IEC 60721-2-9

Edition 1.0 2014-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour
inside

Classification of environmental conditions –
Part 2-9: Environmental conditions appearing in nature – Measured shock and vibration data – Storage, transportation and in-use

Classification des conditions d'environnement –
Partie 2-9: Conditions d'environnement présentes dans la nature – Données de chocs et de vibrations mesurées – Stockage, transport et utilisation

IEC 60721-2-9:2014-03(en-fr)

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CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 2-9: Environmental conditions appearing in nature – Measured shock and vibration data – Storage, transportation and in-use

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International Standard IEC 60721-2-9 has been prepared by IEC technical committee 104: Classification of environmental conditions.

The text of this standard is based on the following documents:

FDIS	Report on voting
104/630/FDIS	104/632/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60721 series, published under the general title *Classification of environmental conditions,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This part of IEC 60721 is intended as part of the strategy for defining an environmental description from measured data acquired at multiple locations whilst a product is either in storage, being transported or in-use at weather or non-weather protected locations. This measured data is normally in the form of acceleration versus time records. This, in turn, will then allow appropriate severities to be chosen from the IEC 60068-2 series [1] [1] of shock and vibration test methods. Environmental levels given in IEC 60721-3 [2] should then be applied, having been updated based upon the strategy described in this standard.

More detailed information may be obtained from specialist documentation, some of which is given in the bibliography.

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[1] Numbers in square brackets refer to the Bibliography.

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 2-9: Environmental conditions appearing in nature – Measured shock and vibration data – Storage, transportation and in-use

1 Scope and object

This part of IEC 60721 is intended to be used to define the strategy for arriving at an environmental description from measured data when related to a product's life cycle.

Its object is to define fundamental properties and quantities for characterization of storage, transportation and in-use shock and vibration data as background material for the severities to which products are liable to be exposed during those phases of their lifecycle.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

None.

3 General

3.1 Introductory remarks

Shock and vibrations measured in storage, transportation platforms and in-use locations can vary considerably from a basic sinusoidal character to pure random, which itself may or may not be normally distributed. If it is the latter, it can be reasonably assumed that the process is a sum of normally distributed random waves of differing amplitudes mixed in a complex manner.

Rarely can a real world environment be classified purely as a sinusoidal vibration and is normally associated with a discrete excitation mechanism such as rotating machinery, aero engines, propellers and is normally mixed with an associated random vibration process. It is then necessary for the specification writer to decide whether to conduct a random vibration test only or to perform one of the mixed mode tests.

Associated with the vibration environment for each life-cycle stage is, potentially, a shock environment which may produce much higher acceleration levels in certain circumstances. Generally speaking, the frequency content for these shocks is contained within the 0 Hz to 200 Hz bandwidth for, say, transportation, assuming that the packaged product is firmly secured to the transport platform base and is not therefore ‘bouncing around’. However, much higher frequencies, maybe in the kHz range, may be present in the in-use stage, again dependent upon the real world scenario.

The process described below is for a random vibration environment, since it is probably the most common form of test conducted. Any statement made therefore about the random process should be interpreted as applying to the alternative process. However, it can equally be applied to the shock environment by calculating the shock response spectrum and conducting the same process on this spectrum as for an acceleration spectral density (ASD) spectrum. It is also equally applicable to sinusoidal data in the form of acceleration versus frequency. However, special attention may be required for this data dependent upon the initial process involved, that is, the acceleration involved, the r.m.s. value or the discrete value at the frequency in question.

Other factors to be considered in this process include:

a) factoring for the random spectra, which may depend upon the eventual purpose of the test programme, for example, robustness, qualification etc.;
b) statistical properties of the environment;
c) statistical properties of the product;
d) time – life cycle profile.

This clause looks at some of the general characteristics that can be expected from the storage, transportation and use of a product.

3.2 Storage

During storage, the product is placed at a certain site for long periods, but not intended for use during these periods. The storage location may be weather-protected, either totally or partially, or non-weather-protected. In any case, in the storage environment the product will undergo handling, thus it may be subjected to severe shock and vibration levels depending on the type of handling devices and storage racks. As a consequence, the product may be subjected to very benign, insignificant shock and vibration levels through to significant levels, such as those transmitted from machines or passing vehicles, and maybe even higher levels of shock and vibration such as that seen when stored close to heavy machines and conveyor belts.

3.3 Transportation

3.3.1 Road

A shock and vibration environment is experienced any time a product is transported by road. The main factors affecting the magnitude and frequency of such an environment are

- the design of the carrying vehicle,
- the velocity of the vehicle,
- the road profile,
- the position of the product in the vehicle,
- the reference axis for the vibration measurements with respect to the vehicle axis, generally a vertical axis is the worst,
- the product itself may influence the vehicle response,
- the payload on the vehicle.

