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**Environmental testing –
Part 2-27: Tests – Test Ea and guidance: Shock**

**Essais d'environnement –
Partie 2-27: Essais – Essai Ea et guide: Chocs**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ENVIRONMENTAL TESTING –

Part 2-27: Tests – Test Ea and guidance: Shock

FOREWORD

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International Standard IEC 60068-2-27 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test

This fourth edition cancels and replaces the third edition, published in 1987, and includes the merging of IEC 60068-2-29, second edition (1987). It constitutes a technical revision.

The major changes with regard to the previous edition concern:

- the merging of IEC 60068-2-29 into this edition of IEC 60068-2-27; Part 2-29 will be withdrawn as soon as this edition is published;
- the introduction of soft packaged specimens as defined in the IEC ad hoc working group document agreed in Stockholm:2000.

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

FDIS	Report on voting
104/448/FDIS	104/457/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.

It has the status of a basic safety publication in accordance with IEC Guide 104.

This standard is to be used in conjunction with IEC 60068-1.

A list of all the parts in the IEC 60068 series, under the general title *Environmental testing*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn,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.

INTRODUCTION

This part of IEC 60068 deals with components, equipments and other electrotechnical products, hereinafter referred to as “specimens”, which, during transportation, storage and handling, or in use, may be subjected either to conditions involving relatively infrequent non-repetitive or repetitive shocks. The shock test may also be used as a means of establishing the satisfactory design of a specimen in so far as its structural integrity is concerned and as a means of quality control. It consists of subjecting a specimen either to non-repetitive or repetitive shocks of standard pulse shapes with specified peak acceleration and duration.

Specification writers will find a list of details to be considered for inclusion in specifications in Clause 11. The necessary guidance is given in Annex A.

ENVIRONMENTAL TESTING –

Part 2-27: Tests – Test Ea and guidance: Shock

1 Scope

This part of IEC 60068 provides a standard procedure for determining the ability of a specimen to withstand specified severities of non-repetitive or repetitive shocks.

The purpose of this test is to reveal mechanical weakness and/or degradation in specified performances, or accumulated damage or degradation caused by shocks. In conjunction with the relevant specification, this may be used in some cases to determine the structural integrity of specimens or as a means of quality control (see Clause A.2).

This test is primarily intended for unpackaged specimens and for items in their transport case when the latter may be considered to be part of the specimen. If an item is to be tested unpackaged, it is referred to as a test specimen. However, if the item is packaged, then the item itself is referred to as a product and the item and its packaging together are referred to as a test specimen. When used in conjunction with IEC 60068-2-47, this standard may be used for testing packaged products. This possibility was included in the 2005 version of IEC 60068-2-47 for the first time.

This standard is written in terms of prescribed pulse shapes. Guidance for the selection and application of these pulses is given in Annex A and the characteristics of the different pulse shapes are discussed in Annex B.

Wherever possible, the test severity and the shape of the shock pulse applied to the specimen should be such as to reproduce the effects of the actual transport or operational environment to which the specimen will be subjected, or to satisfy the design requirements if the object of the test is to assess structural integrity (see Clauses A.2 and A.4).

For the purposes of this test, the specimen is always mounted to the fixture or the table of the shock testing machine during testing.

NOTE The term “shock testing machine” is used throughout this standard, but other means of applying pulse shapes are not excluded.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications.

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 60068-1, *Environmental testing – Part 1: General and guidance*

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

IEC 60068-2-55, *Environmental testing – Part 2-55: Tests – Test Ee and guidance: Bounce*

IEC 60721-3-1, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 1: Storage*

IEC 60721-3-5, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 5: Ground vehicle installations*

Guide 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

3 Terms and definitions

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

NOTE The terms used are, for the most part, defined in ISO 2041^[1] or IEC 60068-1. The following additional terms and definitions are also applicable for the purposes of this standard.

3.1

check point

point located on the fixture, on the table surface of the shock-testing machine or on the specimen as close as possible to the fixing point, and in any case rigidly connected to it

NOTE 1 A number of check points are used as a means of ensuring that the test requirements are satisfied.

NOTE 2 If more than four fixing points exist, the relevant specification should state the number of fixing points to be used as check points.

NOTE 3 In special cases, for example, for large or complex specimens, the check points will be prescribed by the relevant specification if not close to the fixing points.

NOTE 4 Where a large number of small specimens are mounted on one fixture, or in the case of a small specimen where there are a number of fixing points, a single check point (that is the reference point) may be selected for the derivation of the control signal. This signal is then related to the fixture rather than to the fixing points of the specimen(s). This procedure is only valid when the lowest resonance frequency of the loaded fixture is well above the upper frequency of the test.

3.2

fixing point

part of the specimen in contact with the fixture or the table of the shock-testing machine at a point where the specimen is normally fastened in service

NOTE If a part of the real mounting structure is used as the fixture, the fixing points are taken as those of the mounting structure and not of the specimen.

3.3

g_n

standard acceleration due to the earth's gravity, which itself varies with altitude and geographical latitude

NOTE For the purposes of this standard, the value of g_n is rounded up to the nearest unity, that is 10 m/s².

3.4

repetition rate

number of shocks per second

3.5

shock severity

combination of the peak acceleration, the duration of the nominal pulse and the number of shocks

1 Figures in square brackets refer to the bibliography.

3.6

velocity change

absolute value of the sudden change of velocity resulting from the application of the specified acceleration

NOTE The change of velocity is normally considered sudden if it takes place in a time that is short compared with the fundamental period of the test specimen.

4 Description of test apparatus

4.1 Required characteristics

When the shock-testing machine with or without fixture is loaded with the specimen, the waveform measured at the check point(s) shall consist of a pulse approximating to one of the nominal acceleration against time curves given by the broken lines in Figures 1, 2 and 3.

4.1.1 Basic pulse shapes

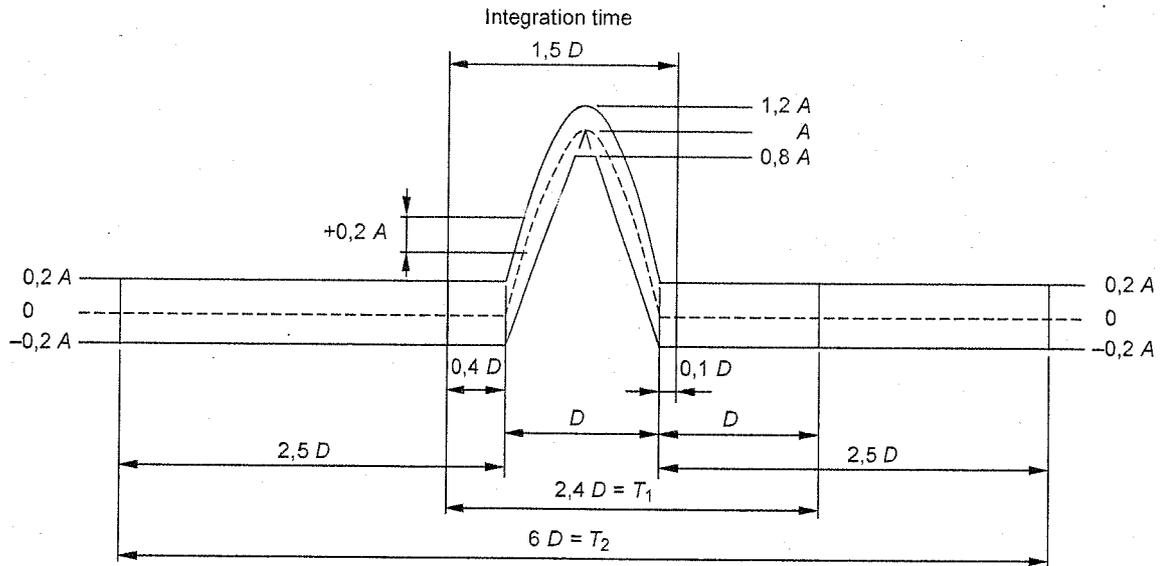
Three types of pulse, namely the half-sine pulse, the final-peak saw-tooth pulse and the trapezoidal pulse, are included in this standard. The choice of pulse shape depends on a number of factors, and the difficulties inherent in making such a choice preclude a preferred order being given in this standard (see Clause A.3).

The specified basic pulse shapes are given below (see Clause A.3):

- half-sine: one half-cycle of a sine wave, as shown in Figure 1;
- final-peak saw-tooth: asymmetrical triangle with short fall time, as shown in Figure 2;
- trapezoidal: symmetrical trapezoid with short rise and fall times, as shown in Figure 3.

The true value of the actual pulse shall be within the limits of tolerance shown by the solid lines in the relevant figure.

NOTE Where it is not practicable to achieve a pulse shape falling within the specified tolerance, the relevant specification should state the alternative procedure to be applied (see Clause A.5).



