METHOD 517.3

PYROSHOCK

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METHOD 517.3

PYROSHOCK

NOTE: Tailoring is essential. Select methods, procedures, and parameter levels based on the tailoring process described in Part One, paragraph 4.2.2, and Annex 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 (paragraph 6.1, 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 fuzes (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 at a duration from 50 microseconds to not more than 20 milliseconds. Acceleration response amplitudes to pyroshock may range from 300 g’s to 200,000 g’s. 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, mid-field or far-field of the pyrotechnic device with the pyroshock environment in the near-field being the most severe, and that in the mid-field or far-field less severe. In general, some structure intervenes between the materiel and location of the pyrotechnic device that results in the “mid-field,” and “far-field.” There is now agreement on classifying pyroshock intensity according to the characteristics of “near-field,” “mid-field,” and “far-field.” This document reflects the current consensus for three regions according to simulation techniques as “near-field,” “mid-field,” and “far-field” for which the definitions are provided in paragraph 1.2.4.

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. Pyroshock is "designed" into the materiel by placement of pyroshock devices for specific use. 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 (paragraph 6.1, 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 to 1,000,000 Hz) and very broadband frequency input.

c. High acceleration (300 g's to 200,000 g's) 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 large detonation force or pressure, and v, the structural velocity, is very small). At the pyrotechnic source, the driving point impedance can be substantially less if the structure material particle velocity is high.

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).

1.2.4 Classification of Pyroshock Zones.

The nature of the response to pyroshock suggests that the materiel or its components may be classified as being in the near-field, mid-field or far-field of the pyrotechnic device. The terms "near-field," "mid-field," and "far-field" relate to the shock intensity at the response point, and such intensity is a function of the distance from the pyrotechnic source and the structural configuration between the source and the response point. The definitions that follow are based on simulation techniques consistent with paragraph 6.1, reference b.

a. <u>Near-field</u>. In the near-field of the pyrotechnic device, the structure material stress wave propagation effects govern the response. A near-field pyroshock test requires frequency control up to and above 10,000 Hz for amplitudes greater than 10,000g's. A pyrotechnically excited simulation technique is usually appropriate, although in some cases a mechanically excited simulation technique may be used.

b. Mid-field. In the mid-field of the pyrotechnic device, the pyroshock response is governed by a combination of material stress wave propagation and structural resonance response effects. A mid-field pyroshock test requires frequency control from 3,000 Hz to 10,000 Hz for amplitudes less than 10,000g's. A mechanically excited simulation technique other than shaker shock is usually required.

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

Distances from the pyrotechnic device have been avoided in these definitions because specific distances restrict structural dimensions and imply point or line pyrotechnic sources with specific weights and densities. The definitions are based on experimental capabilities, but still should be considered guidelines because all structures with their corresponding pyrotechnic devices are different.

1.3 Limitations.

Because of the highly specialized nature of pyroshock, apply it only after giving careful consideration to information contained in paragraph 6.1, references a, b, c, and d. This Method does not apply to the following:

a. 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. The effects experienced by fuze systems that are sensitive to shock from pyrotechnic devices. Shock tests for safety and operation of fuzes and fuze components may be performed in accordance with MIL-STD-331 (paragraph 6.1, reference c).

c. 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 that testing at either the high or low operational temperature may enhance the pyroshock environment.

d. Manned space vehicle testing (see paragraph 6.1, reference a).

e. Secondary effects such as induced blast, EMI, and thermal effects.

f. Effects of hostile weapon penetration or detonation. (Refer to Method 522.2, Ballistic Shock.)

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 microelectronic 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. Use the anticipated life cycle sequence of events as a general sequence guide (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.

NOTE: For materiel design and development, the option of tailoring of a laboratory shock test ***from field measurement information*** is superior to any of the test procedures within this Method, and should be the first laboratory test option. This assumes that the measurement data bandwidth and the laboratory test bandwidths are strictly compatible.

This Method includes five 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 - Mid-field with a Mechanical Test Device. Replication of pyroshock for the mid-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 and weight limitations of an electrodynamic shaker).

d. Procedure IV - 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 and weight limitations of an electrodynamic shaker).

e. Procedure V - 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, mid-field or far-field of the pyrotechnic device. Use Procedure I or II 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, or if there are no prior measured field data. Choose Procedure III, IV, or V based on the frequency content and amplitude of available data, as well as the limitations of the test device. 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.

2.2.2 Difference Among Procedures.

a. Procedure I - Near-field with Actual Configuration. Procedure I is intended to test materiel 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 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. 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 - Mid-field with a Mechanical Test Device. Pyroshock can be applied using conventional high acceleration amplitude/frequency test input devices. Paragraph 6.1, reference b, 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 mid-field of the pyrotechnic device. Consult paragraph 6.1, reference b, for guidelines and considerations for such testing for frequencies between 3,000 and 10,000 Hz. In some cases all three axes may be obtained with one impact to mechanical test device.

d. Procedure IV - Far-field Using a Mechanical Test Device. Pyroshock can be applied using conventional high acceleration amplitude/frequency test input devices. Paragraph 6.1, reference b 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 paragraph 6.1, reference b, for guidelines and considerations for such testing for frequencies less than 3,000 Hz.

e. Procedure V - Far-field Using an Electrodynamic Shaker. On occasion, pyroshock response can be replicated using 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 for frequencies less than 3,000 Hz.

2.3 Determine Test Levels and Conditions.

Having selected one of the five 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 (LCEP), and information provided with this procedure. Consider the following basic information when selecting test levels.

2.3.1 General Considerations - Terminology.

Pyroshock is the most difficult of mechanical environments to measure and, consequently, has more stringent requirements than other mechanical environments. 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. Paragraph 6.1, references a and b detail the tradeoffs among pyroshock measurement techniques. Ensure the guidelines in paragraph 6.1, references b and d, are implemented. 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 517.3-1 provides an acceleration time history plot of a measured near-field pyroshock measured with a laser Doppler vibrometer, 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 arrows at three discrete times are used to identify a pre-pyroshock, pyroshock, and a post-pyroshock response. The pre-pyroshock time interval 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, the third arrow, is of a slightly longer 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. Paragraph 6.1, references b and d, provide guidelines for this. The simplest and most sensitive criterion for validation is an integration of the signal time history after removing any small residual offset (mean), a standard practice for pyroshock data analysis. If the resulting integrated signal has zero crossings and does not appear to monotonically increase, the pyroshock has passed this validation test (net velocity is equal to zero). Figure 517.3-2 provides the velocity plot for the long duration pyroshock on Figure 517.3-1. Further information on interpretation of the integral of the acceleration time history or the velocity time history is shown in Annex A of this Method.

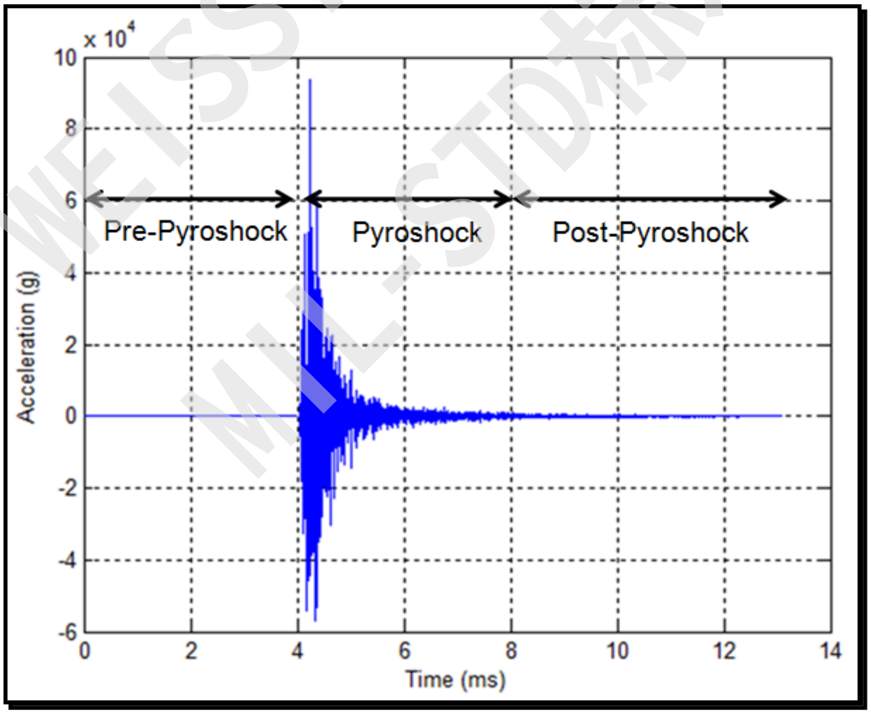

Figure 517.3-1. Full duration near-field, laser pyroshock time history (mean removed, filtered at 200 KHz).

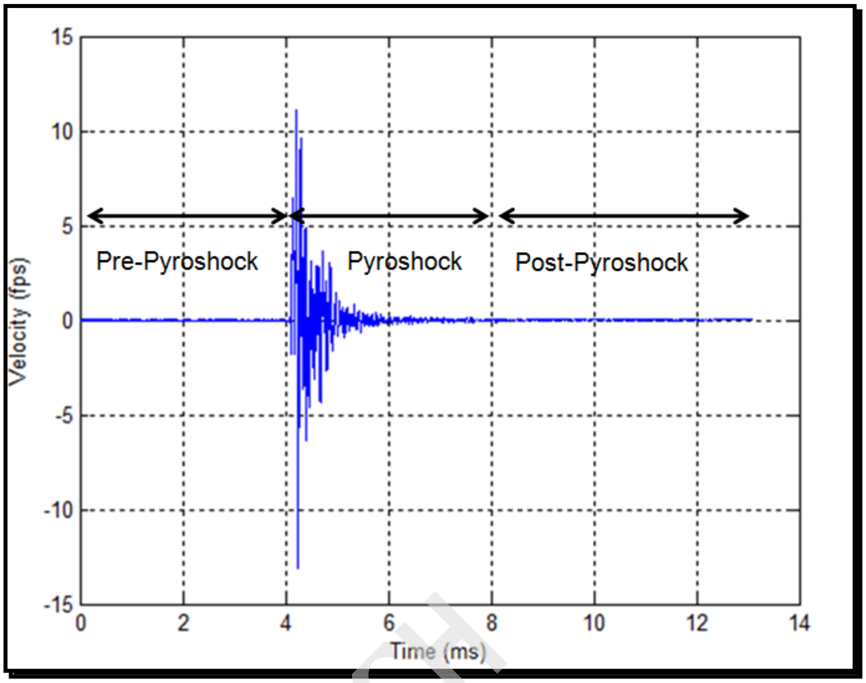

Figure 517.3-2. Full duration near-field, laser pyroshock velocity time history.

(1) Effective Transient Duration: The "effective transient duration," T_e, is defined in this Method to be the minimum length of time that 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 that 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 nature of the event. 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 517.3-1, there is a time interval for the duration of the pyroshock based on the velocity time history in Figure 517.3-2 that clearly shows that the pyroshock event is over after 4 milliseconds. The "effective transient duration," T_e, occurs from 4 milliseconds to 8 milliseconds when the velocity time history in Figure 517.3-2 effectively returns to zero. Consequently, there are 4 milliseconds of pre-pyroshock information, 4 milliseconds of pyroshock, information, and 5 milliseconds of post-pyroshock information. Figure 517.3-3 has the acceleration time history for the same event shown in Figure 517.3-1 (side-by-side measurements), and shows lower amplitudes than the laser Doppler vibrometer data in Figure 517.3-1. This will always occur because the accelerometer has a larger measurement area than the laser Doppler vibrometer that is essentially a point measurement. Thus, the accelerometer acts as a spatial integrator. The initial noise floor level is never obtained after the long duration pyroshock. Figure 517.3-4 contains the integral of Figure 517.3-3, and has the same time intervals as the laser Doppler vibrometer measurement. The magnitude of the SRS at selected natural frequencies (particularly high frequencies) can be quite insensitive to the effective transient duration. As Figure 517.3-5 demonstrates, the low frequency pyroshock SRS slope is + 9 dB/octave to + 12 dB/octave slope (or +1.5 to +2.0 on a log-log plot). The “knee” frequency is the dominant frequency in a pyroshock SRS, at which the slope for the SRS changes from an approximate + 9 dB/octave to + 12 dB/octave slope to an approximately horizontal slope with peaks at the major local structural frequencies. All pyroshock SRS have a knee frequency, even if not properly measured or

quantified. Paragraph 6.1, reference b, details the different SRS characteristics of near-field pyroshock (no "knee" frequency below 10,000 Hz) and mid-field and far-field pyroshock containing a "knee" frequency in their respective frequency ranges.

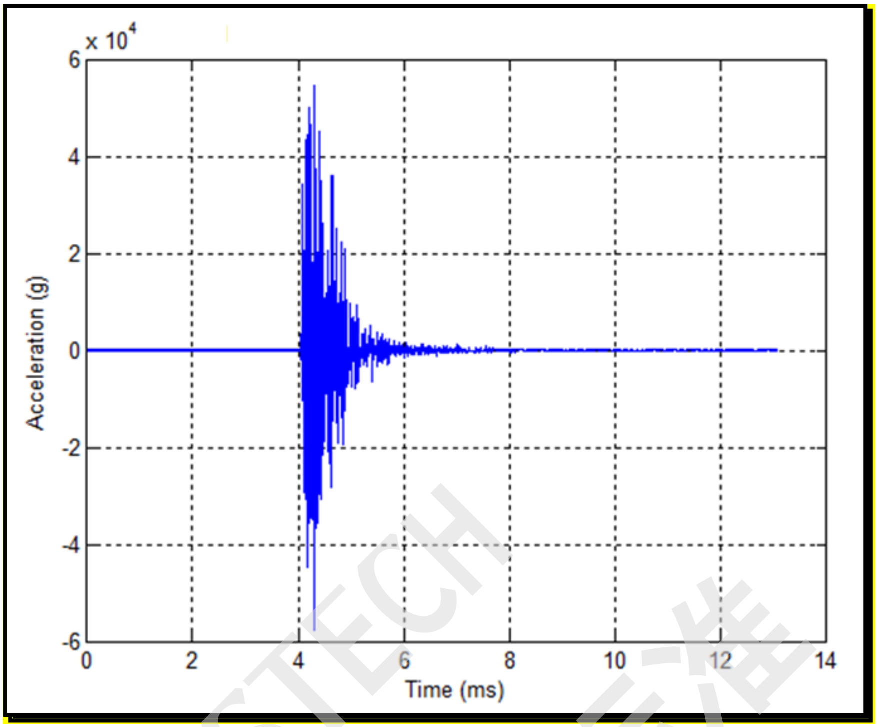

Figure 517.3-3. Full duration near-field, accelerometer pyroshock time history.

