DEVELOPMENT OF THE ALCATEL ETCA PYROSHOCK TEST FACILITY.

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ABSTRACT.

Current launchers and spacecrafts utilise numerous pyrotechnic devices to separate structural subsystems and/or deploy appendages. The firing of these pyrotechnical charges generates severe mechanical shock waves (so-called pyroshocks) that can cause failures in electronic units. Common damages are relay chatter and transfer, failure of magnetic components, failure of relays or crystals, ceramic lift-off, dislodging of contaminants and so on. There is a lack of computational techniques to predict the dynamic behaviour of complex structures when subjected to high amplitude/high frequencies shock waves as well as a lack of damage and failure criteria and so the pyroshock verification is always accomplished experimentally.

Traditional shock testing machines such as drop tables do not produce adequate pyroshock simulation and are often disregarded. Hammer impact machines or electrodynamic shakers are sometimes used but most of the pyroshock machines are based on resonant structures excited either by a mechanical impact (MIPS) or by an explosive charge.

Alcatel ETCA has developed a pyroshock test facility dedicated to electronic unit tests. The facility can utilise several resonant test fixtures that are excited either by a detonating charge, a dropping mass, or a pneumatically fired missile. The test fixture can be a simple plate, a double plate, or a more complex structure. The test item attached to the fixture is subjected to the direct shock wave and to the resonant response of the test fixture which simulates the desired pyroshock. The test set-up is checked and tuned versus the test specification by using a dummy of the test item. When the desired pyroshock is achieved, the nominal tests are performed on the test item.

This paper presents the results of an extensive literature survey as well as the summary of the experience gained through the use of this test facility. The paper also presents examples of shock environments that can be readily simulated at the Alcatel ETCA test facility. A total of about 500 pyrotechnic shock tests have been already performed as well as hundreds of metal-metal impact shock tests. Capabilities of the facility and results of numerous firings are discussed.

1. INTRODUCTION.

The development of the Alcatel ETCA pyroshock test facility started about two years ago. The development has been based on the author's experience gained from participating to full scale testing on Ariane 5 subsystems (main stage separation, fairing separation, …). It also relies on their participation to pyroshock qualification tests performed on several other European test facilities.

The development has conducted to the definition and construction of the test facility described in this paper.

The facility has already been used for the qualification of about 15 electronic units.

2. BACKGROUND.

2.1. Pyroshock generating devices [14b].

Current launchers, payloads and spacecrafts utilise pyrotechnic devices over the course of their missions to separate structural subsystems (e.g., booster, fairing, stage or payload separation from launch vehicles), release of deployable appendages (e.g., solar panels or antenna's), and/or activate on-board operational subsystems (e.g., propellant valves).

A list of commonly used pyrotechnic devices, according to the severity of the shock-environment that they produce, follows:

a. Linear explosives in separation joints (Mild Detonating Fuse – MDF and Flexible Linear Shaped Charge - FLSC),
b. Explosive bolts,
c. Separation nuts,
d. Pin-pullers, pin-pushers, cable-cutters, bolt-cutters.

Examples of pyroshock induced acceleration time histories are shown in Fig.1 and 2.

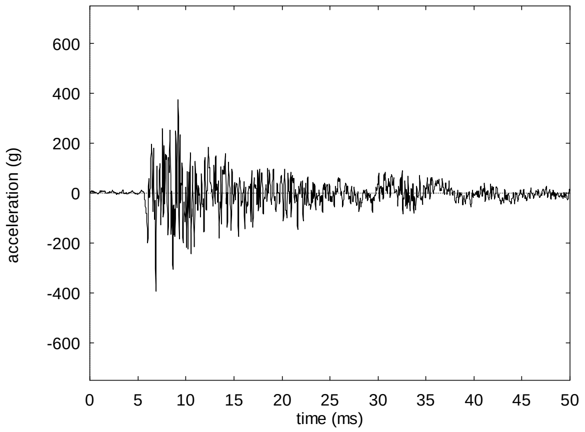


Figure 1. Ariane 5.
Main Stage Separation.

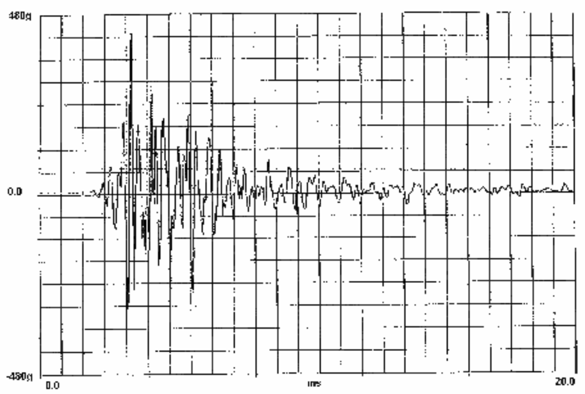


Figure 2. Telecommunication Spacecraft.
Solar Panels Deployment.

2.2. Stress wave propagation [20].

These devices generate compression and shear shock waves that travel at the sonic velocity within the transmitting material. They generate flexural shock waves as well. All these waves propagate through the structures, they are reflected and transmitted through the interfaces and they excite the structure mode shapes. The pyroshock experienced by the electronic units combines direct shock waves with a duration of a few µs with the structural response of the carrying structures with a duration of ten's of ms.

2.3. Pyroshock levels [1].

The numerous reflections and recombinations produce pyroshock levels that vary according to the distance from the source and the complexity of the carrying structure. They are broadly divided into three categories depending on the distance from the pyroshock generation device:

a. Near-field pyroshocks:
- peak accelerations higher or much higher than 5000 g
- substantial spectral content above 100 kHz
- locations from the source lower than 15 cm for line sources,

b. Mid-field pyroshocks
- peak accelerations between 1000 g and 5000 g
- substantial spectral content above 10 kHz
- locations from the source between 15 cm and 60 cm

c. Far-field pyroshocks
- peak accelerations below 1000 g
- spectral content below 10 kHz
- locations from the source above 60 cm

2.4. Pyroshock induced failures.

There is a lack of data concerning pyroshock induced failures in electronic units.

The authors have already experienced the following problems: relay chatter and transfer, failure of relays, magnetic components and crystals, as well as bond fracture.

C.J. Moening paper [14] reports the following failures experienced during ground shock testing:
- Relays and Switches
  - chatter and transfer
  - permanent damage
- Crystals, ceramics, brittle epoxies, glass diodes, wire leads
  - cracks and breakage
  - loss of seals
  - bond fractures
  - shorts
- Particle contaminants in piece parts
- Deformation of small, lightweight structural elements

The failure of brittle magnetic components (ferrite) is worth mentioning as well. Pyroshocks rarely damage structural members.

