Introduction

Welcome to vibration control. This document has two objectives. The first is to introduce the uninitiated to the uses and techniques of vibration control testing. The second is to arm you, old pro or novice, with the information that you will need to win a sale when confronted with a competitive situation.

What is Vibration Control?

The basis for vibration testing is closed loop control of vibratory excitation, more commonly known as vibration control. Imagine yourself a typical test engineer, a product and a set of specifications have been sent to your lab for vibration testing. To do your job, you will need three groups of hardware (see figure 1): 1) an excitation group comprised of a signal generator (output module), a power amplifier and an electromechanical shaker, 2) a feedback circuit made up of an accelerometer, some signal conditioning and a monitoring unit (input module) and 3) a control unit. As shown in the figure, to perform the test, you send a drive signal from the signal generator to the power amplifier and hence to the shaker. The shaker shakes the test article. The level of vibration is sensed by the control accelerometer, which is monitored in the input module. The controller then makes the necessary adjustments to the drive signal so that the vibration level meets the test specifications. That act of adjusting is vibration control.

The control unit is shown in the figure as a black box, but it could easily be a technician adjusting dials and switches. It can just as easily be a computer. Such a computer-based system is the subject of this document.

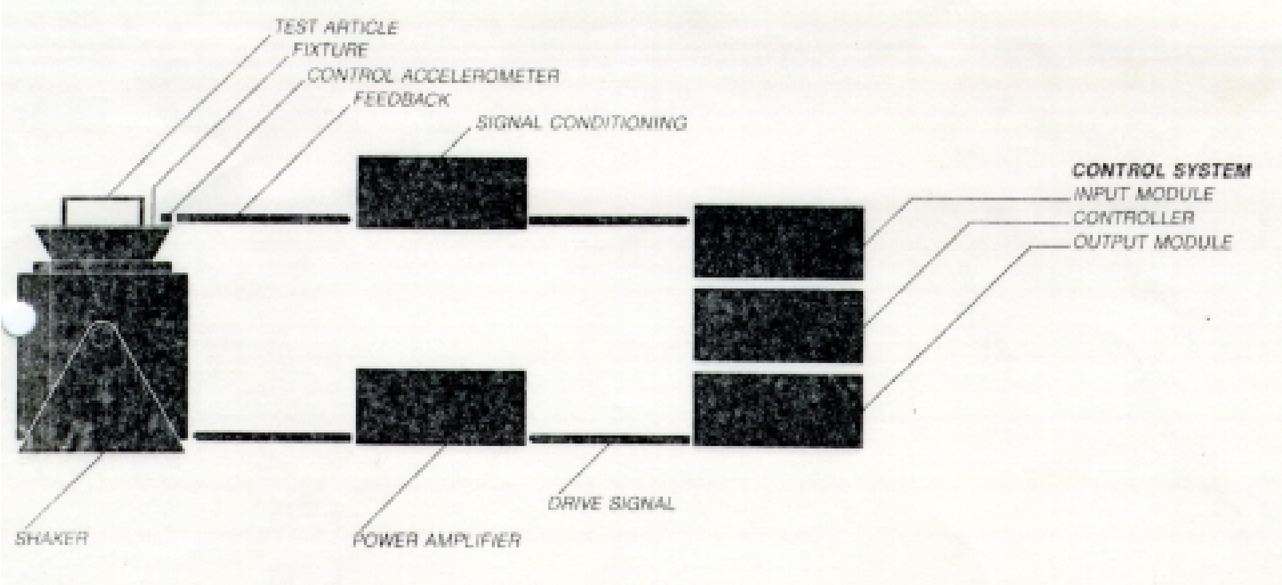

Figure 1: *Generic Vibration Control System*

Types Of Testing

The most commonly used forms of excitations are random noise, swept sine waves or transients (shocks). Random noise is defined by a spectrum that spells out frequencies and magnitudes. The phase of the output spectrum is randomized so that the test article experiences the specified excitation in a random fashion. Random noise is commonly used in aerospace and military applications where attempts are made to duplicate such events as aircraft take-off, rocket launch, or transportation over rough terrain.

The swept sine technique evolved from older technology when only oscillators Where available to provide the drive signals With a sine sweep, the start/stop frequencies, the sweep rates, the excitation levels and the points at which to change level are defined. Many specifications written around sine sweeps remain in force today; however, random noise techniques are proving to be faster and more representative of real world environments and are thus slowly replacing sine sweeps in these specifications.

The last commonly used excitation, a transient or shock, is defined by classical waveforms (half sine, triangular, square, etc. or shock response spectrums or recorded events. Transient excitation attempts to duplicate pyrotechnic events (explosions, gunshots, rocket blasts, space craft stage separations, etc.), drops, crashes, and the like.

