
AMERICAN NATIONAL STANDARD

Shock Test Requirements for Equipment in a Rugged Shock Environment

ANSI/ASA S2.62-2009

Accredited Standards Committee S2, Mechanical Vibration and Shock

Standards Secretariat
Acoustical Society of America
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**Shock Test Requirements for Equipment in a Rugged
Shock Environment**

Secretariat:

Acoustical Society of America

Approved June 9, 2009 by:

American National Standards Institute, Inc.

Abstract

This American National Standard is to be used for testing equipment that will be subjected to shock. It defines test requirements and severity thresholds for a large range of shock environments, including but not limited to shipping, transport, and rugged operational environments. This standard will allow vendors to better market and users to more easily identify equipment that will operate or simply survive in rugged shock environments.

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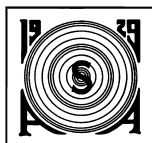
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Foreword

[This Foreword is for information only, and is not a part of the American National Standard ANSI/ASA S2.62-2009 American National Standard Shock Test Requirements for Equipment in a Rugged Shock Environment.]

This standard comprises a part of a group of definitions, standards, and specifications for use in mechanical vibration and shock. It was developed and approved by Accredited Standards Committee S2 Mechanical Vibration and Shock, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S2 is as follows:

Standards, specifications, methods of measurement and test, and terminology in the field of mechanical vibration and shock, and condition monitoring and diagnostics of machines, including the effects of exposure to mechanical vibration and shock on humans, including those aspects which pertain to biological safety, tolerance and comfort.

This standard includes four Annexes. Annexes A and B are normative and considered to be a part of this standard. Annexes C and D are informative and not considered part of this standard.

Accompanying this standard are two ZIP files which contain graphs in ASCII format. These graphs are electronic versions of the ones included in this standard. The standard asks the user to present his/her test data overlaid against the severity thresholds, to make sure the test meets the specified threshold. Having electronic versions of the threshold graphs makes it much easier for the user to present his/her data in the shock test report. These files are provided for the convenience of the user. Use of these graphs is not required for conformance with the Standard.

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Introduction

This standard provides shock test parameters for testing a broad range of equipment, which will ensure inherent levels of shock resistance. The severity thresholds herein can be associated with specific shock environments and should be chosen for a given application on a case-by-case basis. The intent of the standard's requirements is to outline those elements necessary for verification of a successful and accurate shock test, but not the specific method. This standard will allow vendors to better market and users to more easily identify equipment that will operate or simply survive in rugged shock environments.

American National Standard

Shock Test Requirements for Equipment in a Rugged Shock Environment

1 Scope

This American National Standard defines graduated thresholds of shock severity for equipment whose normal use subjects it to some amount of shock. The shock severity thresholds are defined by drop height and shock pulse (type and width) or, alternatively, by velocity change and pseudo velocity shock response spectra. This standard requires that data be measured during a test to verify that a test shock is intense enough to meet a given shock severity threshold. This standard includes test requirements and guidelines to ensure adequate and accurate test results.

2 Terms and Definitions

For the purposes of this standard, the terms and definitions given in ANSI S2.1-2000 and the following apply:

2.1 damage. Failure criterion characterized by permanent degradation in physical appearance that is unrelated to operational performance [*i.e.*, damaged structural joint(s) resulting in snap-fit fractures, but not impairing system/component operation].

2.2 drop shock machine. A shock machine that “include[s] a carriage (or table) on which the item under test is mounted; the carriage can be hoisted up to some required height and dropped onto an anvil. Guides are provided to keep the carriage properly oriented...Programming devices, placed upon the point of impact of the anvil, can be used to control the acceleration vs. time characteristic and the shape of the acceleration pulse”[1].

There are many variants of drop shock machines, two of which are shown in Figure 1 and Figure 2. Figure 1 shows a vertical drop-table shock machine, which is more common and described in the definition above. Figure 2 shows an arc drop shock machine, which accomplishes the drop by swinging the equipment through an arc in the vertical plane. The drop height for this type of drop machine is defined as the vertical component of the arc before it is dropped, which is labeled as “h” in Figure 2.