C.J. Moening also reports 85 pyroshock induced flight failures to compare with 3 vibration induced flight failures.

2.5. Shock Response Spectrum.

The most widely used technique for quantifying pyroshock is the Shock Response Spectrum (SRS). The SRS is a method of reducing the time-history to compare shock motions, to design equipment to withstand shocks, or to formulate laboratory tests simulating environmental conditions. The SRS is viewed as a measure of the damage potential. A SRS is a plot of the maximum response experienced by a single degree-of-freedom (SDOF) system, as a function of its own natural frequency, in response to an applied shock. For pyroshocks, the shock spectrum is calculated from the measured pyroshock time-history applied as a motion of the SDOF system foundation. The response may be expressed in terms of acceleration, velocity, or displacement; these amplitudes may be absolute or relative to motion of the foundation. For pyroshocks, the maximum absolute acceleration is generally used; the maximum absolute positive and negative acceleration responses are also used to check that the pyroshock acts in both directions.

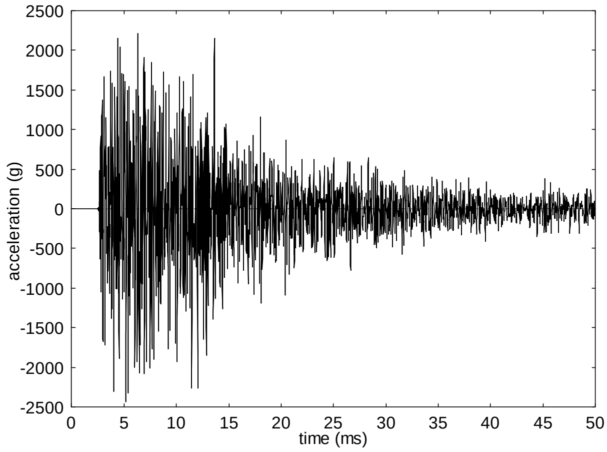


Figure 3a. Acceleration time-history for a pyroshock.

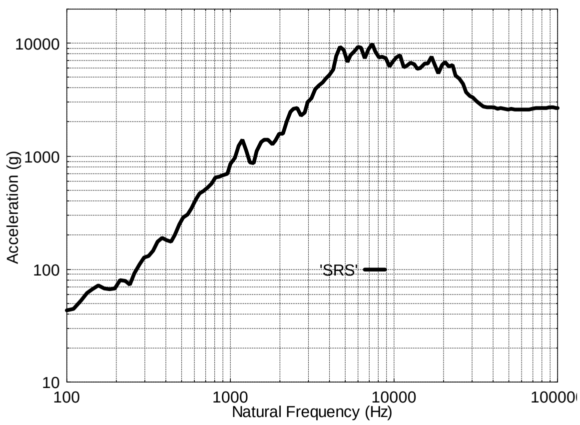


Figure 3b. SRS of a pyroshock. The SRS is calculated from the Fig.3a inset acceleration using a 5 percent damping ratio (dynamic amplification Q = 10).

The absolute acceleration is related to pseudo-velocity or relative displacement by the following relationship:

$$\omega^2.\delta = \omega.v = a$$

for non damped systems with:

- ω = resonance angular frequency,
- δ = maximum spring deflection (maximum relative displacement)
- v = maximum pseudo-velocity
- a = maximum absolute acceleration

On the extreme left of Fig.3b corresponding to very low-frequency SDOF systems, the response approaches an asymptote corresponding to the value of the maximum ground displacement. For very high-frequency systems, the spring is very stiff; therefore, when the ground moves, the spring forces the mass to move in the same way the ground moves, and the mass must have the same acceleration as the ground at any time. The SRS plot asymptotically approaches the maximum ground acceleration line on the extreme right-hand side of Fig.3b. This is used to check the SRS calculation.

2.6. Shock testing facilities [7].

Different types of test facilities can be used for pyroshock tests.

a. Conventional machines.

In all cases, however, conventional drop test machines, where the test item is mounted on a table that free-falls against an arresting device, should never be used. Such machines subject the test item to a large net velocity change, which produces a shock with substantial low frequency energy that can damage the test item in an detrimental way. These machines provide to the test item a kinetic energy that is converted into deformation energy when the shock occurs meanwhile pyrotechnic devices generally produce little or no net velocity change.

Conventional electrodynamic shakers can not simulate adequate SRS's because they are limited in amplitude (300g's) and in frequency range (up to 3 kHz). Some shakers [10] have a special construction allowing them to reach 5000 g's. They are sometimes used but care has to be taken in order them not to generate a time-history that looks like a vibration instead of a pyroshock. Such system tend to act on the dynamic amplification factor in order to get high amplitudes in the SRS while maintaining low amplitude time domain excitation. These electrodynamic shakers are unable to provide sufficient excitation above 5 kHz.

b. Impact devices.

Several test facilities use metal-metal impacts. They utilise a fixture (simple plate, beam, Hopkinson bar, 3-D shell) that is shock excited into resonance by a mechanical impact from a dropping mass, a fired missile, a pneumatic piston, or a pendulum. The MIPS (Mechanical Impact Pyro Shock) simulators are well described [9]. They require a fair amount of trial-and-error tests to achieve the required spectra. In order to improve such kind of process, some systems use a tuneable resonant test fixture impacted by a pneumatic device [8]. They adjust the test fixture fundamental frequency in order to produce typical pyroshock simulations with knee frequencies.

c. Pyrotechnic devices.

Several types of ordnance devices exist. They use a flat plate [13] [15] [18] or a double plate [19] excited by an explosive charge (ordnance device). The magnitude and the shape of the required SRS are controlled by the size/location of the explosive material and the location of the test item on the plate. The advantage of this technique is its ability to achieve high accelerations and high frequencies and to generate transient excitation along all axes at the same time. When such a system is well in hand of the test staff, it can produce pyroshock simulations that match the requirements in all directions at once.

3. TEST SPECIFICATIONS.

The SRS is the most commonly used technique for pyroshock test description. Acceleration values are specified from a low frequency limit of a few hundreds of Hertz to a high frequency limit of 10 kHz. The amplitudes vary widely depending on the test specification. There is a requirement for each of the three orthogonal axes. The most commonly used tolerances are:

- ±6 dB for natural frequencies (f_n) < 3000 Hz
- +9dB/-6dB for natural freq. > 3000 Hz.