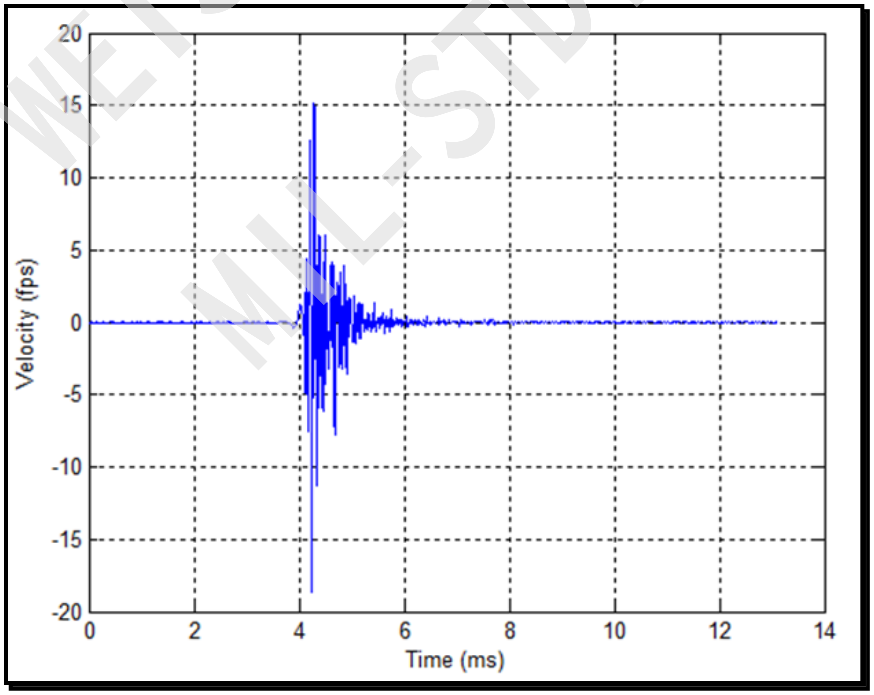

Figure 517.3-4. Full duration near-field, accelerometer pyroshock velocity time history.

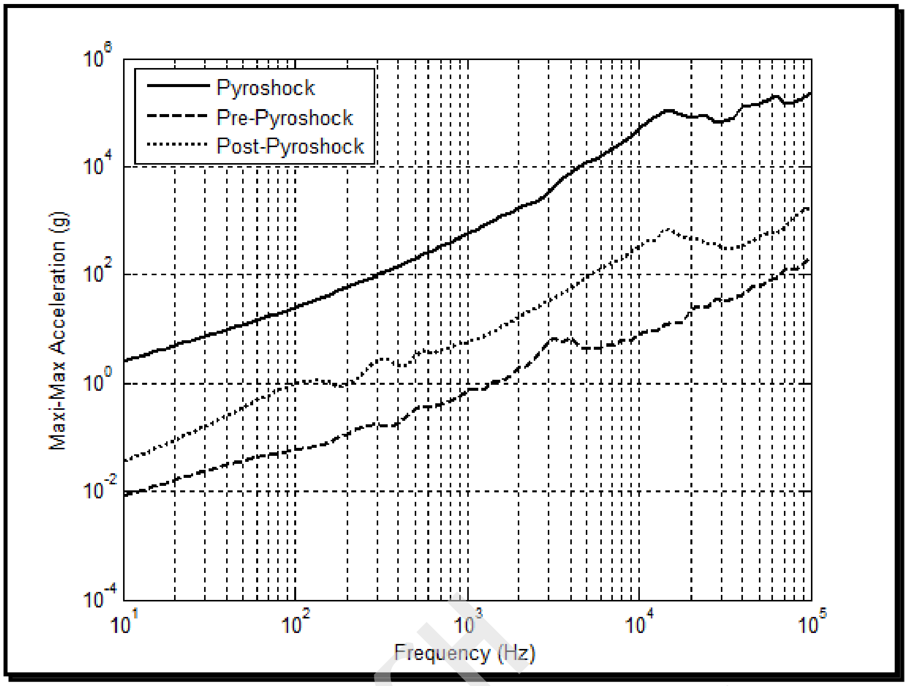

Figure 517.3-5. Acceleration maximax SRS for the pyroshock, pre-pyroshock and post pyroshock (laser).

(2) Shock Response Spectrum analysis: Paragraph 6.1, references e and f, defines the absolute acceleration maximax Shock Response Spectrum (SRS), and provides examples of SRS computed for classical pulses. The SRS value at a given un-damped 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 un-damped 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 un-damped natural frequency being the abscissa, and (2) the maximax absolute acceleration along with the maximax pseudo-displacement plotted in a pair of orthogonal axes (paragraph 6.1, reference e). The maximax pseudo-velocity at a particular oscillator un-damped 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 (paragraph 6.1, 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 un-damped natural frequency of the single degree of freedom system, or (2) multiplying the maximax relative displacement by the un-damped 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 517.3-5 provides the maximax absolute acceleration SRS for the pyroshock record on Figure 517.3-1. Figure 517.3-6 provides the maximax pseudo-velocity for this record on four-coordinate paper. Information below 100 Hz for the maximax acceleration SRS may reveal data anomalies not detected otherwise or confirm erroneous velocity change (see Annex A of this Method). Figure 517.3-6 shows that maximum pseudo-velocity of almost

500 ips occurs above 10,000 Hz. The high velocity change at high frequency is indicative of the damage potential for electronic components. 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 percent 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 percent critical damping) in the processing. It is recommended that the maximax absolute acceleration SRS be the primary method of display for the pyroshock and the maximax pseudo-velocity SRS be the secondary method of display. The maximax pseudo-velocity SRS is useful in cases in which it is desirable to correlate damage of simple systems with the pyroshock.

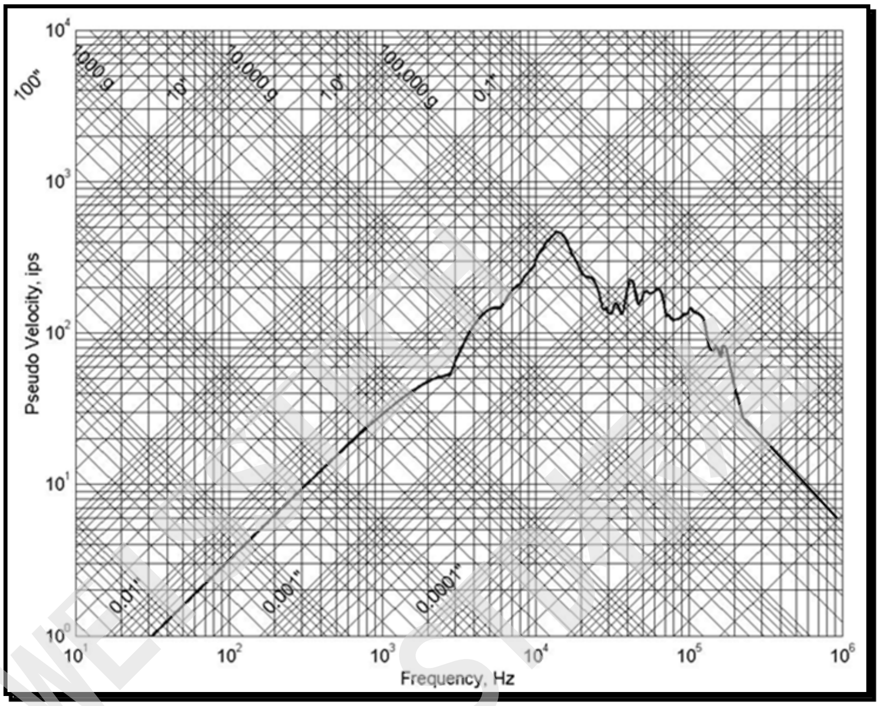

Figure 517.3-6. Maximax pseudo-velocity response spectrum for the pyroshock (laser).

(3) Other Methods: Over the past few years, at least two other techniques potentially useful in processing pyroshock data have been suggested. Paragraph 6.1, reference i, describes the use 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 non-stationary 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. Paragraph 6.1, reference j, explores this reasoning for mechanical shock. Paragraph 6.1, 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.

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. Paragraph 6.1, references a and l, and Method 516.8, Annex B 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 Single Pyroshock Event Measurement System Characterization and Basic Processing.

The following paragraphs discuss basic measurement system acquisition characteristics, followed by a discussion of the correct identification of the parts of a measured pyroshock (in particular the duration of a pyroshock). Information in Method 516.8, Annex A and Annex A of this Method is essential for the processing of measured data for a laboratory test specification.

In this paragraph with its subdivisions, proper identification of a single pyroshock will be illustrated. Once the pyroshock has been correctly identified, processing is generally routine as per the details in paragraph 2.3.1. Pyroshock event identification is important for deciding upon the manner of testing in the laboratory. Within the time domain characterization, anticipating further digital processing, it is assumed the measured data are properly signal conditioned, and subsequently digitized with a minimum of aliased information into the bandwidth of interest (less than five percent) and, in general, the measurement time history has been validated. Details for validation are contained Paragraph 6.1, references b and d.

The following information corresponding to the time domain characterization must be present for assessment by an analyst in establishing pyroshock requirements:

a. Signal bandwidth, i.e., DC to f_{max} where f_{max} is the maximum frequency of interest consistent with the analog, anti-alias filter design built into the analog signal conditioning , i.e., $f_{\mathrm{max}} < f_{\mathrm{AA}}$ where f_{AA} is the 3dB half-power point cut-off frequency of the lowpass analog anti-alias filter. Generally, for SRS analysis in order to get accurate estimates at f_{max}, it is required that the analog, anti-alias rolloff be taken into account so that it does not interfere with the SRS filter estimates at f_{max}. Likewise, digital filters must be in place before digital decimation.

b. Digital signal sample rate F_s, shall be such that the anti-alias filter provides a minimum attenuation as shown in Figure 517.3-7. The digitizing rate shall be at least 1 MHz or higher as per Paragraph 6.1, reference p. Paragraph 6.1, references b and d, recommend a minimum 60 dB/octave anti-alias filter, with the half-power point cut-off frequency set at $f_{\mathrm{c}} < 0.6^* f_{\mathrm{Nyquist}}$. The requirements of this section are an equivalent way to achieve the same aliasing protection with more flexibility in other data parameters. For higher rates of roll-off, f_{c} can be increased, but must never exceed $0.8^* f_{\mathrm{Nyquist}}$. For $10^* f_{\mathrm{max}} < F_s$, re-sampling will be necessary for SRS computation to preserve filtering accuracy. The final sample rate shall meet or exceed ten times the maximum frequency of interest, i.e., $F_s > 10^* f_{\mathrm{max}}$.

c. The data recording instrumentation shall have flat frequency response to at least 100 kHz for all channels at each measurement location. Attenuation of 3 dB at 100 kHz is acceptable. The digitizing rate must be at least 1 MHz or higher so that measurements of peak amplitude to qualify the shock level are accurate. Additional, lower frequency measurement channels, at the same location may be used for lower frequency response measurements.

   It is imperative that a responsibly designed system to reject aliasing is employed. Analog anti-alias filters must be in place before the digitizer. The selected anti-alias filtering must have an attenuation of 50 dB or greater, and a pass band flatness within +/- 1.0 dB and phase linearity to within +/- 5° across the frequency bandwidth of interest for the measurement (see Figure 517.3-7). Subsequent resampling e.g., for purposes of decimation, must be in accordance with standard practices and consistent with the analog anti-alias configuration (e.g. digital filters must be in place before subsequent decimations).

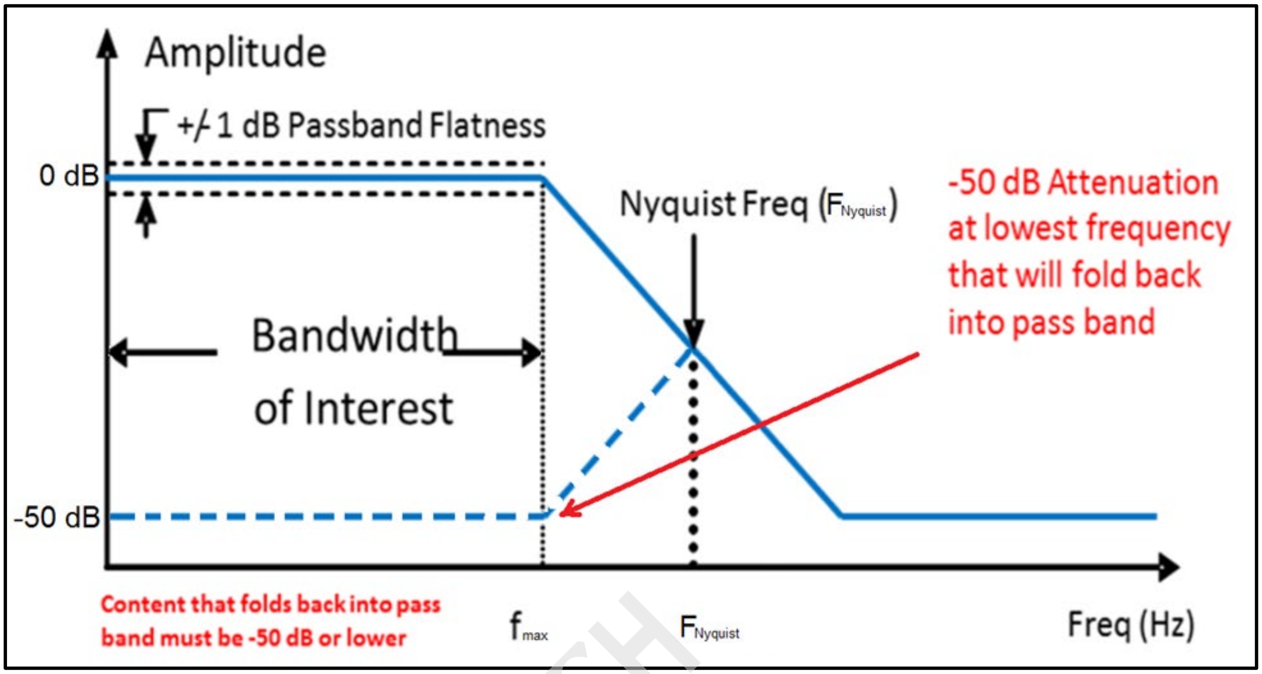

Figure 517.3-7. Filter attenuation (conceptual, not filter specific).

