DYNAMIC BEHAVIOR OF LAUNCH FACILITY FOUNDATION AND SURROUNDING AREAS

by

R. F. Ballard, Jr.

May 1970

Sponsored by National Aeronautics and Space Administration
Kennedy Space Center, Florida

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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MISCELLANEOUS PAPER S-70-20

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Foreword

The investigation reported herein was authorized by the National Aeronautics and Space Administration (NASA) in Defense Purchase Request No. CC-14029 Amendment No. 7, dated 12 January 1968.

This report presents the results of a study related to the dynamic behavior of launch facility foundations and surrounding areas. Field tests were conducted intermittently during the period February 1965 through August 1966.

Engineers of the U. S. Army Engineer Waterways Experiment Station (WES) who were actively engaged in the field investigation, analysis, and report phases of this study were Messrs. R. W. Cunny, Z. B. Fry, Jr., and R. F. Ballard, Jr., of the Soils Division and Messrs. H. C. Greer III and E. L. Estes of the Instrumentation Branch. The work was conducted under the general supervision of Messrs. J. P. Sale and A. A. Maxwell (deceased), Chief and Assistant Chief, respectively, of the Soils Division. This report was prepared by Mr. Ballard.

COL Levi A. Brown, CE, was Director of the WES during the preparation and publication of this report. Mr. F. R. Brown was Technical Director.
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Summary

Ground and structure motions resulting from three Saturn space vehicle launches were recorded at Cape Kennedy, Florida. The purpose of the tests was to determine the actual magnitudes of ground motion at distances from the launch pad as related to motion of the pad itself resulting from the launch of the Saturn vehicles and the dynamic characteristics of the soil material.

Results of vibro/seismic tests revealed that compression-wave velocities below the shallow water table were about 4800 fps and shear-wave velocities ranged from 300 fps near the surface to 1400 fps at a depth of 120 ft.

Data analysis was performed by the following techniques: RMS time-history, frequency spectrum, geometrical configuration, and auto and cross-correlation methods.

Maximum RMS particle velocities varied from about 2.7 ips, 50 ft from the center of the vehicle to about 0.03 ips at a location some 5246 ft distant. Predominant frequencies recorded during all launches were 6.5, 16.5, 27.5 54, and 105 Hz.

Attempts to separate the acoustic from the seismic influence were successful. The dominant frequency of the seismic component was found to be 6.5 Hz and the dominant frequency of the acoustic component is 16.5 Hz.
MEMORANDUM FOR RECORD

Background, purpose, and scope of study

1. At the request of the National Aeronautics and Space Administration (NASA), personnel of the U. S. Army Engineer Waterways Experiment Station (WES); performed dynamic soil tests and recorded ground motions resulting from three space-vehicle launches. Two of the launches were Saturn I vehicles designated SA-9 and SA-10, launched on 16 February and 30 August 1965. A third Saturn I B was launched on 25 August 1966 under the code name AS-202. Ground motions were recorded in the vicinity of Complex 37 during the first two launches. The AS-202 was launched from Complex 34, so motions for the third launch were recorded in that vicinity.

2. The purpose of these tests was to determine the actual magnitudes of ground motion at various distances from the launch pad as related to motion of the pad itself resulting from the launch of a Saturn space vehicle and the dynamic characteristics of the soil material. The scope of this memorandum is an analysis of motion from selected locations deemed representative of acoustic and seismic effects. In addition, results of pertinent in situ tests performed to determine dynamic properties of materials in the vicinity of the launch sites are included.

The investigation

3. Location and description of test site. The tests described in this memorandum were performed within the perimeter of Complexes 34 and 37 and at various locations along a line from Complex 37 toward the base telemetry station, known as TEL 2, at Cape Kennedy. The soils are primarily beach sands with some organic material near the surface and clayey sand at lower depths. Typical borings in the area indicate loose sand from 0 to 10 ft, loose clayey sand from 10 to 18 ft, loose sand from 18 to 22 ft, and very loose clayey sands to a depth of about 200 ft, at which point limestone is encountered. The terrain is undulating, with numerous knolls or dunes, and is covered with scrub brush and palmetto.
4. **Vibro/seismic tests.** Refraction seismic data were collected at each of the transducer group locations that were on a line extending from Complex 37. A total of 12 lines were run, four at each of the three far-field locations. In a similar fashion, vibration tests were also conducted at each of the three far-field locations.

