METHOD 517

PYROSHOCK

NOTE: Tailoring is essential. Select methods, procedures, and parameter levels based on the tailoring process described in Part One, paragraph 4, and Appendix C. Apply the general guidelines for laboratory test methods described in Part One, paragraph 5 of this standard.

1. SCOPE.

1.1 Purpose.

Pyroshock tests involving pyrotechnic (explosive- or propellant-activated) devices are performed to:

a. provide a degree of confidence that materiel can structurally and functionally withstand the infrequent shock effects caused by the detonation of a pyrotechnic device on a structural configuration to which the materiel is mounted.

b. experimentally estimate the materiel's fragility level in relation to pyroshock in order that shock mitigation procedures may be employed to protect the materiel's structural and functional integrity.

1.2 Application.

1.2.1 Pyroshock.

Pyroshock is often referred to as pyrotechnic shock. For the purpose of this document, initiation of a pyrotechnic device will result in an effect that is referred to as a “pyroshock.” “Pyroshock” refers to the localized intense mechanical transient response of materiel caused by the detonation of a pyrotechnic device on adjacent structures. A number of devices are capable of transmitting such intense transients to a materiel. In general, the sources may be described in terms of their spatial distribution - point sources, line sources and combined point and line sources (reference a). Point sources include explosive bolts, separation nuts, pin pullers and pushers, bolt and cable cutters and pyro-activated operational hardware. Line sources include flexible linear shape charges (FLSC), mild detonating fuses (MDF), and explosive transfer lines. Combined point and line sources include V-band (Marmon) clamps. The loading from the pyrotechnic device may be accompanied by the release of structural strain energy from structure preload or impact among structural elements as a result of the activation of the pyrotechnic device. Use this method to evaluate materiel likely to be exposed to one or more pyroshocks in its lifetime. Pyroshocks are generally within a frequency range between 100 Hz and 1,000,000 Hz, and a time duration from 50 microseconds to not more than 20 milliseconds. Acceleration response amplitudes to pyroshock may range from 300 g to 300,000 g. The acceleration response time history to pyroshock will, in general, be very oscillatory and have a substantial rise time, approaching 10 microseconds. In general, pyroshocks generate material stress waves that will excite materiel to respond to very high frequencies with wavelengths on the order of sizes of micro electronic chip configurations. Because of the limited velocity change in the structure brought about by firing of the pyrotechnic device, and the localized nature of the pyrotechnic device, structural resonances of materiel below 500 Hz will normally not be excited and the system will undergo very small displacements with small overall structural/mechanical damage. The pyroshock acceleration environment in the neighborhood of the materiel will usually be highly dependent upon the configuration of the materiel and the intervening structure. The materiel or its parts may be in the near-field or far-field of the pyrotechnic device with the pyroshock environment in the near-field being the most severe, and that in the far-field the least severe. There is not unanimous agreement on classifying pyroshock intensity according to the characteristics of a “near-field” and a “far-field.” It has been suggested that three fields be used for intensity classification, i.e., a "mid-field" in pyroshock intensity intervening between the “near-field” and the “far-field.” This document reflects the current consensus on other than spacecraft material to restrict pyroshock intensity classification to “near-field” and “far-field” for which the definitions are provided in paragraph 1.2.3. In general, some structure intervenes between the materiel and location of the pyrotechnic device.

1.2.2 Pyroshock - momentum exchange.

Pyroshock usually exhibits no momentum exchange between two bodies (a possible exception is the transfer of strain energy from stress wave propagation from a device through structure to the materiel). Pyroshock results in essentially no velocity change in the materiel support structure. Frequencies below 100 Hz are never of concern. The magnitude of a pyroshock response at a given point reasonably far from the pyrotechnic source is, among other things, a function of the size of the pyrotechnic charge. Pyroshock is a result of linear elastic material waves propagating in the support structure to the materiel without plastic deformation of large portions of the structure except at the charge point or line. In general, joints and bolted connections representing structure discontinuities tend to greatly attenuate the pyroshock amplitudes. With regard to measurement technology, accelerometers, strain gages and laser velocimeters are commonly used devices for measurement. In processing pyroshock data, it is important to be able to detect anomalies. A part of this detection is the integration of the acceleration amplitude time history to determine if it has the characteristics of a high frequency velocity trace. Pyroshock is "designed" into the materiel by placement of pyroshock devices for specific utility. Because to a great extent the pyroshock environment is clearly defined by the geometrical configuration and the charge or the activating device, pyroshock response of materiel in the field may be moderately predictable and repeatable for materiel (reference a.).

1.2.3 Pyroshock - physical phenomenon.

Pyroshock is a physical phenomenon characterized by the overall material and mechanical response at a structure point from either (a) an explosive device, or (b) a propellant activated device. Such a device may produce extreme local pressure (with perhaps heat and electromagnetic emission) at a point or along a line. The device provides a near instantaneous generation of local, high-magnitude, nonlinear material strain rates with subsequent transmission of high-magnitude/high frequency material stress waves producing high acceleration/low velocity and short duration response at distances from the point or line source. The characteristics of pyroshock are:

a. near-the-source stress waves in the structure caused by high material strain rates (nonlinear material region) propagate into the near-field and beyond;

b. high frequency (100 Hz-1,000,000 Hz) and very broadband frequency input;

c. high acceleration (300 g-300,000 g) but low structural velocity and displacement response;

d. short-time duration (<20 msec);

e. high residual structure acceleration response (after the event);

f. caused by (1) an explosive device or (2) a propellant activated device (releasing stored strain energy) coupled directly into the structure; (for clarification, a propellant activated device includes items such as a clamp that releases strain energy causing a structure response greater than that obtained from the propellant detonation alone);

g. highly localized point source input or line source input;

h. very high structural driving point impedance (P/v, where P is the detonation large force or pressure, and v, the structural velocity, is very small). At the source, the material driving point impedance can be substantially less for high material particle velocity;

i. response time histories that are random in nature, providing little repeatability and substantial dependency on the materiel configuration details;

j. response at points on the structure that are greatly affected by structural discontinuities;

k. materiel and structural response that may be accompanied by substantial heat and electromagnetic emission (from ionization of gases during explosion);

l. the nature of the response to pyroshock that suggests the materiel or its components may be classified as being in the near-field or far-field of the pyrotechnic device. The terms "near-field" and "far-field" relate to the shock intensity at the response point and such intensity is a function of the distance from the source and the structural configuration between the source and the response point.

(1) Near-field. In the near-field of the pyrotechnic device, the structure material stress wave propagation effects govern the response. In the near-field of an intense pyrotechnic device, the materiel or any portion of the materiel is within 15 cm (6 in) of the point of detonation of the device or a portion of it (in the case of a line charge). If there are no intervening structural discontinuities, the materiel may be expected to experience peak accelerations in excess of 5000 g's and substantial spectral content above 100,000 Hz. The near-field of a less intense pyrotechnic device can be considered to be within 7.5 cm (3 in) with a subsequent reduction in the peak acceleration levels and spectral levels.

(2) Far-field. In the far-field of the pyrotechnic device, the pyroshock response is governed by a combination of material stress wave propagation and structural resonance response effects. For an intense pyrotechnic device, the materiel or any portion of the materiel is beyond 15 cm (6 in) from the device. If there are no intervening structural discontinuities, the materiel may be expected to experience peak accelerations between 1000 g's and 5000 g's, and substantial spectral content above 10,000 Hz. The far-field of a less intense pyrotechnic device can be considered to be beyond 7.5 cm (3 in) with a subsequent reduction in the peak acceleration levels and spectral levels.

1.3 Limitations.

Because of the highly specialized nature of pyroshock, apply it only after giving careful consideration to information contained in references a, b, c, and d.

a. This method does not include the shock effects experienced by materiel as a result of any mechanical shock/transient vibration, shipboard shock, or EMI shock. For these types of shocks, see the appropriate methods in this or other standards.

b. This method does not include the effects experienced by fuze systems that are sensitive to shock from pyrotechnic devices. Shock tests for safety and operation of fuzes and fuse components may be performed in accordance with MIL-STD-331.

c. This method does not include special provisions for performing pyroshock tests at high or low temperatures. Perform tests at room ambient temperature unless otherwise specified or if there is reason to believe either operational high temperature or low temperature may enhance the pyroshock environment.

d. This method does not include guidance related to unplanned test interruption as a result of pyroshock device or mechanical test equipment malfunction in cases in which the pyroshock is being mechanically simulated. Generally, if the pyroshock device malfunctions or interruption occurs during a mechanical shock pulse, repeat that shock pulse. Care must be taken to ensure stresses induced by the interrupted shock pulse do not invalidate subsequent test results. Inspect the overall integrity of the materiel to ensure pre-shock test materiel structural and functional integrity. Record and analyze data from such interruptions before continuing with the test sequence.

e. This method is not intended to be applied to manned space vehicle testing (see reference a).

f. This method does not address secondary effects such as induced blast, EMI, and thermal effects.

g. This method does not apply to effects of hostile weapon penetration or detonation.

2. TAILORING GUIDANCE.

2.1 Selecting the Pyroshock Method.

After examining requirements documents and applying the tailoring process in Part One of this standard to determine where pyroshock effects are foreseen in the life cycle of the materiel, use the following to confirm the need for this method and to place it in sequence with other methods.

2.1.1 Effects of pyroshock.

In general, pyroshock has the potential for producing adverse effects on all electronic materiel. The level of adverse effects generally increases with the level and duration of the pyroshock, and decreases with the distance from the source (pyrotechnic device) of the pyroshock. Durations for pyroshock that produce material stress waves with wavelengths that correspond with the natural frequency wavelengths of micro electronic components within materiel will enhance adverse effects. In general, the structural configuration merely transmits the elastic waves and is unaffected by the pyroshock. Examples of problems associated with pyroshock follow, but the list is not intended to be all-inclusive.

a. materiel failure as a result of destruction of the structural integrity of micro electronic chips;

b. materiel failure as a result of relay chatter;

c. materiel failure as a result of circuit card malfunction, circuit card damage, and electronic connector failure. On occasion, circuit card contaminants having the potential to cause short circuits may be dislodged under pyroshock.

d. materiel failure as a result of cracks and fracture in crystals, ceramics, epoxies, or glass envelopes.