2.3 four coordinate paper (4CP). Also known as tripartite paper. A more in-depth explanation can be found in Annex D.

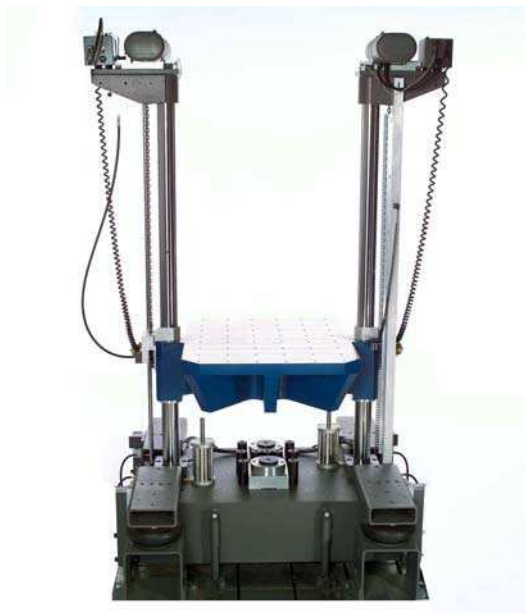


Figure 1 – Example of a vertical drop-table shock machine¹

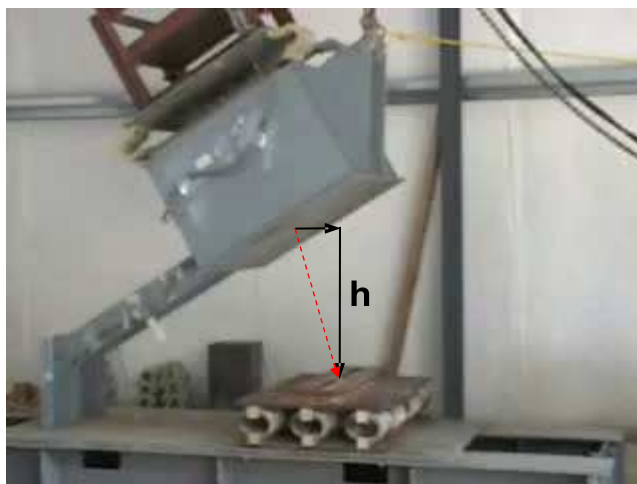


Figure 2 – Example of an arc drop shock machine²

¹ Picture provided courtesy of Lansmont Corporation

² Picture provided courtesy of NTS

2.4 irreversible failure. Failure criterion characterized by an irreversible, environment-induced, inoperative condition or operation outside of tolerances. Irreversible refers to the system/component remaining inoperative or out of tolerance after the environment has been removed.

2.5 malfunction. Failure criterion characterized by an environment-induced inoperative condition or out-of-tolerance operation. However, the process is reversible (*i.e.*, the system/component returns to satisfactory operation upon removal of the environment).

2.6 mechanical shock. “A nonperiodic excitation (*e.g.*, a motion of the foundation or an applied force) of a mechanical system that is characterized by suddenness and severity, and it usually causes significant relative displacements in the system” [1].

2.7 non-operational. Test condition status in which the unit under test (UUT) is not energized or powered. Non-operational includes a dormant state.

2.8 operational. Test condition status in which the UUT is performing its primary function. If the UUT requires external support including power, water, gas, or ventilation, these sources should be provided.

2.9 packaged. Test condition status in which the UUT is ready for shipment or prepared for storage.

2.10 pseudo velocity (PV). Product of the maximum relative displacement of a single-degree-of-freedom system and the angular natural frequency (rad/s).

$$\omega_n = 2\pi f_n \quad (1)$$

$$PV = z\omega_n \quad (2)$$

Where

z = relative displacement

f_n = natural frequency

ω_n = angular natural frequency

2.11 pseudo velocity shock response spectrum (PVSRS). Shock response spectrum showing pseudo velocity vs. frequency. A more in-depth explanation can be found in Annex D and [2].

2.12 shock machine. “A mechanical device that applies a mechanical shock to equipment under test” [1].