5. Seismic tests were conducted at the Cape Kennedy test site using a simple hammer-type refraction seismograph unit, which provides a reliable and quick method of determining the near-surface compressional-wave velocities in this area.

6. The vibration tests were conducted to determine the velocity of shear waves in the soil at various frequencies and the resultant dispersion curve. These tests were performed with a high-frequency electrodynamic vibrator and a low-frequency counter-rotating mass vibrator in accordance with the procedure outlined in WES Miscellaneous Paper (MP) No. 4-577, "A Procedure for Determining Elastic Moduli of Soils by Field Vibratory Techniques," dated June 1963, and WES MP No. 4-691, "Determination of Soil Shear Moduli at Depths by In-Situ Vibratory Techniques," dated December 1964. MP No. 4-577 explains how wavelengths of propagated Rayleigh waves (treated as shear waves) of known frequency are used to determine the elastic moduli of subsurface materials. MP No. 4-691 describes improvements in vibrators and instrumentation that have increased the effective depths of site investigations.

7. **Ground-motion study.** The transducer locations utilized during the three launches are shown as follows:

<table>
<thead>
<tr>
<th>Event</th>
<th>Transducer locations</th>
</tr>
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<tbody>
<tr>
<td>SA-9</td>
<td>On the south pedestal leg of the launch pad (Complex 37)</td>
</tr>
<tr>
<td></td>
<td>1071 ft from the launch pad</td>
</tr>
<tr>
<td></td>
<td>2735 ft from the launch pad</td>
</tr>
<tr>
<td></td>
<td>5246 ft from the launch pad</td>
</tr>
<tr>
<td>SA-10</td>
<td>On the south pedestal leg of the launch pad (Complex 37)</td>
</tr>
<tr>
<td></td>
<td>400 ft from the launch pad (surface and in two borings)</td>
</tr>
<tr>
<td></td>
<td>1071 ft from the launch pad (surface and in two borings)</td>
</tr>
<tr>
<td></td>
<td>2735 ft from the launch pad</td>
</tr>
<tr>
<td></td>
<td>5246 ft from the launch pad</td>
</tr>
<tr>
<td>AS-202</td>
<td>AGCS room directly under the launch pad (Complex 34)</td>
</tr>
<tr>
<td></td>
<td>400 ft from the launch pad</td>
</tr>
<tr>
<td></td>
<td>1000 ft from the launch pad</td>
</tr>
<tr>
<td></td>
<td>1235 ft from the launch pad</td>
</tr>
</tbody>
</table>
8. Each transducer location associated with the ground-motion studies consisted of three pickups oriented vertically, horizontal parallel, and horizontal transverse to a radial line from the wave source. Prior to the launches, cables were strung from a recording van or the control center to each transducer location. During the first cable-laying process (SA-9 launch), it was discovered that rabbits were maliciously attacking the cables already in place, and necessary repairs had to be made to the cables. Numerous methods were employed to prevent this type of damage to the cables, but none were completely effective. During the night prior to launch, the cables were actively patrolled by men and vehicles. Instrument cables were buried during subsequent launches.

9. Arrangements were made for ZULU timing, external power, and audio countdown to the central recording stations.

10. On the day of the launches, the instrumentation was checked and gain controls were set for expected motion computed from NASA acoustic data and previous measurements made by the WES and the U. S. Coast and Geodetic Survey during previous launches.

11. All recordings were made simultaneously on both tape and oscillograms during every launch operation. At the conclusion of data acquisition, oscillograph records were immediately reviewed and duplicates made of magnetic tapes for NASA files.

Data analysis

12. Vibro/seismic tests. Refraction seismic data were so similar that a single composite plot of four of the lines is shown in fig. 1 as a typical example of the compression-wave velocities of the near-surface materials. The unsaturated sand in the upper 6 ft of material has an average velocity of 1050 fps, which appears to be reasonable. The change in velocity indicated by the seismic data to be at an approximate depth of 6 ft roughly correlates with the water table observed at three well-points near each of the three far-field locations. The wave velocity below the water table averages 4800 fps to an undetermined depth, as indicated by all 12 seismic lines. This velocity is about that of water, but it is believed to also be representative of the sand stratum immediately below the water table.