Why Use Vibration Control Testing At All?

DESIGN/DEVELOPMENT

Design/development teams need to simulate real world environments in which their product must operate or survive. Some tests are as simple as dropping the product from a certain height or loading it into the back of a truck and driving over the roughest roads in the area. Others are more elaborate: attempts are made to duplicate the vibration history of a flight into space or a trek across rough terrain in a wrecked vehicle. If the product survives in these lab simulations, the design team has greater confidence that it will survive in actual use. As always, actual use or abuse testing will be the final test.

Lab tests are usually faster and thus can identify weaknesses in the design before expensive and time-consuming field tests are conducted. They are easier to instrument and can yield more data for the design team. Lastly, they are more controllable which means that if a very expensive, one-of-a-kind prototype is showing signs of malfunctioning, the test can be terminated or the energy being applied can be decreased so that the prototype can be saved, modified and re-tested.

QUALITY ASSURANCE

Quality control (QC) teams need to determine if the product coming off the production line functions as designed and if it does so consistently. Requirements such as maintaining the company's integrity, fulfilling contract obligations and minimizing warranty costs will motivate the QC team to do extensive testing. Further impetus is provided by military and aerospace contractors who usually have very stringent vibration test requirements for products, which they buy. Because product failure or malfunction can prove disastrous in their applications, these contractors require very extensive and detailed documentation showing that the products have been tested and that they have functioned correctly in the specified operating environment.

Who Would Use And Buy A Vibration Control System?

The question of who might want to buy a vibration control system can be answered in one of two ways. One way is to look at the product and infer whether or not a need exists. An easy to identify group of customers includes the military, the aerospace industry and the automotive industry. These customers know that vibration testing is necessary and need only be shown that one system or another is best for them. They have developed expertise in vibration testing and will remain a major source of system sales. A second large potential market exists in an area where the need for vibration testing is just now becoming apparent: consumer products companies, smaller electronics firms and manufacturers who make products for a vibration environment and have relied upon outside resources for testing. These customers are less aware of the products available for vibration testing and many of them are not aware of the advantages of owning a vibration test capability. Such customers are more difficult to identify.

The other, and probably better, way to describe a potential customer is to identify the sort of work that his group is doing -regardless of the industry. The market can be broken down into three fundamental categories' design/development, stringent testing/documentation quality control and generalized quality control (see summary in Table I). This way of identifying a buyer will be more fruitful because a company, particularly a large one, may have groups performing all these functions and because the requirements for the control system are directly related to the sort of work being done. You can then determine if vibration testing is required for his work and if you have the system to satisfy it.

The design/development customer needs a high performance system that is flexible, fast and able to generate good documentation. High performance, because he will be testing unknown quantities which may be difficult to control, very expensive or the only one in existence. Flexibility because the form of the excitation will be dictated by the test program or the environment; one test may be a sine sweep, the next a random noise simulation of a rocket launch. Good documentation because designers need good information to interpret test results.

The stringent testing/documentation customer is prevalent in the military, the aerospace and the research worlds. Usually very rigid testing and documentation specifications are handed to them there is no choice. Only a high performance control system will be able to pro vide the control needed for the very rigid specifications. Only a complete system can provide the sort of posttest documentation required.

The final type, the generalized quality control customer, will have less rigorous testing requirements. This customer usually tests parts coming off the end of one or more production lines as quickly as possible. Testing is meant to identify obviously bad parts or to determine the general quality of the production run. The control system for this customer need not be very high performance. Oftentimes, these customers have restrictive budgets and require the lowest-cost solution available. These customers often have several production lines, which must be tested simultaneously, again requiring lower cost solutions.

Distinctions between the last two groups can be, and often are, very fuzzy.

A few points to remember as you are qualifying a customer. The first is that the cost of the control system, which we are discussing in this primer, is actually a smaller part of the cost to a customer to set up a vibration testing capability. A full-scale vibration control system ranges from $40K to $80K depending on the channel count and if every option is purchased. The power amplifier and shaker combination large enough to shake a 44pound (20kilo) instrument vigorously can cost in excess of $200K fairly easily. After installation of the shaker, a power supply, cooling air or water supplies, instrumentation and wiring and purchase of fixturing to hold the parts onto the shaker, the customer could spend $500K before testing a single item. Cost differences between control systems become secondary to performance differences in the context of the entire cost to establish a vibration testing capability.

The working environment for these systems is also quite different from a classical electronics application. At times, unlike most electronic test setups, which try to test the item without disturbing or damaging the test article, vibration tests are often programmed to test the part to failure, even to total destruction. At other times, expensive one-of-a-kind prototypes will be tested and damage will be avoided at all costs. Many times, more than one test will be running simultaneously. For example, a communications set will be mounted onto a shaker for vibration, the shaker in turn installed in an environmental chamber for simultaneous temperature and humidity testing and finally an electronic performance test will be run concurrently.