2.13 shock response spectrum (SRS).

2.13.1 Description of the responses to an applied shock of a series of systems of a specified type as a function of their natural frequencies.

2.13.2 As used in the field of mechanical shock, expression that approximates the maximum responses (displacement, velocity or acceleration) to an applied shock of an assembly of linear single-degree-of-freedom systems, as a function of their natural frequencies.

2.13.3 Shock response spectrum is a generic term. It requires an additional modifier to make its meaning specific, for example acceleration, velocity, pseudo velocity, or displacement shock response spectrum.

2.13.4 If the amount and type of damping of the systems are not given, they are assumed to be zero. Unless otherwise indicated, the responses are maximum absolute values irrespective of sign and the time at which the maximum occurs. This is often referred to as maximax shock response spectrum. If reference is made to other types of shock response spectra, this needs to be stated.

2.13.5 It should be noted that the concept of a shock response spectrum is not fully consistent with the definition of spectrum (see ANSI S2.1-2000).

2.14 unit under test (UUT). Piece of equipment, structure, etc., that is being subjected to a shock test.

3 Requirements of the Standard

3.1 Unit Under Test required information

3.1.1 UUT description

A description of the UUT shall be provided including physical characteristics (*i.e.*, weight, dimensions, etc.) and normal operational characteristics. The description determines the key parameters of testing.

The UUT shall be a production-line item or one that suitably represents those operating in the field. If it is not, differences between the UUT and production/fielded items shall be stated.

3.1.1.1 UUT's primary function

Detailed explanation of the UUT's intended use over its life cycle and when it will be susceptible to a shock load within the specified threshold shall be provided.

3.1.1.2 Hardware configuration

Detailed description of the UUT's hardware configuration, including subassemblies shall be provided.

3.1.1.3 Restrictions or limitations on equipment use

A description of restrictions or limitations on using the equipment (*i.e.*, has to be water-cooled, needs to be operated in conjunction with another system, etc.) shall be provided.

3.1.1.4 Installation instructions

Instructions shall include the following items:

- Description of how the UUT will be installed in the field.
- Description of how the UUT will be installed during the shock test.

UUT installation for the shock test shall emulate field installation or the configuration when it will see the greatest shock load (*i.e.*, transit, shipping, etc.).

3.1.2 Test condition

The status of the UUT during the shock test shall be specified as one of the conditions given below. The UUT test status shall be equivalent to intended field use of the UUT under which it is most likely to experience shock:

- Packaged
- Non-operational
- Operational.

3.1.3 Functionality and operability requirements

Functionality and operability requirements shall determine if equipment meets a specified severity threshold (see Clause 3.2 for definition) after the shock test. Both the UUT performance and failure criterion shall be specified, including requirements for a pre- and post-test functional compliance assessment. If the test condition is operational, concurrent performance shall be included. The failure criterion shall be one of those listed in 3.1.3.2.

3.1.3.1 Performance requirements

Provide a detailed list of the UUT's functionality and operability requirements as well as tests used to verify functional compliance of the equipment before, during, and after the shock test.

3.1.3.2 Failure criterion

Failure criterion shall be one of the following:

- Damage
- Malfunction
- Irreversible failure
- User-defined failure criterion falling outside the definitions of damage, malfunction, or irreversible failure.

3.2 Severity threshold

3.2.1 The severity threshold defines a shock magnitude applied to the UUT. There are ten severity thresholds listed in this standard, which are intended to be guidelines, not boundaries (see 3.2.6.11 for testing beyond Level 10). The shock test should be performed using a drop shock machine with a simple half-sine pulse. The half-sine pulse shall fall within certain tolerances explained in 3.2.3. The pulse width shall be specified along with the severity threshold, the details of which are listed in 3.2.3.4. Only one drop in the primary loading orientation is required; however, optional test sections are included for an angled drop test (see 3.3.3) and a multi-bounce drop test (see 3.2.7). A digital time history in ASCII format (see 3.5) shall be included in the shock test report to verify test results.

