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ENVIRONMENTAL LABORATORY
AND
EQUIPMENT

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

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ENVIRONMENTAL LABORATORY
AND
EQUIPMENT

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Environmental Laboratory

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ABSTRACT

A description of the Atomics International Environmental Laboratory, its test equipment, and the testing techniques used there is presented. Particular emphasis is given to vibration, shock, acceleration and static testing, and to the unique test methods developed by the laboratory staff.

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INTRODUCTION

In the age of rocketry, the demands of launch and flight survival for a variety of familiar devices and not so familiar structures become severe beyond any concept. The simplest and most rugged of devices designed for terrestrial use exhibit surprising shortcomings when one shoots them into space.

The initial jolt comes with rocket engine ignition, when the innocuous term "hard start" describes all aspects of a severe chemical explosion. The engines themselves may be hard pressed to stay together at this point, and indeed, engine structure failures sometimes occur at the time of ignition.

The following several minutes of first stage burning uses energy at a rate equivalent to several hundred thousand powerful automobiles. Releasing this kind of energy in the form of high velocity gas jets by combustion in chambers measuring a few feet to a few yards in diameter, gives rise to powerful vibrations inherent in the turbulent gas flow. These undesirable but unavoidable vibrations, along with useful thrust, are transmitted from the combustion chamber and nozzle to all parts of the vehicle, spanning frequencies ranging from a few cycles per second to several thousand cycles per second simultaneously. Stage separation using explosive charges and vehicle orientation gives rise to additional shocks and accelerative forces.

The three primary mechanical environments to which a rocket vehicle payload is subjected during launch are defined by the foregoing description as shock, vibration, and acceleration. The purpose of environmental evaluation is to produce payloads (by means of analysis, design, and test) that have a high probability of surviving the rigors of riding a rocket vehicle, in good working order. This requires the achievement, in a terrestrial laboratory, of a close approximation of the various conditions of rocket launch and flight.

AI (Atomics International), under contract with the AEC (Atomic Energy Commission), is presently developing a number of nuclear power systems (SNAP) rated from 0.5 to 60 kwe. The company is also studying systems with a power range for lunar and planetary stations. The role of nuclear energy in space is clearly shown in Figures 1 and 2, which indicate that devices such as electric batteries, solar cells, fuel cells, and chemical energy power sources

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Figure 1. Power and Duration Regions for Various Energy Sources. (Chemical includes storage batteries, fuel cells, and cryogenic H_2-O_2 engine. Solar includes both photovoltaic as well as solar mirror systems. The circles indicate basic objectives of developmental SNAP systems.)

all have a useful application in the production of power other than that required for initial launching operations. The choice is clearly dependent on such factors as required life, package weight, total power level required, and system integration.

It is now a generally accepted standard among spacecraft manufacturers that to obtain a very high order of reliability, exhaustive ground testing must be conducted to produce an integrated unit that will function under the extreme environments to which it will be subjected.

It is generally conceded that the exact environments of the spacecraft cannot be duplicated because of the random conditions existing in each flight. To ensure a reliable system, the levels of environmental simulation have been set at a much higher level than normally would be expected on any one flight.

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Figure 2. Comparison of Weight of Solar Cell and Nuclear Power Plants as a Function of Power.

(The range of solar cell specific weights is appropriated for fully oriented areas but does not include the weight of orientation propellant for long durations.)

This, of course extends the required capability of all equipment used in each test. The cost of this specialized equipment requires a very large capital investment that few companies can afford. With a limited budget, as in the case of the AI Environmental Test Unit, a decision was made to concentrate on equipment for a few major environments rather than attempt all-inclusive coverage with submarginal equipment. A study of past spacecraft failures indicated that 25% of all failures resulted from vibration; the AI Environmental Test Unit has, from its inception, paid particular attention to the development of its vibration testing with capabilities in acceleration, acoustic noise, and other environments scheduled for later dates.

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Figure 3. Floor Plan of Environmental Laboratory Building 027

ENVIRONMENTAL LABORATORY

The Environmental Laboratory, a facility of the Environmental Test Unit, is located in Building 027 in the AEC SNAP area, Santa Susana Nuclear Field Laboratory. The facility is used for environmental testing of components, sub-systems, and systems in support of all SNAP programs. Though now thoroughly equipped for shock, vibration, acceleration, and static testing it is planned to expand the laboratory's capability to include acoustic, temperature, humidity, explosive atmosphere, and low-pressure testing. Combined environmental tests can then be conducted to determine the interactions and contributing effects of specific operational environments. At present, certain tests (large centrifuge, acoustics, and low-pressure) must be conducted at outside testing laboratories under the direction of the Environmental Test Unit.

Of paramount importance to this effort is adequate instrumentation to achieve test data of maximum accuracy and validity consistent with the economic factors involved. Instrumentation and data acquisition and presentation are so interdependent that the latter function has become the responsibility of the Instrumentation Unit. A thorough knowledge of the quality of the end product, data, is essential to those charged with the responsibility of installing proper instrumentation. A data processing center, which is part of the laboratory, will be expanded by the acquisition of new equipment to provide quality data as quickly and accurately as possible so results can be reviewed prior to resuming succeeding tests.

FACILITIES

A floor plan of the laboratory is shown in Figure 3. The approximately 8400 ft² are divided by function into distinct areas as discussed in the following text.

High-Bay Area

The high-bay area (30 ft high below the cranehook) occupies 1800 ft² and is serviced by a 5-ton overhead bridge crane. Parallel to the crane travel and spaced 24 in. apart are six holddown slots in the deck to secure the largest test fixtures anticipated for the SNAP programs.

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Figure 4. Control Room

Control Room

The control room (20 by 30 ft) is located opposite the high-bay area and contains three vibration control consoles (Figure 4). Double-glass windows were installed in all walls except the northeast side to allow operators to monitor vibration tests in progress and to restrict noise within the control room to an acceptable level.

Power Amplifier Room

Adjacent to, and northeast of the control room, an external enclosure houses the existing power amplifiers; some additional room has been provided for expansion. Windows between these rooms allow the console operators to check the amplifiers without leaving the control room. The amplifiers are located in this manner to minimize heat and noise in the control room. Ready access to the amplifiers is provided from the outside through seven large doors for the purpose of servicing, repairing, and removing.

Medium-Size Shaker Room

Adjacent to the control room, and opposite the high-bay area, a room has been provided to house the two medium-size shakers. This room is of double-wall construction to reduce the noise level in the remainder of the laboratory. Both shakers are mounted on concrete seismic masses for the purpose of vibration isolation. A jib crane of 1-ton capacity has been installed between the two shakers to allow the mounting of heavy test articles on either shaker or either slip table (Figure 5).

Instrumentation Shop

Adjoining the vibration room is the instrumentation shop where all instrumentation is checked, repaired, calibrated, and stored. Here, in addition to the normal maintenance of equipment, extensive custom design and fabrication of specialized equipment is done to facilitate the conducting of special tests.

Laboratory Offices and Stress Coating Room

Four rooms are provided opposite the vibration and instrumentation shop (see Figure 3). One office is used for recordkeeping, drafting, and writing of reports; the other for data reduction and the analysis and/or inspection of current data on the tests being conducted. In the same area a dark room has been

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Figure 5. Vibration Room. Installation of Reactor on 2nd Shaker

provided where oscillograms can be processed immediately after they are recorded. The fourth room is provided for stress coating. This room has humidity and temperature control to provide the required atmospheric conditions when preparing stress-coated specimens for test.

