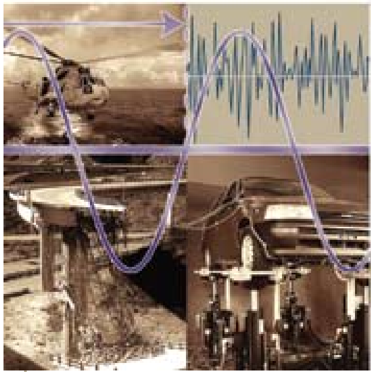

ERI News

your reliability newsletter

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In this issue...

Keys to good HALT and HASS

by Daniel Sharpe

I'm often asked, "What is needed to get HALT/HASS going in a company?" Or, "What's the best way to set up a vibration and shock lab to help improve reliability?" With such a broad range of equipment, procedures, and methods it's important to develop strong fundamentals well before the first test ever commences. By focusing on three key elements: people, procedures, and equipment, we can do ourselves a great favor towards making these programs successful.

Start with people

Investing in HALT (highly accelerated life test), HASS (highly accelerated stress screen) programs, or a shock and vibe lab can be a daunting task. For a HALT or vibration program to be successful it must have support from management and engineering with regard to the goals and values of a particular program. An initial area to focus on with management is getting the right people hired and trained before chambers and vibration systems are considered.

It's critical to have personnel specifically trained and experienced within the vibration and accelerated testing disciplines. While the physics are, for the most past, not very complex, those with little or no experience in these fields can find themselves easily overwhelmed and destined to struggle.

Companies like Equipment Reliability Institute are great starting places to develop people within your organization. They provide specialized training and certification programs to help understand the vibration and testing topics normally not associated with general engineering disciplines. When we look at how much time and money is invested in equipment and lab accommodations, making sure the right people are trained and in place can easily make or break programs like these.

Industry consultants and equipment manufacturer training are also valuable sources of information. While generally not a long-term investment, these options provide management and engineering with experts who can help guide these programs to success and should be involved with program development as early as possible.

Voice of the President

Meeting Wayne in May

I'm going to attend two meetings in May: The IEST's (Institute of Environmental Sciences & Technology) ESTECH 2010 - May 3-6 at the Atlantis Hotel at Reno, Nevada and the ITEA's Test Instrumentation Workshop - May 10-13, at the Tuscany Suites and Casino in Las Vegas, Nevada.

At ESTECH I will talk about "Fixturing - The forgotten keystone of a successful vibration/shock test". I will commence by considering the armature of a typical electrodynamic shaker, and will point out that it often has undesirable resonant motions. Why? Because often the armature resonates, even though its development may have spanned years. The test fixture designer may have only hours. So it is no wonder that fixtures often resonate. I will also discuss problems with attachment bolts. In addition to my announced paragraph topic, I will also recommend

Procedures and organization
Very often in larger companies test programs can fall under business groups that create long -lasting problems. For instance, having the HALT development tool run by a quality or reliability group can often create barriers to a successful HALT culture.

Why? Because a quality or reliability engineer may not have the authority or technical background to implement the important design changes we find in a HALT event. Design engineers may not be accommodating of suggestions made by quality groups after product development phases have reached critical bench-marks. Keeping these powerful tools —HALT/ HASS and vibration and shock— in the hands of the research and design groups is a very important element to remember. Designers need to feel they can freely utilize the benefits of HALT findings in order to ensure a more robust product which is then followed up by a HASS or ESS program guided by a quality or reliability.

Once the design groups have established ownership of HALT, then we need to avoid the use of longstanding procedures which may not fit the HALT test structure, or developing test documents which are too specific and may actually hinder the HALT process.

It's not uncommon to see procedures derived from specifications written in the '50s still being blindly followed in labs today. While documents like DO-160 and IEC 60068 are excellent for reference, we need to focus on tests that actually test our products in meaningful ways.

Looking for ways to cause the product to fail in the lab is the ultimate goal of a HALT event. This will deviate from most longstanding procedures and cultures, which focus only on passing a test, but is important to embrace for these programs to succeed. To reiterate my first point, with properly trained people in place, developing procedures and best practices that assist the HALT process becomes a habit. These tests do little for us, in terms of discovering latent failures and reliability flaws, when we allow procedures to limit what we do in the HALT process.

Equipment is critical
Once people, procedures, and organization have been considered, it's time to place the equipment. Once again we see tremendous advantage in having people with experience and training in these specialized fields. Installing a vibration table or liquid nitrogen -driven HALT chamber has many hidden concerns that must be dealt with, and the sooner they are the better. While equipment manufacturers have come a long way, dedicated company or lab personnel familiar with the various issues of our discipline are, once again, important.