2.1.2 Sequence among other methods.

a. General. See Part One, paragraph 5.5.

b. Unique to this method. Unless otherwise displayed in the life cycle profile and, since pyroshock is normally experienced near the end of the life cycle, schedule pyroshock tests late in the test sequence. In general, the pyroshock tests can be considered independent of the other tests because of their unique nature.

2.2 Selecting a Procedure.

This method includes four pyroshock test procedures:

a. Procedure I - Near-field with an actual configuration. Replication of pyroshock for the near-field environment using the actual materiel and the associated pyrotechnic shock test device configuration.

b. Procedure II - Near-field with a simulated configuration. Replication of pyroshock for the near-field environment using the actual materiel but with the associated pyrotechnic shock test device isolated from the test item, e.g., by being mounted on the back of a flat steel plate. (This normally will minimize testing costs because fewer materiel configurations and/or platforms associated with the test item will be damaged. This can be used for repeated tests at varying pyroshock levels.)

c. Procedure III - Far-field with a mechanical test device. Replication of pyroshock for the far-field environment with a mechanical device that simulates the pyroshock peak acceleration amplitudes and frequency content (other than an electrodynamic shaker because of frequency range limitations of the electrodynamic shaker).

d. Procedure IV - Far-field with an electrodynamic shaker. Replication of pyroshock for the far-field environment using an electrodynamic shaker to simulate the comparatively low frequency structural resonant response to the pyroshock.

2.2.1 Procedure selection considerations.

Based on the test data requirements, determine which test procedure is applicable. In most cases, the selection of the procedure will be dictated by the actual materiel configuration, carefully noting any structural discontinuities that may serve to mitigate the effects of the pyroshock on the materiel. In some cases, the selection of the procedure will be driven by test practicality. Consider all pyroshock environments anticipated for the materiel during its life cycle, both in its logistic and operational modes. When selecting procedures, consider:

a. The operational purpose of the materiel. From the requirements documents, determine the functions to be performed by the materiel either during or after exposure to the pyroshock environment.

b. The natural exposure circumstances for pyroshock. Determine if the materiel or portion of the materiel lies within the near-field or far-field of the pyrotechnic device. If the materiel or a portion of the materiel lies within the near-field of the pyrotechnic device, no special isolation of the materiel exists and, if there are no prior measured field data, apply only Procedure I or II. If no portion of the materiel lies within the near-field of the pyrotechnic device and measured field data exist, apply Procedure III if the processed field data supports the amplitude and frequency range capabilities of the test devices. If the entire materiel lies within the far-field and is subject to structural response, only apply Procedure IV if the processed data supports the comparatively low frequency range (to 3000 Hz) of an electrodynamic shaker. If the entire materiel lies within the far-field and the processed data does not support the electrodynamic shaker comparatively low frequency range, apply Procedure III. In any case, one test will be considered sufficient for testing over the entire amplitude and frequency range of exposure of the materiel. Do not break up any measured or predicted response to pyroshock into separate frequency ranges for the purpose of applying different testing procedures to different frequency ranges.

c. Required data. The test data required to verify that the materiel will survive and function as intended.

d. Procedure sequence. Refer to paragraph 2.1.2.

2.2.2 Difference among procedures.

a. Procedure I - Near-field with Actual Configuration. Procedure I is intended to test materiel (including mechanical, electrical, hydraulic, and electronic) in its functional mode and actual configuration (materiel/pyrotechnic device physical configuration), and to ensure it can survive and function as required when tested using the actual pyrotechnic test device in its intended installed configuration. In Procedure I, it is assumed that the materiel or a portion of the materiel resides within the near-field of the pyrotechnic device.

b. Procedure II - Near-field with Simulated Configuration. Procedure II is intended to test materiel (including mechanical, electrical, hydraulic, and electronic) in its functional mode but with a simulated structural configuration, and to ensure it can survive and function as required when in its actual materiel/pyrotechnic device physical configuration. In this procedure it is assumed that some part of the materiel lies within the near-field of an intense or less intense pyrotechnic device. Make every attempt to use this procedure to duplicate the actual platform/materiel structural configuration by way of a full-scale test. If this is too costly or impractical, employ scaled tests provided that in the process of scaling, important configuration details are not omitted. In particular, only the structure portion directly influencing the materiel may be involved in the test, provided it can be reasonably assumed that the remainder of the structure will not influence materiel response. On occasion, for convenience, a special pyrotechnic testing device may be employed for testing the materiel, e.g., a flat steel plate to which the materiel is mounted and the pyrotechnic charge is attached.

c. Procedure III - Far-field Using a Mechanical Test Device. Pyroshock can be applied utilizing conventional high acceleration amplitude/frequency test input devices. Reference c provides a source of alternative test input devices, their advantages, and limitations. In this procedure, it is assumed that all parts of the materiel lie in the far-field of the pyrotechnic device. Consult reference c for guidelines and considerations for such testing.

d. Procedure IV - Far-field Using an Electrodynamic Shaker. On occasion, pyroshock response can be replicated utilizing conventional electrodynamic shakers. In this procedure, it is assumed that all parts of the materiel lie in the far-field of the pyrotechnic device, and the materiel is subject to the structure platform resonant response alone.

2.3 Determine Test Levels and Conditions.

Having selected one of the four pyroshock procedures (based on the materiel's requirements documents and the tailoring process), complete the tailoring process by identifying appropriate parameter levels, applicable test conditions and applicable test techniques for that procedure. Exercise extreme care in consideration of the details in the tailoring process. Base these selections on the requirements documents, the Life Cycle Environmental Profile, the Operational Environment Documentation (see Part One, figure 1-1), and information provided with this procedure. Consider the following basic information when selecting test levels.

2.3.1 General considerations - terminology.

a. In general, response acceleration will be the experimental variable of measurement for pyroshock. However, this does not preclude other variables of measurement such as velocity, displacement, or strain from being measured and processed in an analogous manner, as long as the interpretation, capabilities, and limitations of the measurement variable and measurement system are well-defined. Pay particular attention to the high frequency environment generated by the pyrotechnic device and the capabilities of the measurement system to faithfully record the materiel's responses. References a and b detail the tradeoffs among pyroshock measurement techniques. In any case, implement the guidelines in reference b. For the purpose of this method, the terms that follow will be helpful in the discussion relative to analysis of response measurements from pyroshock testing. To facilitate the definition of the terms, each of the terms is illustrated for a typical pyroshock measurement. Figure 517-1 provides an acceleration time history plot of a measured far-field pyroshock with the instrumentation noise floor displayed before the pyroshock, the pyroshock, and the subsequent post-pyroshock noise floor. It is important to provide measurement data including both the pre-pyroshock noise measurement and the post-pyroshock combined noise and low level residual structure response. The vertical lines at three discrete times are used to identify a "short duration" truncated pyroshock response and a "long duration" pyroshock response. The pre-pyroshock time interval, before the first vertical line, contains the instrumentation system noise floor and serves as a measurement signal reference level. The pyroshock time interval includes all the significant response energy of the event. The post-pyroshock time interval, after the third vertical line, is of equal duration to the pre-pyroshock time interval and contains the measurement system noise in addition to some of the pyroshock residual noise considered inconsequential to the response energy in the pyroshock. In cases in which the pre-pyroshock and the post-pyroshock amplitude levels are substantial compared to the pyroshock (the pyroshock has been mitigated and/or the measurement system noise is high), the identification of the pyroshock may be difficult and engineering judgment must be used relative to determining the start and the termination of the pyroshock event. In any case, analysis of pre-pyroshock and post-pyroshock measurement information in conjunction with the pyroshock measurement information is essential. Validate all data collected from a pyroshock. Reference b provides guidelines for this. Perhaps one of the simplest and most sensitive criteria for validation is an integration of the signal time history after removing any small residual offset. If the resulting integrated signal has zero crossings and does not appear to monotonically increase, the pyroshock has passed this validation test. Figure 517-2 provides the velocity plot for the long duration pyroshock on figure 517-1.

(1) <u>Effective transient duration</u>: The "effective transient duration," T_e, is the minimum length of time which contains all significant amplitude time history magnitudes beginning at the noise floor of the instrumentation system just prior to the initial most significant measurement, and proceeding to the point that the amplitude time history is a combination of measurement noise and substantially decayed structural response. In general, an experienced analyst is required to determine the pertinent measurement information to define the pyroshock event. The longer the duration of the pyroshock, the more low frequency information is preserved which may be important in far-field test considerations for the pyroshock. For near-field test considerations, in general, the effective transient duration will be much shorter because of the higher ranging of the measurement system. The amplitude criterion requires that the amplitude of the post-pyroshock amplitude time history envelope be no more than 12 dB above the noise floor of the measurement system depicted in the pre-pyroshock amplitude time history. From figure 517-1 there appear to be at least two logical time intervals for the duration of the pyroshock. The first duration is immediately after the end of the high frequency information - the second vertical line on figure 517-1 at approximately 3.5 milliseconds after the beginning of the pyroshock. The second duration is given by the third vertical line on figure 517-1, some 6.6 milliseconds after the beginning of the pyroshock and after some of the apparent low frequency structural response has been attenuated - the third vertical line on figure 517-1. These judgments based on examination of the amplitude time history utilized an amplitude criterion and a low frequency criterion. Figure 517-3 contains a plot of amplitude of the absolute

value of the pyroshock in dB versus time. This figure illustrates the difficulty in coming up with precise criteria for determining the effective duration of a pyroshock. The initial noise floor level is never obtained after the long duration pyroshock. Figure 517-4 illustrates the difference between SRS processing of two different pyroshock durations on figure 517-1, with the SRS, i.e., the short duration pyroshock (3.5 ms), and the long duration pyroshock (6.6 ms). It is clear that the only significant difference is near 100 Hz. The magnitude of the SRS at selected natural frequencies (particularly high frequencies) can be quite insensitive to the effective transient duration.