The important message in these points is that the customer must be encouraged to look beyond his immediate testing needs and thoroughly examine his needs in a control system. He must decide: 1) if he will commit his controller to a single task for an extended period of time or commit it to a variety of tasks, 2) if he wants to save money in the control system portion of his test setup or if he will budget for the control system as the most important part of his setup and 3) if he has needs for a flexible, high performance control system or if he has need of a lower performance system. Because of the relative cost of the system and the difference in working environment, the customer may not expend as much energy making these decisions as might be warranted.

KEY CUSTOMER TYPES

Vibration testers can also be lumped into 5 major industries: the military, aerospace companies, automotive companies, electronics firms and consumer products companies. In general, one could say that the higher the technology the greater the need for controlled vibration testing. Some key industries are:

MILITARY

Defense agencies customarily require vibration control testing for all their radar, communications and electronic equipment. The various projects developing new weapons and equipment for military use rely on controlled vibration testing to solve problems with new prototypes. Once in production, the testing often intensifies with 100% testing of some items and extensive documentation of most items.

AEROSPACE

Military aircraft development programs and commercial aircraft certification requirements have brought a great deal of vibration testing to the aircraft manufacturers. The requirements of various space programs for equipment, which is absolutely reliable, has spurred significant vibration testing efforts. In this environment, the items being tested are very expensive and usually one of three or four in existence.

AUTOMOTIVE

With the increased use of microprocessors and electronics, vibration testing is becoming more and more important in this industry. Before the advent of electronics, a fair amount of testing was done to ensure that bumpers, mirrors, doors and the like would not fail in service. Suspension systems were cycled, steering gear stressed and various mounts flexed with a variety of excitations and control schemes. Actual use of the prototype was and still is one of the most important tests for the automotive industry. Digital vibration control systems have been in use for a number of years and the number continues to grow. The auto companies led the way, manufacturers of trucks, motorcycles, buses and railcars are among the more recent converts.

ELECTRONICS

Both commercial and consumer electronics manufacturers are using vibration testing more and more to ensure that the equipment design and the package design are sufficient to ensure surviving shipment. An unprotected instrument would not survive long on a truck going across country nor on a railcar nor in the hold of a cargo aircraft.

CONSUMER PRODUCTS

A variety of consumer products companies are engaging in vibration testing of some sort to ensure product and package integrity in shipment and handling. An interesting example of the sort of testing being done in this environment is the one done by a well-known dog food manufacturer. Cases of dog food were stacked on pallets and subjected to a controlled shock, which represented the worst drop that a forklift truck could impose on the stack. The object was to find the highest stack and carton design combination, which would survive that shock. The higher stacking meant more product in the same space as a shorter stack. With floor space costing as much as it does today, the savings in space translated to savings in dollars.

Smaller companies are beginning to find that they can profit from an Internal vibration testing capability. These companies often rely on outside testing laboratories to conduct vibration testing, both for production sampling and prototype screening. That dependence is actually quite expensive when you consider that: 1) the testing schedule is driven by the laboratory's priorities and not the company's (meaning that a test-redesign-retest cycle could take weeks or months, rather than days and weeks), 2) a technician, and often times, an engineer, must accompany the test article to the laboratory (meaning many lost hours in transit and waiting for the test to be run) and 3) laboratory labor rates are quite a bit higher than internal labor rates.

A number of smaller companies have found that the investment in a vibration testing capability can be paid off fairly quickly when the lower costs and the time saved (both transit time and waiting time) are considered. A side benefit has been that idle time can be sold, thus generating some revenue as well as saving money. Since the company can dictate the priorities for testing, production schedules be come less dependent on testing schedules because critical production items do not have to wait at an outside lab for available time.

A Little Bit of History

Let's diverge a little to bring in some history and discuss the impact that digital computers have had on the vibration testing world. In the past, sine sweep tests were done with analog oscillators, shock tests were done with drop tables and random vibration tests were done with banks of analog filters. With the ad vent of computerized vibration control systems, the slower and less accurate analog techniques are rapidly losing favor. The next few paragraphs will discuss this digital versus analog competition and will highlight the inadequacies of the analog test systems and techniques.

RANDOM VIBRATION

Analog random vibration control systems do not represent much competition though a few are still sold today. These systems provided the first random noise vibration testing capability. Banks of fixed analog filters, 40 to 100 of them in a rack (see figure 2); allow shaping (modifying levels at discrete frequency points) of the drive spectrum to suit the need, much like an audio equalizer. You could consider each filter equivalent to a line of frequency resolution in a digital system. A tracking filter sweeping through the frequencies provide the response spectrum, which is measured at the test article. These systems have two advantages' 1) lower cost and 2) a simple, easy to understand concept -adjust the gain of the appropriate filter until the response is at the desired level.