We must think long-term about our equipment. If you start a HALT program today, then you'll want to continue into HASS tomorrow. Make sure your labs and facilities can support expansion and new equipment. Make sure the shakers and chambers you buy today will support the tests and products you'll be building in the future.

It's also critical to find equipment manufacturers who offer support for their equipment before and after the sale. Not only should they provide parts and maintenance but also offer training and indoctrination in support of the test culture you're building. We can spend a lot of capital on equipment that will sit for months while an untrained engineer or technician muddles through manuals and schematics. Having an equipment manufacturer who's dedicated to your success in HALT testing will help to avoid this pitfall. Some of the best equipment manufacturers will provide onsite application training, help management to understand the benefits of these tests, and cover industry best practices as well.

Much of what happens in HALT cannot be gleaned just from seminars and articles, but must be learned with hands-on experience. The equipment manufacturers that provide

one simultaneous multiaxis test rather than the current sequential axis testing; one advantage: one fixture instead of three.

At the Test Instrumentation Workshop event at ITEA, my announced subject is "Vibration and Shock are Multiaxis ". For some in the audience, it will be an introduction to simultaneous multiaxis vibration testing using, obviously, three or more shakers. That's well accepted amongst the folks who shake automobiles, using three or more electrohydraulic (servohydraulic) shakers. Those using mechanical and electrodynamic shakers have closed their eyes to the simultaneous multiaxis vibrations commonly found in the "real world." Most use last-century technology: shake the product in its X axis, then shake the product in its Y axis, then shake the product in its Z axis. Three tests. Occasional field failures can lead one to decide that labs have been undertesting. Simultaneous multiaxis using mechanical shakers is something new, and I'll show videoclips. I'll also ask audience members to speak with the military and commercial folks who buy hardware and urge that they adopt Test Method 527 in the October 2008 MIL-STD-810G.

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help in this area should be considered above all others.

Conclusion
In all cases, success or failure of programs I've been involved with has depended on these critical areas: people, procedure/organization, and equipment. When one is neglected or improperly executed things can bog down quickly. Yet, when we dedicate our time and resources to planning these programs, guided by experienced professionals in the fields of HALT/HASS and vibration testing, we can develop these competitive tools and excel in our ever-demanding marketplace.

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Daniel Sharpe is the senior design assurance technician at Rockwell Automation's plant in Mequon, Wisconsin, where the focus is on industrial automation and power control systems. Prior to that, he worked for 13 years for Astronautics Corporation of America, Milwaukee, Wisconsin, developing HALT and HASS strategies for military and commercial avionics systems. Dan has completed Equipment Reliability Institute's Vibration Technologies certification program, and is currently pursuing a degree in business management.

Stories from the Field...

Why you need to see for yourself what happens to your products. What must your products survive in shipping and warehousing?

by Kevin Howard

Story 3: Large machines
Several clients over the past couple of years have been manufacturers of large, heavy, expensive, sophisticated electro-mechanical machines. Curiously, these products from completely different industries exhibited some common problems. One interesting aspect was the lack of pre-shipment transit testing for many of these products.

One product ranges from 16' to 25' in length and weighs about 5000 lb. These products require fine calibration at the manufacturing site, with a precision of about 0.001" between one end of the machine and the other. One of the problems this company wanted to resolve was the recalibration that had to be done to many of the longer machines. Recalibration in the field takes significant time and effort by the installer. The company's initial thought was that shock and vibration in transit was causing the problem. Though shock and vibration problems were causing various problems in the field, they were not the initial input that caused the product to go out of calibration.

The machines are built with finely tuned balance-bubble levelers imbedded into various parts of the products. The product is completely assembled and functionality is verified through an extensive testing cycle. Once the unit is proven to be good, a forklift driver simply picks up the large unit at its center point and places it onto a very long wooden pallet. Watching this maneuver, it was obvious the product sagged far beyond 0.001" from end to end. Once the unit was bolted to the pallet, the standard forklift with 4' long tines then picked up the palletized load from the end to drive it into a truck. The pallet is longer than the product so it can accommodate a number of accessory boxes onto the pallet, resulting in some pallets over 30' in length. As a result, the tips of the forklift

2010 "Open" Courses

Fundamentals of Random Vibration and Shock Testing, Measurement, Analysis, Calibration, HALT, ESS and HASS taught by Wayne Tustin or Steve Brenner at the following locations:

