

A New American National Standard for Shock Testing Equipment

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This article reviews a recently published American National Standard* to be used for testing equipment that will be subjected to shock. This standard provides shock test parameters for testing a broad range of equipment and will ensure inherent levels of shock resistance. 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. The severity thresholds can be associated with specific shock environments and should be chosen for a given application on a case-by-case basis.

American National Standard S2.62-2009 defines graduated thresholds of shock severity for equipment, referred to as unit under test (UUT), whose normal use subjects it to some degree 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 (PVSRs). 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.

Input Characteristics

The shock test should be performed using a drop-shock machine with a simple half-sine pulse. An example of a vertical-drop shock machine is shown in Figure 1. The severity threshold defines a shock magnitude applied to the UUT. There are 10 severity thresholds listed in Table 1, and they are intended to be guidelines, not boundaries. Guidelines for testing above the listed thresholds are included in the standard. A digital time history in ASCII format shall be included in the shock test report to verify test results.

The test pulse shall be compared to a threshold (ideal) half-sine pulse at the specified severity threshold and pulse width. 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 generated using Equations 1, 2 and 3:

$$h = \Delta v^2 / 2g \quad (1)$$

$$\Delta v = v_2 - v_1 \quad (2)$$

$$A = \pi \Delta v / 2D \quad (3)$$

To simulate a drop shock test with only one impact, acceleration data shall be added before and after the pulse as listed in Table 2. An example of a half-sine pulse can be seen in Figure 2, and parameters for this example pulse are shown in Table 3.

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

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. 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 listed in Table 1.



Figure 1. Example of a vertical-drop shock machine.

The drop height for a surface with a specific coefficient of restitution can be calculated using Equation 4. 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.

$$h_r = \frac{(\Delta v / 1 + e_{res})^2}{2g} \quad (4)$$

Other Shock Tests

The simple drop shock test may not be appropriate for some equipment shock environments. Therefore, procedures for other test methods are included in the standard and are described briefly below.

A multibounce drop test is included for testing certain shock characteristics, such as load reversal or successive impacts. These types of shocks can be found in earthquakes, automotive environments, and ships exposed to underwater explosions.

Some equipment may see shock loads from multiple directions, either in service, during transport, or when the shock load occurs. There is a variety of methods for testing equipment in multiple axes, one of which is performing an angled drop test. In an angled drop test, equipment is mounted at an angle so that it will receive a shock load in multiple directions during one test (see figure 4).

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.

- The shock test velocity change (Δv) shall be greater than or equal to the severity threshold Δv listed in Table 1, and shall be verified through the shock test time history.

Nomenclature

Symbol	Definition
h	No-rebound drop height
g	Gravitational acceleration
v_1	Velocity before impact
v_2	Velocity after impact
A	Threshold pulse amplitude
D	Threshold pulse width (pulse duration)
h_r	Drop height with rebound
e_{res}	Coefficient of restitution

*ANSI/ASA S2.62-2009, *Shock Test Requirements for Equipment in a Rugged Shock Environment*, American National Standards Institute, Inc. and Acoustical Society of America, Melville, NY, 2009.

Based on a paper presented at IMAC XXVIII, the 28th International Modal Analysis Conference, Society for Experimental Mechanics, February 2010.

- At all frequencies, 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. At minimum, a frequency range of 3-250 Hz shall be considered.
- 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.
- 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, not the pulse width of an alternative pulse shape.

Test Fixtures

The UUT shall be mounted to the test apparatus in a configuration that simulates the intended service installation. Shock mitigation devices shall not be used, unless they are part of the as built production item. Packaging, extra housing, or any other types of added shock protection shall not be used unless they will be part of the UUT in its normal shock environment (i.e., shipping, production line, etc.).