IEC 303/08

Key (applicable for all three Figures 1 to 3)

- - - nominal pulse
- limits of tolerance

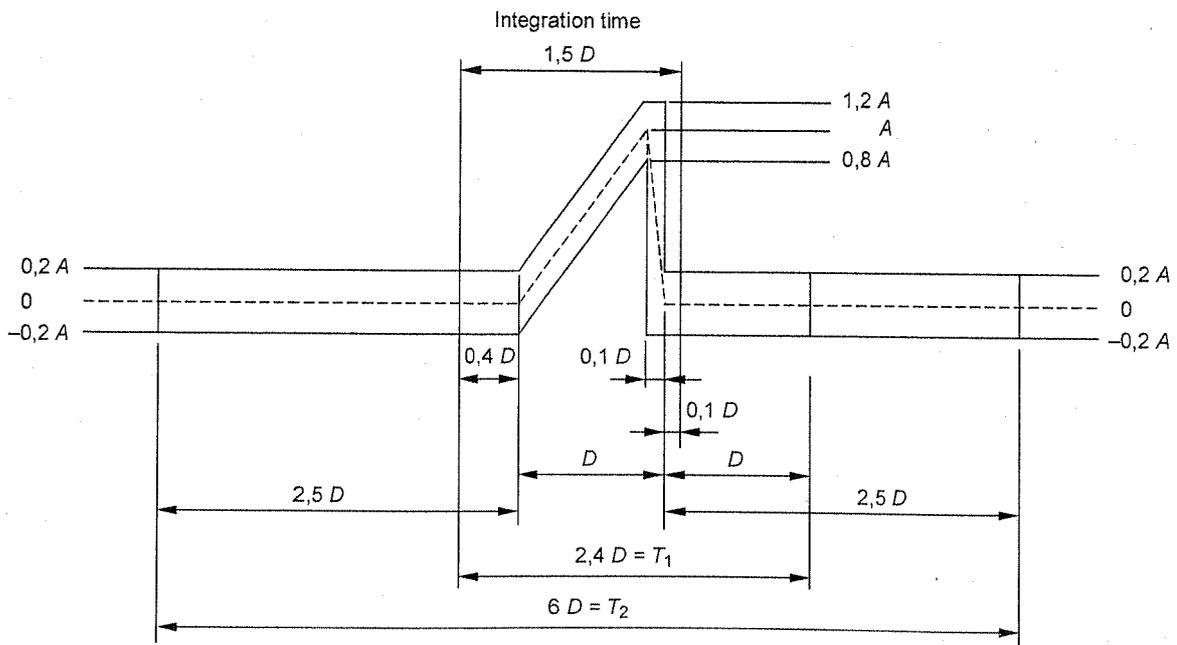
D = duration of nominal pulse

A = peak acceleration of nominal pulse

T_1 = minimum time during which the pulse shall be monitored for shocks produced using a conventional shock-testing machine

T_2 = minimum time during which the pulse shall be monitored for shocks produced using a vibration generator

Figure 1 – Pulse shape and limits of tolerance for half-sine pulse



IEC 304/08

Figure 2 – Pulse shape and limits of tolerance for final-peak saw-tooth pulse

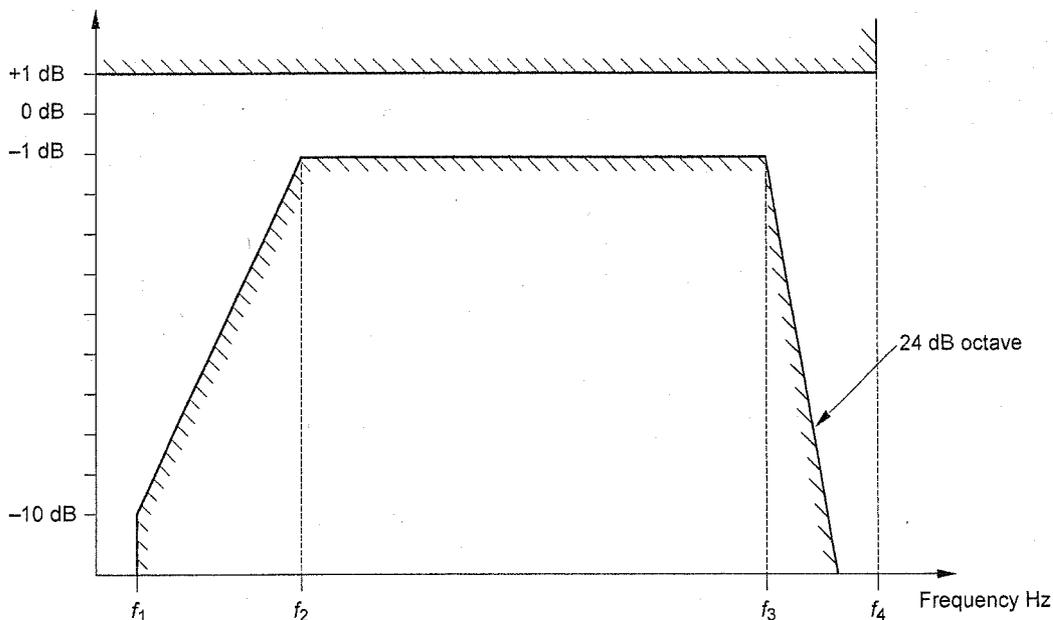
$$f_g = \frac{1,5}{D}$$

where

f_g is the cut-off frequency of a low-pass filter in kHz;

D is the pulse duration in ms.

The frequency response of the overall measuring system, which includes the accelerometer, can have a significant effect on the accuracy and shall be within the limits shown in Figure 4 (see also Clause A.5).



IEC 306/08

Duration of pulse ms	Low-frequency cut-off Hz		High-frequency cut-off kHz	Frequency beyond which the response may rise above +1 dB kHz
	f_1	f_2	f_3	f_4
0,2 and 0,3	20	120	20	40
0,5	10	50	15	30
1	4	20	10	20
2 and 3	2	10	5	10
6	1	4	2	4
11	0,5	2	1	2
16, 18 and 30	0,2	1	1	2

NOTE For shocks of duration equal to or less than 0,5 ms, the value of f_3 and f_4 indicated in Figure 4 may be unnecessarily high. In such instances, the relevant specification should state which alternative values are to be adopted.

Figure 4 – Frequency characteristics of the overall measuring system

4.3 Mounting

The specimen shall be mounted on the table of the shock-testing machine or fixture in accordance with IEC 60068-2-47.

5 Severities

The relevant specification shall prescribe the pulse shape and the shock severity. Shocks shall be applied in all three axes and in both a positive and negative direction, as required by the relevant specification. The effects of gravity shall be considered when considering the attitude of the test. Unless real usage conditions are known or otherwise specified, one of the pulse shapes given in 4.1.1 and a severity shown on the same line in Table 1 shall be used. The preferred combinations are in bold. The corresponding velocity changes are also given in Table 1.

The number of shocks in each direction may be chosen from the following values:

3 ± 0

100 ± 5

500 ± 5

$1\ 000 \pm 10$

$5\ 000 \pm 10$

NOTE If the effects of the known environment on the specimen cannot be reproduced by severities given here, the relevant specification may prescribe an appropriate severity using one of the standard pulse shapes, shown in Figures 1, 2 and 3 (see also Clause A.4).

Table 1 – Severities for shock testing

Peak acceleration (A)		Corresponding duration of the nominal pulse (D)	Half-sine $\Delta V = 2 / \pi AD \times 10^{-3}$	Final-peak saw-tooth $\Delta V = 0,5 AD \times 10^{-3}$	Trapezoidal $\Delta V = 0,9 AD \times 10^{-3}$	Foot-notes
m/s ²	g _n	ms	m/s	m/s	m/s	
50	5	6	0,2^a	0,2	0,3	
50	5	30	1	0,8	1,4	
60	6	11	0,4	0,3	0,6	b
100	10	16	1	0,8	1,4	
100	10	11	0,7	0,6	1	c
100	10	6	0,4	0,3	0,5	
150	15	6	0,6	0,5	0,8	c
150	15	11	1,1	0,8	1,5	
200	20	11	1,4	1,1	2	b
250	25	6	1	0,8	1,4	c
300	30	6	1,1	0,9	1,6	
300	30	18	3,4	2,7	4,9	
400	40	6	1,5	1,2	2,2	c
400	40	11	2,8	2,2	4	
500	50	3	1	0,8	1,4	
500	50	11	3,5	2,8	5	
800	80	6	3,1	2,4	4,3	c
1 000	100	2	1,3	1	1,8	c
1 000	100	6	3,8	3	5,4	
1 000	100	11	7	5,5	9,9	
2 000	200	3	3,8	3	5,4	
2 000	200	6	7,6	6	10,8	
5 000	500	1	3,2	2,5	4,5	
10 000	1 000	1	6,4	5	9	
15 000	1 500	0,5	4,8	3,8	6,8	
30 000	3 000	0,2	3,8	3	5,4	
30 000	3 000	0,3	5,7	4,5	8,1	
50 000	5 000	0,3	9,5	7,5	13,5	d
100 000	10 000	0,2	12,7	10	18	d

^a Preferred pulse shapes are printed in bold letters.