May 10-12, 2010, Santa Clara, California

August 24-26, 2010, Santa Barbara, California

October 20-22, 2010, Orlando, Florida

November 8-10, Boxborough, Massachusetts

Steve Brenner will teach **Military Standard 810G (MIL-STD-810G) Testing - Understanding, Planning and Performing Climatic and Dynamic Tests** on the following dates and locations:

May 17-20, 2010, Cincinnati, Ohio

November 1-4, 2010, Orlando, Florida

Kevin Howard will teach a new course in **Distribution, Packaging and Testing**

September 13-15, 2010 Eden Prairie, Minnesota tines contact just beneath one of the two legs of the machine. No matter how much wood is used in making a pallet, it still flexes a bit, especially with such extreme loads on such a small fork lift tine. The scene was like watching a very long diving board, heavily loaded on one end, being driven over the dock floor and causing bouncing. The combination of too flexible of a product, set onto too flexible of pallet, and then handled with fork tines that were too short and too narrow to appropriately spread the load, all conspired to cause the unit to go out of calibration before ever leaving the parking lot. Simply taking the product back out of the truck and off the pallet would show the amount of degradation due to lack of stiffness.

The solution set for the above problems included:

1. Stiffening the product to allow it to be picked up without noticeable movement.

2. Replacing the wood pallet with a welded steel pallet. Steel pallets are more robust, less flexible, can conceivably be returned for reuse, and can be recycled…something which wood pallets with many nails and screws would never be.

3. Replacing the standard fork lift tines with much longer and wider tines to reduce stress on the product.

It was very interesting to note that the engineers of these incredible machines had never looked at the material handling and dynamic inputs the machines must survive after that final verification on the floor. This same scenario was repeated for the other clients, where products or sub-assemblies rarely received pre-shipment laboratory or field tests.

Story 4: Observing your own tests may be the key to reducing costs

Packaging engineers are supposed to design packages that will survive the distribution system, let alone communicate information, produce an enjoyable out-of-box experience for the consumer upon opening the package, and minimize costs. In lieu of trial shipping all new designs through distribution, most large companies opt to test their packaged product in a laboratory. The tests and their intensity levels are supposed to help assure minimal risk to the business of suffering catastrophic failures in distribution. The problem is that many companies end up with excess packaging due to lab tests that are not reflective of the true hazards found in distribution. Another problem is that lab procedures may not be very sophisticated and cause needless amounts of packaging.

This is a story of a computer company that had set itself a standard for all bare products to have a minimum fragility level of 30 G's, as defined on a shock table using ASTM D-3332[1]. There were three problems:

1. One Division interpreted this requirement as also meaning that a cushioned package should not allow more than 30 G's of shock into the product when dropped from a certain drop height.

2. This site tested the bare product only to the 30 G level, thus leaving open the question as to how much more robust beyond 30 G's the product may actually be.

3. The lab tech did not filter the shock pulse correctly during the free fall drop test. As a result, the jagged pulse reported a peak level of 35 G's. However, if the pulse was filtered correctly, the peak level dropped to the mid-20 G level.

The above drop test caused no product failure. The lab manager decided not to accept the filtered shock pulse since it would mean his historical data would not be seen as accurate. So even though there

Vladimir Valentekovich will teach **Pyrotechnic Shock Testing, Measurement, Analysis and Calibration**

October 12-14, 2010
Santa Clarita, California

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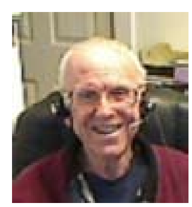
ERI Instructors Assist New Environmental Publication

Have you been receiving Environmental Test & Design or ETD? It's a new newsletter covering the inter-relationship between electronic products, systems and devices and their environments.

Two ERI instructors, Wayne Tustin and Steve Brenner, are on ETD's editorial board.



Can We Make a Date for a Skype Call?

Nominally, you can call wayne.tustin between 8am and say 8pm, occasionally earlier and occasionally later. Scheduling calls is a good idea - either a Skype text message or an e-mail.

was no product or package degradation from the test, and even though there was recognition that filtering correctly would have changed the results, the packaging engineer was forced to increase the amount of cushioning, increase the box size, and increase the costs to the company, all for no apparent value. The point: packaging engineers need to be engaged in the testing of their packages to assure appropriate methods are employed and reflect the true conditions found in the distribution system.

Reference:

(1) ASTM D-3332, Standard Test Methods for Mechanical Shock Fragility of Products, using Shock Machines.

Kevin Howard - Kevin, an ERI Specialist, is a well known leading expert in the field of packaging engineering. Kevin specialized in distribution packaging and testing in school and has applied this knowledge over the past 25 years to generate some of the largest cost savings in packaging history.