The greatest weakness of the analog random vibration systems is that setting up a test takes a long time. An analog system would require anywhere from 20 minutes to 8 hours to equalize before a test could be run -if the test were even controllable. Equalization is a long trial and error effort since gain adjustments are poorly calibrated and tracking filters take a long time to sweep through each trial, With digital systems, more tests are controllable and equalization can be achieved in seconds, minutes at most. The greater dynamic range and more lines of control permit finer adjustments to the drive spectrum, the computer provides speedy and accurate control.

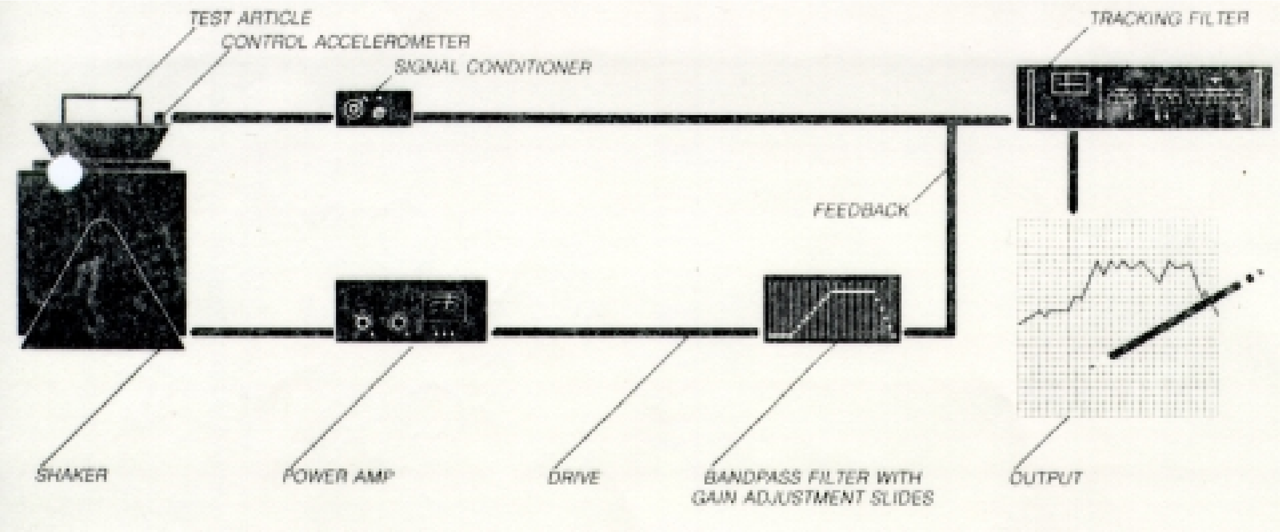

Figure 2: *Analog Random Vibration Control System*

SINE SWEEP

As mentioned earlier, sine sweep testing is still used extensively, though random vibration testing is the accepted practice with newer test specifications, Many testers know only sine sweep testing. Conceptually, it is easier to understand' use an oscillator and vary the frequencies until the test article is stimulated through all the frequencies of interest. Also, vibration test specifications (particularly military ones) are often written using a variation of sine sweep as the testing technique. Rather than fight these circumstances, digital vibration control systems provide sine sweep capabilities. Actually, analog sine sweep systems do enjoy some ad vantages: lower cost, continuous frequencies and greater dynamic range.

Almost all the analog advantages can be countered with the greater flexibility and shaker reliability of the digital system: greater flexibility in data management with the digitized data and computerized output: greater flexibility as a system since changing from one excitation to another is merely a matter of changing software, and greater reliability since a computer tracks and controls the test levels and responses and continually compares the response to the specification. In contrast, analog sine sweep systems use a function generator or oscillator for the drive signal tracking filters and servos to control the response, level controllers to shape the reference spectrum and most times, human controllers to watch the test and to keep track of the test time (see figure 3). This combination gives the analog systems the greater dynamic range, but is inherently less reliable and less capable than a computer based system. The continuous frequencies advantage is more difficult to counter. Some older specifications require the change in frequency during the sweep to be continuous -no discreet steps. Absolutely continuous frequencies are not possible with digital systems simply because the drive signal comes from a DAC. Very small steps are achievable and can thus meet the spirit of the specification, Most users will accept these small digital steps; some will not. Regardless, analog sine vibration control systems are not significant com petition Sine tests are long and tedious events, hence expensive; sine sweep ex citation is not truly representative of a real world environment; and most new test specifications are being written around random vibration.

