Attachment 3

H.V.L NOV 30 1981

ARIZONA NUCLEAR POWER PROJECT

150" Reed Switch Position Transmitter and Litton Electrical Connector

SEISMIC QUALIFICATION TEST

(Sine Sweep Testing)

Test Report

TR-ESE-442

NUCLEAR LABORATORY

POWER
SYSTEMS
COMBUSTION ENGINEERING, INC

COMBUSTION ENGINEERING

DEVELOPMENT DEPARTMENT

TEST REPORT

SEISMIC QUALIFICATION TESTING
SYSTEM 80 REED SWITCH POSITION TRANSMITTER
AND LITTON ELECTRICAL CONNECTOR

ARIZONA NUCLEAR POWER PROJECT - PALO VERDE
NUCLEAR GENERATING STATIONS 1, 2, AND 3
777009

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1.0 INTRODUCTION

The 150" Reed Switch Position Transmitter (RSPT) and the Litton connector are electrical devices which must function in an environment of high temeprature, radiation, humidity and vibration during normal plant operation. In addition, as a Class 1E electrical component, the instrument must perform adequately during seismic environments up to SSE intensities as transmitted up to its mounting location (namely, the CEDM shroud) in a plant.

The subject report describes the procedures which were undertaken to demonstrate the RSPT's ability to withstand the seismic intensities stipulated for the ANPP reactor when it is installed in a representative CEDM. The test specimens had already undergone temperature and radiation aging.

2.0 SUMMARY

2.1 Sine Sweep Testing

Sine sweep tests confirmed the analytically predicted dynamic behavior (natural frequencies) of the ANPP type CEDM. This fact gave assurance that the subsequently conducted qualification effort would address the worst seismic response condition for the ANPP reactor.

The large amount of frequency, damping and mode shape data reported in this document will serve for future correlation efforts with analytical models.

2.2 Seismic Qualification Testing

The two RSPT samples as installed in a representative ANPP type CEDM were exposed to a sufficient number of biaxial "random" multi-frequency input motions of intensities greater than the required OBE and SSE response spectra. The RSPTs were tested in four orientations to allow for their asymmetric design. No adverse transients of failure modes in the electrical performance of the RSPTs were observed in any of the numerous tests. Therefore, the conducted test is proof that the RSPT assembly meets the seismic requirements imposed by the References 2 and 10.

3.0 OBJECTIVES

3.1 Sine Sweep Testing

The objective of the sine sweep test was to identify the dynamic characteristics of the RSPT support structure; namely, of the ANPP type CEDM with the longest nozzle. Natural frequencies and associated mode shapes, as well as modal damping parameters were to be obtained prior to the qualification tests for correlation with analytical predictions.

3.2 Seismic Qualification Testing

The objective of this program was to seismically qualify the ANPP RSPT and the associated Litton electrical connector for commercial service in accordance with the purchaser's requirements of References 3 and 4. Proof was to be established that the RSPT design would remain functional when installed at its permanent location during or following a seismic event of an intensity up to SSE magnitudes. The RSPT was to be exposed to a minimum of five OBE events and one DBE event following the appropriate temperature and radiation aging test programs.

4.0 EQUIPMENT DESCRIPTION

4.1 RSPT

The production RSPT is a transducer device used to determine the position of the CEA within the reactor core. The instrument is housed in a stainless steel tube within the shroud which is positioned adjacent to the extension shaft upper pressure housing of a CEDM.

The production RSPT is essentially a voltage divider network comprised of an array of magnetically actuated reed switches wired to a series chain of resistors. The reed switches, resistors, and wire are mounted on an extruded plastic strip at precise 1.5 inch intervals. A permanent magnet attached to the top of the extension shaft generates the magnetic flux necessary to actuate and deactuate the switches yielding voltage signals proporational to the CEA position. Three additional separate circuits provide contact closures which indicate the Upper Electrical Limit, Lower Electrical Limit, and Dropped CEA position. The RSPT is fabricated in compliance with the drawing of Reference 8 and specifications of Reference 7.

A 150" full length RSPT has been randomly selected from the production line for qualification testing. This test specimen has already undergone thermal and radiation aging.

4.2 Litton Electrical Connectors

The component is a bayonnet locking electrical connector providing the interface connection between the head area cabling and the RSPT. The cable penetrations are designed to seal against fluid entry into the connector. The head area cabling connector is the Litton CIR06-CE-20-33S straight plug. The mating box mounting receptacle which is attached to the RSPT is the Litton CIR02-CE-20-33P.

5.0 TEST DESCRIPTION

5.1 Mechanical Test Set-Up

A full-size 150-inch Control Rod Drive Mechanism (representative of the ANPP design), including the drive shaft, water, conduit and

2 RSPTs (Serial Nos. 597 and 604), were assembled onto the seismic simulation fixture. For this purpose, a special test nozzle had been designed and fabricated. The test set-up simulated the longest CEDM nozzle which, by analysis, had been shown to yield the highest CEDM response characteristics.

For the sine sweep, as well as the seismic qualification tests, the hydraulic actuator of the seismic shaker system was set at a 45° angle, thus providing excitations of similar magnitudes to both axes. Although the CEDM itself is symmetric about its vertical axis, the RSPTs are not, thus, in accordance with the Guidelines of Reference 2, four test orientations were required. This was accomplished by rotating the test nozzle plus CEDM structure once by 90° and by switching the two RSPT samples in each of the two nozzle orientations. Figure 16 depicts the four test orientations. The two RSPT samples provided for the test were inserted in the CEDM shroud and clamped into place. The actuating magnet was attached to the drive shaft and was located near the top position inside the upper pressure housing.

5.2 Instrumentation Set-Up

Two control accelerometers, mounted in a mutually perpendicular arrangement to the base plate (which simulated the reactor head elevation) were used to monitor the excitation levels in the horizontal and vertical axes. Figure 1 indicates the strain gauge locations at the test nozzle which is the highest stressed component of the CEDM design. The stress levels at this location, although not a criterion for the RSPT qualification, were used as an index for the intensity of the seismic event and to help avoid overtesting (failure) by correlating measured stress values to analytically predicted ones.

The response accelerometers indicated in Figure 1 were used to monitor CEDM deflections during sine sweep testing. Accelerometer locations 9, 7, 5, and 3 were also recorded on magnetic tape during the seismic qualification program to be later displayed in the form of time histories and/or response spectra.

All strain gauges (1/4 Bridge Hook-up) and accelerometers were connected over the replay panel to the patch panel of the Digital Vibration Control System. For signal conditioning of the strain gauges, the Unholtz Dickie, Type R, Charge/Voltage Amplifiers were used. Unholtz Dickie, Type H, Charge Amplifiers were used for the response accelerometers and the model 2216-X units for the two control accelerometers.

Selected CEDM nozzle strain gauges were monitored on the visicorder during preliminary and actual test runs. The RSPT electrical performance was monitored on the visicorder during all qualification phases.

For the sine sweep testing, the "SN21T Version - 04" software package of the digital vibration control system was used. This program allows the monitoring of 4 channels of data simultaneously.

For synthesis and on-line analysis of the generated seismic environments, the "SS20T, 3.0 Decade" software package of the digital vibration control system was used. During the tests, selected transducer signals were recorded on a 7-channel tape recorder. Test response spectra of the table input or CEDM component motions were then developed off the tape by playback into analysis software portion of the "SS20T" package.

Documented strain measurements are accurate within 5%, and the acceleration measurements within 10% of indication. All accelerometers had been calibrated within the last 12 months of testing. One non-critical response accelerometer, which showed erroneous indications, was replaced during the early phase of the test program.

5.3 Sine Sweep Test Procedure

The "SN21T Version - 04" software package of the digital vibration control system was employed for the tests. Figure 4 is a typical listing of an input file. For interpretation of the various input parameters, Reference 12 is to be used.

The C-E sinusoidal vibration control system, in conjunction with the MTS hydraulic actuator and control units (See Figure 3), is a closed loop, digital system that provides four-channel, multi-strategy control for performing a variety of swept-sine vibration tests. The system accepts analog input from the seismic table, digitizes the analog data, and continuously controls the amplitude of the resulting control signal so that it matches the amplitude of the specified reference spectrum. The control signal amplitude is regulated by controlling the amplitude and frequency of a sinusoidal drive signal that is generated by a programmable frequency synthesizer.

During the test program, the horizontal table motion was controlled using channel A of the D.V.C. system. The remaining channels B, C, and D monitored selected, calibrated transducer signals and stored them on disc. In this fashion, while maintaining constant acceleration input amplitude over a frequency range as wide as 1 to 33 Hertz, frequency response data was accumulated for all monitoring locations in consecutive sweep cycles. The data was later retrieved from the disc and displayed in a suited manner as phase, response amplitude or transfer function versus frequency. At the completion of the test program, all pertinent files were transferred to tape NL-014 and stored at the Bldg. 5 data center. The developed hard copies, along with the reduced data, are stored in the Nuclear Laboratories, Bldg. 2, Records Room.

5.4 RSPT Electrical Performance Monitoring

With the magnet held in a fixed position (close to the full withdrawn position of CEA travel), the voltage output signals of both RSPTs were recorded on a Visicorder oscillograph and also stored on tape during all seismic test phases of test orientations 3 and 4. Figure 14 renders a block diagram of the basic monitoring scheme. The resolution of the oscillograph recorder was sufficient to detect any transient upsét conditions or voltage signal changes down to five millivolts.

5.5 RSPT Inspection Requirements

The operational specifications and the inspection requirements of the RSPT position indication and the limit switch circuits are outlined in Sections 4.0 and 6.5 of Reference 10, respectively. Prior to and following the seismic qualification test programs, the electrical and functional characteristics of the RSPT assembly were inspected under laboratory ambient conditions in compliance with Section 6.5 of the reference test procedure. The results of inspections were recorded on the pertinent data sheets and are included in Appendix A of this report.

5.6 Simulation of Seismic Test Environment

The test specimens were subjected to 32 seconds of simultaneous horizontal and vertical inputs of random waveform motion. This random waveform consisted of frequencies spaced 1/6 octave apart over the frequency range of 1 Hertz to 25 Hertz as necessary, to envelope the Required Response Spectra of Figures 11 & 12. The technique used to synthesize the shock spectrum was to generate a series of wavelets at discrete frequencies (spaced 1/6 octave apart within the desired frequency range). The occurrence of these wavelets at each frequency (within the available time frame of 32 seconds) was specified in an arbitrary (random) fashion and the amplitude in g's for each wavelet was controlled by the Required Response Spectrum (RRS). At least 3 wavelets, spaced randomly throughout the event, were used at each sixth octave frequency close to the CEDM natural frequencies. The Digital Vibration Control System was used to sum up all the wavelet parameters and to produce a composite waveform that contained energy at all frequencies across the band. At a low test level, this waveform was then converted into shaker table motion by the shaker control units. Initiallly, the program automatically approximated the amplitude of each wavelet assuming that the transfer function of the shaker system is flat. The shock response spectrum of the table response waveform (in horizontal axis only) was then analyzed and compared with the specified RRS. The difference between the two spectra was then used to adjust automatically the wavelet amplitudes and to thereby compensate the drive waveform. This process was repeated until acceptable agreement had been demonstrated. Next, the output level was increased to arrive at the OBE and the DBE test levels. Following each increase in test level, several steps of synthesis were normally required to arrive at a satisfactory drive signal.

In addition to the on-line analysis of the horizontal table motions, both horizontal and vertical control accelerometer response signals were stored on tape and analyzed later over a frequency range of 1-50 Hertz using the "SS20T, 3.0 Decade" software package. Figure 15 shows a listing of the input file for the SSE event analysis. For interpretation of the various input parameters, Reference 14 is to be used. The software capabilities were verified in accordance with the Q.A. requirements as documented in Reference 15.

Figure 17 depicts a horizontal table time history for Test Run 26 (SSE event). The duration of this event was 32 seconds. The maximum value of this acceleration time history (approximately 0.7 g's) is representative of the actual Zero Period Amplitude (ZPA) level reached during this event which easily exceeded the requirements of 0.4 g's (see Figure 12). The character of the wave form reflects the superposition of low, medium, and high frequency pulses which resulted in the generation of a "random" type, multifrequency waveform similar to those of actual earthquakes. The required low frequency excitations for the high ANPP response spectrum peak (at about 2 Hertz) are noticeable even in this acceleration trace.

5.7 Test Procedure, Test Matrix

For more detailed guidelines about the test performance, refer to the test procedure of Reference 10. A listing of all data runs is enclosed as Appendix B to this test report.

6.0 DISCUSSION AND RESULTS

6.1 Sine Sweep Testing

Tables 1 through 5, along with Figures 5 through 10, summarize the results obtained from the sine sweep test. Appendix B renders the complete Test Matrix.

Initial low level sine sweep testing verified the analytically predicted natural frequencies of interest. The experimental frequencies of 2.32, ~ 9.2, and ~ 11.6 Hertz compare favorably with the theoretical values of 2.39, 10.08 and 11 Hertz for vibration modes 1, 2, and 3, respectively. Slight variations in these experimental frequencies with test level were observed especially for the somewhat non-linearly responding vibration modes 2 and 3. Figure 5 exhibits a series of transfer function plots developed for all 9 accelerometer locations along the CEDM height. The three resonance modes can clearly be discerned. The transfer function amplitudes at these resonances were taken from all available frequency response graphs and are listed in Tables 1, 2, and 3, along with damping and strain level information. Figures 8, 9, and 10 render comparisons of experimental and analytical mode shapes. For the purpose of this illustration, the deflections are shown with similar amplitudes. However, no attempt was made here to match the actual test levels analytically. Generally, the mode shapes agree quite well. But, it is also noted that the transfer function levels vary with test intensity, a fact which reflects the variation of damping with test level (especially modes two and three), as well as a certain amount of scatter between repeat test runs. For these reasons, one must view the entire range of test results, rather than using a single test run for possible input to model correlation efforts or extrapolation of results to other plants or higher excitation levels.

Figure 7 shows some blown-up plots of resonance peaks. These graphs were used to determine the modal critical damping properties employing the half-power point technique.

$$c/c_r = \frac{\Delta f}{2f_n} \times 100$$

where

c/c_r = Critical Damping Ratio in (%)

Δf = Width (in Hertz) of Resonance Peak at 0.707 times Peak Amplitude Value

f_n = Resonance Frequency in (Hertz)

For a variety of transducer locations, modal damping properties were obtained, averaged, and listed in Tables 1, 2, and 5. First mode damping values varied between 2.2 and 3.09 percent of critical. The two percent value assumed in the CEDM analyses appears somewhat conservative, however, based on this data, three percent could not be justified.

Second mode damping ranged between 3.5 and almost 6 percent. Surprisingly, this variation showed up when results taken on different test days were compared. The damping values obtained for a wide range of excitation levels (.05 to .25 g's - Table 5), on a single day, is quite consistent. Apparently, the CEDM structure condition (e.g. looseness of coilstack and rotation) as affected by test levels, can change.

Third mode damping values ranged from 2.2 to 3.3 percent of critical. It is of interest to note here that the ANPP CEDM has no additional tie between the upper pressure housing and shroud. This tie, which exists for the TVA and WPPSS plant, has the effect of eliminating one mode and combining the second and third ANPP modes into one.

Modal Strain levels are summarized in Tables 1, 2, and 4. For correlation with analytically predicted stress levels, one must determine the associated deflections by converting transfer function levels into displacements. Considering test file RSSN02 (Table 1), this is done as follows:

ACC/9/Horizontal Control Acc = 59.39 (g/g)

Acceleration Level = Transfer Fct x Excitation

$$= 59.39 \times 0.02 = 1.19 \text{ (g's)}$$

$$\text{Deflection Amplitude} = \frac{9.8 \times g}{f^2} = \frac{9.8 \times 1.19}{2.32^2} = 2.16 \text{ (inches)}$$

The associated maximum nozzle strain = 175 με or 81 με/inch deflection at CEDM Top (First Mode).

Following the seismic qualification program, static load deflection tests (incrementally deflect CEDM top and monitor strain gauges 7 & 8), as well as simple dynamic tests (manually excite first mode), were conducted to verify the observed CEDM strain versus deflection ratio. The detailed results given in Appendix C confirm the shaker table data.

6.2 Seismic Qualification Testing

The ANPP reactor design calls for 87 CEDMs with 16 different nozzle lengths. Earlier analyses has shown that the CEDM type with the longest nozzle would tend to respond in the most critical manner. Therefore, this nozzle condition was selected for testing. The stipulated seismic intensities for the reactor head elevation are shown in Figures 11 and 12 for the OBE and the SSE event, respectively. It had been decided earlier to perform the tests with the hydraulic actuator set up at a 45° angle with the horizontal plane, thereby providing equal input motions in the vertical axis and in the horizontal axis. During the tests, the horizontal control accelerometer was used for the synthesis of the random type waveforms. The Required Response Spectra (RRS) used for the synthesis represented the envelope of the vertical RRS and the horizontal RRS, whereby the latter was constructed from two horizontal spectra (using the Root-Sum-of-the-Square technique).

Figure 13 shows a diagram of the instrumentation hook-up and control logic. The RSPTs were placed inside the CEDM shroud and connected to recording equipment as shown in Figure 14. The RSPT locations during the four test orientations are identified on Figure 16.

During the course of the test program, the RSPTs were exposed to at least 30 and 10 seismic disturbances, each intensity range equal to at least that of the OBE and the SSE type earthquakes, respectively. The official test log is enclosed as Appendix B, which includes a minimum of 5 OBE and 1 SSE events in each test orientation. In all test cases, no transient upset or anomalous conditions were found in the RSPT signal traces.

The signal loss observed during one test run was due to a monitoring cable break (cable was inadequately secured at power supply). The inspections conducted prior to and following the seismic qualification tests revealed no changes in the functional characteristics of the two specimens as provided for testing (Appendix A).