The end to end alias rejection of the final digitized output must be shown to meet the requirements in Figure 517.3-7. The anti-alias characteristics must provide an attenuation of 50 dB or greater for frequencies that will fold back into the passband. Spectral data including SRS plots may only be presented for frequencies within the passband (between 0 and f_{max}). However, this restriction is not to constrain digital data validation procedures that require assessment of digitally acquired data to the Nyquist frequency (either for the initial ADC or subsequent resampled sequences). It should be noted that it is possible that certain sensor/signal conditioning systems may display substantial "out-of-band" frequency content, i.e., greater than f_{Max} but less than the Nyquist frequency, in digital processing. For example, a Fourier spectra estimate over the duration of the shock may display "general signal" to "noise" that seemingly contradicts the filter attenuation criterion displayed in Figure 517.3-7. In this case the signal conditioning/digitizing system must be subject to the "verification of alias rejection" described in the paragraph to follow. If the signal conditioning system is verified as non-aliasing then the substantial frequency content between f_{Max} and the Nyquist frequency can be digitally filtered out if desired.

Verification of alias rejection should start by establishing the dynamic range within the pass band in terms of the signal to noise ratio (SNR). The voltage-based $SNR = 20\log_{10}\left(V_{FullScale} / V_{Noisefloor}\right)$ must be ≥ 60dB. Once sufficient SNR is verified, establishing the alias rejection characteristics may be determined using an input sine wave with a magnitude of 0.5 * full scale range and at the lowest frequency range that can impinge i.e., be aliased into f_{Max}, and then confirming (using the IEEE 1057 sine wave test procedure or through inspection of the time domain data) that the alias rejection is sufficient at this frequency for the signal conditioning system.

For a conventional multi-bit ADC such as flash or successive approximation design, if a 1 million sample/second digitizing rate is used, for example, then $f_{Nyquist}$= 500 KHz. Theory says that if a signal above the Nyquist Ratio is present, it will "fold over" into a frequency below the Nyquist ratio. The equation is:

Fa = absolute value [(Fs*n)-F], where

Fa = frequency of "alias"

F = frequency of input signal

Fs = sample rate

n = integer number of sample rate (Fs) closest to input signal frequency (F)

Hence, the lowest frequency range that can fold back into the 100 KHz passband is from 900 KHz to 1.1 MHz.

It should be noted that Sigma Delta (SD) digitizers “oversample” internally at a rate several times faster than the output data rate and that analog anti-alias filtering is still required. For illustrative purposes, consider an example for a SD digitizer with a bandwidth of interest up to 100 KHz that samples internally at $f_s = 8$ million samples/second. The internal analog based Nyquist frequency by definition is 4 MHz, hence the analog anti-alias filter should attenuate 50 dB or more content that can fold back into the 100 KHz pass band (7.9 MHz to 8.1 MHz and similar bands that are higher in frequency). Figure 517.3.8 illustrates sampling frequencies, Nyquist frequencies, and frequency bands that can fold back into the bandwidth of interest for both conventional and over sampling digitizers, such as the Sigma Delta. Observe that for the example SD design, there is significant bandwidth above the 100 KHz desired f_{Max} and the Nyquist rate that is not useable due primarily to quantization error, an artifact of the single bit SD design. The output of a SD ADC will be digitally filtered and resampled yielding a new effective sampling rate f_{DR} which in turn yields a new Nyquist rate for the decimated signal of $f_{DR}/2$. Through careful selection the digital filter cutoff frequency, the majority of noise between $f_{DR}/2$ and f_s is removed while maintaining a nearly flat frequency response through f_{Max}. The SD oversampling rate $OSR = f_s/f_{DR}$, which is directly correlated to dynamic range, is one of several design parameters for a SD ADC. Most reputable vendors will provide a detailed specification sheet associated with their products, however, it is strongly recommended that one verifies aliasing rejection and noise floor characteristics as recommended above prior to employing any signal conditioning/digitizing system in the acquisition of critical field data.

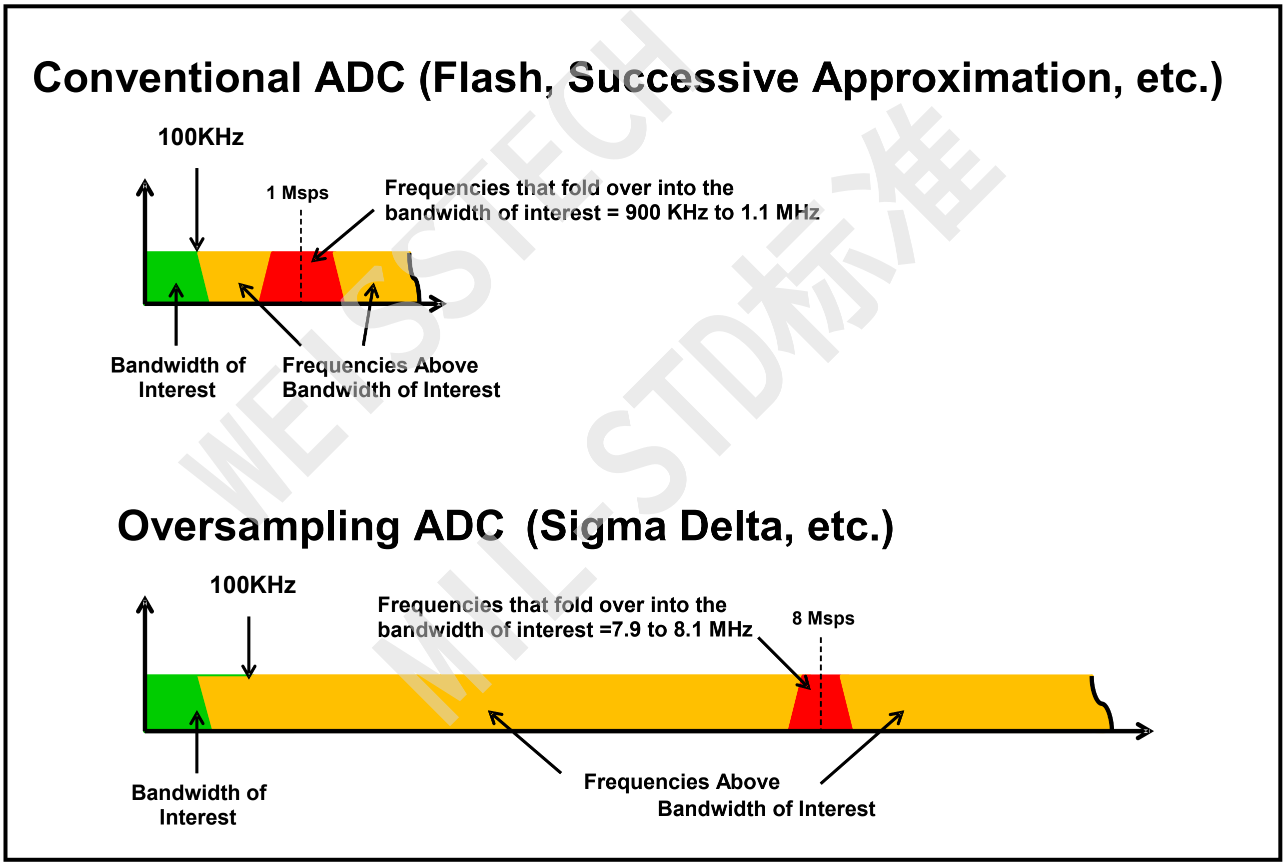

Figure 517.3-8. Illustration of sampling rates and out of band “fold over” frequencies for Conventional and Oversampling (Sigma-Delta) based data acquisition systems.

d. A noise gage is required for pyroshock measurements because it assists in the identification of anomalies in the data. The noise gage, or inert accelerometer may be purchased from most accelerometer manufacturers. Additionally, the noise gage may also be the same transducer as for other measurement channels and simply suspended near, but not on, the materiel.

2.3.3 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 (paragraph 6.1, reference a).

2.3.3.1 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 (reference energy) and E_n (new energy), 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:

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

In using 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. Paragraph 6.1, reference a, discusses conditions under which this scaling law may lead to over-prediction for $E_n > E_r$ or under-prediction when $E_n < E_r$.

2.3.3.2 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 (in meters) 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:

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

In using 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 517.3-9 from paragraph 6.1, reference a, displays the ratio of $\mathrm{SRS}(f_n|D_2)$ to $\mathrm{SRS}(f_n|D_1)$ 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 paragraph 6.1, reference a, before applying this scaling relationship.

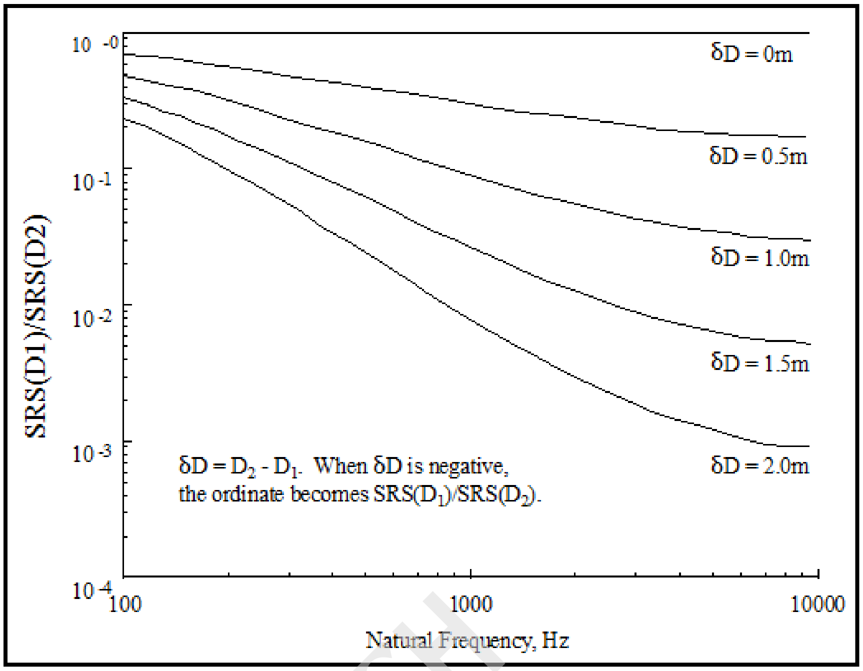

Figure 517.3-9. Empirical scaling relationship for shock response spectrum as a function of the distance from the pyrotechnic source.

2.3.3.3 Measured Data Available From Pyroshock.

a. If measured acceleration data are available, the acceleration data shall be validated prior to use. The best indicator of the acceleration data quality is its integral or velocity time history as in paragraph 6.1, references b and d, that shall reflect the physical test configuration that is, in general, zero before and after a pyroshock test. Anomalies in the velocity time history shall be investigated as per paragraph 6.1, references b and d, and their source documented. If the requirements of Paragraph 2.3.2 of this document, were not used to prevent aliasing contamination of the data, then exceptions to these criteria shall be documented and sufficiently justified to prove that digital aliasing of the data has not occurred. Additionally, if all components in the data acquisition system do not have linear phase-shift characteristics in the data passband, and do not have a passband uniform to within one dB across the frequency band of interest, exceptions to these criteria shall be documented and sufficiently justified to prove that data contamination have not occurred.

b. If measured data are available, the data may be processed using 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 paragraph 6.1, references b and d, 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. The frequency range over which the SRS is computed, (i.e., natural frequencies of the SDOF system filters) as a minimum, includes the data signal conditioning bandwidth, but should also extend below and above this bandwidth. In general, the "SRS Natural Frequency Bandwidth" extends from an octave below the lowest frequency of interest, up to a frequency at which the "flat" portion of the SRS spectrum has been reached (that may require going an octave or more above the upper signal conditioning bandwidth). This latter SRS upper frequency, $f_{SRS\ max}$, requirement helps ensure no high frequency content in the spectrum is neglected, and is independent of the data bandwidth upper frequency, f_{max}. As a minimum, this SRS upper frequency should exceed f_{max} by at least ten percent, i.e., $1.1 f_{max}$. The lowest frequency of interest is determined by the frequency response characteristics of the mounted materiel under test. Define f_1 as the first mounted natural frequency of the materiel (by definition, f_1 will be less than or equal to the first natural frequency of a materiel component such as a circuit board) and, for laboratory testing purposes, define the lowest frequency of interest as $f_{min} < f_1/2$ (i.e., f_{min} is at least one octave below f_1). $f_{SRS\ min}$ can then be taken as f_{min}. The maximax SRS is to be computed over the long time duration and over the frequency range from f_{min} to $f_{SRS\ max}$.$> 1.1\, f_{max}$. 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 B of Method 516.8 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 B of Method 516.8, and paragraph 6.1, reference l of this Method, references a and 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 uses a one-sided tolerance interval approach.

c. 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.

d. 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 for a duration, T_e, shall be collected 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, IV, and V, the form of shock test SRS may vary with axes. Use an SRS shaker shock replication method when using Procedure V; do not use classical shock pulse forms, e.g., half-sine, terminal-peak saw tooth, etc., in the testing.