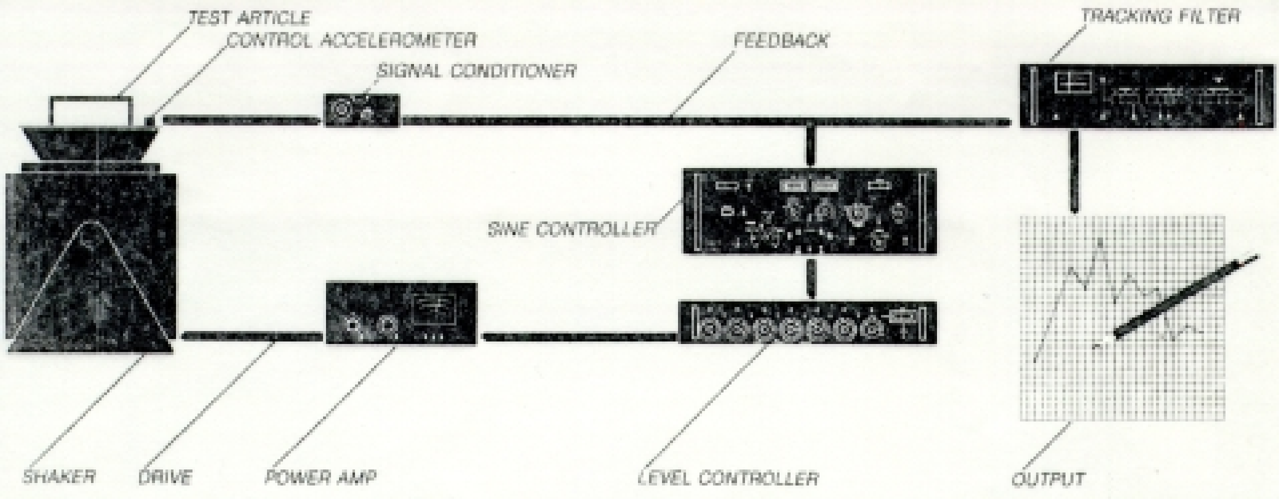

Figure 3: *Sine Sweep Test System*

SHOCK TEST (TRANSIENT) SETUPS

Early in the history of vibration testing, drop tables were conceived A drop table is basically a pair of stiff columns, a good heavy base and an adjustable drop plate which holds the test article (see figure 4) An accelerometer mounted on the drop plate records the event on a chart recorder The trace is the document which indicates whether or not the proper shock has been applied to the test article The number and shape of lead energy absorbers placed under the drop plate deter mines the shape of the shock. The shaping of the absorbers was and is an art Each new test setup, and sometimes, each new test article, requires a number of trial drops to get the right combination Digital systems with an electrodynamics shaker and amplifier have already replaced many drop tables Digital systems pro vide preprogrammed waveforms or pulses which can be output one at a time or in a series. They permit transient tests to be run using recorded data as the control pulse -not at all possible with a drop table. From test to test, the pulses are more repeatable with a digital system Drop table tests will not go away, however Many of these tests require high displacements or very high energy levels; shakers cannot provide these. Since most digital systems also have a measurement capability, they can still be used to document the tests and thus, save time in reducing the data.

