Improper Environmental Stress Screening can damage your product—Part II

[This article is continued from* TEST'*s October/November 1998 issue, pages 22–23, where the author discussed the advantages and disadvantages of repetitive shock for ESS.]

By EDWARD HOWE
Howe Consulting
San Jose, California

Electrodynamic shakers (EDS) advantages—

- Gives authentic, true, controllable random vibration, including random-on-random from 20 Hz or lower, to 3,000 Hz, with no damaging high frequencies (Figures 2* and 3);
- Offers uniform three-axis vibration inputs with low-weight, tilted honeycomb head expander that can meet three-axis qualification test requirements *in one setup* (Figures 4 and 5);
- Meets recommendations of IES Management & Technical Guidelines for the ESS Process for the Step Stress Concept-Relation of Environmental Levels between 20 Hz or lower to 3,000 Hz. Specifically this prevents product damage by maintaining product screen level below design limit and higher than the design requirement throughout all frequency ranges. To avoid product damage throughout production-level ESS, no stress should be allowed to exceed the design limit at any frequency as shown in Figure 7;
- Can shape spectral density (G^2/Hz) to virtually any profile without misleading filtering;
- Low technical risk;
- Equipment available at most subcontractors/suppliers, and environmental test laboratories;
- Can offer simultaneous vibration and thermal cycling by wheeling a movable thermal type chamber over vibration table;
- Offers separate vibration and thermal cycling if necessary to reduce costs.

EDS Disadvantages—

- If simultaneous thermal cycling is specified, then *an initial investment* is required to retrofit existing or to fabricate a new, movable thermal chamber to attain a 40 degrees C per minute maximum capability product ramp rate. Currently the author recommends 25 degrees C ±3.5 degrees C product ramp rate as effective for most electronics.[6]** The fastest thermal ramp rates currently imposed on MIL semiconductors are specified as 10, 18, and 21.5 degrees C per minute using fluids, not air. There is no specified maximum thermal ramp rate identified on commercial or industrial-grade semiconductors;[7]
- Requires *initial one-time, nonrecurring investment* of lightweight carbon composite, and aluminum-epoxy bonded honeycomb head expander mounted to a tilted, welded magnesium conical adapter skewed to generate vibration in three axes. When this was practiced in late 1996, early 1997 at Quanta Laboratories it was proven successful for a 20 x 20-inch head expander operating at room temperature (Figure 4);
- It is slightly more difficult to mount test articles on the tilted surface of the honeycomb expander head than a conventional horizontal surface, which results in a small increase in setup labor;
- Limited to *useful* frequency range between five Hz to 3,000 Hz. However, above 2,000 Hz is usually not required;
- High stress vibration and thermal proof tests of composite, tilted head expander have started, are in process and will be reported at a later date (Figures 2, 3, and 5).

Facts of life about accelerated testing and a final warning about seductive models—

"Accelerated testing is always promoted in positive terms. There is never any down side or negative consequence. However, I would like to leave you with a final word of caution: when we apply exaggerated environmental test conditions, we face the very real risk that the undesirable effects of invalid assumptions and poorly defined boundary conditions will equal or outweigh the good that we hope to achieve.

"There are no 'magic' math models that simply, conveniently, and accurately determine the life of manufactured assemblies and products. When all is said and done, good accelerated testing relies on more than good laboratory procedures. Ultimately, success depends on ensuring that everyone has reasonable expectations of what these product development tools can and cannot do."[8]

[The author adds: This includes exaggerated, positive-sounding claims of large reduction in production ESS time. Time reduction claims are based upon high levels of product vibration, excessive high and low temperature range levels, excessively rapid rates of change in temperature, all of which often result in early field life-cycle damage.]