2.3.3.4 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 517.3-10 from paragraph 6.1, reference m, provides SRS estimates for four typical aerospace application pyrotechnic point source devices. Figure 517.3-11 from paragraph 6.1, 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 517.3-10 with distance from the source. Information on Figures 517.3-10 and 517.3-11 come from paragraph 6.1, reference n. This reference also recommends the attenuation of the peak SRS across joints be taken to be 40 percent 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 517.3-12 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 paragraph 6.1, reference o. Either 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, Procedure III, or Procedure IV, cognizant of the information contained in paragraph 6.1, reference b. Generally, a test transient is deemed suitable if it's 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 percent of that of the normal pyroshock response transient duration (T_e). (See paragraph 4.2.2 for test tolerances.)

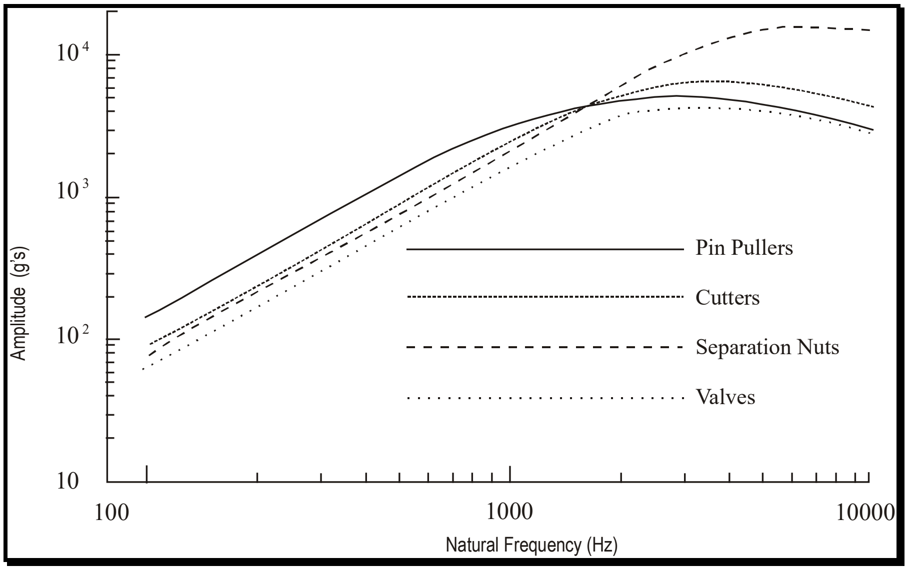

Figure 517.3-10. Shock response spectra for various point source pyrotechnic devices.

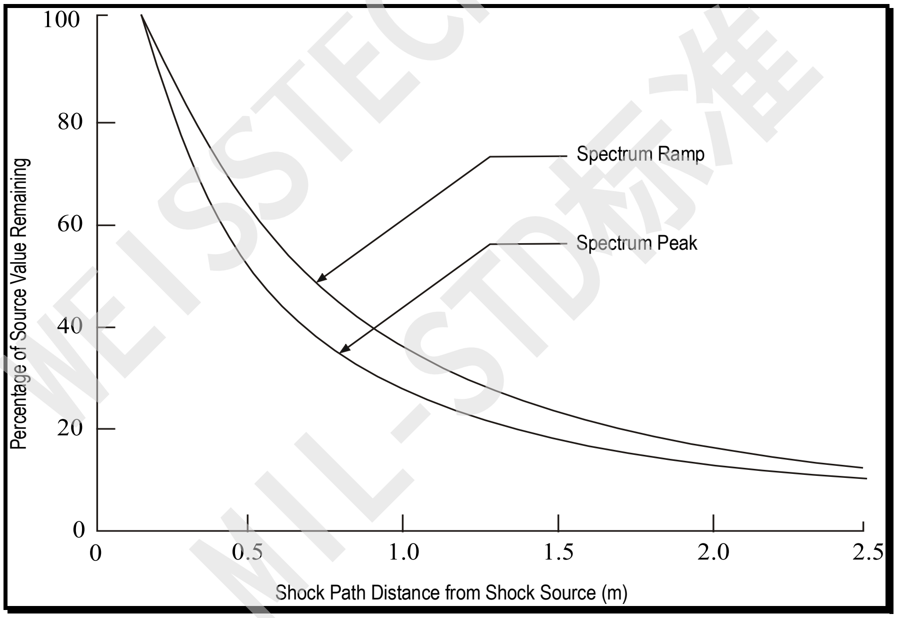

Figure 517.3-11. Shock response spectrum versus distance from pyrotechnic source.

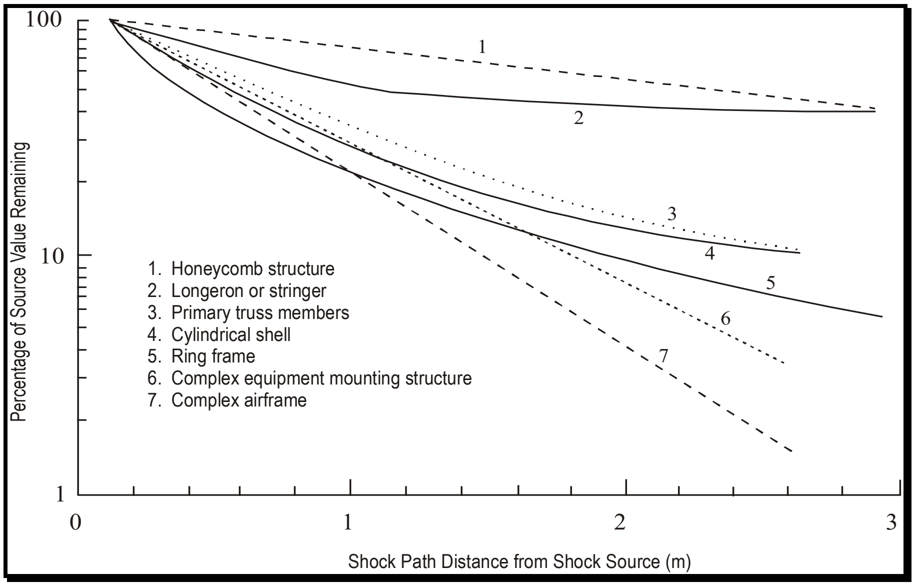

Figure 517.3-12. Peak pyroshock response versus distance from pyrotechnic source.

2.3.4 Test Axes, Duration, and Number of Shock Events.

2.3.4.1 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, Te 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 best indicator of the acceleration data quality is its integral or velocity time history as in paragraph 6.1, references b and d, that shall reflect the physical test configuration that is, in general, zero before and after a pyroshock test. Anomalies in the velocity time history shall be investigated as per paragraph 6.1, references b and d, and their source(s) documented. If the requirements of Paragraph 2.3.2 of this document, i.e. an anti-aliasing filter with attenuation as shown in Figure 517.3-7.were not used to prevent aliasing contamination of the data, then exceptions to these criteria shall be documented and sufficiently justified to prove that digital aliasing of the data has not occurred. Additionally, all components in the data acquisition system shall have linear phase-shift characteristics in the data passband, and shall have a passband uniform to within one dB across the frequency band of interest. 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.

There is a general convention in the evaluation of the pyroshock specifications that a specification with a velocity change of 50 ips or less is mild enough that testing is not required. However, specific programs may require testing for specifications of 50 ips or less if there are components that may be sensitive to even these low velocity changes.

2.3.4.2 Procedure I - Near-field with an Actual Configuration.

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. The objective of the test is to test the physical and functional integrity of the materiel under pyroshock in the near-field of the pyrotechnic device.

2.3.4.3 Procedure II - Near-field with a Simulated Configuration.

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 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 one test shock will satisfy the requirements for all directions of all three orthogonal axes. At the other extreme, a total of three 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 materiel under pyroshock in the near-field of the pyrotechnic device.

2.3.4.4 Procedure III - Mid-field with a Mechanical Test Device.

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 mid-field of the pyrotechnic device.

2.3.4.5 Procedure IV - Far-field with a Mechanical Test Device.

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 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.

2.3.4.6 Procedure V - Far-field with an Electrodynamic Shaker.

For Procedure V, 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 adequately conduct a pyroshock test.

a. General. Information listed in Part One, paragraphs 5.7 and 5.9, and Part One, Annex 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, IV, or V is used, or the size and distribution of the pyrotechnic charge if Procedure I or II is used.

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

c. Tailoring. Necessary variations in the basic test procedures to accommodate LCEP requirements and/or facility limitations.

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, Annex A, Tasks 405 and 406 of this Standard.

b. Specific to this Method.

(1) A means of assessing any damage to fixture/materiel configurations before continuing the tests. 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.

(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.

3.3 Post-Test.

The following post test data shall be included in the test report:

a. General. Information listed in Part One, paragraph 5.13; and in Annex A, Task 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.

(5) Any deviations from the original test plan.

4. TEST PROCESS.

4.1 Test Facility

Pyroshock can be applied using 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 Procedures III and IV, paragraph 6.1, reference b, 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 mid-field of the pyrotechnic device. Consult paragraph 6.1, reference b, for guidelines and consideration for such testing. For Procedures IV and V, 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 definition of the far-field as well as the limitations of the electrodynamic shaker in addition to the acceleration amplitude limitations. 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 Procedures I and II, the mechanical exciter and the fixturing configuration in Procedure III, and the mechanical exciter and electrodynamic shaker and the fixturing configuration in Procedures IV and V.

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 is necessary to attach a calibration load, and obtain measured data under test conditions to be compared with the desired test response. Exercise caution so that the pre-test shocks do not degrade the resonating plate configuration. Calibration is crucial for Procedures III and IV. Before the test item is attached to the shock apparatus, it is necessary to attach a calibration load and obtain measured data under test conditions to be compared with the desired test response. For Procedure V, using 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, attach a calibration load, and obtain measured data under test conditions to be compared with the desired test response. Additional tolerances and calibration procedures are provided in Part One, paragraphs 5.2 and 5.3.2, respectively.

4.2.2 Tolerances.

The following are guidelines for test tolerances for pyroshock for the five 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" (paragraph 6.1, reference e), a tolerance may be specified in terms of an average of the measurements within a "zone." 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 tolerances and calibration procedures are provided in Part One, paragraphs 5.2 and 5.3.2, respectively.

4.2.2.1 Procedure I - Near-field with an Actual Configuration and Procedure II - Near-field with a Simulated Configuration.

If prior measured data are available, or a series of pyroshocks are performed, all acceleration maximax SRS shall be computed at the center frequency of one-twelfth octave bands. The individual SRS values (points) are to be within - 3 dB to + 6 dB for a minimum of 80 percent of the SRS values in the bandwidth from 100 Hz to 20 kHz. For the remaining 20 percent of the SRS values in the frequency band, the individual SRS values are to be from - 6 dB to + 9 dB. Ensure at least 50 percent of the individual SRS values exceed the nominal test specification.

4.2.2.2 Procedure III- Mid-field with a Mechanical Test Device.

If prior measured data are available, or a series of pyroshocks are performed, all acceleration maximax SRS shall be computed at the center frequency of one-twelfth octave bands. The individual SRS values (points) are to be within - 3 dB to + 6 dB for a minimum of 90 percent of the SRS values in the bandwidth from 100 Hz to 20 kHz. For the remaining 10 percent of the SRS values in the frequency band, the individual SRS values are to be from - 6 dB to + 9 dB. Ensure at least 50 percent of the individual SRS values exceed the nominal test specification.

4.2.2.3 Procedure IV - Far-field with a Mechanical Test Device.

If prior measured data are available, or a series of pyroshocks are performed, all acceleration maximax SRS shall be computed at the center frequency of one-twelfth octave bands. The individual SRS values (points) are to be within - 3 dB to + 6 dB for a minimum of 90 percent of the SRS values in the bandwidth from 100 Hz to 20 kHz. For the remaining 10 percent of the SRS values in the frequency band, the individual SRS values are to be from - 6 dB to + 9 dB. Ensure at least 50 percent of the individual SRS values exceed the nominal test specification.

4.2.2.4 Procedure V - Far-field with an Electrodynamic Shaker.

If prior measured data are available, or a series of pyroshocks are performed, all acceleration maximax SRS shall be computed at the center frequency of one-twelfth octave bands. The individual SRS values (points) are to be within - 1.5 dB to +3 dB for a minimum of 90 percent of the SRS values in the bandwidth from 10 Hz to 3 kHz. For the remaining 10 percent of the SRS values in the frequency band, the individual SRS values are to be from - 3 dB to + 6 dB. Ensure at least 50 percent of the individual SRS values exceed the nominal test specification.

