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## Space systems — Acoustic testing

*Systèmes spatiaux — Essais acoustiques*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

# Space systems — Acoustic testing

## 1 Scope

This document provides guidance for test providers and interested parties to implement acoustic tests of aerospace systems, subsystems, modules and units for applicable spacecraft programs. This document specifies a framework to meet test and process requirements and acts as a supplement to ISO 15864.

The acoustic test system, the technical requirements and the procedures for acoustic tests in reverberant chambers are described. Furthermore, the criteria for the manual test interruption and evaluation are also described.

The technical requirements in this document can be tailored to fulfil the objectives of tests.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15864:2004, *Space systems — General test methods for space craft, subsystems and units*

ISO 14620, *Space systems — Safety requirements*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

### 3.1

#### **acoustic reverberation chamber**

acoustic chamber built in hard and highly reflective surface walls such that the sound field therein becomes diffused

### 3.2

#### **diffuse sound field**

sound field that has uniform energy density in a given region so that all directions of energy flux at all parts of the region are equally probable

### 3.3

#### **sound pressure**

$p$

root mean square value of instantaneous sound pressure over a given time interval, unless specified otherwise

Note 1 to entry: Normally given in Pa.

**3.4**  
**sound pressure level**  
**SPL**

$L_p$   
expressed by

$$L_p = 20 \lg(p/p_0)$$

where

$p$  is root mean square value of instantaneous *sound pressure* (3.3) over a given time interval (Pa);

$p_0$  is reference pressure at threshold (Pa),  $p_0 = 20 \mu\text{Pa}$ .

**3.5**  
**overall sound pressure level**  
**OASPL**

value computed from *one-third-octave* (3.13) or octave band sound pressure levels,  $L_i$

$$L_g = 10 \lg \sum_{i=1}^m 10^{L_i/10}$$

where

$L_g$  is the overall sound pressure level in dB;

$L_i$  is the *sound pressure level* (3.5) in one-third-octave or octave band;

$m$  is the number of one-third-octave or octave bands.

**3.6**  
**bandwidth**

difference between the nominal upper and lower cut-off frequencies

**3.7**  
**centre frequency**

geometric mean of the nominal cut-off frequencies of a pass-band

Note 1 to entry: The definition of *octave* (3.12) and third-octave bands preferred centre frequency values refers to ISO 266.

**3.8**  
**cut-off frequency of acoustic horn**

frequency below which an acoustic horn becomes increasingly ineffective

**3.9**  
**measurement point**

specific points spatially distributed in the sound field at which *sound pressure levels* (3.4) are measured during test

**3.10**  
**control point**

*measurement points* (3.9), spatially distributed inside the reverberant chamber, whose signals are used for the sound pressure level test control

**3.11**  
**multipoint control**

control achieved by using the average of the signals at the *control points* (3.10)

**3.12****octave****1/1 Oct**

interval between two *centre frequencies* (3.7) which have a ratio equal to 2

**3.13****one-third-octave****1/3 Oct**

interval between *centre frequencies* (3.7) which have a ratio equal to  $2^{1/3}$

**3.14****test level tolerances**

allowance of superior limit and inferior limit of a test level

**3.15****closed-loop control****feedback control**

system where the output acts upon the process in such a way as to reduce the difference between the measured value and the desired set-point value to zero

[SOURCE: ISO 16484-2:2004, 3.41]

**3.16****open-loop control**

control action not using any automatic means of deviations from the target value

**3.17****statistical DOF**

number of independent variables in an estimate of some quantity

**3.18****root mean square****RMS**

<of a time varying quantity> obtained by squaring the amplitude at each instant, obtaining the average of the squared values over the interval of interest and then taking the square root of this average

**3.19****power spectral density****PSD**

measure of the distribution of the energy (squared amplitude) of the signal as a function of frequency

**3.20****broadband reverberant field**

includes signals over a relative large frequency range of 22,5 Hz ~ 10 000 Hz (1/3 oct)

**4 Abbreviated terms**

All abbreviated terms in [Table 1](#) are applied to this document.

**Table 1 — Abbreviated terms**

Oct	Octave
DOF	Degree of freedom
PSD	Power spectral density
RMS	Root mean square
SPL	Sound pressure level
OASPL	Overall sound pressure level

## 5 Test purpose

The purpose of acoustic test is to demonstrate the ability of the test specimen to endure acoustic levels imposed by the launch vehicle and to validate unit random vibration test levels. Depending on the product development stage, it can include qualification of the design with margin, detection of workmanship defects, flaw of material and manufacturing failures.

