Improper Environmental Stress Screening Can Damage Your Product

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Applied properly, Environmental Stress Screening (ESS) is recognized as a very effective tool to precipitate, identify, and correct patent (normally detectable), latent (normally hidden), and intermittent defects in design, qualification testing, and manufacturing production processes. However, unless product input and output stress stimuli are knowledgeably controlled and tailored to your specific product, ESS can damage product.

The purpose of this article is to point out the numerous misconceptions and pitfalls that are not obvious when applying repetitive shock (RS) vibration to design, production, or qualification test hardware and that are seldom recognized by electronics manufacturers until it is too late.

Repetitive shock or electrodynamic shakers?—RS (pneumatic hammer) ESS equipment, so-called 6 degree of freedom (6DoF) vibration equipment has been hailed by original equipment manufacturers (OEMs) as new technology's answer to effective, highly accelerated reliability testing. More and more companies continue to make substantial investments in this equipment. Sales advertising and convincing seminars identify RS equipment as the magical answer to durability testing to bring newly developed hardware into the marketplace quickly and economically with dependable, reliable, robust designs. It is also promised as being a great vehicle to precipitate manufacturing process defects in production hardware.

This author had supported the philosophy of using RS equipment for more than 10 years. However, after actual test evaluation and receiving numerous reports from a variety of both commercial and military companies experiencing problems, including allegations of induced damage to hardware, it has become a matter of technical courtesy and an ethical obligation to alert peers who may have already or may soon become mesmerized by the apparent success of RS vibration equipment. Representatives of some of these companies who have purchased RS equipment are politically embarrassed to make known that these combined RS temperature-vibration chambers are now used solely for high-rate-of-change thermal chambers, while the vibration feature has been mothballed.

To avoid allegations of hidden monetary motives, it is openly revealed that for over four years the author has worked with Dr. Hong S. Liu, president of Quanta Laboratories in Santa Clara, California, designing, testing, and evaluating tilted (vectored) fixtures for use with single-axis electrodynamic shakers (EDS). These have been shown to provide uniform vibration input in three mutually orthogonal axes simultaneously. Dr. Liu has a patent on this type of fixture and a tilted, lightweight table expander head that replaces the conventional, heavier, magnesium expander head. This author has received no monetary remuneration from use of the tilted fixtures or table expander heads, nor from sales of EDS equipment.

Red alert words of caution: Once a firm locks into ESS equipment or processes that are not effective cost-wise or technically, it is monumentally difficult—as well as politically threatening—to justify later to management the high cost of making a change back to more traditional and supportable methods. A wrong decision may give the deceptive appearance of having good immediate payback and return on investment, but can prove disastrous in the future when shortening a product's life by inducing early life failure damage that may not be detected until after hardware is fielded.

Here are some types of electronics materials and natural resonant frequency damage domains:

- 3,000–5,000 Hz for gold wirebonds;[1]
- 4,000–8000 Hz for 99 percent pure aluminum, 1 percent silicon wires;[1]
- 10,000 Hz and above for most aluminum geometries;[1]
- 5,000–10,000 Hz for transistor cans containing glass;[2]
- 7,000 Hz for glassy pedestal transistor cans.[2]

RS equipment advantages—

- Quasi-random or pseudo-random, triaxial vibration and thermal cycling is done simultaneously;
- Cost and ease of use appears reasonable for Highly Accelerated Life Testing (HALT), and Proof Of Screen (POS) on prototypes placed *in center of table*;
- High rate of change of thermal chamber is effective, depending upon load capacity;
- Accessibility from both sides of chamber provides ease and labor economy of access for assembly and instrumentation for those chambers having this feature;
- EMI in chambers is very low, practically not measurable.