4.2.3 Instrumentation.

In general, acceleration will be the quantity measured to meet a specification, with care taken to ensure acceleration measurements can be made that provide meaningful data (paragraph 6.1, references b and d). 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 Doppler vibrometer. In these cases, give special consideration to the measurement instrument amplitude and frequency range specifications in order to satisfy the calibration, measurement and analysis requirements. With regard to measurement technology, accelerometers, strain gages and laser Doppler vibrometers are commonly used devices for measurement. In processing pyroshock data, it is important to be able to detect anomalies. For example, it is well documented that accelerometers may offset or zeroshift during mechanical shock, pyroshock, and ballistic shock (paragraph 6.1, references a, b, t andu). Additional discussion on this topic is found in the ballistic shock method. 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. In addition, instrumentation to measure test item function may be required. In this case, obtain suitable calibration standards and adhere to them. Transducer performance continues to improve with time, however, inventories across all laboratories may not be of the latest generation, and thereby making detailed calibrations critical in understanding individual transducer performance.

a. Accelerometers. Ensure the following:

(1) Amplitude Linearity: It is desired to have amplitude linearity within 10 percent over the entire operating range of the device. Since accelerometers (mechanically isolated or not) may also show zeroshift (paragraph 6.1, references a, b, t and u), there is risk in not characterizing these devices over their entire amplitude range. To address these possible zeroshifts, high pass filtering (or other data correction technique) may be required. Such additional post-test correction techniques increase the risk of distorting the measured pyroshock environment. Consider the following in transducer selection:

(a) It is recognized that accelerometers may have both non-linear amplification and non-linear frequency content below 10,000 Hz (paragraph 6.1, references a, b, t and u). In order to understand the non-linear amplification and frequency characteristics, it is recommended that shock linearity evaluations be conducted at intervals of 20 to 30 percent of the rated amplitude range (inclusive of the maximum rated range) of the accelerometer to identify the actual amplitude and frequency linearity characteristics and useable amplitude and frequency range. Additionally, the shock pulse duration for the evaluations is calculated as:

$$T_D = \frac{1}{2 f_{\max}}$$

Where T_D is the duration (baseline) of the acceleration pulse and f_{max} is the maximum specified frequency range for the accelerometer. For Near-field pyroshock f_{max} is 100,000 Hz. For Mid-field and

Far-field pyroshock f_{max} is 10,000 Hz. If Hopkinson bar testing is used for these evaluations then care must be taken to make sure that a non-dispersive pulse duration is used (paragraph 6.1, reference 5). In absence of techniques for addressing 100,000 Hz characterizations and considering durations limitations associated with non-dispersive reference requirements, a Hopkinson bar (0.75 inch diameter) may be used with a 20 microsecond reference pulse duration, T_D. The roll-off in frequency response of this greater than nominal duration reference must be considered in evaluating linearity. The requirements for shock amplitude and duration are subject to the usual shock tolerance requirements of $\pm$ 15%. In addition, it is recognized that the lower limit for Hopkinson bar testing is usually 5,000 g. Therefore, in order to span the full accelerometer range as defined above, it may be necessary to use more than one calibration apparatus, i.e. a drop ball calibrator as well as a Hopkinson bar.

(b) For cases in which response below 2 Hz is desired, a piezoresistive accelerometer measurement is required.

(2) Frequency Response: A flat response within ± 5 percent across the frequency range of interest is required. Since it is generally not practical or cost effective to conduct a series of varying pulse width shock tests to characterize frequency response, a vibration calibration is typically employed. For the case of a high range accelerometer (200,000 g) with low output, there may be SNR issues associated with a low level vibration calibration. In such cases a degree of engineering judgment will be required in the evaluation of frequency response with a revised requirement for flat frequency response to be within ± 1 dB across the frequency range of interest. .

(3) Accelerometer Sensitivity: The sensitivity of a shock accelerometer is expected to have some variance over its large amplitude dynamic range.

(a) If the sensitivity is based upon the low amplitude vibration calibration, it is critical that the linearity characteristics of the shock based "Amplitude Linearity" be understood such that an amplitude measurement uncertainty is clearly defined.

(b) Ideally, vibration calibration and shock amplitude linearity results should agree within 10 percent over the amplitude range of interest for a given test.

(4) Transverse sensitivity should be less than or equal to 7 percent.

(5) The measurement device and its mounting will be compatible with the requirements and guidelines provided in paragraph 6.1, reference a.

(6) Unless it is clearly demonstrated that a piezoelectric accelerometer (mechanically isolated or not) can meet the pyroshock requirements and is designed for oscillatory shock (not one-sided shock pulses), recommend piezoresistive accelerometers be used for high intensity, near-field pyroshock events. Piezoresistive or piezoelectric accelerometers may be used in scenarios in which levels are known to be within the established (verified through calibration) operating range of the transducer (mid-field and far-field), thereby avoiding non-linear amplification and frequency content.

b. Other Measurement Devices. Ensure any other measurement devices used to collect data are demonstrated to be consistent with the requirements of the test, in particular, the calibration and tolerance information provided in paragraph 4.2.

c. Signal conditioning. Use signal conditioning compatible with the instrumentation requirements on the materiel. In particular, filtering will be consistent with the response time history and frequency content requirements. Use signal conditioning compatible with the requirements and guidelines provided in paragraph 6.1, references b and d. 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 an analog, linear phase shift filter over the frequency range of interest. Use an analog anti-alias filter configuration, other signal conditioning, and the data acquisition system that:

(1) Meets aliasing requirements in Figure 517.3-7.

(2) Has phase linearity to within +/- 5° in the data passband.

(3) Has a passband uniform to within one dB across the frequency band of interest.

(4) Has unit step response with less than 10% (1 dB) overshoot.

d. Additional Pyroshock Requirements. Additional requirements are necessary for pyroshock measurement, especially near-field and mid-field pyroshock. The requirements of Paragraph 2.3.2 of this document must be used to prevent aliasing contamination of the data. Slew rate specifications are also important because slew rate contamination can alter the low frequency content of the data, and become part of an erroneous specification as per Appendix A of this document. To prevent distortion caused by spurious electrical noise, the data recording instrumentation shall be capable of recording a signal of one half full scale voltage in 1 microsecond without slew rate distortion. For example, if a system is capable of ± 10 volts full scale = 20 volt peak-to-peak, then a slew rate of 10 volt/μsecond is required. Exceptions to these criteria shall be documented and sufficiently justified to prove that aliasing and other contamination of the data has not occurred.

4.2.4 Data Analysis.

a. Analyze pyroshock data for the extended bandwidth of 10 Hz to 100,000 kHz to examine the low frequencies for data contamination, and to ensure the high frequency content has been captured.

b. For digital filters used to meet the previous requirement, use a filter with linear phase-shift characteristics and a pass band flatness within one dB across the frequency range specified for the accelerometer (see paragraph 4.2.3).

c. Ensure the analysis procedures are in accordance with those requirements and guidelines provided in paragraph 6.1, references b and d. In particular, validate the pyroshock acceleration amplitude time histories according to the procedures in paragraph 6.1, reference d. Integrate each amplitude time history to detect any anomalies in the measurement system, e.g., cable breakage, slew rate of amplifier exceeded, data clipped, unexplained accelerometer offset, etc. Compare the integrated amplitude time histories against criteria given in paragraph 6.1, references b and d, and Annex A of this Method. For all Procedures to detect emission from extraneous sources, e.g., EMI, configure an accelerometer as a noise gage (without acceleration sensing element or just another accelerometer that is not attached to the unit under test) and process its response in the same manner as for the other accelerometer measurements. If this noise gage exhibits any characteristic other than very low level noise, consider the acceleration measurements to be contaminated by an unknown noise source in accordance with the guidance in paragraph 6.1, references b and d.

4.3 Test Interruption.

Test interruptions can result from two or more situations, one being from failure or malfunction of test equipment. The second type of test interruption results from failure or malfunction of the test item itself during operational checks.

4.3.1 Interruption Due To Laboratory Equipment Malfunction.

a. If the test excitation fails to function, refer to local SOPs.

b. 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.

4.3.2 Interruption Due To Test Item Operation Failure.

Failure of the test item(s) to function as required during operational checks presents a situation with two possible options. These decisions are made on a case by case basis, with test item cost and schedule considerations, as well as overall materiel cost and schedule requirements.

a. The preferable option is to replace the test item with a "new" one and restart from Step 1.

b. A second option is to replace / repair the failed or non-functioning component or assembly with one that functions as intended, and restart the entire test from Step 1.

NOTE: When evaluating failure interruptions, consider prior testing on the same test item and consequences of such.

4.4 Test Execution.

4.4.1 Preparation for Test.

4.4.1.1 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 Procedures II through V from previously processed data if available, otherwise use the calibration levels.

c. Ensure the pyroshock signal conditioning and recording devices have adequate amplitude range and frequency bandwidth as per paragraph 4.2.3. It may be difficult to estimate a peak signal and, therefore, the amplitude range for the instrumentation. 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.

d. A noise gage is required for pyroshock measurements. The noise gage or inert accelerometer may be purchased from most accelerometer manufacturers. Additionally, the noise gage may also be the same transducer as for other measurement channels, and simply suspended near, but not on, the structure. In either case, ensure the noise accelerometer has the same signal conditioning as the other accelerometer channels.

4.4.1.2 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 Step 7. 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).

4.4.2 Test Procedures.

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

4.4.2.1 Procedure I - Near-field with an Actual Configuration.

Step 1 Following the guidance of paragraph 6.1, reference b, select the 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 this Method.

Step 2 Subject the test item (in its operational mode) to the test transient by way of the pyrotechnic test device.

Step 3 Record necessary data that show the shock transients, when processed with the SRS algorithm, are within specified tolerances.

Step 4 Perform an operational check of the test item. Record performance data. If the test item fails to operate as intended, follow the guidance in paragraph 4.3 for test item failure.

Step 5 If the integrity of the test configuration can be preserved during test, repeat Steps 2, 3, and 4 a minimum of three times for statistical confidence. Otherwise proceed to Step 6.

Step 6 Document the test series, and see paragraph 5 for analysis of results.

4.4.2.2 Procedure II - Near-field with Simulated Configuration.

Step 1 Following the guidance in this Method, select test conditions and calibrate the shock apparatus as follows:

a. Select accelerometers and analysis techniques that meet the criteria outlined in this Method.

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

Step 3 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 photographs 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 4 Conduct an operational check of the test item. Record performance data. If the test item fails to operate as intended, follow the guidance in paragraph 4.3.2 for test item failure.

Step 5 Repeat Steps 1 through 4 for each orthogonal axis that is to be tested unless the test shock meets the test specification in more than one axis at a time. Repeat steps 1 through 4 as necessary to demonstrate the test specification has been met in all three axes.

Step 6 Document the test series, and see paragraph 5 for analysis of results.

4.4.2.3 Procedure III - Mid-field Using Mechanical Test Device.

Step 1 Following the guidance of this Method, select test conditions and calibrate the shock apparatus as follows:

a. Select accelerometers and analysis techniques that meet the criteria outlined in this Method.

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 axis.

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

Step 2 Subject the test item (in its operational mode) to the test pyroshock.

Step 3 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 4 Conduct an operational check of the test item. Record performance data. If the test item fails to operate as intended, follow the guidance in paragraph 4.3.2 for test item failure.

Step 5 Repeat Steps 1 through 5 for each orthogonal axis that is to be tested unless the test shock meets the test specification in more than one axis at a time. Repeat steps 1 through 5 as necessary to demonstrate the test specification has been met in all three axes.

Step 6 Document the tests, and see paragraph 5 for analysis of results.

4.4.2.4 Procedure IV - Far-field Using Mechanical Test Device.

Step 1 Following the guidance of this Method, select test conditions and calibrate the shock apparatus as follows:

a. Select accelerometers and analysis techniques that meet the criteria outlined in paragraph 6.1, reference d.

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

Step 3 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. If they do not, either replace the shock isolation or redesign it.

Step 4 Conduct an operational check of the test item. Record performance data. If the test item fails to operate as intended, follow the guidance in paragraph 4.3.2 for test item failure.

Step 5 Repeat Steps 1 through 4 for each orthogonal axis that is to be tested unless the test shock meets the test specification in more than one axis at a time. Repeat steps 1 through 4 as necessary to demonstrate the test specification has been met in all three axes.

Step 6 Document the tests, and see paragraph 5 for analysis of results.

4.4.2.5 Procedure V - Far-field Using Electrodynamic Shaker.

Step 1 Following the guidance of this Method, select test conditions and calibrate the shock apparatus as follows:

a. Select accelerometers and analysis techniques that meet the criteria outlined in paragraph 6.1, reference d.

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. If not within tolerances, determine the problem and correct it as necessary.

e. Remove the calibration load and install the actual test item on the electrodynamic shaker, paying close attention to mounting details.

Step 2 Subject the test item (in its operational mode) to the test electrodynamic pyroshock simulation.

Step 3 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 4 Conduct an operational check on the test item. Record performance data. If the test item fails to operate as intended, follow the guidance in paragraph 4.3.2 for test item failure.

Step 5 Repeat Steps 1 through 4 for each orthogonal axis that is to be tested unless the test shock meets the test specification in more than one axis at a time. Repeat steps 1 through 4 as necessary to demonstrate the test specification has been met in all three axes.

Step 6 Document the tests, and see paragraph 5 for analysis of results.

5. ANALYSIS OF RESULTS.

In addition to the guidance provided in Part One, paragraphs 5.14 and 5.17; and Part One, Annex A, Task 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. Once the source of the failure is identified, re-testing is required.

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. Once the source of the failure is identified, re-testing is required.

5.3 Procedure III - Mid-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 516.8.

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. Once the source of the failure is identified, re-testing is required.

5.4 Procedure IV - 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 516.8. 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. Once the source of the failure is identified, re-testing is required.

5.5 Procedure V - 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 516.8. 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. Once the source of the failure is identified, re-testing is required.

6. REFERENCE/RELATED DOCUMENTS.

6.1 Referenced Documents.

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6.2 Related Documents.

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(Copies of Department of Defense Specifications, Standards, and Handbooks, and International Standardization Agreements are available online at https://assist.dla.mil.

Requests for other defense-related technical publications may be directed to the Defense Technical Information Center (DTIC), ATTN: DTIC-BR, Suite 0944, 8725 John J. Kingman Road, Fort Belvoir VA 22060-6218, 1-800-225-3842 (Assistance--selection 3, option 2), http://www.dtic.mil/dtic/; and the National Technical Information Service (NTIS), Springfield VA 22161, 1-800-553-NTIS (6847), http://www.ntis.gov/.

METHOD 517.3, ANNEX A

GUIDELINES FOR ADDITIONAL PYROSHOCK TIME HISTORY VALIDATION AND PROCESSING

1. INTRODUCTION.

This Annex provides additional guidelines for pyroshock time history assessment including validation, i.e., to detect any measurement system anomalies that would invalidate the measurement. For massive field shock measurement programs where time and budget constraints do not allow validation of individual pyroshocks, at least one pyroshock time history from the near-field, mid-field, and far-field must be individually validated, and careful examination of the time history for each subsequent shock from the measurement channel be examined for gross anomalies. Consistency relative to the test specification for processed information is acceptable as long as any inconsistency is investigated under pyroshock time history validation. The best indicator of pyroshock accelerometer data quality is the integral or velocity time history. As the examples below show, many anomalies in the accelerometer data cannot be detected from the acceleration plot or the shock response spectrum (SRS), especially if the SRS is only plotted down to 100 Hz.