There are two types of acoustic tests. The first test addresses the specimen functional compatibility with acoustic environment.

The second test addresses mechanical resistance of the structures. In this case, the use of accelerometers shall be required to measure responses to low levels before and after high load testing.

## 6 General

- a) If there is no condition for a reverberant field acoustic test (RFAT), a direct field acoustic test (DFAT) may be applied.
- b) For compact specimen, random vibration may replace the acoustic test if analysis and/or heritage data show that the payload responses are clearly dominated by random vibration compared to the acoustic field. It is important to make a decision knowing that vibration tests do not reach high frequency contents; whether the structure is sensitive to acoustic loads and the region that the equipment is embedded shall also be considered. The decision shall be made by customers.
- c) Generally, all structures and components requiring acoustic testing should be subjected to a broadband reverberant field. The corresponding acoustic random noise source shall have an approximate normal amplitude distribution.

## 7 Test system

### 7.1 Test facility

In general, an acoustic reverberation test facility is composed of a chamber system, gas supply system, sound source system, control system and measurement system. An example of acoustic reverberant test facility is shown in [Figure 1](#).

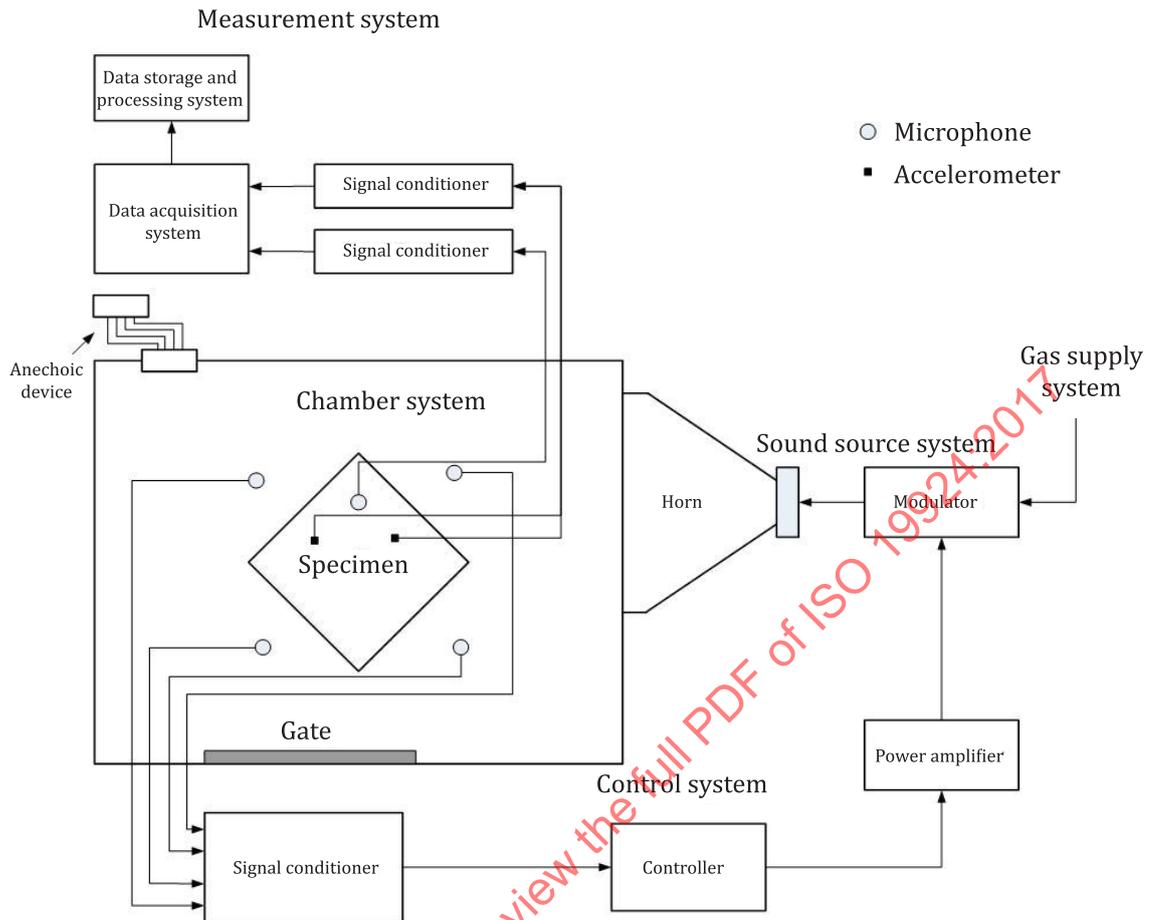


Figure 1 — General composition of the acoustic reverberation test facility

## 7.2 Equipment requirement

### 7.2.1 Chamber system

Chamber system general requirements are as follows.

