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Environmental tests for aircraft equipment — Steady-state acceleration

Essais en environnement des équipements aéronautiques — Essais d'accélération constante

Reference number
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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 2669 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 5, *Environmental and operational conditions for aircraft equipment*.

This second edition cancels and replaces the first edition (ISO 2669:1978), of which it constitutes a technical revision.

Annex A forms an integral part of this International Standard.

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Introduction

The tests specified in this International Standard aim to determine the performance characteristics and to confirm the structural integrity and safety of airborne equipment and airborne equipment mountings when they are subjected to gradually changing acceleration forces generated by an aircraft manœuvre such as turn, pull-out, roll, etc. For example, the tests would be expected to indicate:

a) any change in operating state and any variations in performance;

b) any jamming occurring in moving parts and any variation in their path;

c) any reduction in the free travel and change in the suspension characteristics of the anti-vibration mountings that could damage the operating state and capability of anti-vibration;

d) any breakage or any weakness in the fastenings mounting devices or structure of the equipment that could constitute a hazard to the aircraft or its occupants.

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Environmental tests for aircraft equipment — Steady-state acceleration

1 Scope

This International Standard specifies two types of steady-state acceleration test and establishes five severity grades of acceleration forces used to simulate a gradually changing acceleration environment representative of that which civil aircraft equipment can encounter in operational use.

The emergency landing case is not within the scope of this International Standard; reference should be made to ISO 7137 for this case.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7137:—[1], *Aircraft — Environmental conditions and test procedures for airborne equipment.*

3 Apparatus

3.1 General characteristics

3.1.1 A centrifuge should be used for producing the required acceleration forces.

3.1.2 In special cases, if stated by the relevant equipment specification, inflight testing or any other method that can produce linear acceleration may be used instead of a centrifuge.

3.1.3 The apparatus shall be capable of producing the specified acceleration forces within ± 10 % at all points in the equipment.

3.1.4 The apparatus shall be fitted with the electrical, hydraulic and/or pneumatic input and output connections needed to operate the equipment under test and to conduct operational checks. The loss of the connections shall not exceed the limit specified in the relevant specification.

3.1.5 The test apparatus shall be equipped with an adjustable acceleration system, and any additional vibration due to the test apparatus shall be maintained within the tolerance specified in the relevant specifications.

3.1.6 The centrifuge shall be equipped with an adjustable mass balance system to compensate for any out-of-balance forces due to the mass of the test item.

3.2 Special cases

3.2.1 If, because of the excessive size of the equipment, it is not possible to maintain the tolerance specified in 3.1.3 at all points in the equipment, the relevant equipment specification may relax requirements on those parts not considered to be sensitive to specified acceleration forces.

1) To be published. (Revision of ISO 7137:1992)

3.2.2 During functional tests in vertical directions carried out with equipment sensitive to gravity or inversion and which could cause malfunctions, a special centrifuge, inflight test bed or other apparatus which reproduces the required acceleration shall be used.

3.2.3 Care should be taken when interpreting results of functional performance tests carried out on equipment subjected to acceleration tests using a centrifuge, if the equipment contains rotating parts with appreciable moments of inertia (e.g. a rate gyro). The relevant equipment specification shall state if the equipment may be tested on a centrifuge, if it is necessary to use other apparatus, or if special requirements for the tests need specifying.

3.2.4 Acceleration grade 0 is defined as a gradually changing acceleration which causes equipment to become weightless. For equipment sensitive to zero gravity, a special test procedure may be required and should be detailed in the relevant equipment specification.

3.3 Monitor system

3.3.1 An acceleration pickup, an angular velocity pickup or other method may be used to measure acceleration forces directly or indirectly. The accuracy of the acceleration measuring device shall be one-third of the tolerance specified in the relevant equipment specification or better. In some cases, several accelerometers may be located on the equipment under test to determine the acceleration at various places on the equipment.