(2) Shock Response Spectrum analysis: Reference e defines the absolute acceleration maximax Shock Response Spectrum (SRS) and provides examples of SRS computed for classical pulses. The SRS value at a given undamped oscillator natural frequency, f_n, is defined to be the absolute value of the maximum of the positive and negative acceleration responses of a mass for a given base input to a damped single degree of freedom system. The base input is the measured shock over a specified duration (the specified duration should be the effective transient duration, T_e). For processing of pyroshock response data, the absolute acceleration maximax SRS has become the primary analysis descriptor. In this measurement description of the pyroshock, the maximax absolute acceleration values are plotted on the ordinate with the undamped natural frequency of the single degree of freedom system with base input plotted along the abscissa. A more complete description of the pyroshock (and potentially more useful for pyroshock damage comparison in the far-field) can be obtained by determining the maximax pseudo-velocity response spectrum and plotting this on four-coordinate paper where, in pairs of orthogonal axes, (1) the maximax pseudo-velocity response spectrum is represented by the ordinate with the undamped natural frequency being the abscissa, and (2) the maximax absolute acceleration along with the maximax pseudo-displacement plotted in a pair of orthogonal axes (reference e). The maximax pseudo-velocity at a particular oscillator undamped natural frequency is thought to be more representative of the damage potential for a shock since it correlates with stress and strain in the elements of a single degree of freedom system (references f, g, and h). The maximax pseudo-velocity response spectrum can be computed either by (1) dividing the maximax absolute acceleration response spectrum by the undamped natural frequency of the single degree of freedom system, or (2) multiplying the maximax relative displacement by the undamped natural frequency of the single degree of freedom system. Both means of computation provide essentially the same spectra except possibly in the lower frequency region, in which case the second method of computation is more basic to the definition of the maximax pseudo-velocity response spectrum. Figure 517-5 provides the estimate of the maximax absolute acceleration SRS for the pyroshock record on figure 517-1. Figure 517-6 provides the estimate of the maximax pseudo-velocity for this record on four-coordinate paper. Note that information below 100 Hz is not considered valid for processing in these measurements. In general, compute the SRS over the pyroshock event duration and over the same duration for the pre-pyroshock and the post-pyroshock events with twelfth octave spacing and a Q = 10 (Q=10 corresponds to a single degree of freedom system with 5% critical damping). If the testing is to be used for laboratory simulation, use a second Q value of 50 (Q=50 corresponds to a single degree of freedom system with 1% critical damping) in the processing. It is recommended that the maximax absolute acceleration SRS be the primary method of display for the pyroshock, with the maximax pseudo-velocity SRS as the secondary method of display and useful in cases in which it is desirable to correlate damage of simple systems with the pyroshock.

(3) Energy Spectral Density: Reference a mentions the Energy Spectral Density (ESD) estimate for a pyroshock of duration T_e. In this description, the properly scaled magnitude of the Fourier Transform of the total pyroshock is computed at a uniformly spaced set of frequencies and displayed as a two-dimensional plot of amplitude versus frequency. The amplitude units are ($units^2$-sec/Hz). In determining the ESD estimate, it is important that the Fast Fourier Transform block size is picked such that all of the pyroshock event is contained within the block but excessive noise beyond the duration of the pyroshock be removed by zero-padding within the block. The ESD description is useful for comparing the distribution of energy within the frequency band among several pyroshocks. However, if adjacent frequency components are not averaged, the percentage of normalized random error in the ordinate is 100%. By averaging n adjacent ordinates, the percentage

of normalized random error decreases as $1/\sqrt{n}$ with a decreased frequency resolution. Computation of the ESD estimates for the pre-pyroshock and the post-pyroshock provide useful information relative to the distinct frequency character of the pyroshock as compared to the frequency character of the pre-pyroshock noise and the post-pyroshock combination noise and structural response. Figure 517-7 provides ESD estimates for the pyroshock and the pre-pyroshock and post-pyroshock events on figure 517-1.

(4) Fourier Spectra: Reference a mentions the Fourier Spectra (FS) estimate for a pyroshock of duration T_e. In this description, the properly scaled square root of the magnitude of the Fourier Transform of the total pyroshock is computed at a uniformly spaced set of frequencies and displayed as a two-dimensional plot of amplitude versus frequency. The amplitude units are (units-sec). In determining the FS estimate, it is important that the Fast Fourier Transform block size is picked such that all of the transient is contained within the block, but excessive noise beyond the duration of the transient be removed by zero-padding the block. For the FS estimate, this description is useful for noting outstanding frequency components within the overall frequency band amongst pyroshocks. If adjacent frequency components are not averaged, the percentage normalized random error in the ordinate is 100%. By averaging n adjacent ordinates, the percentage of normalized random error decreases as $1/\sqrt{n}$ with a decreased frequency resolution. Computation of the FS estimates for the pre-pyroshock and the post-pyroshock provide useful information relative to the distinct frequency character of the pyroshock as compared to the frequency character of the pre-pyroshock noise and the post-pyroshock combination noise and structural response. Figure 517-8 provides FS estimates for the pyroshock and the pre-pyroshock and post-pyroshock events on figure 517-1. These plots correspond to the ESD plots on figure 517-7.

(5) Other methods: Over the past few years, at least two other techniques potentially useful in processing pyroshock data have been suggested. Reference i describes the utilization of time domain or temporal moments for comparing the characteristics of the pyroshock over different frequency bands. The usefulness of this technique resides in the fact that if the pyroshock can be represented by a simple nonstationary product model, the time domain moments must be constant over selected filter bandwidths. Thus, the pyroshock can be characterized by a model with potential usefulness for stochastic simulation. Reference j explores this reasoning for mechanical shock. Reference k describes the use of wavelets for vibration. It has been suggested that wavelet processing may be useful for pyroshock description, particularly if a pyroshock contains information at intervals of time over the duration of the shock at different time scales, i.e., different frequencies. It is likely that this form of processing may become more prevalent in the future as the level of examination of transients becomes more sophisticated and if wavelet processing is shown to be more useful for description of phenomenon with substantial randomness.

b. In general, for pyroshock tests, a single response record is obtained. At times, it may be convenient or even necessary to combine equivalent processed responses in some appropriate statistical manner. Reference l and method 516.5, Annex 516.5A of this standard discuss some options in statistically summarizing processed results from a series of tests. In general, processed results, either from the SRS, ESD, or FS are logarithmically transformed in order to provide estimates that are more normally distributed. This is important since often very little data are available from a test series, and the probability distribution of the untransformed estimates cannot be assumed to be normally distributed. In general, the combination of processed results will fall under the category of small sample statistics and needs to be considered with care. Parametric or less powerful nonparametric methods of statistical analysis may usually be effectively applied.

2.3.2 Test conditions - shock spectrum transient duration and scaling.

Derive the SRS and the effective transient duration, T_e, from measurements of the materiel's environment or, if available, from dynamically scaled measurements of a similar environment. Because of the inherent high degree of measurement randomness and limited response prediction methodology associated with the response to a pyroshock, extreme care must be exercised in dynamically scaling a similar event. For pyroshocks, there are two known scaling laws for use with response from pyroshocks that may be helpful if used with care (reference a).

2.3.2.1 Pyroshock source energy scaling (SES).

The first scaling law is the Source Energy Scaling (SES) where the SRS is scaled at all frequencies by the ratio of the total energy release of two different devices. For E_r and E_n, the total energy in two pyrotechnic shock devices, the relationship between the SRS processed levels at a given natural frequency f_n and distance D_1 is given by the following expression:

$$SRS(f_n \mid E_n, D_1) = SRS(f_n \mid E_r, D_1)\left(\sqrt{\frac{E_n}{E_r}}\right)$$

In utilizing this relationship, it is assumed that either an increase or decrease in the total energy of the pyrotechnic shock devices will be coupled into the structure in exactly the same way, i.e., excessive energy from a device will go into the structure as opposed to being dissipated in some other way, e.g., through the air. E_n and E_r may come from physical considerations related to the pyrotechnic device or be computed from ESD estimates (or in the time domain by way of a Parseval form relationship) where it is assumed that the time history measurements quantify the energy difference. Reference a discusses conditions under which this scaling lawmay lead to over-prediction for $E_n > E_r$ or under-prediction when $E_n < E_r$.

2.3.2.2 Pyroshock response location distance scaling (RLDS).

The second scaling law is the Response Location Distance Scaling (RLDS) where the SRS is scaled at all frequencies by an empirically derived function of the distance between two sources. For D_1 and D_2, the distances from a pyrotechnic shock device (point source), the relationship between the SRS processed levels at a given natural frequency, f_n, is given by the following expression :

$$SRS(D_2) = SRS(D_1)\exp\left\{\left[-8\times10^{-4}\ f_n^{\ (2.4f_n - 0.105)}\right](D_2 - D_1)\right\}$$

In utilizing this relationship it is assumed that D_1 and D_2 can be easily defined as in the case of a pyrotechnic point source device. Figure 517.5-9 from reference a displays the ratio of $SRS(f_n|D_2)$ to $SRS(f_n|D_1)$ as a function of the natural frequency, f_n, for selected values of D_2-D_1. It is clear from this plot that, as the single degree of freedom natural frequency increases, there is a marked decrease in the ratio for a fixed D_2-$D_1 > 0$ and as D_2-D_1 increases the attenuation becomes substantial. This scaling relationship when used for prediction between two configurations, relies very heavily upon (1) similarity of configuration and (2) the same type of pyrotechnic device. Consult reference a before applying this scaling relationship.