Kevin will be teaching a new course in "Distribution Packaging and Testing - Design for Distribution - Proven Methods for Reducing Costs and Damages" on September 13-15, 2010 at Eden Prairie, Minnesota

The Full Circle of Engineering Education

by Tom Irvine

I express greetings to the readers of this newsletter. This article has several related themes. The main purpose is to give an overview of the engineering education process, relating theory to practical application. As part of this overview, I express gratitude to the scientists, mathematicians, and engineers who have guided my own education. This education is the foundation of my engineering career, as my experiences demonstrate.

Like many of you, I spent my college years taking meticulous notes as the engineering professors at Arizona State University wrote one partial differential equation after another on the chalkboard. I became immersed in the theories of Newton, Bernoulli, Euler, Gauss, Fourier, and Laplace. I also studied the theories of Lord Rayleigh, Jacobi, Galerkin, Bessel, and Lagrange in acoustic and vibration graduate courses. Every engineering problem had a neat and tidy solution, as evidenced by the format of each question in the final exams. The whole Universe behaved in a well-ordered and predictable manner. Even when the Universe began to stray into some random pattern, a Fourier transform could easily be taken to restore order in terms of a series of sine waves. I entered the workforce at Motorola eager to show my expertise by perhaps solving a differential equation, thereby saving the company vast sums of money. There were no differential equations, however. My idealism thus hit a brick wall. Instead, I discovered that engineering as practiced in industry was a completely different world than engineering as taught at the university. Engineers in industry have little time to muse upon theory. Rather, they rely on empirical approaches! These empirical case histories are incorporated into military and industry standards. Examples of well-used standards include:

- MIL-STD-810E, Military Standard, Environmental Test Methods, Department of Defense, Washington D.C., 1988.
- MIL-STD-1540C, Test Requirements for Launch, Upper-Stage, and Space Vehicles, Department of Defense, Washington D.C., 1994.

Find *all* the Failure Modes

Here is an old story .... one that bears repeating.

Back around 1955, some of our then-new autopiloted rockets were failing at ignition or at liftoff. Of those that survived liftoff, most veered off course and had to be destroyed in flight.

Why? Vibration was blamed. More rigorous vibration was adopted.

But failures persisted.

Why? We were using old-fashioned one-frequency-at-a-time sine vibration tests. Scientists of that era, examining telemetered records of in-flight vibration found that rocket-induced vibration was "different." That spectra were continuous, different from the discrete-line spectra found on propeller-driven aircraft. Continuous-spectra "random" vibration was adopted. Why? To find all the failure modes. By and large, we have been successful. Most launches are successful.

But we still have occasional vibration-induced failures.

Why? Because we (most of us) still shake our hardware with the last -century practice of sequential axis testing. 3 tests. Even though our triaxial accelerometers and triaxial force sensors tell us that X, Y and Z vibration axes exist simultaneously.

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- NAVMAT P-9492, Navy Manufacturing Screening Program, Department of Navy, May 1979.
- Himelblau, Piersol, et al., IES Recommended Practice 012.1: Handbook for Dynamic Data Acquisition and Analysis, Institute of Environmental Sciences and Technology, Mount Prospect, Illinois.

As a newly hired engineer, I had to set aside theory in order to make room for the empirical case history approach. I was particularly bewildered by the "shock response spectrum," an empirical tool for shock testing. Fortunately, some managers gave me photocopies of papers by authors such as Himelblau, Steinberg, Caruso, Szymkowiak, Moening, and Chu.

A particularly useful paper was "Understanding and Measuring the Shock Response Spectrum" by Tustin and Hieber. Curiously, this paper was offered as a Spectral Dynamics technical publication rather than in a college textbook. I soon discovered that some of the most practical information available was given as tutorials in vendor catalogs and in equipment user manuals.

I left Motorola to take a position at Orbital Sciences Corporation in 1988. My first task was to apply empirical approaches to the initial Pegasus launch vehicle. This vehicle would be carried to an altitude of 40,000 feet by a B-52 aircraft. It would deliver a small satellite into low earth orbit.

One of my duties was to measure pyrotechnic shock levels during ground tests, as generated by the linear shape charge used for stage separation. Next, I derived the avionics component qualification shock test levels. I carried out the component shock tests using a resonant beam and a pendulum hammer. The electrical engineers became very anguished as crystal oscillators and other components detached from circuit boards due to the severe shock loading. We fixed the design problems. The initial Pegasus launch, made on April 5, 1990, was a success.