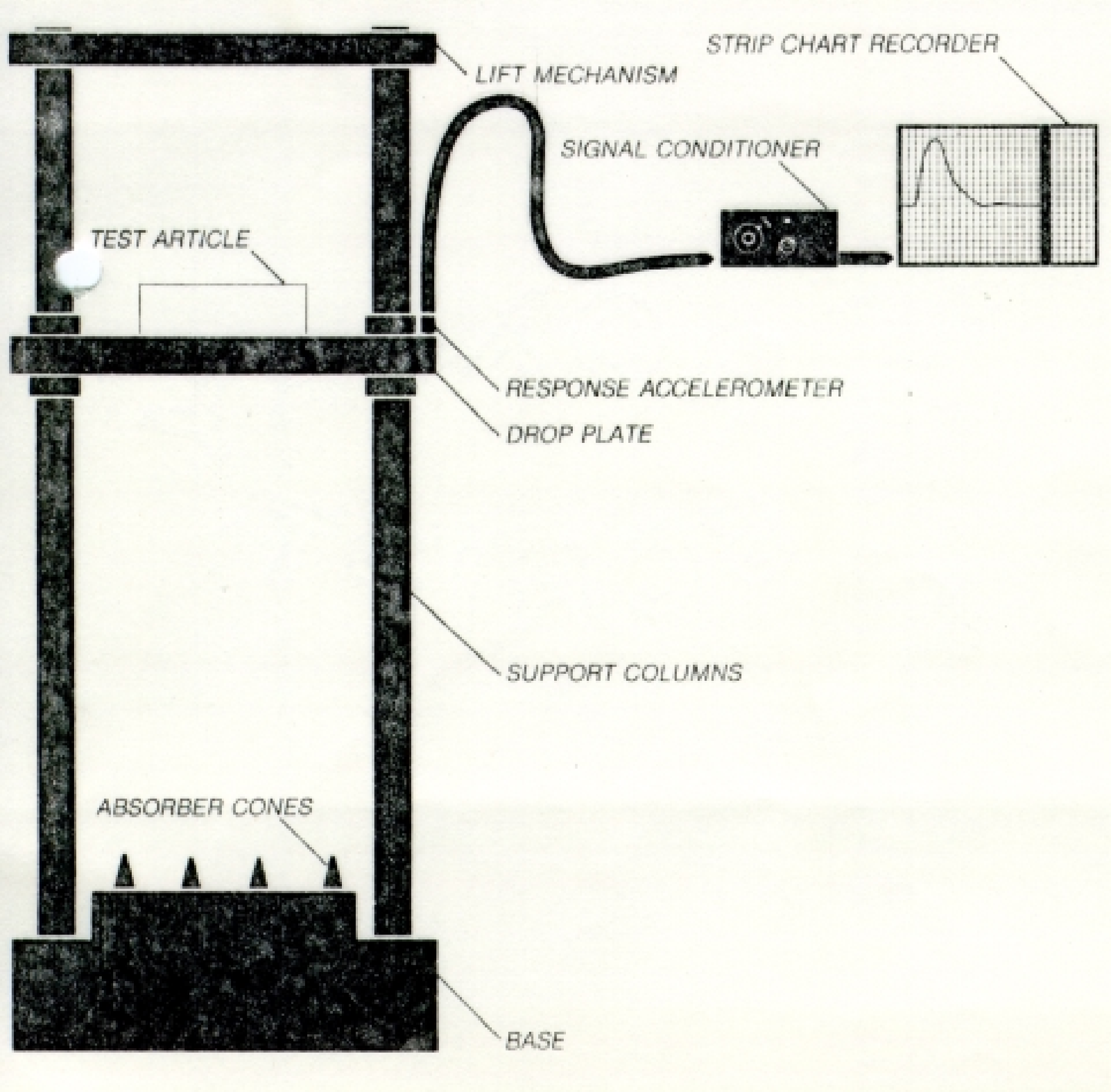

Figure 4: *Drop Table*

Glossary

ABORT LIMITS describe minimum and maximum amplitude levels, which constitute a valid test. If these limits are exceeded then the test is aborted. The higher limit minimizes the possibility of damage from too much energy being put into the test. The lower limit will shut off the test when it has been invalidated because too little energy has been put into the test article. With the m+p international controller, the user would enter these limits as plus or minus dB values from the reference spectrum.

ABORT TIME is the amount of time, which the system takes to ramp the drive signal down to zero. If the drive signal were simply turned off during an abort, the result would likely be a large transient. Considerable damage could be done to the test article.

ALARM LIMITS are limits set inside the abort limits. When these limits are exceeded, warning lights are turned on letting you know that the test is nearing an abort condition.

BREAKPOINT is the point in the reference spectrum where the line outlining the spectrum changes the slope. The spectrum can be specified with frequency and magnitude as breakpoints or as frequency and slope. With more breakpoints, more complex reference spectrums can be setup for use in testing.

CHANNELS are the input lines to the ADC. Each channel will represent an accelerometer on the test article or the fixture.

CHANNEL AVERAGING describes the technique of averaging two or more accelerometer signals and using that average as the feedback for control. This technique is used most often in random vibration control.

COMPRESSION SPEED is a term unique to sine sweep testing. It is a figure of merit, which describes the slew rate with which an analog sine sweep test system can respond to a step change in amplitude. A digital system is usually capable of generating a greater amplitude change than a shaker system can respond to. With the digital system, the compression speed figure becomes a measure of how much quickly you allow the computer to correct the drive level to match the reference level.

COLA (constant output level amplitude) is a constant level sine wave, which is the same frequency as the frequency excitation. Customarily, this COLA signal is unfiltered and is used as the synching signal for a tracking filter in an analog sine sweep system.

CONTROL ACCELEROMETER describes the one accelerometer on a test article or the holding fixture, which is designated as the source of the feedback signal. On occasion, ore than one accelerometer can be designated (see Channel Averaging).

CONTROL LOOP is the circuit, which connects the controller the signal generator, the power amplifier, the shaker, the control accelerometer, the signal conditioning for that accelerometer and finally, the input module for the system.

