BS EN 61373:2010

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BSI Standards Publication

Railway applications — Rolling stock equipment — Shock and vibration tests

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National foreword

This British Standard is the UK implementation of EN 61373:2010. It is identical to IEC 61373:2010. It supersedes BS EN 61373:1999 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/9, Railway Electrotechnical Applications, to Subcommittee GEL/9/2, Railway Electrotechnical Applications - Rolling stock.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Amendments/corrigenda issued since publication

Date	Text affected
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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 61373

September 2010

ICS 45.060

Supersedes EN 61373:1999

English version

Railway applications -
Rolling stock equipment -
Shock and vibration tests
(IEC 61373:2010)

Applications ferroviaires -
Matériel roulant -
Essais de chocs et vibrations
(CEI 61373:2010)

Bahnanwendungen –
Betriebsmittel von Bahnfahrzeugen –
Prüfungen für Schwingen und Schocken
(IEC 61373:2010)

This European Standard was approved by CENELEC on 2010-09-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 9/1386/FDIS, future edition 2 of IEC 61373, prepared by IEC TC 9, Electrical equipment and systems for railways, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61373 on 2010-09-01.

This European Standard supersedes EN 61373:1999.

The main technical changes with regard to the EN 61373:1999 are as follows:

– change of the method to calculate the acceleration ratio which has to be applied to the functional ASD value to obtain the simulated long-life ASD value;

– addition of the notion of partially certified against this standard;

– suppression of Annex B of the EN 61373:1999 due to the new method to calculate the acceleration ratio;

– addition of guidance for calculating the functional RMS value from service data or the RMS value from ASD levels of Figures 2 to 5.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-06-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-09-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61373:2010 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application 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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60068-2-27	2008	Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock	EN 60068-2-27	2009
IEC 60068-2-47	2005	Environmental testing - Part 2-47: Tests - Mounting of specimens for vibration, impact and similar dynamic tests	EN 60068-2-47	2005
IEC 60068-2-64	2008	Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance	EN 60068-2-64	2008
ISO 3534-1	2006	Statistics - Vocabulary and symbols - Part 1: General statistical terms and terms used in probability	-	-

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INTRODUCTION

This standard covers the requirements for random vibration and shock testing items of pneumatic, electrical and electronic equipment/components (hereinafter only referred to as equipment) to be fitted on to railway vehicles. Random vibration is the only method to be used for equipment/component approval.

The tests contained within this standard are specifically aimed at demonstrating the ability of the equipment under test to withstand the type of environmental vibration conditions normally expected for railway vehicles. In order to achieve the best representation possible, the values quoted in this standard have been derived from actual service measurements submitted by various bodies from around the world.

This standard is not intended to cover self-induced vibrations as these will be specific to particular applications.

Engineering judgement and experience is required in the execution and interpretation of this standard.

This standard is suitable for design and validation purposes; however, it does not exclude the use of other development tools (such as sine sweep), which may be used to ensure a predetermined degree of mechanical and operational confidence. The test levels to be applied to the equipment under test are dictated only by its location on the train (i.e. axle, bogie or body-mounted).

It should be noted that these tests may be performed on prototypes in order to gain design information about the product performance under random vibration. However, for test certification purposes the tests have to be carried out on equipment taken from normal production.

RAILWAY APPLICATIONS – ROLLING STOCK EQUIPMENT – SHOCK AND VIBRATION TESTS

1 Scope

This International Standard specifies the requirements for testing items of equipment intended for use on railway vehicles which are subsequently subjected to vibrations and shock owing to the nature of railway operational environment. To gain assurance that the quality of the equipment is acceptable, it has to withstand tests of reasonable duration that simulate the service conditions seen throughout its expected life.

Simulated long-life testing can be achieved in a number of ways each having their associated advantages and disadvantages, the following being the most common:

a) amplification: where the amplitudes are increased and the time base decreased;
b) time compression: where the amplitude history is retained and the time base is decreased (increase of the frequency);
c) decimation: where time slices of the historical data are removed when the amplitudes are below a specified threshold value.

The amplification method as stated in a) above, is used in this standard and together with the publications referred to in Clause 2; it defines the default test procedure to be followed when vibration testing items for use on railway vehicles. However, other standards exist and may be used with prior agreement between the manufacturer and the customer. In such cases test certification against this standard will not apply. Where service information is available tests can be performed using the method outlined in Annex A. If the levels are lower than those quoted in this standard, equipment is partially certified against this standard (only for service conditions giving functional test values lower than or equal to those specified in the test report).

Whilst this standard is primarily concerned with railway vehicles on fixed rail systems, its wider use is not precluded. For systems operating on pneumatic tyres, or other transportation systems such as trolleybuses, where the level of shock and vibration clearly differ from those obtained on fixed rail systems, the supplier and customer can agree on the test levels at the tender stage. It is recommended that the frequency spectra and the shock duration/amplitude be determined using the guidelines in Annex A. Equipment tested at levels lower than those quoted in this standard cannot be fully certified against the requirements of this standard.

An example of this is trolleybuses, whereby body-mounted trolleybus equipment could be tested in accordance with category 1 equipment referred to in the standard.

This standard applies to single axis testing. However multi-axis testing may be used with prior agreement between the manufacturer and the customer.

The test values quoted in this standard have been divided into three categories dependent only upon the equipment's location within the vehicle.

Category 1 Body mounted

<u>Class A</u> Cubicles, subassemblies, equipment and components mounted directly on or under the car body.

Class B Anything mounted inside an equipment case which is in turn mounted directly on or under the car body.

NOTE 1 Class B should be used when it is not clear where the equipment is to be located.

Category 2 Bogie mounted

Cubicles, subassemblies, equipment and components which are to be mounted on the bogie of a railway vehicle.

Category 3 Axle mounted

Subassemblies, equipment and components or assemblies which are to be mounted on the wheelset assembly of a railway vehicle.

NOTE 2 In the case of equipment mounted on vehicles with one level of suspension such as wagons and trucks, unless otherwise agreed at the tender stage, axle mounted equipment will be tested as category 3, and all other equipment will be tested as category 2.

The cost of testing is influenced by the weight, shape and complexity of the equipment under test. Consequently at the tender stage the supplier may propose a more cost-effective method of demonstrating compliance with the requirements of this standard. Where alternative methods are agreed it will be the responsibility of the supplier to demonstrate to his customer or his representative that the objective of this standard has been met. If an alternative method of evaluation is agreed, then the equipment tested cannot be certified against the requirement of this standard.

This standard is intended to evaluate equipment which is attached to the main structure of the vehicle (and/or components mounted thereon). It is not intended to test equipment which forms part of the main structure. Main structure in the sense of this standard means car body, bogie and axle. There are a number of cases where additional or special vibration tests may be requested by the customer, for example:

a) equipment mounted on, or linked to, items which are known to produce fixed frequency excitation;
b) equipment such as traction motors, pantographs, shoegear, or suspension components which may be subjected to tests in accordance with their special requirements, applicable to their use on railway vehicles. In all such cases the tests carried out should be dealt with by separate agreement at the tender stage;
c) equipment intended for use in special operational environments as specified by the customer.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-47:2005, *Environmental testing – Part 2-47: Tests – Mounting of specimens for vibration, impact and similar dynamic tests*

IEC 60068-2-64:2008, *Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance*

ISO 3534-1:2006, *Statistics – Vocabulary and symbols – Part 1: Probability and general statistical terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60068-2-64 and in ISO 3534-1 apply as well as the following.

3.1
random vibrations
a vibration the instantaneous value of which cannot be precisely predicted for any given instant of time

3.2
Gaussian distribution ; normal distribution
a Gaussian, or normal, distribution has a probability density function equal to (see Figure 1):

$$P_x(x) = \frac{1}{\sigma\sqrt{2.\pi}} \cdot e^{\frac{-(x-\bar{x})^2}{2.\sigma^2}}$$

where:

c is the r.m.s value;

x is the instantaneous value;

$\bar{x}$ is the mean value of x.