Assembly and Test Area

The central area between the offices and the instrumentation shop and vibration room is referred to as the assembly and test area. As the name implies, this area is used for the assembly of small systems, installation of instruments, and for conducting static, pressure, and other tests not requiring a high overhead. To facilitate testing, four holddown slots, on 2-ft centers, have been provided for the length of the area, in addition to a utility trench for containment of power cables, water lines, and other connections. At present a small centrifuge is located at one end of this bay.

Shop and Acoustic Area

To complete the laboratory, the northwest section, which was formerly Building 625, has been converted to a shop and acoustic area. The latter is soundproofed and contains a large viewing window for the operator of the control console which will be located outside of the room. In time it is planned to install a traveling wave and a reverberation chamber in this room.

VIBRATION

The majority of the workload of the laboratory lies in the field of vibration testing. Each component that becomes a part of a SNAP system is vibration tested at least once. In most cases, the same component is tested many times, first as a component, then as part of a subsystem and again when the subject part is integrated into a complete SNAP system. In all cases, these tests require vibration in three axes; a time consuming procedure involving remounting and reorientation of the transducers. Experience has proven that even though a part or a subassembly may be qualified for one SNAP package, the advances in technology are so rapid that subsequent models will contain new and updated components. Consequently, a high volume of tests continues up to and including the final flight article. Added to this volume is the unpredictable number of tests involved in normal research and development work where the same part or unit may be tested many times with fixes, repairs, or alterations occurring between each test.

Figure 6. Model A249 Shaker

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At present, the laboratory is equipped with four fixed-shaker complexes ranging from 2250 force-lb to 30,000 force-lb capacity. All systems are complete with slip table, control consoles and amplifiers except the small 2250 force-lb shaker, which can be driven from one of the two 7500 force-lb complexes. The shakers are water-cooled* by individual heat exchangers and are served from a common cooling tower located just outside the southeast wall of the laboratory.

30,000 Force-lb Shaker System

The 30,000 force-lb shaker system consists of a Ling shaker head (Model A249) a Microflat slip table, a Ling console and signal generator (Model R-1008) and a Ling power amplifier (Model PP175/240).

The Model A249 shaker is presently located parallel to the southeast wall of the high-bay area (Figure 6), a location that allows the mounting of the complete SNAP assembly directly on the shaker head or the slip table by using the overhead traveling crane. The frame of the shaker is welded to steel blocks (24 by 72 by 4-1/2 in.), which in turn are bolted to the floor with twenty-two 3/4-in. bolts. Although formerly portable, the present mounting was made necessary by the "walking" of the shaker when imparting high-force, low-frequency loadings to the SNAP assembly mounted on the slip table. The shaker has a frequency range of 5 to 2000 cps and a maximum displacement of 1 in.

The armature head is 28-7/8 in. in diameter with 21 mounting holes tapped for 1/2 in. , 20 NC bolts; maximum hole spread is 26-7/8 in. When an object, which is to be vibrated vertically, is too large to be secured directly to the armature head, a magnesium fixture (looking like a large solid salad bowl) is interposed between the armature and the test item. This increases the bolting diameter up to 58 in. The fixture increases the height by 12 in. and adds about 1700 lb to the load.

For lateral testing, vibration specimens are mounted on a slip table. The shaker head is rotated 90 degrees from the vertical and an attachment is bolted to both the head and the slip table, the latter being an 85- by 66- by 3-in. -thick magnesium plate weighing about 1200 lb.

*The MB Model C-60 shaker is oil-cooled.

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Figure 7. 7500 Force-lb Shaker With SNAP Component in Test

The following are first fundamental resonances of the shaker system:

Shaker - upright (bare)	armature, no load	1616 cps
Shaker - upright	armature, plus fixture	530 cps
Shaker - horizontal	armature, bullnose driver	350 cps

The workload on the large assemblies has reached a point where a second 30,000 force-lb shaker head has become a necessity. As the installation, calibration, and standby time greatly exceeds the actual running time, a second set of power amplifiers is not presently considered necessary. A switching system will be installed so that either shaker head can be operated on a share-the-time basis. In the interim, and in anticipation of the second shaker head, another slip table has been procured. This table will be mounted on the opposite side of the shaker head from the first table. The shaker head will be able to service either table by rotating 180 degrees. Considerable test time will be saved with this arrangement as two test setups can be carried on simultaneously.

7500 Force-lb Shaker Systems

The medium size or 7500 force-lb shaker is considered the workhorse of the laboratory. Two Ling A246 shaker heads are each capable of producing a 10 g load on a 682-lb payload. As the specified maximum loading does not normally exceed 7.5 g, the shaker will accommodate all but the largest sub-assemblies in the SNAP program (Figure 7). For very light objects the head can deliver outputs in excess of 50 g. The shakers have a frequency range of 5 to 3000 cps and a displacement of 1 in.

One shaker head is controlled from a Ling R-1003 console and the other from a R-1003-A console. Both have their individual Ling PP20-24C power amplifiers.

The armature head has a square mounting pattern, 11 in. on each side, tapped for 16 holes, 3/8 in., 16 NC threads. For larger test specimens to be vibrated in the vertical direction, a 27-in.-diameter fixture, with a maximum hole spacing of 25 in., is available. Size and location of the holes are flexible and can be drilled and tapped to suit the specific test. The fixture adds 175 lb to the test load. Each shaker has a magnesium slip table, 3 by 40 by 48 in., weighing 330 lb. Each shaker head and slip table block is mounted in a structural steel cradle which in turn is secured to a seismic mass. This prevents

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Figure 8. Control Room

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any "walking" of the head or block in relation to each other. It should be noted that this shaker can be used for combined testing as it will stand a wide temperature variation (-100 to 350°F), humidity to 100%, and almost unlimited altitude operation.

6000 Force-lb Shaker System

An MB Model C60, 6000 force-lb shaker has been acquired recently. This will add to the productivity of the medium-size shaker group which must handle the bulk of the routine tests. The shaker will be located just outside the control room (Figure 8) in the low ceiling part of the high-bay area. As the control console and the amplifier will be in one unit (MB Model T452), the combination will be located adjacent to the shaker head. To conserve on capital expenses, an existing granite block, formerly used with the 2250 force-lb shaker, will be provided with a 40- by 48-in. slip plate and used with the 6000 force-lb shaker.

The shaker head armature is 13-3/4 in. in diameter with thirteen 3/8-in., 24 NF tapped holes divided between two bolt circles, one 6 in. and one 12 in. Fixtures used with the A246 shakers will be adapted to this shaker.

2250 Force-lb Shaker System

The small shaker (Ling Model 245) is rated 10-g for 202 lb, or 20-g for 90 lb. With the acquisition of the 6000 force-lb shaker the small shaker will be considered as the portable unit. It will normally be stored and used in the vibration room (with 750 force-lb shakers) but capable of being used in any part of the laboratory. It will still be controlled by the R-1003 console located in the control room and driven by one of the PP20-24C power amplifiers. As the power requirements are small, compared with the larger shakers, no problem should exist in running cabling to any part of the laboratory through the permanent utility trenches. No slip table will be provided as the shaker will be used only with small specimens and a fixture bolted to the armature head will be adequate for tests in the lateral direction (horizontal). In the vertical direction and with a 70-lb adapter the shaker will still accommodate specimens that will fit a maximum 21-in. diameter hole spacing.