3.3.2 When the acceleration is measured with an angular velocity pickup, the angular velocity may be defined by using the following equation:

$$n^2 = \frac{a}{0{,}0012d}$$

where

n is the rotational frequency of the arm, in revolutions per minute;

a is the acceleration value required by the test, in numbers of g (standard acceleration of free fall: $g_n = 9{,}806\ 65\ m/s^2$);

d is the distance, in metres, from the rotary shaft of the centrifuge to the position on the equipment under test at which the acceleration value a is to be applied.

3.3.3 When the acceleration is measured using an acceleration pickup, it may be located, in accordance with practice, at the geometric centre, the centre of mass, or the rotary surface, depending on the position of sensitive parts of the equipment under test.

4 Equipment mounting

4.1 Orientation

The equipment under test shall be mounted on the apparatus in such a way that it can be successively orientated in the six directions of acceleration defined by an orthogonal reference system. The relevant equipment specification shall define the reference system.

4.2 Mounting method

The orientation may be set by using an adjustable table which is integral with the apparatus or with a special fixture attached to the apparatus.

The equipment shall be attached to the adjustable table or fixture by its fastenings or mounting devices, as defined in the installation manual for the equipment.

If equipment fitted with an absorber is to be tested, the relevant equipment specification shall define whether the equipment should be installed together with the absorber on the centrifuge.

4.3 Supply connections

The connection and orientation to the equipment of any electrical, hydraulic or pneumatic supplies shall simulate as closely as possible those used in practice.

5 Classification of tests

5.1 Severity

The equipment shall be classified in accordance with the appropriate severity grade given in table 1 as a function of environmental and operational conditions. For light and transport aircraft, grade 1 or 2, as applicable, shall be stated in the relevant equipment specification.

Table 1 — Equipment severity grades

Equipement severity grade	Intended for installation in
0	Equipment subject to zero gravity (e.g. spacecraft)
1	Transport aircraft
2	Light aircraft
3	Helicopters
4	High-performance aircraft Aerobatic aircraft

5.2 Types of test

Two types of steady-state acceleration test are specified in table 2. The relevant equipment specification shall state which type of test is to be carried out.

Table 2 — Classification of tests

Type of test	Purpose and requirement of test
1 Functional	1) To check the good running order of the equipment under the imposed acceleration forces. 2) The equipment shall be in operation during the acceleration phase and the performance shall be monitored (see 8.1.2).
2 Structural	1) To check equipment for structural integrity under the imposed acceleration forces, i.e. for structural strength or stiffness of the equipment. 2) To check the equipment and its mounting for safety, i.e. for any structural damage that would constitute a hazard to the aircraft or its occupants. 3) Normally, the equipment shall not be in operation during the acceleration phase. Where it is essential for equipment to operate correctly in emergency situations (e.g. crash recorder) the performance of the equipment shall be monitored (see table 3, category C).

5.3 Categories of equipment

The equipment under the imposed acceleration forces shall be classified in accordance with requirements of function, structural integrity and safety as shown in table 3. The relevant equipment specification shall state the category of the equipment.

6 Test sequence

6.1 General case

For category A and category B equipment, the functional and structural integrity tests shall be carried out in the following order:

a) one functional test with performance check in accordance with 8.1 once in each of the six attitudes;

b) one structural integrity test with performance check in accordance with 8.2 once in each of the six attitudes.

For category C equipment, the functional and structural tests are identical.