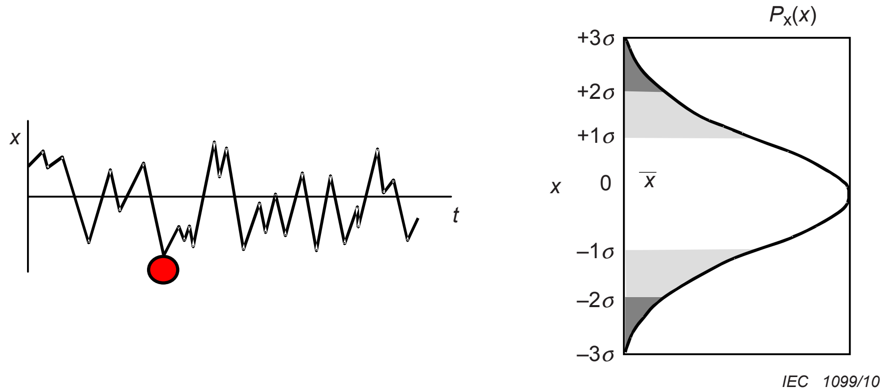


Figure 1 – Gaussian distribution

NOTE According to Figure 1, the probability that the instantaneous acceleration value is between ± a is equal to the zone under the probability density curve $P_x(x)$. This means that the instantaneous acceleration value between:

- 0 and 1σ represents 68,26 % of the time,
- 1σ and 2σ represents 27,18 % of the time,
- 2σ and 3σ represents 4,30 % of the time.

3.3
Acceleration Spectral Density
ASD
mean-square value of that part of an acceleration signal passed by a narrow-band filter of a centre frequency, per unit bandwith, in the limit as the bandwith approaches zero and the averaging time approaches infinity

3.4
components
pneumatic, electrical, or electronic parts located inside a cubicle

3.5
cubicle
whole equipment, including mechanical parts and especially the structure (e.g. converter, inverter, etc.) composed of mounted components

4 General

This standard is intended to highlight any weakness/error which may result in problems as a consequence of operation under environments where vibration and shock are known to occur in service on a railway vehicle. This is not intended to represent a full life test. However, the test conditions are sufficient to provide some reasonable degree of confidence that the equipment will survive the specified life under service conditions.

Compliance with this standard is achieved if the criteria in Clause 13 are met.

The test levels quoted in this standard have been derived from environmental test data, as referred to in Annex A. This information was submitted by organizations responsible for collecting environmental vibration levels under service conditions.

The following tests are mandatory for compliance with this standard:

Functional random test	The functional ramdom test levels are the minimum test levels to be applied in order to demonstrate that the equipment under test is capable of functioning when subjected to conditions which are likely to occur in service, on railway vehicles. The degree of functioning shall be agreed between the manufacturer and the end user prior to tests commencing (see 6.3.2). Functional test requirements are detailed in Clause 8. The functional tests are not intended to be a full performance evaluation under simulated service conditions.
Simulated long-life test	This test is aimed at establishing the mechanical integrity of the equipment at increased service levels. It is not necessary to demonstrate ability to function under these conditions. Simulated long-life testing requirements are detailed in Clause 9.
Shock testing	Shock testing is aimed at simulating rare service events. It is not necessary to demonstrate functionality during this test. It will however be necessary to demonstrate that no change in operational state occurs, that there is no visual deformation and that mechanical integrity has not changed. These points shall be clearly demonstrated in the final test report. Shock testing requirements are detailed in Clause 10.

5 Order of testing

A possible order of testing is as follows:

Vertical, transverse and longitudinal simulated long-life testing by increased random vibration; followed by vertical, transverse and longitudinal shock testing; followed by transportation and handling (when identified/agreed) and finally by vertical, transverse and longitudinal functional random testing.

NOTE Transportation and handling tests are not a requirement of this standard, and are therefore not included in this standard.

The order of testing may be altered to minimize re-jigging. The order of testing shall be recorded in the report. Performance tests in accordance with 6.3.3 shall be undertaken before and after simulated long-life testing, during which time transfer functions shall be taken for comparison purposes in order to establish if any changes have taken place as a result of the simulated long-life testing.

The orientation and direction of excitation shall be stated in the test specification and included in the report.

6 Reference information required by the test house

NOTE 1 Additional general information can be found in IEC 60068-2-64.

NOTE 2 For general mounting of components refer to IEC 60068-2-47.

6.1 Method of mounting and orientation of equipment under test

The equipment under test shall be mechanically connected to the test machine by its normal devices of attachment, including any resilient mount, either directly or by utilising a fixture.

As the method of mounting can significantly influence the results obtained, the actual method of mounting shall be clearly identified in the test report.

Unless otherwise agreed it is preferred that the equipment shall be tested in its normal working orientation with no special precautions taken against the effects of magnetic interference, heat or any other factors upon the operation and performance of the equipment under test.

Wherever possible, the fixture shall not have a resonance within the test frequency range. When resonances are unavoidable, the influence of the resonance on the performance of the equipment under test shall be studied and identified in the report.

6.2 Reference and check points

The test requirements are confirmed by measurements made at a reference point and, in certain cases, at check points, related to the fixing points of the equipment.

In the case of large numbers of small items of equipment mounted on one fixture, the reference and/or check points may be related to the fixture rather than to the fixing points of the equipment under test, provided the lowest resonant frequency of the loaded fixture is higher than the upper test frequency limit.

6.2.1 Fixing point

A fixing point is a part of the equipment under test in contact with the fixture or vibration testing surface at a point where the equipment is normally fastened in service.

6.2.2 Check point

A check point shall be as close as possible to a fixing point and in any case shall be rigidly connected to it. If four or less fixing points exist, each one is defined as a check point. The vibration at these points shall not fall below the specified minimum limits. All check points shall be identified in the test report. In the case of small items of equipment where the size, weight and complexity of the mechanical structure do not merit multipoint checking, the report shall identify how many check points were used and their locations.

6.2.3 Reference point

The reference point is the single point from which the reference signal is obtained in order to confirm the test requirements, and is taken to represent the motion of the equipment under test. It may be a check point or a fictitious point created by manual or automatic processing of the signals from the check points.

For random vibration if a fictitious point is used, the spectrum of the reference signal is defined as the arithmetic mean at each frequency of the acceleration spectral density (ASD) values of the signals from all check points. In this case, the total r.m.s. value of the reference signal is equivalent to the root mean square of the r.m.s. values of the signals from the check points.

Total r.m.s. value of the reference point = $\sqrt{\dfrac{\Sigma_{i=1}^{i=n_c}(r.m.s._i)^2}{n_c}}$

where n_c is the number of check points.

The report shall state the point used and how it was chosen. It is recommended that for large and/or complex equipment a fictitious point is used.

NOTE Automatic processing of the signals from the check points using a scanning technique to create the fictitious point is permitted for confirmation of the total r.m.s. acceleration. However, it is not permitted for confirmation of the ASD level without correcting for such sources of error as analyzer bandwidth, sampling time, etc.

6.2.4 Measuring point

A measuring point is a specific location on the equipment under test at which data is gathered for the purpose of examining the vibration response characteristics of the equipment. A measuring point is defined before commencing the tests detailed in this standard (see Clause 7).

6.3 Mechanical state and functioning during test

6.3.1 Mechanical state

If the equipment under test has more than one mechanical condition in which it could remain for long periods when fitted to a railway vehicle, two mechanical states shall be selected for test purposes. At least one of the worst states shall be selected (for example, in the case of a contactor, the mechanical state which affords the least clamping pressure).

When more than one state exists, the equipment under test shall spend equal time in both states selected during vibration and shock testing, the levels of which are as specified in Clauses 8, 9 and 10.

6.3.2 Functional tests

If required, the functional tests shall be specified by the manufacturer and agreed between manufacturer and customer prior to commencement of the tests. They shall be carried out during the vibration tests at the levels stated in Clause 8 of this standard.

Functional tests are aimed at verifying the operational capability and are not to be confused with performance tests. They are only intended to demonstrate a degree of confidence that the equipment under test will perform in service.

NOTE 1 Functional tests will not be conducted during shock testing unless previously agreed between the manufacturer and end user.

NOTE 2 In the case where the functional tests are modified, this has to be detailed in the report.

6.3.3 Performance tests

Performance tests shall be carried out prior to commencement, and upon completion of all the tests specified. The performance test specification shall be defined by the manufacturer and shall include tolerance limits.

6.4 Reproducibility for random vibration tests

Random vibration signals are not repeatable in the time domain; no two similar length time samples from a random signal generator can be overlaid and shown to be identical. Nevertheless it is possible to make statements about the similarity of two random signals and set tolerance bands on their characteristics. It is necessary to define a random signal in a way which ensures that should the test be repeated at a later date, by a different test house or on a different item of equipment, the excitation is of a similar severity. It should be noted that all the following tolerance boundaries include instrumentation errors but exclude other errors, specifically random (statistical) errors and bias errors. The measurements are taken at the check/reference point(s).