In addition to the five main shakers, one 20 force-lb and two 50 force-lb shakers are available; these are considered portable and are usually used in modal vibration surveys on the assembled SNAP units.

Figure 9. Limiter System

CONTROL EQUIPMENT AND TECHNIQUES

All three consoles are capable of programming sinusoidal vibration to the shakers. The range is 5 to 2000 cps on the large shaker, 5 to 3000 cps on the medium shakers, and 5 to 5000 cps on the small shaker. The bandwidths noted can be programmed for a constant octave sweep of 1/2 to 116 min. The customary procedure is to specify a g level, a frequency range, and the time of sweep. A constant displacement and/or acceleration level is automatically maintained or controlled by the control console utilizing a voltage signal generated by an accelerometer mounted on the shaker head and/or the slip plate close to the specimen. The sweep (time) is by a log progression that provides the same number of reversals at each discrete frequency. The overall time is set and the sweep progresses automatically, usually from the lowest to the highest frequency even though the reverse is equally as convenient. The control can be disengaged to allow a manual sweep or search, and a dwell at any required point, when necessary. Or, by use of built-in limit switches any desired frequency band can be scanned repeatedly (up and down) and automatically.

Limiter

As part of the control system a complex has been installed called a limiter system. The object of this system is to control the input to the shaker head so that any one of five transducers will not exceed a predetermined level. These five transducers are strategically located on the test specimen at points which are considered to be critical at high g forces. A level is assigned to each transducer, above which a loading might induce failure; these levels need not be the same. In operation (Figure 9) the control console maintains a predetermined table input utilizing the accelerometers located on the table or base near the specimen as sensors. The multilevel selector control is used to set the upper limits of the five transducers. As the outputs of the five transducers approach their set limits, the multilevel selector will auction and always select the circuit having the highest level (percentage-wise). When one circuit reaches its limit the circuit selector will allow the limit system to supercede the control system. The input to the shaker head is then reduced and maintained at this or at a lower level until the output of the transducers again falls below their preset level, at which time the control is returned to the control circuit.

An example may be the simplest way to describe this. Let us say that five transducers are placed at critical areas of the specimen, points A, B, C, D, and E. Let us assume that for the purpose of the test, the input to the table is set at 2 g. Now A and C are considered very critical points and they should not be subjected to more than 5 g loading while B and D could withstand 7 g and E up to 8 g. Each of the circuits are set to their prescribed value and the test started at the 2 g level. At 20 cycles the natural frequency of point A is being approached and the transmissibility factor reaches 1:2-1/2 (5 g). From this point on through the natural frequency range the input will be reduced so that the output at A will never exceed 5 g. At another frequency, say 65 cps, the loading at B approaches 7 g, in which case B will now control the shaker input. In other words, any one of the five transducers closest to their preset value will exercise control whenever necessary. This is an excellent system but like many others has limitations which are usually a result of design compromises. To make control action of the five transducers ultra-rapid, transients result that are far more violent than the levels that are to be controlled. A too slow response will, at times, allow a short duration runaway that might be catastrophic.

Safety Control

To alleviate the possibility of allowing any damaging transients to exist in the above system, a safety control has been provided. This is an entirely independent circuit and at present it will monitor two critical points. In the near future this will be enlarged to encompass five control points. This circuit is built to provide an immediate cutoff of power to the shaker system. The pickups or transducers are usually located in the same critical areas as established for the limiter controls. The level set for the safety control is slightly above (10 to 20%) that of the adjoining limiter and will provide a positive cutoff if the transient is large (amplitude x duration) or if a few adjacent peaks exceed the preset limit. This arrangement is necessary as many "spikes" occur at various times due to a transient but their values are relatively small and therefore also their potential for damage. If every "spike" was allowed to shut off the equipment, the test would be unnecessarily interrupted. A compromise was reached to activate the circuit on an energy basis rather than a maximum peak. This system has worked rather well with two circuits and should be ultrasafe, within the reality of electrical gear, when five circuits are installed.

Sine-Random Vibration

A short discussion may be appropriate at this point to clarify the difference between the two systems of testing, sinusoidal and random. Sinusoidal vibration occurs when the shaker head moves equal distances from a center point (displacement) in a periodic motion. The frequency rate is controlled by an oscillator and the distance traveled by the shaker head (amplitude) is controlled by the load and the amount of power supplied to the shaker head. Power is the rate of doing work and is proportional to the square of the amplitude of a harmonic vibration. As frequency is a function of time, only two variables are involved, frequency and amplitude.

On the other hand, random vibration is one whose instantaneous amplitude is not predictable or, in other words, the g value at any frequency is constantly changing and does not reach the same value in any periodic time interval. Although an instantaneous finite value is not predictable, the probability of a given value being within a certain range is predictable on a statistical basis and this usually occurs in the form of a Gaussian or normal distribution.

The sinusoidal vibration of the specimen has its greatest value as a design tool. The mathematical analysis is clear and easy to apply to many real test items. While pure sinusoidal input is seldom encountered in actual operating conditions, it is the best approach for determining resonant frequencies and corresponding attenuation factors. When excessive amplification is observed at a particular frequency in a test item or if structural damage actually occurs as a result of sinusoidal input the design remedies are usually quite apparent and can be incorporated in the process of development. Dwelling at a resonant frequency with sinusoidal input is also valuable in determining the fatigue life of individual components, subassemblies, and complete structures. On the other hand, random vibration has its greatest value in being a practical representative input that can be handled in a terrestrial laboratory. While it is not completely representative of the vibration encountered from rocket engine ignition and operation, it can be adjusted to such a level of intensity that differences in frequency distribution vs amplitude are minimized. Obviously, a taped record of an actual flight is not necessarily the most representative and significant input to be used as test input. As the flight vibration is almost entirely random, which by definition is not exactly repeatable, then any one flight would not duplicate another and is only representative of that one flight.

Figure 10. Vibration Response of Flight Test

Figure 11. Average Power Level

Figure 12. Desired Power Spectrum

As a specific example, in Figure 10 curve (a) represents the vibration response of the flight of one missile. Curve (b) represents the response of an identical missile; the lack of correlation between the two is quite evident. If enough data is acquired to be statistically significant, then each band of frequencies could be analyzed separately and an average power level (g^2/cps) could be established. When plotted against the frequency spectrum, the curve would look something like that shown in Figure 11. This curve, with its various plateaus, would be extremely hard to describe in any general specification and furthermore, if a new series of flight test data from the same family of missiles were analyzed, the resultant curve would be similar but not the same as the original curve. A flat curve drawn as shown in Figure 11 would satisfy the requirement of easy description and would not deviate too far from the highs and lows of the original curve. To satisfy the requirements of including a safety factor in testing, the curve is usually displaced upward by various amounts depending on the type of test specified.