13. Vibration tests were also conducted at each far-field location. These data likewise were virtually the same for each location and are represented by typical plots. Fig. 2 shows the shear-wave velocity as a function of approximate depth (one-half the wavelength) and indicates an increase with depth ranging from 300 fps near the surface to 1400 fps.
Fig. 1. Velocity determinations from seismic tests

Note: Composite averages of transverses 5-5, 6, 7, and 8 at location 3.
Fig. 2. Shear wave velocity versus depth
at a depth of 120 ft. The computed Poisson's ratio above the water table was 0.41 and below the water table, 0.48. Elastic moduli versus approximate depth are shown in fig. 3. These data were computed in accordance with MP No. 4-577, cited in paragraph 6. As a matter of analytical interest, the data shown in figs. 4 and 5 are representative of frequency as a function of wavelength and shear-wave velocity, respectively. These plots appear to show a straight line power function relationship. It can be stated unequivocally that the signal quality of the steady-state waves generated in the sand materials at Cape Kennedy resulted in some of the most consistent vibration data yet acquired at any test site by the WES.

14. **Ground-motion study.** A root mean square (RMS) particle velocity time-history analysis was performed for all data channels. Data presented in this form show the arrival times and duration of wave trains more clearly than the conventional velocity time-history oscillograms. A typical example of data in the RMS format is shown in fig. 6. In this example, the times of the SA-9 ignition and lift-off events are labeled. Utilizing the RMS time-histories in conjunction with the actual oscillograph records, which were calibrated in terms of RMS particle velocity, plots were made showing the maximum RMS velocity recorded at each seismic station during the SA-9, SA-10, and AS-202 launches. Figs. 7, 8, and 9 are plots of vertical, radial, and transverse modes, respectively, while fig. 10 presents the average of all three modes. It will be noted that the first location is shown to be located at a distance of 50 ft. This measurement is referenced to the center of the space vehicle. No data are shown at the 50-ft location for the AS-202 launch because this station was located in the AGCS room, which is underneath the launch pad at Complex 34, and was not subjected to the degree of acoustic blast recorded during the SA-9 and SA-10 launches. The amplitudes reflected in figs. 7, 8, 9, and 10 are, of course, the sum of all acoustic and seismic wave trains. An attempt to separate acoustic from seismic energy will be made later in this discussion.

15. **Field data were analyzed for frequency content by the use of a heterodyne-type frequency analyzer (Gulton Ortholog Model WA-1).** Time compression techniques were employed in processing the data. The linear spectral density (LSD) analysis is designed to show which frequencies contribute most to overall amplitudes during the time frame chosen for analysis. The data were analyzed in two frequency spectrum segments, 0 to 50 Hz and 25 to 500 Hz, so that optimum analyzer (machine constants) benefits could be obtained. All active data channels were subjected to frequency spectrum analysis following return to WES after each launch operation.
Fig. 3. Moduli versus depth
Fig. 4. Frequency versus wave length (dispersion)
Fig. 5. Frequency versus velocity
On the pad...

2735 ft from the pad.

Fig. 6. RMS velocity time-history, vertical motion.
Fig. 7. Vertical mode amplitude
Fig. 9. Transverse mode amplitude
Fig. 10. Average amplitude, all components
16. It should be stated that the amplitudes of the LSD plotted by the analyzer for any particular frequency represent values averaged over the entire record. Thus, the instantaneous amplitudes may be much higher or lower for any instantaneous time interval within the record.

17. Typical examples of LSD analysis are shown in figs. 11 and 12. This particular example is applicable to data recorded at the 2735-ft location during the SA-9 launch. It was not deemed necessary to present the myriad plots obtained for all stations since it will suffice to say that far-field prime frequencies were similar during all launches. It will be observed that the predominant frequencies are: 6.5, 16.5, 27.5, 54, and 105 Hz. The lower frequencies (6.5 and 16.5 Hz) exhibit, by far, the greatest magnitudes. No frequencies higher than 105 Hz contributed greatly toward recorded motions at stations located beyond 400 ft from the launch pads.

18. Acoustic-seismic comparison. Needless to say, the acoustical pressures resulting from the launch of a space vehicle with the size and thrust of the Saturn 1 and 1B are of considerable magnitude. As an example, at an acoustic station adjacent to a WES seismic station 400 ft from the SA-10 launch, sound-pressure levels were recorded in excess of 140 db. In other terms, this is a pressure level of about 0.03 psi. The acoustic measurements are regularly made by NASA personnel and published in the format shown in fig. 13, which was extracted from NASA TR-184, Part II, October 21, 1965, entitled, "Results of Sound Pressure Level Measurements During SA-10 Launch."