6.2 Special cases

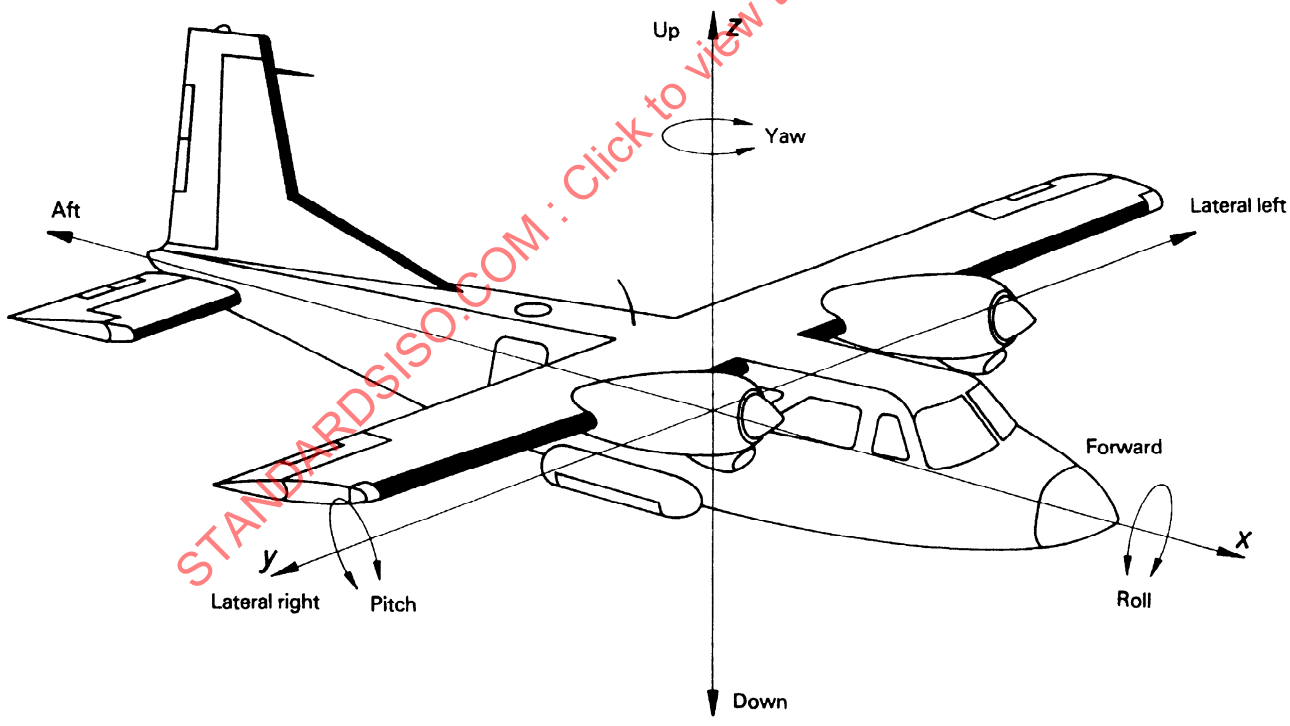
In order to reduce the number of operations necessary for re-orientating the equipment on the test apparatus, the structural integrity test may immediately follow the functional test unless prohibited by the relevant equipment specification.

7 Acceleration severity grades

Functional testing shall be carried out in accordance with table 4. Structural testing shall be carried out in accordance with table 5. Directions of the aircraft acceleration are shown in figure 1.

Table 3 — Equipment categories

Equipment category	Operational requirements	Test requirements	
		Functional test	Structural test
A	Equipment not required to function in manœuvre state.	Equipment required to operate before and after, but not during the acceleration phase.	Equipment not required to function during and after the acceleration phase, but which must remain free from structural damage that would cause hazard to aircraft or its occupants.
B	Equipment required to function reliably in manœuvre state.	Equipment required to function before, during and after the acceleration phase.	Equipment required to function before and after, but not during the acceleration phase. After the test, the structural integrity shall remain unimpaired.
C	Equipment required to function normally in emergency situations (for example crash recorder, safety devices, etc.).	Equipment required to be tested in accordance with more severe grade and to function before, during and after the acceleration phase.	Structural integrity and functional tests are required to be conducted together. After the test, the structural integrity shall remain unimpaired.



NOTE — For the "up" acceleration tests, mount the equipment in the centrifuge with the top of the equipment facing toward the centre of the centrifuge. For the "forward" acceleration tests, mount the front end of the equipment facing toward the centre of the centrifuge.