A test may be programmed to follow certain levels but in reality it never quite does as shown in Figure 12. The curve in this case (of a very simple object) lies well within the area bound by a ± 3 db limit. Note this is for a simple object whose natural frequency is beyond the range of this test. Most test specimens are made up of many parts, each having their own natural frequency. When testing with a random vibration, all their natural frequencies could be excited at the same time. On the other hand, damping and interaction between parts results in a complex reaction that is usually not predictable by any known theory. The reaction, if plotted, might look something like the curve in Figure 13. Here you notice a peak and a valley that deviate well beyond the boundary established at ± 3 db. This indicates some amplification at one frequency and attenuation at another. To satisfy the test requirements, the input power in the frequency bandwidth containing the peaks must be reduced and that containing the valley must be increased, thus the function of the equalizer/analyzer.

Equalizer/Analyzer

The equalizer/analyzer, used in conjunction with the control console, is an assembly of equipment used to analyze, program, and control the random input to the shaker head. As the test programs call for random noise at one or more discrete power levels as described in the Sine-Random Vibration Section, the

Figure 13. Power Spectrum Before Equalization

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Figure 14. Equalizer-Analyzer Equipment

output is called White Noise.* Two or more generators are used and their signals are fed through the equalizer/analyzer, amplified to a programmed level and then fed to the shaker head.

When testing components/structures containing parts with various natural frequencies, excursions from the desired level will occur. The analyzer part of the equipment monitors each frequency band and indicates the amount of deviation from the programmed level. The equalizer, as the name implies, increases or decreases the power in the various specific bands. In the manual system, a control is provided for each band; this is adjusted up or down until the accompanying meter reaches the desired input level.

Two equalizer/analyzer systems are in common use, the manual control and the automatic servo-adjusted control. The former is the older system and was the only equipment available until recently. The manual control system has a number of limitations such as wide frequency bands (50 cps), inability to adequately perform below 50 cycles, the lack of precise setting which requires considerable experience, and (even with a trained operator) a long adjustment time. The most important feature, of course, is that while the system is being equalized, especially a complex structure, the time necessary to make the adjustments is many times longer than the time specified for the test.

The newer automatic equalizer/analyzer can adequately control frequencies from 10 to 2000 cps. The bands are narrower, 25 cps from 170 to 2000 cps, but most important is the low frequency range, 10 to 170 cps where the band-pass filters average about a 14-cps width. This newer system, with a servo control for each band, can make the necessary adjustments in a matter of seconds and will compensate for drift throughout the test.

The equipment now in the Environmental Laboratory is of the manual type (Figure 14) but is scheduled to be replaced in the near future by the more modern automatic equipment.

*White Noise is a spectra that contains all frequencies, with all having the same amplitude.

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Figure 15. Wave Form Synthesizer and Slope Plug-In Unit

SHOCK TEST

The laboratory is equipped with a Barry 15575 Varipulse drop tester with a 100-lb capacity and a 66-in. drop. A 6-in. Hi-Gee tester, 25,000 force-lb capacity has been placed in storage for lack of current use.

In the last year there has been little need for either machine. A unique technique has been developed by the laboratory personnel in which a shaker head can be programmed to produce a single pulse or shock. Details of this testing technique can be found in AI Report NAA-SR-8162. The heart of this system is the Exact Type 200 Waveform Synthesizer with a Type F Variable Slope plug-in unit (Figure 15). This test method will produce a half sine wave with little or no overshoot. Shocks can be programmed from 2 to 80 g and with durations of from 1 to 12 ms. This test technique can be set up for use in 30 min by an experienced operator and the test will be exactly repeatable as long as the control equipment is not readjusted.

The advantages of this testing technique are quite obvious. To test with the drop table or the Hi-Gee tester requires setup time and often special fixtures to hold the specimen in the correct axis and for a particular shock. The weight and size that could be accommodated were limited and large assemblies, such as a radiator-condenser, could not be tested. The present methods can be utilized on all the shakers and along any axis. Any article that can be mounted on the vibration head or slip table can be shocked, the magnitude (g level) depending on the combined weight to be moved.

This technique is so outstanding that most vibration laboratories in this country have adopted or plan to utilize this method of testing.

STATIC TEST

Static tests on objects as large as the SNAP 2 combined with the Agena, can be performed in the high-bay area of Building 027. For static tests requiring lesser roof heights, the low bay in the new addition can be utilized. Holddown slots imbedded in the concrete provide ample securing points for any tests within our loading capabilities. With an abundant supply of existing steel framing (erector sets) any type of fixture can be assembled in a minimum of time.

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Figure 16. 10PSM-1A Static Test Equipment

The basic equipment consists of a Rucker hydraulic test stand, capable of developing 5000 psi, a load maintainer (pressure proportioning device) of 10 channels, rated at 10,000 psi, 30 hydraulic load cylinders of various sizes, and a number of Baldwin SR-4 load cells with electronic strain indicators. In addition, auxiliary equipment, such as Dillon Dynameters, Starret dial indicators, and calibrating devices are on hand.

Figure 16 shows a buildup static test fixture for the 10 PSN-1A.

The readout equipment consists of 200 channels of Budd digital strain indicators. These are extremely accurate and adequate for any test that does not require real-time readouts as they must be read in sequence. Automatic recording equipment is not available.

Figure 17 shows a test of a SNAP 10A power system leg on a Tatnall static test machine.

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Figure 17. Static Test

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Figure 18. Installing Pump on Centrifuge

CENTRIFUGE

The laboratory has in operation a Trio-Tech G-338-3 centrifuge. It is of adequate size to test the majority of the components used in the SNAP programs. For larger specimens, outside laboratories are utilized. The present equipment will handle objects as large as 24 by 18 in., loads up to 100 lb, and has a range of 1 to 75 g.

The rotating arm is provided with a center pivot that allows the static balancing of the test specimen on one end by counter-weights on the other. When this operation is complete, the pivot is locked out and the arm becomes a rigid member with the center shaft. For safety purposes the arm is contained in a heavy-gage, round steel housing called the tub enclosure. The door in this housing (Figure 18) is hinged on one side and supported by a floor caster on the other and is commonly known as the clam-shell. The door is approximately one-third of the housing itself, a feature which is a decided improvement over some of the earlier models. Easy access is thus provided to both platforms on the arm without having to lean or crawl into the enclosure. The arm is driven by a 3-hp synchronous motor through a mechanical transmission which is infinitely variable from zero to top speed. This unit is actuated by a rotating handwheel located on the control console. The control console is mounted on the centrifuge enclosure and contains, in addition to the speed control, start and stop buttons, a digital speed counter, tachometer, acceleration measuring system, and instrumentation jacks.

For instrumentation from the rotating arm, 16 coil-silver slip rings are provided, each rated at 5 amps at 110 vac. To allow visual observation of the test in progress, a television camera is mounted at the hub, directed toward the test article. Either wide angle, normal, or telephoto lenses can be used but the setup must be made prior to the test.

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Figure 19. SNAP 10A TE Pump Mount-Cup Type Stress Coating Cracking Under Static Loading

STRESS COAT

Stress coat is a trade name for a lacquer which becomes a brittle coating when applied to an object and allowed to dry. When the coated article is subjected to a static stress, which exceeds a certain minimum amount, the lacquer coating will start to crack (Figure 19); the cracks will run at right angles to the heaviest tension stress. By the density of the cracks, an overall stress distribution as well as an estimate of stress magnitude can be determined. By controlled conditions of application, the coating can be made to start strain cracking at 0.0005 to 0.003 in./in. Stress coat is often used as a prelude to mounting strain gages for subsequent tests. With the knowledge of the stress distribution of the major stresses, the strain gages can be oriented correctly. Stress coat is an experimental nondestructive procedure which can give quantitative data of from 5 to 25% accuracy. When prepared under the best climatic controlled conditions, an accuracy of ± 5 to $\pm 10\%$ is claimed by the manufacturer and under poor conditions ± 10 to $\pm 25\%$. Although the latter may seem rather large, the results are never given quantitative status without further tests. By using various lacquers or combinations thereof, a range of sensitivities can be predetermined and calibrated.