Historically, the road transport environment was simulated in the laboratory using sinusoidal vibration. Today, it is more usual to use random vibration and the strategy defined in this standard applies to that technique. It is also normal practice to include both road transport and handling shocks in a test regime as the content can be very different. The relevant specification will need to specify if this is a requirement.

3.3.2 Rail

Rail environments depend upon the suspension design which, in modern trains, is air based. Nevertheless, not all trains are modern, especially when dealing with freight transportation, thus high level and wide frequency range environments extending to high values can be anticipated. The air-based suspension system provides a very smooth, therefore generally low level, low frequency environment. Shunting shocks may produce significantly higher acceleration levels, depending on buffer design. The main factors affecting the magnitude and frequency content of this environment are

– the type of wagon suspension system,
– the rail profile,
– the position of the product on the wagon,
– the buffer type and impact speed in shunting.

3.3.3 Air

3.3.3.1 General

Air transport can take the form of either a jet or propeller driven aircraft, including rotary wing aircraft. The chosen platform can change dramatically the environment experienced by a transported product.

3.3.3.2 Jet

For jet engine aircraft, the environment is random in nature and the magnitude and frequency content of the shock and vibration will vary depending upon position within the cargo space, but can extend up to 2 000 Hz.

3.3.3.3 Propeller

In the case of propeller driven aircraft, the environment can be principally a sine wave at engine rotor and blade pass frequencies and harmonics on top of a general random background. These frequencies vary depending upon the aircraft, but are normally most dominant in the frequency range up to 200 Hz. In this case, sine-on-random simulations may be appropriate. Generally, the nature of the environment becomes less sinusoidal as the distance from the rotary excitation source increases. In this case, random-on-random simulation may be more appropriate or, more simply, a random profile with discrete frequency intervals at higher amplitude to simulate the increased levels. The inline propeller environment can become quite large and it is a location to be avoided if a product is sensitive to these frequencies.

3.3.4 Sea

Sea transport can be a combination of sinusoidal components such as engine and propeller, and random components, e.g. sea state excitation, the location of the cargo space in the ship and cargo position within the space. The main factors affecting the magnitude and frequency content of this environment are

– the size of the ship,
– the velocity of the ship,
– position of the cargo in the ship,
– the severity of the port cargo handling.

3.4 In-use

This phase of the life cycle of a product can vary significantly, influenced by a number of factors such as the mounting arrangements and position within, say, a building, the location of that building and the proximity of shock and vibration generating sources. In-use is not just limited to products that may be installed indoors; it also covers all those situations where a product is used within its design and operational mode. Clearly this can lead to a significant number of environments that the product has to meet.

The product may or may not be weather protected during this phase of its life cycle, exposing it to a different combination of environments. Perhaps the principle difference during this phase is that the product would normally need to function and operate over a much wider spectrum of environments than during any other phase.

Equally, these environments may be the most benign a product experiences in which case it may be transportation that results in the more damaging scenarios.

To clearly formulate any sort of test level and to decide on the types of environment requires an intimate knowledge of how the product is to be used and it is essential to ensure that the product is not used outside of its proven capability.

4 Shock and vibration data

The data that is acquired during a field measurement exercise generally takes the form of acceleration versus time data, measured with a suitable accelerometer and instrumentation system. The data may be recorded in either an analogue or digital format permitting a number of analysis processes to be applied to the data.

This data is normally processed into one of the following forms, dependent upon its nature:

- peak acceleration versus frequency for sinusoidal data;
- shock response spectrum for shock data;
- acceleration spectral density (ASD) versus frequency for random data.

The strategy adopted in this standard can be applied equally to each form of data.

5 Description of the methods

5.1 General

In order to allow some flexibility for the strategy to be adopted, two methods are given: the first one is a simple approach and the second utilises a statistical approach. There are other methods available and can be found in the bibliography. The chosen method should always be stated in the relevant specification.

5.2 ASD envelope method

The most common way to arrive at an envelope limit for the acceleration spectral density values at all measurement points is to superimpose the spectral curves and then select and plot the maximum spectral value at each frequency resolution bandwidth. This will produce an unsmoothed envelope which can be smoothed using a series of straight lines. To provide some consistency, these straight lines normally have slopes of (0, ±3 or ±6) dB/octaves.

The primary advantage is that this approach is easy to apply. The consequent disadvantage is that the straight line process becomes subjective and a series of envelopes would be obtained by different people.

Other disadvantages are as follows:

a) differing results can be obtained dependent upon the frequency resolution of the spectra being enveloped;

b) it cannot be guaranteed that the spectral envelope at a given frequency will encompass the spectral value of the response at another location on the platform.

5.3 Normal tolerance limit method

A more definitive way to arrive at a conservative limit for the spectral values of the structural responses on a transport platform is to compute a normal tolerance limit for the predicted spectra in each frequency resolution bandwidth.