2.3.2.3 Measured data available from pyroshock.

a. If measured data are available, the data may be processed utilizing the SRS, FS, or ESD. For engineering and historical purposes, the SRS has become the standard for measured data processing. In the discussion to follow, it will be assumed that the SRS is the processing tool. In general, the maximax SRS spectrum (absolute acceleration or absolute pseudo-velocity) is the main quantity of interest. With this background, determine the shock response spectrum required for the test from analysis of the measured environmental acceleration time history. After carefully qualifying the data, to make certain there are no anomalies in the amplitude time history, according to the recommendations provided in reference b, compute the SRS. The analysis will be performed for Q = 10 at a sequence of natural frequencies at intervals of at least 1/6 octave and no finer than 1/12th octave spacing to span at least 100 to 20,000 Hz, but not to exceed 100,000 Hz. When a sufficient number of representative shock spectra are available, employ an appropriate statistical technique (an enveloping technique) to determine the required test spectrum. Annex 516.5A of method 516.5 references the appropriate statistical techniques. Parametric statistics can be employed if the data can be shown to satisfactorily fit an assumed underlying probability distribution. When a normal or lognormal distribution can be justified, Annex 516.5A and reference l provide a method for estimating such a test level. Test levels based upon a maximum predicted environment defined to be equal to or greater than the 95th percentile value at least 50 percent of the time utilizes a one-sided tolerance interval approach.

b. When insufficient data are available for statistical analysis, use an increase over the maximum of the available spectral data to establish the required test spectrum to account for randomness and inherent variability of the environment. The degree of increase is based upon engineering judgment and is supported by rationale for that judgment. In these cases, it is often convenient to envelope the SRS by computing the maximax spectra over the sample spectra and proceed to add a +6dB margin to the SRS maximax envelope over the entire frequency range of interest.

c. When employing the pyroshock method, determine the effective transient duration, T_e, from the measurement time histories of the environmental data as suggested in paragraph 2.3.1. For all procedures, the pyroshock amplitude time history used for the SRS analysis will be T_e in duration. In addition, measurement data will be collected for a duration, T_e, just prior to the pyroshock, and duration, T_e, just after the pyroshock for subsequent analysis. In general, each individual axis of the three orthogonal axes will have approximately the same shock test SRS and average effective duration as a result of the omni-directional properties of a pyroshock in Procedure I and Procedure II. For Procedures III and IV, the form of shock test SRS may vary with axes. Use an SRS shaker shock replication method when using Procedure IV; do not use classical shock pulse forms, e.g., half-sine, terminal-peak saw tooth, etc., in the testing.

2.3.2.4 Measured data not available from pyroshock.

If a database is not available for a particular configuration, use configuration similarity and any associated measured data for prescribing a pyroshock. Because of the sensitivity of the pyroshock to the system configuration and the wide randomness and variability inherent in pyrotechnic measurements, the tester must proceed with caution. As a basic guide for pyroshock testing, figure 517-10 from reference p provides SRS estimates for four typical aerospace application pyrotechnic point source devices. Figure 517-11 from reference a provides information on the attenuation of the peaks in the SRS, and of the ramp in the SRS of the point sources on figure 517-10 with distance from the source. Information on figure 517-10 and figure 517-11 come from reference m. Reference m also recommends that the attenuation of the peak SRS across joints be taken to be 40% per joint for up to three joints, and that there be no attenuation of the ramp portion (portion linearly increasing with frequency on the log log plot) of the SRS. Figure 517-12 provides the degree of attenuation of the peak amplitude time history response as a function of the shock path distance from the source for seven aerospace structural configurations. This information was summarized from reference n. The SES scaling law or the RLDS scaling law may provide guidance. In most cases, either Procedure II or Procedure III are the optimum procedures for testing, with the smallest risk of either substantial undertest or gross overtest, when Procedure I is not an option. Proceed with caution with Procedure II or Procedure III, cognizant of the information contained in reference c. Generally, a test transient is deemed suitable if its SRS equals or exceeds the given SRS requirement over the minimum frequency range of 100 to 20,000 Hz and the effective transient duration (T) of the test transient is within 20% of that of the normal pyroshock response transient duration (T_e). (See paragraph 4.2.2 for test tolerances.)

2.3.3 Test axes, duration, and number of shock events.

2.3.3.1 General.

A suitable test shock for each axis is one that yields an SRS that equals or exceeds the required test SRS over the specified frequency range when using a specified duration for the test shock time history, and when the effective transient duration of the shock (T_e) is within twenty percent of the specified T_e value. For Procedure I, T_e is not specified, but is measured. Properly validate the test data and determine the maximax acceleration SRS for Q = 10, and at least at 1/12-octave frequency intervals. The following guidelines may also be applied. For materiel that is likely to be exposed once to a given pyroshock event, perform one shock for each appropriate environmental condition. For materiel that is likely to be exposed more frequently to pyroshock events and there are little available data to substantiate the number of pyroshocks, apply three or more at each environmental condition based on the anticipated service use. Application of three or more shocks in one configuration is for enhancement of statistical confidence.

2.3.3.2 Procedure I.

For Procedure I, subject the test item to a sufficient number of suitable shocks to meet the specified test conditions or at least three shocks, whichever is greater. The objective of the test is to test the physical and functional integrity of the materiel under service use pyroshock in the near-field of the pyrotechnic device.

2.3.3.3 Procedure II.

For Procedure II, subject the test item to a sufficient number of suitable shocks to meet the specified test conditions or at least three shocks. The objective of the test is to test the structural and functional integrity of the materiel under pyroshock in the near-field of the pyrotechnic device.

2.3.3.4 Procedure III.

For Procedure III, subject the test item to a sufficient number of suitable shocks to meet the specified test conditions or at least three shocks. The measured response test requirements may be satisfied along more than one axis with a single test shock configuration. Consequently, it is conceivable that a minimum of three test shock repetitions will satisfy the requirements for all directions of all three orthogonal axes. At the other extreme, a total of nine shocks are required if each shock only satisfies the test requirements in one direction of one axis. The objective of the test is to test the structural and functional integrity of the system under pyroshock in the far-field of the pyrotechnic device.

2.3.3.5 Procedure IV.

For Procedure IV, subject the test item to a sufficient number of suitable shocks to meet the specified test conditions or at least three shocks. The measured response will generally not be omni-directional. For Procedure IV, it may be possible, but highly unlikely, to simultaneously meet the test requirements along more than one axis with a single test shock configuration. Consequently, it is conceivable that a minimum of three test shock repetitions could satisfy the requirements for all directions of all three orthogonal axes. At the other extreme, a total of nine shocks are required if each shock only satisfies the test requirements in one direction of one axis. The objective of the test is to test the structural and functional integrity of the system under pyroshock in the far-field of the pyrotechnic device.

2.4 Test Item Configuration.

See Part One, paragraph 5.8. Configure the test item for pyroshock as would be anticipated for the materiel during service giving particular attention to the details of the mounting of the materiel to the platform. For Procedure II, provide special justification for the selection of the test item configuration. Pyroshock response variation is particularly sensitive to the details of the materiel/platform configuration.

3. INFORMATION REQUIRED.

3.1 Pretest.

The following information is required to conduct a pyroshock test adequately.

a. General. Information listed in Part One, paragraphs 5.7 and 5.9, and Part One, Appendix A, Task 405 of this standard.

b. Specific to this method.

   (1) Test system (test item/platform configuration) detailed configuration including

      (a) location of the pyrotechnic device
      (b) location of the materiel

(c) the structural path between the pyrotechnic device and the materiel and any general coupling configuration of the pyrotechnic device to the platform and the platform to the materiel including the identification of structural joints
(d) distance of the closest part of the materiel to the pyrotechnic shock device

(2) Pyroshock environment, including

(a) type of pyrotechnic device
(b) if charge related - size of pyrotechnic device charge
(c) if charge effect - stored strain energy in primary device
(d) means of initiation of the pyrotechnic device
(e) anticipated EMI or thermal effects

(3) Effective duration of pyroshock if Procedure III or Procedure IV is used, or the size and distribution of the pyrotechnic charge if Procedure I or Procedure II is used.

(4) General materiel configuration including measurement points on or near the materiel.

3.2 During Test.

Collect the following information while conducting the test:

a. General. Information listed in Part One, paragraph 5.10, and in Part One, Appendix A, Tasks 405 and 406 of this standard.

b. Specific to this method.

(1) A means of assessing damage to fixture/materiel configurations before continuing the tests in Procedures I, II, and III.

(2) A record of previous shock time history information for analysis.

(3) An SRS analysis capability to determine if specified pyroshock levels are being replicated in Procedures II, III, and IV.

3.3 Post-test.

Record the following post-test information.

a. General. Information listed in Part One, paragraph 5.13, and in Appendix A, Tasks 405 and 406 of this standard.

b. Specific to this method.

(1) Duration of each exposure as recorded by the instrumented test fixture or test item, and the number of specific exposures.

(2) Any data measurement anomalies, e.g., high instrumentation noise levels, loss of sensors or sensor mount as a result of testing, etc.

(3) Status of the test item/fixture after each test.

(4) Status of measurement system after each test.

4. TEST PROCESS.

4.1 Test Facility.

Pyroshock can be applied utilizing actual pyrotechnic devices in the design configuration or in a simulated configuration, conventional high acceleration amplitude/frequency test input devices or, under certain restricted circumstances, an electrodynamic shaker. The pyroshock apparatus may incorporate a compressed gas shock tube, metal-on-metal contact, ordnance-generated pyroshock simulator, actual pyrotechnic device on a scale model, actual pyrotechnic device on a full scale model, or other activating types. For Procedure I or Procedure II, references related to ordnance devices must be consulted. For Procedure III, reference c provides a source of alternative test input devices, their advantages and limitations. In Procedure III it is assumed that all parts of the materiel lie in the far-field of the pyrotechnic device. Consult reference c for guidelines and consideration for such testing. For Procedure IV, it is assumed that all parts of the materiel lie in the far-field of the pyrotechnic device and the measured or predicted data are consistent with the 3000 Hz frequency limitations of the electrodynamic shaker in addition to the acceleration amplitude limitations. It is also important to note that for large materiel, the velocity input of the shaker may exceed the velocity of the materiel under the actual pyroshock environment. For velocity sensitive materiel, this may constitute an overtest. In the ensuing paragraphs, the portion of the test facility responsible for delivering the pyroshock to the materiel will be termed the shock apparatus. Such shock apparatus includes the pyrotechnic shock device and the fixturing configuration in Procedure I and Procedure II, the mechanical exciter and the fixturing configuration in Procedure III, and the electrodynamic shaker and the fixturing configuration in Procedure IV.

4.2 Controls.

4.2.1 Calibration.

Ensure the shock apparatus is calibrated for conformance with the specified test requirement from the selected procedure. For Procedure I there is no pre-shock calibration other than ensuring the configuration is in accordance with the test plan. For Procedure II, before the test item is attached to the resonating plate, it will be necessary to attach a calibration load and obtain measured data under test conditions to be compared with the desired test response. Caution must be exercised so that the pre-test shocks do not degrade the resonating plate configuration. For Procedure III, calibration is crucial. Before the test item is attached to the shock apparatus, it will be necessary to attach a calibration load and obtain measured data under test conditions to be compared with the desired test response. For Procedure IV, utilizing the SRS method with proper constraints on the effective duration of the transient, calibration is necessary. Before the test item is attached to the shock apparatus, it will be necessary to attach a calibration load and obtain measured data under test conditions to be compared with the desired test response. For Procedure II, Procedure III, and Procedure IV, remove the calibration load and perform the shock test on the actual test item. Additional calibration procedures are provided in Part One, paragraph 5.3.2 and Part One, paragraph 5.2, respectively.