19. It can be readily seen in fig. 13 that the maximum sound-pressure level was recorded in the shaded frequency band from 12 to 31.5 Hz, and it peaked at 16 Hz. In numerous cases, when observing acoustic data obtained during the SA-9, SA-10, and AS-202 launches, the prominent acoustic frequencies appear to develop in the range above 16 Hz.

20. After the SA-9 and SA-10 launches, WES ground-motion data were subjected to critical analysis from the standpoint of acoustic-seismic separation. This was undertaken at the suggestion of Messrs. J. H. Deese and R. H. Jones, both of NASA. Incl 1 is a memorandum written by Mr. Jones discussing the acoustic-seismic effects. Verbal discussions prior to the inception of this memorandum prompted the conduct of pure acoustic tests on the WES seismic transducers. Results of these tests, shown in entirety in Incl 2, led to the conclusion that the instruments were indeed acoustically isolated and any acoustic component noted in the seismic data would be the result of mechanical coupling and not pure acoustic energy.
Test period analyzed, Zulu 1437:06.0 to 1437:34.0
Effective filter band width, cps 1.25
Sweep time, sec 1000
Smoothing time constant, sec 2
Loop time, sec 3.5

Fig. 11. Frequency spectrum analysis, 0-50 Hz. Vertical motion measured 2735 ft from the pad
Test period analyzed, Zulu 1437:06.0 to 1437:34.0
Effective filter band width, cps 10
Sweep time, sec 2040
Smoothing time constant, sec 20
Loop time, sec 28

Fig. 12. Frequency spectrum analysis, 25-500 Hz. Vertical motion measured 2735 ft from the pad
Fig. 13. Spectral distribution, SA-10 launch. Measurements made 400 ft from Complex 37.
(After Fig. 60, NASA TR-184, Part II)
21. Further acoustic-seismic investigations were undertaken by Dr. R. A. Weiss in his WES Contract Report No. 3-158, "Ground Motion Due to Surface Sources," June 1966, pp 45-66. In this analysis, Dr. Weiss used a rectangular shape, analogous to the Complex 37 launch pad, as a common source of ground motions. The problem was approached essentially in the calculation of geometry-load factors. This approach may be briefly summarized by saying that the effect of the extended area of the source on the far-field ground motion is represented by calculating an effective (or equivalent) point-source function, which involves the geometry-load factors of the source (which are highly frequency-dependent functions). Using actual dimensions of the launch pad (which is actually trapezoidal, but sufficiently close to a rectangular shape to warrant its use), from which maximum and minimum amplitudes can be predicted for far-field ground motions, one can determine the corresponding critical frequencies from a dispersion curve such as already shown in fig. 4. These frequencies can then be compared with a frequency spectrum analysis of the far-field ground motion observed during a missile launch. Dr. Weiss explains that the relative strength of the acoustic component can be estimated by noting that at the critical frequencies corresponding to zero (negligible) ground-motion transmission, the motion recorded is due to the acoustic component alone. Figs. 14 and 15 depict the acoustic-seismic separation as interpreted by Dr. Weiss.

22. Auto and cross-correlation. One of the most powerful techniques used to describe the properties of random fluctuations in the time domain is the correlation function. The correlation concept can establish a measure of similarity between two waveforms or the relative influence of one signal upon another. The autocorrelation function refers to the dependency of a random signal upon a time-shifted version of itself, and provides a convenient means of determining the presence of a periodic signal obscured in a background of random noise. The cross-correlation function may be employed to establish a possible cause-and-effect relationship between a disturbing signal source and a reverberant condition. For example, cross-correlation is useful in determining the transmission paths and propagation velocities of a random vibration source. By using one recorded signal as the reference source, other signals recorded at different locations can be cross-correlated with the reference thereby extracting the periodic signals from random noise.