Figure 17 shows the synthesized table acceleration time history for an SSE event. Since the Required Response Spectrum has a high spectrum peak at about 2 Hertz, the waveform clearly reflects these large, low frequency components superimposed by higher frequency contributions. Typical strain and RSPT time histories are shown for the OBE and the SSE events in Figures 18 and 19, respectively. With the exception of a small "ripple" (less than 3 milliseconds), all RSPT monitoring traces are undisturbed. The strain gauges reflect the response characteristics of the CEDM and reveal an overwhelming response (proportional to deflection) at its fundamental frequency. Peak CEDM component strain levels are listed in Table 6 for all test runs. The maximum values (635 $\mu\varepsilon$ for OBE and 770 $\mu\varepsilon$ for SSE events) are well within material allowables.

Figure 20 renders OBE Test Response Spectra for all four test orientations. The analyses of the table motions was performed at 1/6th octave increments over a frequency range of 1 to 50 Hertz. In all cases, the graphs demonstrate complete envelopment of the Required Response Spectra (vertical lines show actual test intensity, spectrum curve reflects RRS). A seismic table resonance was responsible for the high spectrum peak above 30 Hertz.

Horizontal and Vertical Test Response Spectra are shown in Figure 21 for the SSE event. Again, complete envelopment of the requirement is demonstrated. Additional table acceleration time histories are given in Figure 22.

In order to capture the resulting seismic intensities at the RSPT mounting locations (CEDM shroud), four response accelerometers Nos. 3, 5, 7, and 9 were monitored and recorded on tape. Unfortunately, the tape channel recording the CEDM top motions was set up improperly which resulted in attenuation of higher frequency signal components. The test response spectra shown in Figures 23 and 24 capture the true seismic intensities at all four shroud elevations, whereby the Acc 9 curve was extrapolated using data from the other 3 locations. These response spectra (2% damping) exemplify the large CEDM response at about 2.3 Hertz. Some contribution from CEDM Mode 2 is apparent at 10 Hertz. The response spectrum peaks above 30 Hertz are due to the table resonance mentioned earlier.

Figures 25 and 26 summarize the acceleration time histories as recorded at the four shroud elevations during OBE and SSE event simulations. Accelerometer 3, 5, and 7 traces are basically unfiltered and some of the higher acceleration spikes may actually be caused by impacts (e.g. coilstack shifting at Acc 3 location). However, this fact would not influence the response spectrum character across the frequency range of interest (1-30 Hertz) which is shown in Figures 23 and 24.

Prior to seismic testing, RSPT Sample No. 604 was removed from test Loop 7A after 1730 hours of thermal aging at 375°F for a performance check and a visual inspection. The visual inspection showed some deterioration of the silgard encapsulant and the diallyl phthalate mounting strip. Based on this inspection, it was decided to waive future visual inspections of both RSPT's until the entire qualification program had been completed. Therefore, details of the above visual inspection and the final visual inspection will be documented in the final qualification report.

7.0 REFERENCES

1. IEEE Standard Number 323, 1974, General Guide for Qualifying Class 1 Electrical Equipment for Nuclear Power Generating Stations.
2. IEEE Standard Number 344, 1975, Guide for Seismic Qualification of Class 1 Electrical Equipment for Nuclear Power Generating Stations.
3. Specification Number SYS80-MD-0311, Revision 02, Design Specification for Control Element Drive Mechanism.
4. Specification Number 14273-MD-0311, Revision 02, Project Design Specification for CEDM for Arizona Nuclear Power Project - Palo Verde Nuclear Generating Stations, 1, 2, and 3.
5. Document Number QC-28-05 FW NPM-W CEDM/PLCEDM Design Control Procedure, dated 9/19/74.
6. Document Number 00000-NLE-070, Revision 0, Procedure for Control of Measuring and Test Equipment.
7. Manufacturing Specification for the Class 1E Reed Switch Position Transmitter, Specification Number 00000-ESE-203, Revision 01.
8. Drawing CEDM-E-R1000, Revision 02, Reed Switch Assembly.

9. Drawing D-STD-162-003, Revision 01, Magnet Assembly and Details.

10. Test Procedure 00000-ESE-323, "Seismic Qualification Testing System 80 RSPT and Litton Electrical Connector - ANPP," K. H. Haslinger, July 31, 1981.

11. Test Report TR-ESE-285, "SCE CEDM-RSPT Seismic Qualification Test," K. H. Haslinger, May 15, 1979.

12. Operating Manual for Sinusoidal Vibration Control System," Time/Data Division. Document 1923-5124, December, 1977.

13. Q.A. Verification of Time/Data Sinusoidal Vibration Control Code Version 04, C-E Analysis Report Nos. S669-100 and S669-101.

14. Operating Manual for Shock Spectrum Synthesis and Analysis System, Time/Data Division, Document 1973-5127, July, 1977, TR-ESE-424.