3.2.2 Table 1 lists the no-rebound drop height required for a drop shock test at each specific threshold. For information on a drop shock test with a rebound, see 3.2.5. The shock test may also be performed with other pulse shapes or alternative shock tests, but shall be subject to additional requirements (see 3.2.4).

Table 1 – No-rebound severity threshold drop heights

Threshold	h (mm)
Level 1	51
Level 2	204
Level 3	459
Level 4	816
Level 5	1275
Level 6	1835
Level 7	2498
Level 8	3263
Level 9	4130
Level 10	5099

3.2.3 Half-sine pulse

3.2.3.1 Half-sine pulse characteristics

When conducting a drop shock test using a half-sine pulse, the pulse shall fall within certain criteria to be classified as a “half-sine pulse”. The test pulse shall be compared to a threshold (ideal) half-sine pulse at the specified severity threshold and pulse width. To generate a threshold half-sine pulse, see 3.2.3.2. The test pulse shall match the threshold pulse within certain tolerances on pulse shape, amplitude, and width. Half-sine pulse tolerances are specified in 3.2.3.3.

3.2.3.2 Half-sine pulse generation

A no-rebound severity threshold half-sine pulse shall be generated for the specific severity threshold and pulse width chosen by the tester. A half-sine pulse can be generated³ using Equations (3) to (5) and the parameters given below. An example of a half-sine pulse can be seen in Figure 3 and parameters for this example pulse are shown in Table 2.

$$h = \frac{\Delta v^2}{2g} \quad (3)$$

$$\Delta v = v_2 - v_1 \quad (4)$$

Where

v_1 = velocity before impact

v_2 = velocity after impact

h = no-rebound drop height (see 3.2.5 for information on rebounds)

g = gravitational acceleration = 9.80665 m/s²

$$A = \frac{\pi \Delta v}{2D} \quad (5)$$

Where

A = threshold pulse amplitude (peak acceleration)

D = threshold pulse width (pulse duration)

To simulate a drop shock test with only one impact, acceleration data shall be added before and after the pulse.

<u>Added Data:</u>	0 – 0.4D ms	0 g	Beginning of pulse
	end of pulse – 1 s	0 g	UUT stops and remains at rest (could have residual movement in actual test)

$$\left(Acceleration [g] = Acceleration \left[\frac{m}{s^2} \right] \times \frac{1}{9.80665 \text{ m/s}^2} \right) \quad (6)$$

³ UERDTools was used to create all plots in this standard.