6.4.1 Acceleration spectral density (ASD)

The ASD shall be within ±3 dB (range ½ × ASD to 2 × ASD) of the specified ASD levels as shown in the appropriate Figures 2 to 5. The initial and final slope should not be less than those shown in Figures 2 to 5.

6.4.2 Root mean square value (r.m.s.)

The r.m.s. of the acceleration at the reference point over the defined frequency range shall be that specified in Figures 2 to 5 ± 10 %.

NOTE With respect to the low frequency content it may be difficult to obtain ±3 dB. In such cases it is only important for the test value to be noted in the report.

6.4.3 Probability density function (PDF)

Unless otherwise stated, for each measuring point the time series of the measured acceleration(s) shall have a distribution with a PDF which is approximately Gaussian and a crest factor (ratio of the peak to r.m.s. values) of at least 2,5.

NOTE Figure 6 shows the tolerance bands of the cumulative PDF.

6.4.4 Duration

The total duration of exposure to the prescribed random vibration in each axis shall not be less than that specified (see 8.2 and 9.2).

6.5 Measuring tolerances

The vibration tolerances shall conform to 4.3 of IEC 60068-2-64.

6.6 Recovery

The initial and final measurements shall be taken under the same conditions (for example, temperature). In order to enable the equipment under test to attain the same conditions as existed for the initial measurements, (if necessary) a period for recovery shall be allowed after testing and before the final measurements are made.

7 Initial measurements and preconditioning

Before commencing any testing, the equipment shall be subjected to a performance test according to 6.3.3. Where the nature of such testing is outside the physical capability of the test house, the tests shall be conducted by the manufacturer who shall provide a statement that the item under test conformed with the performance tests prior to the vibration and shock testing identified in this standard. It is the responsibility of the manufacturer to define the location of the measuring points which shall be clearly identified in the report.

Transfer functions shall be calculated from the random signals taken from the reference point and measuring points, which shall be defined by the manufacturer. Where panels are removed for examination or instrumentation, they shall be replaced during the testing.

The transfer functions shall be taken under the test conditions specified in Clause 8 for categories 2 and 3 equipment and in Clause 9 for category 1 equipment.

The measurement shall aim to achieve a coherence of at least 0,9. If this is not possible, a minimum of 120 spectral averages (or 240 statistical degrees of freedom for linear averaging) shall be taken with 0 % overlap.

8 Functional random vibration test conditions

8.1 Test severity and frequency range

The equipment shall be tested with the relevant r.m.s. value and frequency range given in Table 1. When the orientation at which the equipment will be installed is unclear or unknown, the test shall be carried out in the three axes with the r.m.s. value given for the vertical axis.

Table 1 – Test severity and frequency range for functional random vibration tests

Category	Orientation	RMS m/s^2	Frequency range
1 Class A Body mounted	Vertical Transverse Longitudinal	0,750 0,370 0,500	Figure 2
1 Class B Body mounted	Vertical Transverse Longitudinal	1,01 0,450 0,700	Figure 3
2 Bogie mounted	Vertical Transverse Longitudinal	5,40 4,70 2,50	Figure 4
3 Axle mounted	Vertical Transverse Longitudinal	38,0 34,0 17,0	Figure 5
NOTE 1 These test values are intended to represent typical service values as highlighted in Annex A, and are the			

minimum test levels to be applied to the equipment under test for a full certification. Where actual measured data exists the functional vibration test conditions listed above may be increased by using the method shown in Annex A and the equations shown in Annex D.

NOTE 2 By using the method shown in Annex A and the equations shown in Annex D, actual measured data may conduce to functional test values lower than the minimum test levels quoted in Table 1. These low functional test values may be applied to the equipment under test with prior agreement between the manufacturer and the customer. In such case the equipment tested cannot be fully certified against the requirements of this standard. The equipment tested is partially certified (only validated for service conditions giving functional test values lower than or equal to those specified in the test report).

8.2 Duration of functional vibration tests

NOTE 1 The object of this test is to demonstrate that the equipment under test is unaffected by the applied test levels which are representative of those expected in service.

NOTE 2 It is envisaged that these tests would not normally take less than 10 min.

The duration of the functional vibration test shall be sufficient to allow all the specified functions to be completed.

8.3 Functioning during test

The functional tests agreed with the customer (see 6.3.2) shall be carried out during functional random vibration testing.

9 Simulated long-life testing at increased random vibration levels

9.1 Test severity and frequency range

When the orientation at which the equipment will be installed is unclear or unknown, the equipment shall be subjected to the vertical test levels of Table 2 in all three axes.

Table 2 – Test severity and frequency range

Category	Orientation	RMS 5 h test period m/s^2	Frequency range
1 Class A Body mounted	Vertical Transverse Longitudinal	4,25 2,09 2,83	Figure 2
1 Class B Body mounted	Vertical Transverse Longitudinal	5,72 2,55 3,96	Figure 3
2 Bogie mounted	Vertical Transverse Longitudinal	30,6 26,6 14,2	Figure 4
3 Axle mounted	Vertical Transverse Longitudinal	144 129 64,3	Figure 5

NOTE If the functional test values are issued from actual measured data, the long life test values are obtained by using the acceleration ratio calculated in Annex A.

9.2 Duration of accelerated vibration tests

All categories of equipment shall be subjected to a total conditioning time of 15 h. This shall normally be divided into periods of 5 h conditioning in each of three mutually perpendicular axes. If during the course of testing overheating of equipment is felt to be a problem, (i.e. vibration of rubber parts, etc.) it is permissible to stop the tests for a period of time in order to allow the equipment to recover. However, it must be noted that the total duration of 5 h vibration shall be achieved. If tests are stopped then this shall be stated in the report.

NOTE 1 It is not necessary for equipment to function during this test.

NOTE 2 It is possible by prior agreement to reduce the amplitude of vibration. However, it is essential that the duration of the test period be increased in accordance with the method shown in Annex A. This is not a preferred option and should be limited to category 3 axle mounted equipment.

10 Shock testing conditions

10.1 Pulse shape and tolerance

The equipment under test shall be subjected to a sequence of single half sine pulses each with a nominal duration of D and a nominal peak amplitude of A conforming to IEC 60068-2-27 (see Figure 7 for values of D and A).

The transverse acceleration shall not exceed 30 % of the peak acceleration of the nominal pulse in the intended direction in accordance with IEC 60068-2-27.

Figure 7 shows pulse shape and tolerance limits.

10.2 Velocity changes

The actual velocity change shall be within ±15 % of the value corresponding to the nominal pulse shown in Figure 7.

Where the velocity change is determined by integration of the actual pulse shown, it shall be evaluated over the integration time interval shown in Figure 7.

10.3 Mounting

The equipment under test shall be connected to the test machine in accordance with 6.1.

10.4 Repetition rate

In order to allow the equipment under test to recover from any resonance effects sufficient time shall be allowed to elapse between the application of shocks.

10.5 Test severity, pulse shape and direction

Values are given in Table 3.

Table 3 – Test severity, pulse shape and direction

Category	**Orientation**	**Peak acceleration** A m/s^2	**Nominal duration** D ms
1 Class A and class B Body mounted	Vertical Transverse Longitudinal	30 30 50	30 30 30
2 Bogie mounted	All	300	18
3 Axle mounted	All	1 000	6

NOTE 1 See Figure 7 for pulse shape details.

NOTE 2 The heavy equipment, for which there is not test bench sufficiently sized to carry out the shock tests, will be the subject of appropriate test conditions (reduction of the acceleration peak values), by prior agreement between the manufacturer and the customer.

10.6 Number of shocks

18 shocks (three positive and three negative in each of the three orthogonal axes) as specified in IEC 60068-2-27 shall be applied to the equipment. This test shall be repeated for each mechanical state as identified in 6.3.1.

10.7 Functioning during test

It is not necessary for the equipment to operate during tests. Nevertheless some equipment may have to retain its functional integrity; this shall be verified as requested by the manufacturer or the customer in the test specification unless otherwise stated in the relevant product standard.

11 Transportation and handling

Where transportation and handling tests are specifically requested by the end user, they shall be in accordance with IEC 60068-2-27.

12 Final measurements

On completion of the tests, the equipment shall be subjected to a performance test according to 6.3.3. Owing to the nature of such testing, it may be outside the capability of the test house. In such cases, the tests will be conducted by the manufacturer who shall provide a statement that the item under test conformed with the performance tests after the vibration and shock testing identified in this standard.

Transfer functions shall be calculated from the random signals taken from the reference point and measuring points, which shall be defined by the manufacturer. Where panels are removed for examination or instrumentation, they shall be replaced during the testing.