Author's editorial comments on repetitive shock (RS) equipment—

- It is *perceived* and promoted by RS OEMs that the in-phase excitation forces of a tilted-head expander in three orthogonal axes are not as effective as RS independent phase forces. However, the effect of the independent phase excitation forces with three-axes rotational vibration has not been proven adequately strong to effectively precipitate defects, plus the author believes that it has not been proven empirically (experimentally) by comparison screening of same product samples;
- It has been alleged to the author by

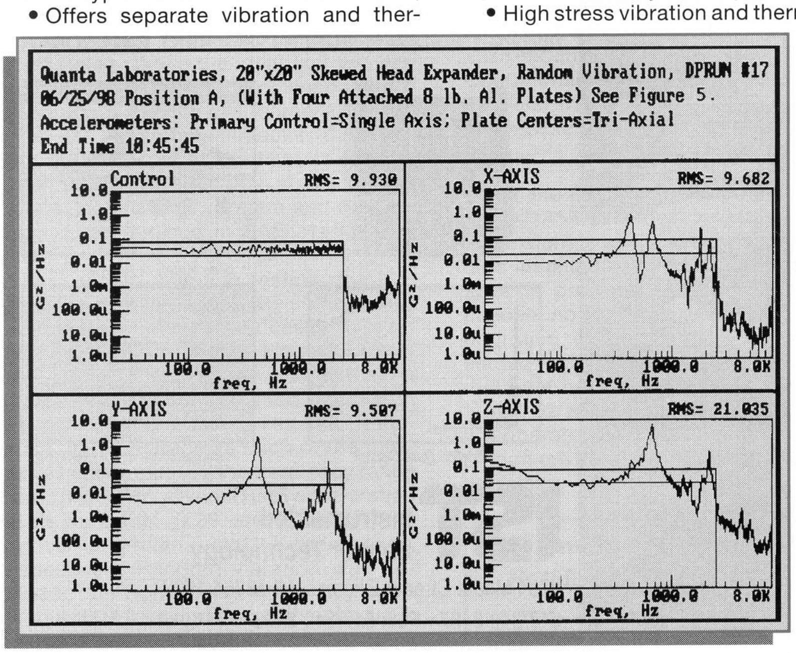

FIG. 2*—Electrodynamic shaker, product output G^2/Hz.

***Edward Howe** is owner of Howe Consulting, San Jose, CA. He has prime responsibility for consultation in Environmental Stress Screening and Producibility (technology for dependable design, manufacturing, and test processes) involving electronics. He holds a mechanical engineering degree from Steven's Institute of Technology and is a licensed Professional Engineer. Since 1989 he has developed course syllabi and instructed ESS seminars for Quanta Labs, the American Society for Quality Control, the US Army Tank Automotive Command, many military and commercial companies from Asia, the US, Canada, and Europe.*

**Figure 1 appeared in Part I of this article—October/November 1998 issue, pages 22-23.*
***References 1–5 were used in Part I of this article.*

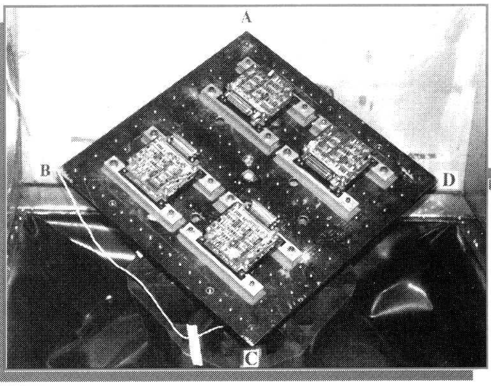

FIG. 4—Quanta's patented ESS test system (skewed head expander).

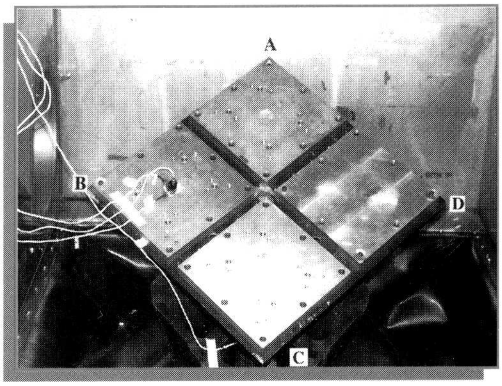

FIG. 5—Skewed head expander with eight-pound aluminum plates.

technical representatives of RS equipment OEMs that the deficiency of vibration input (G^2/Hz) at low frequency can be overcome by special design of product fixturing. To date, requests to demonstrate performance of such fixturing has been avoided and no experiential proof has been observed for *production* application with multiple products in a batch run;

• Reports keep coming in from *many* firms who have RS equipment and have decided not to use the vibration capability because of non-repeatability and because it is believed to induce damage that shortens product life. Many of these firms continue to use the RS chambers solely for high-rate thermal cycling;

• Rather than depend upon very smooth, polished, ESS anecdotal advertising, factually demonstrated ESS information is a must. The scientific approach must be taken to avoid damage to electronics products during assembly testing and ESS to help electronics manufacturers decrease capital equipment, floor space, and labor costs while increasing quality and production throughput;

• It is alleged that lots of defect fallout during RS ESS verifies equipment effectiveness. In reality, many of these defects are introduced or induced into the product, not from inappropriate design, but because design limits are exceeded in the ESS process.