- Generally, the shape of the chamber is a polyhedron. The surface of the reverberation chamber shall be smooth and rigid enough.
- The maximum OASPL of the chamber system shall be higher than the requirement of the tests to be performed.
- The chamber shall have enough channels that are connected to the control and measurement system outside the chamber to meet the requirement of the customers.
- The volume of the reverberation chamber should be 10 times bigger than the volume of the test specimen if it is possible. In all cases, the volume of the reverberation chamber shall be large enough to achieve the adequate test environment taking into account the volume of the test specimen. The geometrical size of the reverberation chamber also defines the homogeneity of the SPL in the low frequency third-octave bands. Chamber size shall be considered when low-frequency noise loading is an essential test objective.

### 7.2.2 Sound source system

Generally, the sound source system is composed of modulators, power amplifiers and horns.

- a) The achievable sound spectrum shall meet the test requirements.
- b) Taking into account the reverberation time of the chamber and the additional damping of acoustic modes introduced by test articles and test installations, the sound power of the sound source system (i.e. number and type of the sound modulators and horns) shall meet the test requirements.
- c) The operational frequency range of the modulators and power amplifiers shall meet the test requirements.
- d) In order to well represent the broadband frequency test requirements, different cut-off frequency horns can be used.

### 7.2.3 Control system

Generally, the control system is composed of the controller, the control microphones and signal conditioners or signal pre-amplifiers.

- a) The control system shall have the function of multi-inputs average control.
- b) The control system shall be able to store controlled time history of SPL.
- c) The control system should allow calibration.
- d) The measurement range of the microphones shall meet the test requirements.
- e) 1/1 octave or 1/3 octave closed-loop control or open-loop control method may be used.
- f) It should be possible to control power spectral density on an equal scale according to the test requirements.
- g) The control system should have the function to interrupt the test in adequate sequence when needed.

### 7.2.4 Measurement system

Generally, the measurement system is composed of sensors, signal conditioners, data acquisition system, data storage and processing system.

- a) The measurement system shall be able to acquire accelerometers, microphones and other required sensors, e.g. strain gauges and force sensors. The frequency range of the accelerometers, strain gauges and force sensors should be at least 10 Hz ~ 2 000 Hz. For microphones, the range should be at least 10 Hz ~ 12 000 Hz.
- b) The data acquisition system shall have enough measurement channels to meet the requirement of the customers.
- c) Measurement uncertainties shall meet the requirements of the customers.

All equipment shall be calibrated and used in the valid period.

## 8 Test technical requirements

### 8.1 Laboratory environment

The laboratory environment shall follow the requirements of the related technical documents.

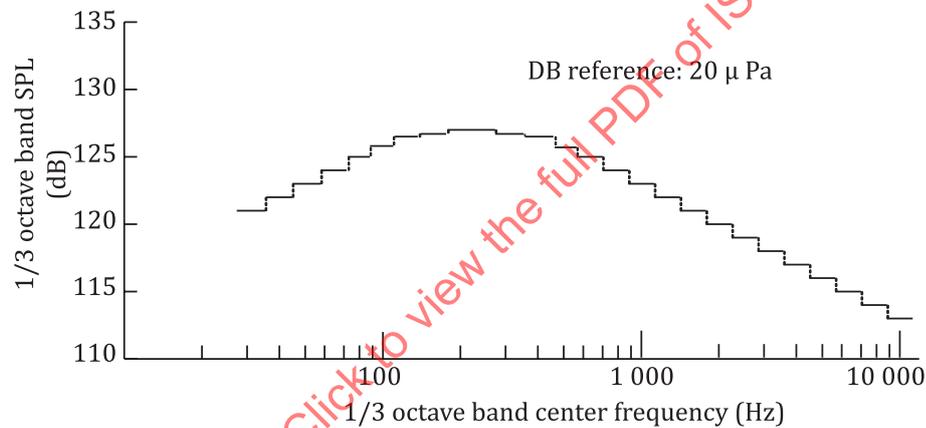
## 8.2 Test condition and tolerance

### 8.2.1 Test condition

Test condition is specified in the respective launch vehicle user manual and design standard, generally including

- octave band or 1/3 octave band centre frequency,
- spectral SPL,
- OASPL,
- test level tolerance, reference to [8.2.3](#), and
- test duration, etc.