The transfer functions shall be taken under the test conditions specified in Clause 8 for categories 2 and 3 equipment and in Clause 9 for category 1 equipment.

The measurement shall aim to achieve a coherence of at least 0,9. If this is not possible a minimum of 120 spectral averages (or 240 statistical degrees of freedom for linear averaging) with 0 % overlap, shall be taken.

Any changes in the transfer functions or other measurements shall be investigated and explained in the test report.

13 Acceptance criteria

On successful completion of all of the following tests, the equipment shall be considered suitable for test certification:

a) performance according to 6.3.3 remains within the defined limits;

b) function according to 6.3.2 remains within the defined limits;

c) no visual deformation and mechanical integrity has not changed.

Engineering judgment is required.

14 Report

Upon completion of all or part of the tests, final measurements and functional checks, the test house shall issue a comprehensive report to their customer. The report shall describe the execution of the tests and their effect on the equipment together with:

a) the summary which shall identify changes which have occurred during the tests. Serial numbers/identification shall be quoted;
b) details of the instrumentation and test procedures used, which shall be made available on request. They may be included in the report but this is not mandatory;
c) methods of mounting which shall be reported as identified in 6.1;
d) method and order of testing used. The report shall also include figures showing the location of all checking and measuring positions;
e) functional tests carried out and values obtained pre-test and post-test;
f) results of tests from check and reference positions together with observations against the set objectives and acceptance criteria. The report shall contain all the check point graphs which shall be in the format of Figures 2 to 7. They shall also contain the tolerance bands in order to demonstrate that the tests remained within the tolerance limits stated in this standard;
g) all observations done when functional test during vibration and/or function verification during shock are required.

NOTE Where special tests have been carried out which exceed the requirements of this standard they may be included in the report.

15 Test certificate

Test certificate shall include all of the following information:

– description of equipment tested;
– manufacturer's name;
– equipment type and issue/modification status;
– equipment serial number;
– test house report number;
– report date;
– product test specification.

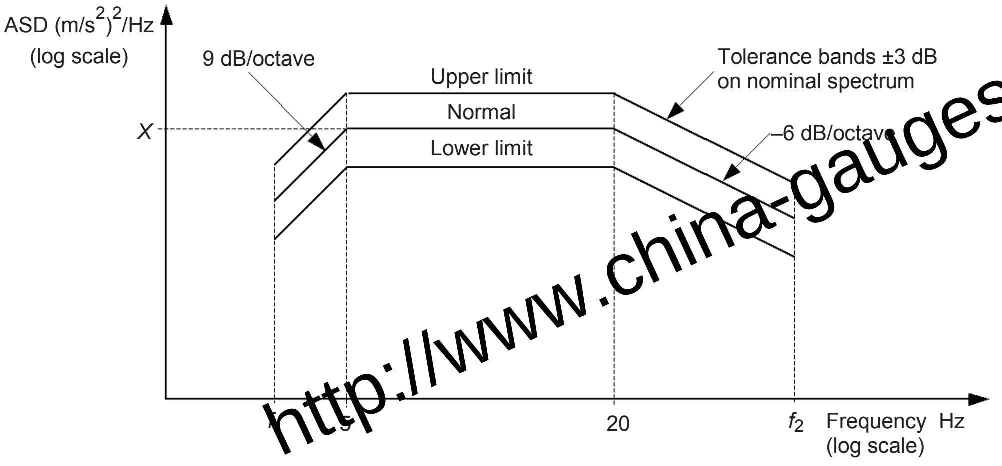
This certificate shall be signed by authorised representatives of the test house and the manufacturer.

NOTE An example of a typical type test certificate is shown in Annex C.

16 Disposal

The equipment, having satisfied the test objectives and acceptance criteria, may be refurbished to a standard agreed between the manufacturer and the end user, and placed in operational service.

For traceability purposes, it is the responsibility of the manufacturer to identify clearly all items which have been tested in accordance with this standard.



IEC 1100/10

when mass ≤500 kg: f_1 = 5 Hz f_2 = 150 Hz

when mass >500 kg≤1 250 kg: $f_1 = \frac{1\,250}{\text{mass}} \times 2\,\text{Hz}$ $f_2 = \frac{1\,250}{\text{mass}} \times 60\,\text{Hz}$

when mass >1 250 kg: f_1 = 2 Hz f_2 = 60 Hz

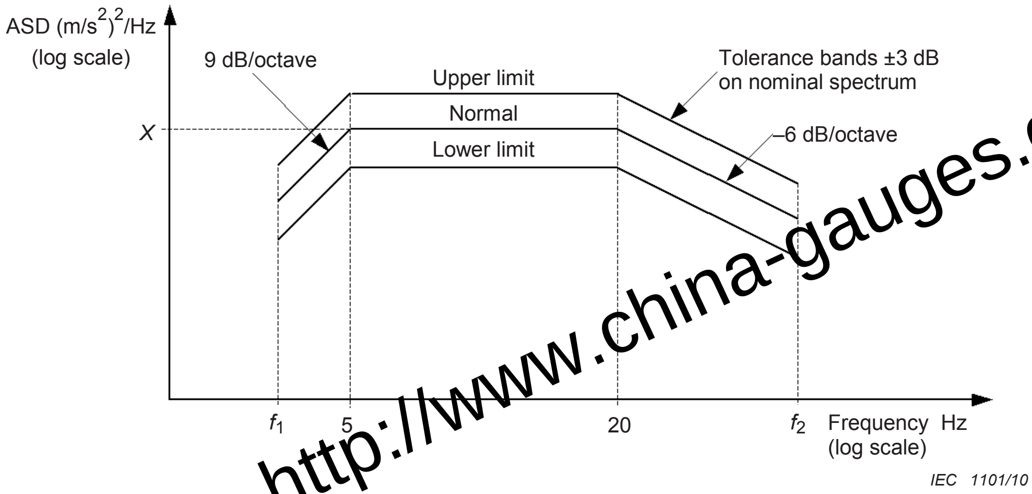
	Vertical	Transverse	Longitudinal
Functional test ASD level $(m/s^2)^2$/Hz	0,0166	0,0041	0,0073
RMS value m/s^2 2 Hz to 150 Hz	0,750	0,370	0,500
Long-life test ASD level $(m/s^2)^2$/Hz	0,532	0,131	0,234
RMS value m/s^2 2 Hz to 150 Hz	4,25	2,09	2,83

NOTE 1 For items with test frequencies over than 2 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 2 For items with test frequencies less than 150 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 3 If frequencies above f_2 are known to exist they may be included, the amplitude being established by extending the 6 dB/octave decay line until it intersects the maximum frequency required. In such cases the r.m.s. levels shall be increased.

Figure 2 – Category 1 – Class A – Body-mounted – ASD spectrum



when mass ≤500 kg: f_1 = 5 Hz f_2 = 150 Hz

when mass >500 kg≤1 250 kg: $f_1 = \frac{1\,250}{\text{mass}} \times 2\,\text{Hz}$ $f_2 = \frac{1\,250}{\text{mass}} \times 60\,\text{Hz}$

when mass >1 250 kg: f_1 = 2 Hz f_2 = 60 Hz

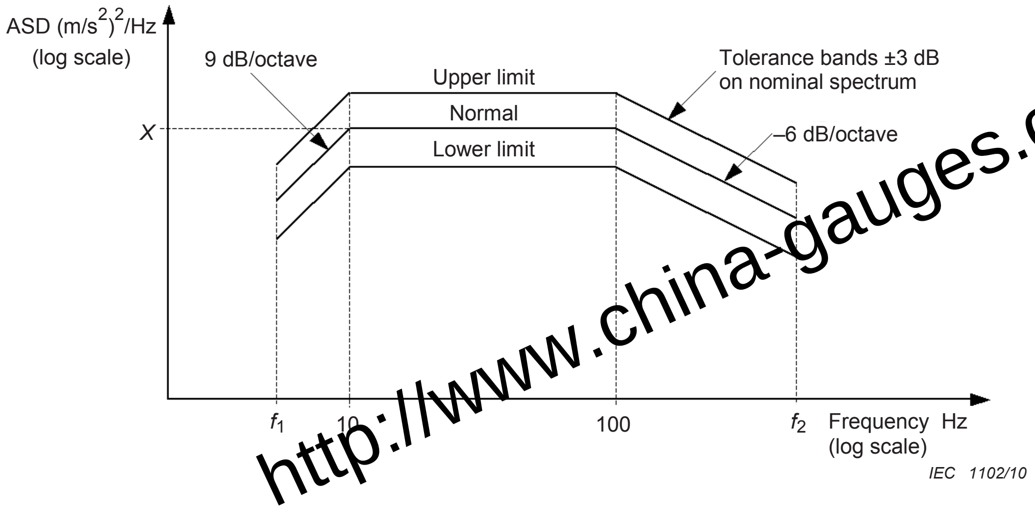
	Vertical	**Transverse**	**Longitudinal**
Functional test ASD level $(m/s^2)^2/Hz$	0,0301	0,0060	0,0144
RMS value m/s^2 2 Hz to 150 Hz	1,01	0,450	0,700
Long-life test ASD level $(m/s^2)^2/Hz$	0,964	0,192	0,461
RMS value m/s^2 2 Hz to 150 Hz	5,72	2,55	3,96

NOTE 1 For items with test frequencies over than 2 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 2 For items with test frequencies less than 150 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 3 If frequencies above f_2 are known to exist they may be included, the amplitude being established by extending the 6 dB/octave decay line until it intersects the maximum frequency required. In such cases the r.m.s. levels shall be increased.