Table 2 – Example half-sine pulse parameters for Figure 3

Threshold	h (mm)	Δv (m/s)	D (ms)	A (g)
Level 2	203.9	2.0	40.00	8.01

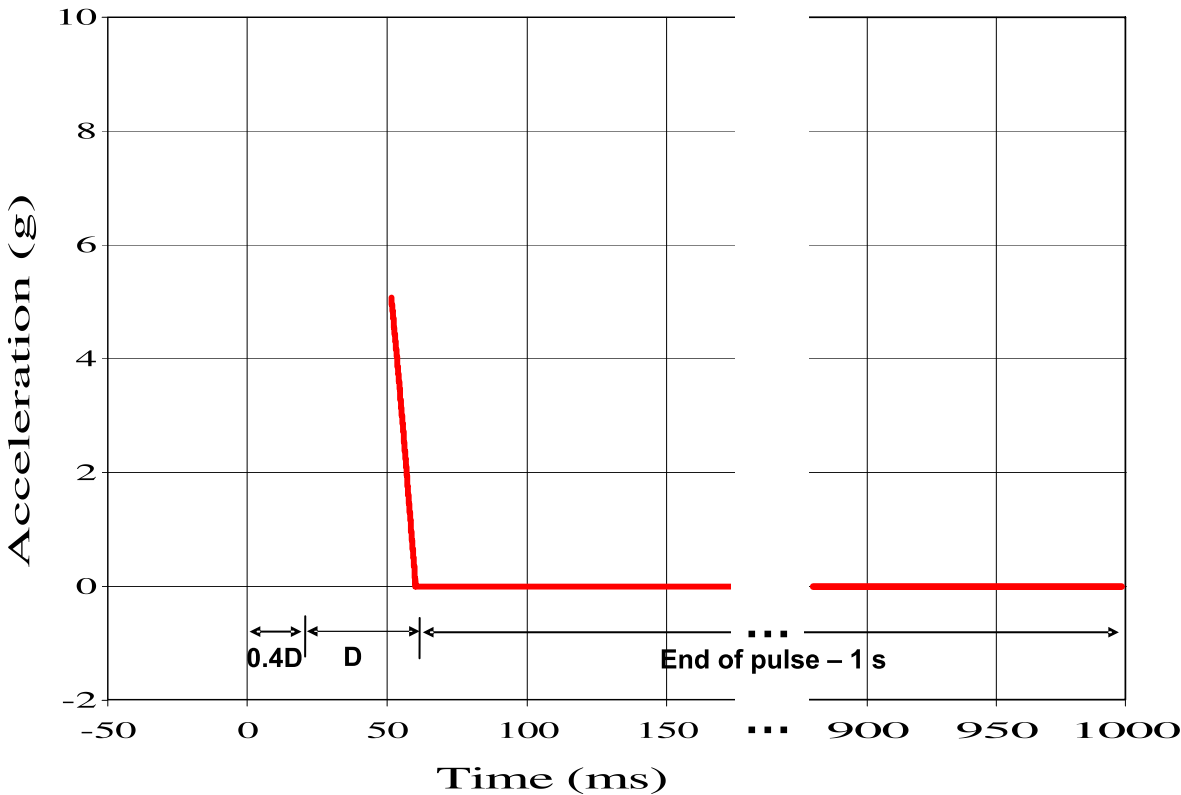


Figure 3 – Half-sine pulse example: Level 2, 40 ms

3.2.3.3 Half-sine pulse tolerance

The threshold half-sine pulse generated in 3.2.3.2 represents an “ideal” half-sine pulse. The actual test pulse shall meet the threshold ideal half-sine pulse, within specific tolerances for acceleration and pulse width. The test pulse width (D_{TP} – see Figure 4 for example) should be within $\pm 10\%$ of the chosen pulse width (see Equation (7) for calculating test pulse width).

$$D_{TP} = \frac{t_{\text{end}} - t_{\text{beg}}}{0.8718} \tag{7}$$

Where

- D_{TP} = test pulse width
- t = time
- t_{beg} = $t(0.2A)$, at the beginning of the pulse
- t_{end} = $t(0.2A)$, at the end of the pulse

The beginning and end of the threshold ideal half-sine pulse are clearly defined. The beginning and end times of the actual test pulse have to be interpreted from the measured data, which aren’t as well defined. In an attempt to more clearly define the beginning and end times for the test pulse, t_{beg} and t_{end} are defined as times when the test pulse amplitude is equal to 20% of the threshold pulse amplitude. The times at which a threshold ideal half-sine pulse are equal to 20% of the threshold pulse amplitude are

$(0.4 + 0.0641) \times D$ and $(0.4 + 0.9359) \times D$, respectively, which results in an apparent pulse width of $0.8718 \times D$. To compensate for the shorter apparent pulse width, $(t_{\text{end}} - t_{\text{beg}})$ is divided by 0.8718 to obtain D_{TP} .