^b Recommendations given in RTCA DO 160E/F: 6 g "functional shock", 3 per direction; 20 g "crash shock", 1 per direction.

^c Preferred severities for repetitive shocks.

^d These shocks may not be achievable within the stringent requirements of this standard.

6 Preconditioning

The relevant specification may call for preconditioning.

7 Initial measurements and functional performance test

The specimen shall be submitted to visual, dimensional, functional and any other checks as prescribed by the relevant specification.

8 Testing

The number of shocks prescribed by the relevant specification shall be applied successively in each direction of three mutually perpendicular axes of the specimen. When testing a number of identical specimens, they may be oriented so that the shocks are applied simultaneously along these three axes (see Clause A.7).

Where the attitude of the specimen, when mounted or transported, is known, and since shocks are generally of greatest significance in one direction of one axis, the relevant specification shall state the specified number of shocks that shall be applied and in which axis, direction and attitude. Otherwise, three axes and two directions shall be tested. For example, usually the highest levels of shock acceleration are along the vertical axis. When the attitude during transportation is known, the shocks should be applied in what will be the vertical axis in the upward direction. Where the attitude is unknown, the specified number of shocks shall be applied in each of the axes prescribed by the relevant specification (see Clause A.7).

The relevant specification shall state whether the specimen shall operate during testing and if any functional monitoring is required.

9 Recovery

It is sometimes necessary to provide a period of time after testing and before final measurements to allow the specimen to attain the same conditions, for example of temperature, as existed for the initial measurements. The relevant specification shall then prescribe the conditions for recovery.

10 Final measurements

The specimen shall be submitted to the visual, dimensional and functional checks and any others as prescribed by the relevant specification.

The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen shall be based.

11 Information to be given in the relevant specification

When this test is included in a relevant specification, the following details shall be given in so far as they are applicable, paying particular attention to the items marked with an asterisk (*) as this information is always required.

	Clause
a) Pulse shape*	4.1.1 and A.3
b) Tolerances	4.1.1 and A.5
c) Velocity change	4.1.3 and A.6
d) Cross axis motion	4.1.4
e) Excitation axis, testing attitude and testing axes*	8
f) Method of mounting*	4.3

g) Severity*	5 and A.4
h) Directions and number of shocks*	5 and 8
i) Preconditioning	6
j) Initial measurements	7
k) Functional performance test	7
l) Operating modes and functional monitoring	8
m) Recovery	9
n) Acceptance and rejection criteria*	10
o) Final measurements	10

12 Information to be given in the test report

As a minimum the test report shall show the following information:

1. Customer (name and address)
2. Test laboratory (name and address)
3. Test report identification (date of issue, unique number)
4. Test dates
5. Purpose of the test (development test, qualification)
6. Test standard, edition (relevant test procedure)
7. Test specimen description (unique identity, drawing, photo, quantity, comments on initial status of test specimen, etc.)
8. Mounting of test specimen (fixture identity, drawing, photo excitation axis)
9. Excitation axis (testing attitude and testing axes)
10. Performance of test apparatus (cross motion, etc.)
11. Measuring system, sensor location (description, drawing, photo)
12. Uncertainties of measuring system (calibration data, last and next date)
13. Initial, intermediate or final measurements
14. Required severities (from test specification)
15. Test severities with documentation (measuring points)
16. Test results (comment on status of test specimen)
17. Observations during testing and actions taken
18. Summary of test
19. Test manager (name and signature)
20. Distribution (list of those receiving report)

NOTE A test log should be written, where the test is documented as, for example, a chronological list of test runs with test parameters, observations during testing and actions taken, and data sheets on measurements made. The test log can be attached to the test report.

Annex A (normative)

Selection and application of pulse shapes – Guidance

A.1 Introduction

The test described in this standard provides a method to represent the effects on a specimen when subjected to transportation or during operation. The test does not necessarily reproduce the real environment.

The parameters given are standardized and suitable tolerances are chosen in order to obtain similar results when a test is carried out at different locations by different people. The standardization of values also enables components to be grouped into categories corresponding to their ability to withstand certain severities given in this standard.

A.2 Applicability of test

Many specimens are liable to be subjected to shocks during use, storage and handling and transportation. These shocks will be at widely varying levels and will also be of a complex nature.

The shock test provides a convenient method for establishing the ability of a specimen to withstand conditions of both non-repetitive and repetitive shocks. The test is performed on the specimen when mounted to the fixture or table of the shock-testing machine. If the specimen is installed or transported as loose cargo and subjected to repetitive shocks, then the test shall be performed according to IEC 60068-2-55 (see Annex C).

The shock test is also suitable for structural integrity tests on component type specimens for qualification and/or for quality control purposes. It is normal under these circumstances to utilize high acceleration shocks with the main purpose of applying a known force to the internal structure of a specimen, particularly those containing cavities, that is hollow spaces, (see Clause 1).

To ensure that all test information is provided, the specification writer should refer to Clause 11 of this standard.

A.3 Pulse shapes (see Clause 1)

For test purposes, there are three 'classical' shock pulse shapes which are in general use and any of these may be used (see also 4.1.1 and Table 1).

The half-sine pulse has application when reproducing the effects of a shock resulting from impact with, or retardation by, a linear rate system, for example impact involving a resilient structure.

The final-peak saw-tooth pulse has a more uniform response spectrum than the half-sine and trapezoidal pulse shapes.

The trapezoidal pulse produces a higher response over a wider frequency spectrum than the half-sine pulse. It should be applied when the purpose of the test is to reproduce the effects of shock environments such as the "explosive bolt" phase of a space probe/satellite launch.

NOTE The half-sine pulse shape is the most generally applicable. The trapezoidal pulse shape is not primarily intended for component type specimens.

Information on the shock response spectra associated with these pulses is given in Annex B.

Where the shock response spectrum of the operational/transportation environment is known, reference should be made to Figures A.1, A.2 and A.3 in order to select the shape of the pulse most nearly conforming to it. Where the shock response spectrum of the operational/transportation environment is not known, reference should be made to Tables A.1 and A.2 which list the test severities and pulse shapes applicable to specimens intended for various classes of transportation and operational use.

For packaged items, the shocks encountered during handling and transportation are often of a simple nature which makes it possible to use a half-sine pulse derived from the observed velocity change.