23. Both the auto and cross-correlation methods were utilized by WES in processing the AS-202 launch data with the Princeton Applied Research signal correlator (model 100). Results of autocorrelation attempts were satisfactory, but the obvious approach to satisfy the desired objective proved to be the cross-correlation function. Establishing the vertical
Fig. 14. Frequency spectrum analysis, 0-50 Hz. Vertical motion measured 2735 ft from the pad.
(From WES Contract Report 3-158)
Fig. 15. Frequency spectrum analysis, 0-50 Hz. Vertical motion measured 5246 ft from the pad.
(From WES Contract Report 3-158)
SUBJECT: Dynamic Behavior of Launch Facility Foundation and Surrounding Areas

pickup under the launch pad as reference, cross-correlations were performed with the other three vertical pickups located 400, 1000, and 1235 ft from the launch pad. Wave velocities ranging from 1111 to 1236 fps were determined and a predominant repetitive frequency of about 14 Hz was observed. This frequency compares favorably with the prominent 16 Hz observed on the frequency spectrum analysis for all three Saturn launches. Since the velocity of this wave is approximately that of sound, it follows that the motions associated with 14 to 16 Hz result from an acoustic coupling.

Conclusions

24. The following conclusions were drawn from the interpretation and analysis of data associated with launches of space vehicles SA-9, SA-10, and AS-202.

a. Compression-wave velocities below the very shallow water table were about 4800 fps.

b. Shear-wave velocities ranged from 300 fps near the surface to 1400 fps at a depth of about 120 ft.

c. Predominant frequencies recorded during all launches were 6.5, 16.5, 27.5, 54, and 105 Hz. (Higher frequencies were recorded on the launch pad that were not of sufficient magnitude to influence movement recorded at far-field locations.)

d. The frequencies of 6.5 and 16.5 Hz contributed the greatest influence toward maximum recorded motions.

e. The geometry of the launch pad plays a significant role in determining the frequency spectrum of the ground motion resulting from a seismic source.

f. At high frequencies (probably above 12 Hz), the ground motion is due mainly to the acoustic component.

g. The dominant frequency of the seismic component is 6.5 Hz and the dominant frequency of the acoustic component is 16.5 Hz.

R. F. BALLARD, JR.
Physicist
Vibratory Loads Section
TO: Chief, Measurements Systems Division, PC
FROM: Chief, Operations Branch, PC-3
SUBJECT: Trip Report

Purpose of Trip: To Investigate Seismic Activities at MSFC on Saturn V Firings.

Persons Contacted: Mr. Kenneth Crane, PEVE (Brown Engineering)
Mr. Richard Tedrick, PEVE (Brown Engineering)
Mr. Robert Turner, AERO
Dr. Ilmarn Dalins, Research Projects

1. Introduction:

From discussions with Ken Crane, PEVE, and Robert Turner, AERO, it was learned that some seismic investigations have been conducted on the Saturn Static Firings by four organizations at MSFC. At present, only Dr. Dalins, of Research Projects, located at Research Institute is active in the field. The other organizations have determined that the seismic waves created by static firing of the Saturn SIC stage are not of sufficient amplitude to be of concern to their respective organizations. All persons contacted agreed that the true seismic wave, that is the wave resulting from the firing transmitted entirely through the earth, is negligible, and in fact is difficult to distinguish from the background seismic noise. The major apparent seismic reading is obtained from the acoustic waves which are propagated through the air, at a significantly slower speed than the seismic wave, but couple to the earth and cause a shallow seismic disturbance.

2. Past MSFC Seismic Measurements:

2.1 Test Division - Mr. Richard Tedrick stated that at early Saturn I static firings, Test Division had made some attempts to measure seismic activity associated with static firings but were unable to detect significant amplitude prior to arrival of the acoustic waves.

2.2 PEVE - PEVE has made seismic measurements on both SIB and SIC static firings. These measurements were made on Spragdenner Portable Blast

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and Vibration Seismograph SN2723. Measurements were made in and near Building 4610. Kyle Labs made seismic measurement outside of Building 4200 in May of 1964. No significant readings were obtained until arrival of the acoustic wave. Accelerometers placed on building columns in the basement of Building 4610 set for 1G max failed to register any signal above the background noise. The distance from the static test stands to Building 4610 are 8,600 and 6,200, respectively, from the SIB and SIC test stands.

2.3. AERO - Mr. Bob Turner stated that several seismic measurements had been made at the Metro station located near Martin and Rideout Roads. He could not distinguish any seismic signals prior to arrival of the acoustic wave.