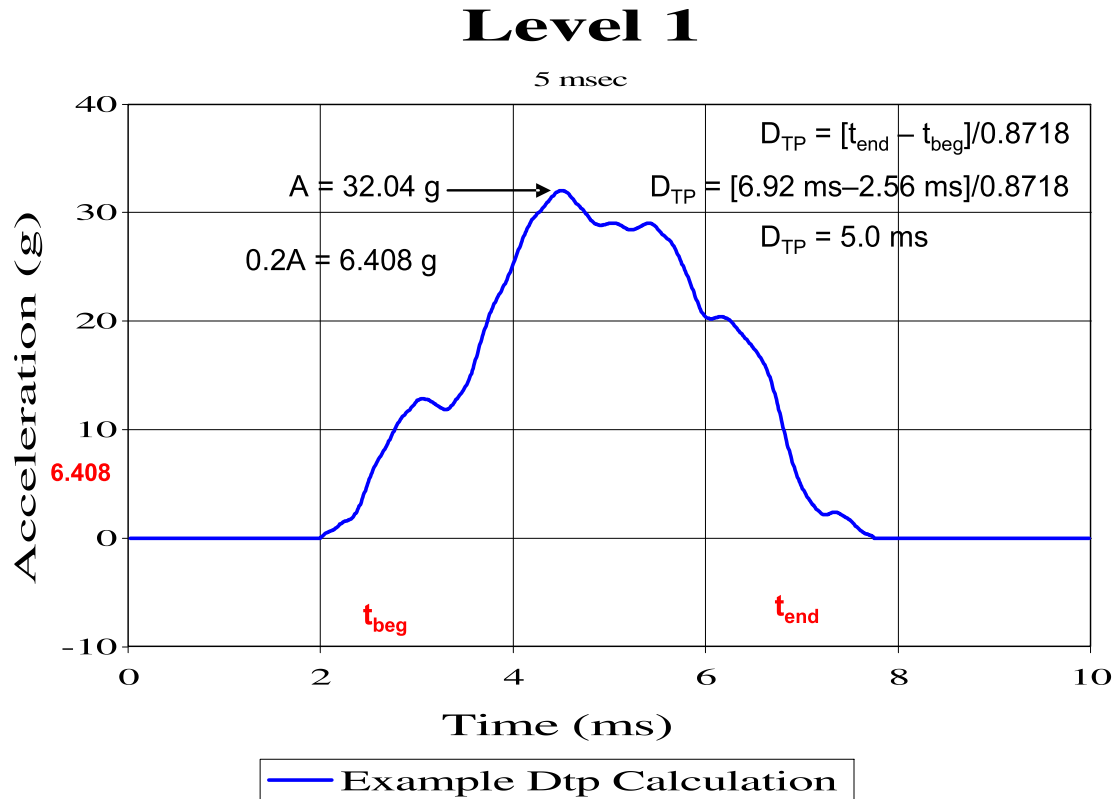


Figure 4 – Example Test Pulse Width (D_{TP}) Calculation

During and after the test pulse, the amplitude of the acceleration should be within $\pm 0.15 \times A$, the threshold ideal half-sine pulse's maximum amplitude. Before the test pulse, the acceleration amplitude should be within $\pm 0.05 \times A$ at $t = 0 \text{ ms}$ and $\pm 0.15 \times A$ at $t = 0.4D \text{ ms}$. Between $t = 0 \text{ ms}$ and $t = 0.4D \text{ ms}$ the tolerance varies linearly. Figure 5 shows a threshold ideal half-sine pulse (black line) with acceleration tolerance bands (blue and green lines). Table 3 summarizes the acceleration amplitude tolerances.