RS equipment disadvantages—

- Cannot effectively shape spectral density profile (g^2/Hz), hammer input is what you get;
- Poor PSD spectrum control, spikes equivalent to Mt. Everest peaks, Mariana's trench lows (Figure 1);
- Difficult to eliminate high energy input at frequencies between 2,000–20,000 Hz, which can break sensitive solder wire junctions of integrated circuits and small components (Figure 1);
- Analog and digital vibration filtering are deceptive because they only cut off, or condition, recorded data, they do not cut off high-frequency *damage stimulation stress* to product;[3]
- Often not available at supplier's or subcontractor's facilities;
- Expensive, approximately $200,000+ with peripheral support and safety equipment for 36" x 36" or equivalent RS chambers, which does not include training for skilled engineers or technicians to operate equipment;
- Allows no flexibility to do separate vibration and thermal cycling to reduce costs by increasing throughput;
- Challenging economically and questionable technically for application to production or customers spares orders;
- Poor X, Y, Z gRMS product uniformity at one location on table, worse at multiple locations;[4]
- The need to use limited-location sweet spots (experientially equalized vibration level locations) reduces production throughput, plus it is labor-intensive to find equalized locations;
- Vibration tables must be re-tuned, or sweet spots rediscovered when changing ESS products, which requires trained specialists, and is labor-intensive. Alleged automatic, programmed re-tuning is often not efficacious;
- Often not repeatable on previously used sweet spots (locations where g^2/Hz are not vastly different) when another chamber of same model (e.g., 30" x 30" RS table) is used and even when same serial number chamber is used again;

• Has poor uniformity of vibration across table, which means when multiple units are screened some may be understressed and some overstressed. Either way, this can result in early fallout in field operation;[4]

• High risk in *substituting* for qualification test vibration specifications. Has low displacement (energy) below 300–400 Hz and almost none below 100–200 Hz. Nearly all important shipping and handling frequencies are in range below 300 Hz. This means that a key purpose of ESS to do Highly Accelerated Stress Screening (HASS) prior to qualification testing to ensure passing is *violated*. Therefore hardware failures can be encountered in qualification test as well as in fielded products in which electronics see large displacements at low frequencies which are not reproduced when using RS shakers;

• One RS OEM company president admitted to the author, "Your company cannot write a suitable, repeatable manufacturing process procedure for any supplier to use directly."..."[4]

• Robust designs have been identified by RS OEMs as being a prerequisite if a product is expected to pass HALT and HASS. Overkill design usually results in overkill costs and extended schedules. In a military or commercial environment, either of these can threaten competitive position and devastate sales.

6DoF high-frquency summary—Significant and strong PSD levels are generated in the 2,000–6,000 Hz range by 6DoF machines. Where extreme caution is not taken, 6DoF vibration will overstress small parts that are defect-free to destruction, or worse, weaken them to be broken in the service environment. Unfortunately, there is no caution that can be taken to preclude this high-frequency overstress condition.[5]

Overall summary—6DoF vibration frequency range from 0–20,000 Hz does not relate to product life cycle or the service-field environment. 6DoF vibration is simply that vibration which can be generated by an air hammer arrangement. 6DoF shaker design bears witness to a total disregard for military product vibration screening considerations.[5]

gRMS-to-gRMS variance for multiple units mounted on 6DoF shakers is significant and uncontrolled. Recall the Lockheed Martin card test and the Dr. Liu and Howe paper.[5]

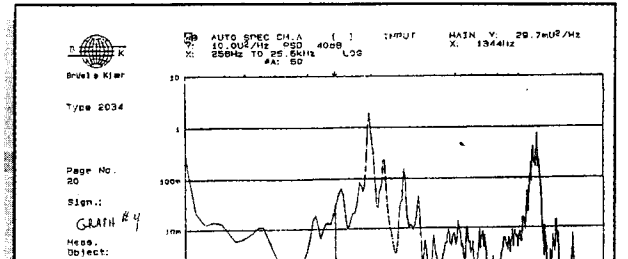

FIG. 1—Repetitive shock stimulus measurements from 256 Hz to 25,600 Hz.

[This article will continue in TEST's December/January 1998-99 issue with a discussion of the advantages and disadvantages of electrodynamic shakers for ESS.]

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