase with the lowest voltage when operating into a balanced load.

3.2.10.2 Unbalanced Load

Unless otherwise specified, the voltage displacement between phases (highest to lowest) shall not exceed 3 VRMS when operating into a one-third unbalanced load (see 2.2.8 herein). Maximum output voltage between phases shall not exceed 4 VRMS when operating into a two-thirds unbalanced load (see 2.2.9 herein).

3.2.10.3 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 single-phase current (a load of approximately 1/9 and 2/9 of the full three-phase rating of the unit respectively) shall be connected successively to each phase.

b. When the unit is carrying a unity 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 of the rated full load single-phase output current (a load of approximately 1/9 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 single-phase 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 3.2.10.2.

3.2.11 Phase Displacement (3-Phase Inverters)

Unless otherwise specified, the displacement between corresponding zero crossings of the waveform shall be between the limits of 118° and 122° when operating into a balanced load.

3.2.12 Phase Rotation (3-Phase Inverters)

The inverter shall have phase rotation A-B-C. This shall be verified by test.

3.2.13 Reverse Polarity

For DC Input Voltage, a means shall be provided for protecting the inverter from the application of reverse polarity input voltage. This may be done in conjunction with an input circuit breaker. The protection means may be provided mechanically, which requires visual verification, or electronically, which requires testing.

3.2.14 Starting

Unless otherwise defined, the inverter shall be capable of starting under all specified conditions. During starting, the output voltage shall not exceed the limits in Figure 1. For inverters with nominal output voltages other than 115 VRMS the values in Figure 1 shall be multiplied by the ratio of the nominal voltage to 115 VRMS.

3.2.15 Influence on Electrical System

The inverter shall not unduly influence an aircraft DC power supply system. Peak-to-mean input ripple currents shall not exceed the values specified in Table 2 when the inverter is operated from a low impedance low ripple source, such as a battery.

TABLE 2 - INPUT RIPPLE CURRENTS

Inverter Rating (VA)	Peak-to-Mean Input Ripple Current Maximum (Amperes)
Under 30	0.5
30 - 90	1
91 - 200	2
201 - 500	5
501 - 1000	10
1001 - 2500	20
Over 2500	25

3.2.16 Insulation Resistance

Insulation resistance testing shall be performed as follows:

- between the 28(270) VDC inputs and frame and a test voltage of 50 VDC (330 VDC, or as specified).

- between the DC inputs and frame with the AC outputs connected to frame and a test voltage of 200 VDC.

At the maximum rated operating temperature, the measured insulation resistance shall not be less than 10M ohms.

NOTE: Frame connected filters may be disconnected for this test.

3.3 Minimum Performance Under Environmental Test Conditions

The inverter shall meet the requirements of the following paragraphs by actual test, similarity, and/or analysis. Unless otherwise specified, the applicable terms, environmental and test conditions and procedures referenced are in accordance with RTCA Document DO-160.

3.3.1 Temperature Test

The inverter shall be tested in accordance with the applicable low temperature test in Section 4 of DO-160. Upon completion of the test, the inverter shall meet the requirements of 5.2 and 5.4 herein.

The inverter shall be tested in accordance with the applicable high temperature test in section 4 of DO-160. The unit shall be tested in a condition which simulates its specified operating environment. 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 5.2 and 5.4 herein.

3.3.2 Temperature/Altitude Test

The inverter shall be tested at the maximum temperature/altitude condition for the equipment declared by the manufacturer in accordance with Section 4 of DO-160. Upon completion of the test, the inverter shall meet the requirements of 5.2 and 5.4 herein.

3.3.3 Humidity Test

The inverter shall be tested in accordance with the applicable humidity test in Section 6 of DO-160. Upon completion of the test, the inverter shall meet the requirements of 5.2 and 5.4 herein.

3.3.4 Shock Test

The inverter shall be tested in accordance with the applicable operational and crash safety shock tests in Section 7 of DO-160. Upon completion of the operational shock test, the inverter shall meet the requirements of 5.2 and 5.4 herein.

3.3.5 Vibration

The inverter shall be tested in accordance with the applicable vibration test in Section 8 of DO-160. The inverter shall be operated at the nominal input voltage and at full load with unity power factor, and meet the minimum performance requirements of 5.2 and 5.4 during and after the test. Unless otherwise declared, the inverter output shall be in accordance with the manufacturer's declared tolerances.

3.3.6 Audio Frequency Conducted Susceptibility

The inverter shall be tested in accordance with the applicable audio frequency conducted susceptibility test in Section 18 of DO-160, for the category as declared by the manufacturer. Unless otherwise specified, the inverter output shall be in accordance with the manufacturer's declared tolerances when tested at nominal input voltage and at full load with unity power factor. Voltage modulation should be monitored during this test and shall not exceed the limits as defined in Section 16 of DO-160.

3.3.7 Induced Signal Susceptibility

Unless otherwise specified, the inverter shall be tested in accordance with the applicable induced signal susceptibility test in Section 19 of DO-160 for the equipment category as declared by the manufacturer. The inverter shall be operated at the nominal input voltage and at full load with unity power factor, and meet the minimum performance requirements of 5.4 herein during and after the test.

3.3.8 RF Susceptibility (Radiated and Conducted)

Unless otherwise specified, the inverter shall be tested in accordance with the applicable radio frequency susceptibility test in Section 20 of DO-160 for the equipment category as declared by the manufacturer. The inverter shall be operated at the nominal input voltage and at full load with unity power factor, and meet the minimum performance requirements of 5.4 herein during and after the test.

3.3.9 Emission of RF Energy (Conducted and Radiated)

Unless otherwise specified, the inverter shall be tested in accordance with the applicable radio frequency energy emission test in Section 21 of DO-160 for the equipment category as declared by the manufacturer.

3.3.10 Acoustical Noise

The manufacturer shall establish the maximum sound level allowable when measured in planes 1 foot from each of the six sides. The calibration devices or standards used shall be directly traceable to the National Institute of Standards and Technology. Measurements shall be made with the inverter supported in a manner to minimize acoustic transmission and reflection by the support structure.