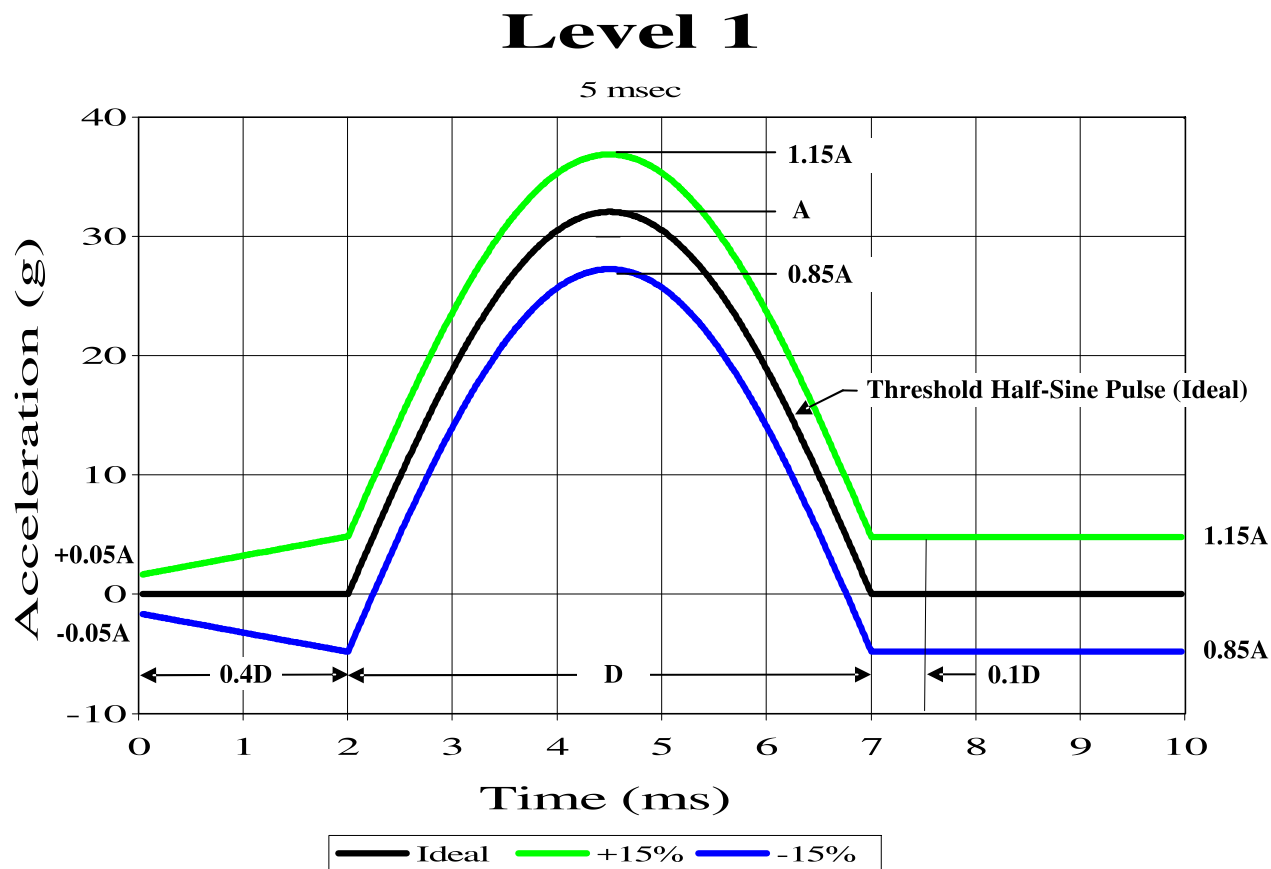


Figure 5⁴ – Threshold half-sine pulse (ideal) with tolerance bands

Table 3 – Acceleration amplitude tolerances

Time (ms)	t = 0	0 < t < 0.4D	0.4D ≤ t ≤ 1.4D	t > 1.4D
Acceleration Amplitude Tolerance (g)	±5%	varies linearly	±15%	±15%

3.2.3.4 Pulse width

The particular application and intended environment of the UUT will determine what acceleration it shall endure, and subsequently what pulse width to choose for testing. To choose a particular pulse width, the vendor should talk to their users, or look in Annex C for examples of similar equipment.

The pulse width of the shock test shall meet tolerances specified in 3.2.3.3 and be verified with the shock test time history (see 3.5). A range of 5 to 50 ms is suggested for each threshold; however, vendors may want to test above or below this range to fit certain user environments.

⁴ This figure was based on the half-sine pulse tolerance in reference [4] (p.7).

As part of this shock certification, the vendor shall list the pulse width of the half-sine pulse, in addition to the severity threshold. For pulse shapes other than half-sine or alternative shock tests, see 3.2.4.

EXAMPLE Equipment "A" is qualified to Level 3, 30 ms.
Equipment "B" is qualified to Level 8, 2 ms.

3.2.4 Alternative shock tests

For any test other than a drop shock test using a half-sine pulse, the test shall fulfill the four criteria listed below. This includes pulse shapes other than half-sine, such as step, saw-tooth, and trapezoidal, as well as other alternative shock tests, such as hammer machines, floating shock platforms, and impact tests. See Annex A for an explanation of velocity change, Δv , and PVSRS.