References

1. Lau, John H., Pecht, M. G., and Lall, Pradeep, "*Influence of Temperature on Microelectronics and System Reliability,*" page 779.

"Transistors with glass & ceramic components have a history overstressing and breaking wire leads in the 4000 to 7000 Hz frequency range which is not encountered in normal operation. Crystals are also caused to break at high frequencies. Fractures are encountered with solder to gold embrittled joints which are relatively new. In the Chapter on *Mechanics of Wirebond Interconnects,* *22.3.8 Vibration Fatigue* reports that: *"Harman found that vibration forces that occur in the field are seldom severe enough to cause metallurgical fatigue or other bond damage... Shaft calculated the resonant frequency as well as centrifuge-induced forces for gold and aluminum wire bonds having various geometries. The minimum excitation frequency that might induce resonance and thus damage gold wire bonds having typical geometries was found to be in the range of 3-5 kHz. For most aluminum wirebond geometries, the resonant frequencies required to damage the bonds were found to be greater than 10 kHz."*

2. Bastien, Gilbert J., report on "*High Frequency Vibration (5-10 kHz) in ESS,*" presented at Tandem Computers, Inc., Cupertino, California, Sept. 7–8, 1995, submitted to IEEE/CMPT Technical Committee on ESS and Reliability Testing.

3. Quote of 03-06-97 in personal telephone conversation between the author and an RS technical consultant.

"We use two filters, one analog and one digital. Nonetheless high frequency stress stimulus is put into the product even though the spectral density G^2/Hz data shown in the display is filtered (conditioned) to appear as if it doesn't exist, or as if it drops off rapidly which it does not:

--The analog filter affects the display only, nothing is done to attenuate or to modify the actual vibration stimulus to the product

--The digital filter does signal conditioning in the zero to 3,000 Hz frequency range for recording and conditioning the G^2/Hz calculation to Grms. It does nothing to attenuate or to modify the actual vibration stimulus to the product which ranges up to and beyond 20 kHz."

4. Howe, Edward, and Liu, Dr. H. S., "*Environmental stress screening, equipment: search, evaluation, design, experimentation,*" TEST Engineering & Management, Aug./Sept. 1994, page 10.

"Tight ESS tolerances? *Some equipment manufacturers claim uniform, repeatable vibration tolerances are not needed. Assuming design ruggedization (a robust design to begin with) as a precursor to HALT, all units can be subjected to an ESS level high enough to precipitate flaws/defects, say these manufacturers. Papers have been published by an RS OEM supporting this flawed reasoning, such as 'Is Uniformity and Repeatability Essential to Vibration and Temperature Screening?' This published paper claimed that the Proof of Screen (POS) is sufficient to verify that no serious damage has been imposed upon the product screened. The article has some strong points to consider. However, there are also weak points, which include:*

• To conserve \$ and product assets, POS is often conducted at the center of a RS table. This is not representative of a production run where either understress or overstress is imposed upon a number of products located at different positions on the table which has very large variations in G^2/Hz;