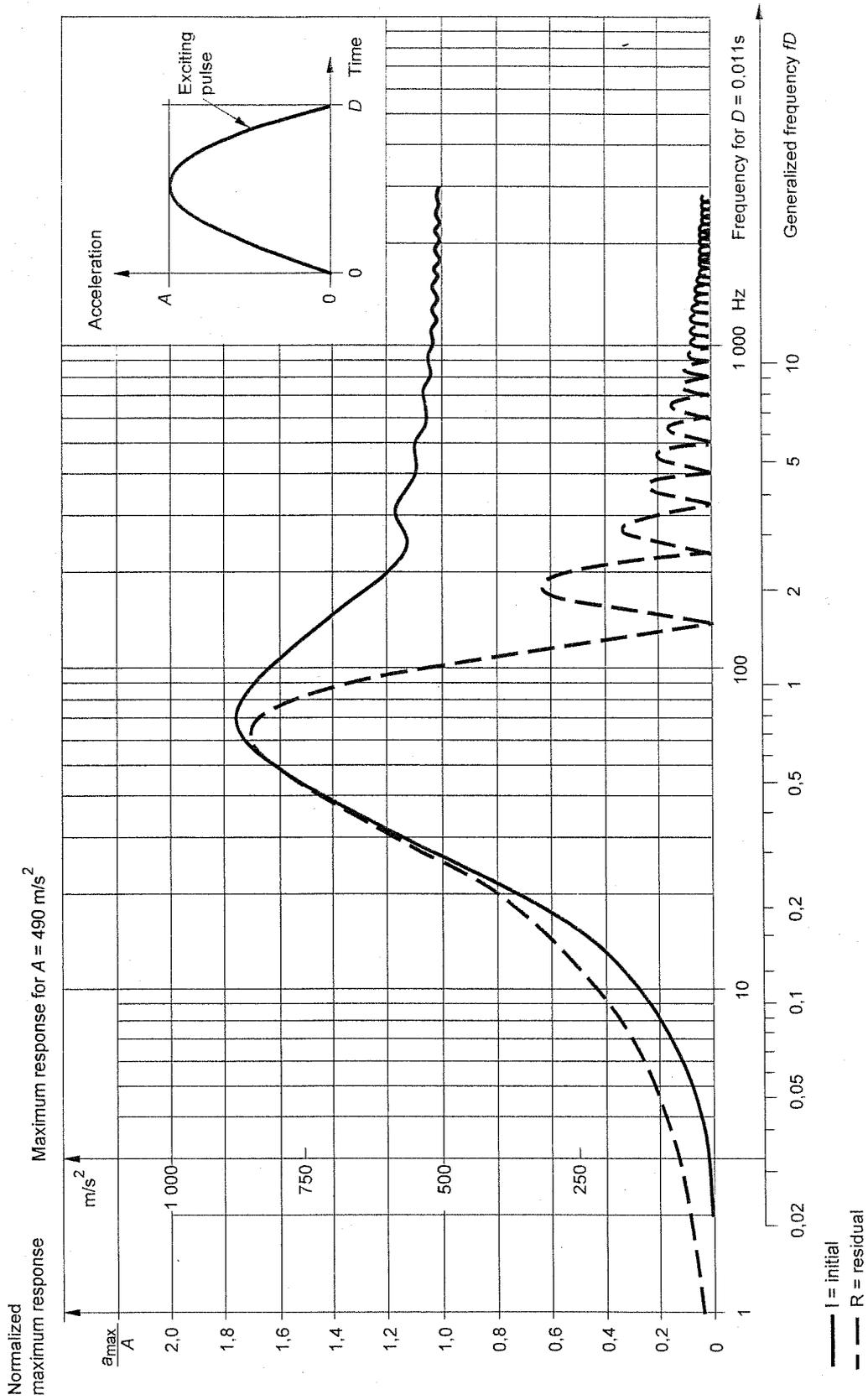


Figure A.1 – Shock response spectrum of a symmetrical half-sine pulse

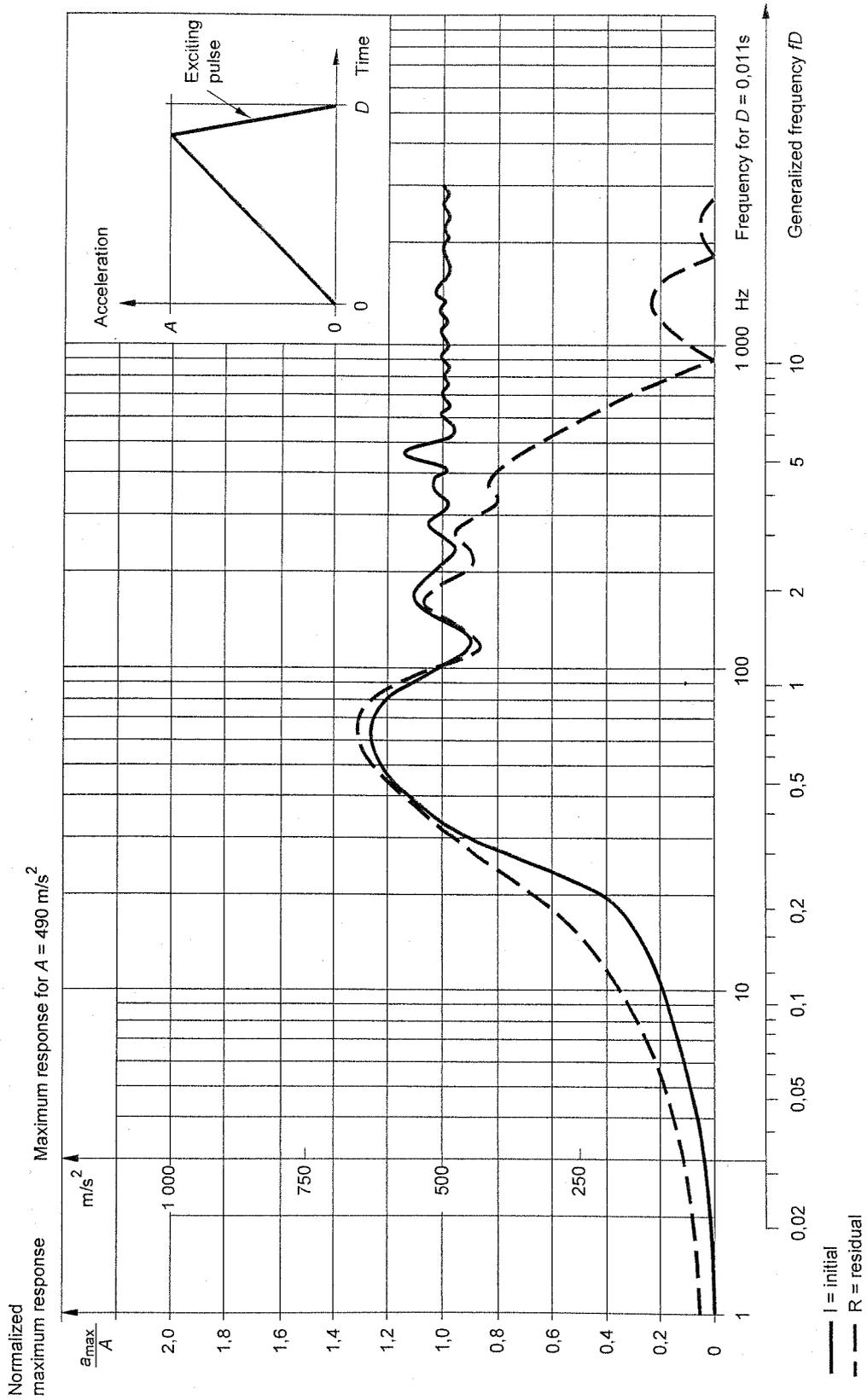


Figure A.2 – Shock response spectrum of a final-peak saw-tooth pulse

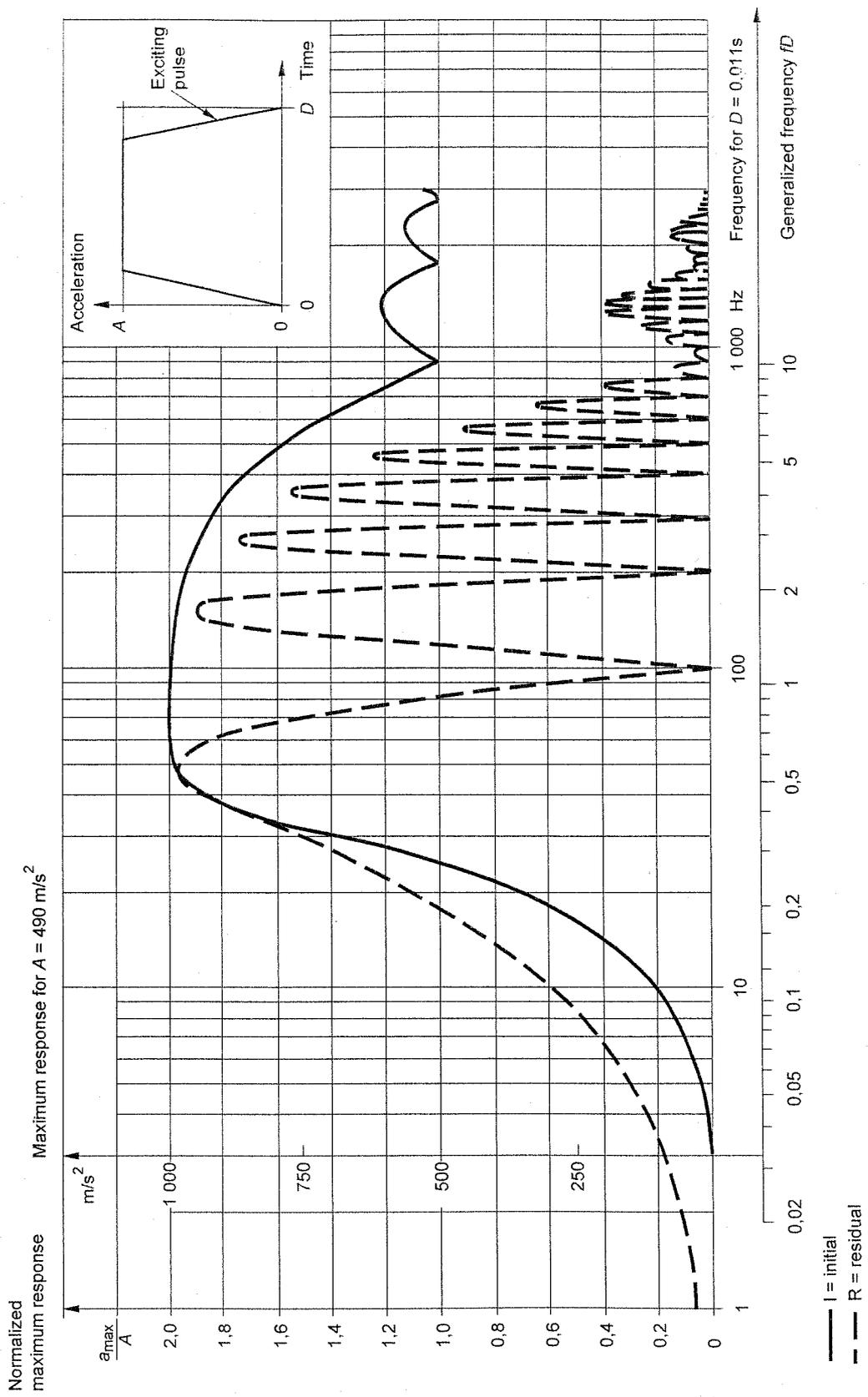


Figure A.3 – Shock response spectrum of a symmetrical trapezoidal pulse

A.4 Test severity

Whenever possible, the test severity and the shape of the shock pulse applied to the specimen should be related to the environment to which the specimen will be subjected, during either transportation, storage and handling, or operation, or to the design requirements if the object of the test is to assess structural integrity.