Other specifications use a different kind of tolerances:

- ± 6 dB for natural frequencies < 1000 Hz
- +6 dB/-0dB for 1000 Hz < fn < 6000 Hz
- ± 6 dB for fn> 6000 Hz.

The SRS positive and negative peaks must be close to each other (for example 3 dB). Sometimes there are additional requirements on acceleration pulse decay and peak velocity.

Some examples are given in Fig.4.

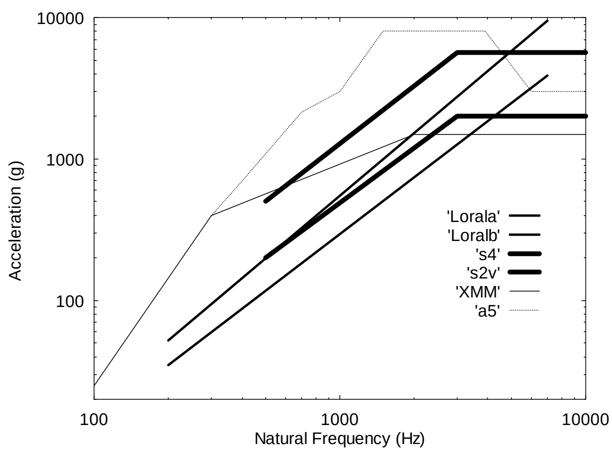


Figure 4. Specified Pyroshock Spectra. Out-of-plane direction.

Some specified SRS's have an increasing amplitude with frequency; some others do not, they have a knee frequency with a constant acceleration above this frequency. The second type of specification is usually more difficult to achieve on a pyroshock test facility.

The maximum specified frequency is usually 10 kHz. In some case, it can reach 25 kHz (Ariane 5 specification).

4. ALCATEL ETCA PYROSHOCK TEST FACILITY DESCRIPTION.

4.1. Statement of the problem.

The objective, when the project started two years ago, was to develop a versatile system able to achieve:

- every type of specified response spectrum,
- in each of the three directions,
- for a wide variety of electronic units weighing up to 50 kg,
- within a tighten time schedule
- according to quality standards.

At the beginning, the system was mainly dedicated to Alcatel ETCA electronic units. Nowadays, several other companies use it.

The first system definition has been a hard work because a wide variety of equipment and techniques exist. There is neither a standard excitation method nor a standard test fixture and so we decided to develop a system able to use:

- different excitations (explosive charges, dropping masses or pneumatically fired missile)
- and a wide variety of test fixtures.

4.2. Test facility description.

The facility utilises several resonant test fixtures that are excited either by a detonating charge, a dropping mass, or a pneumatically fired missile. The test fixture can be a simple plate, a double plate, or a more complex structure. The test item attached to the fixture is subjected to the direct shock wave and to the resonant response of the test fixture which simulate the desired pyroshock. The test set-up is checked and tuned versus the test specification by using a dummy test item in a trial-and-error process. When the desired pyroshock is achieved, the nominal tests are performed on the test item.

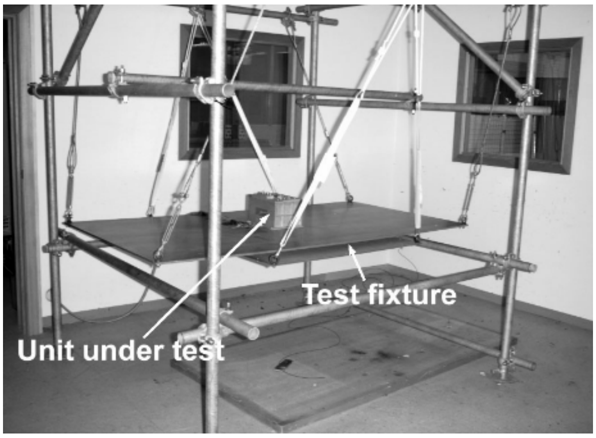


Figure 5. Alcatel ETCA Blast room for ordnance excited pyroshock tests.

The main parts of the test facility are:

- the test fixture,
- the shock generating devices,
- the data acquisition system,
- the data analysis system.

The facility also uses a supporting device. For ordnance tests, the system is mounted within a blast room.

In order to perform a pyroshock test, the test hardware is secured to a test fixture. The assembly is supported off the floor by ropes that are attached to the supporting structure. The shock generating devices are installed (ordnance placed under the test fixture, air gun, or dropping mass and its guide pipe) and the test is performed.

4.2.1. Test fixtures.

The test facility employs several test fixtures that are assembled from the plates and structures defined in table 1. Additional test fixtures are developed to match the requirements better and better and/or to speed up the process. The choice of an adequate test fixture is the most important parameter in this trial-and-error process.

Type	Identific.	Dimensions (mm)
Steel plate	AC1	2440 x 1220 x 15
Steel plate	AC3	657 x 500 x 8
Stainless Steel plate	AC4	1200 x 1000 x 5
Steel plates	AC8,9,10	1000 x 1000 x 10
Al plates	AL1,8,9	2020 x 1022 x 10
Al plate	AL4,10,11	800 x 600 x 5
Steel corner plate	EAC1	545x305/545x210
Steel corner plate	EAC2	600x410/600x300
Aluminium corner plate	EAL1	350x350/350x200

Table 1. Some of the test fixtures.

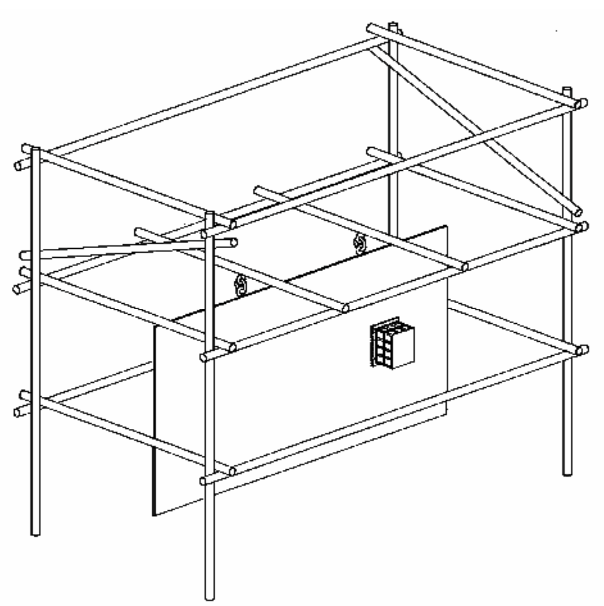


Figure 6a. Simple Plate Test Fixture.