4.2.2 Tolerances.

The following are guidelines for test tolerances for pyroshock for the four procedures. All tolerances are specified on the maximax acceleration SRS. Any tolerances specified on the pseudo-velocity SRS must be derived from the tolerances on the maximax acceleration SRS and be consistent with those tolerances. For an array of measurements defined in terms of a "zone" (reference e) a tolerance may be specified in terms of an average of the measurements within a "zone". It should be noted, however, this is in effect a relaxation of the single measurement tolerance, and that individual measurements may be substantially out of tolerance while the average is within tolerance. In general, when specifying test tolerances based on averaging for more than two measurements within a zone, the tolerance band should not exceed the 95/50 one-sided normal tolerance upper limit computed for the logarithmically transformed SRS estimates, or be less than the mean minus 1.5dB. Any use of "zone" tolerances and averaging must have support documentation prepared by a trained analyst. Additional test tolerance procedures are provided in Part One, paragraph 5.3.2 and Part One, paragraph 5.2, respectively.

4.2.2.1 Procedures I and II.

If prior measured data are available or a series of pyroshocks are performed, all acceleration maximax SRS computed with a one-twelfth octave frequency resolution are to be within –3 dB and +6dB over a minimum of 80% of the overall frequency bandwidth from 100 Hz to 20 kHz. For the remaining 20% part of the frequency band, all SRS are to be within –6dB and +9dB. Ensure that at least 50% of the SRS magnitudes exceed the nominal test specification.

4.2.2.2 Procedure III.

If prior measured data are available or a series of pyroshocks are performed, all acceleration maximax SRS computed with a one-twelfth octave frequency resolution are to be within –3 dB and +6 dB over a minimum of 90% of the overall frequency bandwidth from 100 Hz to 10 kHz. For the remaining 10% part of the frequency band all SRS are to be within –6dB and +9dB. Ensure that at least 50% of the SRS magnitudes exceed the nominal test specification.

4.2.2.3 Procedure IV.

If prior measured data are available or a series of pyroshocks are performed, all acceleration maximax SRS computed with a one-twelfth octave frequency resolution are to be within –1.5 dB and +3 dB over a minimum of 90% of the overall frequency bandwidth from 10 Hz to 3 kHz. For the remaining 10% part of the frequency band all SRS are to be within –3 dB and +6 dB. Ensure that at least 50% of the SRS magnitudes exceed the nominal test specification.

4.3 Instrumentation.

In general, acceleration will be the quantity measured to meet specification with care taken to ensure acceleration measurements can be made that provide meaningful data (reference b). For pyroshock measurements in and close to the near-field, loss of measurement system integrity is not unusual. On occasion, more sophisticated devices may be employed, e.g., laser velocimeter. In these cases, give special consideration to the measurement instrument amplitude and frequency range specifications in order to satisfy the measurement and analysis requirements.

a. Accelerometer.

(1) Transverse sensitivity of less than or equal to 5%.

(2) An amplitude linearity within 10% from 5% to 100% of the peak acceleration amplitude required for testing.

(3) For all pyroshock measurement procedures a flat frequency response within ±10% across the frequency range 10 - 20,000 Hz. The devices may be of the piezoelectric type or the piezoresistive type. Use measurement devices compatible with the requirements, guidelines, and precautions provided in reference b.

b. Signal conditioning. Use signal conditioning compatible with the instrumentation requirements on the materiel. In particular, filtering will be consistent with the response time history requirements. Use signal conditioning compatible with the requirements and guidelines provided in reference b. In particular, use extreme care in filtering the acceleration signals either (1) directly at the attachment point, i.e., mechanical filtering to reduce the very high frequencies associated with the pyroshock, or (2) at the amplifier output. Never filter the signal into the amplifier for fear of filtering bad measurement data and the inability to detect the bad measurement data at the amplifier output. The signal from the signal conditioning or recording device must be anti-alias filtered before digitizing with a linear phase shift filter over the frequency range of interest.

4.4 Data Analysis.

a. Digitizing will not alias more than a 5 percent measurement error into the frequency band of interest (100 Hz to 20 kHz).

b. For filters used to meet the previous requirement, use a filter having linear phase-shift characteristics.

c. A filter (if used) with a pass band flatness within one dB across the frequency range specified for the accelerometer (see paragraph 4.3).

d. Analysis procedures will be in accordance with those requirements and guidelines provided in reference b. In particular, the pyroshock acceleration amplitude time histories will be validated according to the procedures in reference b. Each amplitude time history will be integrated to detect any anomalies in the measurement system e.g., cable breakage, slewrate of amplifier exceeded, data clipped, unexplained accelerometer offset, etc. The integrated amplitude time histories will be compared against criteria given in reference b. For Procedure I and Procedure II to detect emission from extraneous sources, e.g., EMI, configure an accelerometer without sensing element and process its response in the same manner as for the other accelerometer measurements. If this accelerometer exhibits any character other than very low level noise, consider the acceleration measurements to be contaminated by an unknown noise source in accordance with the guidance in reference b.

4.5 Test Execution.

4.5.1 Preparation for test.

4.5.1.1 Preliminary steps.

Prior to initiating any testing, review pretest information in the test plan to determine test details (e.g., procedures, test item configuration, pyroshock levels, number of pyroshocks):

a. Choose the appropriate test procedure.

b. Determine the appropriate pyroshock levels for the test prior to calibration for Procedure II, Procedure III, and Procedure IV from previously processed data if this is available.

c. Ensure the pyroshock signal conditioning and recording device have adequate amplitude range and frequency bandwidth. It may be difficult to estimate a peak signal and range the instrumentation appropriately. In general, there is no data recovery from a clipped signal, however, for over-ranged signal conditioning, it is usually possible to get meaningful results for a signal 20 dB above the noise floor of the measurement system. In some cases, redundant measurements may be appropriate - one measurement being over-ranged and one measurement ranged at the best estimate for the peak signal. The frequency bandwidth of most modern recording devices is usually adequate, but one must make sure that device input filtering does not limit the signal frequency bandwidth.

4.5.1.2 Pretest checkout.

All items require a pretest checkout at standard ambient conditions to provide baseline data. Conduct the checkout as follows:

Step 1. Conduct a complete visual examination of the test item with special attention to micro-electronic circuitry areas. Pay particular attention to its platform mounting configuration and potential stress wave transmission paths.
Step 2. Document the results.
Step 3. Where applicable, install the test item in its test fixture.
Step 4. Conduct an operational checkout in accordance with the approved test plan along with simple tests for ensuring the measurement system is responding properly.
Step 5. Document the results for comparison with data taken during and after the test.
Step 6. If the test item operates satisfactorily, proceed to the first test. If not, resolve the problem and restart at Step 1.
Step 7. Remove the test item and proceed with the calibration (except for Procedure I).

4.5.1.3 Procedures.

The following procedures provide the basis for collecting the necessary information concerning the platform and test item under pyroshock.

a. <u>Procedure I - Near-field with actual configuration</u>.

Step 1. Following the guidance of reference c, select test conditions and mount the test item (in general there will be no calibration when actual hardware is used in this procedure). Select accelerometers and analysis techniques that meet the criteria outlined in reference b.
Step 2. Perform a functional check on the test item.

Step 3. Subject the test item (in its operational mode) to the test transient by way of the pyrotechnic test device.

Step 4. Record necessary data that show the shock transients when processed with the SRS algorithm are within specified tolerances. This includes test setup photos, test logs, and plots of actual shock transients. For shock-isolated assemblies within the test item, make measurements and/or inspections to ensure these assemblies did attenuate the pyroshock.

Step 5. Perform the functional check on the test item. Record performance data.

Step 6. Repeat steps 2, 3, 4, and 5 a minimum of three times for statistical confidence if the integrity of the test configuration can be preserved during test.

Step 7. Document the test series.

b. Procedure II - Near-field with simulated configuration.

Step 1. Following the guidance of reference b, select test conditions and calibrate the shock apparatus as follows:

(a) Select accelerometers and analysis techniques that meet the criteria outlined in reference b.

(b) Mount the calibration load (an actual test item, a rejected item, or a rigid dummy mass) to the test apparatus in a manner similar to that of the actual materiel service mount. If the materiel is normally mounted on shock isolators to attenuate the pyroshock, ensure the isolators are functional during the test.

(c) Perform calibration shocks until two consecutive shock applications to the calibration load produce shock transients that, when processed with the SRS algorithm, are within specified tolerances for at least one direction of one axis.

(d) Remove the calibrating load and install the actual test item on the shock apparatus paying close attention to mounting details.

Step 2. Perform a functional check on the test item.

Step 3. Subject the test item (in its operational mode) to the test pyroshock.

Step 4. Record necessary data that show the shock transients when processed with the SRS algorithm are within specified tolerances. If requirements are given in terms of more than one axis, examine responses in the other axes to ensure the test specification has been met. This includes test setup photos, test logs, and photos of actual shock transients. For shock isolated assemblies within the test item, make measurements and/or inspections to assure the isolators attenuated the pyroshock.

Step 5. Perform the functional check on the test item. Record performance data.

Step 6. Repeat steps 1, 2, 3, 4, and 5 three times for each orthogonal axis that is to be tested if the test shock did not meet the test specification in the other axes.

Step 7. Document the test series.

c. Procedure III - Far-field using mechanical test device.

Step 1. Following the guidance of reference b, select test conditions and calibrate the shock apparatus as follows:

(a) Select accelerometers and analysis techniques that meet the criteria outlined in reference b.

(b) Mount the calibration load (an actual test item, a rejected item, or a rigid dummy mass) to the test apparatus in a manner similar to that of the actual materiel service mount. If the materiel is normally mounted on shock isolators to attenuate the pyroshock, ensure the isolators are functional during the test.

(c) Perform calibration shocks until two consecutive shock applications to the calibration load produce waveforms that, when processed with the SRS algorithm, are within specified tolerances for at least one direction of one axis.