It is often suitable to perform, on the same specimens, a test of non-repeated shocks (three shocks in each axis and in each direction) using higher levels of stress to determine the ability of the specimen to withstand the maximum stress that it may encounter during its normal life.

Also a test of repeated shocks at lower levels of stress may be conducted to determine the ability of the specimen to withstand the repeatedly occurring shocks, maybe during operation, during which the effect of material fatigue may be determined.

The transportation environment is frequently more severe than the operational environment and in these circumstances the test severity chosen may need to be related to the former. However, although the specimen may only need to survive the transportation environment, it will normally be required to function during the operational environment, where appropriate. Therefore, it may be necessary to carry out shock tests under both conditions, with measurements of certain parameters after the "transportation environment" test and functional checks during the "operational environment" test.

Consideration should be given to the possible need to allow an adequate safety margin between the test severity and the conditions of the real environment.

When the real operational or transportation environment is unknown, the appropriate severity should be selected from Table 1 which lists the test severities applicable for various classes of transportation and operational use.

It is emphasized that the shock test is empirical and is basically a robustness test conducted in order to give a measure of confidence. It is not intended to simulate precisely the real environment.

In determining the test severity, the specification writer should take into account the information given in relevant standards in the IEC 60721 series, namely IEC 60721-3-1 and IEC 60721-3-5, remembering that these publications list values of shocks encountered in practice whereas the intention of this standard is to standardize shock pulses for testing that are likely to produce the same effects as real life shocks.

Table A.1 – Examples of pulse shapes and test severities typically employed for various applications

NOTE 1 This table lists severities which are not mandatory but are typical for the various applications. It should be remembered that there will be instances where real severities differ from those shown in the table.

NOTE 2 Severities given in Table A.1 relate to test of non-repetitive shocks (three shocks in each axis and in each direction). For test severities of repetitive shocks see Table A.2.

Severity			Pulse shape	Component use	Equipment use
Peak acceleration		Duration			
m/s ²	g _n	ms			
150	15	11	Half-sine Final-peak saw-tooth Trapezoidal		General test for robustness, handling and transport Land-based items permanently installed or only transported by road, rail or air in secured shock-resistant packages
300	30	18	Half-sine Final-peak saw-tooth Trapezoidal		Structural integrity of mountings Installed or transported in a secured position on normal road or rail vehicles or in transport aircraft
500	50	11	Half-sine Final-peak saw-tooth Trapezoidal ^a	Items in secured packages transported by wheeled vehicles (normal road and rail) subsonic or supersonic transport aircraft, merchant ships or light marine craft Items mounted in equipment transported by, or installed in, wheeled vehicles (normal road or rail) subsonic or supersonic transport aircraft, merchant ships or light marine craft Items for installation in heavy industrial equipment	Items installed or transported in a secured position in full cross-country vehicles Items carried loose in normal road or rail vehicles for long periods Items used in industrial areas and subjected to shock from mechanical handling equipment, for example: dock cranes, fork-lift trucks
1 000	100	6	Half-sine Final-peak saw-tooth Trapezoidal ^a	Items in secured packages transported by cross-country vehicles Items mounted in equipment transported by or installed in cross-country vehicles Items mounted in equipment installed in subsonic or supersonic transport aircraft Items mounted in equipment carried loose in road or rail vehicles for long periods	Severe handling shocks on road or rail transport High-intensity shocks due to ignition, stage separation of rockets (space vehicles), aerodynamic buffeting and re-entry of space vehicles Portable items
5 000	500	1	Half-sine	Structural integrity tests on semiconductors, integrated circuits, microcircuits and micro-assemblies with or without sensors	Blast excited shocks, on land, sea or air
15 000	1 500	0,5	Half-sine	Structural integrity tests on semiconductors, integrated circuits and microcircuits	

^a Not primarily intended for component-type specimens.

Table A.2 – Examples of severities typically employed for various applications

NOTE Table A.2 lists severities which are not mandatory but are typical for the various applications. It should be remembered that there will be instances where the real severities differ from those shown in the table.

Severity			Number of shocks in each specified direction	Component use	Equipment use
Peak acceleration		Duration			
Equivalent m/s ²	g_n	ms			
100	10	16	1 000	Transportation of fragile items by road, excluding cross-country	General robustness test and for items installed or transported in a secured position in wheeled vehicles with no cross-country requirement
150	15	6	4 000	Minimal robustness test and for items of general application with main mechanical load occurring during transportation	Items installed in control equipment of stationary or heavy mobile machinery, for example, in the vicinity of power plants
250 ^a	25	6	1 000		Items installed or transported in a secured position in full cross-country vehicles. Items installed in mechanical handling equipment, for example, dock cranes, fork-lift trucks
400	40	6	1 000	Transportation of items intended for use in equipment of a non-portable nature	Items which may be carried loose in wheeled vehicles (road or rail) for occasional journeys, for example, delivery
400 ^a	40	6	4 000	Items for use in transportable equipment	Transportable items which are repeatedly carried loose in any type of vehicle, rail, road or cross-country
1 000	100	2	4 000	Lamps and spring contacts, for example for keys, telephones for switchboards	

^a It is recommended that the test severities of 250 m/s² and 400 m/s² should only be specified for specimens with a nominal mass of less than 100 kg. For heavier specimens, the 100 m/s² severity is generally more appropriate.

A.5 Tolerances

The test method described in this standard is capable of a high degree of reproducibility when the tolerance requirements relating to basic pulse shape, velocity change and cross axis motion are complied with.

However there are certain exceptions to these tolerance requirements which are primarily applicable to specimens which provide a highly reactive load, that is with mass and dynamic responses which would influence the characteristics of the shock-testing machine. In these cases, it is expected that the relevant specification will specify relaxed tolerances and/or state that the values obtained shall be recorded in the test report.

When testing highly reactive specimens it may be necessary to carry out preliminary shock testing to check the characteristics of the loaded shock testing machine. With complex specimens, where only one or a limited number is provided for test, the repeated application of shock prior to the definitive test could result in an over-test and possibly unrepresentative cumulative damage. In such instances, it is recommended that whenever possible the preliminary checking should be carried out using a dynamically representative specimen (such

as rejected equipment), or, when this is not available, it may be necessary to use a weighted space model, which should as a minimum, have the correct mass and centre of gravity disposition. However, it needs to be noted that a space model is unlikely to have the same dynamic response as the real specimen.

If a low-pass filter is used, its cut-off frequency should be so chosen that the basic pulse deformation is negligible. Potentially damaging high-frequency effects should previously have been determined by other means, for example a vibration test.

The frequency response of the overall measuring system, including that of the accelerometer, is an important factor in the achievement of the required pulse shape and severity and needs to be within the tolerance limits shown in Figure 4. When it is necessary to employ a low pass filter to reduce the effect of any high-frequency resonances inherent in the accelerometer, the amplitude and phase characteristics of the measuring system will need to be considered in order to avoid distortion of the reproduced waveform.

For shocks of duration equal to or less than 0,5 ms, f_3 and f_4 indicated in Figure 4 may be unnecessarily high. In such instances, the relevant specification should state which alternative values are to be adopted.

A.6 Velocity change

For all pulse shapes the actual velocity change is specified in Table 1. This velocity change may be determined in a number of ways, including:

- the impact velocity for shock pulses not involving rebound motion;
- the drop and rebound height where free fall facilities are used;
- integration of the acceleration/time curve.

When specifying integrating techniques, unless otherwise stated, the actual velocity change should be determined by integrating between the limits of $0,4D$ before the start of the pulse and $0,1D$ beyond the pulse, where D is the duration of the nominal pulse. It should be noted, however, that determination of the velocity change using the electronic integrating method can be difficult and may require the use of elaborate facilities. The cost implication should be considered before invoking this method.

One purpose of specifying the velocity change and its associated tolerance is to encourage the test laboratory to achieve a pulse equivalent to the nominal pulse, that is central within the tolerance boundaries of the pulse (see Figures 1, 2 and 3). In this way, the reproducibility of the test is maintained.

Another purpose is associated with the shock response spectra of pulses (see Clause B.3).

A.7 Testing

One of the basic requirements of the test is to apply shocks in each of six directions. When it is unnecessary to test in all six directions, for example because of symmetry or because there are clearly directions in which the effects of the shock would be less, the relevant specification may modify the number of directions. In practice, the number of specimens available, their complexity, cost and possible orientation, are factors which may also need to be taken into consideration.

