

Specification for

General requirements for equipment in aircraft —

Part 2: All equipment —

Section 3: Environmental conditions —

Subsection 3.1: Vibration

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Contents

	Page
Foreword	ii
1 Scope	1
2 Conditions for testing	1
2.1 Mounting	1
2.2 Mounting of specimens	1
2.3 Vibration system	1
3 Severities	2
3.1 Equipment location	2
3.2 Vibration categories	3
3.3 Duration for specified service environment	3
3.4 Category and duration for unspecified service environment	4
3.5 Special environments	5
4 Testing procedure	5
4.1 Initial measurements	5
4.2 Testing	5
4.3 Initial resonance search	5
4.4 Endurance	5
4.5 Final resonance search	6
4.6 Final measurements	6
5 Information required in the relevant specification	7
Appendix A Guidance on the use of the specification	10
A.1 Data required	10
A.2 Details of test procedure	10
A.3 Numerical examples of application of specification	10
Appendix B General concepts of the specification	17
B.1 General requirements	17
B.2 Basis of the specification	18
B.3 Derivation of specification data and procedures	19
B.4 Alternative test procedures	20
B.5 Test sequence	20
B.6 Tolerances	21
Figure 1 — Test spectra for equipment Regions A, B and C (civil)	7
Figure 2 — Test spectra for equipment Regions C (military) and D	8
Figure 3 — Minimum sinusoidal test levels for equipment Regions A and B	8
Figure 4 — Minimum sinusoidal test levels for equipment Regions C and D (i) Region C (civil) (ii) Region C (military) and Region C	9
Table 1	4
Table A.1 — Subsonic jet transport aircraft — Mean flight duration 1 hour equipment region A	14
Table A.2 — Subsonic jet transport aircraft — Mean flight duration 1 hour equipment region B	15
Table A.3 — Light piston-engined propeller-driven aircraft — Mean flight duration 1 hour equipment region A	16
Table A.4 — Light piston-engined propeller-driven aircraft — Mean flight duration 1 hour equipment region B	17

Foreword

General. This subsection of 3G 100-2 replaces Clauses **216–218** of 2G.100-2:1962.

The tests dealt with in this subsection are applicable to complete units of airframe equipment, hereinafter referred to as specimens, which are subjected to conditions involving vibration. It must be clearly stated in the individual equipment specification if a specimen tested separately has to function during vibration or merely to survive conditions of vibration. In either case, the individual specification should always prescribe the acceptable tolerance on performance within which the specimen may be considered satisfactory or otherwise.

The purpose of the tests described in this subsection is to determine under conditions of vibration:

- 1) any mechanical weakness,
- 2) any degradation in specified performance.

It is emphasized that vibration testing always demands a degree of engineering judgment, and that both the supplier and purchaser should be cognizant of this.

Consideration should be given to the possibility that environments other than vibration may cause changes in dynamic characteristics. If this possibility exists the individual specification should state whether any special environmental conditions apply to the vibration test, such as temperature, pressure, steady acceleration, magnetic fields, or other electrical environments.

Guidance on the use of the specification is given in Appendix A; information on the general concepts upon which it is based is contained in Appendix B.

Definition of test stages. Generally there are three distinct stages in the tests:

- 1) *Initial resonance search (4.3)*. The specimen is vibrated over the whole specified range of frequency up to the specified level. It is checked functionally and examined for any frequency-dependent effects, such as mechanical resonances, and malfunctioning. These vibration characteristics, their frequencies and the levels at which they occur are noted.
- 2) *Endurance (4.4)*. A random vibration is normally the best representation of an aircraft vibrational environment and is therefore preferred for the endurance stage of the test. There are alternative methods, however, and the individual specification must prescribe which of the following of these should be employed:
 - a) *Wide band random motion (4.4.2)*. Random vibration of prescribed spectrum level, frequency range, amplitude distribution and duration.
 - b) *Narrow band random motion (4.4.3)*. Narrow band random sweeps of prescribed level, bandwidth, amplitude, distribution, sweep rate, frequency range and duration.
 - c) *Sinusoid with frequency sweep (4.4.4)*. Sine wave sweeps of prescribed level, sweep rate, frequency range and duration.
 - d) *Sinusoid at resonance frequencies (4.4.5)*. Sine wave at selected resonance frequencies of prescribed level and duration.
- 3) *Final resonance search (4.5)*. After the endurance stage, the specimen is re-examined for correct functioning and for vibration characteristics as in the initial resonance search. The frequency for each effect determined in the initial and later in the final resonance search is compared. The individual specification may state what action should be taken if any change of frequency occurs.

Test procedures. In order to achieve a measure of standardization and to allow comparison of products of different manufacturers, testing programmes have been grouped into a number of separate, alternative procedures which should be selected and prescribed by the individual specification.

Although procedure (1) below should cover the majority of applications of the vibration test, the individual specification may allow certain modifications in specific cases.

1) The general and preferred test procedure is as follows:

Initial resonance search (4.3).

Endurance by wide band random vibration (4.4.2).

Final resonance search (4.5).

2) When procedure (1) is not applicable or cannot be followed, other test procedures which may be specified are:

a) Initial resonance search (4.3).