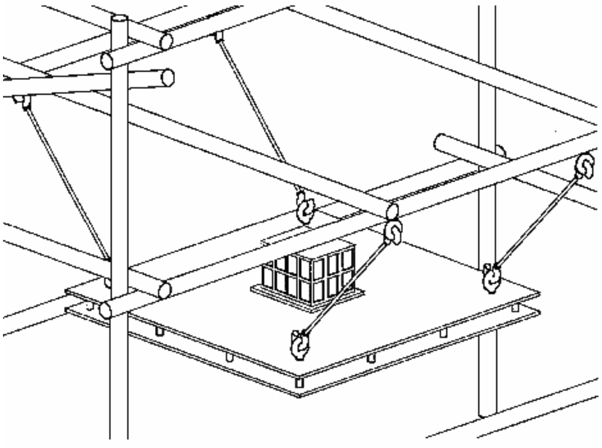


Figure 6b. Double Plate Test Fixture..

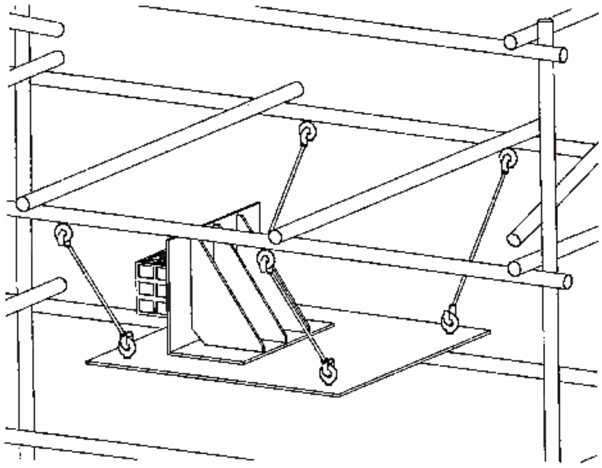


Figure 6c. Simple plate/corner plate assembly.

The supporting structure is made of steel pipes and special holding devices; it can be easily modified to any test fixture.

4.2.2. Shock generating devices.

a. <u>Dropping mass</u> (metal-metal impact) [16].

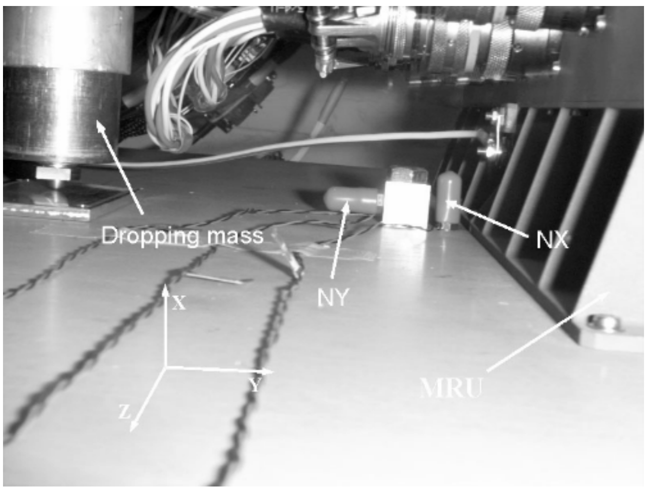


Figure 7a. Dropping Mass Test Set-up.

A cylindrical mass is dropped from a given height onto a small plate ("anvil") attached to the test fixture. The mass has a removable tip. The magnitude and shape of the resulting shock are controlled by the following parameters:

- test fixture (type, material),
- impact direction (// or ⊥ to test item mating plane),
- distance from impact point to test item,
- anvil material (hard steel, stainless steel, Al 5754-0, Al 6061-T6, Al7075-T73),
- hitting tip material
- weight of the dropping mass
- drop height

For several practical reasons, the hitting tip material is harder than the anvil material.

b. Air gun (metal-metal impact).

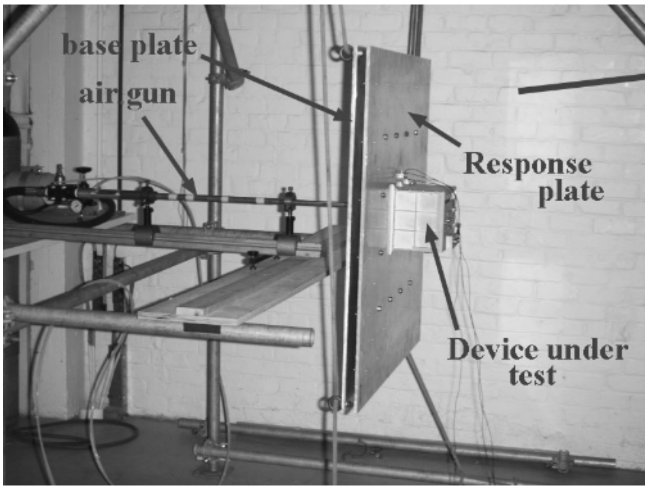


Figure7b. Air gun Test Set-up.

A cylindrical missile is fired from an air gun on a small plate ("anvil") attached to the test fixture. The following parameters are used to control the magnitude and shape of the resulting shock:

- test fixture (type, material),
- impact direction (// or ⊥ to test item mating plane),
- anvil material (hard steel, stainless steel, Al 5754-0, Al 6061-T6, Al7075-T73),
- missile material,
- missile weight,
- missile speed (or air pressure).

The missile material is harder than the anvil material.

c. Explosive.

The test item is mounted to one side of the test fixture. The explosive charge is usually attached to the backside or the edges of the test fixture (contact explosion). It can also be mounted on a second test fixture not in direct contact with the primary test fixture (non-contact explosion).

A detonating cord (10 g/m) and non-electrical (NONEL) detonators are used. The detonating cord length can vary from 0 to 1m. The explosive charge propagates at about 7km/s, so that the cord will complete its detonation in less than 0.1µs. The explosive is unconfined.

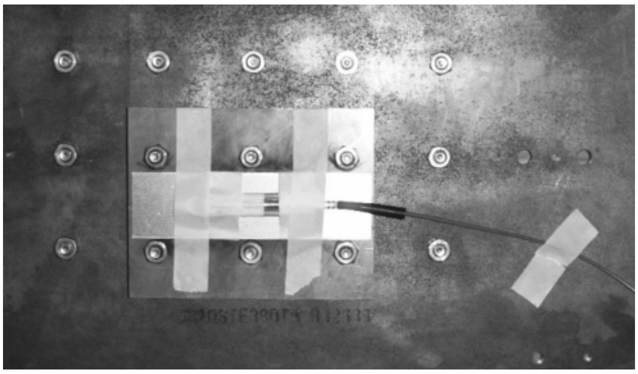


Figure 7c. Explosive charge.