Figure 3 – Category 1 – Class B – Body-mounted – ASD spectrum



when mass	≤100 kg:	$f_1 = 5$ Hz	$f_2 = 250$ Hz
when mass	>100 kg≤250 kg:	$f_1 = \frac{250}{\text{mass}} \times 2$ Hz	$f_2 = \frac{250}{\text{mass}} \times 100$ Hz
when mass	>250 kg:	$f_1 = 2$ Hz	$f_2 = 100$ Hz

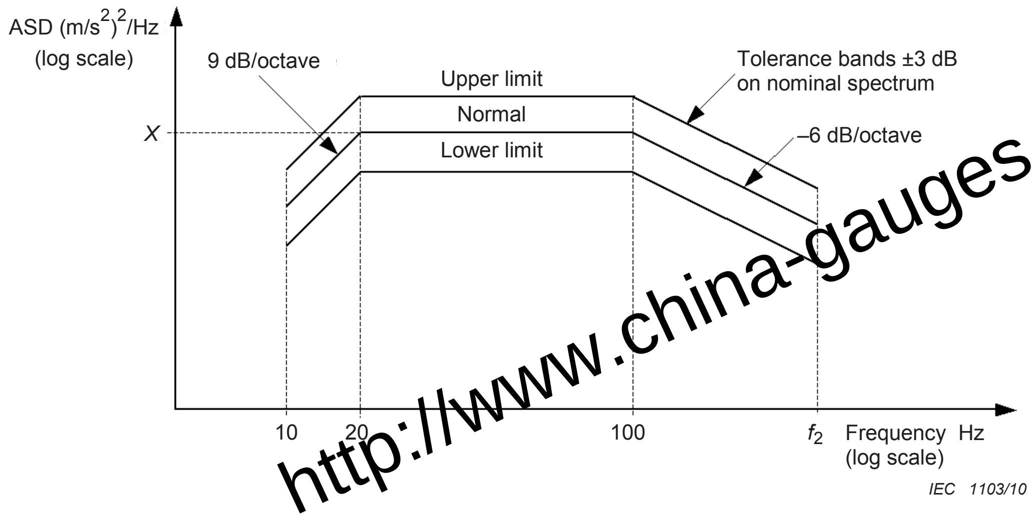
	Vertical	**Transverse**	**Longitudinal**
Functional test ASD level $(m/s^2)^2$/Hz	0,190	0,144	0,0414
RMS value m/s^2 2 Hz to 250 Hz	5,40	4,70	2,50
Long-life test ASD level $(m/s^2)^2$/Hz	6,12	4,62	1,32
RMS value m/s^2 2 Hz to 250 Hz	30,6	26,6	14,2

NOTE 1 For items with test frequencies over than 2 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 2 For items with test frequencies less than 250 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 3 If frequencies above f_2 are known to exist they may be included, the amplitude being established by extending the 6 dB/octave decay line until it intersects the maximum frequency required. In such cases the r.m.s. levels shall be increased.

Figure 4 – Category 2 – Bogie mounted – ASD spectrum



when mass ≤50 kg: f_2 = 500 Hz

when mass >50 kg≤125 kg: $f_2 = \frac{125}{\text{mass}} \times 200$ Hz

when mass >125 kg: f_2 = 200 Hz

	Vertical	**Transverse**	**Longitudinal**
Functional test ASD level $(m/s^2)^{2/}$Hz	8,74	7,0	1,751
RMS value m/s^2 10 Hz to 500 Hz	38,0	34,0	17,0
Long-life test ASD level $(m/s^2)^2$/Hz	124,9	100,2	25,02
RMS value m/s^2 10 Hz to 500 Hz	144	129	64,3
NOTE 1 For items with test frequencies less than 500 Hz the r.m.s. levels shall be lower than those quoted above. NOTE 2 If frequencies above f_2 are known to exist they may be included, the amplitude being established by extending the 6 dB/octave decay line until it intersects the maximum frequency required. In such cases the r.m.s. levels shall be increased.			

Figure 5 – Category 3 – Axle mounted – ASD spectrum

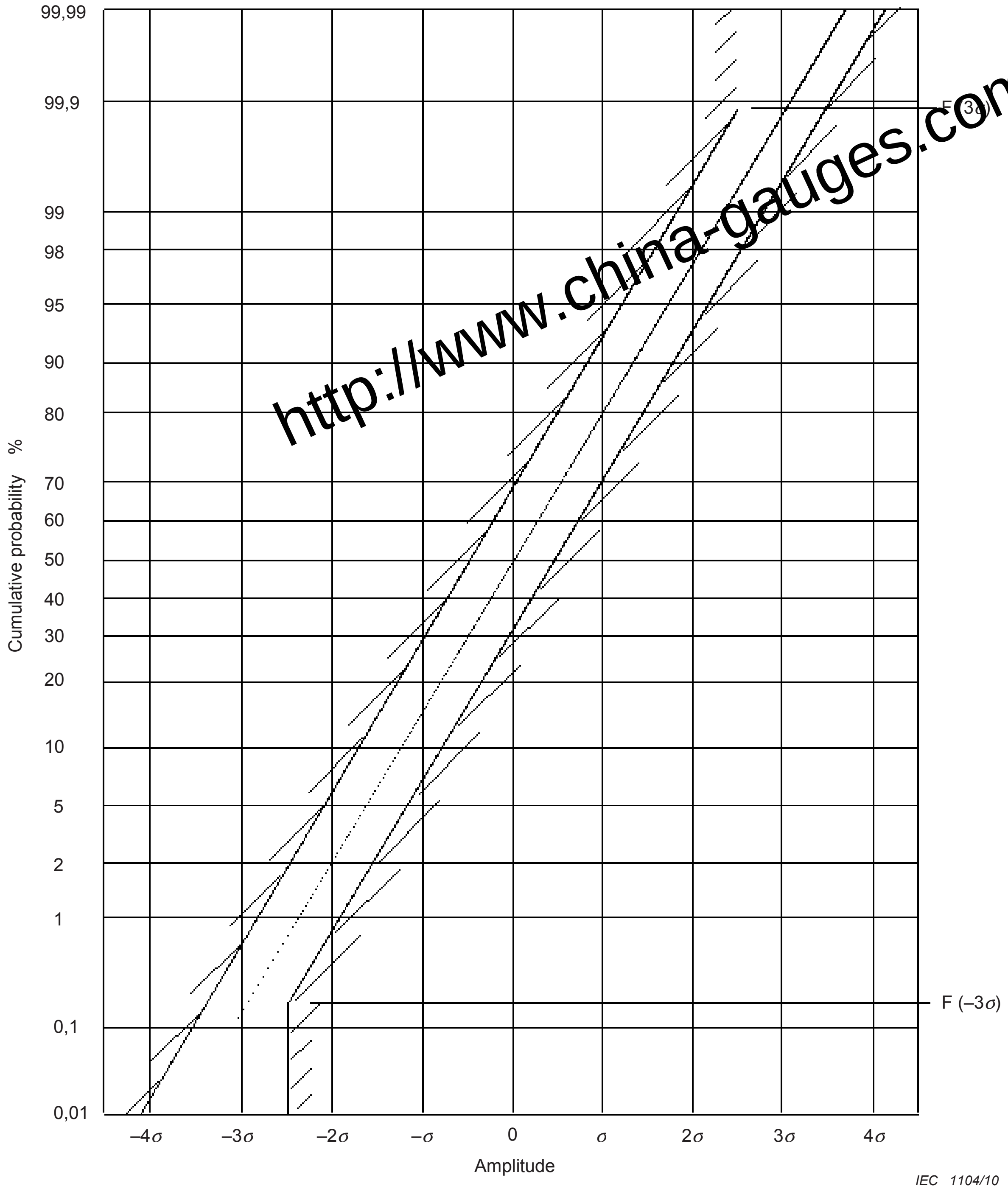
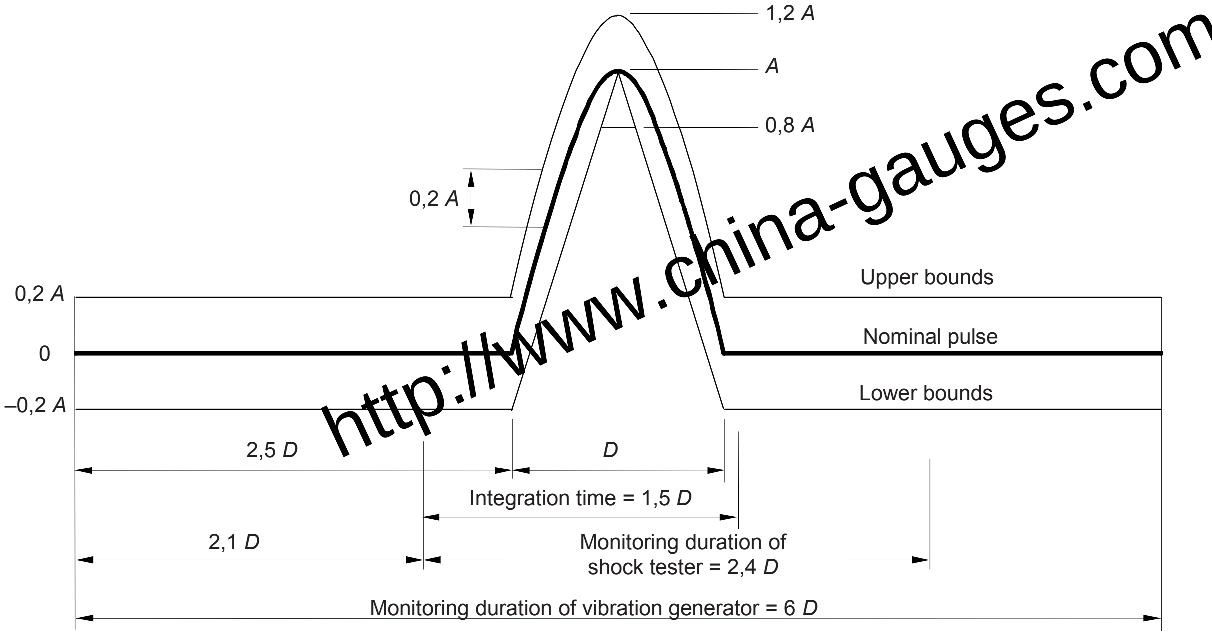