In preparing a specimen for test an aluminum undercoating is first sprayed on the object to provide a uniform bright working background. The lacquer is next applied and allowed to dry under controlled conditions of temperature and humidity. This degree of control has a direct bearing on the accuracy of the results. With every application to a test specimen, several standard calibration strips are also coated and allowed to dry under the same conditions. After drying the strips are placed in a jig called a Calibrator which applies known strains to the calibration strip and the stress loading is noted when the coating just starts to fracture. A comparison of these cracks with those noted on the test article provides the basis for a correlation of stress levels. Continued strain applications beyond this point resulting in large width cracks degrades the quantitative accuracy as it is above the threshold strain value.

10-3-63

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Figure 20. Typical Instrumentation. Dyna-Monitors, Oscillographs and X-Y Recorders.

INSTRUMENTATION

The primary objective of any test is accurate recorded data in an easily readable or reproducible form. The majority of the data produced in the Environmental Laboratory is from accelerometers and/or strain gages.

The laboratory, at present, has four Visicorder oscillographs of 36 channels each (Figure 20). In most cases it has been found impractical to use all 36 channels with any degree of accuracy. Eighteen to 20 channels are normally used, limiting the trace to approximately 1/2-in. double amplitude. Traces can usually be measured to 0.01 in.; this means a capability of reading to 0.2 g when the maximum excursion represents 10 g. For each reading, the sequence of events is as discussed in the following text.

The output of each accelerometer is connected to an Endevco Model 2702B Dyna-Monitor. This is a system for monitoring and amplifying the signals up to 3000:1. A precision meter is part of the system and will read in g's or other parameters. By means of a range selector switch, the meter will read six different ranges up to a 3000 millivolt input.

The signal, after passing through the power amplifier, is used to drive a channel of the Visicorder oscillograph. By careful observation of the Dyna-Monitor meters and adjustment of the range selector, the excursions of the traces on the oscillograph can be controlled to reasonable heights.

The output of the power amplifier can also be connected to the magnetic tape recorder and/or the Electro-Instruments X-YY Recorder. The latter will plot amplitude of g in the Y axis and by connecting the X drive to the Ling Console oscillator, the plot will represent either g vs frequency or amplitude vs frequency. The Y' system is similar to the Y so signals from two accelerometers can be plotted against frequency simultaneously.

The placing of data on a magnetic tape is currently the most desirable system of data acquisition. With this method, data is stored in all its fidelity and it can be played back or reproduced without the loss of quality. The oscillograph, on the other hand, has two means of presenting data. The daylight paper will produce traces that can be read as the test progresses, but will fade after a few weeks, until all the information is lost. The second method requires a photofixing process which takes at least 1 hr. When the oscillogram data is

finally available, it is final data and no alternations in test can ordinarily be made. If two adjacent channels have had wide excursions, the data may be superimposed and unreadable, therefore it is lost. Inversely, some of the channels may have so little amplitude (incorrect amplifier gain) that the closest possible readings may still result in a large percentage of error. Paper speed may be such (slow) that the frequencies cannot be counted nor can the trace shapes be ascertained; on the other hand, the speed may be such that too frequent stoppage of tests will result in order to replace the paper. The permanent oscillograph records are not amenable to any reduction other than visual inspection. With data recorded on magnetic tape, the data can be analyzed in different ways such as amplitude vs time, frequency vs amplitude, determination of phase angle and it can also be filtered to eliminate or reduce the background noise, without any change in original quality or calibration.

Analysis of random data requires repetitious interrogation (usually by means of a tape loop) of the frequency spectra by bandwidths, within a definite time interval. Therefore, random data must be placed on magnetic tape.

Tape Recorders

The present complement of tape recorders in the laboratory consists of one 7-, two 14-, and one 3-channel magnetic tape recorders. Additional recording heads can be obtained for the latter machine to convert it to a 14-channel recorder. The present plans call for this recorder to be used as a loop reproduce machine until such time as a specialized machine for this purpose can be obtained. It will then be converted to a 14-channel recorder.

As more sophisticated tests are conducted on complete assemblies, more simultaneous channels of information are required. As the largest standard tape recorder has 14 channels, two machines would not necessarily produce 28 channels of information. On each tape reproduced there must be certain basic information for the purpose of correlation. The table input must be recorded on each tape as a basis to allow for comparison of outputs to inputs, directly, so that idiosyncrasies of each machine are apparent. When comparing two tapes, a timing base is essential to take care of any small inaccuracies in the transport speed. So, instead of 28 channels of information, the sum total is reduced to 25 channels. To obtain numerous channels now required, the ganging of recorders could result in a very large capital investment in addition to large operative costs, i. e., tape.

A multicarrier system has been developed (Figure 21) that is similar in operation to a telemetry system where many bits of information may be combined on a single channel. Each transducer, when monitoring a test, produces an electrical signal which is converted to a frequency modulated (FM) signal by means of voltage controlled oscillator (VCO). This signal, now called a sub-carrier, with a center frequency at some level between 25 and 85 kc, is fed to a mixer where two or more subcarriers are combined on one channel and recorded on magnetic tape. In this case, only five subcarriers are used in conformance with the Inter Range Instrument Group (IRIG) standards for this range.

As 14 channels are available on each tape, the output of 70 transducers can be recorded at the same time.

Figure 21. Multicarrier System

For the reduction of this data, additional special equipment is required. When recording a number of simultaneous channels it is necessary to provide as many amplifiers and VCO's as there are transducers to record (70), also,

as many mixers, record amplifiers, as there are channels (14). To duplicate all these channels on the data reduction side would be convenient, but extremely expensive, so the compromise is to have at least two demodulator (discriminators) 10 signal amplifiers (5 each), providing 10 separate bits of information. This means that to reduce all 70 channels the tape would have to be processed at least eight times or more, as channels 1 and 2 (oscillator and table input) must appear as a basis of correlation for each track. The outputs for each track can be recorded on an oscillograph or on an X-YY' plotter, or be recorded on another tape for the purpose of making loops and subsequent reductions.

It is expected that this multicarrier system should be acquired during the next fiscal year.

DATA REDUCTION

The least developed area of the laboratory is in the region of data reduction. Up until recently, all reduction was performed by taking oscillograph records, blocking out points of interest, counting the frequency and measuring the amplitudes. In turn, this raw data was processed (calibrations added) and the results presented on an appropriate plot. To increase the capability of the data reduction staff, a Gerber Digital Data Reader was acquired along with an IBM output writer. This speeds the operation of reading but does not relieve the chore of processing the data or plotting the results. If and when the requirement exists, an IBM card punch will be acquired and a program designed so that all computations and plots will be accomplished automatically.

The preceding discussion concerned sinusoidal vibration only, as random vibration is not amenable to hand reduction.