Depending on the number of identical specimens available and the mounting arrangements, particularly in the case of components, the specimens may be oriented to allow the requirements of the specification to be satisfied with a minimum number of shocks or shock applications.

When only one specimen is available for non-repetitive shock testing, 18 shocks need to be applied but the test will then take on a somewhat different character with the possibility of it being non-representative. It is important, therefore, that the relevant specification writer give this matter adequate thought.

Equipment type specimens, which will always be either operational or transported on their normal base, need only be subjected to shocks when mounted on that base. A specimen which, during transportation, may be placed on more than one of its faces should be tested in each of the axes and directions defined in the relevant specification. Bearing in mind the empirical nature of the test, three mutually perpendicular directions would normally be adequate.

The requirement that between shocks any relative motion within the specimen be substantially zero is intended to ensure reproducibility of the test. Otherwise, re-excitation of the resonance(s) of the specimen at different phases of its resonance(s) decay is possible which could give varying results for identical specimens.

NOTE In order to assess whether the conditions stated have been satisfied, the test engineer may make use of the following formula which is not intended for general use and should not be referred to in specifications:

$$R \equiv \frac{f_{res\ min}}{10} \quad (A.1)$$

where R is the repetition rate and $f_{res\ min}$ is the lowest resonance frequency.

Where the internal motion of the specimen cannot be observed, for example in an enclosed item, the relevant specification will need to indicate the course of action. In many cases, particularly for components, no action will be necessary.

Annex B (informative)

Shock response spectra and other characteristics of pulse shapes

B.1 Introductory remark

In order to utilize improved techniques in shock testing and to allow for further development of shock testing machines, Test Ea requires one of three pulse shapes, with a stated severity, to be applied to the specimen fixing points and does not restrict the testing to specific machines. The choice of pulse shape and severity should be made in accordance with technical considerations appropriate to the project or type of specimen.

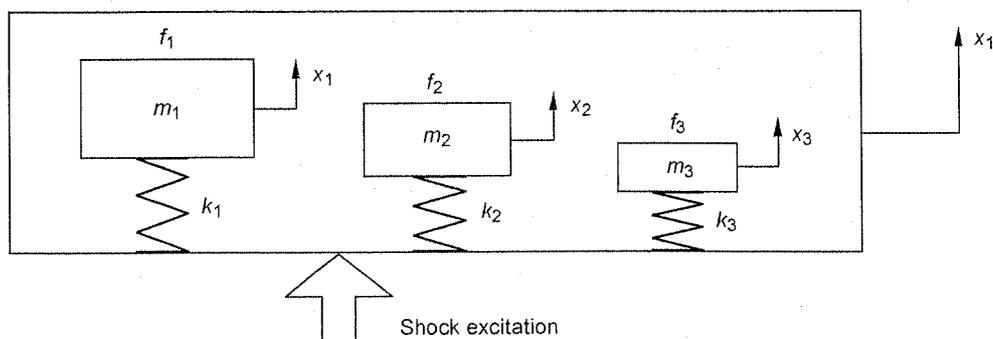
All methods should be regarded as acceptable from the standpoint of reproducibility of the specified test condition and for reproducing the effects of actual shock environments. In order to obtain tests which are both reproducible and which can be related to practical application, certain basic concepts have been taken into consideration in producing the test procedure for the shock test. The concepts involved are given below. See further ISO 8568 [2].

B.2 Shock response spectrum concept

The acceleration shock response spectra of various pulse shapes give a useful measure of the damage potential of the shocks in many important practical cases. It must be recognized, however, that from certain points of view, they have limited applicability.

The acceleration shock response spectrum can be regarded as the maximum acceleration response to a given shock excitation of undamped mass-spring systems as a function of the resonance frequencies of the systems. The maximum acceleration of oscillatory systems determines in most cases the maximum mechanical stress of attachments and the maximum relative displacement of elastic members.

Let the framework of Figure B.1 be subjected to a shock excitation with a given pulse shape, for example a time history of the acceleration $d^2x_f/dt^2 = a(t)$. The response of the system will be oscillations with different acceleration time histories for the masses, m , depending on the resonance frequency (f_1, f_2, f_3 , etc.).



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Key

- m mass
- k spring constant
- x displacement relative to a fixed coordinate system

Figure B.1 – Framework or box containing oscillatory systems of which f_1 , f_2 and f_3 are examples of resonance frequencies

An example of pulse shape with peak value A and duration D is shown in Figure 2a, giving response accelerations $d^2x_1/dt^2 = a_1(t)$, etc., as shown in Figure B.2b.

The shock response spectra (Figure B.2c) result from an infinite number of resonance frequencies and are plots of the different extreme acceleration responses a_{\max} in Figure 2b as functions of resonance frequency for the undamped linear mass-spring system.

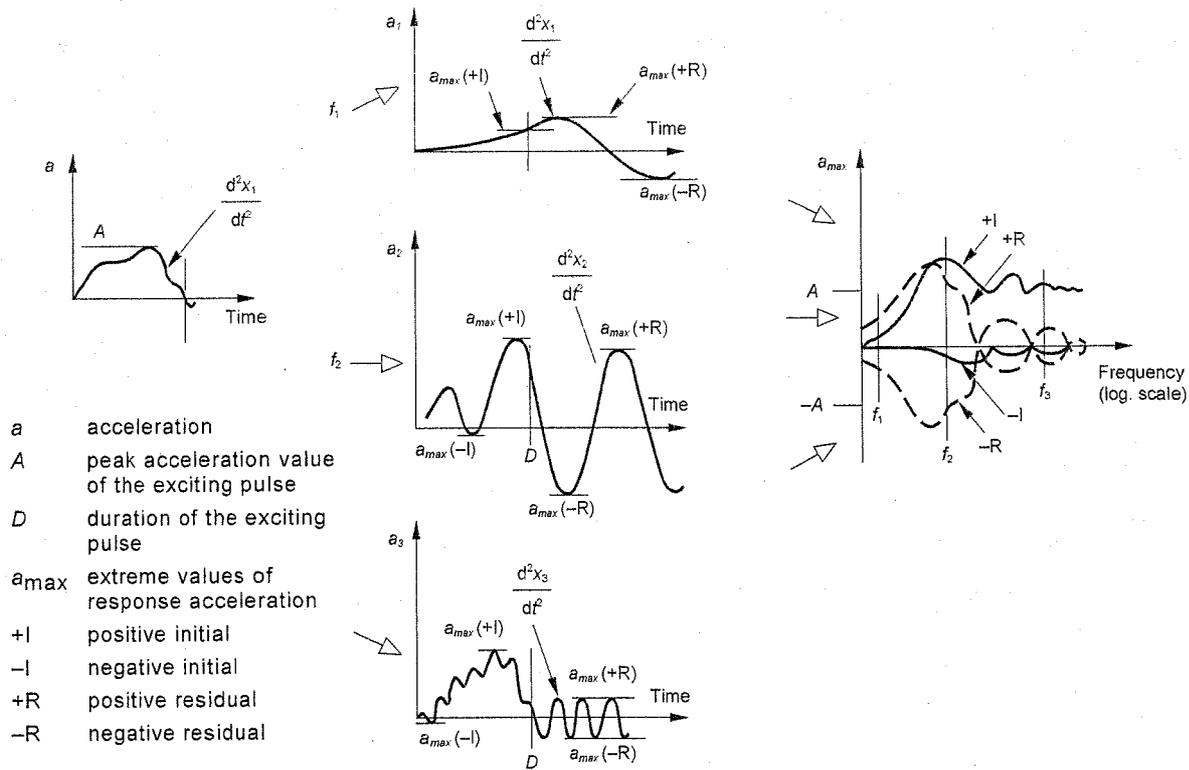
The positive initial shock spectrum, +I, in Figure B.2c is the plot of the maximum response occurring during the pulse duration in the same direction as the exciting pulse: the $a_{\max}(+I)$ in Figure B.2b.

The positive residual shock spectrum, +R, is the plot of the same maximum response occurring after the pulse duration and in the same direction as the pulse: the $a_{\max}(+R)$.

The negative initial shock spectrum, -I, is the plot of the maximum response during the pulse in the opposite direction to the exciting pulse: the $a_{\max}(-I)$.

The negative residual shock spectrum, -R, is the plot of the maximum response after the pulse in the opposite direction to the pulse: $a_{\max}(-R)$.

All four spectra are shown in Figure B.2c with the examples of resonance frequencies of the framework also noted.



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Figure B.2a – Exciting pulse

Figure B.2b – Responses for f_1, f_2 and f_3

Figure B.2c – Spectra which result from an infinite number of frequencies, with f_1, f_2 and f_3 shown as finite points on the continuous curves

Figure B.2 – Shock response spectrum concept

As the damping is assumed to be zero, the response after the pulse duration is a steady sinusoidal oscillation around zero acceleration. Thus the positive residual and negative residual are images in the frequency axis of each other. Usually, only the positive residual is shown in presenting acceleration response spectra.