As an example, the acoustic test level could be 138 dB OASPL with the 1/3 octave band sound pressure level as plotted in [Figure 2](#).



Curve values					
1/3 octave band center frequency (Hz)	Minimum SPL (dB)	1/3 octave band center frequency (Hz)	Minimum SPL (dB)	1/3 octave band center frequency (Hz)	Minimum SPL (dB)
31	121	250	127	2 000	120
40	122	315	126,7	2 500	119
50	123	400	126,5	3 150	118
63	124	500	125,7	4 000	117
80	125	630	125	5 000	116
100	125,7	800	124	6 300	115
125	165,5	1 000	123	8 000	114
160	126,7	1 250	122	10 000	113
200	127	1 600	121	Overall	138

Figure 2 — Exemplary acoustic level

### 8.2.2 Fill effect

The acoustic sound pressure level in the area between the payload and the payload fairing increases as the gap decreases. This increase in acoustic pressure levels due to payload fill effects has been measured in tests. Thus for large payloads, a fill factor is often used to adjust the acoustic test level for this effect. The fill factor shall be taken out of the customer specification. For information, the calculation of the fill factor is referred to in [Annex A](#).

### 8.2.3 Test level tolerances

The tolerances shall follow the requirements of the related technical documents, if not specified otherwise, the following test level tolerances can be used.

- a) Octave band
  - 63 Hz ~ 2 000 Hz: -3 dB ~ +3 dB.
  - 31,5 Hz, 4 000 Hz ~ 8 000 Hz: -5 dB ~ +5 dB.
  - OASPL: -1,5 dB ~ +1,5 dB.
- b) 1/3 Octave band
  - 22,5 Hz ~ 40 Hz: -5 dB ~ +5 dB.
  - 50 Hz ~ 2 000 Hz: -3 dB ~ +3 dB.
  - 2 250 Hz ~ 10 000 Hz: -5 dB ~ +5 dB.
  - OASPL: -1,5 dB ~ +1,5 dB.
- c) Test duration: -0 % ~ +10 %.
- d) Statistical DOF:  $\geq 100$ .

### 8.3 Specimen configuration requirements

The specimen configuration shall be as described in ISO 15864:2004, 7.15.3 to 7.15.6.

### 8.4 Specimen installation requirements

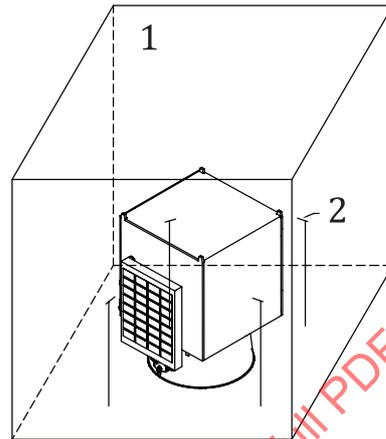
- a) The specimen should be supported in the nominal centre of the reverberation chamber. The main surfaces of the specimen should not be parallel to any chamber surface. The distance between the specimen's exterior surface and the corresponding wall of chamber shall be not less than 1,0 m.
- b) All exterior surfaces of the specimen shall be exposed to the acoustic field without any sheltering.
- c) Acoustic tests in a reverberation chamber should be conducted with the test specimen in the launch configuration mounted on a test fixture simulating the dynamic flight mounting conditions, but being low frequency decoupled from the chamber floor and wall structure born vibration. The resonance frequency of the mounting system for the specimen should be small enough to avoid the coupling effect between the specimen and acoustic chamber, for example, lower than 25 Hz or 1/4 of the minimum interested resonant frequency of objectives, whichever is less.
- d) The cables or any other attachments connecting to the specimen shall not generate additional restriction and sound source.
- e) The specimen should be electrically grounded and the grounding resistance should not be higher than 1  $\Omega$ .

### 8.5 Control requirements

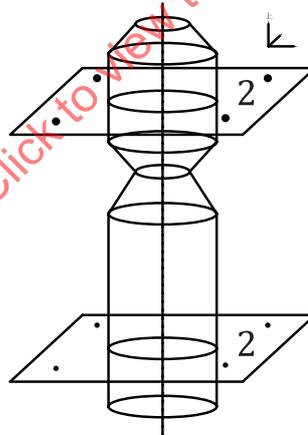
The control requirements of acoustic test are as follows.