(d) Remove the calibrating load and install the actual test item on the shock apparatus paying close attention to mounting details.

Step 2. Perform a functional check of the test item.

Step 3. Subject the test item (in its operational mode) to the test pyroshock.

Step 4. Record necessary data that show the shock transients when processed with the SRS algorithm are within specified tolerances. If requirements are given in terms of more than one axis, examine responses in the other axes to ensure the test specification has been met. This includes test setup photos, test logs, and photos of actual shock transients. For shock isolated assemblies within the test item, make measurements and/or inspections to assure the isolators attenuated the pyroshock.

Step 5. Perform the functional check on the test item. Record performance data.

Step 6. Repeat steps 1, 2, 3, 4, and 5 three times for each orthogonal axis that is to be tested if the test shock did not meet the test specification in the other axes.

Step 7. Document the tests.

d. Procedure IV - Far-field using electrodynamic shaker.

Step 1. Following the guidance of reference b, select test conditions and calibrate the shock apparatus as follows:

(a) Select accelerometers and analysis techniques that meet the criteria outlined in reference b.

(b) Mount the calibration load (an actual test item, a rejected item, or a rigid dummy mass) to the electrodynamic shaker in a manner similar to that of the actual materiel. If the materiel is normally mounted on shock isolators to attenuate the pyroshock, ensure the isolators are functional during the test.

(c) Develop the SRS wavelet or damped sine compensated amplitude time history based on the required test SRS.

(d) Perform calibration shocks until two consecutive shock applications to the calibration load produce shock transients that, when processed with the SRS algorithm, are within specified test tolerances for at least one direction of one axis.

(e) Remove the calibrating load and install the actual test item on the electrodynamic shaker paying close attention to mounting details.

Step 2. Perform a functional check on the test item.

Step 3. Subject the test item (in its operational mode) to the test electrodynamic pyroshock simulation.

Step 4. Record necessary data that show the shock transients, when processed with the SRS algorithm, are within specified tolerances. If requirements are given in terms of more than one axis, examine responses in the other axes to ensure the test specification has been met. This includes test setup photos, test logs, and photos of actual shock transients. For shock isolated assemblies within the test item, make measurements and/or inspections to assure the isolators attenuated the pyroshock.

Step 5. Perform the functional check on the test item. Record performance data.

Step 6. Repeat steps 2, 3, 4, and 5 three times for each orthogonal axis that is to be tested if the test shock did not meet the test specification in the other axes.

Step 7. Document the tests.

5. ANALYSIS OF RESULTS.

In addition to the guidance provided in Part One, paragraphs 5.14 and 5.17, and Part One, Appendix A, Tasks 405 and 406, the following information is provided to assist in the evaluation of the test results. Analyze in detail any failure of a test item to meet the requirements of the system specifications and consider related information such as:

5.1 Procedure I - Near-field with Actual Configuration.

Carefully evaluate any failure in the structural configuration of the test item, e.g., minute cracks in circuit boards, that may not directly impact failure of the functioning of the materiel but that would lead to failure in its in-service environment conditions.

5.2 Procedure II - Near-field with Simulated Configuration.

Carefully evaluate any failure in the structural configuration of the test item, e.g., minute cracks in circuit boards, that may not directly impact failure of the functioning of the materiel but that would lead to failure in its in-service environment conditions.

5.3 Procedure III - Far-field Using Mechanical Test Device.

The mechanical shock simulation will, in general, provide a more severe low frequency environment (comparatively large velocity and displacement) than the actual pyroshock event and, hence, any structural failures, e.g., deformed fasteners or mounts, may be more akin to those found in the SRS prescribed shock tests described in method 516.5. If this is the case and the cause of the structural failure is not readily apparent, another procedure may be required to satisfy the test requirements.

5.4 Procedure IV - Far-field Using Electrodynamic Shaker.

The mechanical shock simulation will, in general, provide a more severe low frequency environment (comparatively large velocity) than the actual pyroshock event and, hence, any structural failures may be more akin to those found in the SRS prescribed shock tests described in method 516.5. If this is the case and the cause of the structural failure is not readily apparent, another procedure may be required to satisfy the test requirements.

6. REFERENCE/RELATED DOCUMENTS.

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p. Himelblau, Harry, Dennis L. Kern, Allan G. Piersol, and Sheldon Rubin, Guidelines for Dynamic Environmental Criteria (Preliminary Draft), Jet Propulsion Laboratory, California Institute of Technology, March 1997.

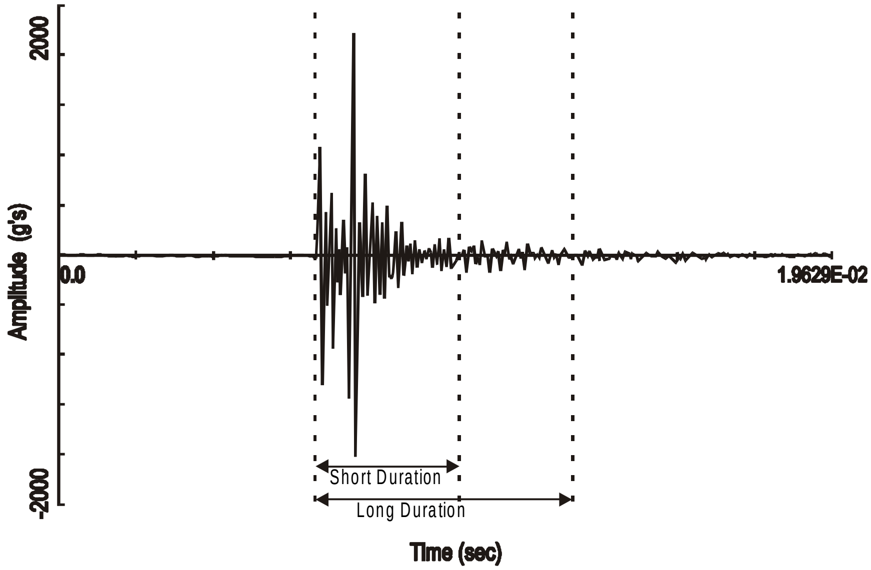

FIGURE 517-1. Total event pyroshock time history.

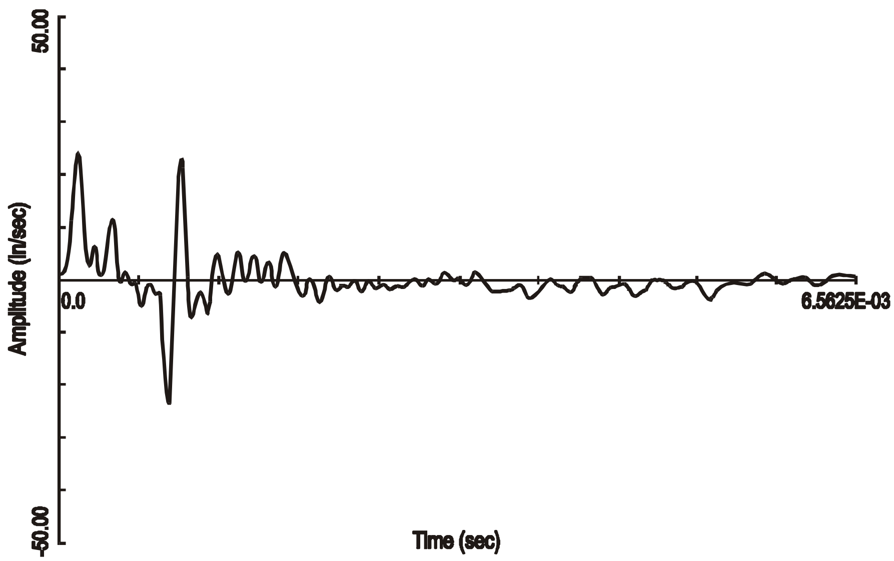

FIGURE 517-2. Long duration pyroshock velocity time history.

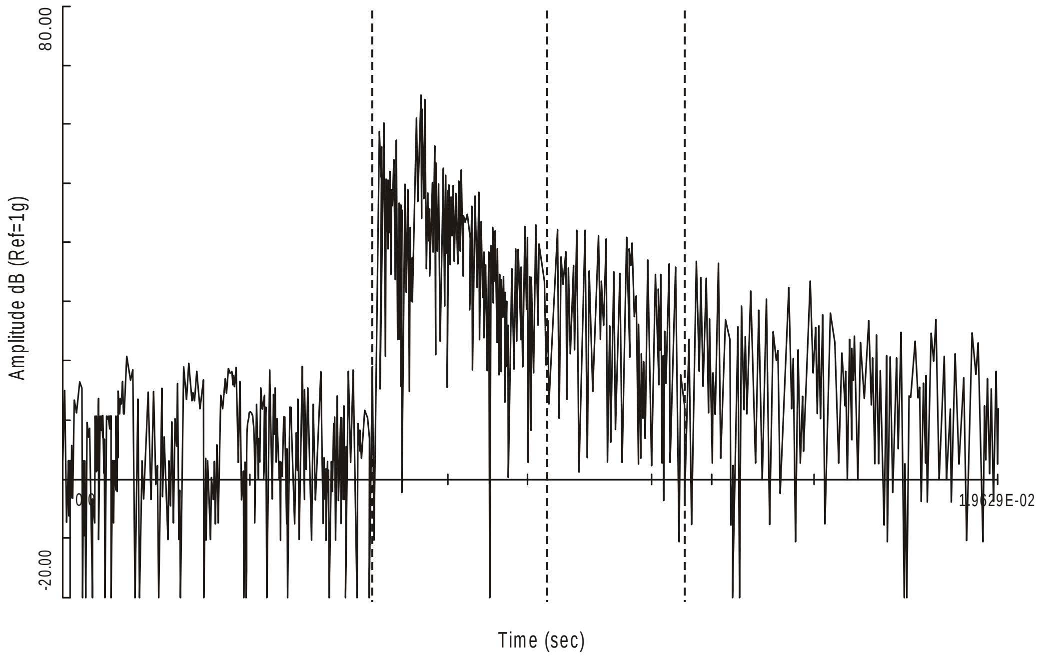

FIGURE 517-3. Absolute value magnitude time history.