15. J. P. Thompson, "Q.A. Verification of 3.0 Decade WAE Synthesized SRS Analysis Program," S863-113, dated May 2, 1979.

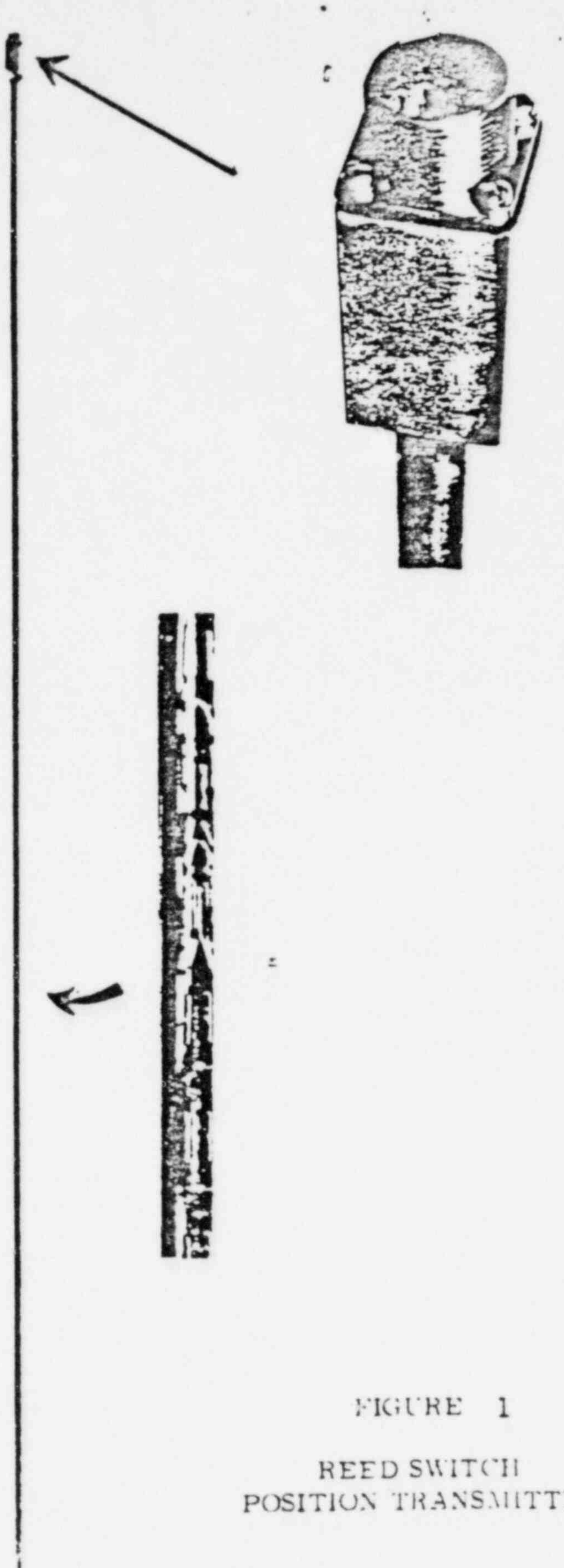


FIGURE 1

REED SWITCH
POSITION TRANSMITTER

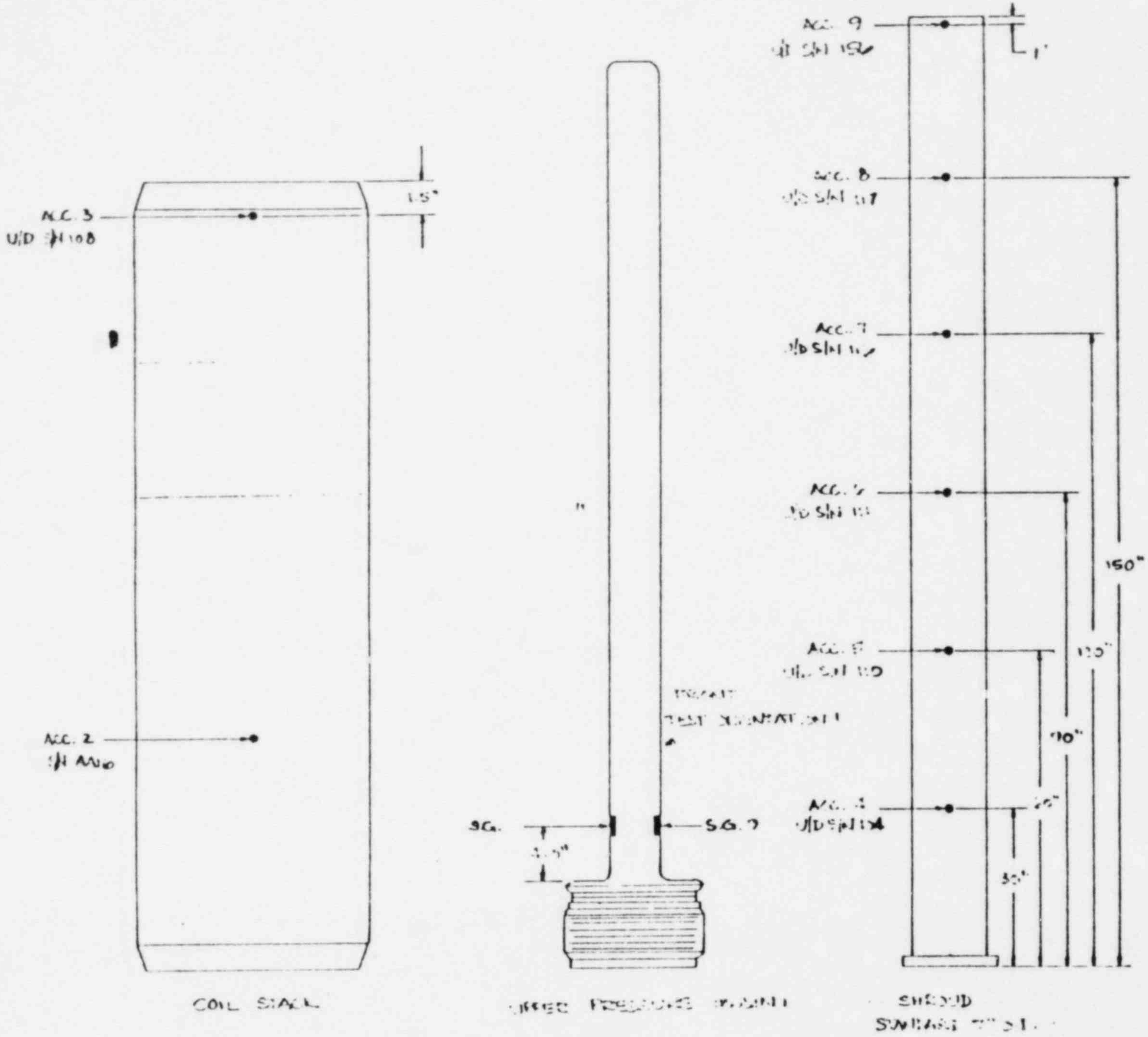


FIGURE 2A ANPP RSPT SEISMIC QUALIFICATION TEST - INSTRUMENT LOCATIONS

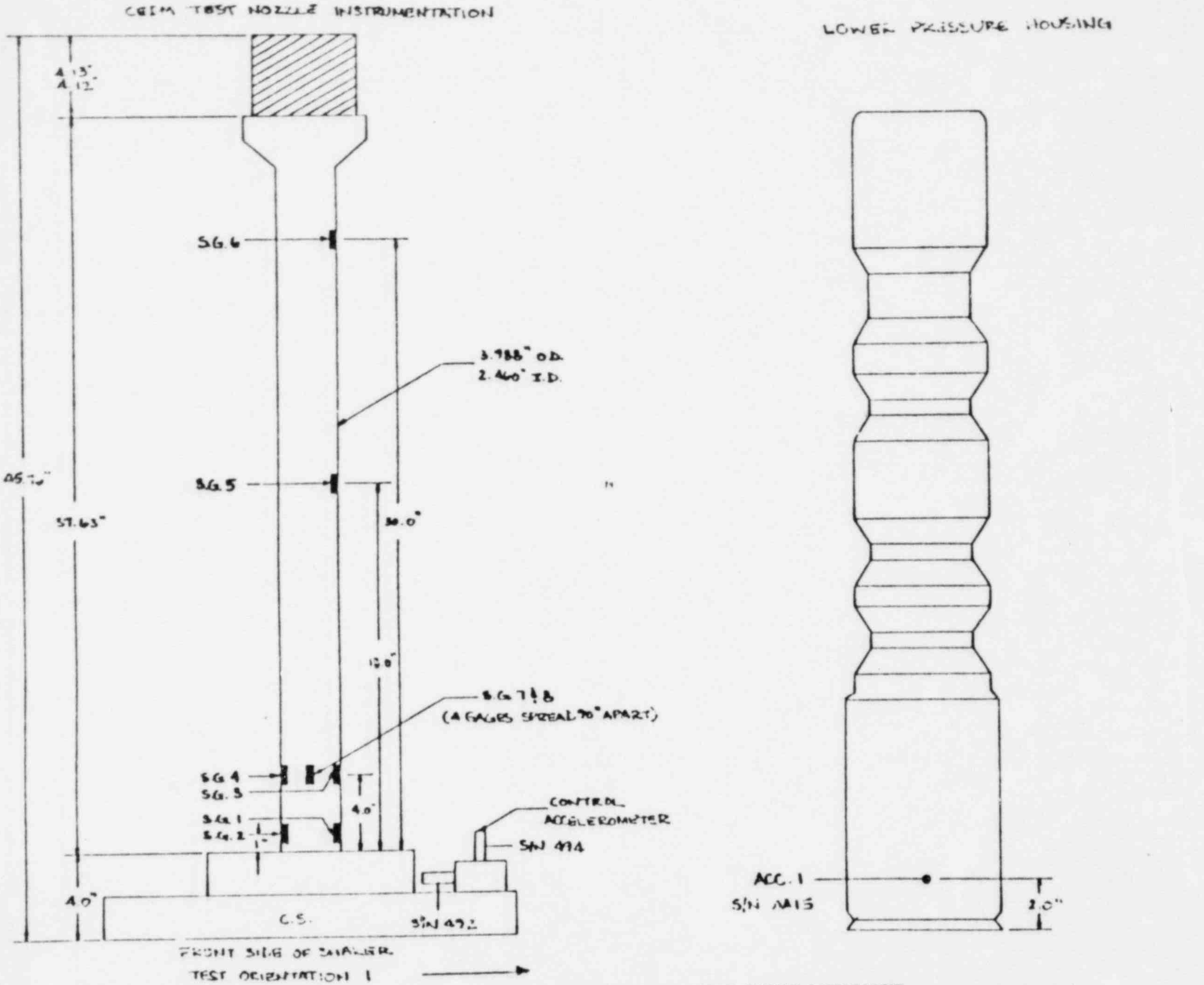


FIGURE 2B ANPP RSPT SEISMIC QUALIFICATION TEST - INSTRUMENT LOCATIONS

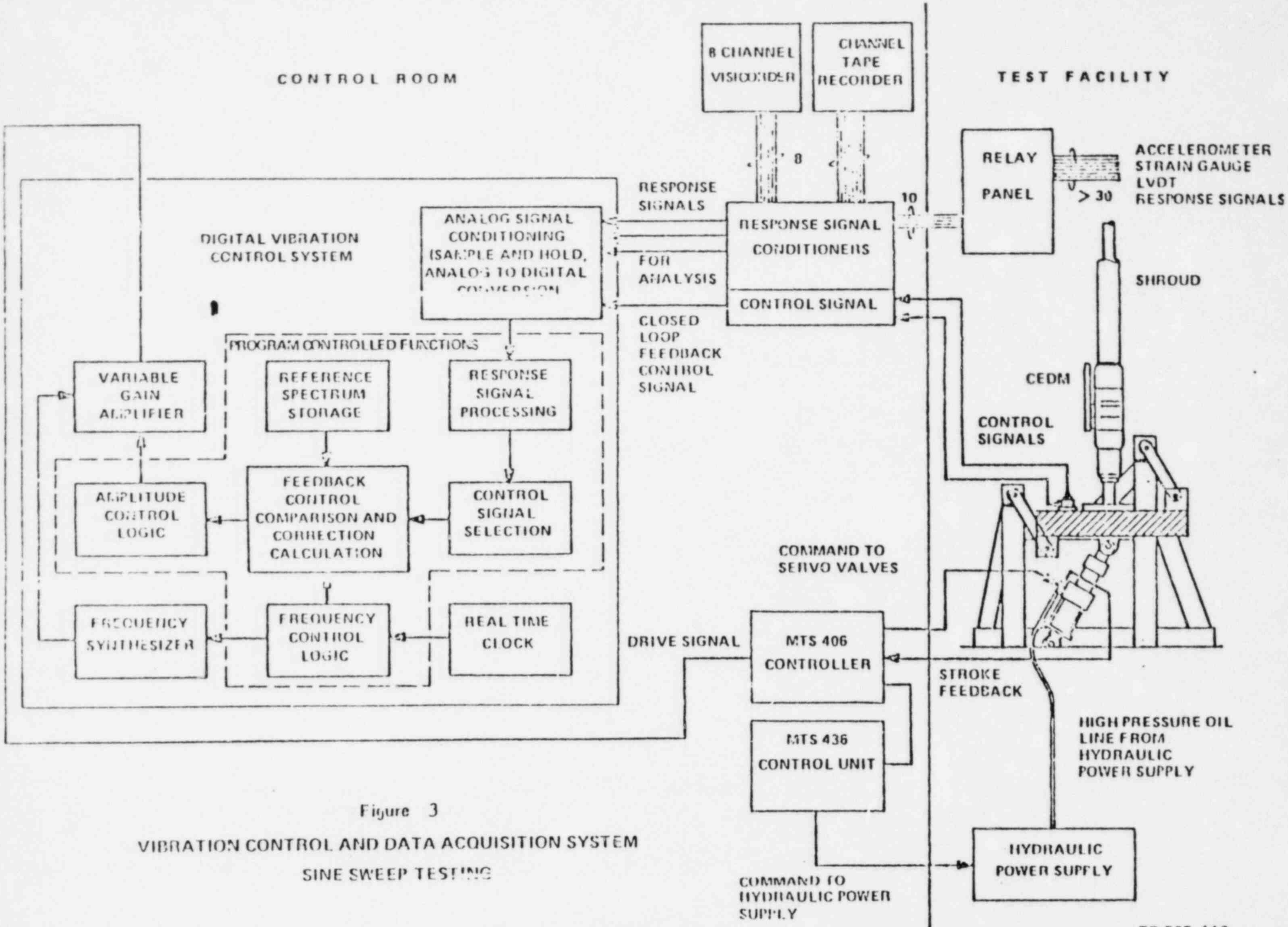


Figure 3

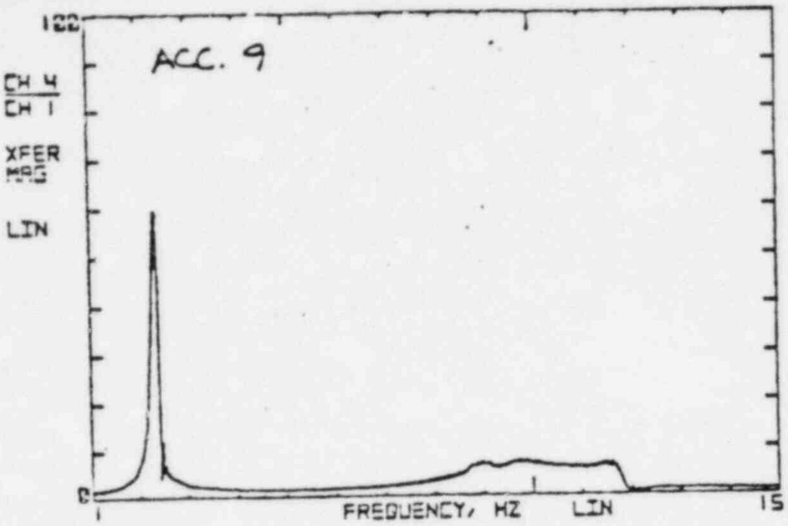
VIBRATION CONTROL AND DATA ACQUISITION SYSTEM

SINE SWEEP TESTING

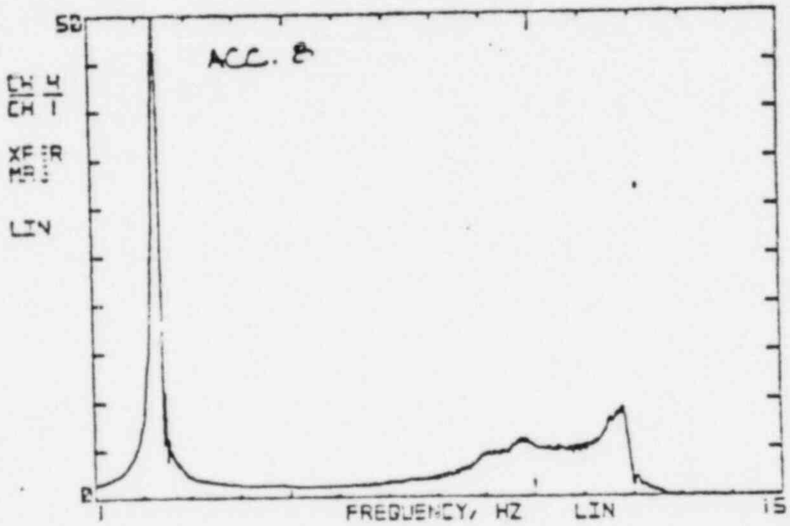
```
1 TEST ID: RSSN02
2 HEADING: ANPP RSPT SINE SWEEP

SWEEP PARAMETERS:
3 MODE  2-LOG(DEC), 1-LOG(OCT), 0-LIN: 2
4 START, END FREQ, HZ: 1.000,28.00
FREQ RANGE, DEC=1.447
5 SPECIFICATION  1-RATE, 0-DURATION: 1
  RATE, DEC/MIN: .2000
SWEEP DURATION -- HRS, MIN, SEC: 0,7,14

TEST LENGTH:
6 SPECIFICATION  1-TIME, 0-SWEEP CYCLES: 0
  CYCLES: 1.000
TEST TIME -- HRS, MIN, SEC: 0,7,14
7 START-UP TIME, SEC: 15.00
8 SHUT-DOWN TIME, SEC: 5.000

REFERENCE SPECTRUM:
9 UNITS 1-METRIC, 0-NON-METRIC: 0
10 SPECTRUM LIMITS:
    DISPLACEMENT, IN(P-P): 4.000
    VELOCITY, IN/SEC: 12.50
    ACCELERATION, G: .2500

 11 TYPE, VALUE, FREQ: 2,.02000,28.00
    ALARM LIMIT +DB, -DB: 3.000,-3.000
    ABORT LIMIT +DB, -DB: 10.00,-10.00

 12 TEST LEVEL (DB BELOW REF): 0.

 13 CONTROL CHANNELS: 1
    PROCESS 3-AVG ABS, 2-FUND, 1-PEAK, 0-RMS: 2

 14 LIMIT CHANNELS: 0
 15 AUXILIARY CHANNELS: 2,3,4
    PROCESS 3-AVG ABS, 2-FUND, 1-PEAK, 0-RMS: 2
    MAXIMUM EXPECTED G: 3.000
 16 ACCEL SENS, MV/G:
    CH 1: 10000.
    CH 2: 10000.
    CH 3: 10000.
    CH 4: 10000.
 17 FILTER  1-PROPORTIONAL BW, 0-FIXED BW: 1
    BW, %: 50.00

 18 REFERENCE CHANNEL: 1
 19 RESPONSE CHANNEL: 2
 20 MONITOR CHANNEL: 1

 21 COMPRESSION SPEED  2-HIGH, 1-NORMAL, 0-LOW: 2
 22 LOOP-CHECK FREQ(HZ), MAX DRIVE(VOLTS): 5.000,.2000

 REFERENCE LEVELS:
  MAX DISPLACEMENT, IN(P-P): .3914
  MAX VELOCITY, IN/SEC: 1.230
  MAX ACCELERATION, G: .02000
  MIN ACCELERATION, G: .02200
  ACCELERATION RANGE, DB: 0.

 CORRECTIONS? N
 SAVE? Y
 1-RT11, 0-PUNCH: 1
 DEVICE: RK0

  STORED RSSN02

 >
```

FIGURE 4

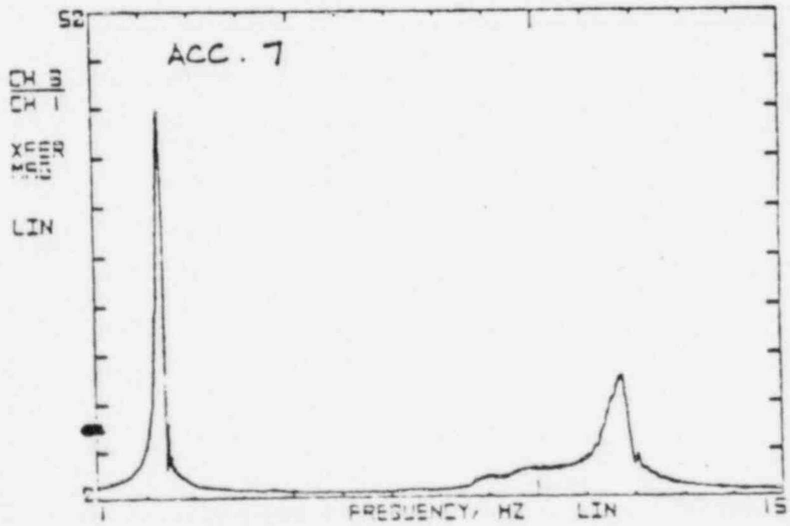
TYPICAL INPUT LISTING - SINE SWEEP TEST



RUN 1 RSSNO2
RNFF RSPT SINE SWEEP

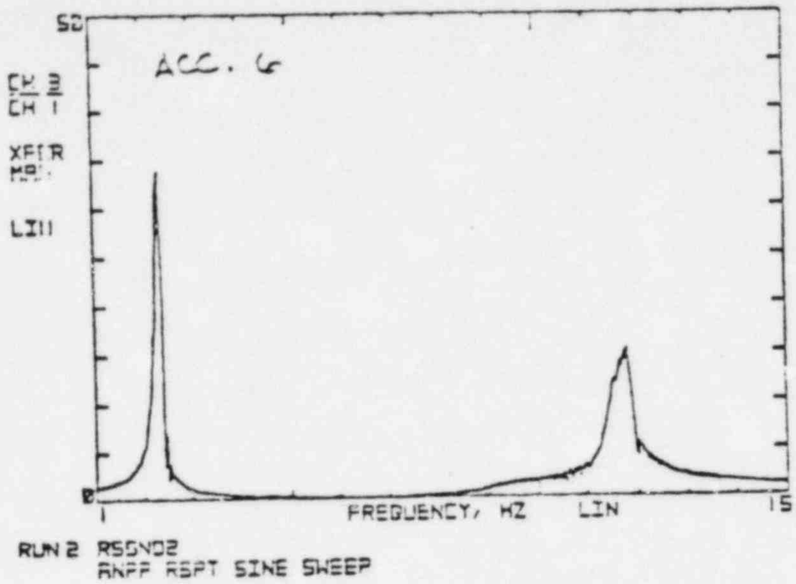


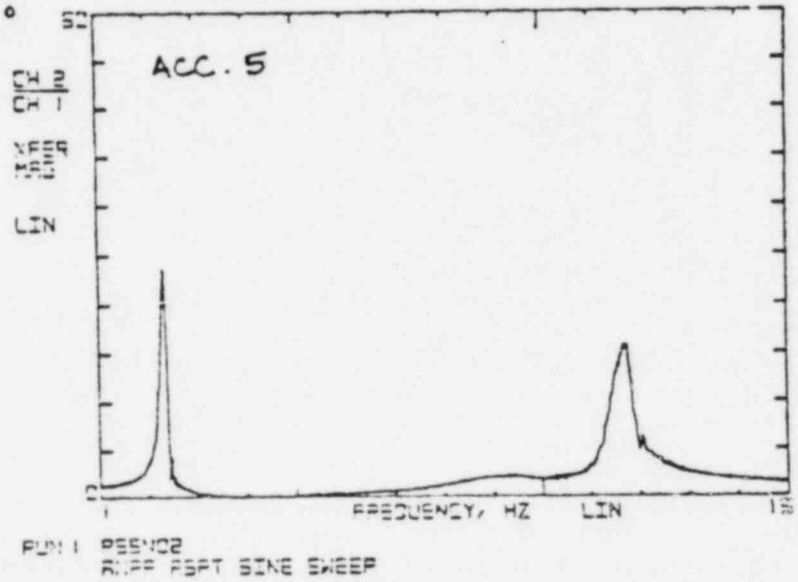
RUN 2 RSSNO2
RNFF RSPT SINE SWEEP



RUN 1 RSSNO2
RNFF RSPT SINE SWEEP

FIGURE 5A TYPICAL SINE SWEEP TRACES - TRANSFER FUNCTION
TEST FILE RSSNO2 - 0.02 g's EXCITATION





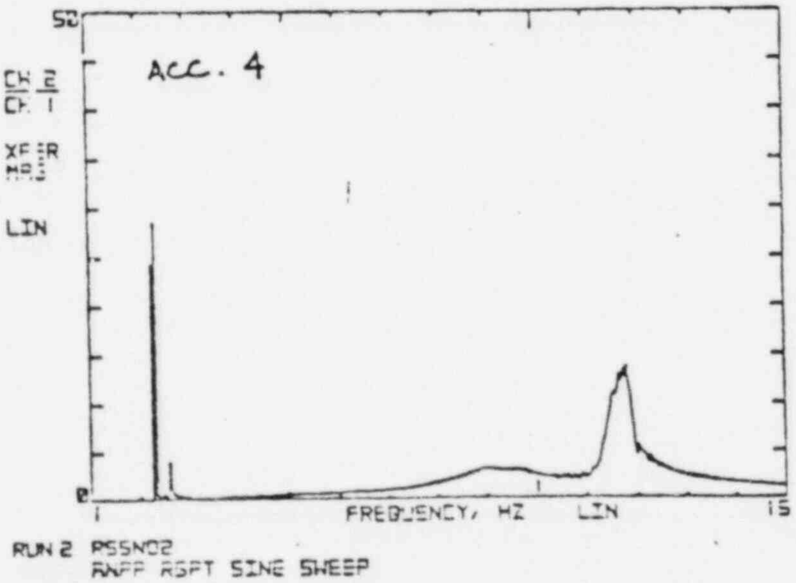
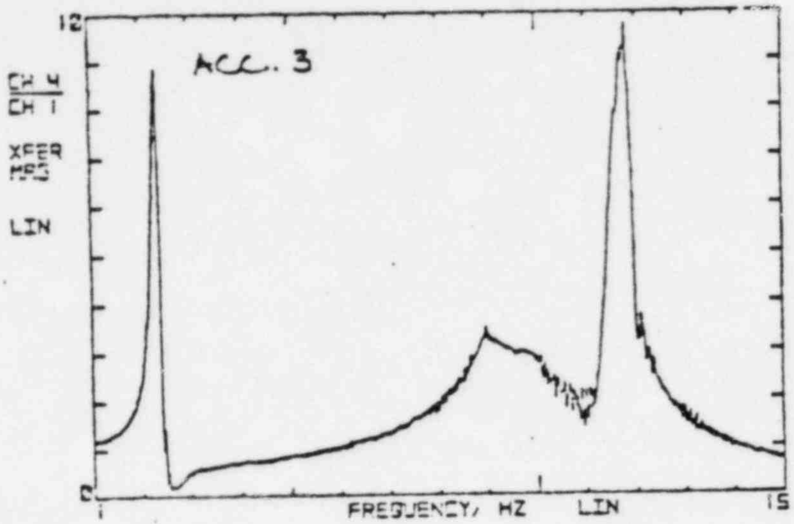
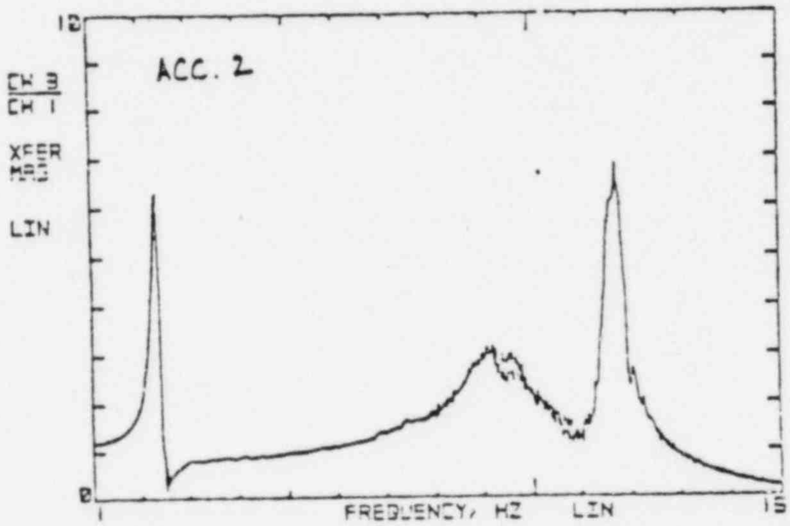


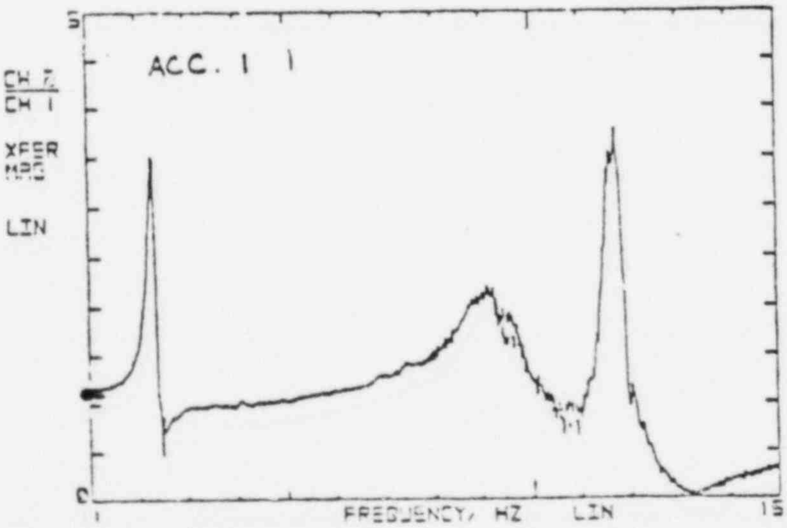
FIGURE 5B TYPICAL SINE SWEEP TRACES - TRANSFER FUNCTION
TEST FILE RSSN02 - 0.02 g's EXCITATION



