EDITORIAL

Pyroshock Testing Update

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Pyroshock, also called pyrotechnic shock, testing may be required for test items, subsystems, and full-scale systems that must withstand an explosive event such as an explosive charge to separate two stages in a multistage rocket, and the resulting high-frequency (thousands of Hertz, even as high as 1 MHz), high-magnitude stress waves with very short wavelengths that propagate throughout the structure.

Pyroshock was once considered a relatively mild environment, compared to other shock and vibration environments for aerospace and other structures. Although pyroshock rarely damages structural members, pyroshock can easily cause failures in electronic test items as well as material failures that are sensitive to the high-frequency pyroshock energy. Pyroshock testing was born with the publication of a significant number of flight failures in 1986 by C. J. Moening. Measurement and testing in this area is still an art, and accurate prediction of shock levels at a particular material point is generally still not possible.

The environment created by pyrotechnic devices varies with the distance from the detonation and the intervening structure and its material wave attenuation properties. During the last year, new definitions for near-field pyroshock, mid-field pyroshock, and far-field pyroshock have been adopted in the updated version of MIL STD 810 Method 517 (Version G). That is, the near-field pyroshock, mid-field pyroshock, and far-field pyroshock are now the same in MIL STD 810G Method 517 and the Institute of Environmental Sciences and Technology (IEST) *Pyroshock Testing Recommended Practice* as shown in Table 1 and the spectra definitions below.

The definitions and table values are quantified in terms of the shock response spectra (SRS). The SRS, with an appropriate damping value, is the most widely used tool to analyze pyroshock data and is calculated using acceleration measurements near components and subsystems that must be qualified separately. The Jet Propulsion Laboratory will be revising its NASA-STD-7003 during the upcoming year, and the current NASA near-, mid-, and far-field pyroshock are also shown in Table 1. Both the NASA-STD-7003 and the MIL-STD-810G, Method 517 are available on the Internet for no cost.

Pyroshock Spectra. *Near-field Pyroshock* – frequency control up to and above 10,000 Hz for amplitudes greater than 10,000 g. A pyrotechnically excited simulation technique is usually appropriate, although in some cases a mechanically excited simulation technique may be used.

Mid-field Pyroshock – requires frequency control from 3,000 to 10,000 Hz for amplitudes less than 10,000 g. A mechanically excited simulation technique other that shaker shock is usually required.

Far-field Pyroshock – requires frequency control no higher than 3,000 Hz for amplitudes less than 1,000 g. A shaker shock or a mechanically excited simulation technique is appropriate.

Table 1. Comparison of shock response spectra pyroshock definitions.

Document	Region	Acceleration Amplitude, g	Freq, Hz	Distance from Source: Intense	Distance from Source: Mild
NASA STD 7003	Near field	>5,000	>100,000	<6 in.	<1 in.
	Mid field	1,000-5,000	>10,000	6-24 in.	1-6 in.
	Far field	<1,000	<10,000	>24 in.	>6 in.
IEST RP Pyroshock Test	Near field	>10,000	>10,000	–	–
	Mid field	<10,000	3-10,000	–	–
	Far field	<1,000	<3,000	–	–
MIL STD 810 Method 517	Near field	>10,000	>10,000	–	–
	Mid field	<10,000	3-10,000	–	–
	Far field	<1,000	3,000	–	–

The IEST *Pyroshock Testing Recommended Practice* (PTRP) has been revised and updated with additional topics as described below. Some topics represent advances in the art of pyroshock testing, and others are included in response to recent problems that have been expressed by the pyroshock community. The PTRP is in final review during April '09 by the IEST pyroshock testing working group in preparation for ESTECH2009 in May '09.

A new section on pyroshock variability is included in the revised PTRP; this variability is quantified in terms of SRS. Opportunities to make multiple detonations of pyrotechnic devices with the same structure are *rare*. By its nature, pyroshock is highly variable or unrepeatable, but in many cases, program decisions are made based on one pyroshock data set. The reason for this is usually cost, but there is also a very real problem in the timing and availability of actual complete system hardware and components. That is, a new program typically begins with a set of new requirements for components and complete system performance. A portion of the complete system is assigned to an individual or groups of engineers for development.