The sources of pyroshock data contamination have been known for some time (more than 20 years): electromagnetic noise (or other noise sources), digital aliasing, and offsets in the data. Electromagnetic noise is always a potential problem with pyroshock testing, especially when explosives are detonated. The high frequency electromagnetic pulse can be eliminated in some cases, but in many cases, the electromagnetic pulse creates an additional environment that can cause invalid data contaminated by the inadequate response to the pulse by the signal conditioner and/or data acquisition system (DAS). The cause of digital data aliasing is, but not limited to, inadequate analog filtering prior to digitization and inadequate bandwidth of the DAS. Offsets in the acceleration data are generally caused by accelerometer malfunction and, in some cases, DAS problems such as inadequate slew rate capability as shown below.

2. ALIASED DATA.

The data shown in Figure 517.3A-1 are a complex shock that starts with a near-field pyroshock followed by two mechanical shock events as shown in paragraph 6.1, reference r. The accelerometer used to measure these data is a piezoresistive type. These data were sampled at 25,000 Hz, and taken with a data acquisition system (DAS) that has an “anti-aliasing Bessel filter” that is - 3 dB at a 20,000 Hz cutoff frequency, as per manufacturer’s specifications. This specification means that the filter attenuation is only 80 dB down in a decade (200,000 Hz), and that the data are severely aliased. For example, the sample rate of 25,000 Hz gives a Nyquist frequency (highest frequency that can be resolved at the given sample rate) of 12,500 Hz. Consequently, the anti-aliasing filter provides no protection at all at this sample rate, or even at the higher sample rates of up to 100,000 Hz. The recommended practice for pyroshock data is an anti-aliasing filter that is 60 dB/octave, and the cutoff frequency should be at least one octave below the Nyquist frequency as per paragraph 6.1, references b, d, and f. The requirements of Paragraph 2.3.2 of this document are an equivalent way to achieve the same aliasing protection with more flexibility in other data parameters. Additionally, the recommended practice is to sample at least ten times higher than the desired bandwidth of the measurement in order to achieve 5% or less amplitude error as per paragraph 6.1, references b, d, and f.

The integral of the data shown in Figure 517.3A-1 is in Figure 517.3A-2. The velocity should start and end at zero because the materiel on which the data were taken starts in a stationary position, and is in that same position at the end of the complex shock. However, the velocity time history clearly shows the characteristics of aliasing as per paragraph 6.1, reference p.

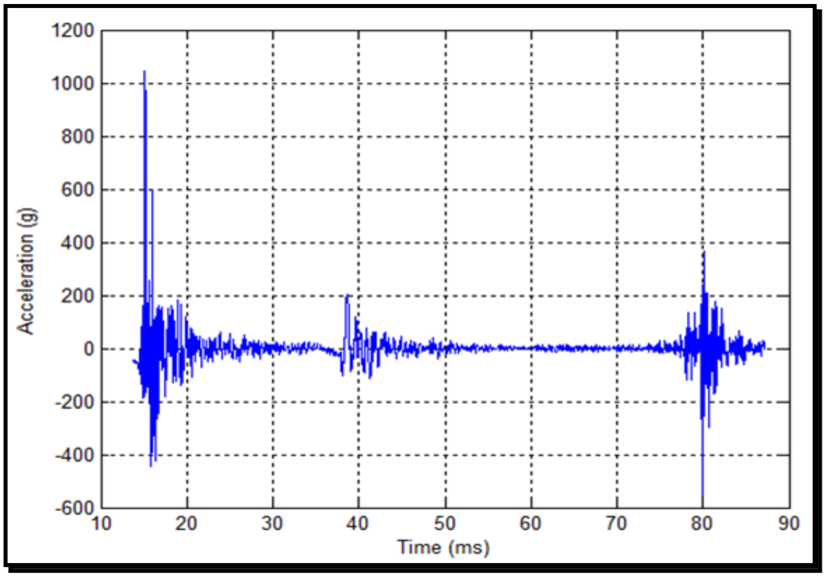

Figure 517.3A-1. A near-field pyroshock followed by two mechanical shock events.

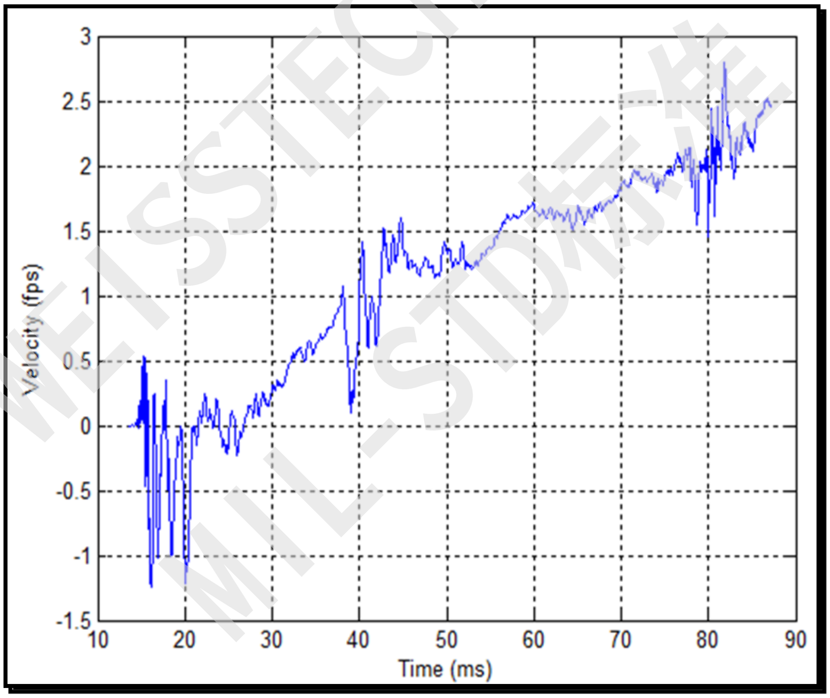

Figure 517.3A-2. The integral of the acceleration data in Figure 517.3A-1.

The discrete Fourier transform in Figure 517.3A-3 shows additional verification of the aliasing problem. An anti-aliasing filter with 60 dB/octave attenuation has 10 decade/decade slope on a log-log plot. Clearly the discrete Fourier transform in Figure 517.3A-3 does not have this attenuation and even starts to increase as it approaches the Nyquist frequency, an additional indication of aliasing. The positive and negative shock response spectra (SRS) are shown in Figure 517.3A-4.

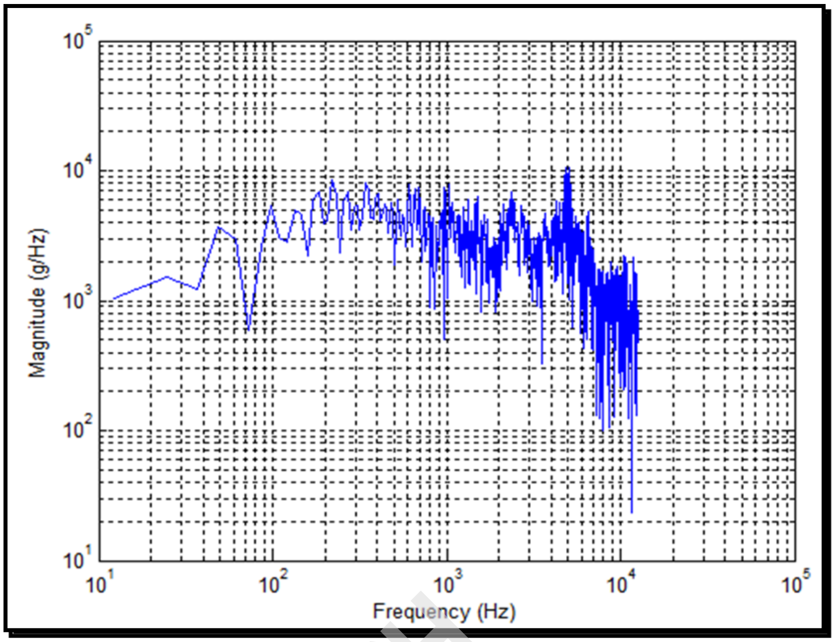

Figure 517.3A-3. Discrete Fourier transform of the data in Figure 517.3A-1.

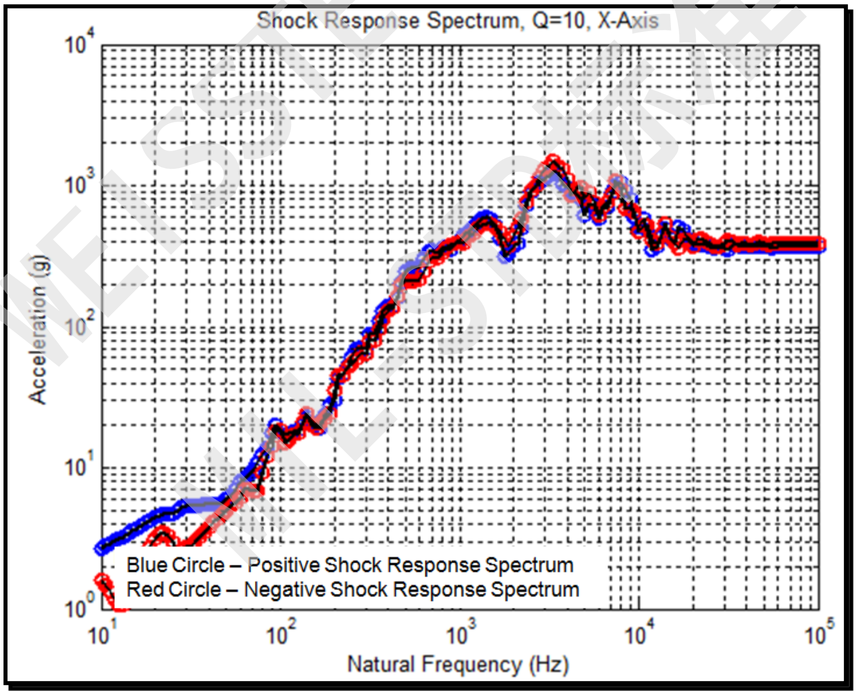

Figure 517.3A-4. The shock response spectra of the acceleration data in Figure 517.3A-1 (Q=10).

These two SRS are plausible, especially if the SRS is not plotted below 100 Hz. Additionally, the positive and negative SRS show agreement that indicates good pyroshock data. In summary, the problems with these data are: inadequate sample rate, inadequate anti-aliasing filter, and inadequate zero time before and after the complex shock. The problems can be assessed by an inspection of the accelerometer and DAS specifications. However, these are problems that cannot be detected by examination of the acceleration time history and the SRS alone and emphasize the importance of integrating the acceleration time history as per paragraph 6.1, references b and d.

3. SLEW RATE CONTAMINATED DATA.

These near-field data were recorded at a government facility that routinely conducts pyroshock testing. Triaxial accelerometer data were recorded during the firing of explosives located on a steel plate, but only the in-axis accelerometer data (data sensing the strongest response) are discussed and analyzed as per paragraph 6.1, references q and s. The raw in-axis accelerometer data are shown in Figure 517.3A-5 and appear to have the general characteristics of near-field pyroshock data. The data are very symmetrical visually. The integral of the accelerometer data is shown in Figure 517.3A-6 and indicates a velocity change that is inconsistent (and therefore erroneous) with a pyrotechnic test that has a zero velocity change.

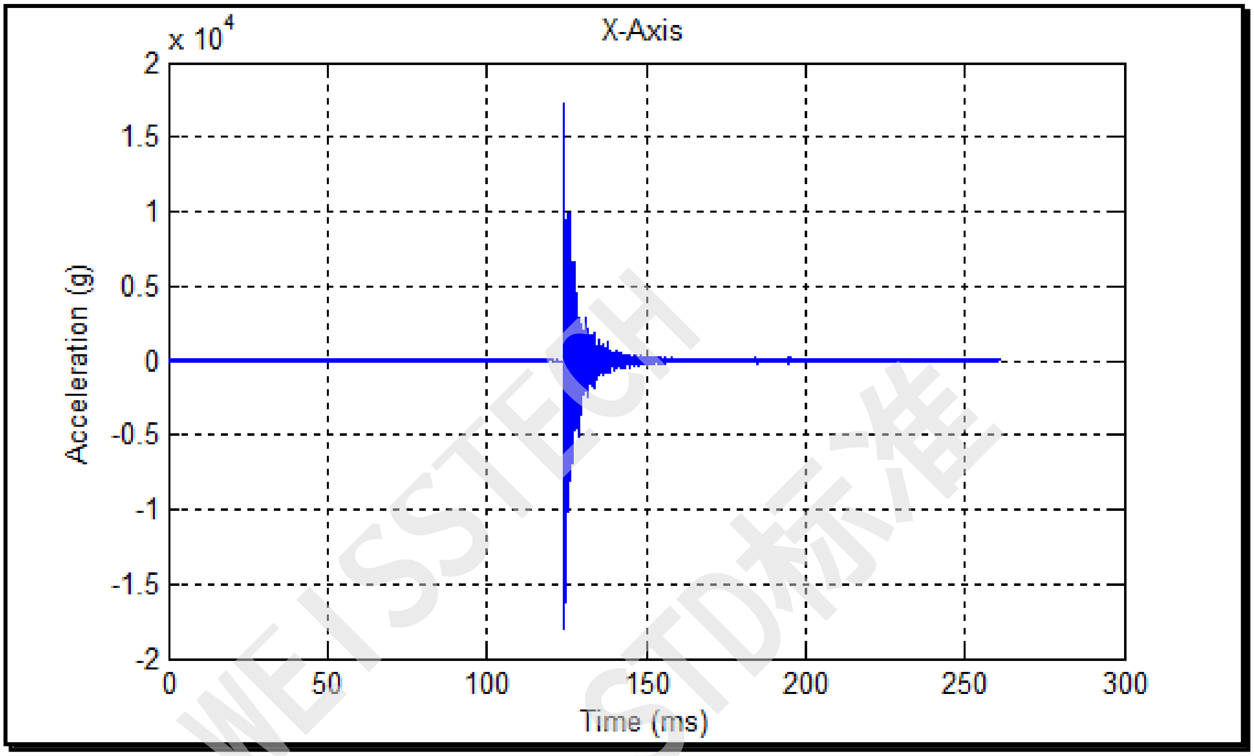

Figure 517.3A-5. A near-field pyroshock acceleration time history.