Endurance by narrow band random sweep (4.4.3).

Final resonance search (4.5).

Procedure *a* should only be used for specimens of a heterogeneous nature in which the simultaneous excitation of resonance frequencies that occurs with wide band random excitation may not result in higher stresses at any point than would occur if each resonance bandwidth were similarly but separately excited.

b) Initial resonance search (4.3).

Endurance by sinusoid with frequency sweep (4.4.4).

Final resonance search (4.5).

Procedure *b* is not recommended for specimens whose dynamic and fatigue characteristics are unknown since it may result in overtesting. It may, nevertheless, be used for such specimens if random vibration test equipment is not available.

c) Initial resonance search (4.3).

Endurance at resonance frequencies (4.4.5).

Final resonance search (4.5).

Procedure *c* is suitable only for specimens all of whose resonance frequencies are clearly evident.

Electrical and mechanical functioning of specimens. The specimen should be functioning during the initial and final resonance searches, and during the endurance test, if required by the individual specification.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 21 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This subsection of 3G 100-2 relates to tests for complete units of airframe equipment subjected to aircraft vibration.

2 Conditions for testing

2.1 Mounting

2.1.1 The specimen shall be mechanically connected to the vibration generator table either directly or by means of a fixture as specified below.

2.1.2 Mounting fixtures shall be such as to enable the specimen to be vibrated along the various axes specified in 4.2. With the specimen mounted, the requirements of 2.3.1 and 2.3.2 shall be met throughout the frequency range.

2.1.3 If it is necessary to provide brackets in order to connect the specimen [or the normal means of attachment of the specimen (see 2.2)] to the vibration generator the brackets shall be designed to be effectively rigid within the frequency range to be covered by the vibration tests.

2.2 Mounting of specimens

2.2.1 Specimens, with or without isolators, shall be fastened to the vibration generator table or fixtures by their normal means of attachment or terminations, or as stated in the individual specification. The use of any additional stays or straps shall be avoided. Any connections to the specimen (such as cables, pipes, wires, etc.) should be so arranged that they impose restraints typical of operational conditions.

2.2.2 A specimen intended for use with a vibration isolation system should normally be tested with its isolators. If it is not practicable to carry out the vibration test with the appropriate isolators, i.e. if the equipment is mounted with other equipments in a common mounting system, or if the dynamic characteristics of the isolators are very variable (e.g. temperature dependent), then it may be tested without the isolators at a different level of vibration. This level shall be determined by taking into account the most severe transmissibility function of the isolator system in each axis, as stated in the individual specification. The individual specification may require an additional test on a specimen with the external isolators removed in order to demonstrate the minimum acceptable structural resistance to vibration.

2.2.3 The individual specification shall state whether the effect of gravitational force is important. For this case the specimen shall be so mounted that the force acts in the same direction as it would in use. Where the gravitational force is not important, the specimen may be mounted in any attitude.

2.2.4 The relevant specification should state, if significant, the maximum level of magnetic interference to which the specimen under test may be subjected.

2.3 Vibration system

2.3.1 *Required characteristics.* The characteristics of the vibration generator when loaded for test shall be as stated in 2.3.1.1 to 2.3.1.4.

2.3.1.1 *Basic motion.* The vibration generator shall be capable of generating a motion such that the fixing points of the specimen are moving substantially in phase and in straight parallel lines.

2.3.1.2 *Transverse motion.* The maximum r.m.s. vibration level at the fixing points in any direction perpendicular to the intended direction including that due to rocking, torsional vibration, etc., shall not exceed 25 % of the specified vibration level.

NOTE In some cases, e.g. for large specimens, it may be difficult to achieve the figure of 25 %. In such cases the value should be noted and agreed.

2.3.1.3 *Distortion with sinusoidal excitation.* With the exception of the driving frequency, the total r.m.s. distortion of the acceleration at the fixing points of the specimen shall not exceed 25 % of the actual acceleration corresponding to the specified amplitude at the driving frequency. If this value is exceeded it shall be compensated for by increasing the driving amplitude so as to restore the amplitude at the fundamental frequency to the specified value. Where this cannot be done the distortion value shall be noted and agreed. The distortion measurement shall cover the frequency range up to 5 000 Hz or five times the driving frequency, whichever is the greater.

2.3.1.4 Selection of measuring and reference points. The test is controlled by measurements made at measuring and reference points related to the fixing points of the specimen.

1) *Fixing point.* A fixing point is the surface of the specimen in contact with the bracket or vibration table.

2) *Measuring point.* A measuring point is normally a fixing point. It shall be as close as possible to the fixing point and in any case should be rigidly connected to the fixing point.

If there are four or less fixing points, each shall be used as a measuring point. If there are more than four fixing points, four representative points shall be selected for use as measuring points.

NOTE For large specimens the relevant specification should designate the measuring points.

3) *Reference point.* The signal from the reference point is taken to represent the motion of the specimen. Unless otherwise specified in the relevant specification, the signal from the reference point shall be the average of the signals from the measuring points.

The relevant specification may call for the reference point to be one of the measuring points or may select some other point.