So what pyroshock requirements do the engineers use? A conventional practice is to use requirements for another complete system that are considered "similar" to the new system. This approach may be justified in the early stages of a program, but as components and subsystems mature later on, more realistic specifications must be created.

At this point, a mock system may be constructed and used for detonation of actual pyrotechnic devices; the quality of the mock system components greatly affects the nearby acceleration measurements and, consequently, the accuracy of the resulting SRS specifications. This is evident with simple structures as well as complex structures. Two examples of the variability of pyroshock are included to emphasize the unrepeatability of pyroshock as well as give a basis for the ±6 dB tolerance and +3 dB +6 dB margins typically added to pyroshock specifications. The availability of these data sets of multiple pyroshock measurements is relatively recent and provides new intuition into the pyroshock phenomena.

Three new resonant techniques for pyroshock simulation have been added to the IEST PTRP:

- Full-scale or complete system tests with a resonant fixture
- Three-axis pyroshock simulations for mid-field pyroshock
- Three-axis pyroshock simulations for near-field pyroshock

In full-scale tests, the pyrotechnic source and a portion of the adjacent structure may be replaced by a resonant plate or fixture designed so that the first mode of the plate or fixture corresponds to the dominant frequency produced by the pyrotechnic device and the associated structure. The resonant plate or fixture should be attached to the test structure in a manner that simulates the mechanical linkage of the pyrotechnic source. When this attached plate or fixture is excited into resonance by a mechanical impact, the response of the plate or fixture should provide the desired input to the test structure.

A resonant fixture has successfully simulated three-axis component shock response spectra with **one impact to the resonant fixture** for frequencies up to 4000 Hz on a full-scale weapon structure weighing 400 pounds and also may be used for satellite structures. This test configuration is a major step toward eliminating overtesting in mechanical simulation of pyroshock that creates unrealistic mechanical failure of the unit under test.

The overtesting occurs because all pyroshock resonant fixture simulations described in the previous IEST PTRP require that the test item be attached to the fixture and tested in three separate axes. Also, all pyroshock simulation methods have some cross-axis response in addition to the intended in-axis response, so overtesting the test item routinely occurs. In some cases, however, all three axes may be tested with **one impact on a thick resonant fixture** to simulate **mid-field** pyroshock or **near-field** pyroshock.

These fixtures must be designed for the specific test requirement and for specific, small, test items. Time history magnitudes of 1000 to 80,000 g with knee frequencies in excess of 15,000 Hz have been obtained and are demonstrated in the figures of the IEST PTRP as both acceleration time histories and positive and negative shock response spectra calculated in one-sixth octave bands. Again, these test configurations are a major step toward eliminating overtesting in mechanical simulation of pyroshock that creates unrealistic mechanical failures of the unit under test. Additionally, the cost of the pyroshock simulations described above are significantly less, and the tests are more repeatable than testing with the detonation of pyrotechnic devices.

Finally, a new section on corrupted pyroshock data is included in the revised PTRP. Recent events in the pyroshock testing community in 2008 have shown that corrupted pyroshock data are still being taken at both government agencies and private companies. Upon request, I analyzed a set of corrupted data in one case. The sources of data corruption and contamination appear to be the usual culprits that have been known for some time – digital aliasing and offsets in the data. The remedies for these problems are readily available, so why are corrupted pyroshock data still acquired? In response to the PTRP reviewers in the pyroshock community, this section was added and describes practices that cause corrupted pyroshock data and the recommended practices for acquiring uncorrupted data.

The author solicits comments from practicing pyroshock professionals on the IEST PTRP, as revised with the proposed changes and additions described above. These comments may be made at the session to review the IEST PTRP at ESTECH 2009, The IEST 55th Annual Meeting, May 4-7, St. Charles, IL, or directly to the author and chair of the IEST Pyroshock Testing Working Group, vilshock@comcast.net. S/V