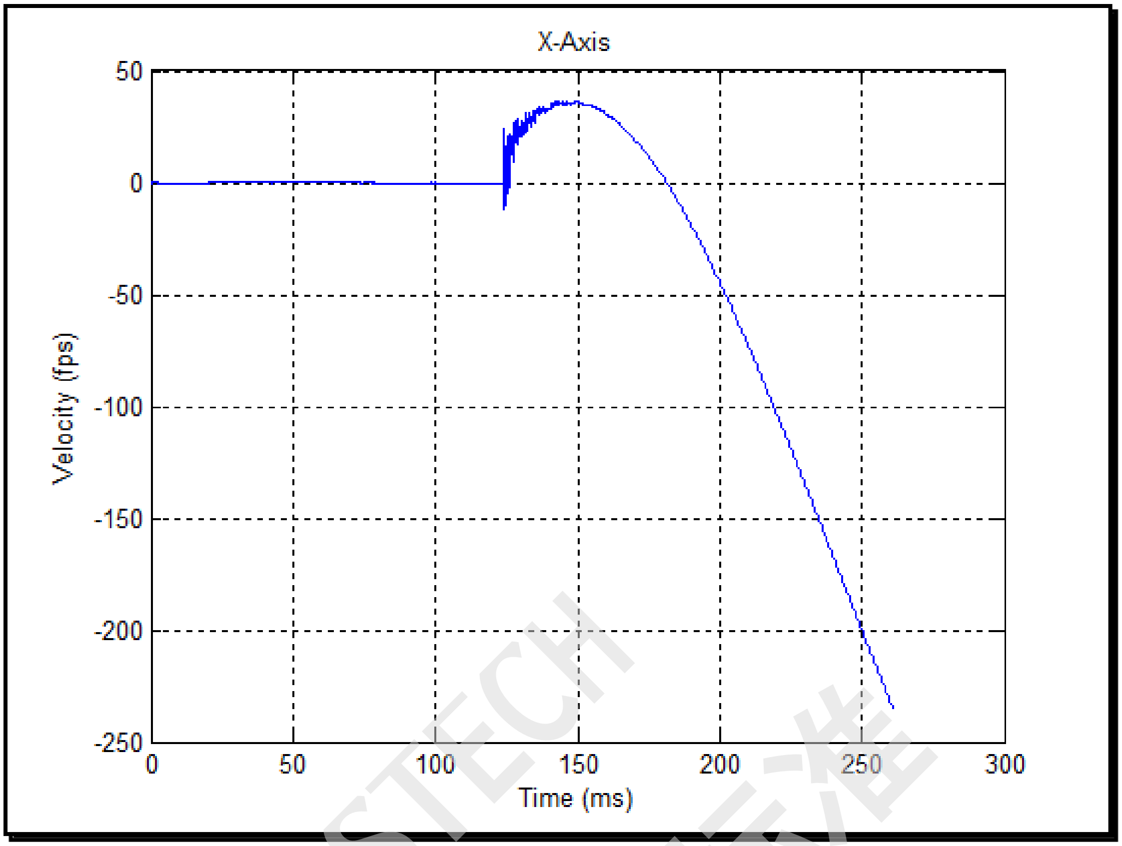

Figure 517.3A-6. The integral of the acceleration data in Figure 517.3A-5.

There is significant frequency content above 10,000 Hz at magnitudes above 10,000 g as evidenced by the discrete Fourier transform (DFT) in Figure 517.3A-7 and the shock response spectrum (SRS) in Figure 517.3A-8. The data were taken with hardware frequently used for pyroshock: a piezoelectric (PE) accelerometer with an internal mechanical low-pass filter and an internal electrical low-pass filter, a signal conditioner with 20,000 Hz cutoff frequency, a 4-pole Butterworth, low-pass “anti-aliasing” filter, and a data acquisition system (DAS) with sigma-delta architecture. Both the accelerometer and the signal conditioner are manufactured by the same company, and the DAS is manufactured by a second company. It is clear from DAS specifications that the anti-aliasing is inadequate, Figure 517.3A-7 shows that the roll-off of the data is not 60 dB/octave or 10 decade/decade slope on a log-log plot as per paragraph 6.1, references b, d, and f and indicates that aliasing is possible. In this case, the problems with the SRS start substantially above 100 Hz as shown in Figure 517.3A-8. A wavelet analysis was performed on these data as per paragraph 6.1, reference q, and the erroneous part of the data removed with this analysis is shown in Figure 517.3A-9 that has a magnitude of +800/-500 g or about 4% of the amplitude in Figure 517.3A-5 and has a highly oscillatory time history that is the response to the combined environment of pyroshock acceleration and noise by either the signal conditioner, the associated DAS, or both. The two characteristics of slew-rate problems are present in Figure 517.3A-9: low-frequency modulation (800 Hz as shown in the SRS) and an offset. A direct comparison of the two SRS for Figure 517.3A-5 and Figure 517.3A-9 is made in Figure 517.3A-10, and the curves directly overlay each other up to a frequency of 800 Hz, depicting the low-frequency contamination. Also, Figure 517.3A-12 shows that the upper-frequency limit of the wavelet correction is 800 Hz and does not change the high-frequency content above 800 Hz that is crucial to creating an accurate pyroshock specification from the SRS. What was assumed to be a structural response in the original SRS of Figure 517.3A-8 is now revealed as a DAS slew rate limitation.

SRS comparison of the erroneous data and the original data are in Figure 517.3A-10 and show the contaminated data are the cause for the erroneous SRS in Figure 517.3A-8. The contamination occurs at a frequency of 800 Hz and below. However, if just the high frequency positive and negative shock response spectra are examined, then the data looks reasonable. Figure 517.3A-11 has an SRS calculated with the corrected acceleration time history, and the results are consistent with near-field pyroshock. The SRS in Figure 517.3A-11 can now be used to create a specification with a high degree of confidence because the low-frequency asymptote is correct and the high-frequency content has been preserved. The positive and negative SRS in Figure 517.3A-11 show good agreement typical of a pyroshock or a pyroshock simulation. More details concerning the data analysis are in paragraph 6.1, reference q.

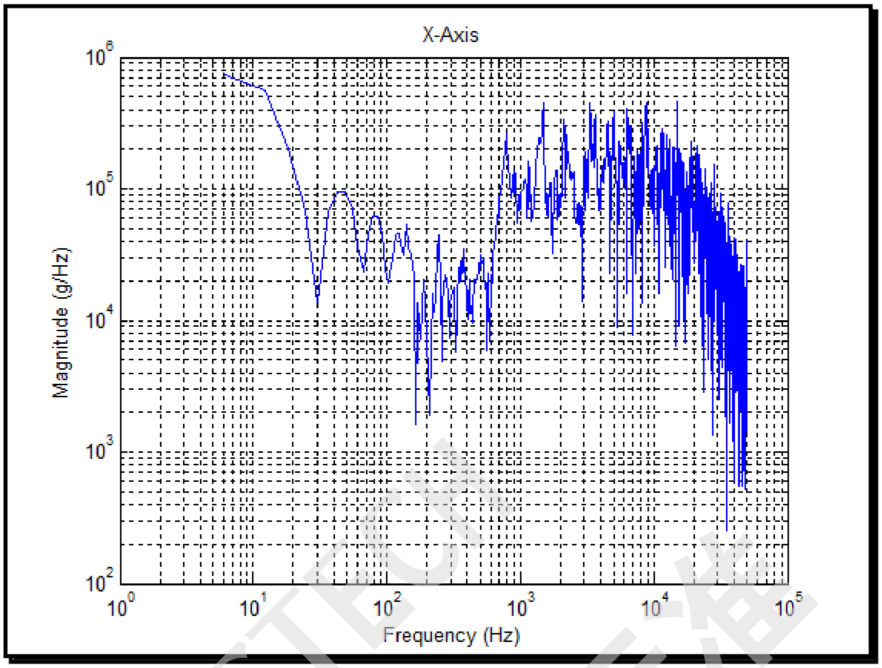

Figure 517.3A-7. Discrete Fourier transform of the data in Figure 517.3A-5.

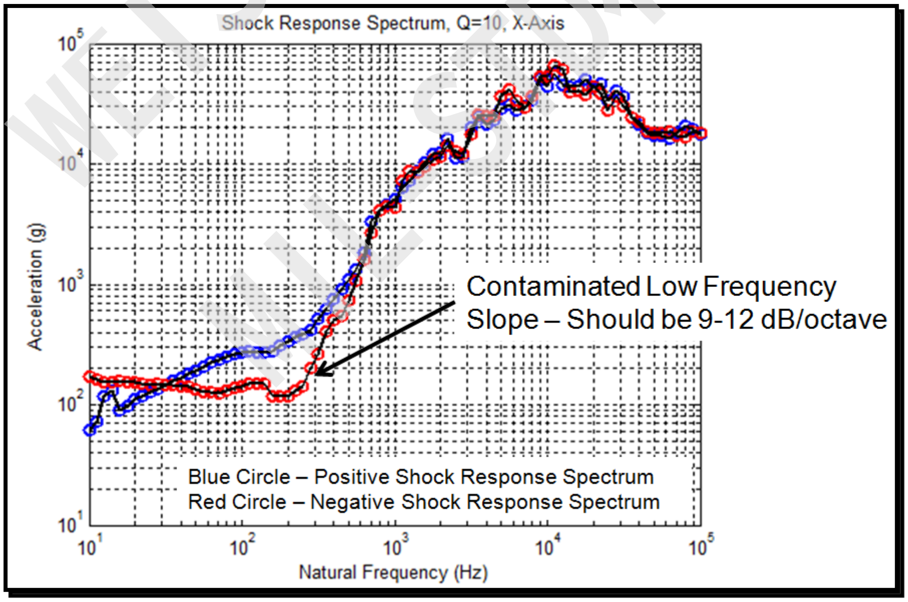

Figure 517.3A-8. Shock response spectrum of the acceleration time history in Figure 517.3A-5 (Q=10).

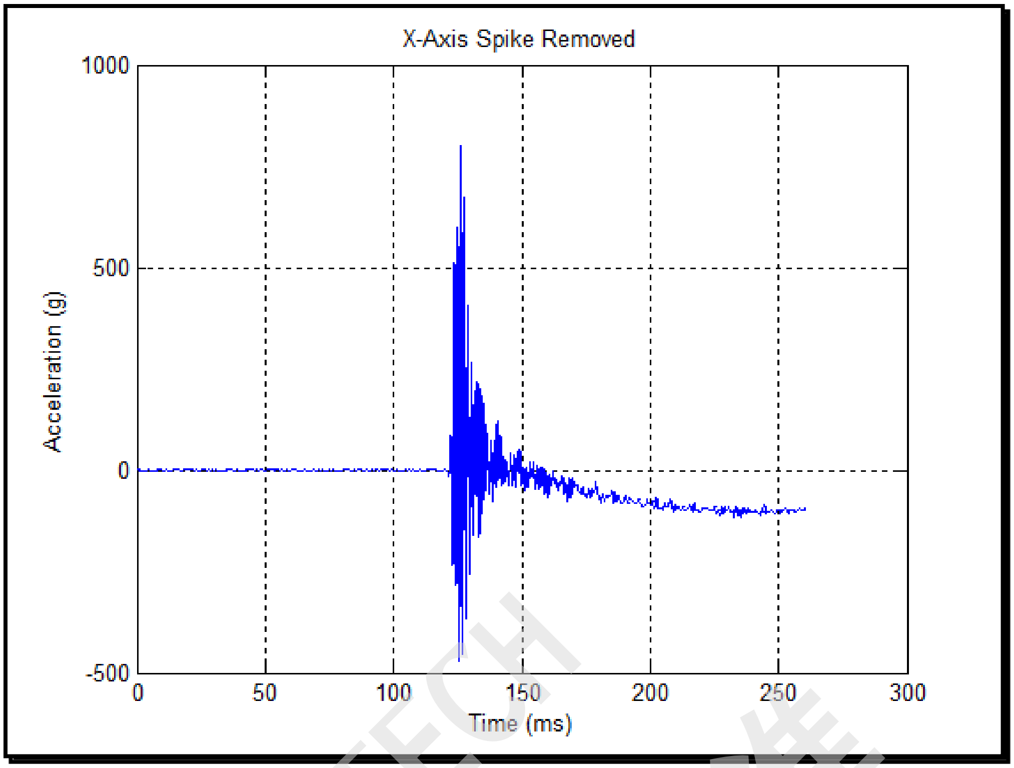

Figure 517.3A-9. Time history of wavelet correction removed from the acceleration time history in Figure 517.3A-5.

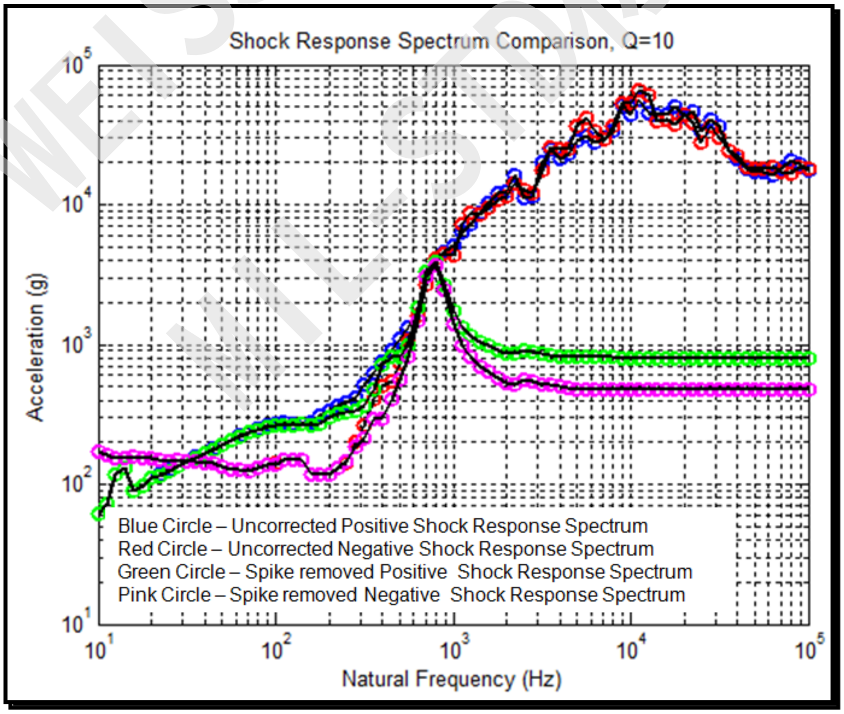

Figure 517.3A-10. Shock response spectrum comparison for corrupted acceleration (Figure 517.3A-5) and removed wavelet correct (Figure 517.3A-9) (Q=10).