Future plans in the data reduction area envision automation as much as possible. It is planned to have the bulk of the data reduction performed by the Data Acquisition and Reduction Center. However, it is also necessary that the laboratory have a basic capability in this activity. When conducting a test on a major assembly, certain factors must be ascertained such as power, level, amplitude, transmissibility factors and phase shifts, before the next series of tests are conducted. To this end a minimum of two channels of data (preferably more) will be necessary to obtain the minimum quick-look information. In the near future, two circuits plus an oscillator output will be available where input

and output amplitudes can be compared and their ratio (transmissibility) can be plotted against frequency. By the addition of the oscillator circuit, a plot of the two channels can be obtained showing their phase angle relationship. This is only for sinusoidal vibration. In the more distant future, this same capability will be available for random vibration.

DATA ACQUISITION AND REDUCTION CENTER

The Data Acquisition and Reduction Center (DARC), a part of the Nuclear Operations Department, can now provide analysis of test data produced in the Environmental Laboratory.

A cross spectral density analyzer is available. This is a special purpose analog computer which, in conjunction with frequency modulated recording transports and signal conditioning devices, makes it possible to determine the dynamic response characteristics of a system being subjected to sinusoidal or random perturbations. Random signals, such as vibration and noise data, are diagnosed and displayed in the form of gain and phase angle on X-YY plotters for Nyquist diagrams or Bode plots. Plots of log gain vs log frequency and phase angle vs log frequency are generated at the same time. Much of the information obtainable with cross spectral density techniques cannot be obtained in any other way.

The vibration analysis-transmissibility system can be used to analyze the relative motion of various parts of a composite structure under dynamic environment conditions. The energy levels transmitted through a structure are amplified and attenuated in individual parts of the structure; therefore, designs can usually be modified to minimize the energy transmitted in critical areas. The mechanical gain and phase relationship between any two components are automatically plotted for a vibrating structure under either random or sweep sinusoidal excitation.

The types of plots that can be produced are:

SINUSOIDAL VIBRATION

Root mean square vs frequency	RMS vs f
Acceleration vs frequency	G vs f
Force vs frequency	F vs f
Displacement vs frequency	d vs f
Phase angle vs frequency	ϕ vs f
Root mean square vs phase angle	RMS vs ϕ
Amplitude vs phase angle	a vs ϕ
Displacement vs time (usually decay plot)	Y vs t
Displacement vs frequency vs time	d vs f vs t

RANDOM VIBRATION

Root mean square vs frequency	RMS vs f
Power spectral density vs frequency	g^2/cps vs f
Power ratio (transmissibility vs frequency)	P_1/P_0 vs f
Phase angle vs frequency	ϕ vs f
Mechanical impedance	Z vs f

PERSONNEL

The Environmental Group is made up of two units; the Environmental Evaluation Unit and the Measurements and Data Unit. The Environmental Evaluation Unit is made up of approximately five engineers and eight technicians, in charge of programming and conducting all the tests assigned to the laboratory. Normally, an engineer will be assigned one or more projects which become his responsibility throughout the test or series of tests, regardless of machines or equipment used. The engineer is relieved of responsibility only when he completes the final report. Technicians are assigned to support the engineer on a "floating" basis, with some consideration as to their specialized talents and training. The engineers are available as consultants so that requesters will write specifications that are meaningful and test plans that are within the capability of the laboratory. It is extremely important that the responsible engineer be consulted on the design and construction of test jigs and fixtures as they constitute a major contributing factor in the overall aspect of each test. Assigning the complete responsibility of fixture design and construction to the unit is

becoming more prevalent. The engineers and technicians are encouraged to consider new and improved methods of testing and they are allowed to conduct their experiments whenever a lull period occurs. One such fruitful effort resulted in the method of using the shaker head to produce a shock without the removal of the specimen from the machine. This method now has nationwide acceptance. The laboratory staff has gained considerable unique experience in the testing of large (soft) articles. These tests have been complicated by having a center of gravity located at a considerable distance above the forcing plane.

The Measurements and Data Unit at present consists of five engineers and three technicians. The unit is responsible for all the test equipment and instrumentation in the environmental laboratory. It is their charge to maintain the equipment in the highest state of proficiency and if a breakdown does occur, to know the equipment so well that the minimum amount of time is spent in detecting and rectifying the malfunctioned part. Breakdowns are costly, principally in manpower and delays in schedules. This unit is charged with the installation of all transducers on a specimen under test, the assembly and interconnection of all the data acquisition equipment, including the checkout of the complete system. As new testing techniques are developed, it often occurs that new equipment and instrumentation are also necessary to meet specific problems. Two such systems, the five position limiter and the multiple safety control are examples of devices which were developed to improve control and prevent catastrophic damage to the integrated SNAP test systems.

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APPENDIXES

The following appendixes present a listing of laboratory equipment specifications and a photographic sampling of SNAP hardware in test.

APPENDIX A

VIBRATION SHAKERS - SPECIFICATIONS

Make	Model	Force-lb Rating (Vector)	Frequency Range (cps)	Maximum Load (Vector)		Maximum Stroke at Double Amplitude (in.)	Table Size (in.)	Environment Range
				(g)	(lb)			
Ling-Temco	249	30,000	5 - 2,000	5 10 20 100	5604 2604 1104 Max	1	28-3/8	Temp: -100° to +300°F Alt: unlimited Humidity: 100%
Ling-Temco	A246	7,500	5 - 3,000	10 20 100	678 303 Max	1	16-1/4	Temp: -100° to +300°F Alt: unlimited Humidity: 100%
MB	C60	6,000	5 - 3,000	120 100	2 20	1	13-3/4	Temp: -100° to +300°F Alt: 0 to 250,000 Humidity: 0 to 100%
Ling-Temco	245	2,250	5 - 5,000	10 20	202.5 90	1	8-13/16	Temp: -100° to +300°F Alt: unlimited Humidity: 0 to 100%
MB	-	50	5 - 10,000	50	6	0.5	1-1/8	-
Vibrasonics	-	20	20 - 24,000	10	2	3/8	1/4 x 28 (mounting platform)	-

Note: Majority of fixtures contain 2 x 2-in. hole spacing, tapped 3/8 in., 24 NF threads.

APPENDIX B

Static Test Equipment

- 1 Rucker Model A-189 Hydraulic test stand 5000-lb pressure)
- 1 Challenger 10M Load Maintainer (10 channels, 10,000 psi)
- 30 Load cylinders of various sizes
- 12 SR-4 Load cells and 5 strain indicators and readouts
- 25 Dial indicators with magnetic stands
- 6 1000-lb Dillon Dynameters
- 15 500-lb Dillon Dynameters
- 2 Budd Model A-110 Digital strain indicators
- 1 200-channel Budd console and strain indicators

Extensive supply of frame set structure (H beams, angles, plates, and special fittings) which like "erector set" is precut and predrilled with lengths and hole spacing, respectively, that permits easy and rapid erection of static test structures)

APPENDIX C

Specifications for the G-338-3 Centrifuge

Manufacturer	TRIO-TECH
Model	G-338-3
G-range	1 to 75 g's
Speed	0 to 300 rpm
Speed accuracy	1.5% max above 10 rpm
	0.1 drive/min. above 10 rpm
Specimen size	24 by 24 by 18 in.
Weight	100 lb max
Centrifugal load capacity	2000 g lb each end
G-range	75 g's at 34 in. radius
Radius of gyration	22 in. min; 46 in. max
Acceleration time	30 to 60 sec
Deceleration	30 to 60 sec
Slip rings	16 low-noise instrumentation rated at 5 amp at 1110 vac