Instrumentation

Instrumentation shall be used on all shock tests conducted for use with this standard. A transient time history of the entire shock event shall be recorded for verification that the shock input meets the specified severity threshold. All transducers used to record the shock event shall survive the specified severity threshold. The measurement(s) should be of the shock input to the equipment rather than the response of the equipment. Transducer(s) shall be placed as close as possible to the load path or attachment point of

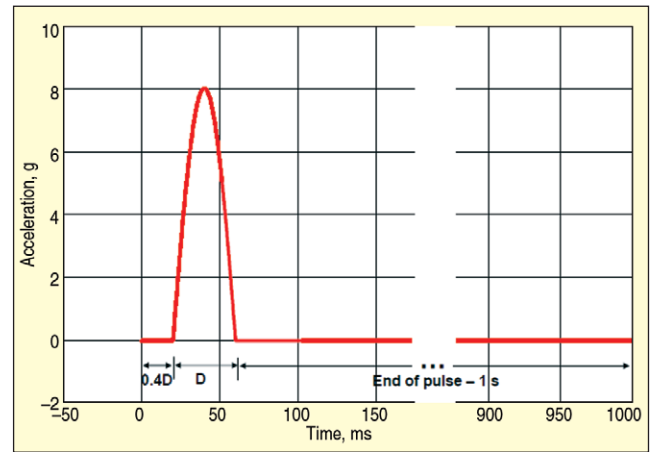


Figure 2. Half-sine pulse example: Level 2, 40 ms.

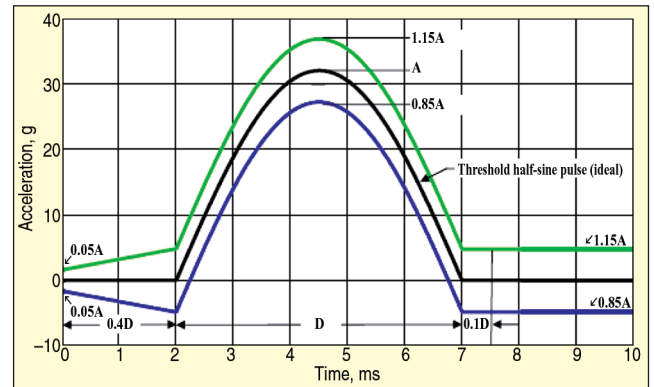


Figure 3. Threshold half-sine pulse (ideal) with tolerance bands.

Table 1. No-rebound severity threshold drop heights.

Severity Threshold	Velocity Change, m/s	Drop Height, mm
1	1.0	51
2	2.0	204
3	3.0	459
4	4.0	816
5	5.0	1275
6	6.0	1835
7	7.0	2498
8	8.0	3263
9	9.0	4130
10	10.0	5099

Table 2. Data added to threshold (ideal) half-sine pulse.

Description	Time Range, s	Added Data, g
Beginning of pulse	0.0 - 0.4D	0.0
UUT stops and remains at rest	End of pulse - 1.0s	0.0

Table 3. Parameters for example half sine pulse in Figure 2

Threshold	h, mm	Δv , m/s	D, ms	A, g
Level 2	203.9	2.0	40.0	8.01

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

Severity Threshold	Drop Height for $e_{res}=0\%$, mm)	Drop Height for $e_{res}=100\%$, mm)
1	51	13
2	204	51
3	459	115
4	816	204
5	1275	319
6	1835	459
7	2498	625
8	3263	816
9	4130	1032
10	5099	1275

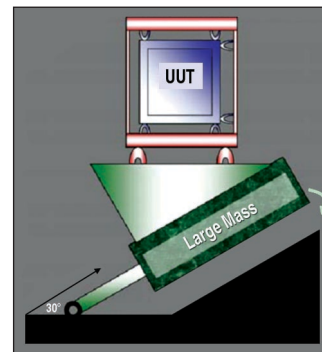


Figure 4. Schematic of a 30°-angled drop test.

the UUT to the fixture (shock table, deck, rigid mount, etc.). The testers may choose, for their information, to install transducers to record internal responses of the UUT; however, any internal measurements shall not be used to satisfy the requirements of this standard.

Instrumentation shall be calibrated in accordance with ISO 16063-1:1998, ISO 18431-4:2007, or by the instrumentation manufacturer's guidelines.


The instrumentation manufacturer's calibration guidelines should be traceable back to the National Institute of Standards and Technology (NIST), otherwise specific details of how the instrumentation was calibrated shall be included in the report.

Acceptance Criteria

There are two acceptance criteria that shall be met for the UUT to be considered shock certified to the chosen severity threshold:

- All functional and operability requirements shall be successfully met and no failure criterion shall occur.
- The shock test performed shall be at or above the specified severity threshold.

Acknowledgements

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