NONEL detonators are used for safety issues but also because they generate less electromagnetic pulse than electrical detonators. This is especially important when operating electronic units are tested.

The magnitude and shape of the resulting pyroshock are controlled by:

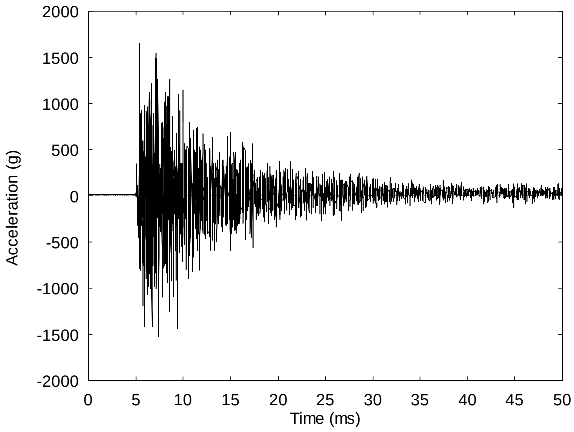
- test fixture (type, material),
- contact or non-contact explosion,
- location and size of the explosive charge,
- explosive charge mounting details,
- location of the test item on the test fixture.

4.2.3. Data Acquisition.

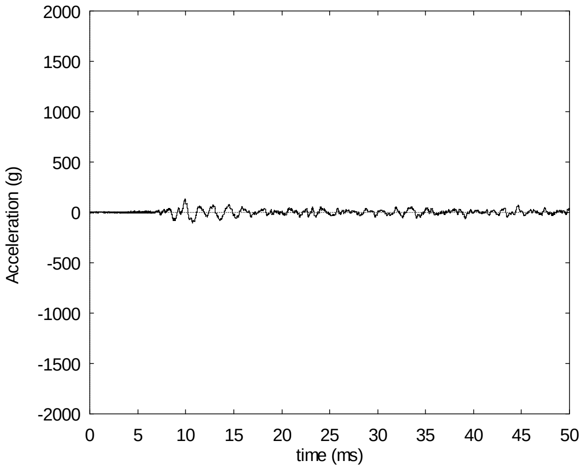
We use accelerometers and direct digital recording on a computer system. Tape recording is avoided because of its low dynamic range and poor operational performances.

ENDEVCO Model 7255 accelerometers (Pyrotron®) are used. They have been developed for pyroshock measurement purpose. They include a built-in mechanical filter to prevent the high frequency high acceleration peaks to reach the active crystal and create noise and zero shift. They also include a built-in low pass electronic filter with a 10 kHz cut-off frequency. These accelerometers are directly screwed on the test fixture through their integral stud. The electrical connecting wires are directly soldered to the accelerometer terminals in order not to have an electrical connector close to the shock source and so to eliminate any connector induced noise.

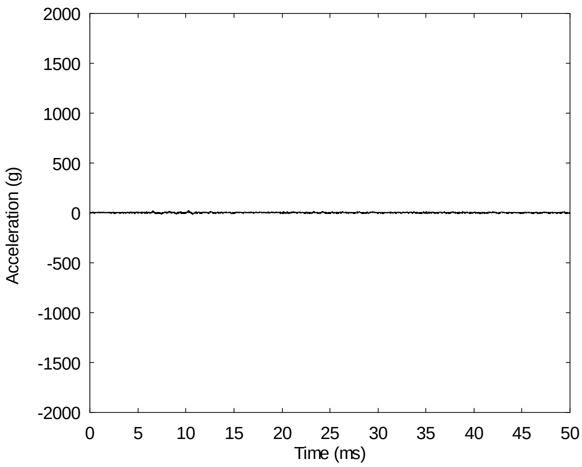
For ordnance tests, the accelerometers are protected against the direct airborne shock wave by means of a special device. The connecting cables are not attached to the test item or to the structure but directly carried away from the accelerometer in the opposite direction from the shock source.



Measurement Accelerometer



Test a: unprotected accelerometer



Test b: protected accelerometer

Figure8a: Results of two tests performed with a freely suspended accelerometer located close to the measurement accelerometers but not touching.
Test a: unprotected accelerometer.
Test b: protected accelerometer.

The accelerometers are fed by a PCB power supply. Elliptic DIFA anti-aliasing filters are used (80 dB/oct). The data are directly acquired and stored through two 8-channels Nicolet BE 490-XE acquisition modules (12 bit resolution, 1 MHz sampling rate, 128 K samples on-board memory) on a PC platform. Each module provides simultaneous sample and hold to avoid unwanted time skew between channels.

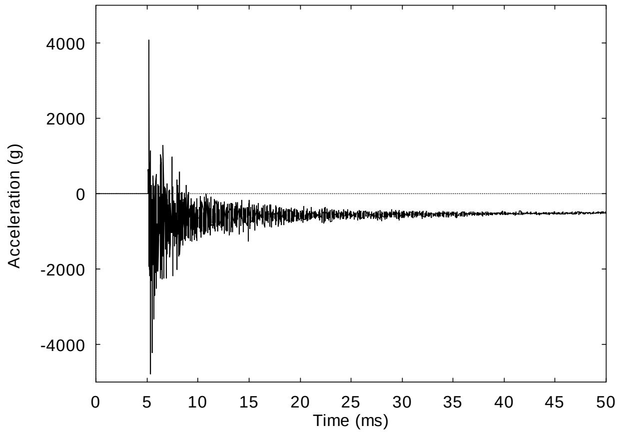


Figure8b: Zeroshift.

4.2.4. Data Analysis.

As explained in §2.5., the input transient is defined in terms of an acceleration at the oscillator base, and the response in terms of an absolute acceleration of the oscillator mass. After acquisition, the absolute acceleration SRS is computed. Several methods exist. They work in frequency domain or in time domain. The following four methods have been evaluated:

- direct integration of the Duhamel integral [5],
- Cox method [6],
- Smallwood method [17],
- Newmark method (direct integration of the time domain equation) [2].

The first method is much too time consuming and has been disregarded. The other three give accurate results. The Smallwood method is the faster one, and has been

Method	Relative Speed
Smallwood	100 %
Cox	210 %
Newmark	290 %

Table 2. SRS Calculation Methods. Computation Speeds.

recommended by several authors [1]. Nevertheless, we have selected the Newmark method because it is faster enough (the calculation of about 100 SRS frequency lines from a 16 k sample block size takes about 10 sec on a Pentium 166 MHz 32MB) and well known. In the Newmark method, the accuracy and stability criteria are based on the Δt selection. The Δt has to be small enough to:

a. describe the acceleration input (related to the sampling rate and filtering),
b. get accuracy and avoid instability (Δt is a fraction of the SDOF natural period).