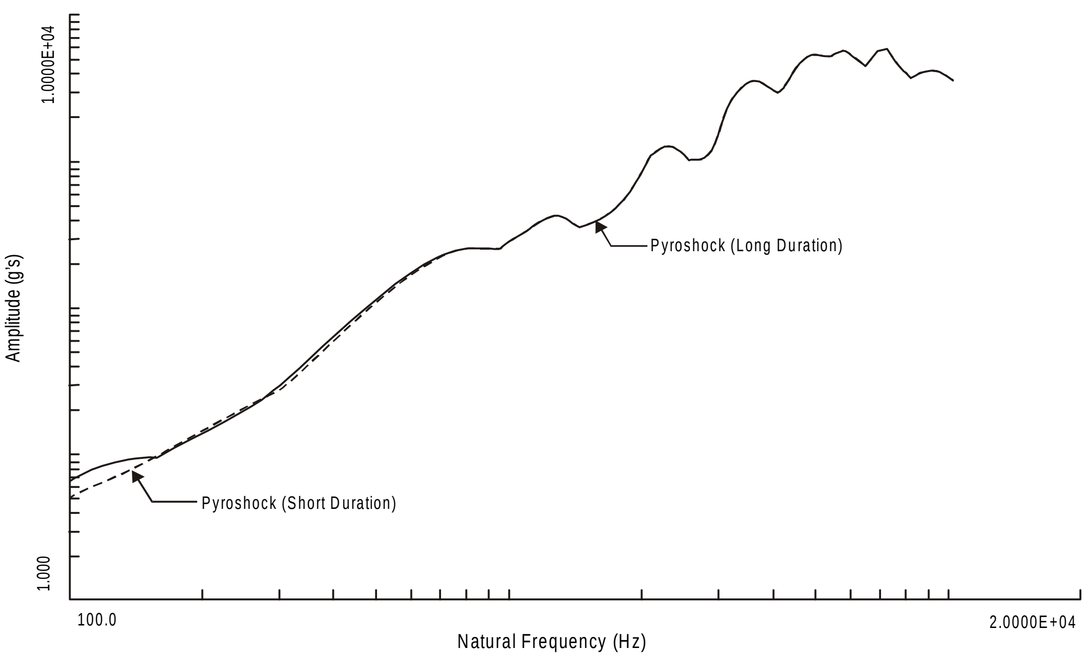

FIGURE 517-4. Acceleration maximax SRS -(long vs short duration).

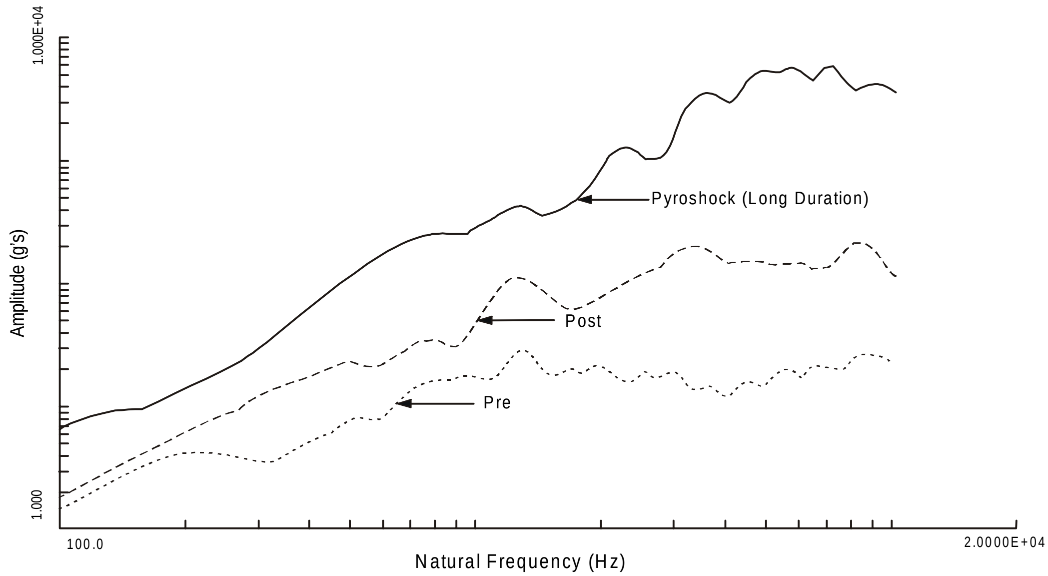

FIGURE 517-5. Acceleration maximax SRS for the pyroshock, pre-pyroshock & post pyroshock.

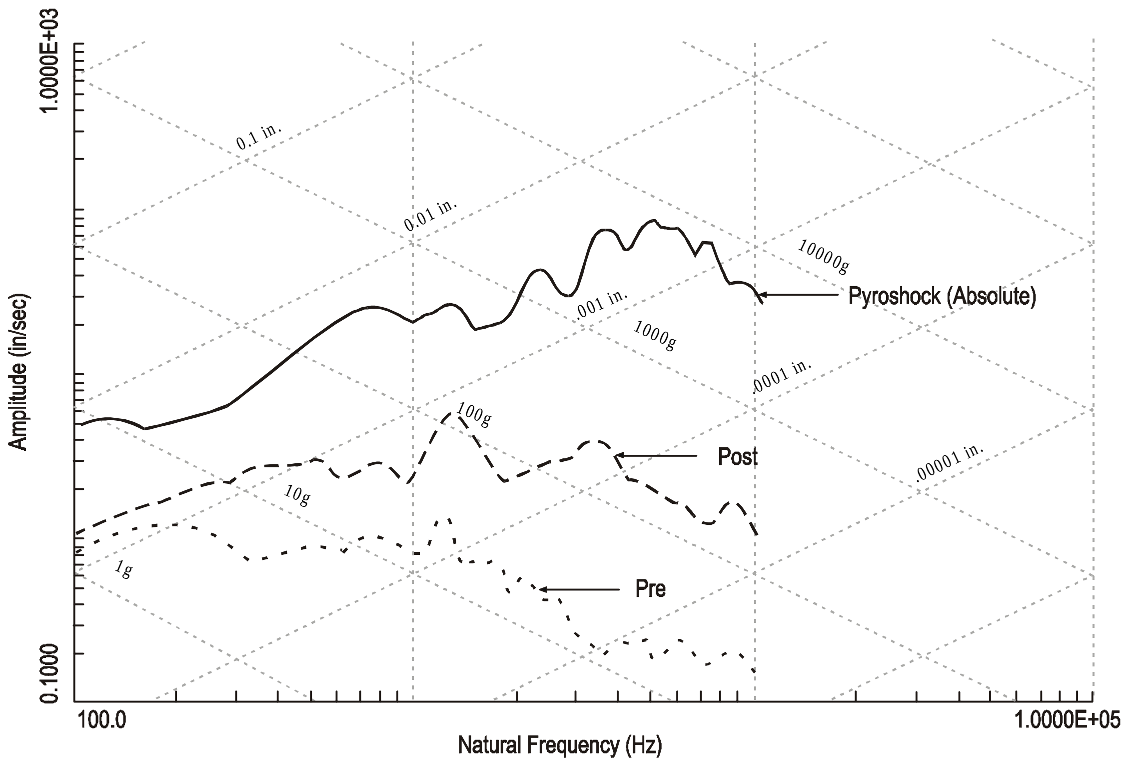

FIGURE 517-6. Maximax pseudo-velocity response spectrum for the pyroshock, pre-pyroshock and post pyroshock.

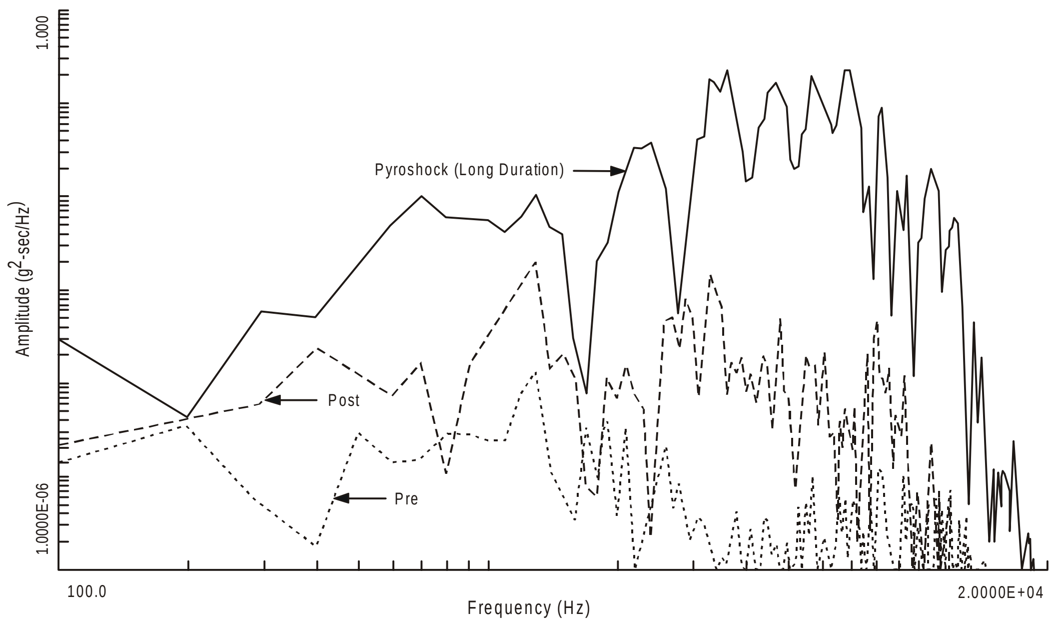

FIGURE 517-7. Acceleration energy spectral density estimates.