DELTA f is the frequency value between two adjacent points on a given spectrum; the increment value from one frequency point to another. It is a function of the number of lines and the span of the spectrum; relationship is delta f = (span/number of lines). It indicates the resolution, which is available with the span and lines combination chosen for testing. Example: 512 Hz span, 256 lines yields delta f or 2Hz.

DRIVE SPECTRUM is that spectrum of frequency and amplitude values, which are output through the signal generator to the power amplifier and shaker.

EQUALIZATION describes the process of modifying a drive spectrum based on the feedback; the process is repeated at each level change. In other words, each time you move up in test level, the output is corrected to keep the test article response within specified levels. Fast equalization is important to keep testing time down and important to keep testing time down to keep from over testing the test article.

ERROR SPECTRUM is the resultant spectrum when the response spectrum is subtracted from the reference spectrum. It helps the test engineer identify difficult to control frequencies, if any are present.

EXTREMAL AVERAGING is a technique, which uses one or more accelerometers overriding the control accelerometer to minimize the risk of damage to parts, which are mounted away from the control accelerometer. The best way to explain extremal averaging (also known as extremal control (is through an example. Consider a solar panel mounted on a communications satellite undergoing a test. Should the panel be excited at its resonance, it would be badly damaged. By mounting an accelerometer on the panel and setting a maximum level for that accelerometer, extremal averaging can be used, as the level approaches the high limit for the panel accelerometer. The computer adjusts the drive signal in the offending frequencies so that the limit is not exceeded.

FIXTURE describes a holding frame or adapter plate, which is necessary with virtually every vibration testing setup to hold the test article on to the shaker. Since the shaker-mounting bolt patters are generally fixed or at least somewhat limited in configuration, an adapter is necessary for the immense variety of packages, which can be tested. Most fixtures are welded aluminum or magnesium and are designed for a specific shaker and package combination.

g's are units of acceleration. Most vibration spectrums are specified with g's for amplitude.
English units: g= 32.17 ft/sec^2
Metric units: g = 9.81 m/sec^2

GUARDBAND describes the portion of a measured spectrum, which is discarded after the FFT computation. This portion of the spectrum may contain alias products, which would lead to false corrections of the drive spectrum. As an example, consider a 1024 time record taken at a 110 kHz sampling rate. After the FFT, the resulting spectrum will contain 512 kHz in the frequency domain. Of these 512 points, 256 may be contaminated with alias products and are therefore discarded. The remaining in spectrum is 256 points covering 0 to 2.5 kHz. The guardband is the 256 points covering 2.501 to 5 kHz.

LEVEL SCHEDULE is the table of Excitation energy levels and the times to maintain each level for a vibration test. This table can be specified by the user arbitrarily or it may be specified by some test specification. The levels are usually specified as dB relative to maximum acceleration; time varies from seconds to hours.

LINES describe the number of frequency intervals in the span used for testing. Standard breaks are multiples of two from 64 to 100. Our competition offers 100 through 800 lines. With more lines comes more resolution (finer definitions of the spectra); more lines also means more computation time.

LOOP TIME is the time required to gather enough spectral information to satisfy statistical requirements of the test setup, perform the computations and update the drive spectra. More averaging and more lines result in longer loop times.

MICRODOT is a specific type of shielded cable and terminated with lightweight miniature connectors. It is widely used to correct accelerometers to signal conditioning.

MISSION PROFILE is a loosely defined term referring to the vibration history of a device in use such as a rocket flight or airplane takeoff and landing sequence. It can refer to a specific random vibration spectrum or a series of spectra over time or random spectra in conjunction with transients (i.e. stage separations on rockets) ad infinitum. It may be a transcription of a record event or merely the best estate by engineers of the vibrations during a given mission. The salient point to remember is that a mission profile is representative of the vibration environment that a device will experience.

NOTCHING describes the suppression of the drive signal in certain frequencies to respond to structure or system induced resonances in the control loop. Since some energy is being applied with those resonances, the drive signal must be notched or lowered in amplitude in those frequencies to keep the test within the abort limits. The term is most specific to sine sweep testing.

REFERENCE SPECTRUM also known as the specified spectrum, is that setoff frequencies and amplitudes which the vibration control system will test to. In other words, the control system will modify the drive signal until it gets a response, which matches this reference spectrum within the limited that you programmed.

REMOTE ABORT describes the ability to abort a test outside the control of the control system. Most systems will provide three abort capabilities: controller initiated from a button on the system and remotely initiated via some switch, which is activated by events, or devices separate from the control system. By wiring any of a number of normally closed switches to the remote abort port on the control system, a tester can remotely abort a test by opening one of the switches. Some of the functions which might typically be included in this circuit are a pressure switch to shut down the test if the shaker cooling water supply drops drastically or an overtravel switch to shut down the test if the shaker head travels too far or a pushbutton by the test article which a technician could use to abort the test if a problem develops at the test site.