The negative initial spectrum is everywhere less in magnitude than the positive initial spectrum for the pulse shapes of concern here. The shock-testing procedure therefore requires testing in both directions along each axis. The maximum acceleration for the parts will then be determined by the positive initial spectrum in both directions. The negative initial spectrum is therefore omitted in the following.

The envelope of the positive initial and positive residual spectra shows the maximum response acceleration of the masses whenever it occurs. It is called the “maximax” shock response spectrum. However, in order to convey the requisite information clearly, the initial and residual spectra are plotted separately. In practice, it is often difficult to find the precise pulse duration. In such cases, it is impracticable to determine these spectra individually.

The spectra can easily be generalized with respect to peak value and duration for all shocks with the same pulse shape. If, instead of f and a_{max} , the coordinate scales fD and a_{max}/A are chosen, the shock spectra will be valid for any shocks of the same pulse shape. The spectra

given here have therefore two coordinate scales: a_{\max}/A as a function of fD and a_{\max} as a function of f for a particular example of duration and peak acceleration.

B.3 Use of first-order shock response spectra in practical cases

In components and equipments, the internal parts generally form more complicated systems than undamped systems, for instance series-connected multi-degree-of-freedom systems with damping, as shown in Figure B.3. In this case, shock excited oscillations in one outer system may cause damage to an inner system by coupled resonance effects. These effects can be described by sets of higher order shock spectra, valid for given combinations of resonance frequencies of the mass-spring subsystems.

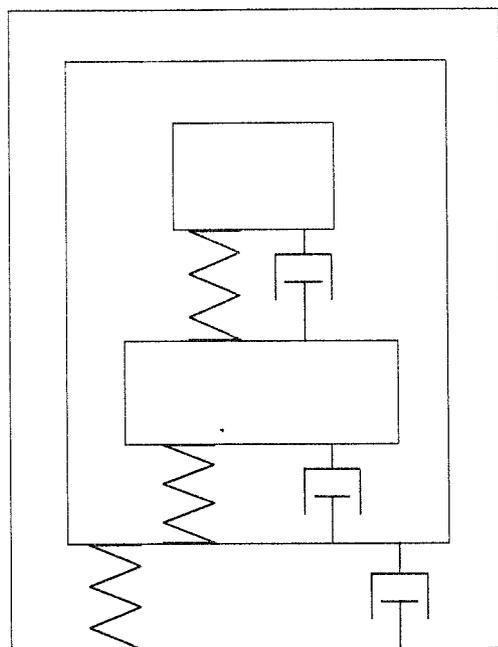
If the resonance frequencies of the series-connected systems are separated to any significant extent, the first-order shock spectrum gives a reasonable measure for comparing the damage potential of shocks of different pulse shapes.

The highest acceleration of the internal masses will be reached when resonances are excited during the period of the pulse. In this case, the oscillation acceleration will be superimposed upon that of the pulse itself. Hence, it will be evident from Clause B.3 that the greatest liability to damage in this respect will be when using short rise time pulses.

In general, damping will decrease the response at medium frequencies during the pulse and at both medium and higher frequencies after the pulse. The damping will decrease both the amplitude and the duration of oscillation and attenuates thereby the response of any inner system. The damage potential of a shock is therefore in general lower for damped systems than for undamped, particularly for multi-degree-of-freedom systems. The shock response spectra of undamped systems represent the worst possible cases.

Acceleration shock response spectra therefore do not describe completely the damage potential of the shock. Nevertheless, this simplified presentation is sufficient to allow an appropriate pulse shape to be chosen for actual configurations.

Before comparing shock response spectra, accurate shock-testing requires a judgement of the importance of prolonged response oscillations represented by the residual spectra compared to the short responses represented by the initial spectra. The judgement should be based on possible failure modes.



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Figure B.3 – Framework containing damped multi-degree-of-freedom system

B.4 Shock response spectra of nominal pulse shapes

The acceleration shock response spectra of the recommended nominal pulse shapes are shown in Figures A.1, A.2 and A.3.

The form of the spectra for the same pulse shape is the same irrespective of pulse duration due to the use of non-dimensional scales. The normalized frequency scale fD allows frequency scales for any duration D to be determined. The generalized response scale, a_{\max}/A , allows the determination of acceleration scales for any peak value A .

At low frequencies and for $fD < 0,2$, the initial spectra are nearly the same, while the residual spectra are nearly proportional to the velocity change of the pulse. This is one reason for the additional tolerance requirement on velocity change. The trapezoidal pulse shape has the highest velocity change for a given peak acceleration and duration.

In the intermediate frequency range $0,2 \leq fD \leq 10$, the initial spectra show differences in level depending mainly on the rise time of the pulse. The final-peak saw-tooth pulse has the longest rise time and shows the lowest response for a given value. The trapezoidal pulse shows the highest response for a given peak acceleration value due to the short rise time and the flatness of the peak, allowing even the low-frequency oscillations to reach their peak before the instantaneous value of the originating pulse falls. The residual spectrum of the saw-tooth pulse also shows a relatively high and smooth course up to the first zero at approximately $fD = 10$. The frequency of this zero depends on the ratio of the rise and fall times, the frequency increasing the steeper the fall of the final peak. The residual spectra of the half-sine and trapezoidal pulses have repeated zeros beginning at relatively low frequencies, approximately $fD = 1$. This is due to the symmetry of these pulses and is a great disadvantage from the point of view of reproducibility of the tests. Slight changes in pulse duration or symmetry may cause considerable changes in residual response and give different test results.

At higher frequencies, the initial spectra approach $a_{\max}/A = 1$ and the residual spectra zero. This is illustrated by the fact that a mass on a very stiff spring follows closely the acceleration-time history of the exciting pulse. The statement is valid for all pulse shapes having finite rise and fall times.

B.5 The effect of ripple

Oscillatory systems with low or no damping are very sensitive to ripple on the pulse. As an example, the effect on the shock spectrum of a half-sine pulse is shown in Figure B.4.