APPENDIX D

LABORATORY TEST EQUIPMENT

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
AMPLIFIERS					
Carrier Amplifier, CEC Type 1-1127	0-3,000 cps flat 0-5,000 cps overall, $\pm 2\%$	4	8	2 element, 120 strain gage - vari reluctance trans- ducer	(in) 1.0 mv (out) galvanometer 48.2 ma
Cathode Follower Amplifier, Columbia Research Model 4000	0-5,000 cps	1	1	Accelerometers Transducers	-
Amplifier & Power Supply, Endevco Model 2616	0-5,000 cps	3	5	Accelerometer Amplifiers	
Galvanometer Amplifier, Minneapolis Honeywell Model T6GA	5-5,000 cps	6	2	Visicorder 1012	Signal amplifying to Brush recorders, oscilloscopes, and galvanometers
Power Amplifier, McIntoch	5-16,000 cps	1	1	All audio use	250 w
ANALYZERS					
Distortion Analyzer, Hewlett Packard Model 330B	5-50,000 cps	1	1	-	Audio frequency measure- ment and distortion ana- lyzer of frequency applied
Spectrum Analyzer, Panoramic Sonic Model LP18A2M	20-20,000 cps	1	1	Vibration Data re- duction equipment	Used for harmonic content and power spectral density analysis

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
CALIBRATORS					
Precision Calibrator RMS-AC-DC, Balantine Model 320	1-10,000 mv ac-dc	1	1	-	For calibrating instruments with either ac or dc precision voltages
CONSOLES					
Strain Gage Indicator, Budd Model C-10T Budd Model C-10LC	0-3,000 cps 0-5,000 cps	2	2	Carrier amplifier to read strain gages	Unit 1: 1 readout indicator (visual), 10 units of switch and balance, and 10 channels in each unit Unit 2: same
Data Channel Calibration Console 1 oscillator 1 ac-dc VTVM 1 amplifier 1 frequency counter 1 shaker 1 power supply and amplifier	5-5,000 cps	1	2	-	Calibrating accelerometers and data channels
Shock Pulse Generator Console 1 bandpass filter 1 waveform synthesizer 1 oscilloscope	5-10 msec	1	3	1/2 sine wave	
Accelerometer Standards Console 1 accel., velocity, displacement indicator	5-5,000 cps	2	1	-	For calibrating accelerometers for servo systems requiring exact (mv) calibration/G

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
CONSOLES (continued)					
1 dc vacuum tube volt-meter					
1 oscillator					
1 shaker head					
1 charge amplifier					
1 frequency counter					
1 amplifier					
Data Reduction Console		1	1		Analyze transmissibility,
Spectral Dynamics Auto-					complex response, perodic
matic Mechanical Im-					wave harmonic or fourier,
pedance Measuring System					duel or single power
2 log voltmeters					spectral density, mechani-
1 master control unit					cal impedance, apparent
2 channel tracking filter					mass, inertness, com-
1 carrier generator					pliance, mobility, stiff-
1 log frequency converter					ness and phase relation
1 phase meter					
Repair Console	-	-	1	-	*See note below
1 frequency counter					
1 oscilloscope					
1 sweep sync.					
1 dc VTVM & ohmeter					
1 dc microvoltmeter					
1 ac VTVM					
1 audio oscillator					
1 decade potentiometer					
1 decade resistor					
2 dc low-voltage power					
supplies					

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APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
CONSOLES (continued)					
Frequency Standard & Servo System Calibration Console	-	-	1		*See note below
1 shortwave WWV receiver					
1 audio oscillator					
1 comparison scope					
1 ac VTVM					
1 ac-dc power supply					
1 Hewlett Packard Scope					
CONVERTERS					
Log Converter, Mosley Model N165T2	dc	1	1	All signal plotting from oscillator audio, voltage frequency	Part of MB shaker system
Ac-Dc Converter, Mosley Type A-1	5-10,000 cps	1	1	-	-
Log Frequency Converter, Houston Model HLFC-120	5-5,000 cps	1	1	-	-
COUNTERS					
Digi-Mark, Chadwick- Helmuth Model 420R	0-10,000 cps	1	3	All amplifiers to count frequency, and all oscillators	(in) 0-5 (out) galvanometer for visual readout on recording
Electronic Counter, Hewlett Packard Model 523B	1-99,999 cps	1	1	Frequency oscil- lator	-
Electronic Counter, Hewlett Packard Model 521AR	1-9,999 cps	1	5	Frequency oscil- lator	Visual frequency or event counting readout

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
DETECTORS					
VHF Detector, Hewlett Packard Model 417A	20-500 mc	1	1	-	Detecting energy within frequency range
DYNAMONITORS					
Endevco, Model 2702C	5-5,000 cps	3	13	Piezoelectric transducer-accel.	(in) 10 mv (out) galvanometer 8.5 v
Endevco, Model 2704	5-5,000 cps	3	6	Piezoelectric transducer-accel.	(in) 10 mv (out) galvanometer 8.5 v
Endevco, Model 2702B	5-5,000 cps	3	7	Piezoelectric transducer-accel.	(in) 10 mv (out) galvanometer 8.5 v
FILTERS					
Filter, Krohn Hite Model 330MR	0.2-20,000 cps	1	4	Vibration systems	Variable fixed
Bandpass Filter, Krohn Hite Model 330M	0.2-20,000 cps	1	6	-	For frequency filtering
Tracking Filters, Spectral Dynamics Model SD1012	2-20,000 cps	1	8	Vibration equip- ment and data re- duction systems	Frequency discrimination for servo systems (sine) 1 data analysis 2 mixed sine, random vibration control 3 power spectral density 4 high db peak or notch filters
GENERATORS					
Waveform Synthesizer, Exact 200	-	1	3	Shock equipment	For synthesizing wave shapes

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Range
GENERATORS (continued)					
Random Noise Generator, General Radio Type 1390B	0-20,000 cps 0-500,000 cps (2 ranges)	1	1	Random vibration systems	-
Square Wave Generator, Hewlett Packard Model 211A	10-10,000 cps	1	1	-	-
INDICATORS					
Load Indicator, Baldwin- Lima-Hamilton Type 120	-	1	4	-	Measurement of loading forces
METERS					
Milliohm Meter, Keithley	0.0015-10 ohm	1	2	-	-
Megohm Meter, Keithley	0.5-500,000 meg	1	1	-	-
Integrating Digital Volt- meter, Dymec Model 2401A	1 mv 1,000 vdc	1	2	-	Without converter reads frequency 1-100,000 cps
VTVM, Hewlett Packard Model 410B	ac-dc & ohms	-	1	-	-
Ac VTVM, Hewlett Packard Model 400DR	-	-	2	-	-
Dc Micro Voltmeter, Hewlett Packard Model 425AR	-	-	1	-	-
Frequency Meter, Hewlett Packard	10-10,000	-	1	-	-