In our case (SDOF system), the accuracy criterion gives always Δt much shorter than the stability criterion (this criterion is related to MDOF equations where the high natural frequencies have to be damped out in order not to create numerical instability). For the low frequency oscillators, the first criterion supersedes. With the increasing of the frequency, the second criterion is acting.

Positive and negative SRS's.

Positive and negative SRS's are computed. These two curves are the plot of the maximum positive and negative absolute acceleration responses of the SDOF systems. They are of course enveloped by the maximum absolute response curve. They are used to check the SRS measurement quality as well as the validity of the pyroshock test simulation.

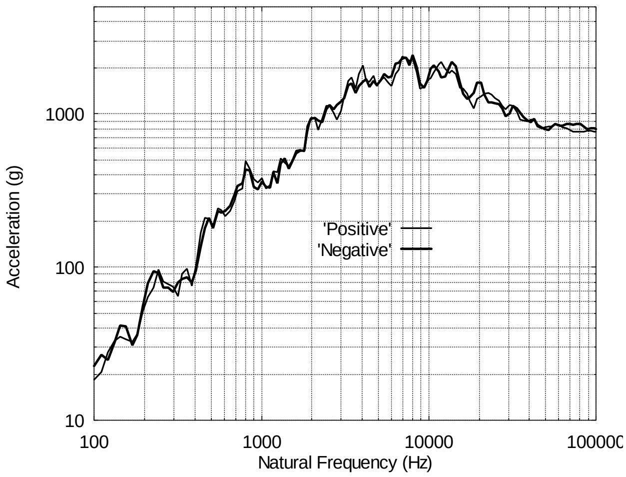


Figure 9. Positive and Negative SRS's.

4.3. Test facility operation.

For pyroshock simulation, the three types of test facility can be used i.e. ordnance test facility, dropping mass test facility or fired missile test facility. In all cases, a dummy test item is needed.

The test sequence is as follows:

a. Select a test fixture and an excitation system according to past experience and engineering feeling (usually, the ordnance excitation is chosen because it gives excitation in all three directions).
b. Attach the dummy and related control accelerometers to the test fixture.
c. Perform the pyroshock test and compute SRS's.
d. Compare to the specified level in all three directions.
e. Select new test parameters and go back to step c or to step a if necessary.
f. When the trial-and-error process gives good results, attach the test item and perform the nominal test. If the specified SRS's are not achieved in all axes, go back to step a for a second (and third) additional test sequence.

In most cases, the pyroshock excitation in the axis perpendicular to the test item mating plane is higher than the excitations in the in-plane directions and so two test set-ups are enough to achieve the specified values in all three directions. In a number of cases, one test configuration gives good results in all three directions with one firing.

4.4. Test range.

A total of about 500 pyrotechnic shock tests have been already performed as well as hundreds of mechanical impact shock tests. The current test facility test range has been defined for all three directions. It is shown in Fig.10 for the direction perpendicular to the test item mating plane.

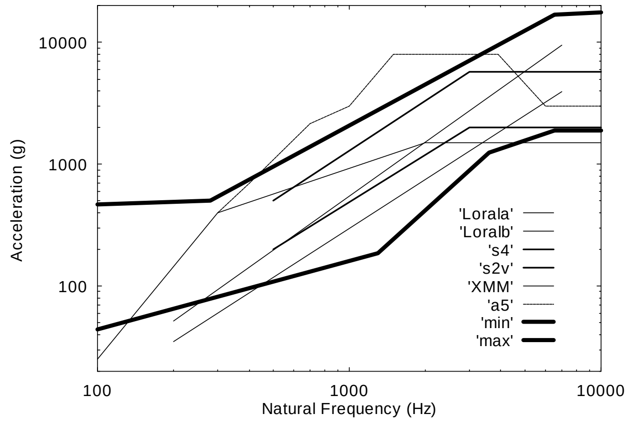


Figure 10. Ordnance Excited Pyroshock Tests. Out-of-plane direction. Test Range as compared with some specified levels.

All tests are fully documented and the associated test results (time history and SRS's) are stored in a database that is used for the selection of the test parameters for further tests. A computer program that scans the matching of the past tests according to new specified levels is under development.

4.5. Repeatability.

The test has to be repeatable when all the control parameters are the same. This is of primary importance. The difference between two test results has to be much lower than the test tolerances in at least three cases:

a. from test to test to allow the trial-and-error process but also to allow the performance of additional tests when several firings at the same level are requested,
b. after dismounting of the dummy and mounting of the test item,
c. after entire dismounting of the test fixture.

Requirement (a) and (b) are almost always achieved. Requirement (c) is often achieved but, in some cases, additional adjustments are needed.

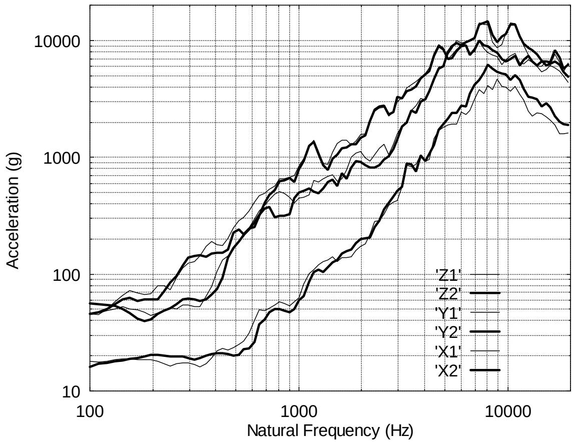


Figure 11. Ordnance Excited Pyroshock Tests.
All directions (Z: out-of-plane).
Test repeatability according to requirement a.

5. EFFECT OF SOME PARAMETERS.

5.1. Mechanical impacts.

For mechanical impact, the main parameters affecting the shock amplitude, shape and direction are the type of test fixture, the impact direction, the distance from impact point to test item, the anvil material, hitting tip material, the dropping mass weight and drop height, the missile material, weight and speed. Hereafter, three of them are discussed. Additional information is given in [3].

5.1.1. Effect of the type of excitation.

The dropping mass excitation gives more amplitude at low frequency than the air gun does.