• Temperature and vibration variations ➔

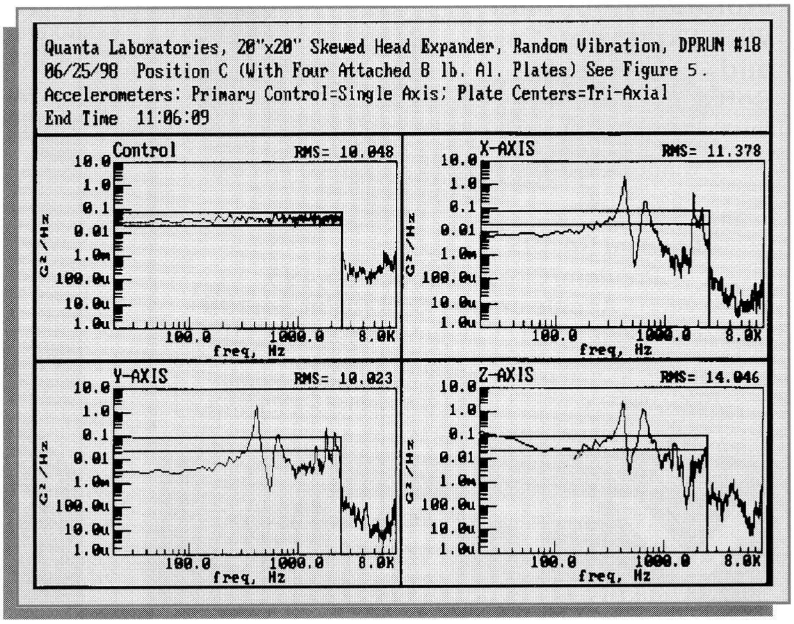

FIG. 3—Electrodynamic shaker, product output G^2/Hz.

Improper ESS (continued)

throughout the chamber are identified to be 'without concern for the variation if and only if a proper POS has been done.' This implies a very robust design to begin with, which is not always an available luxury in either commercial or military electronics, whether in new or already manufactured products... Nevertheless, a screen is a process, and like all manufacturing processes, it must be controlled within practical limits to be repetitively effective. Therefore, the authors aggressively propose the need for <u>practical uniformity of vibration response</u>."

5. Walkowiak, Paul, United Defense Limited Partnership, White Paper, "*Assessment of 6DoF Vibration Screening*," circa 1997.

6. Pachucki, Dennis, two ESS technical papers on Taguchi Design of Experiments with Sun Microsystem Computer Corporation's boards: • IEEE, May 1994 ECTC, 1,800 large (8.5 x 11") printed circuit boards; • IES, May 1995, 600 small (3.25 X 5.75") printed circuit boards. This second experiment proved 20 degrees C per minute product ramp rate to be reasonably effective to avoid overkill. Mr. Pachucki told the author to remind peers that ESS must be tailored to the product. Therefore, different vibration levels and different ramp rates should be developed for different products.

7. MIL-STD-883D, Test Methods and Procedures Microelectronics, Method 1011.9, Thermal shock. Note—fluids, not air—are used.

8. Caruso, Hank, "Taking a look at Gs and Degrees™," TEST Engineering & Management, Dec./Jan. 1997-98, page 7.

SINGLE-AXIS ELECTRODYNAMIC SHAKER (EDS)
& REPETITIVE SHOCK (RS) SHAKER
COMPARISON USING SAME FOUR PRINTED CIRCUIT BOARDS

Percent variation in three axes (X, Y, Z) of same product in similar positions as shown in Figure 4

Equipment*	Position A	Position B	Position C	Position D
RSS	41%	41%	38%	38%
EDS	2%	11%	11%	11%

Note: * RSS shaker table was 30 x 30 inches, EDS shaker was 20 x 20 inches with skewed expander head. Testing completed at Quanta Laboratories, Santa Clara, California, December 1996, January 1997.

FIG. 6.

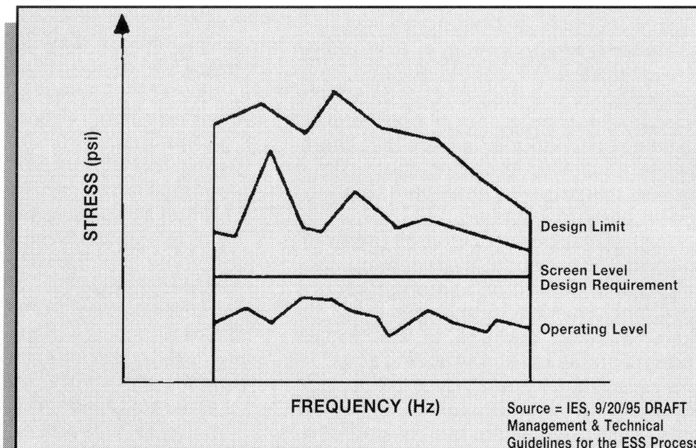

FIG. 7—Step stress concept—relation of environmental levels.