Figure 1 — Direction of aircraft acceleration

Table 4 — Acceleration severity grades (functional test)

Severity grade	Acceleration for arbitrarily mounted equipment		Acceleration for non-arbitrarily mounted equipment					
	Categories A and B	Category C	Categories A and B					Category C
			Forward	Aft	Up	Down	Lateral (left and right)	
1	4*g*	6*g*	1,5*g*	1,5*g*	3*g*	1,5*g*	1,5*g*	6*g*
2	7*g*	10*g*	2*g*	2*g*	4,5*g*	2*g*	2*g*	10*g*
3	8*g*	12*g*	2*g*	2*g*	6*g*	3*g*	4*g*	12*g*
4	10*g*	15*g*	2,5*g*	2,5*g*	8*g*	3,5*g*	4*g*	15*g*

NOTE — The acceleration for the non-arbitrarily mounted equipment categories A and B is that at the centre of gravity of the aircraft. For equipment severity grades 1, 2 and 4, the additional acceleration forces due to manœuvre loads for equipment not mounted at the centre of gravity can be calculated from the equation and correction methods specified in annex A.

Table 5 — Acceleration severity grades (structural test)

Severity grade	Acceleration for arbitrarily mounted equipment	Acceleration for non-arbitrarily mounted equipment				
	Categories A and B	Categories A and B				
		Forward	Aft	Up	Down	Lateral (left and right)
1	6*g*	2*g*	2*g*	4,5*g*	2*g*	2*g*
2	10*g*	3*g*	3*g*	7*g*	3*g*	3*g*
3	12*g*	3*g*	3*g*	9*g*	4,5*g*	6*g*
4	15*g*	4*g*	4*g*	12*g*	5,5*g*	6*g*

NOTES

1 For category C equipment, the structural test and functional test are identical. They shall be carried out using the acceleration for category C equipment given in table 4.

2 The acceleration value for non-arbitrarily mounted equipment categories A and B is that at the centre of the aircraft. For equipment severity grades 1, 2 and 4, the additional acceleration forces due to manœuvre loads for equipment not mounted at the centre of gravity can be calculated from the equation and correction methods specified in annex A.

8 Procedures

8.1 Functional test procedure (all categories)

The procedures specified in 8.1.1 to 8.1.4 shall be repeated in each of the six attitudes, unless the equipment under test is symmetrical in both structure and performance. In this case, it may be tested in only one of the six attitudes, provided the acceleration is that for the most severe mounting attitude.

The relevant equipment specification may waive the test requirement for any of the six attitudes in which the equipment is known to be insensitive to acceleration.

8.1.1 Initial measurements

Mount the equipment on the test apparatus. Carry out a visual check of the appearance and mounting attitudes of the equipment. Operate the equipment and check the electrical and mechanical performance parameters as stated in the relevant specification.

8.1.2 Acceleration test

Operate the equipment in accordance with the functional test given in the relevant equipment specification for a minimum period of 5 min. With the equipment still operating, progressively increase the acceleration to the severity grade specified for the equipment category over a minimum period of 15 s.

Maintain this acceleration for a minimum of 60 s during which time functional performance measurements should be made. Progressively decrease the acceleration to zero taking at least 15 s. Repeat the procedure for all attitudes specified by the relevant equipment specification.

8.1.3 Intermediate measurements

During the period of increasing or decreasing acceleration, the equipment operating state shall be monitored. During the period of constant acceleration, the performance parameters shall be checked for compliance with the requirements stated in the relevant specification.

8.1.4 Final measurement

After the test, put the equipment into operation. Check for electrical and mechanical performance parameters as stated in the relevant equipment specification. Category C equipment shall be checked visually for structural integrity and, where dimensions are critical, appropriate measurements should be made against the relevant equipment specification.