Figure 6 – Cumulative PDF tolerance bands



Category	Orientation	Peak acceleration A m/s²	Nominal duration D ms
1 Class A and class B Body mounted	Vertical Transverse Longitudinal	30 30 50	30 30 30
2 Bogie mounted	All	300	18
3 Axle mounted	All	1 000	6
NOTE Some category 1 equipment intended for specific applications may require additional shock testing with peak accelerations A of 30 m/s^2 and duration D of 100 ms. In such cases these test levels should be requested and agreed prior to testing.			

Figure 7 – Pulse shape and limits of tolerance for half-sine pulse

Annex A
(informative)

Explanation of service measurements, measuring positions, methods of recording service data, summary of service data, and method used to obtain random test levels from acquired service data

A.1 General

Rail vehicle shock and vibration varies depending on vehicle speed, rail/track conditions and other environment factors. To assess whether equipment attached to rail vehicles will perform satisfactorily for many years without failure, a design/test specification is required.

To establish a realistic test specification it is necessary to obtain measured service data and base test levels on this data. The following data and means are used to obtain it:

– Standard measuring positions used for axle, bogie and body-mounted categories (see Clause A.2).

– Service data obtained from rail operators and equipment manufacturers utilising a two-page questionnaire (see Clause A.3).

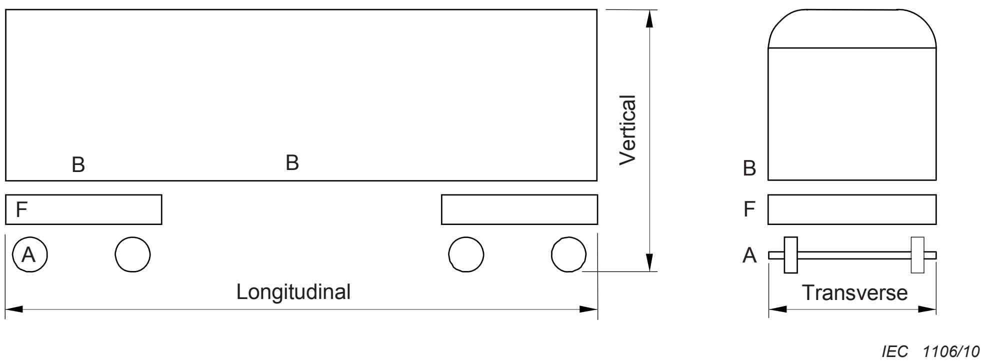
– Summarised service data obtained (see Clause A.4).

– Method used to obtain random test levels from the acquired service data (see Clause A.5).

– Test levels obtained from service data using the method in Clause A.5 (see Clause A.6).

NOTE When service data is available for the actual rail vehicles/network, test levels may be calculated using the method in Clause A.5.

A.2 Standard measuring positions used for axle, bogie and body-mounted categories (Figure A.1)



Key

A Axle measuring position for vertical, transverse and longitudinal axes

F Frame (bogie) measuring position for vertical, transverse and longitudinal axes

B Body measuring position for vertical, transverse and longitudinal axes

Figure A.1 – Standard measuring positions used for axle, bogie (frame) and body

A.3 Service data obtained from rail operators and equipment manufacturers utilizing a two-page questionnaire

For each measuring position Table A.1 should be completed.

Table A.1 – Environment data acquisition summary of the test parameters/conditions

Measurement position.......................... **Measurement direction**........................	
Test parameter/Condition (Question)	Comments (Answer)
General	
1 Reason for measuring vibration levels	....
2 Location of railway system	....
3 Type of vehicle measured	....
4 Special test or normal service	....
5 Vehicle speed	....
Main conditions	
6 Weather conditions (°C, % RH, rain, snow)	....
7 Axle loading of vehicle measured	....
8 Type of rail (UIC grade)	....
9 Rail foundation (sleepers, ballast)	....
10 Type of rail jointing (welded, jointed)	....
Additional conditions	
11 Wheel condition, profile, conicity	....
12 Rail condition (vertical r.m.s. amplitude)	....
13 Length of track used for measurements	....
14 Number and radius of bends	....
15 Number of crossings and points	....
16 Other exclusive events (bridges, tunnels)	....
17 Configuration of train and total mass	....
18 Tractive effort (drive vehicles only)	....
Recording	
19 Type of recording (FM, DR, PCM, DAT)	....
20 Frequency range (lower and upper)	....
21 Amplitude range (maximum and minimum)	....

Table A.1 *(concluded)*

Test parameter/Condition (Question)	Comments (Answer)
Time domain analysis	
22 Bandwidth of time domain analysis	....
23 Sampling frequency	....
24 Total number of samples or total time of all records	....
25 Max. acceleration (m/s^2, positive)	....
26 Min. acceleration (m/s^2, negative)	....
27 RMS value	....
28 Amplitude resolution	....
29 RMS m/s^2 based on the density function	....
Frequency analysis (Recommended bandwidth 150 Hz body; 250 Hz bogie and 500 Hz axle)	
30 Band width of frequency analysis/cut off frequency of anti-aliasing filter	....
31 Sampling frequency of corresponding time record	....
32 Frequency resolution (delta f) or number of frequency lines	....
33 Number of samples at data acquisition (block length)	....
34 Lower frequency limit	....
35 Type of time window and record length at acquisition/analysis	....
36 Number of averages (time records)	....
37 Overlap ($0 \le 0_t < 1$) and total number of samples	....
38 ADC resolution (dynamic range)	....
39 The inherent noise level of the instrumentation	....
40 Total r.m.s. m/s^2 based on ASD	....
Graphs required	
41 Acceleration spectral density spectrum for frequency domain analysis	....
42 Probability density distribution for time domain analysis	....

A.4 Summarized service data obtained

See Table A.2.