- a) A minimum of three control microphones should be utilized.
- b) Control microphones shall be located in proximity to each major dissimilar face of the specimen at a minimum distance of 0,5 m. The distance can be 1 m if the specimen's exterior surface is more than 2,0 m far away from the corresponding wall of chamber.

- c) In addition, the control microphones should be located at the medium height of the specimen and within one plane that is perpendicular to the specimen's vertical axis. For special applications, microphones may be located within two or more planes perpendicular to the specimen's vertical axis. Microphones should be distributed equally in each plane. An example of microphones' distribution is shown as [Figure 3](#).
- d) Microphones may be located in other positions according to special test requirements.
- e) The mean-square value of signals from all control microphones in each frequency band shall be used for the control.



a) Microphones position of four points average controlling



b) Microphones position of eight points average controlling

**Key**

- 1 acoustic chamber  
2 microphone

**Figure 3 — Examples of microphone distribution**

## 8.6 Measurement requirements

### 8.6.1 Structure response measurement

The requirements of structure response measurement are as follows.

- a) If required, the monitoring of the specimen vibration should be performed on the basis of acceleration and/or strain measurements. Interface loads, displacement or velocity response may also be monitored.
- b) The monitoring equipment shall be capable of measuring overall vibration response with the upper frequency larger than 2 000 Hz. This instrumentation shall have a nominally flat frequency response over the frequency range of interest and be suitable for the application and the type of measurement. The average analysis times should be sufficiently longer to ensure the confidence; statistic DOF should be greater than 100.

### 8.6.2 Sound measurement

The requirements of sound measurement are as follows.

- a) The sound measurement system shall be capable of measuring sound pressure levels in the frequency range between 22,4 Hz and 11 200 Hz in either octave or third-octave bands, with centre frequencies between 31,5 Hz/25 Hz (octave/third-octave) and 8 000 Hz/10 000 Hz (octave/third-octave).
- b) The microphones shall be capable of random incidence measurements. They shall be capable of measuring peak values of at least three times the maximum RMS value.
- c) The instrumentation shall be capable of measuring sound pressure levels at least 10 dB higher than the specified test level. This capability refers both to the overall level and to individual frequency band levels.
- d) Uncertainty of the measurements shall be better than 1 dB.

## 8.7 Safety

The requirements of safety are as follows.

- a) Test operators shall be technically trained and qualified.
- b) The specimen's technical and safety status should be confirmed before the test.
- c) All test operators shall manipulate test equipment according to the relevant operating rules and shall follow technical safety rules.
- d) The specimen's placement, suspending, transporting and installation shall follow relevant rules.

The safety requirements of ISO 14620 shall be applied.

## 9 Test procedure

### 9.1 Test flow

The acoustic test includes three stages: before the test, test implementation and after the test, as shown in [Figure 4](#).

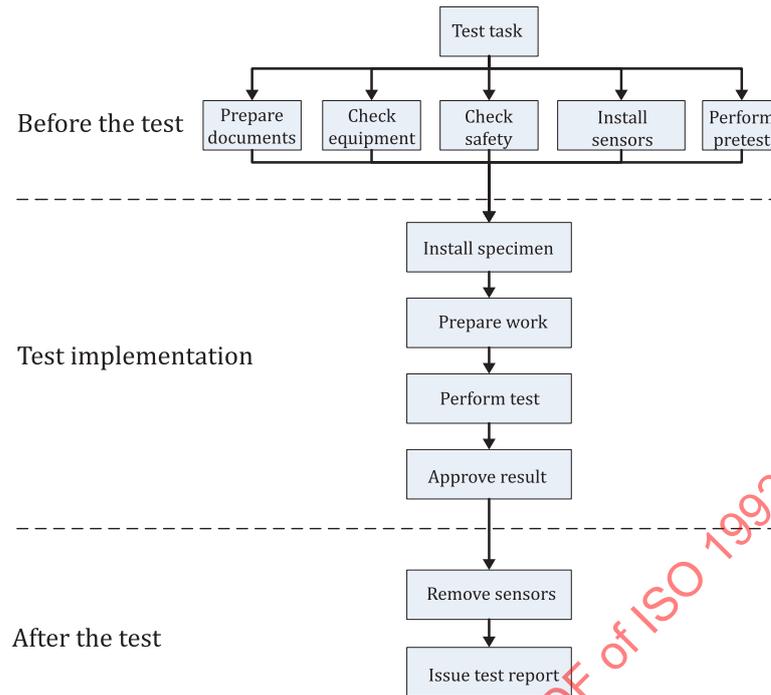


Figure 4 — Test flow

## 9.2 Test procedure

If not specified otherwise, the following requirements should be applied.