RUN 3 RSSN02
RNPP RSPT SINE SWEEP

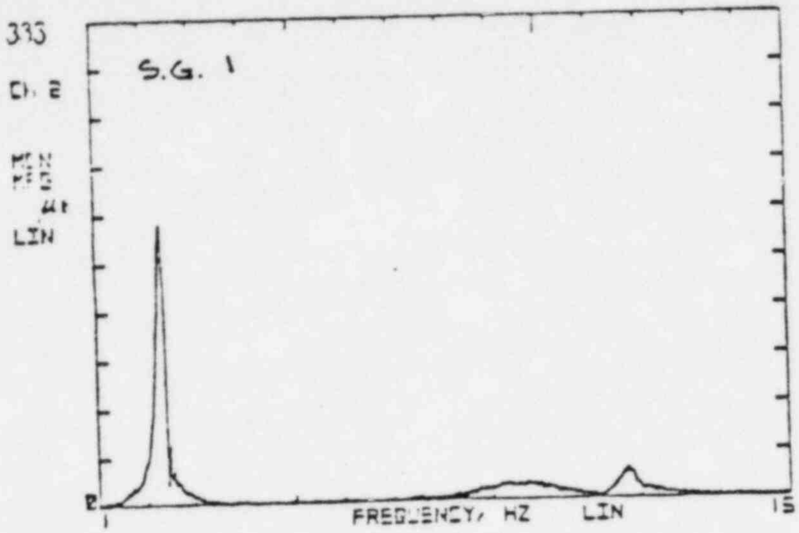


RUN 7 RSSN02
RNPP RSPT SINE SWEEP

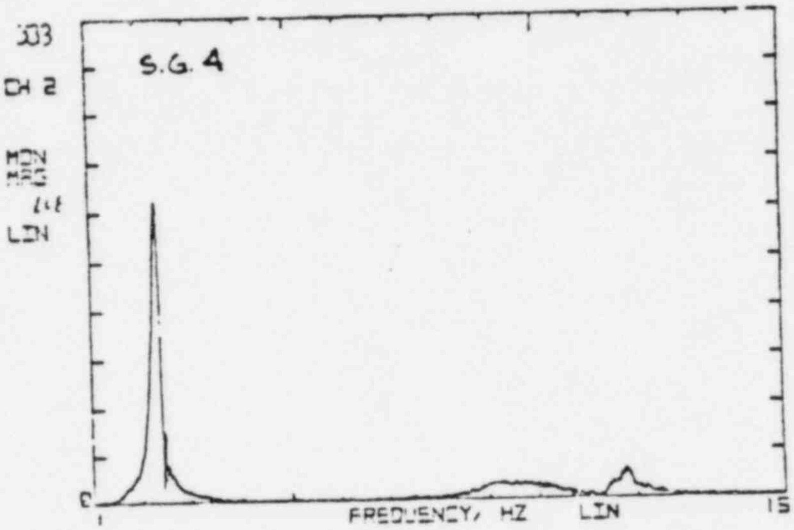


RUN 7 RSSN02
RNPP RSPT SINE SWEEP

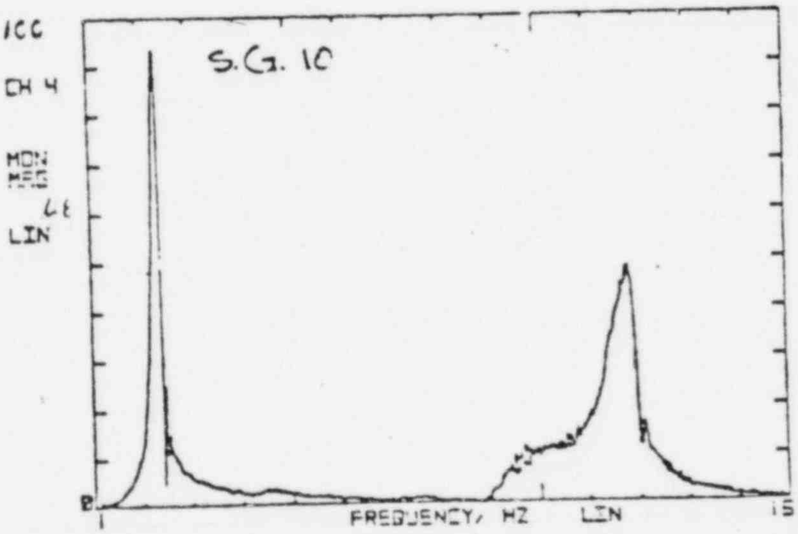
FIGURE 5C TYPICAL SINE SWEEP TRACES - TRANSFER FUNCTION
TEST FILE RSSN02 - 0.02 g's EXCITATION