2.4 Research Projects - Dr. Dalins has the responsibility to investigate damage claims filed against MSFC. He has made seismic recordings both at MSFC, and at KSC. Within sixty days, he hopes to have operational, six highly portable 3 axis stations which will measure displacement.

3. Seismic Activities at KSC:

During the SI Program seismic measurements have been made by three separate organizations. The Coast and Geodetic Survey under Air Force/Pan Am contracts attempted measurements on many of the Saturn I launches. The Corps of Engineer Waterways Experiment Station made measurements for Mr. Deese of the Future Studies Office. Ballistics Research Laboratory (BRL) AFG, Md., made some measurements on approximately three launches and were sponsored partially by the Safety Office. The amplitude of the signals recorded were at least from five to ten times greater after the arrival of the acoustic wave. Except at locations extremely close to the launch pad, the true seismic wave is often obscured by other seismic disturbances such as ocean waves, road traffic, etc.

4. Inconsistencies:

Seismic data can be recorded from instruments designed to measure either displacement, velocity, or acceleration. Often the waves are treated as sinusoidal and the data is converted to the other two properties through straight integration or differentiations. Since the data is far from being a sine wave, one must be very careful when comparing data taken by different organizations. No attempt has been made to determine the affect of the acoustic wave on the seismic pick-up instruments. Their
delicate construction would appear to make them extremely microphonic. Geophones have been placed at several depths, in pipes below the ground to escape the acoustic environment by the Corps of Engineers. These submerged geophones recorded higher values than the geophones located at the surface. It is suspected that the sound wave was transmitted through the water down the pipe and essentially amplified the acoustic effect on the geophones. Acoustic isolation is planned by the Corps in future efforts.

5. Conclusions:

The pure seismic wave created by Saturn launches is insignificant. The seismic wave particularly near the surface caused by acoustic coupling with the earth might be significant where extremely delicate equipment is involved. Separation of the data into microphonic pick-ups of the instruments and earth surface disturbances has never been attempted and would appear too desirable if accurate and consistent data is necessary. Since the major cause of the seismic activity is acoustic, and each and every structure will react in some complex relationship to both the acoustic and the seismic excitation, it appears that seismic data would be of minor importance except in rare cases. Vibration measurement on particular structure would appear more desirable and useful.

Ralph H. Jones

cc:
K. Sendler, PA
J. Deese, MC
Memorandum

TO: R.B. Upson
FROM: A.B. Gore/D.R. Ingalls

DATE: 31 August 1966

LAB-1/66

ISS PROJECT-MILA

FEDERAL ELECTRIC CORPORATION

SUBJECT: Effect of Pure Acoustic Energy on MB Seismic Transducer

I. Results

No output was observed from any of the transducer coils with 103 dB of Random Noise or 100 dB of Sine Wave Energy Applied.

II. Test Procedure

A. Equipment

1. B&K piston phone # 4220
2. B&K condenser mike # 2613
3. B&K mike amplifier # 2603
4. CR random noise generator # 1390B
5. SKL band pass filter # 302A
6. McIntosh power amplifier 70 watts
7. KLH model 6 acoustic suspension speaker system - woofer only
8. Tektronix # 321A scope
9. Eckol anechoic chamber # 666-250
10. H.P. 202 CR oscillator

B. Test Hookup

[Diagram of test setup with labeled components]

ANECOIC CHAMBER
C. Test Method

1. Calibration of the B&K mike & miko amplifier was performed using the B&K piston phone at 123.8 DB.

2. The acoustic energy in the chamber was provided by the random noise generator fed through the bandpass filter, (set to pass 4 cycles through 500 cycles), amplified by the McIntosh and fed into the KLH woofer.

3. Transducer isolation from mechanical coupling was accomplished by suspending it with lacing cord from the ceiling of the chamber.

4. The McIntosh was set to provide 108 DB of sound pressure level, (the maximum available with this equipment), as measured on the mike amplifier, and each of the three transducer coils were monitored on the .010V/CH range of the scope. No change in the output was noted.

5. Approximately 100 db of the sine wave energy was then introduced in the chamber at different frequencies between 4 & 500 cycles in an attempt to produce resonance within the transducer. Again no change in the output was noted at any frequency.

III. Conclusion

A. In view of the above test results, it would appear that any acoustic component noted in the seismic data would be a result of mechanical coupling and not pure Acoustic Energy.

D.R. Ingalls
Testing Technician

A.B. Goro
Meas. Lab Supervisor