### 9.2.1 Before the test

#### 9.2.1.1 Preparation of the test documents

According to the outline requirements, the test documents shall be prepared according to ISO 15864:2004, 4.9. The test documents should be reviewed by the customer.

#### 9.2.1.2 Equipment check

- The test setup shall be as specified in the test requirements.
- It shall be ensured that the performance capability of the test equipment meets the test requirements.
- All the equipment shall be calibrated and used in the valid period.

#### 9.2.1.3 Safety check

- Functional check of the emergency power supply system of the laboratory shall be performed.
- Safety check of the test equipment shall be performed.
- Item check shall be performed to verify if there are any explosive, combustible, poisonous materials or high pressure vessels on the specimen so that appropriate safety measures can be taken.

#### 9.2.1.4 Installation of the sensors

Sensors shall be installed and checked according to the test procedure.

#### 9.2.1.5 Pretest

##### 9.2.1.5.1 Pretest with empty chamber

The spectrum of pretest shall meet the test requirements. During the pretest, the position of the microphones shall be identical with that of the actual test.

##### 9.2.1.5.2 Pretest with tested specimen

If required, the tested specimen shall be pretested with low sound pressure level (6 dB below the test sound pressure level). The absorption due to the specimen itself shall be evaluated and its value shall be included in the acoustic spectrum applied during the pretest with the empty specimen.

#### 9.2.2 Test implementation

If not specified otherwise, the following requirements should be applied.

- a) The test specimen shall be positioned in accordance with [8.4](#).
- b) Visual inspection and function test of the specimen should be performed.
- c) For the microphones for control, monitoring shall be installed in accordance with [8.5](#).
- d) The parameters of the control and measurement systems shall be set and the readiness of all systems for the test shall be verified.
- e) Pretest should be performed to measure the structure response and to check the control and measurement systems.
- f) The test spectrum shall be applied for the specified time. During the tests, the test specimen shall be operated in a duty cycle typical of that to be employed at launch and during boost and monitored to verify that interface and interoperability requirements are met.
- g) The test result shall be evaluated against pass-fail criteria according to test requirements.
- h) Consider the positioning of accelerometers to demonstrate structural integrity, low level reference runs before and after testing.

#### 9.2.3 After the test

- a) Visual inspection of the specimen should be performed.
- b) The measurement cables, microphones and supports shall be removed.
- c) The specimen shall be removed out of the chamber.
- d) The data shall be processed and the test reports shall be issued.

### 10 Test interruption and handling

#### 10.1 Test interruption

If the following situations appear, the test shall be interrupted.

- a) test equipment failure;

- b) the technical requirements cannot be met because of over or under test;
- c) specimens or ground test equipment failure.

## 10.2 Interruption handling

Interruption handling follows these principles.

- a) If the test is interrupted because of test equipment failure, the test should only be continued after the failure had been eliminated and it is made sure there is no effect on the specimen.
- b) The test shall be interrupted if the technical requirements cannot be met because of over or under test. After finding out the reason, the parameters should be reset and the test should be performed again. For under test, the test duration before interruption is invalid. For over test, it shall be ensured there is no effect on the specimen and the test may be restarted from the interruption point (The test duration is the total of the duration before and after the interruption).
- c) If the test is interrupted because of specimens or ground test equipment failure, the test should only be continued after the interference or failure had been eliminated.

## 11 Test data and result evaluation

### 11.1 Test data

Generally, acoustic test data are as follows:

- a) control and measurement microphone curves;
- b) structure response of the test specimen;
- c) environment data of laboratory;
- d) status data of the equipment;
- e) status data of the test specimen.

Test data requirements shall be compliant to ISO 15864:2004, 4.9.5.

### 11.2 Result evaluation

After test, the results should be evaluated according to the following criteria:

- a) conformance of the control results with the test requirements;
- b) conformance of the measurement results with the test requirements;
- c) conformance of the overall results with the test objectives.

## 12 Test documents

Test documentation shall be compliant to ISO 15864:2004, 4.9.