RUN 4 PSSNO2
RNFP RSPT SINE SWEEP

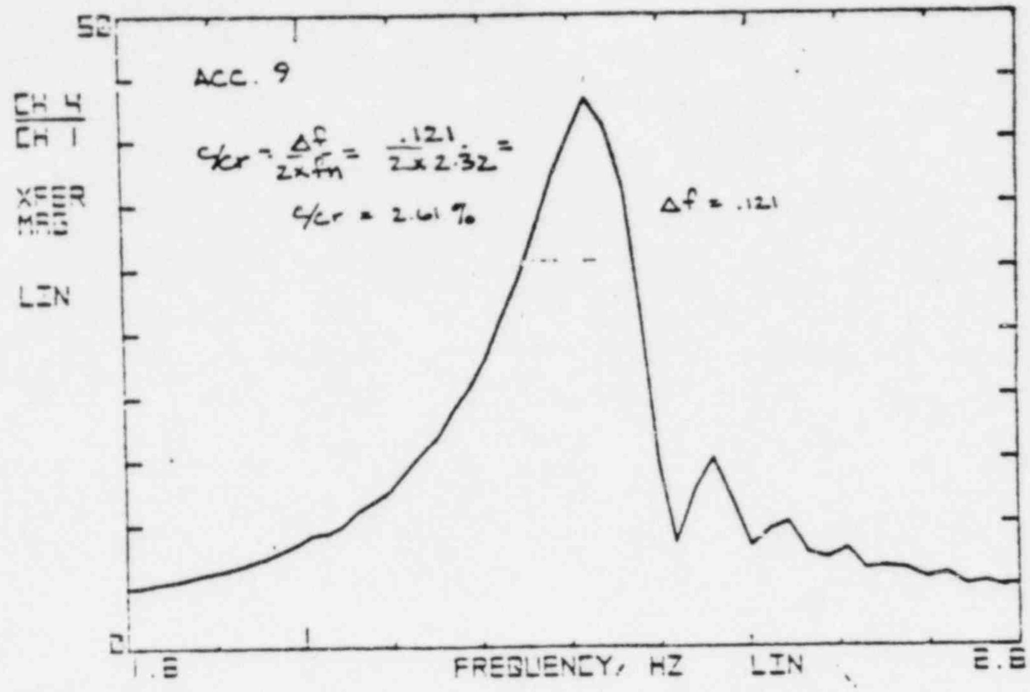


RUN 5 PSSNO2
RNFP RSPT SINE SWEEP

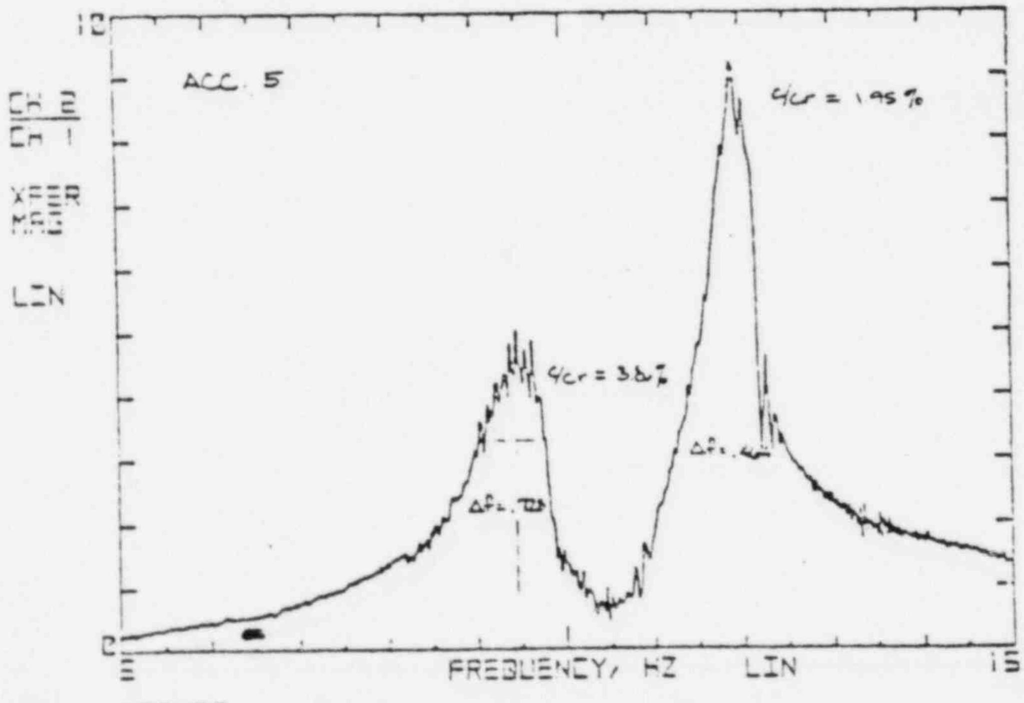


RUN 6 PSSNO2
RNFP RSPT SINE SWEEP

FIGURE 6 TYPICAL SINE SWEEP TRACES - STRAIN FREQUENCY RESPONSE PLOTS
0.02 g's EXCITATION



RUN I RSSNDS
ANPP CEDM .05G SINE SWEEP



RUN I RSSNDS
ANPP CEDM .05G SINE SWEEP

FIGURE 7

DETERMINATION OF MODAL DAMPING PROPERTIES FROM
BLOWN-UP SINE SWEEP TRACES

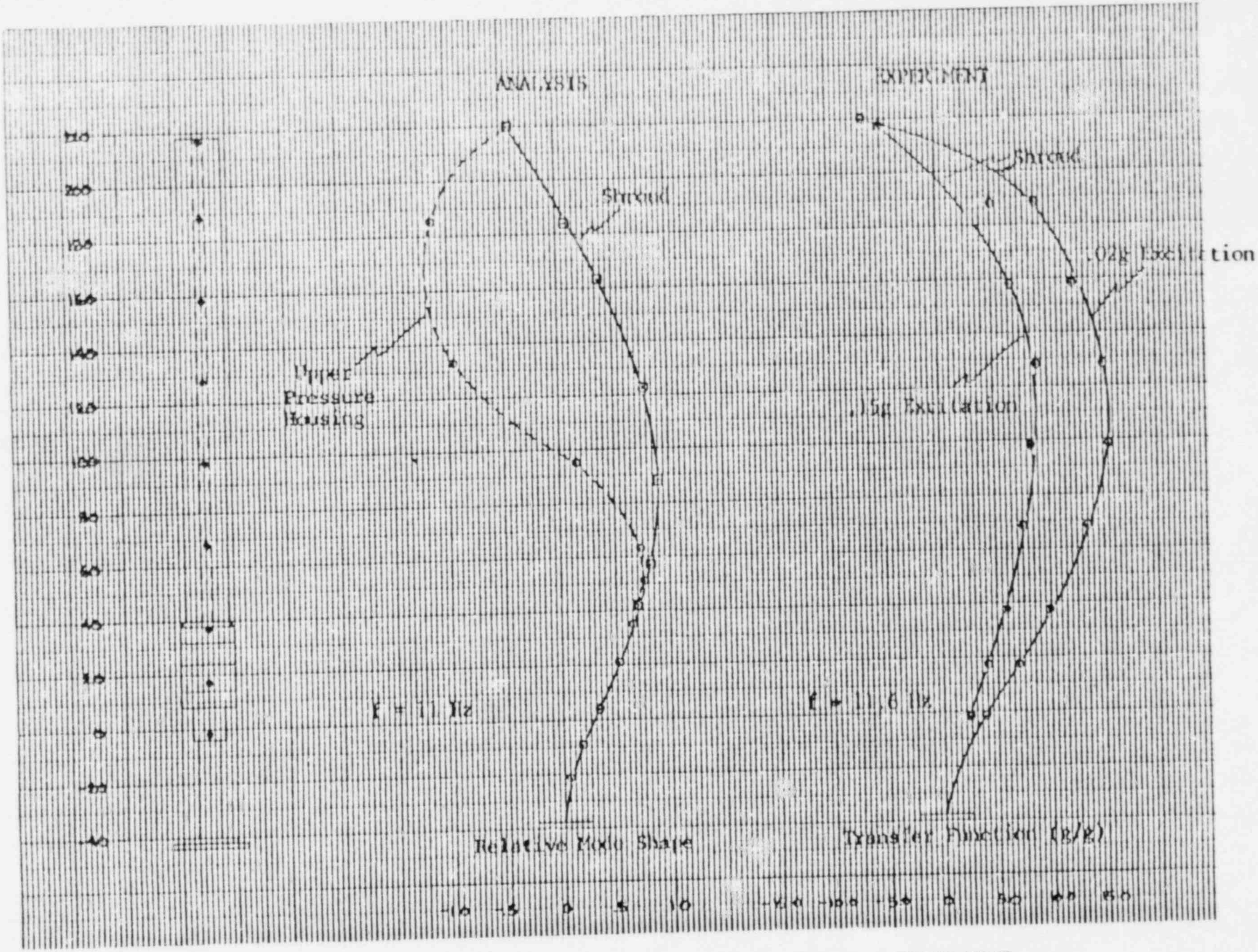


FIGURE 10 COMPARISON OF EXPERIMENTAL AND ANALYTICAL MODE SHAPES - THIRD MODE

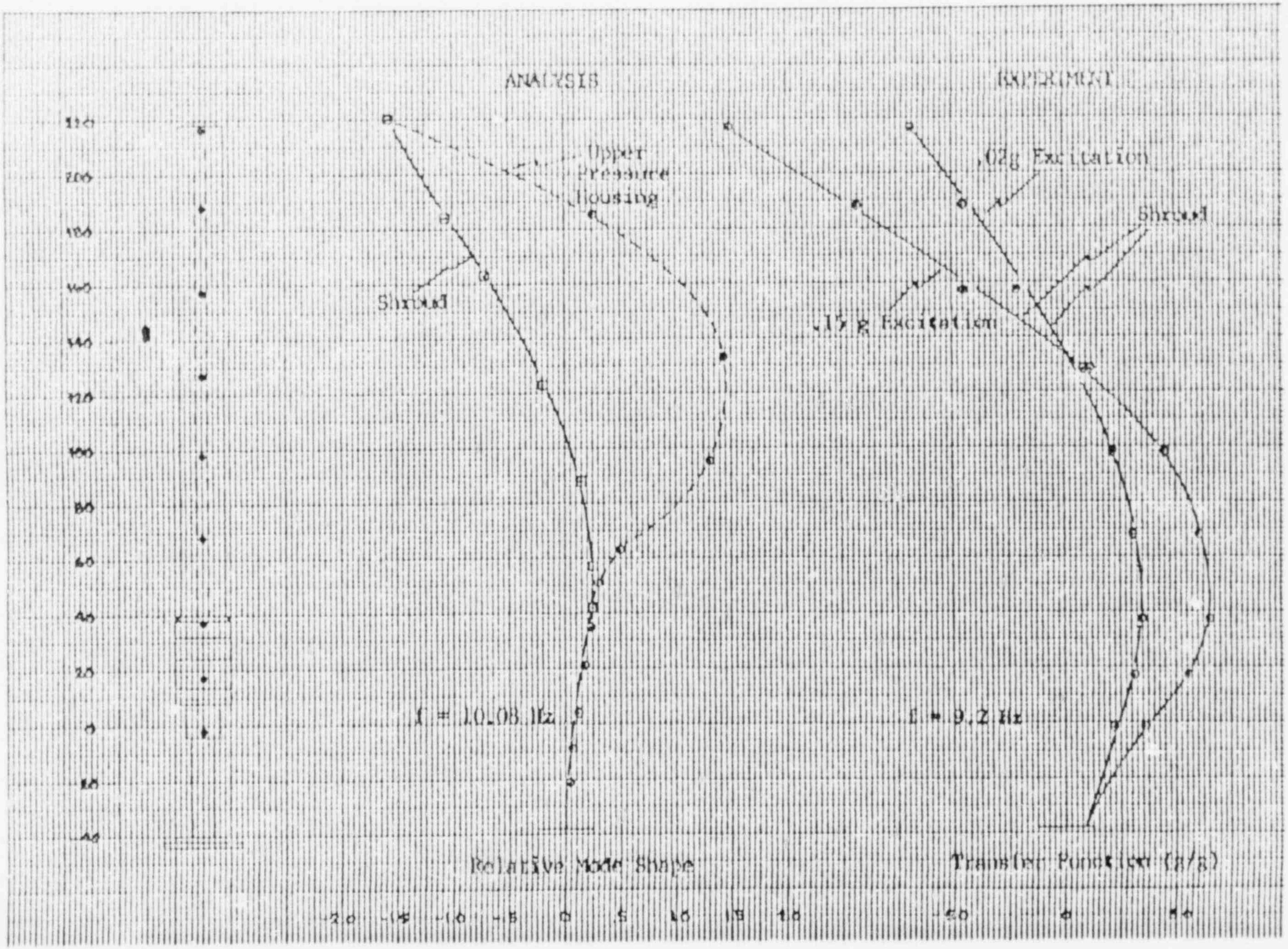


FIGURE 9 COMPARISON OF EXPERIMENTAL AND ANALYTICAL MODE SHAPES - SECOND MODE

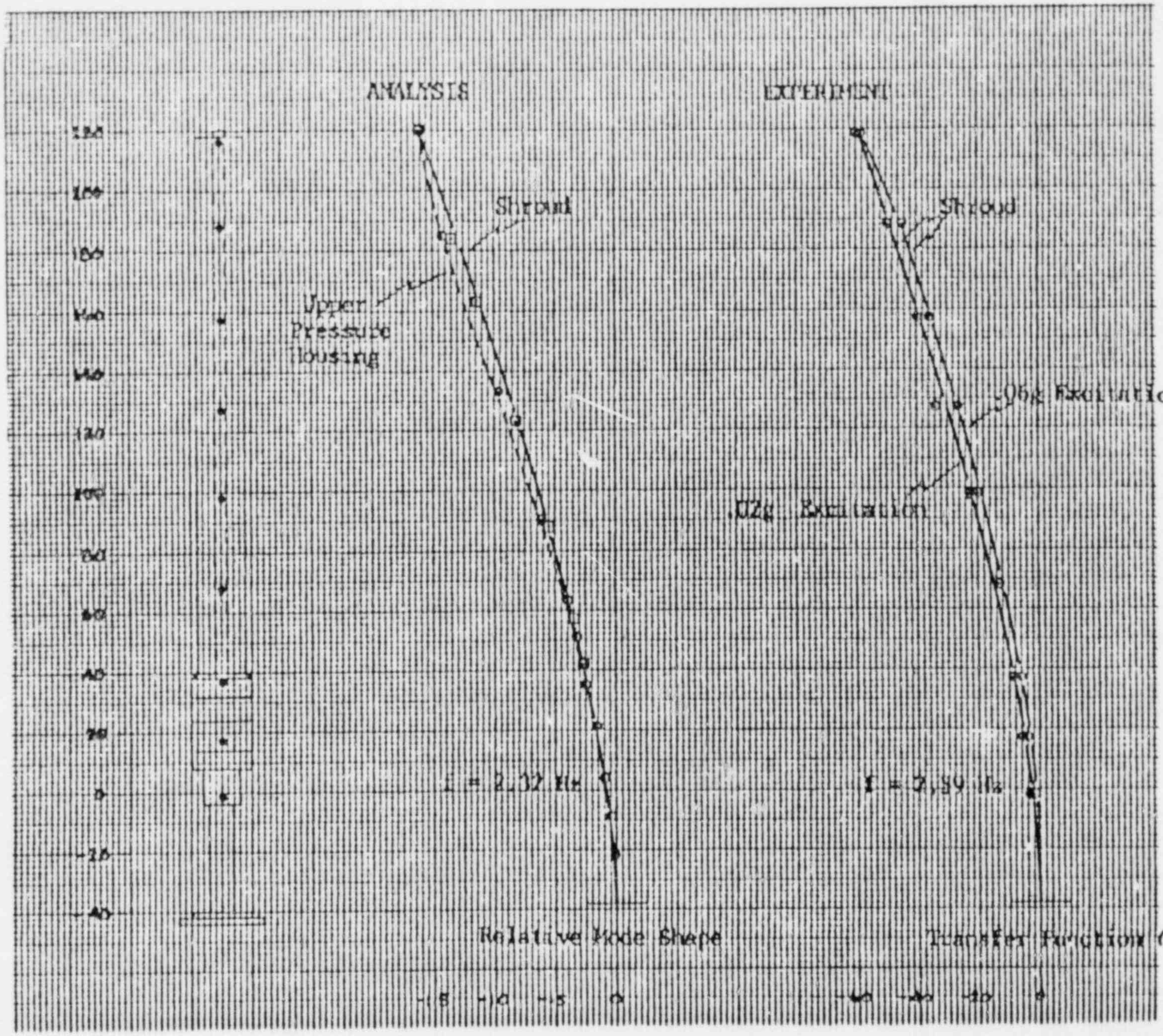


FIGURE 8 COMPARISON OF EXPERIMENTAL AND ANALYTICAL MODE SHAPES - FIRST MODE

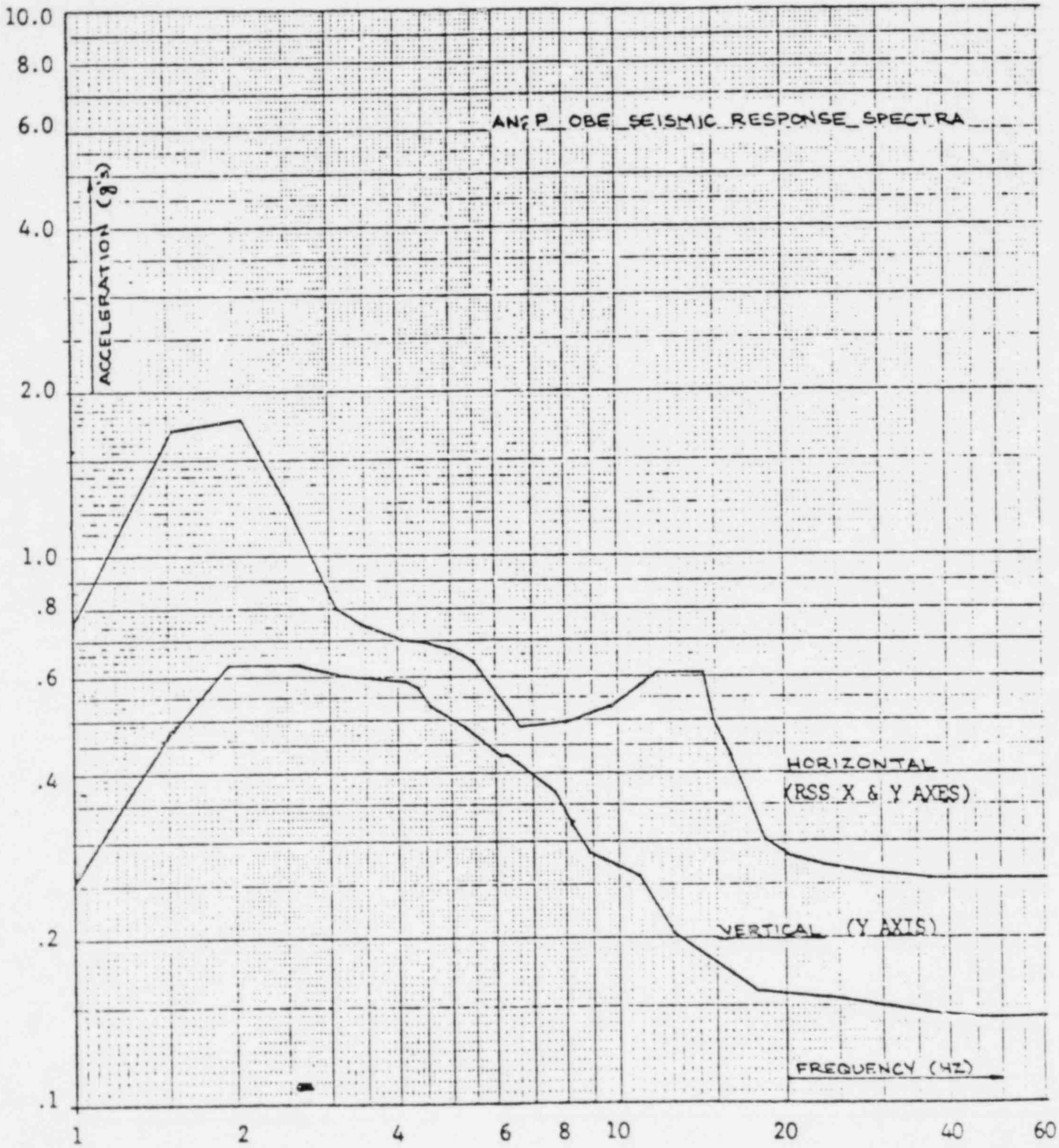


FIGURE 11 OBE REQUIRED RESPONSE SPECTRA - ANPP RSPT QUALIFICATION TEST, 2% DAMPING

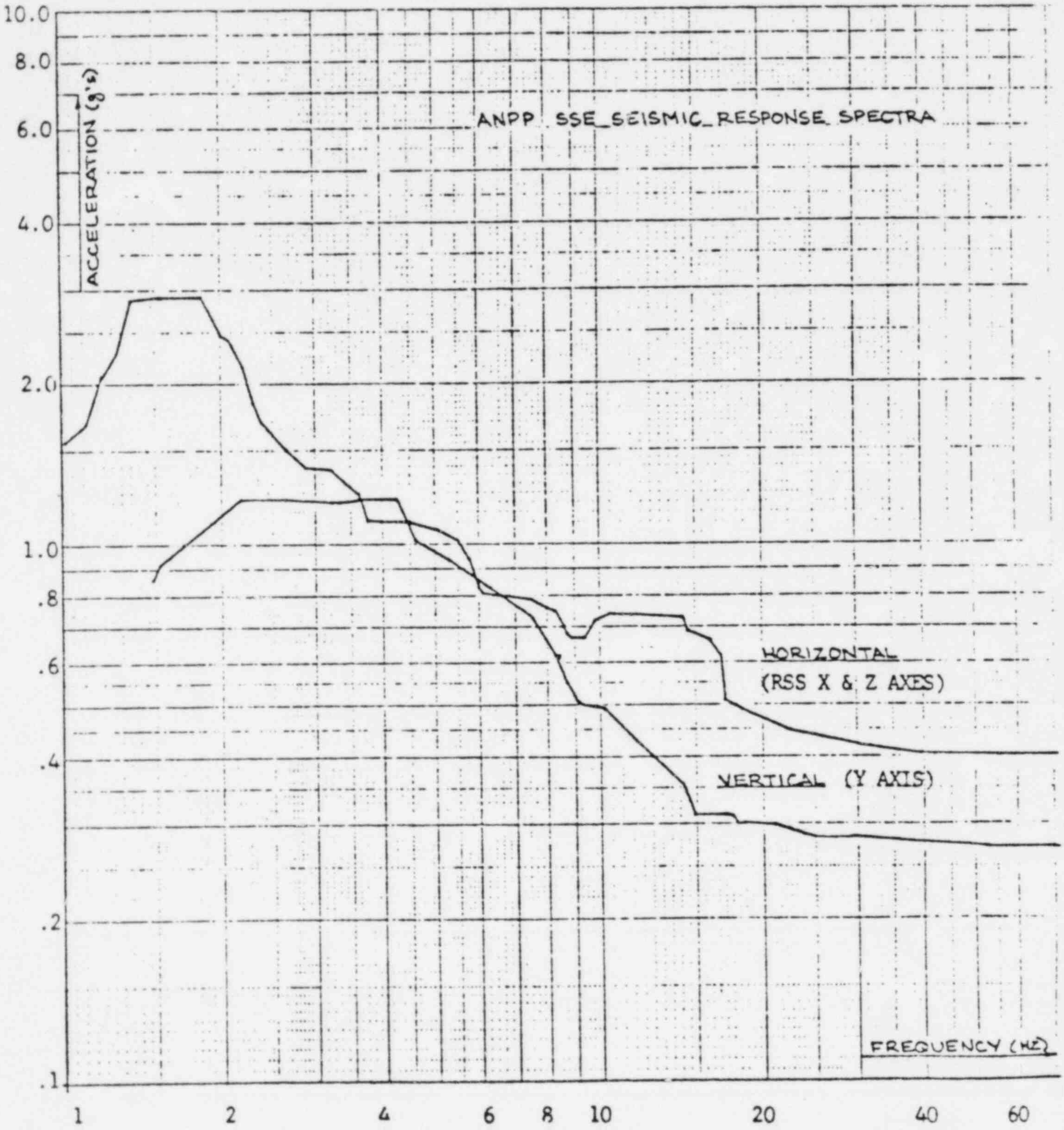


FIGURE 12 SSE REQUIRED RESPONSE SPECTRA - ANPP RSPT QUALIFICATION TEST, 2% DAMPING

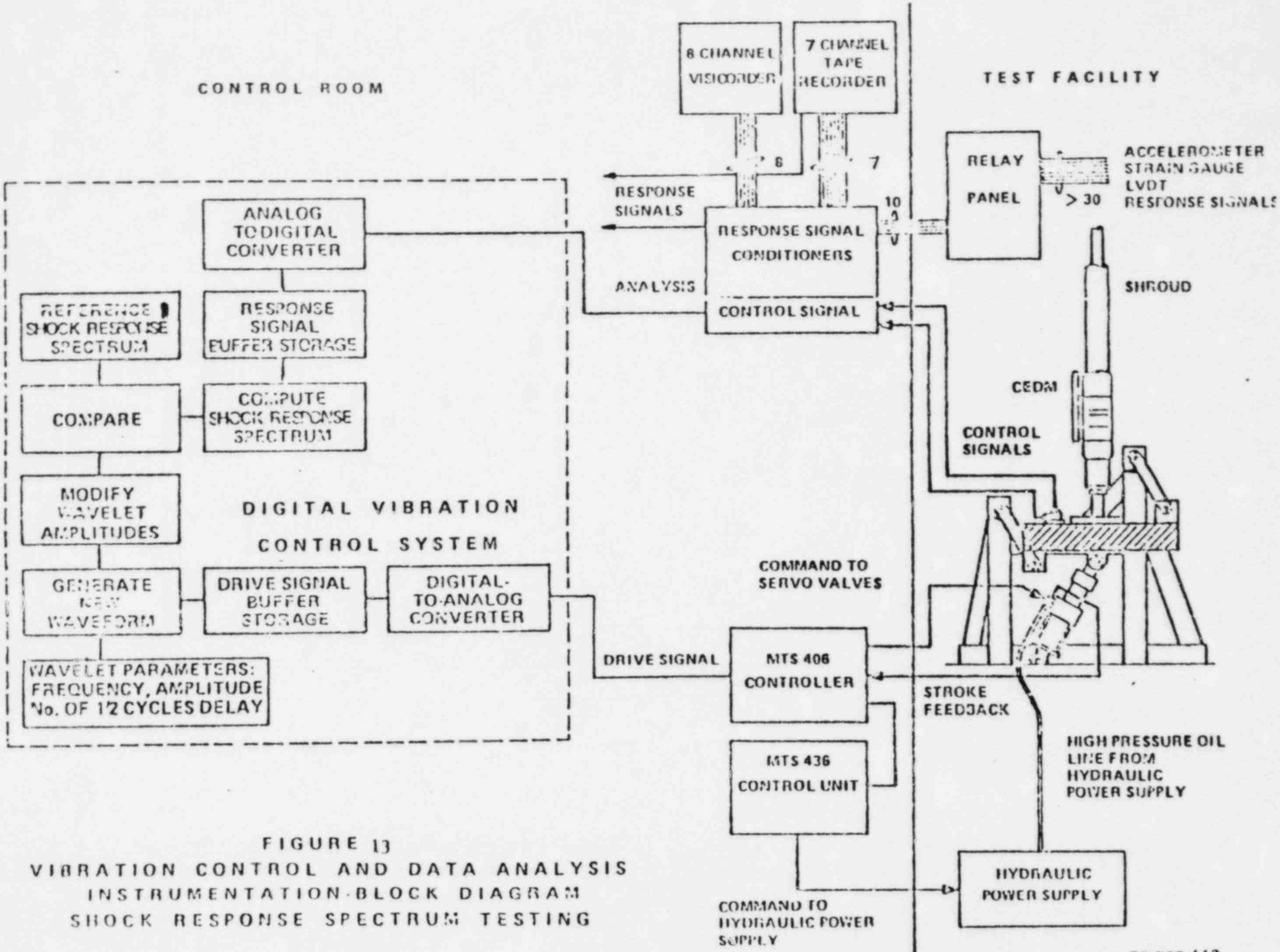


FIGURE 13
VIBRATION CONTROL AND DATA ANALYSIS
INSTRUMENTATION BLOCK DIAGRAM
SHOCK RESPONSE SPECTRUM TESTING

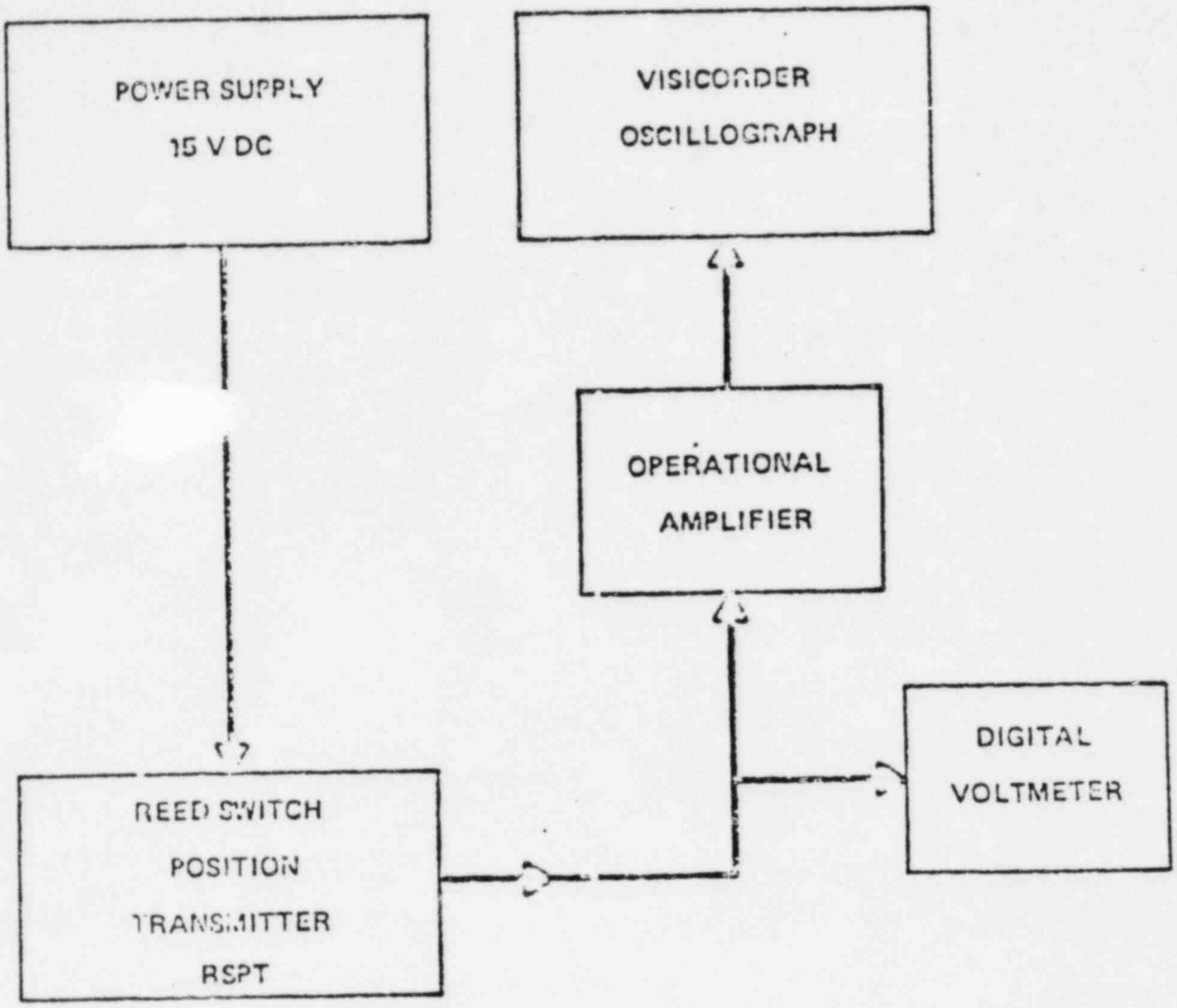


FIGURE 14