2.3.2 Vibration level tolerances

2.3.2.1 Random motion excitation. Equalization of the flat portion of the spectrum shall be within ± 3 dB of the prescribed values when measured with a narrow band analysis system. The overall r.m.s. vibration level for the flat portion of the spectrum shall not be less than the specified value. The test equipment shall be designed to have a Gaussian amplitude distribution but the peak to r.m.s. acceleration ratio need not exceed 3 to 1. The specified r.m.s. *g* level shall be within ± 1 dB.

NOTE The narrow band analysis system should have a resolution equal to or better than one-third octave for frequencies greater than 60 Hz. The frequency range up to 60 Hz should contain not less than four analysis bands.

2.3.2.2 Sinusoidal excitation. Monitoring shall be such that the actual vibration level in the required direction at the reference point is not less than the specified value but should be within the following tolerances:

displacement level $+15\%$, -0%

acceleration level $+10\%$, -0%

In some cases, e.g. for large specimens, it may be difficult to achieve the figures quoted at some discrete frequencies within the frequency range. In such cases it is expected that a wider tolerance or an alternative method of assessment will be specified.

2.3.3 Frequency tolerances

2.3.3.1 Measurement of frequency for resonance determination shall be made with an accuracy of $\pm 0.5\%$ or 0.5 Hz, whichever is the greater.

2.3.3.2 Frequency tolerances in other cases shall be ± 1 Hz up to 50 Hz and $\pm 2\%$ over 50 Hz.

2.3.4 Sweep method. A sweep is a traverse of the specified frequency range once in both directions, for example 10 Hz — 1 000 Hz — 10 Hz. The sweeping shall be continuous and logarithmic, and the sweep rate shall be approximately one octave per minute. A linear sweep approximation may be used provided the actual sweep rate does not exceed one octave per minute at any time and the dwell time in each octave above 60 Hz is approximately the same as with the logarithmic sweep. Whilst resonance search testing, it may be necessary to decrease sweep rate, or temporarily stop the sweep, particularly for low-frequency high-Q systems. However, undue dwell time on resonance should be avoided.

3 Severities

A vibration severity is defined by the combination of the parameters: frequency range, vibration level and duration. The vibration conditions in aircraft are divided into a number of categories each of which is associated with one or more flight conditions and equipment locations.

3.1 Equipment location. There are four equipment regions A, B, C, and D, as follows:

Region A. The extremities of the aircraft, and any part in which equipment is mounted close to the aircraft skin so that transmission paths from the structure to the equipment are short.

Region B. The central fuselage of the aircraft, but excluding parts of the central fuselage in which equipment is in Region A.

Region C. Equipment racks and instrument packs designed to hold a number of units whose location is within the fuselage but not on structure directly affected by the jet efflux.

Region D. Close proximity to a main power plant, but excluding direct contact with the power plant (which is not covered by this specification).

3.2 Vibration categories

3.2.1 Regions A and B. There are five vibration categories for Regions A and B, each of which is associated with a flat acceleration spectral density between lower and upper frequency limits f_1 and f_2 respectively (Figure 1). The acceleration spectral densities are:

Category	Acceleration spectral density (g^2/Hz)
1	0.001
2	0.005
3	0.01
4	0.02
5	0.05

The frequency limits f_1 and f_2 are determined for any category by the flight condition of the aircraft and the equipment location, as shown in Table 1.

3.2.2 Region C

3.2.2.1 Region C (civil). The constant spectral density for this region, Category 0, is shown in Figure 1 and has the value of $0.0005 \text{ g}^2/\text{Hz}$ between $f_1 = 10 \text{ Hz}$ and $f_2 = 500 \text{ Hz}$ with a decrease of 3 Db/octave from 500 Hz to 2 000 Hz. Levels for this region have been prepared from flight measurements and the endurance test duration for this region shall be 50 h at these levels.

3.2.2.2 Region C (military). (Under consideration: in the meantime it is suggested that the equipment be treated as for Region B.)

3.2.3 Region D. (Under consideration: in the meantime it is suggested that the equipment be treated as for Region A.)

3.3 Duration for specified service environment

3.3.1 The individual specification will state the expected life (in hours) which the equipment will spend in each of the flight conditions listed in Table 1.

3.3.2 The information given under **3.3.1** determines the severity of the vibration test.

3.3.3 The equipment region and duration of flight conditions given in the individual specification shall be converted, by means of the tables in **3.2.1**, **3.2.2** and **3.2.3** into total durations in each category within each frequency range.

3.3.4 The vibration endurance test shall have a 50-hour duration at a level appropriate to the most severe category of wide band random motion vibration given under **3.3.1**. However, where the service duration in the most severe category plus the equivalent duration in that category due to the remaining categories is t hours, where $t < 50$, the test duration shall be t hours.

If t_1 is the test duration at an acceleration spectral density of S_1 , then the duration t_2 of an equivalent test at a spectral density S_2 is given by:

$$t_2 = t_1 \left(\frac{S_1}{S_2} \right)^{2.5}$$

The acceleration spectral density levels given in **3.2** may be used directly in the formula for calculating the duration in one category which will be equivalent to a specified duration in any other.