The pace of the Pegasus program had been understandably frenetic. Afterward, I had time to review what we had actually done. During this period, I came across another set of papers by authors such as Piersol, Smallwood, and Nelson. These authors seemed well versed in the empirical methods, yet they seemed equally comfortable with mathematical theory. I revisited my Thomson vibration textbook from college. I was surprised that Thomson had actually discussed a form of the shock response spectrum. His presentation was brief, but the essential pieces were given. In the great tradition of college textbooks, the substantial steps of the derivation were left as a "student exercise."

I then realized that I could derive the equations underlying the shock response spectrum starting from Newton's law and continuing with Laplace transforms. The arbitrary base excitation function required a convolution integral, but the integral could be modeled with a series for the case of digital data. A Z-transform could then be used to derive a corresponding digital recursive filtering algorithm. Enlightenment! A bridge between the practical empirical approach and venerable theory! T.S. Elliot wrote, "We shall not cease from exploration, and the end of all our exploring will be to arrive where we started and know the place for the first time."

ERI includes two of my mentors, Wayne Tustin and the late Allan G. Piersol. Each has written a myriad of tutorials, papers, and books, as well as teaching numerous courses in shock and vibration testing and analysis. I invite you to take advantage of their courses.

Tom Irvine - Tom has over twelve years experience in mechanical engineering, specializing in acoustics, shock, vibration, and signal processing. Tom has written programs to perform digital filtering, shock response spectrum analysis, Fourier transforms and other functions.

Should we shake in all axes simultaneously? I think so. Prototypes of your automobile have long been simultaneously shaken in all axes, guarding against simultaneous inputs from the road during driving maneuvers. Guarding against simultaneous inputs from the railcar carrying them from factory to dealer. We lack space here to show such tests, but I'll be happy to send you a couple of PowerPoint slides to use in your discussions.

A few US Army, Air Force and Navy labs have piled up three ED (electrodynamic) shakers to simultaneously shake in multiple axes. I'll be happy to send you a couple of PowerPoint slides.

Why is this done? Why was Test Method 527 added to Military Standard 810G? To find more failure modes. Could your lab do likewise? Certainly. Or your lab could invest in factory-assembled multiple ED shakers. I'll be happy to send you a couple of PowerPoint slides.

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Visit ERI at LinkedIn and join one of our groups, such as *Vibration and Shock Testing*, where you can comment on multiaxis vibration testing, on hammers for repetitive shock (as in ESS, HALT & HASS) and other subjects.

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Resonant Ruth

Resonance Lessened by Damping – Resonant Ruth's Car Gets New Shocks

"Daddy," complains Resonant Ruth one evening, "My car almost makes me sick. It bounces so much."

"Hmmm," responds her father. "Let's go look at your car."

Standing in front of her car, her father encourages Resonant Ruth to step onto and then to stand on her car's front bumper, while he holds Ruth's hand. "Now, I want you to thrust downward with your legs in a slow, rhythmic manner. Experiment with f_f, your forcing frequency. Find what f_f gives the greatest vertical response."

It takes Ruth only a few seconds to get her car bouncing well. "Now step off and watch what happens," directs her father. They observe that Ruth's car continues to bounce at what her father explains is one of the car's natural frequencies f_n, though with lessening peak-to-peak motion. After perhaps 3 cycles, Ruth's car is motionless.

"Do all cars do that?" asks Ruth.

"No," answers her father. "Let's go repeat that experiment on my car."

Much different. His car hardly respond to Ruth's vibratory excitation.

When she has stepped off, his car has already come to rest.

"Ruth, I want you to diagnose your car's problem. My car doesn't have it. Tomorrow tell your friend Joe, the mechanic, about how your car behaves and about our experiment. Ask how he's going to solve your problem."

They go back in the house, whre her father picks up the newspaper.

Ruth thinks about what she has observed. "My car likes to bounce at that natural frequency f_n. I'll bet it's another example of resonance. Certain road conditions at certain speeds must excite that resonance. Daddy's car doesn't bounce as much in my test. Daddy's car is newer than mine. When my car was newer, it didn't bounce as much on these roads that I drive. Something on my car must have gotten worn."

Resonant Ruth interrupts her father's newspaper to tell him her theory. "You're right, Ruth. Tomorrow, ask Joe to let you watch while he puts your car up on his hoist. Then he can show you what's worn."

Let's flash forward to the next evening. "Daddy, my car is OK again. I have four new shock absorbers, piston affairs that help the springs carry my car, yielding to bumps and dips but recovering quickly. The resonance is more damped. Joe says I have lowered the 'Q' of my suspension's resonance. I feel much safer now."

"And you are much safer, Ruth. New 'shocks,' when needed, are a good investment in comfort and safety," approves her father.

By Wayne Tustin

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