Table A.2 – Summary of the r.m.s. acceleration levels obtained from the questionnaire

Category	Max. level m/s^2 r.m.s.	Average level m/s^2 r.m.s.	Standard deviation	Number of values
1				
Body vertical	1,24	0,49	0,26	19
Body transverse	0,43	0,29	0,08	15
Body longitudinal	0,82	0,30	0,20	8
2				
Bogie vertical	[illegible],6	3,1	2,3	14
Bogie transverse	7,0	3,0	1,7	10
Bogie longitudinal	4,1	1,2	1,3	9
3				
Axle vertical	43	24	14	19
Axle transverse	39	20	14	17
Axle longitudinal	20	11	6	9
NOTE Use method shown in Clause A.5 to obtain the test levels in Clause A.6.				

A.5 Method used to obtain random test levels from the acquired service data

In order to reduce the test time the increased amplification method has been chosen for this standard. To perform a simulated long-life random vibration test, following assumptions have been employed:

a) There is a proportional relationship between given acceleration and generated stress ($\sigma = \frac{M\gamma}{S}$ where σ is the stress, M the mass, γ the acceleration and S the section).

b) The damage is proportional to the number of cycles multiplied by the stress range to a power.

From the assumption a), the relationship between damage and stress range can be applied to obtain the simulated long-life test level, i.e. the acceleration ratio of long-life test to functional test. The assumption b) yields following expression:

$$\text{Damage} = \alpha.\Delta\sigma^m N_f$$

where

N_f is the number of cycles;

$\Delta\sigma$ is the stress range;

m is the power (typically 3 to 9);

α is a constant.

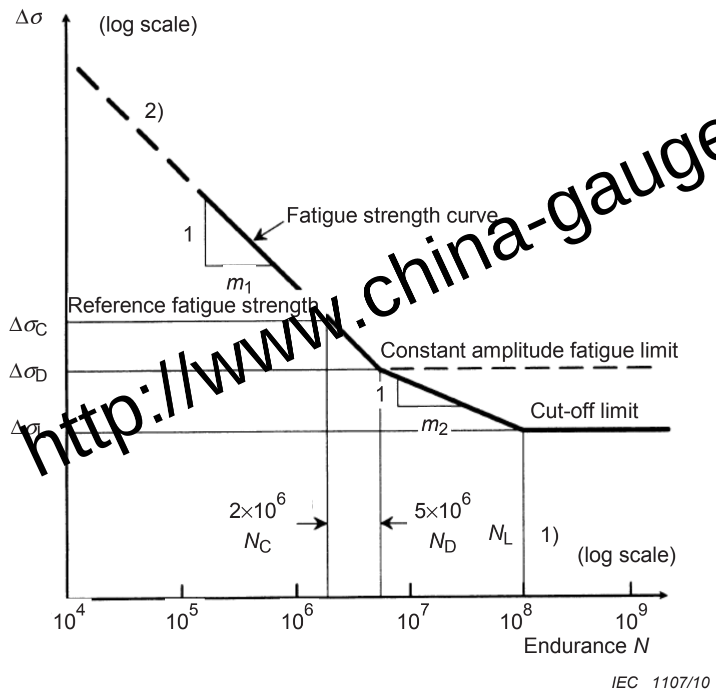


Figure A.2 – Typical fatigue strength curve

This relationship is derived from fatigue strength formulae:

$$N \le 5\times10^6 \quad : \log(N) = \log(a) - m_1 \log(\Delta\sigma)$$

$$5\times10^6 \le N \le 100\times10^6 : \log(N) = \log(b) - m_2 \log(\Delta\sigma)$$

where: $m_2 = m_1 + 2$

The fatigue strength formulae may be expressed in the following form:

$$N \le 5\times10^6 \quad : N = \frac{10^{\log(a)}}{\Delta\sigma^{m_1}}$$

$$5\times10^6 \le N \le 100\times10^6 : N = \frac{10^{\log(b)}}{\Delta\sigma^{m_2}}$$

$$N \le 5\times10^6 \quad : \alpha_1 N \Delta\sigma^{m_1} = 1$$

$$5\times10^6 \le N \le 100\times10^6 : \alpha_2 N \Delta\sigma^{m_2} = 1$$

For stress ranges below the cut-off limit: $\Delta\sigma_L$ at 100×10^6 cycles (see Figure A.2), the corresponding number of cycles is infinite. That means stress ranges below the cut-off limit do not induce any damage.

In order to have the same level of damage during a 5 h test as in the service life, the functional ASD values have to be amplified.

The vehicle service life is taken to be 25 years at 300 days/year for 10 h/day. This corresponds to 75×10^3 h or 270×10^6 s. As the minimum frequency specified in the functional ASD curves is 2 Hz (Categories 1 and 2) or 10 Hz (Category 3), the minimal number of cycles N_s corresponding to the service life (540×10^6 cycles for categories 1 and 2; 2 700×10^6 cycles for category 3) is above the cut-off limit of 100×10^6 cycles. The stress range to consider for the service life: $\Delta\sigma_s$ is $\Delta\sigma_L$ and the number of cycles to consider for the service life: N_s is 100×10^6 cycles.

The test duration is 5 h = 18 000 s. The minimal frequency specified in the functional ASD curves is 2 Hz (Categories 1 and 2) or 10 Hz (Category 3). The minimal number of cycles N_t corresponding to the test duration is $0{,}036\times10^6$ cycles (Categories 1 and 2) or $0{,}18\times10^6$ cycles (Category 3). The stress range to consider for the test: $\Delta\sigma_t$ is therefore on the first part of the fatigue curve.

The acceleration ratio which has to be applied to the functional ASD value to obtain the simulated long-life ASD value is given by the expression:

$$\text{acceleration ratio} = \frac{\Delta\sigma_t}{\Delta\sigma_s} = \frac{(\alpha_2 N_s)^{(1/m_2)}}{(\alpha_1 N_t)^{(1/m_1)}}$$

Considering the constant amplitude fatigue limit $\Delta\sigma_D$ at 5×10^6 cycles, α_1 and α_2 may be expressed as:

$$\alpha_1 = \frac{1}{N_D \Delta\sigma_D{}^{m_1}} = \frac{1}{5\times10^6\,\Delta\sigma_D{}^{m_1}} \quad \text{and} \quad \alpha_2 = \frac{1}{N_D \Delta\sigma_D{}^{m_2}} = \frac{1}{5\times10^6\,\Delta\sigma_D{}^{m_2}}$$

$$\text{acceleration ratio} = \frac{\left(\dfrac{N_s}{5\times10^6\,\Delta\sigma_D{}^{m_2}}\right)^{(1/m_2)}}{\left(\dfrac{N_t}{5\times10^6\,\Delta\sigma_D{}^{m_1}}\right)^{(1/m_1)}} = \frac{\left(5\times10^6\right)^{(1/m_1)} N_s{}^{(1/m_2)}}{\left(5\times10^6\right)^{(1/m_2)} N_t{}^{(1/m_1)}}.$$

With $m_1 = 4$ (typical for metals):

for categories 1 and 2 the acceleration ratio value is: 5,66;

for category 3 the acceleration ratio value is: 3,78.

For the purpose of this standard, an environmental survey was performed. The data obtained has been compiled as r.m.s. levels and the variation in level as a standard deviation. See Table A.2.

Category 1. Body Class B

Functional random test level = average service level + 2 standard deviations.

All other categories

Functional random test level = average service level + 1 standard deviation.

Simulated long-life random test level = functional random test level × acceleration ratio

(See Table A.3 for calculated test values.)

A.6 Test levels obtained from service data using the method in Clause A.5

See Table A.3.

Table A.3 – Test levels obtained from service data using the method shown in Clause A.4

RMS acceleration levels m/s²				
Category	**Functional RTL**		**Simulated long-life RTL**	
	Class A	Class B	Class A	Class B
1				
Body vertical	0,750	1,01	4,25	5,72
Body transverse	0,370	0,450	2,09	2,55
Body longitudinal	0,500	0,700	2,83	3,96
2				
Bogie vertical	5,40		30,6	
Bogie transverse	4,70		26,6	
Bogie longitudinal	2,50		14,2	
3				
Axle vertical	38,0		144	
Axle transverse	34,0		129	
Axle longitudinal	17,0		64,3	

AS = Average service level

STD = Standard deviation

RTL = Random test level

FRTL = Functional random test level

SLLRTL = Simulated long-life random test level

Class A = Category 1. Body-mounted equipment directly connected to car body structure

Class B = Category 1. Assemblies/components mounted within equipment connected directly to the car body structure.