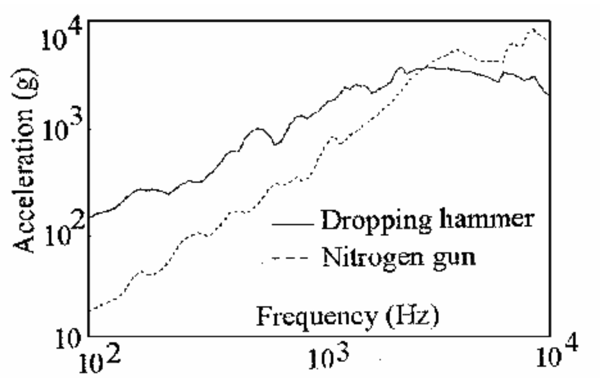


Figure 12a. Dropping Mass or Air Gun excitations.

5.1.2. Effect of air pressure (air gun).

There is an amplitude increase over the entire frequency range when the air (or nitrogen) pressure is increased. Nevertheless, this increasing effect is limited above a specified air pressure because of plastic deformation of the anvil at the impact point.

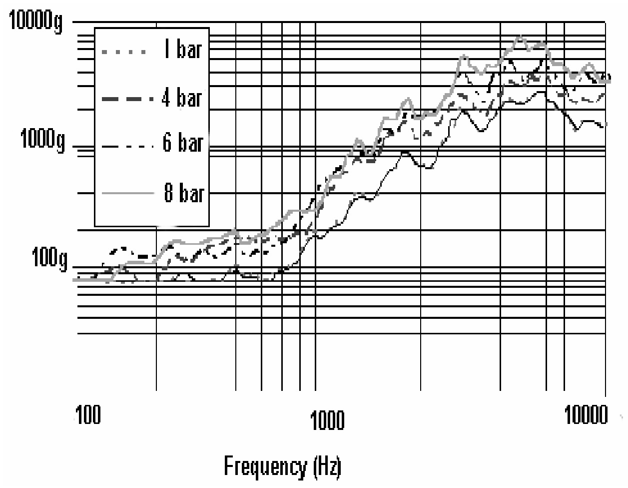


Figure 12b. Effect of Air Pressure.

5.1.3. Effect of impact head material (dropping mass).

A comparison is made between two shocks obtained with an impact head made of steel and an impact head made of brass. This parameter affects the SRS shape. The SRS amplitude increases or decreases when varying the drop height.

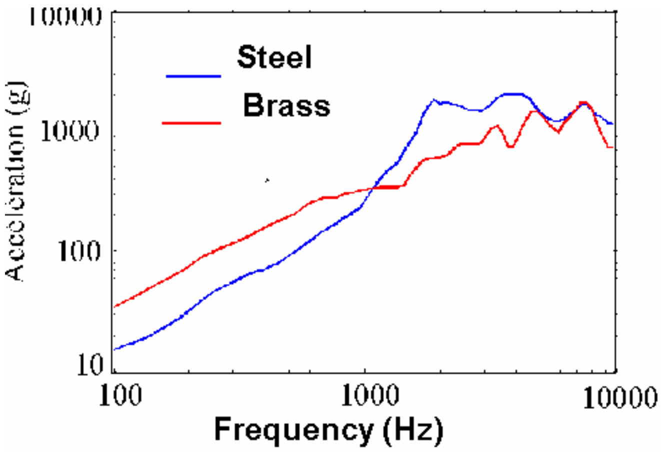


Figure 12c. Effect of Impact Head Material.

5.2. Pyrotechnic mode of operation.

In case of an ordnance test, the main parameters affecting the shock amplitude, shape and directions are the type of test fixture, the location and size of the explosive charge, the explosive charge mounting details and the location of the test item on the test fixture. Hereafter, three of them are discussed.

5.2.1. Effect of the type of test fixture.

The type of test fixture is the most important parameter to succeed in the trial-and-error process. It allows to cover a wide area of the SRS diagram above 1500 Hz.

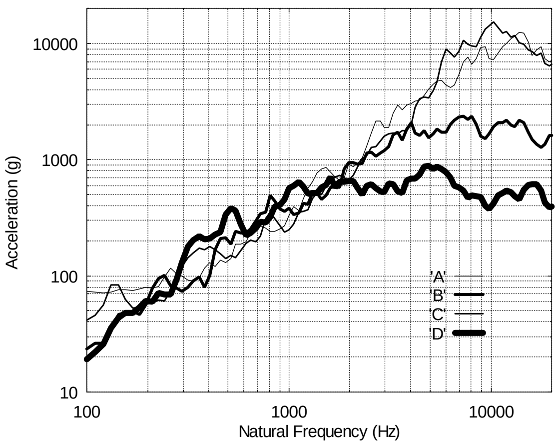


Figure 13a. Effect of the Test Fixture Set-up.

5.2.2. <u>Effect of contact/non-contact explosion.</u>

The explosion generates both airborne and structure-borne loads. Usually, the explosive is directly attached to the test fixture and both loads act together. In some cases, the explosive is attached to a second test fixture located at some distance of the first one. That allows to decrease the high frequency content close to the test item.

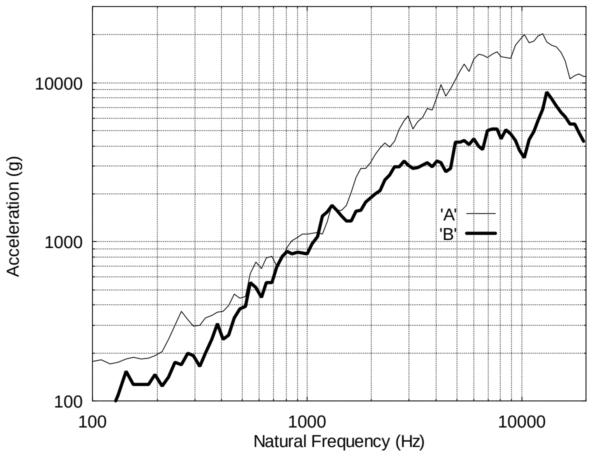


Figure 13b. Effect of Contact/Non-Contact Explosion.

5.2.3. <u>Effect of explosive location.</u>

The explosive location modifies the spectral content as well as the amplitude as shown on Fig.13c. However, this parameter is mainly used to equalise the relative amplitude and shape of the SRS's measured in the three directions.

5.3. Advantages/ disadvantages.

Explosive testing is more difficult to implement than mechanical testing due to numerous safety issues but it has a number of advantages.

- It generates high accelerations and high frequencies.
- One firing gives excitation in all directions.
- The impact location can be easily modified.
- The pyroshock levels experienced by the test item through its fixation points are more uniform than the levels obtained with mechanical impacts.