BLOCK DIAGRAM FOR MONITORING OF RSPT ELECTRIC OUTPUT DURING SEISMIC QUALIFICATION TEST

```
1 HEADING:ANPP SSE
2 SENSITIVITY(MV/G):990.
3 SHOCK RESP DEFN 0-ABS ACCEL 1-REL DISPL:0
4 DAMPING COEFF:.02
5 MAX FREQ:50
6 # OF DECADES 0-2 1-2.3 2-2.6 3-3:3
7 WAVE PARAMETERS
        FREQ    AMPL
   1     1.        1.53
   2     1.12      1.95
   3     1.25      2.21
   4     1.41      2.87
   5     1.58      2.92
   6     1.77      2.92
   7     1.99      2.5
   8     2.23      2.07
   9     2.51      1.61
  10     2.81      1.42
  11     3.16      1.38
  12     3.54      1.26
  13     3.98      1.21
  14     4.46      1.1
  15     5.01      1.07
  16     5.62       .98
  17     6.3        .83
  18     7.07       .79
  19     7.94       .76
  20     8.91       .66
  21    10.         .72
  22    11.21       .73
  23    12.58       .73
  24    14.12       .73
  25    15.84       .66
  26    17.78       .49
  27    19.95       .47
  28    22.38       .44
  29    25.11       .44
  30    28.17       .44
  31    31.62       .44
  32    35.48       .44
  33    39.81       .44
  34    44.65       .44
  35    50.1        .44
 8 PEAK WAVELET AMPL(V):10.
 9 AUTO MODE LEVEL SEQ 0-FULL 1-1/2 2-1/4 3-1/8 4-1/16 5-DON
   FIRST:5
 10 EXTERNAL TRIGGER MODE 0-NO 1-YES:1
 11 ALARM BAND 1
     +DB LIMIT:3.
     -DB LIMIT:-3.
     UPPER FREQ, HZ:50.
```