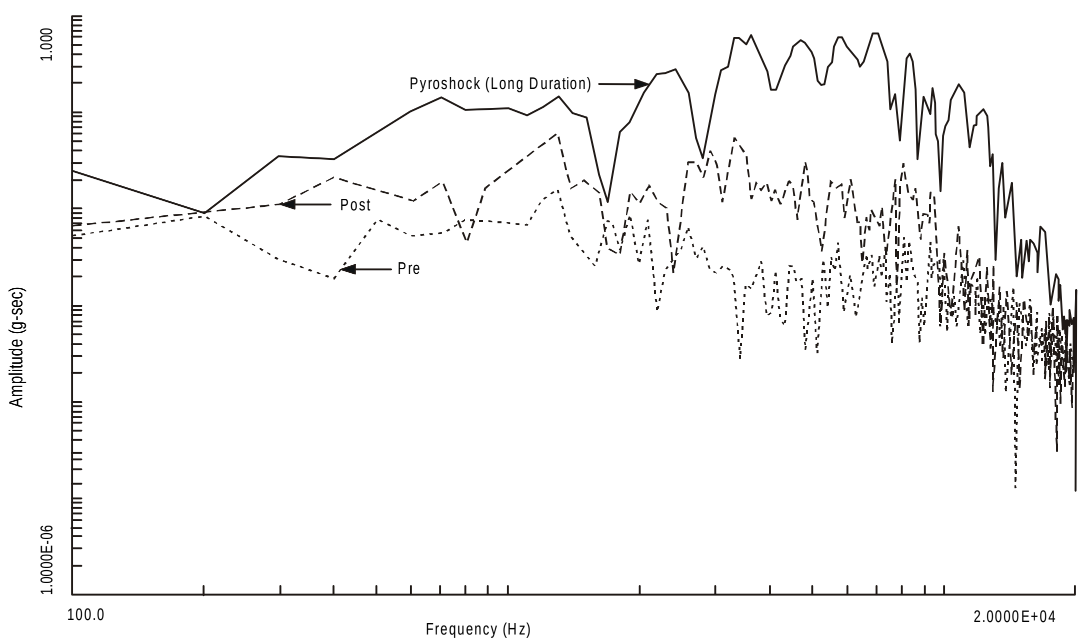

FIGURE 517-8. Acceleration Fourier transform estimates.

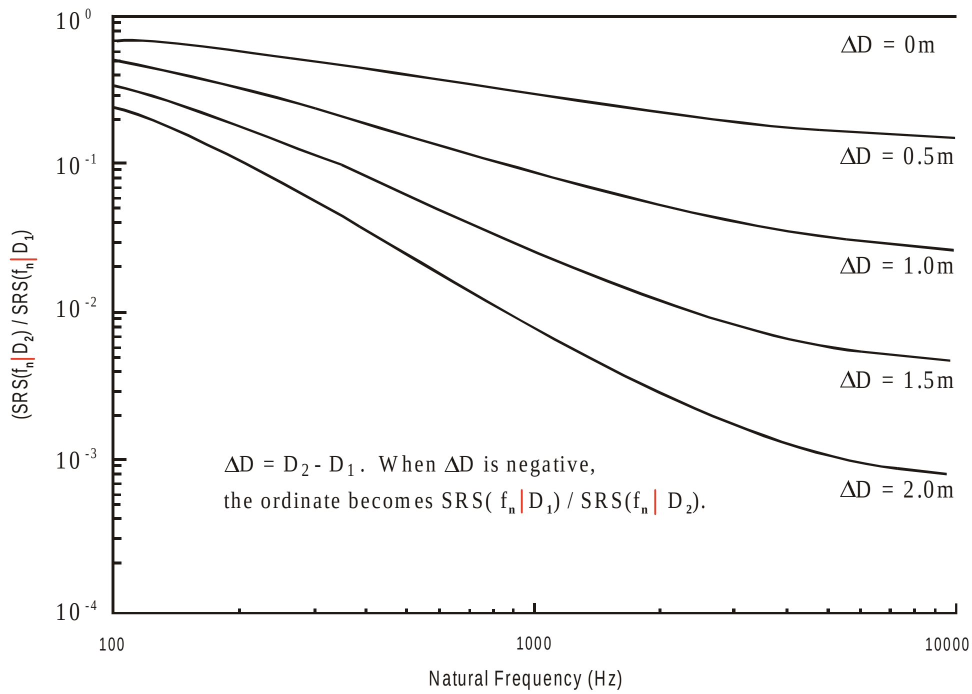

FIGURE 517-9. Correction of shock response spectrum for distance from pyrotechnic source.

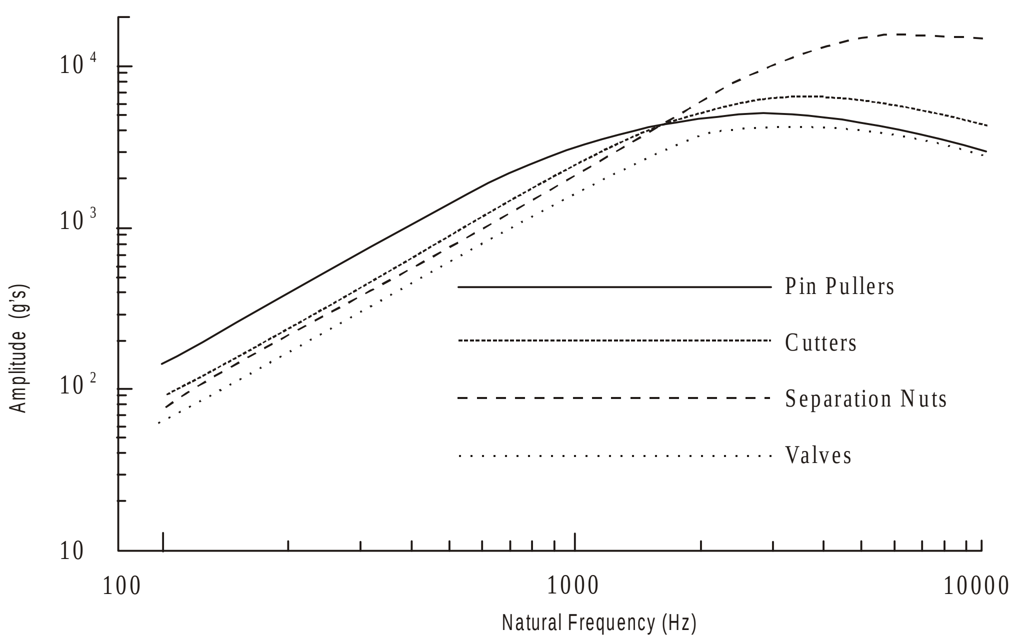

FIGURE 517-10. Shock response spectra for various point source pyrotechnic devices.

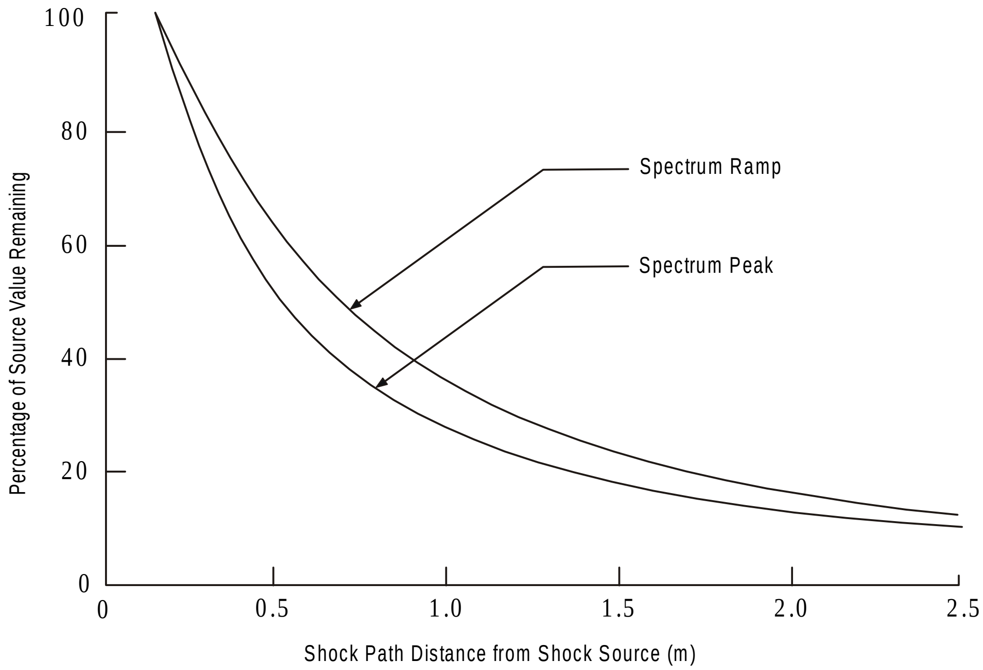

FIGURE 517-11. Shock response spectrum vs distance from pyrotechnic source.

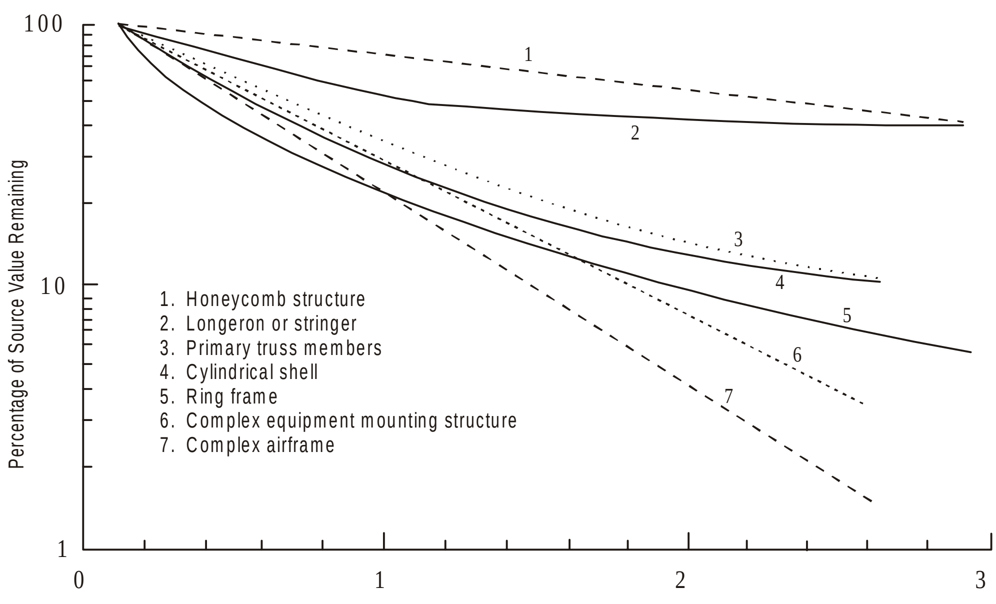

FIGURE 517-12. Peak pyroshock response vs distance from pyrotechnic source.