Normal tolerance limits only apply to normally distributed random variables. The variation in the spectral response data of different data sets on a transport platform in relation to stationary, non stationary and transient dynamic loads is generally not normally distributed. However, there is considerable evidence [3] that the logarithm of the spectral values does have an approximately normal distribution. Therefore, by making the following transformation:

$$y = \log_{10} x$$

a normal tolerance limit can be predicted. Specifically, the normal tolerance limit (NTL) for y is defined as that value of y that will exceed at least a portion β (beta) of all possible values of y with a confidence of γ (gamma), and is given by:

$$\mathrm{NTL}_y = \tilde{y} + C\,S_y$$

where

$\tilde{y}$ is the sample average;

S_y is the sample standard deviation;

C is a constant taken from Table 1.

This is called the normal tolerance factor.

The normal tolerance limit in the original engineering units of x can be retrieved by:

$$NTL_x = 10^{NTLy}$$

NOTE If the spectral data is not logarithmically normally distributed, other statistical methods exist to establish tolerance limits for other distributions, or even without reference to a specific distribution [3].

Annex A shows a worked example for both methods. For the normal tolerance limit method, it is recommended that the 95/50 limit (1,78 in Table 1) is used, i.e. the limit will exceed the response spectral values for at least 95 % of all points on the transport platform with a confidence of 50 %. However, other tolerance limits may be computed if there is a reason to use a more conservative value. It should be noted that an increase in level of some 7,8 dB exists when going from the 95/50 limit (1,78 in Table 1) to the 95/90 limit (3,4 in Table 1). The relevant specification would need to justify such an increase.

Table 1 – Normal tolerance factors, C

n [a]	γ [b] = 0,50			γ = 0,75			γ = 0,90		
	β [c] = 0,90	β = 0,95	β = 0,99	β = 0,90	β = 0,95	β = 0,99	β = 0,90	β = 0,95	β = 0,99
3	1,50	1,94	2,76	2,50	3,15	4,40	4,26	5,31	7,34
4	1,42	1,83	2,60	2,13	2,68	3,73	3,19	3,96	5,44
5	1,38	**1,78**	2,53	1,96	**2,46**	3,42	2,74	**3,40**	4,67
6	1,36	1,75	2,48	1,86	2,34	3,24	2,49	3,09	4,24
7	1,35	1,73	2,46	1,79	2,25	3,13	2,33	2,89	3,97
8	1,34	1,72	2,44	1,74	2,19	3,04	2,22	2,76	3,78
9	1,33	1,71	2,42	1,70	2,14	2,98	2,13	2,65	3,64
10	1,32	1,70	2,41	1,67	2,10	2,93	2,06	2,57	3,53
12	1,32	1,69	2,40	1,62	2,05	2,85	1,97	2,45	3,37
14	1,31	1,68	2,39	1,59	2,01	2,80	1,90	2,36	3,26
16	1,31	1,68	2,38	1,57	1,98	2,76	1,84	2,30	3,17
18	1,30	1,67	2,37	1,54	1,95	2,72	1,80	2,25	3,11
20	1,30	1,67	2,37	1,53	1,93	2,70	1,76	2,21	3,05
25	1,30	1,67	2,36	1,50	1,90	2,65	1,70	2,13	2,95
30	1,29	1,66	2,35	1,48	1,87	2,61	1,66	2,08	2,88
35	1,29	1,66	2,35	1,46	1,85	2,59	1,62	2,04	2,83
40	1,29	1,66	2,35	1,44	1,83	2,57	1,60	2,01	2,79
50	1,29	1,65	2,34	1,43	1,81	2,54	1,56	1,96	2,74
∞	1,28	1,64	2,33	1,28	1,64	2,33	1,28	1,64	2,33

[a] n is the number of sample spectra.

[b] γ is the confidence coefficient.

[c] β is the limit that will be exceeded for at least a chosen percentage number of times.

As in the previous method this will produce an unsmoothed envelope which can be smoothed using a series of straight lines. To provide some consistency, these straight lines normally have slopes of (0, ±3 or ±6) dB/octaves.

The normal tolerance limit method offers a number of advantages such as

a) being a statistical approach, it provides a limit that will exceed a defined portion of the spectra with a defined confidence,

b) it is not as sensitive to the frequency resolution bandwidth as the ASD envelope method.

The potential disadvantage is that the procedure is sensitive to the assumption that at all measurement points the distribution of the platform response spectral values is lognormal.

As before, a further disadvantage is that the straight line process becomes subjective and a series of envelopes would be obtained by different people.

5.4 Product axis

5.4.1 Known axis

Whichever method is chosen to compile an environmental definition, and if it is known that a product will be stored, transported or used in a well defined orientation, then the procedure shall be repeated for each major orthogonal axis of the product or of the product in its packaging.