FIGURE 15 TYPICAL INPUT LISTING - SHOCK RESPONSE SPECTRUM TEST
ANPP - SSE EVENT

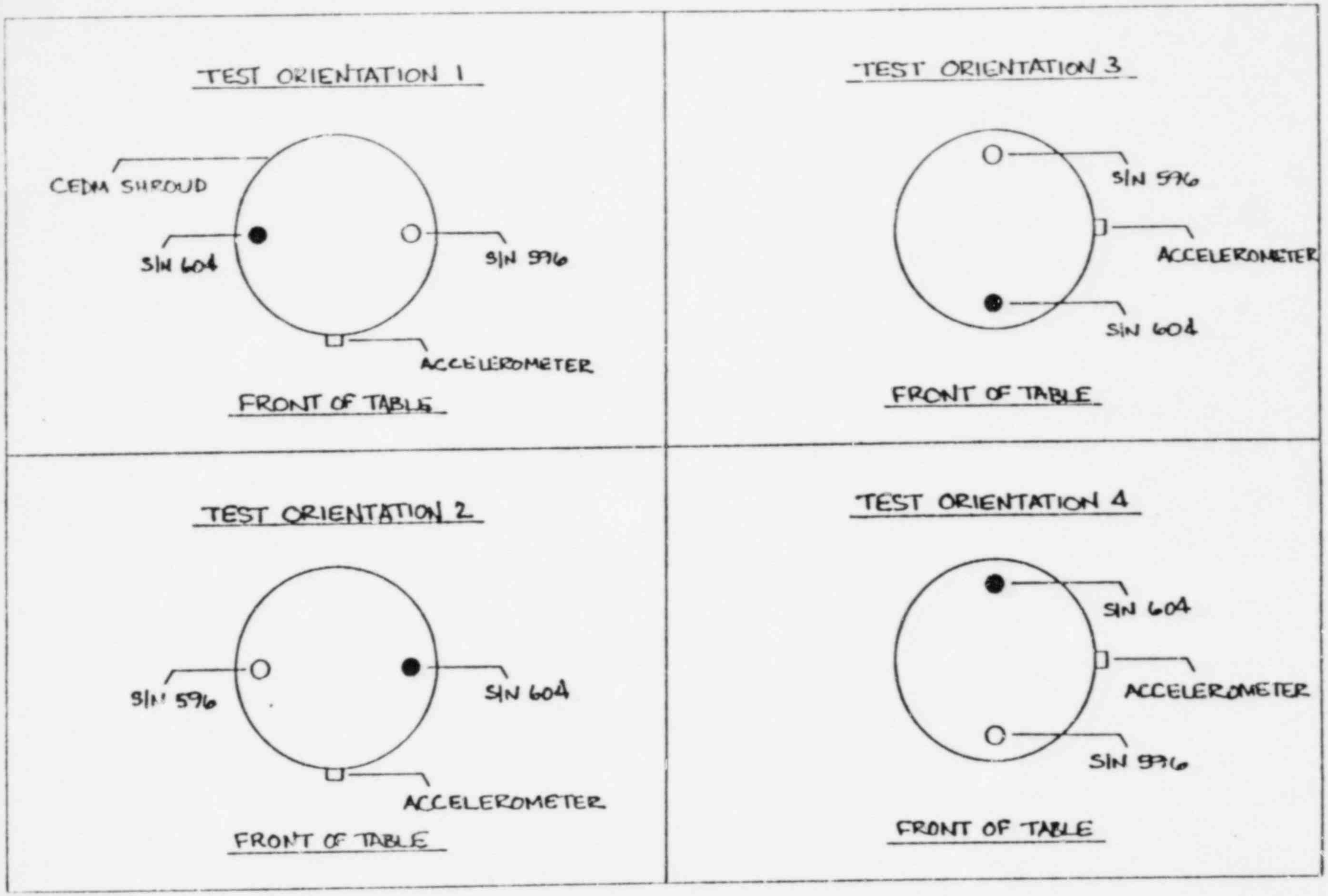


FIGURE 16

POSITION OF TEST SPECIMENS DURING TEST ORIENTATIONS 1 THROUGH 4 - TOP VIEW

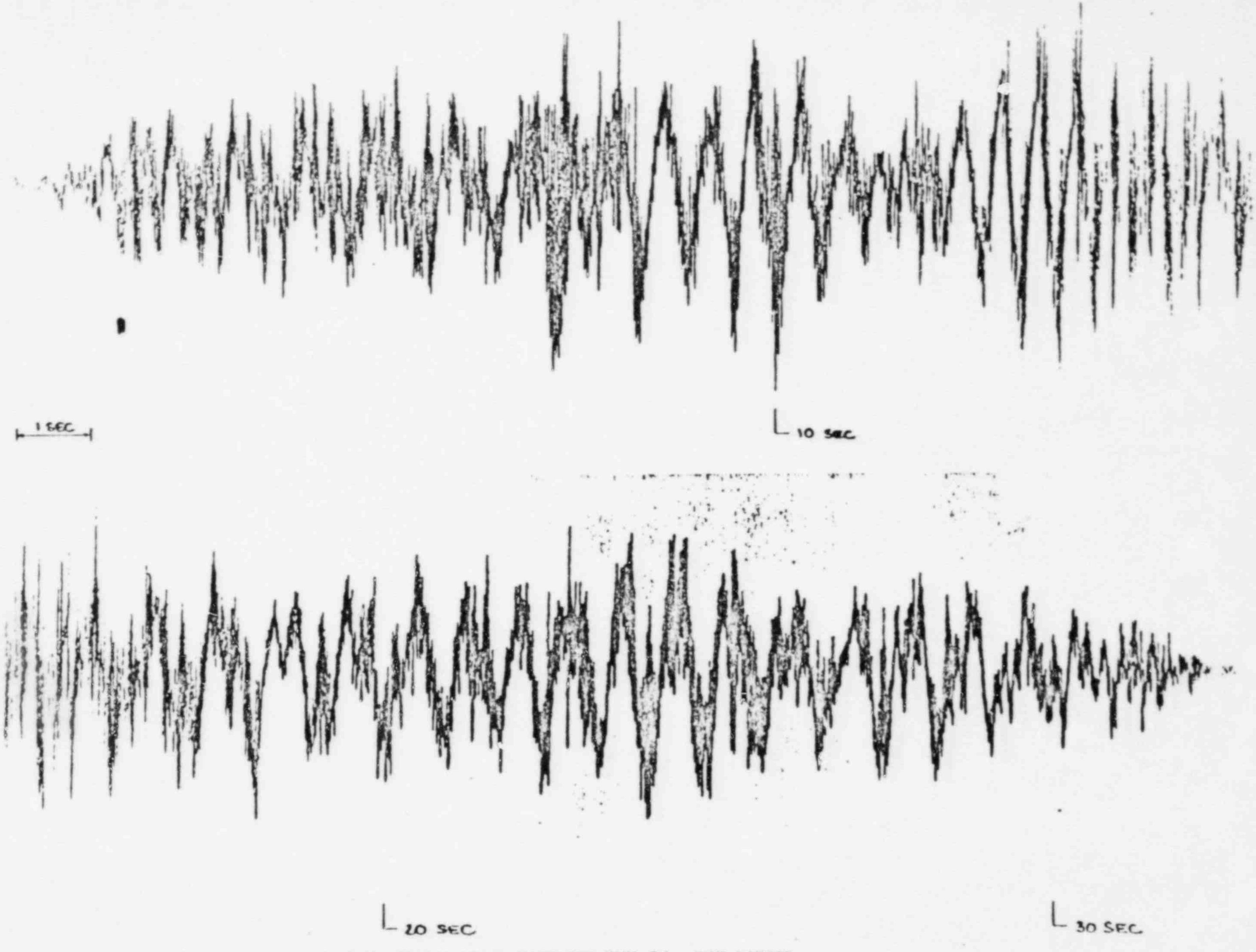


FIGURE 17 HORIZONTAL TABLE TIME HISTORY RUN 26 SSE EVENT

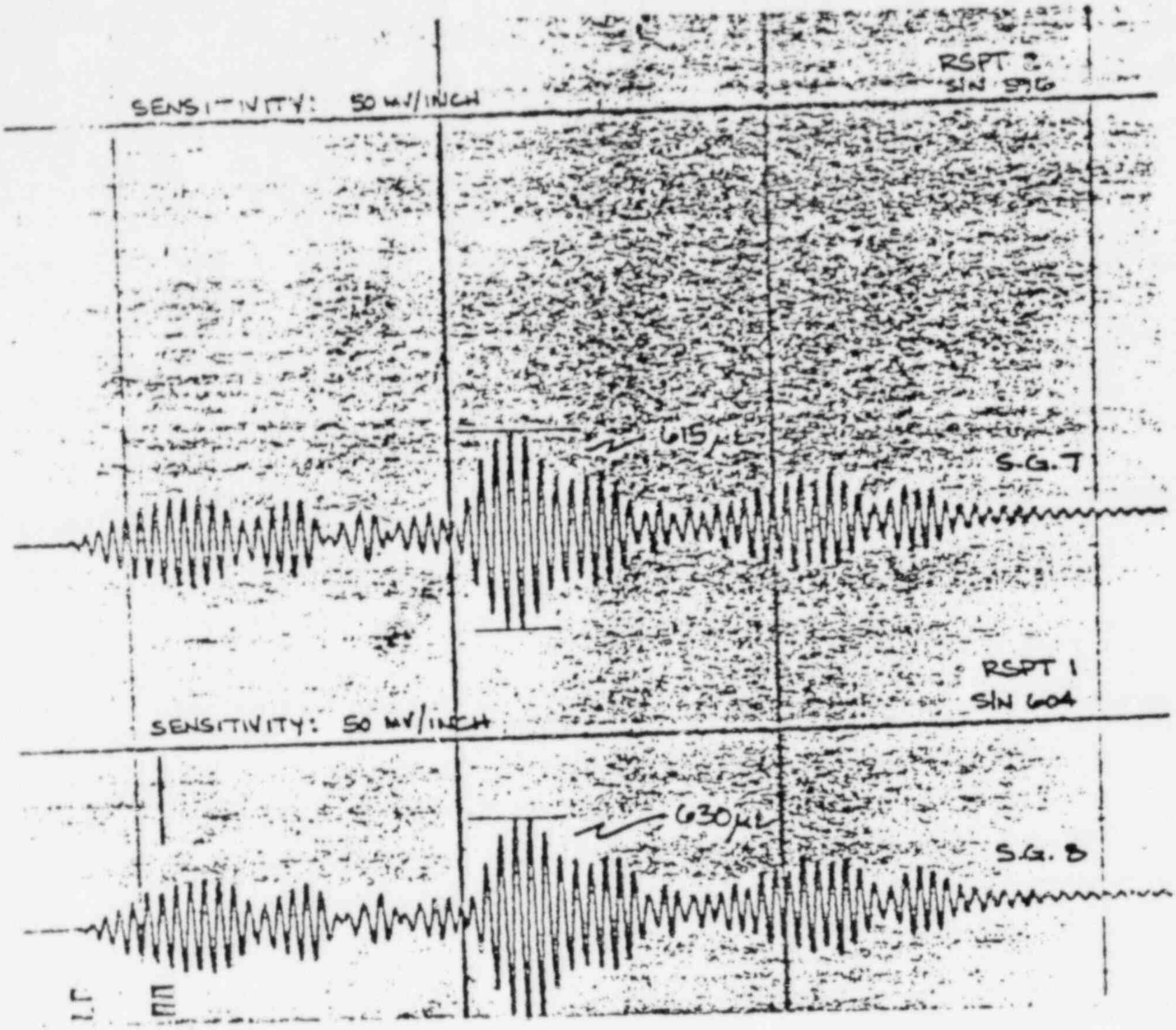


FIGURE 18

STRAIN AND RSPT TIME HISTORIES
OBE EVENT TEST ORIENTATION 3

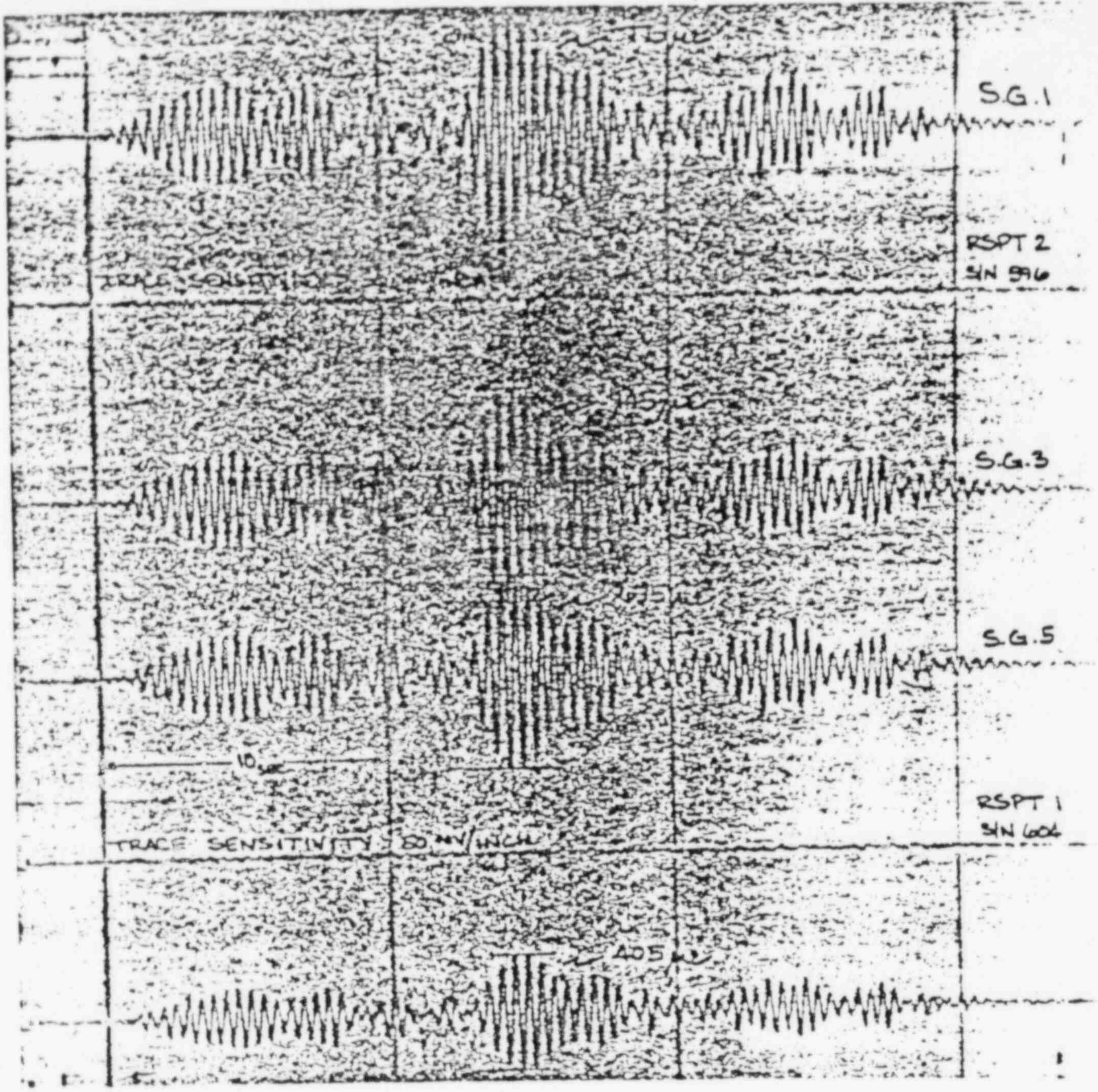


FIGURE 19

STRAIN AND RSPT TIME HISTORIES

SSE EVENT TEST ORIENTATION 1

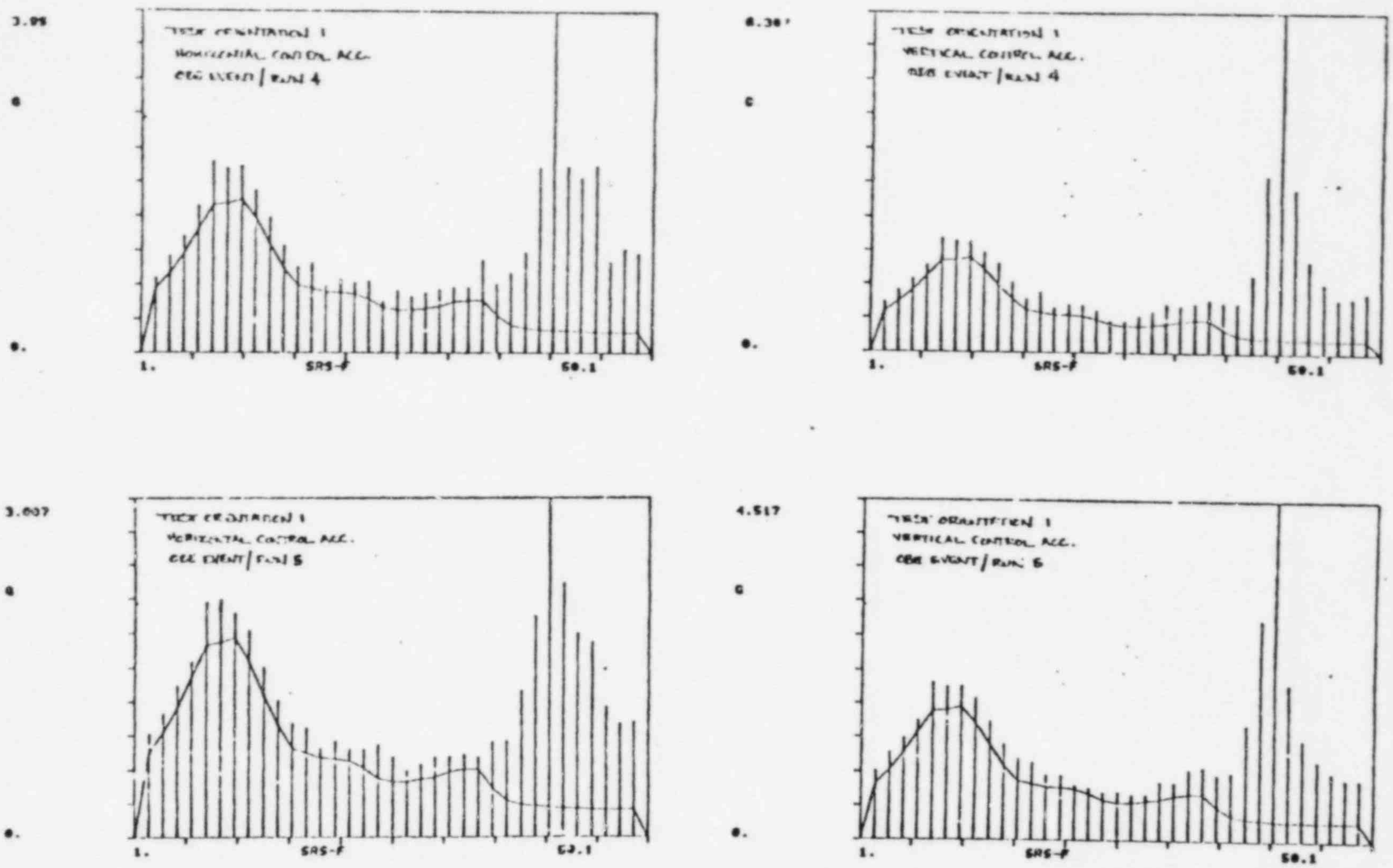


FIGURE 20A HORIZONTAL AND VERTICAL TEST RESPONSE SPECTRA - OBE EVENT
TEST ORIENTATION 1 - RUN NOS. 4 & 5

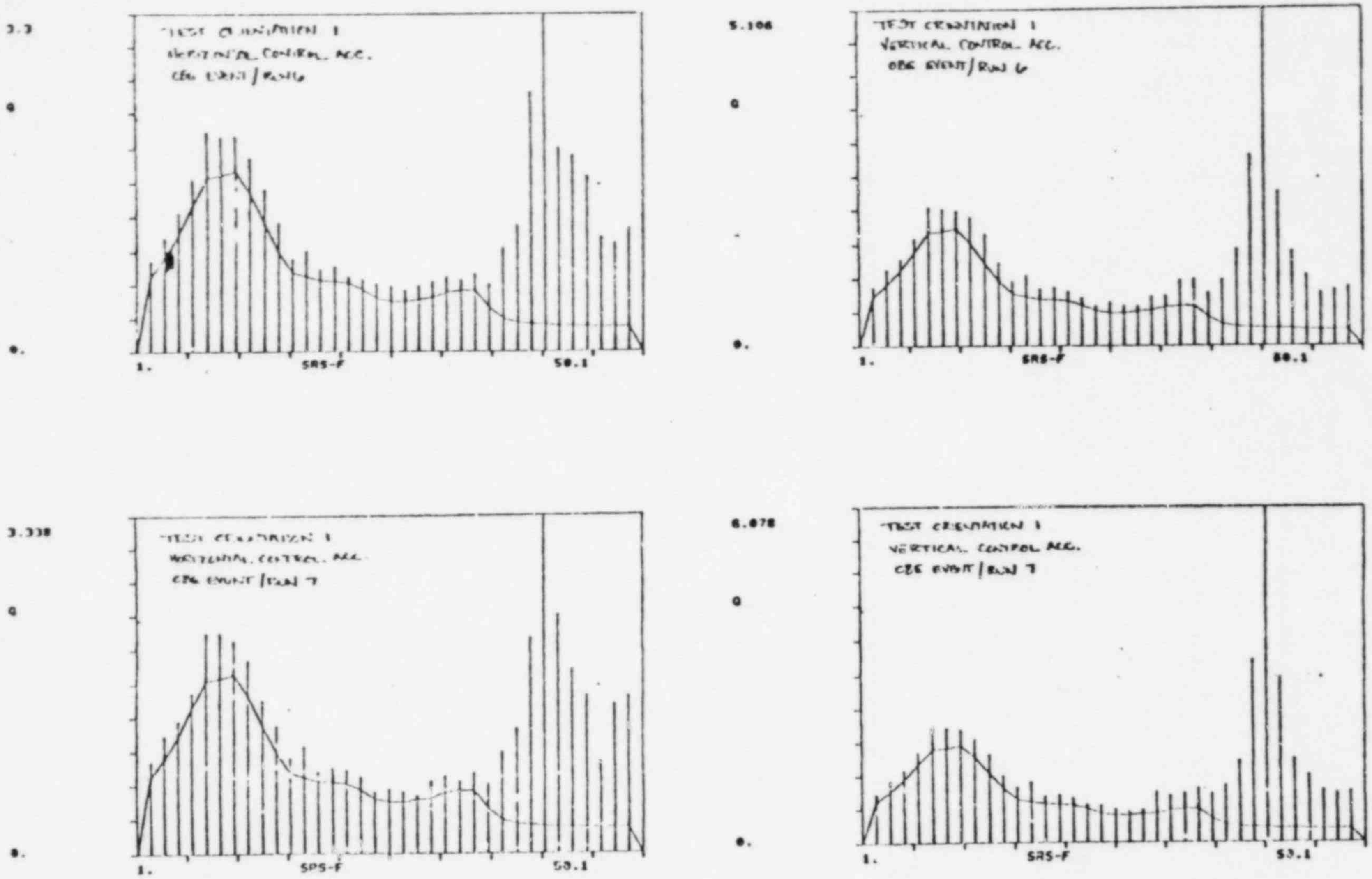


FIGURE 20B HORIZONTAL AND VERTICAL TEST RESPONSE SPECTRA - OBE EVENT
TEST ORIENTATION 1 - RUN NOS. 6 & 7

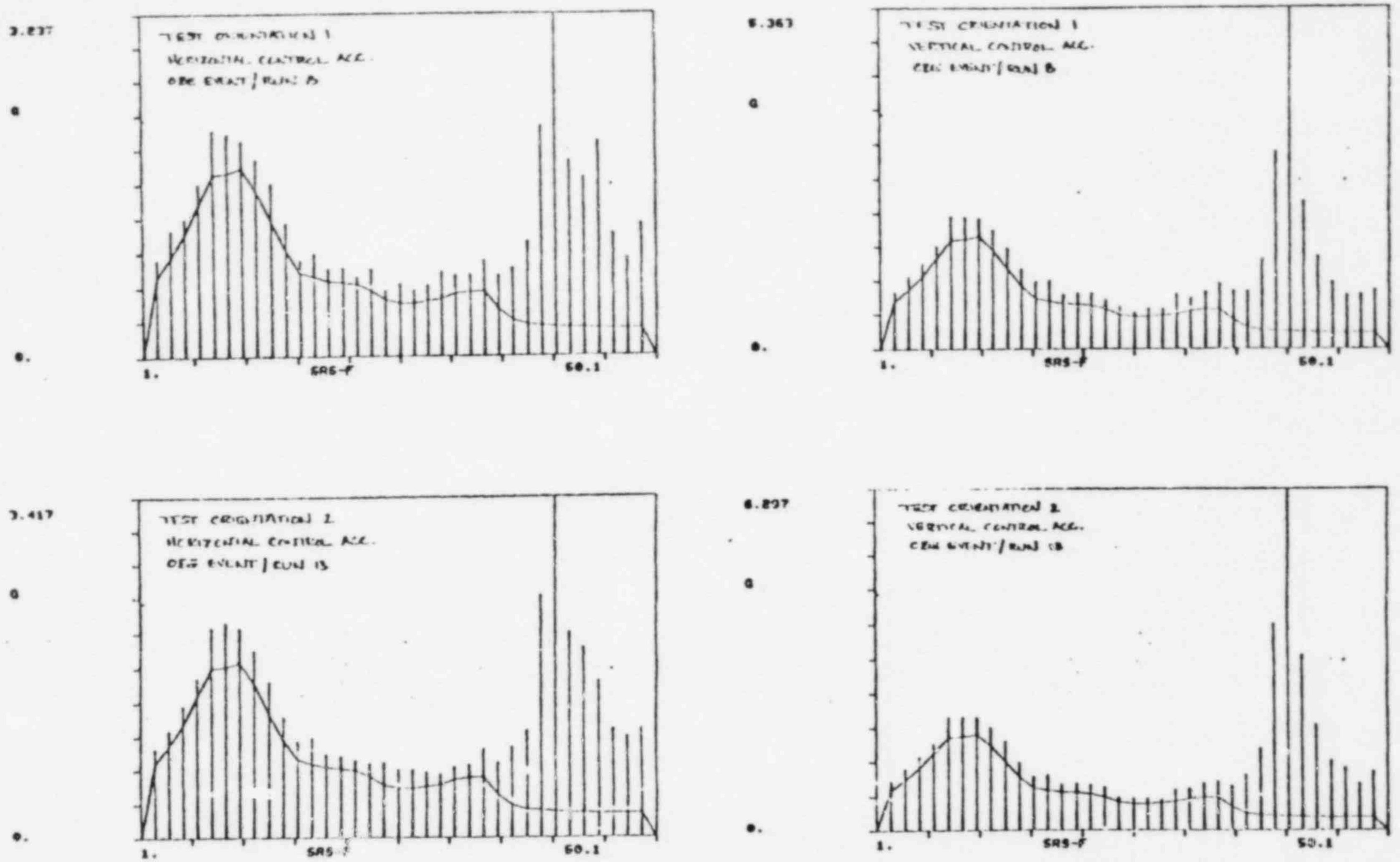


FIGURE 20C HORIZONTAL AND VERTICAL TEST RESPONSE SPECTRA - OBE EVENT
TEST ORIENTATION 1 - RUN NO. 8, TEST ORIENTATION 2 - RUN NO. 13

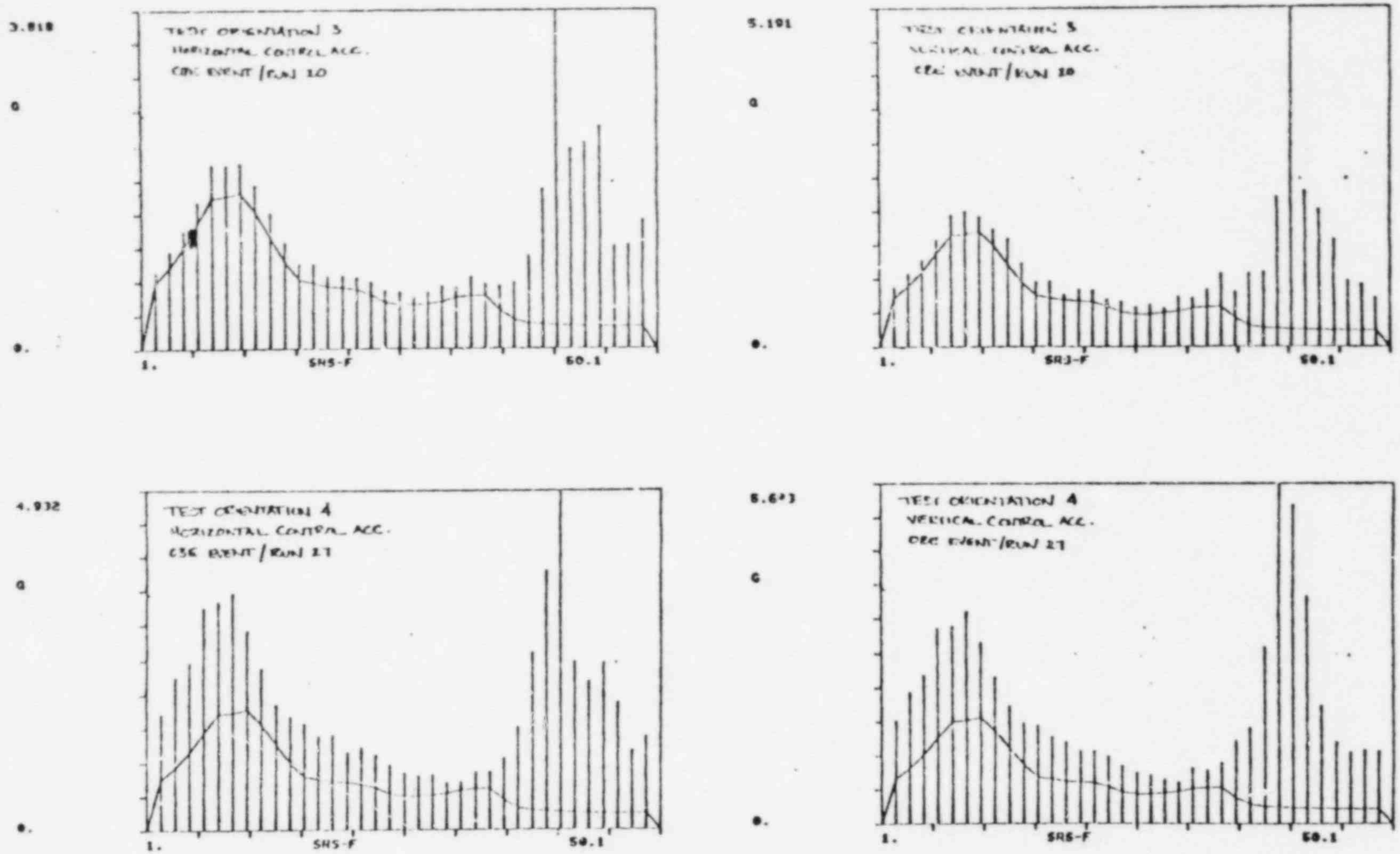


FIGURE 20D HORIZONTAL AND VERTICAL TEST RESPONSE SPECTRA - OBE EVENT
TEST ORIENTATION 3 - RUN NO. 20, TEST ORIENTATION 4 - RUN NO. 27