1. The shock test velocity change (Δv) shall be greater than or equal to the severity threshold Δv listed in Table A.1, and shall be verified through the shock test time history (see 3.5).
2. At all points, the test PVSRS shall be greater than or equal to the severity threshold PVSRS at the specified half-sine pulse width, both at 5% and 25% damping (see A.3.2).
 - a. The test shall meet both the 5% and 25% damped PVSRS to ensure an actual shock test.
 - b. For single-bounce tests, each threshold PVSRS goes from 3 – 2000 Hz. Ideally, the test spectra should span this whole frequency range; however, at a minimum the test spectra shall span 3 – 250 Hz. For information on lower and upper frequency bounds, see D.5.
 - c. For the multi-bounce test, each threshold PVSRS goes from 1 – 2000 Hz. Ideally, the test spectra should span this whole frequency range; however, at a minimum the test spectra shall span 1 – 250 Hz. For information on lower and upper frequency bounds, see D.5.
 - d. For more information on damping, see D.8.
3. Characteristics of the alternative shock test shall be listed in the shock test report. This includes the pulse shape, type of shock test, the time history, and all details of the shock test.
4. The words "alternative shock test" shall be listed along with the severity threshold level and pulse width. As noted above, a threshold level with a specific half-sine pulse width shall be chosen. The pulse width listed shall be for the half-sine pulse used to generate the severity threshold PVSRS (see A.3.2.3 for PVSRS generation), not the pulse width of an alternative pulse shape.

EXAMPLE Equipment "A" is qualified to Level 2, 40 ms (alternative shock test).
Equipment "B" is qualified to Level 6, 5 ms (alternative shock test).

NOTE 1 In this example, equipment "A" was tested using a drop shock test with a trapezoidal pulse, and equipment "B" was tested using a floating shock platform. They are labeled in a similar manner, even though they were tested differently. The actual test method shall be specified in the shock test report.

NOTE 2 Using other pulse shapes or alternative shock tests to meet the specified severity threshold may result in more severe tests.

3.2.5 Rebounds

Table 1 lists the no-rebound drop height for each severity threshold. A true "no-rebound" drop shock test is not possible, because it would require a perfectly inelastic collision (coefficient of restitution equal to zero). However, rebounds can be greatly reduced through cushioning or soft landing pads. For a drop shock test with considerable rebound (high coefficient of restitution), the drop heights listed in Table 1 will produce a more severe test (higher velocity change, Δv) than the threshold requirement. Table A.1 lists

Δv 's equivalent to the minimum no-rebound drop heights for each severity threshold (see A.2 for an explanation of velocity change, Δv).

A lower drop height may be used for a drop shock test; however, the test velocity change, Δv , shall be greater than or equal to the velocity change, Δv , listed in Table A.1. Velocity change shall be verified through the shock test time history (see 3.5).

The drop height for a surface with a specific coefficient of restitution can be calculated using Equation (8). A comparison of threshold-equivalent drop heights for tests with 0% and 100% rebound (coefficient of restitution equal to 0 and 1, respectively) can be seen in Table 4. Drop heights for actual drop shock tests should be somewhere between the two values listed for each threshold, depending on the amount of rebound in the test.

$$h_r = \frac{\left(\frac{\Delta v}{1 + e_{res}} \right)^2}{2g} \quad (8)$$

Where

h_r = drop height (with rebound)

e_{res} = coefficient of restitution

If the coefficient of restitution for a test surface is not known, it shall be determined through "calibration" tests. Equation (9) can be used in conjunction with these tests.

$$e_{res} = \left| \frac{v_2}{v_1} \right| \quad (9)$$

Table 4 – Drop heights for 0% and 100% rebound

Threshold	h (0%) (mm)	h (100%) (mm)
Level 1	51	13
Level 2	204	51
Level 3	459	115
Level 4	816	204
Level 5	1275	319
Level 6	1835	459
Level 7	2498	625
Level 8	3263	816
Level 9	4130	1032
Level 10	5099	1275