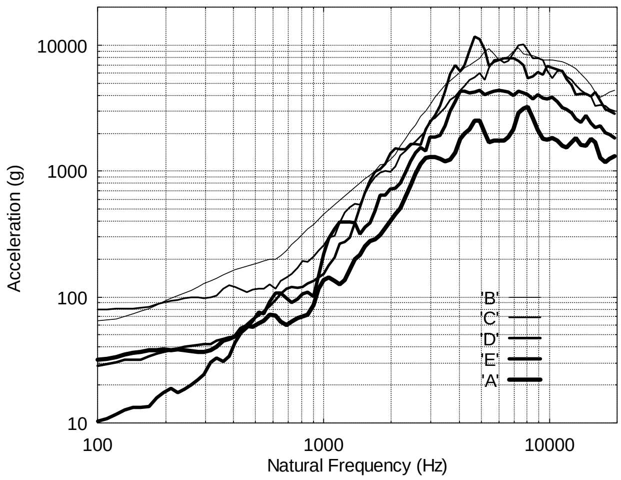


Figure 13c. Effect of Explosive Location.

Unfortunately, it has a number of disadvantages.

- Numerical simulation is very difficult.
- The decreasing of the amplitudes at high frequency is difficult.
- The ordnance test generates dust.

6. CASE HISTORIES.

After more than one year of operation, a large number of qualification and development tests has been performed. In most cases, an explosive charge has been used.

Three ordnance test results are shown hereafter (tests A, B, and C). Z axis is the direction perpendicular to the test item mating plane. The X and Y axes are parallel to the in-plane directions.

In each test, the three SRS plots are the result of one firing. In ordnance tests, it is possible to meet the requirements in all directions at once when an appropriate test set-up has been defined.

In test B, the required spectrum had a knee frequency at 3 kHz i.e. a flat amplitude from 3 to 10 kHz. This shape is sometimes difficult to achieve in the in-plane directions.

In most cases, the Z axis response has the highest amplitude compared to X and Y axes whatever the test fixture, the type and location of the excitation device.

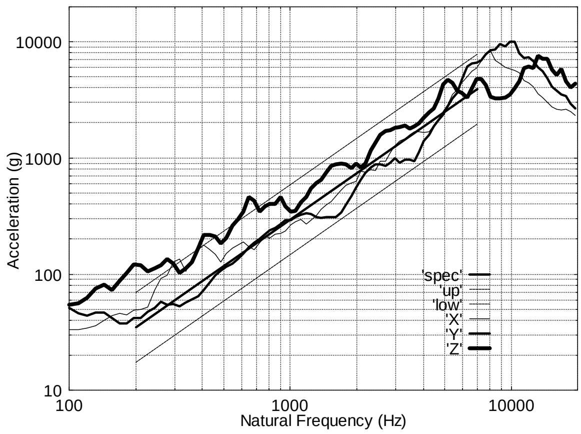


Figure 14a. Unit A.

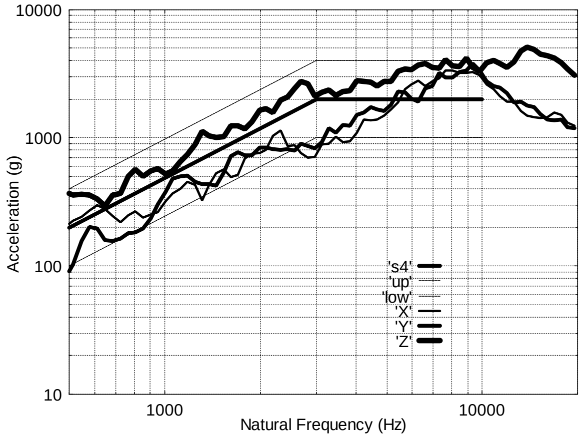


Figure 14b. Unit B.

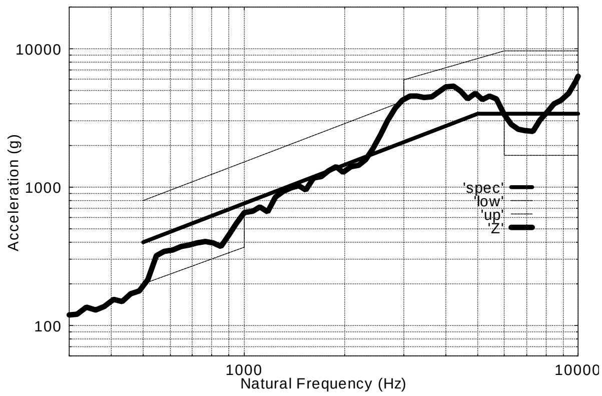


Figure 14c1. Unit C. Out-of-plane direction.

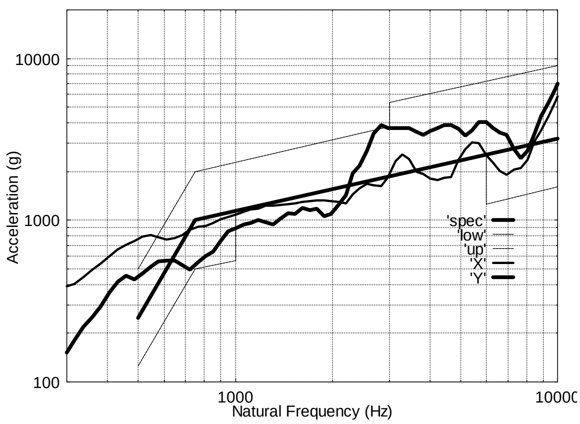


Figure 14c2. Unit C. In-plane directions.

8. CONCLUSION.

The Alcatel ETCA pyroshock test facility provides a versatile capability for shock testing of electronic units according to a wide range of test specifications to be met in the three directions. The test facility has already been used successfully on numerous programs.

Achieving the desired Shock Response Spectra requires a dedicated and innovative test staff, as well as a thorough understanding of the test facility. Unfortunately, the use of the test facility remains tedious and expensive. As the experience (and the database) grows with each new test campaign, the set-up time and costs will be reduced.

Additional improvements are needed to increase the level of confidence in the use of this test facility:

- development of a dedicated methodology and associated computational technique to simulate the facility dynamic behaviour,
- test fixture optimisation,
- measurements in the in-plane directions and in the low frequency range.

In the author's opinion, there is a need for standardisation work in the fields of pyroshock specifications and pyroshock testing techniques. The test specifications (SCC) of small electronic components (relays, crystals, …) should be reviewed as well because they only specify low g levels (50 to 200g) at low frequency (6 or 11 ms).

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