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
METERS (continued)					
VOM, Tripplett Model 630-NA	-	-	6	-	-
Phase Meter, AD-YO Type 320-AB	5-5,000 cps	1	1	Vibration equip- ment	Phase angle measurement
Impedance Bridge, General Radio Type 1560A					
Automatic Frequency Meter, Solid State Electronic Corporation	0-5,000 cps 0-500 cps 0-50 cps (3 ranges)	1	1	Any oscillator	-
OSCILLOSCOPES					
Memo Scope, Hughes Oscil- lator Model 105A	ac 1 mv 1,000 v		1	-	Image retention Measuring ac and resistance also measures resistance 1 milli ohm and 1 meg
Low Frequency Standard, Hewlett Packard Model 100D	10-10,000 cps	1	1	-	For calibration
Single Beam Scope, Tektronix 502	-	-	1	-	Signal observation & meas- uring voltage, visual readout
Single Beam Scope, Tektronix 535	-	-	1	-	Same
Signal Beam Scope, Tektronix 545	-	-	1	-	Same
Dual Beam Scope Tektronix 555	-	2	3	Shock Instrument- ation	Same

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
OSCILLOSCOPES (continued)					
Plug-in Units for Tektronix Scopes					
High Gain, Differential (dc) Preamp, Type D	dc to 350 kc 1 mc/cm to 50 v/cm, Variable 1 mc/cm sweep speed	-	2	Oscilloscopes for work requiring dc coupling at sensi- tivities as high as 1 mv/cm	-
Wide Band, Differential Calibrated Preamp, Type G	dc to 20 mc 0.05 v/cm to 20 v/cm	-	1	Oscilloscopes for work requiring differential	Input with a high rejection ratio for inphase signals. Also combined with wide band width and excellent transient response.
Strain Gage, Preamp, Type Q	-	-	1	-	-
Differential Comparature, Type Z	-	-	1	-	-
Time Base Generator, Type T	-	-	1	-	-
Dual Beam Rack Mount Scopes, Hewlett Packard Model 122AR		2	2	-	-
STROBE EQUIPMENT					
Strobe Lights, Chadwick Helmuth Model 126R	5-1,000 cps	1 1	8 5	-	-
Strobe Camera, Chadwick Helmuth Model 370C	8-24 frames/ sec	1	2	-	Observing & photographing cyclic motion. Sixteen MM pulse operated

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APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
STROBE EQUIPMENT (continued)					
Lights, General Radio Strobe Attack	20-5,000 rpm	1	1	-	For strobing and dis- cerning rpm
OSCILLATORS					
Function Generator, Hewlett Packard Model 202A	5-50,000 cps	1	1		Output waveform; sine, square, or triangle
Audio Oscillator, Hewlett Packard Model 1206A	6-10,000 cps	1	5	Vibration and audio equipment	For operating & servicing
Cycling Oscillator & Servo, Bruel Kjoel Type 1018	5-5,000 cps	1	1	-	Controlled frequency for vibration testing
Audio Signal Generator, Hewlett Packard Model 206A	2-2,000 cps	1	1		
PLOTTERS					
XY Plot Autograph, Mosley Model 55	$1-10^3$ mv/in.	1	1	Vibration & data reduction equip- ment	-
X-YY' Plotter, Electro Instruments Model 480	$1-10^3$ mv/in.	1	2	Vibration & data reduction equip- ment	-
POWER SUPPLIES					
Hewlett Packard Model 721A	0-30 vdc	-	3	-	General purpose
Hewlett Packard Model 722AI	0-60 vdc	-	2	-	General purpose

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APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Range
POWER SUPPLIES (continued)					
Regitron, Electronic Measurements Model 236 AMK	0-6,000 vdc	-	1	-	General purpose
Gates Electronic Model G30.10FR	0-10 amp dc	-	1	-	-
RECORDERS					
Brown Temperature, Honeywell Type 153	0-1,000° F	1	1	-	Temperature measurements ±300 to -65° F
Tape Recorder, Ampex FR1200	dc to 20,000 cps	14	1	Recording vibration & shock equipment, data reduction equipment	1-in. tape 1-7/8 in./sec -60 in./sec 1.00 rms input
Tape Recorder, Ampex Model FR1100	dc to 20,000 cps	7	1	Recording vibration & shock equipment, data reduction equipment	1-in. tape 1-7/8 in./sec -60 in./sec 1.00 rms input
Tape Recorder, CEC Model PR3300	dc to 20,000 cps	14	1	Recording vibration & shock equipment, data reduction equipment	1 in. tape 1-7/8 in./sec -60 in./sec 1.00 rms input
Visicorder Recorder, Minneapolis Honeywell Model 1012	-	36	3	-	-
Event Recorder, Lockheed Model 170	-	12	4	-	Counting (g) peaks

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Range
TV EQUIPMENT					
Camera, Dage Model IMRGS-10 and Model 63A	-	1	2	-	-
Monitor, Dage Model IMRGS-10 and Model 63A	-	1	2	Camera centrifugal test or any observation requiring closed circuit TV	-
TRANSDUCERS					
Accelerometers	dc-10,000 cps	-	75 miscel- laneous sensiti- vities	-	-
Pressure Transducers, CEC	0-5 lb	1	3	CEC Amplifier	Measure pressure, psi
MISCELLANEOUS					
Temperature Controller, Fenwell	0-3,000° F	1	1	-	-
Tube Checker, Hickock Model 630-NA	-	1	1	-	-
Transistor Checker, Hickock Model 870	-	-	1	-	-
Potentiometer, Deka-box, Electro Scientific Model DV 412	input resis- tor 10,000 ohm 0-full scale in 10,000 steps	1	6	Servo RF Units	-

APPENDIX D (Continued)

Instrument Type	Range	Channels Per Unit	No. Units in Lab	Used With	Remarks
MISCELLANEOUS (continued)					
Capacitor, Dekka-box, Electro Measurements Inc., Decade resistors, Model DV655	0-1 meg	1	3	-	-
Decade capacitors, Model DC40	0-1, 111,000 micro-micro farads	1	2	-	-
Cameras, Polaroid, Hewlett Packard Model 196A	-	-	1	Oscilloscopes only	-
Tektronics Model C-12	-	-	1		-

APPENDIX E

Representative Tests of SNAP Components

4-5-63

7561-5250

Figure E-1. SNAP 10A PSM1A Systems Unit With Heat Shield
Longitudinal Vibration Test

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6-15-62

7580-54155B

Figure E-2. SNAP 10A Converter Module Mockup Section Vibration Survey

7-10-62

7561-5403B

Figure E-3. SNAP 10A Expansion Compensator
Vibration Test - Dual Installation

7-10-62

7561-5402B

Figure E-4. SNAP 2/10A Shield Longitudinal Vibration Test
(Rotated Axis)

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5-25-63

7561-51225

Figure E-5. Converter Modules Lateral Test

5-17-63

7561-52110

Figure E-6. SNAP 10A Static Test Showing Side Loading Bands Over Foamed Plastic and Deflection Dial Gages

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1-17-63

7561-55100

Figure E-7. SNAP 10A Titanium Converter Section (Lower)
Static Compression Loading

9-9-62

7561-5507

Figure E-8. Control Drum Bearing Test

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8-10-62

7561-5504B

Figure E-9. SNAP 2 Honeycomb Panel Section Plus Emissivity Coating
Vibration at Second Bending Mode

9-12-62

7568-5007

Figure E-10. SNAP 8 Reactor Core Mockup Installation of Internal Instrumentation for Vibration Test