Example: Calculation of test level using method in Clause A.5.

Body vertical

AS = 0,49 (from Table A.2)

STD = 0,26

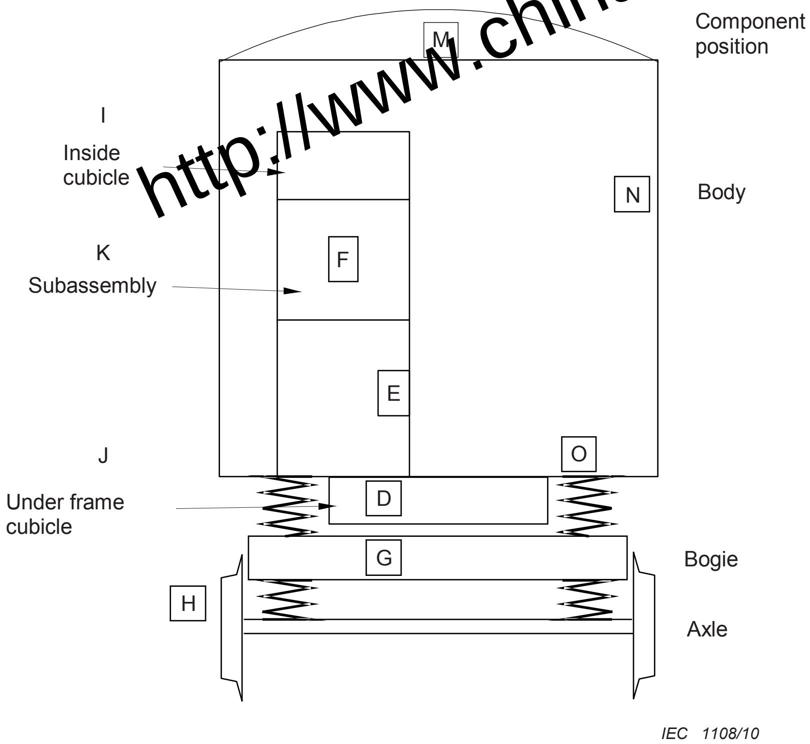
FRTL = AS + STD = 0,750 Class A

SLLRTL = FRTL × Acceleration ratio = 4,25 Class A

Annex B
(informative)

Figure identifying general location of equipment on railway vehicles and their resulting test category

NOTE These categories do not apply for vehicles with only one level of suspension.



Category	Location	Description of equipment location
1 Class A	M N O I and J	Components which are mounted directly on to or under the car body
1 Class B	D	Components mounted into an underframe cubicle which is in turn fixed to the car body
1 Class B	K and E	Components mounted into a large internal cubicle which is in turn fixed to the car body
1 Class B	F	Components mounted into subassemblies which are in turn mounted into a cubicle which is in turn fixed to the car body
2	G	Cubicles, subassemblies, equipment and components which are mounted on the bogie of a railway vehicle
3	H	Subassemblies, equipment and components or assemblies which are mounted on to the axle assembly of a railway vehicle

Figure B.1 – General location of equipment on vehicles

Annex C
(informative)

Example of a type test certificate

The following equipment has been tested to the requirements outlined in IEC 61373: Railway applications – Rolling stock equipment – Shock and vibration tests.

DESCRIPTION OF EQUIPMENT:
....
....
....

EQUIPMENT TYPE No. .... **MANUFACTURER'S NAME**: ....
....
....

ISSUE/MODIFICATION STATUS:................. **SERIAL No.** ....
....
....

TEST HOUSE REPORT No. .... **REPORT DATE:**..
....
....

PRODUCT TEST SPECIFICATION No.:
....
....

<u>Comments:</u>
....
....
....

1) Test house................................ Position.............. Date...............

2) Manufacturer............................ Position.............. Date..............

Annex D
(informative)

Guidance for calculating RMS values from ASD values or levels

D.1 General

This annex provides equations for calculating functional RMS values from service data and for calculating functional or long-life test RMS values from ASD levels presented in Figures 2 to 5.

Service data are *ASD* measured values ($(m/s^2)^2$/Hz) on a frequency range (f_1–f_2).

D.2 Symbols

ASD_i ASD value ($(m/s^2)^2$/Hz) of the measured data number “i”

f_i Frequency value (Hz) of the measured data number “i”

D.3 Calculation of the functional RMS value from the service data

Assumption: service data measured at a standard measuring position specified in Clause A.1 comprise “n_1” measured values: (f_i ; ASD_i).

The corresponding *RMS* measured value is given by the following equation:

$$\mathrm{RMS} = \sqrt{\sum_{i=2}^{n_1}\left[\frac{(\mathrm{ASD}_i + \mathrm{ASD}_{i-1})\times(f_i - f_{i-1})}{2}\right]} \qquad \text{(D.1)}$$

From “n_2” *RMS* measured values, the functional RMS value is calculated using Annex A with the following equations:

$$\mathrm{AS} = \frac{\sum_{i=1}^{n_2} \mathrm{RMS}_i}{n_2} \qquad \text{(D.2)}$$

$$\mathrm{STD} = \sqrt{\frac{\sum_{i=1}^{n_2} (\mathrm{RMS}_i - \mathrm{AS})^2}{n_2}} \qquad \text{(D.3)}$$

For categories 1A, 2 and 3: functional RMS value $= AS + STD$ (D.4)

For category 1B: functional RMS value $= AS + (2 \times STD)$ (D.5)

D.4 Calculation of the RMS values from ASD levels of Figures 2 to 5

Functional or long-life test RMS value is equal to the root square of the corresponding ASD spectrum surface (see Figure D.1).

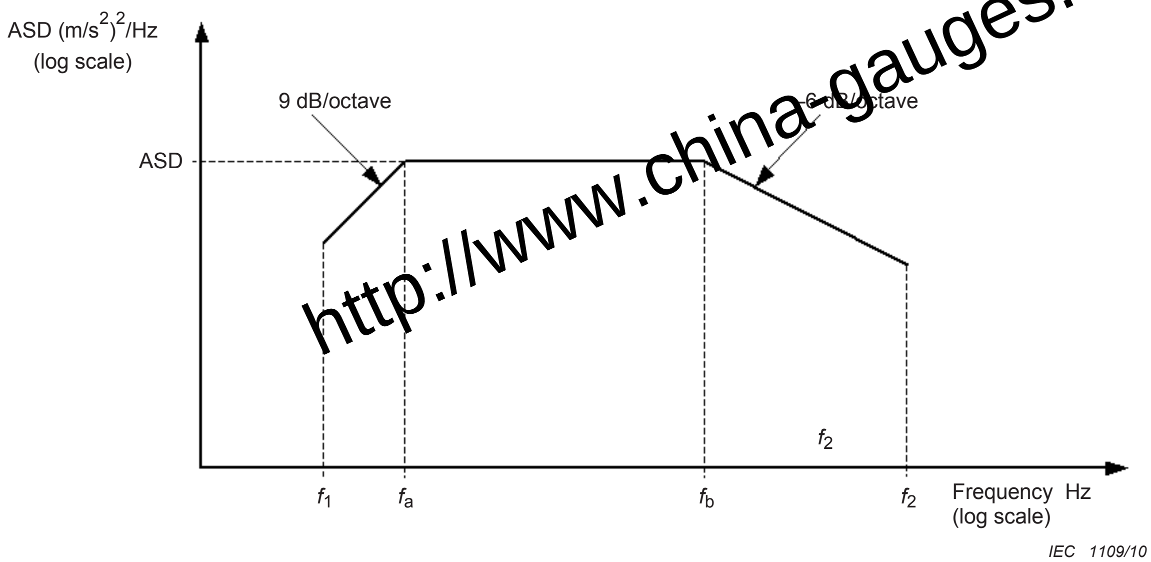


Figure D.1 – ASD spectrum

The RMS value is calculating using the following equation: (D.6)

$$RMS = \sqrt{\frac{ASD \times f_a^{\left(\frac{-0,9}{\log(2)}\right)} \times \left(f_a^{\left(\frac{0,9}{\log(2)}+1\right)} - f_1^{\left(\frac{0,9}{\log(2)}+1\right)}\right)}{\frac{0,9}{\log(2)}+1} + ASD\left(f_b - f_a\right) + \frac{ASD \times f_b^{\left(\frac{0,6}{\log(2)}\right)} \times \left(f_2^{\left(\frac{-0,6}{\log(2)}+1\right)} - f_b^{\left(\frac{-0,6}{\log(2)}+1\right)}\right)}{\frac{-0,6}{\log(2)}+1}}$$

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