RESPONSE SPECTRUM is the spectrum measured at the test article. It is the spectrum returned by the control accelerometer.

SCHEDULE is synonymous with level schedule

SLOPE refers to the slope of the line connecting two breakpoints in a reference spectrum.

SRS in an acronym for Shock Response Spectrum testing. See Appendix A.

TEST ARTICLE describes the item, device or structure, which is fastened to the shaker and vibrated.

TRANSIENT CAPTURE describes the technique of recording a transient vibration event. A control system can perform transient vibration testing using this recorded transient as the reference pulse.

Appendix A

SHOCK RESPONSE SPECTRUM TESTING

One of the oldest techniques for defining a shock or large transient is the shock response spectrum method. This technique evolved from efforts in the 1930's to quantify the energy put into a ship when firing a battery of large caliber guns. It has since been used to characterize shocks from such events as stage separations of rockets; explosive separations of holding payloads onto rockets; tank cannon firings and earthquakes. By quantifying the shock and performing some testing, engineers can associate the potential for such a shock to damage equipment mounted in the vicinity.

Imagine yourself as an early test engineer faced with the task of measuring the shock with firing a 3-gun battery of 16-inch guns on a battleship. Remember that the time is the 1930's. HP was no more than a whimsy in 3 men's minds at that time. Electronic instrumentation was of the tube type and virtually confined to communications. How would you measure such a high energy, short duration shock?

Test engineers faced with that task were quite imaginative in developing the shock response spectrum (SRS) technique. They built mechanical bandpass filters with center frequencies and bandwidths based on octaves (full, ½, 1/3, 1/6, etc.). Each filter was essentially a spring, a damper and a mass. Varying the spring constant and mass changed the center frequency; varying the damping changed the bandwidth. Arrays of these bandpass filters were installed in key location son the ship just before the test firing. The maximum oscillation of each filter represented the maximum shock energy in that filter's bandwidth. A pen attached to the mass traced the maximum oscillation on a piece of paper; technicians transcribed the results to graph paper. The result was a spectrum made up of the center frequencies of each filter in the horizontal axis and the maximum oscillation value or amplitude of that filter in the vertical axis.

As instrumentation developed, these mechanical filters gave way to sets of accelerometers and electronic bandpass filters at each test location. Current techniques use one accelerometer at each test location and FFT analyzers to process the data, either on-line or from recordings.

The basic shock synthesis testing technique (testing to a SRS reference), through very old, is still used by many engineers. Some controversy exists over the validity of such testing in light of the capability of today's instrumentation. Proponents of shock synthesis testing claim that other techniques do not adequately characterize the maximum force associated with a shock. The greatest argument for the body of knowledge built up around SRS measurements. In the hands of an experienced engineer, damage potential can be well correlated to the SRS measurement. This correlation of damage potential and measurement values has not been well developed for the other techniques. Those supposing shock synthesis testing point out that for any given SRS an infinite number of time waveforms can be found to generate that spectrum. This is true since timing the phase of each frequency component is ignored with a shock response spectrum; only the displacement or amplitude of that frequency component is monitored. The contention is that a very powerful and damaging pulse can have the same SRS as a much less damaging one. Further complications occur when different testers synthesize different pulses for the same SRS. One tester will pass the test article, the other will fail it.

Regardless of the validity of the arguments, shock synthesis testing will continue to be used in vibration testing no other technique has been as well correlated or as heavily used in the past. It is likely that transient vibration testing or random vibration testing will eventually replace this technique, but not soon.

MECHANICS OF SHOCK SYNTHESIS TESTING

Reference spectra for shock synthesis testing are derived in the same manner as any other form of testing: field measurements or best engineering estimates of the spectrum. Constructing the test setup requires a bit more expertise than the other techniques and requires some trial and error as well.

The response is typically described in one of three ways: primary, residual or composite. A primary response is the response measure while the shock is being applied to the article or structure. A residual response is the response, which occurs after the shock has ceased. Finally, as the name implies, a campsite response is the response, which occurs both during and after the application of the shock.

The shock is synthesized from damped sinusoidal pulses representing each center frequency used in the analysis. The user can specify damping values for each sinusoid and relative timing for the pulses independent of the software's designations. This flexibility allows the user to shape a synthesized pulse to better satisfy his testing needs rather than rely upon the software's default values. This manipulation is a trial and error proposition. The user will redesignate certain values, synthesize a shock and try a short test to measure the SRS. If he is lucky, a few iterations should net him the correct answer. This process is the art of testing.