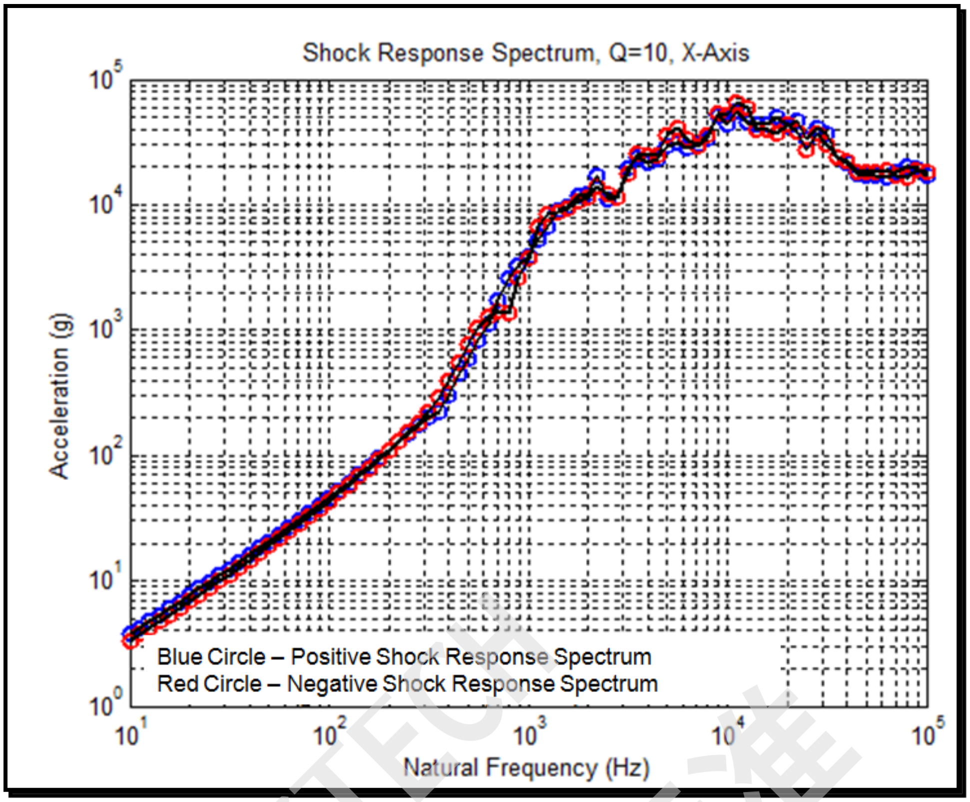

Figure 517.3A-11. Shock response spectrum calculated for the wavelet corrected acceleration time history. (Q=10).

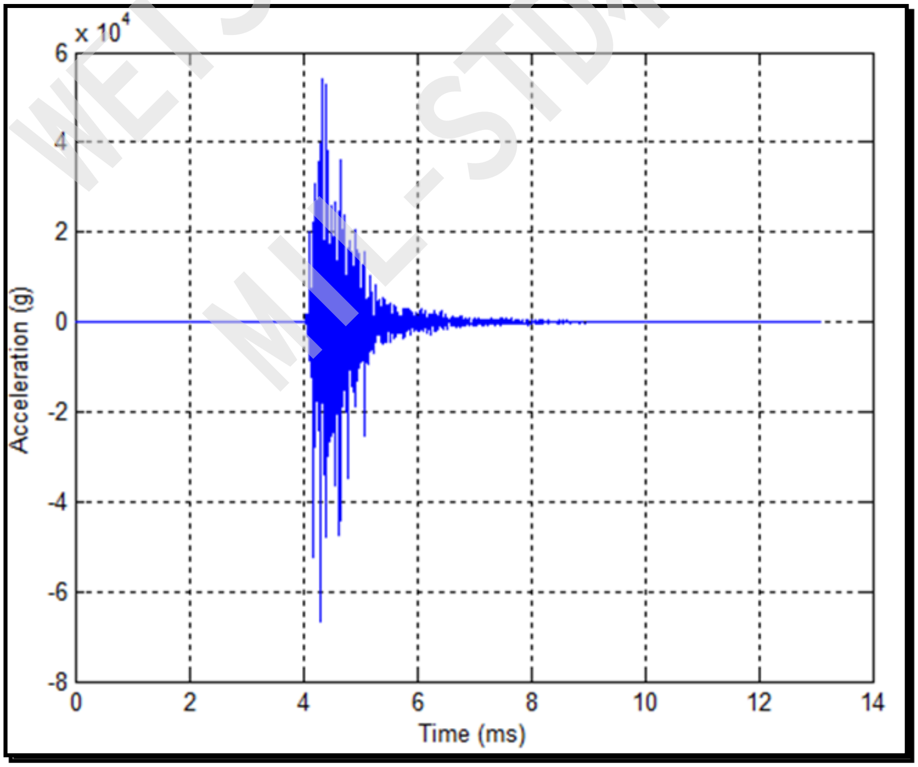

Figure 517.3A-12. A near-field pyroshock acceleration time history.

4. ACCELEROMETER DATA WITH BASE STRAIN EFFECTS.

Although piezoresistive (PR) accelerometers are recommended for pyroshock measurement, these accelerometers will quite often respond to the initial compressive wave from the pyroshock with a base strain response. The base strain will create an additional velocity change in the acceleration time history. Although the strain pulse is generally not detectable in the acceleration time history, the velocity change will be evident in the integral of the acceleration.

The base strain induced into the case of a PR accelerometer during installation may be relieved with hammer taps during the initial steps in the Procedure.

Example acceleration time histories are in Figure 517.3A-12 and Figure 517.3A-14; the corresponding velocity time histories obtained by integrating the acceleration are shown in Figure 517.3A-13 and Figure 517.3A-15.

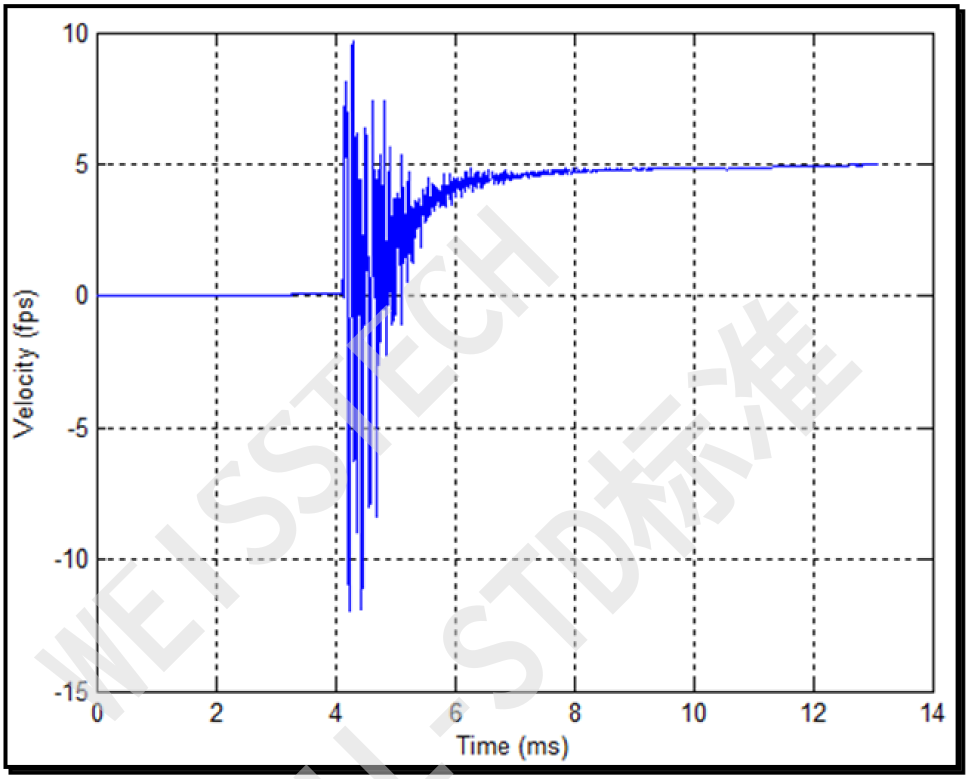

Figure 517.3A-13. The integral of the acceleration data in Figure 517.3A-12.

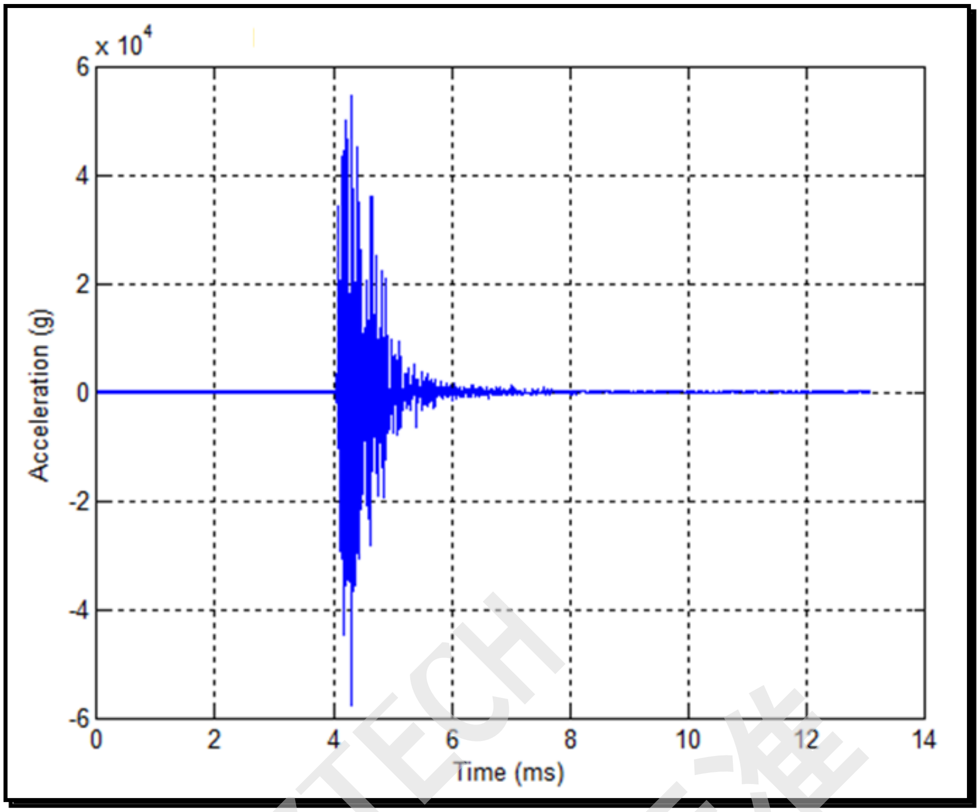

Figure 517.3A-14. A near-field pyroshock acceleration time history.

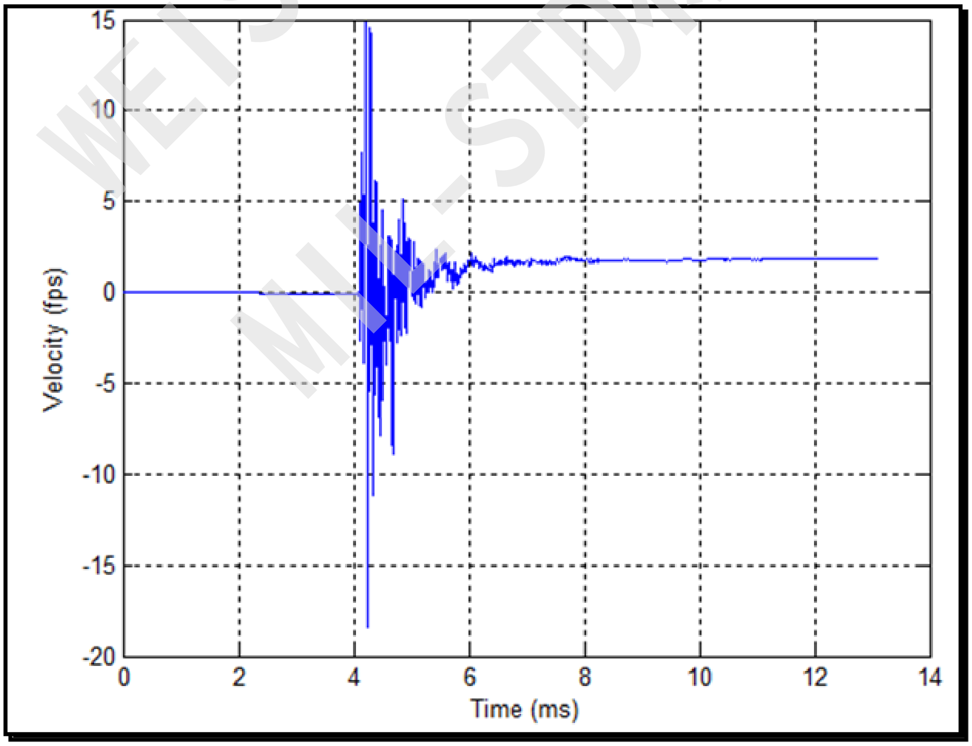

Figure 517.3A-15. The integral of the acceleration data in Figure 517.3A-14.