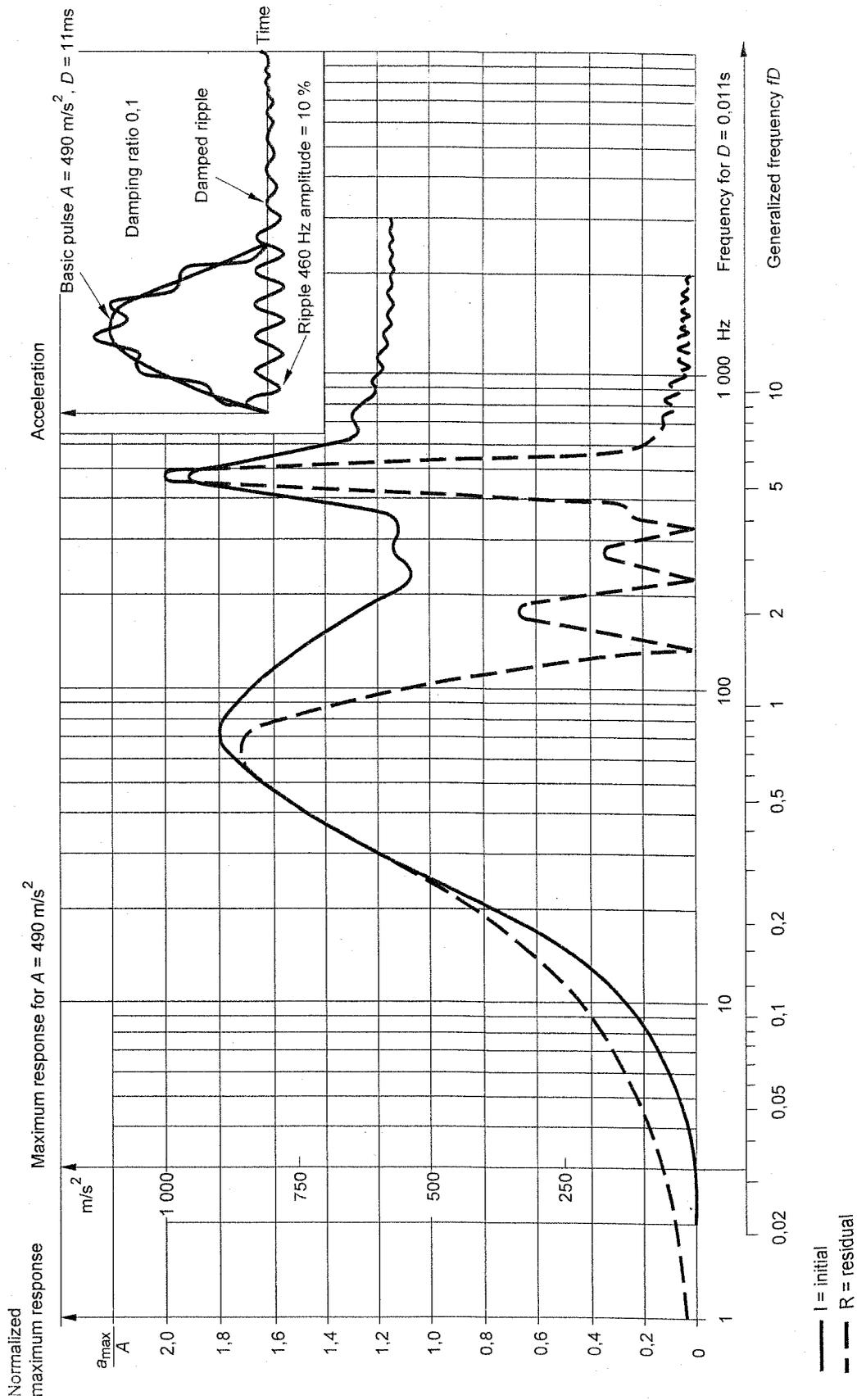


Figure B.4 – Shock response spectrum of a half-sine pulse with ripple

A 460 Hz signal of 50 m/s^2 ($5 g_n$) amplitude is superimposed on the nominal 500 m/s^2 ($50 g_n$) and 11 ms half-sine pulse (10 % ripple, $Q = 5$). After the nominal pulse a damping ratio of 10 % is applied to the ripple. This produces a theoretical pulse comparable with the actual pulses which may be obtained by shock generators. The effect as can be seen is considerable, especially on the residual spectrum. An increase of the ripple to 20 % would increase the peak values to around $a_{\text{max}}/A = 4$. In general, ripple should therefore be avoided as far as possible in order to preserve reproducibility of the test.

Ripple frequencies in the low-frequency range (where $fD < 0,2$) have a negligible effect. Frequencies in the higher ranges (where $fD \geq 0,2$) give peaks at the ripple frequency, the response increasing with higher frequencies for a constant ripple amplitude. The residual spectrum is always relatively more affected than the initial. The initial spectrum of the pulse shape with short rise time, the trapezoidal, is sensitive only to high-frequency ripple. The initial spectrum of the final-peak saw-tooth is very sensitive to ripple in the whole intermediate and high-frequency range.

Ripple which is only slightly damped and therefore extends for an appreciable time after the end of the nominal pulse can affect the residual spectrum considerably.

When excessive ripple is present, the results of a shock test could be significantly different from those obtained in a test where ripple is within the specified tolerance bands. The tolerance bands around the nominal pulse shapes are intended to take care of permitted ripple as well as other shape distortions.

B.6 Reproducing the effects of various shock pulses by a single pulse

The recommended shock pulses are not intended to simulate the shocks encountered in practice, but to reproduce the effects of the real environment. For shock testing, therefore, consideration of the shock spectra of the real environment is necessary. However, this information is often limited to a statistical distribution of peak acceleration or to an estimation of design level.

It is often possible to reproduce with a single pulse the effects of a number of shocks of given peak value and varying duration.

Figure B.5 provides a comparison of the response spectra of a series of half-sine pulses with the response spectrum of a single saw-tooth waveform of higher peak value. Although there is some over-testing with regard to the initial spectrum, there is a considerable degree of overlap of these spectra.

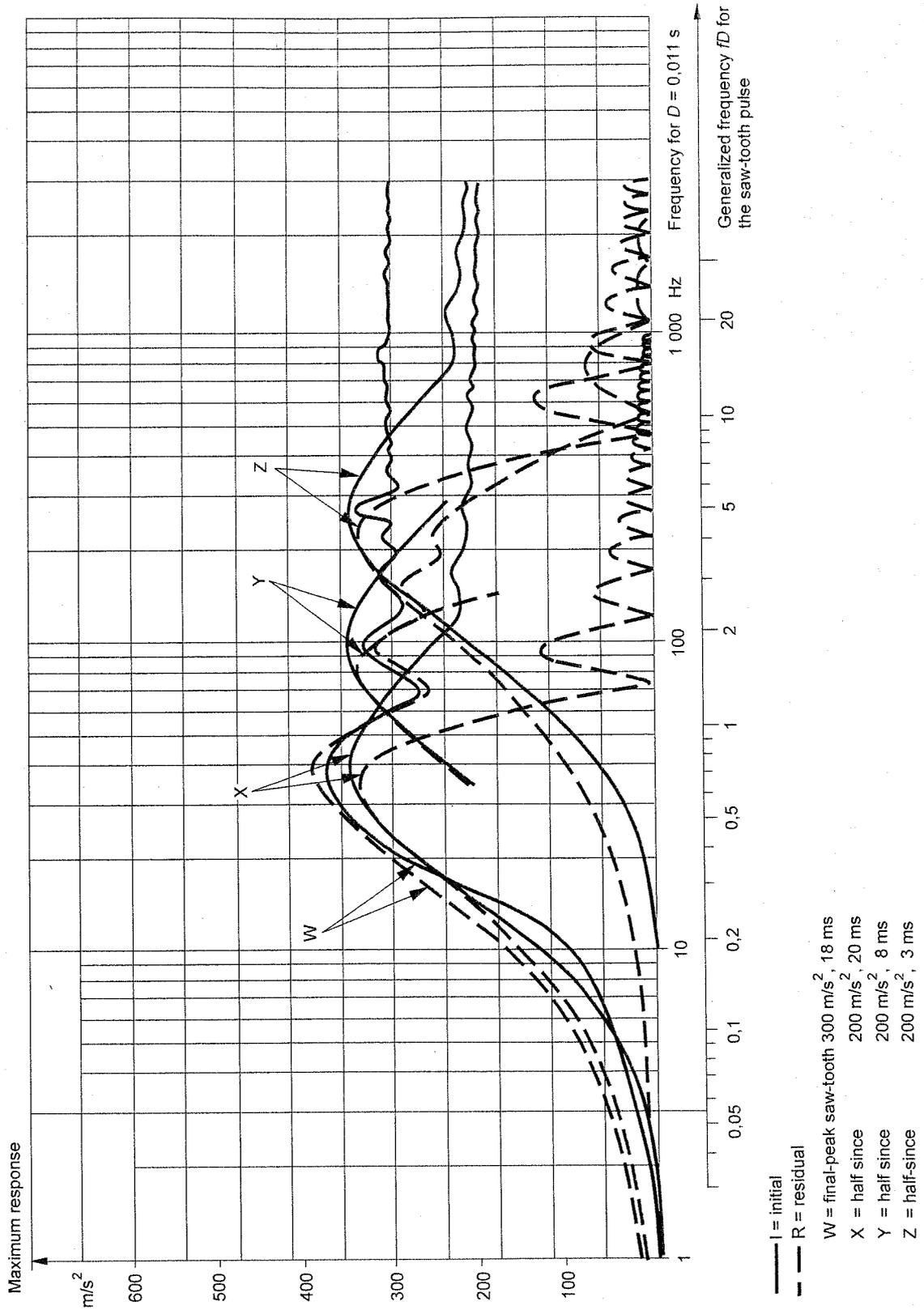


Figure B.5 – Spectrum of a final-peak saw-tooth 300 m/s², 18 ms pulse compared with the spectra of 200 m/s² half-sine pulses with durations between 3 ms and 20 ms

Annex C (informative)

Comparison between impact tests

Test Ec: Rough handling shocks, primarily for equipment-type specimens
(IEC 60068-2-31)^[3]

Intended to assess the effects of knocks or jolts likely to be received primarily by equipment-type specimens during repair work or rough handling on a table or bench.

Free fall

Intended to assess the effects of falls likely to be experienced due to rough handling. It is also suitable for demonstrating a degree of robustness.

Free fall repeated

Intended to reproduce the effects of repetitive falls likely to be received by certain component type specimens, for example connectors in service.

Test Ee and guidance: Bounce
(IEC 60068-2-55)

Intended to reproduce the effects of the repetitive shock conditions experienced by specimens which may be carried as loose cargo in wheeled vehicles travelling over irregular surfaces.

Test Ei: Shock – Shock response spectrum synthesis
(IEC 60068-2-81)^[4]

Intended for general application to specimens, when simulation is required of transient responses of a complex nature for the specimens.

Shock tests are performed on the specimen when mounted to the shock testing machine. Drop and topple, free fall, repeated free fall and bounce tests are performed with the specimen free.

Bibliography

- [1] ISO 2041:1990, *Vibration and shock – Vocabulary*
 - [2] ISO 8568:1989, *Mechanical shock – Testing machines – Characteristics and performance*
 - [3] IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens²*
 - [4] IEC 60068-2-81:2003, *Environmental testing – Part 2-81: Tests – Test Ei: Shock – Shock response spectrum synthesis*
 - [5] ISO/IEC 17025: 2005, *General requirements for the competence of testing and calibration laboratories*
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² Currently bearing the title « Basic environmental testing procedures – Part 2-31: Tests – Test Ec: Drop and topple, primarily for equipment-type specimens”. A second edition, which will replace the first edition (1969), is actually in preparation and will bear this slightly re-worded title.