8.2 Structural test procedure (categories A and B)

The functional test procedure shall be applied (see 8.1).

8.2.1 Initial measurements

Carry out a visual check of the appearance and the mounting attitudes of the equipment.

8.2.1.1 There is no performance check for category A equipment.

8.2.1.2 Put category B equipment into operation and check the electrical and mechanical performance parameters as stated in the relevant equipment specification.

8.2.2 Acceleration test

With the equipment in its non-operating state, evenly increase acceleration to the value specified in the relevant equipment specification over a period greater than 15 s. Maintain this state for 15 s to 60 s, then evenly decrease acceleration to zero over a period greater than 15 s.

8.2.3 Intermediate measurements

During the test, there is usually no check for performance. If required, the intermediate measurement shall be conducted in accordance with the requirements specified in the relevant equipment specification.

8.2.4 Final measurements

For category A equipment, visually check the equipment and its mounting for structural damage that could constitute a hazard to the aircraft or its occupants. Where damage is evident, dimensions should be checked against the relevant equipment specification.

For category B equipment, visually check the structure for deformation, scratches, dents, cracks, or other changes that could affect structural integrity. Put the equipment into operation and check the electrical and mechanical performance parameters as specified in the relevant equipment specification.

9 Information to be included in the relevant equipment specification

When the test is a requirement in the relevant equipment specification, the following details shall be supplied, as far as they are applicable:

a) appropriate test apparatus (3.1.1 to 3.1.6);

b) relaxation of acceleration forces (3.2.1);

c) orientation of the equipment (4.1);

d) identification of any symmetry axes or sensitive axes in the equipment (8.1, 8.2);

e) indication of whether the equipment is sensitive to gravity, weightlessness and rotary motion (3.2.2, 3.2.3);

f) equipment mounting requirements (4.2, 4.3);

g) equipment severity grade and testing acceleration value (5.1, clause 7);

h) types of test (5.2);

i) equipment category (5.3);

j) essential performance parameters (including tolerances) to be checked during functional testing and critical dimensions to be maintained (8.1);

k) items to be checked in structural test tolerance and failure criteria including dimensions (8.2);

l) test sequence (clause 6);

m) variations in number of test attitudes (if necessary) (8.1, 8.2);

n) other special requirements.

Annex A
(normative)

Additional accelerations

The additional accelerations at a distance from the centre of gravity may be calculated as shown in table A.1 (see figure 1).

Table A.1 — Additional accelerations

Manœuvre	Equipment location	Additional acceleration or centripetal accelerations		Correction methods
		Direction	Equation	
Pitch	On the fuselage	Up and down	$\Delta a_{z\Theta} = \frac{d\ddot{\Theta}_{max}}{g_n}$ where $\Delta a_{z\Theta}$ is the additional acceleration induced by pitch change, in numbers of g; d is the fore or aft distance of equipment from the centre of gravity of the aircraft, in metres; $\ddot{\Theta}_{max}$ is the maximum pitch angular acceleration, in radians per second squared; g_n is the standard acceleration of free fall (g_n = 9,806 65 m/s^2).	For functional testing, the test levels specified in table 4 plus $\Delta a_{z\Theta}$. For structural testing, 1,5 times the new levels for functional testing.
		Forward and backward	$a_{x\Theta} = \frac{d\dot{\Theta}^2_{max}}{g_n}$ where $a_{x\Theta}$ is the centripetal acceleration induced by pitch change, in numbers of g; d is the fore or aft distance of equipment from the centre of gravity of the aircraft, in metres; $\dot{\Theta}_{max}$ is the maximum pitch angular velocity, in radians per second; g_n is the standard acceleration of free fall (g_n = 9,806 65 m/s^2).	For functional testing, if $a_{x\Theta}$ or $a_{x\Psi}$ calculated from the equations in this table are greater than the fore and aft test levels specified in table 4, then the greater of the two shall be used. For structural testing, 1,5 times the new test levels for functional testing.