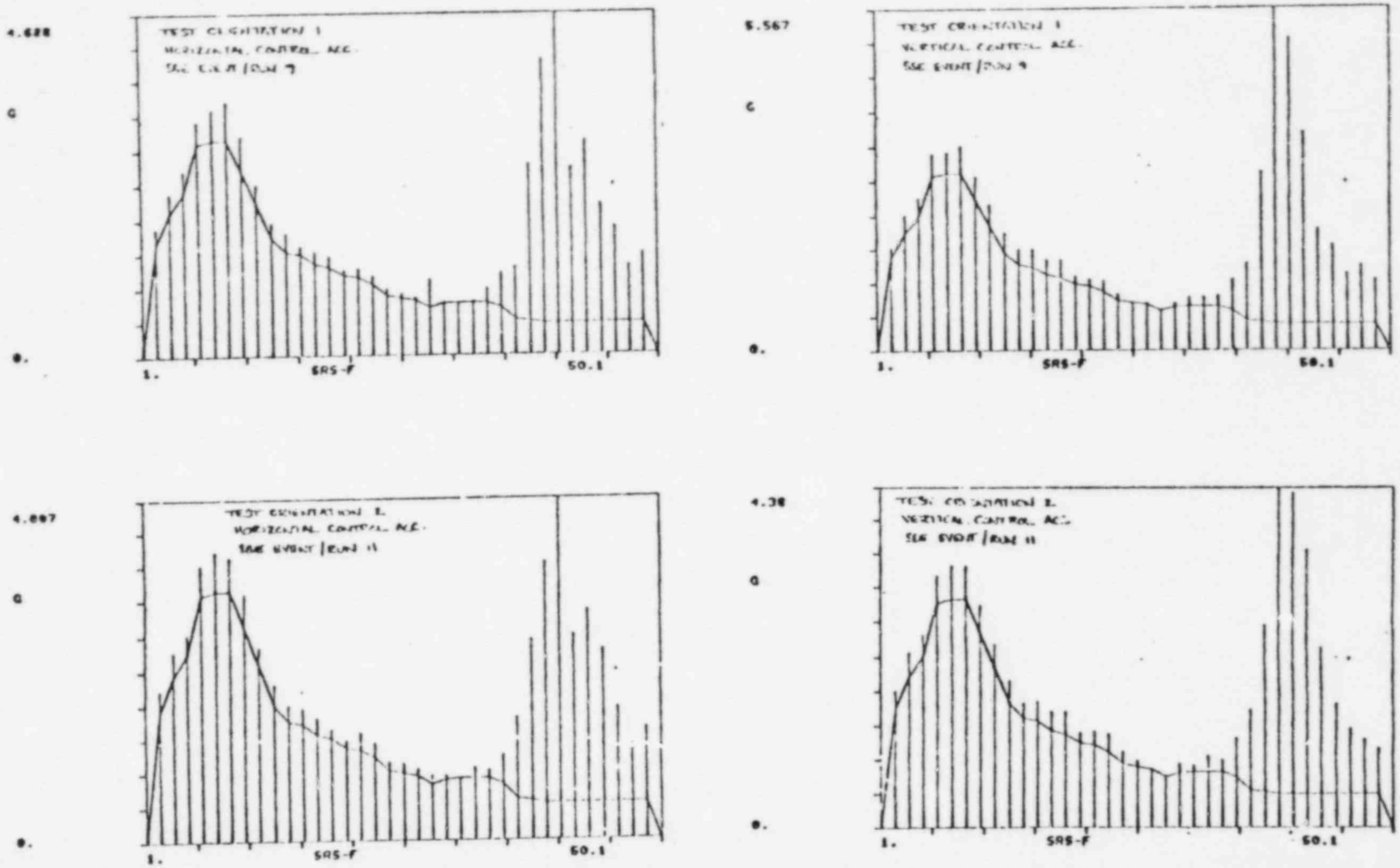


FIGURE 21A HORIZONTAL AND VERTICAL TEST RESPONSE SPECTRA SSE EVENT
TEST ORIENTATION 1 - RUN NO. 9, TEST ORIENTATION 2 - RUN NO. 11

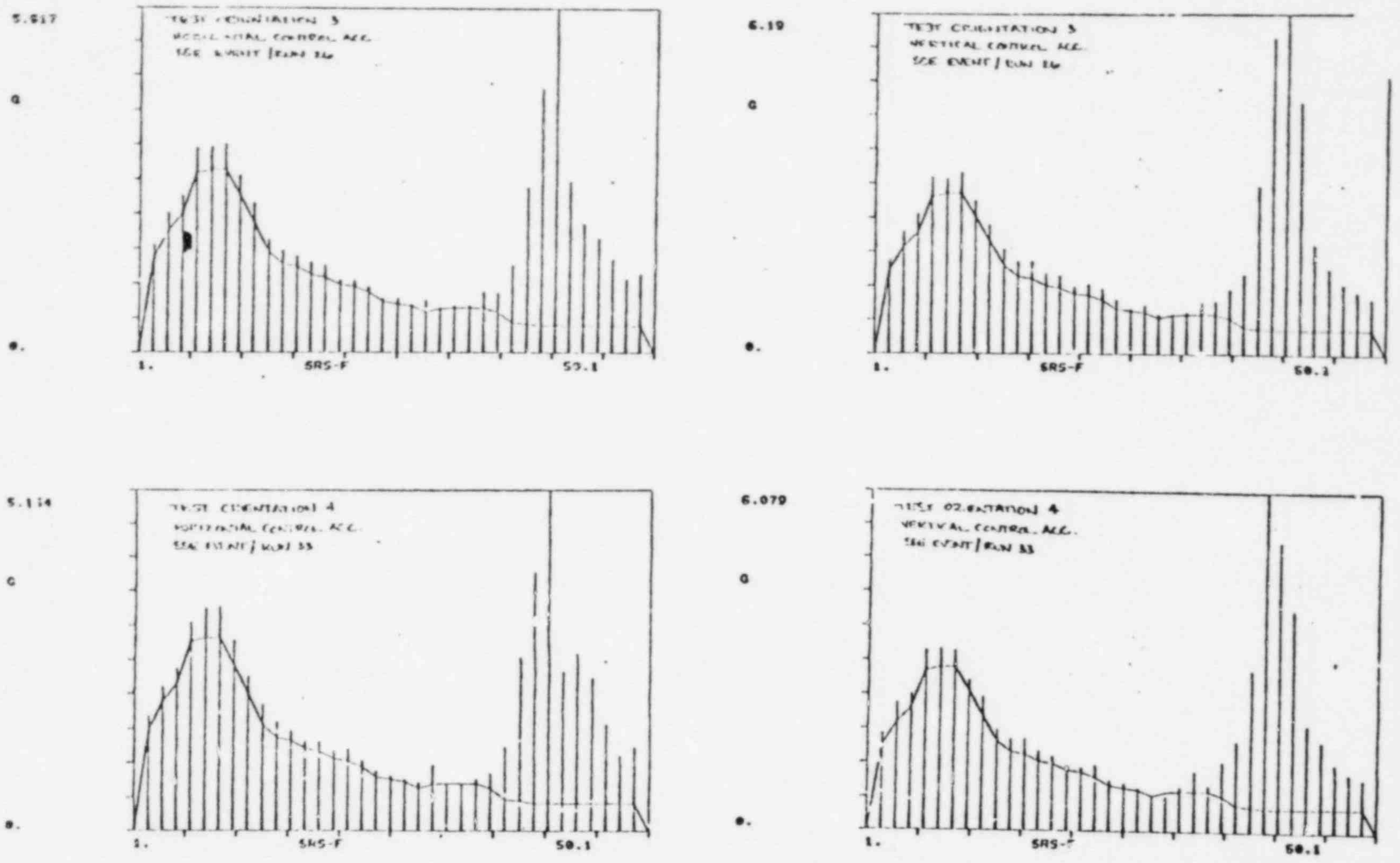


FIGURE 21B HORIZONTAL AND VERTICAL TEST RESPONSE SPECTRA SSE EVENT
TEST ORIENTATION 3 - RUN NO. 26, TEST ORIENTATION 4 _ RUN NO. 33

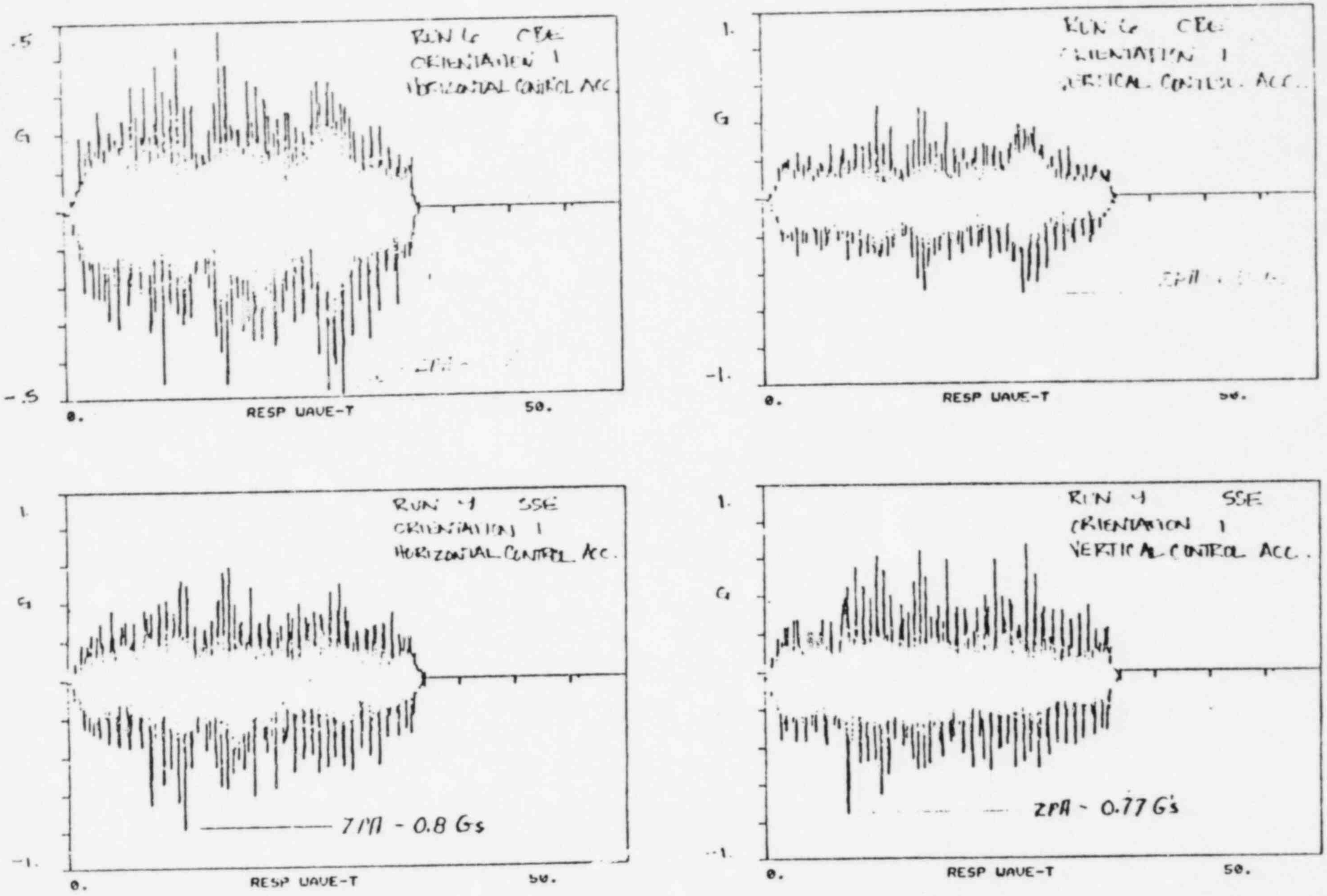


FIGURE 22 HORIZONTAL AND VERTICAL TABLE TIME HISTORIES, OBE AND SSE EVENT TEST ORIENTATION 1

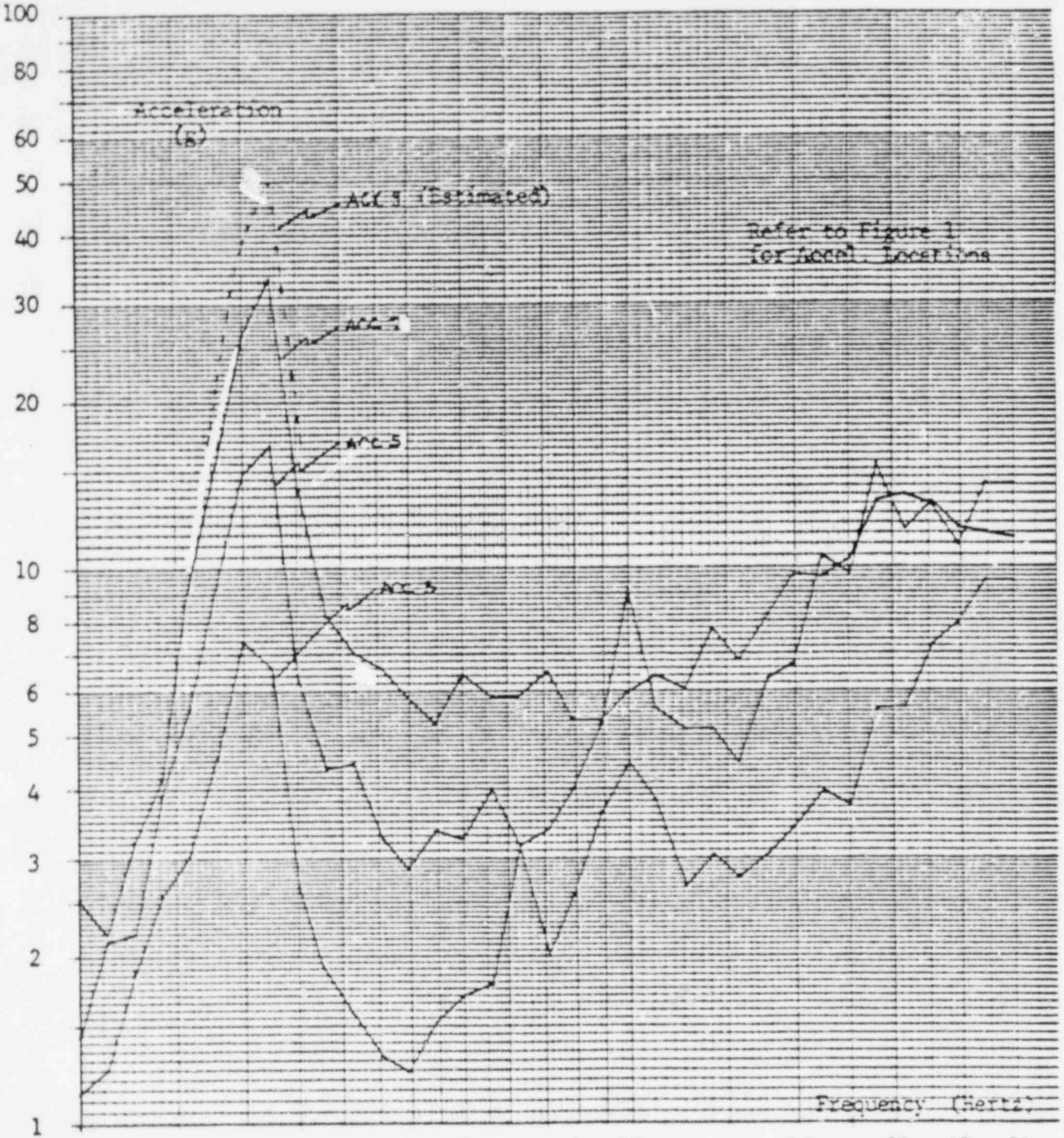


FIGURE 23

RESPONSE SPECTRA OF DIFFERENT SHROUD ELEVATIONS
OBE EVENT ORIENTATION 1 2% DAMPING

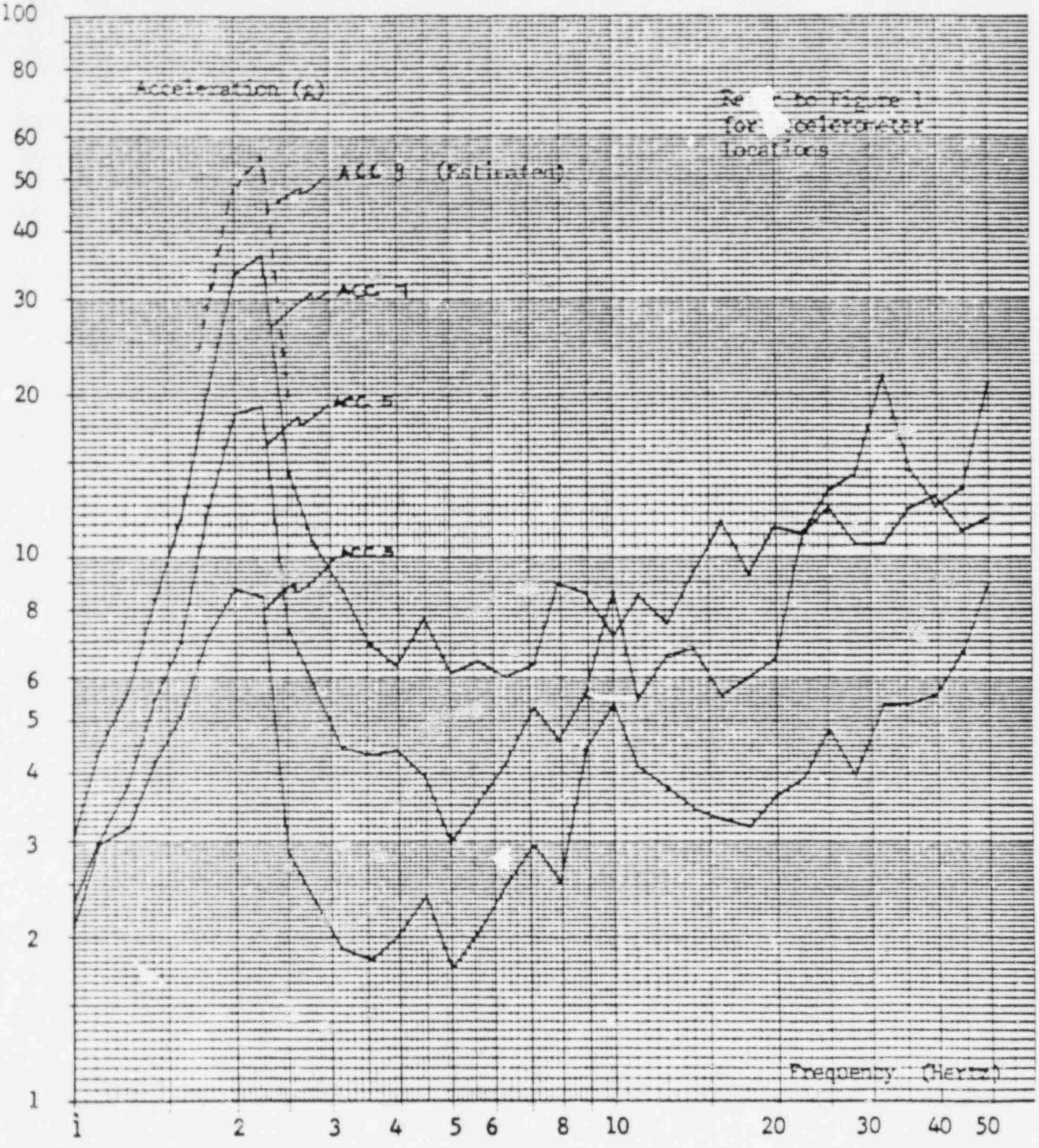


FIGURE 24

RESPONSE SPECTRA AT DIFFERENT SHROUD ELEVATIONS
SSE EVENT ORIENTATION 1 2% DAMPING

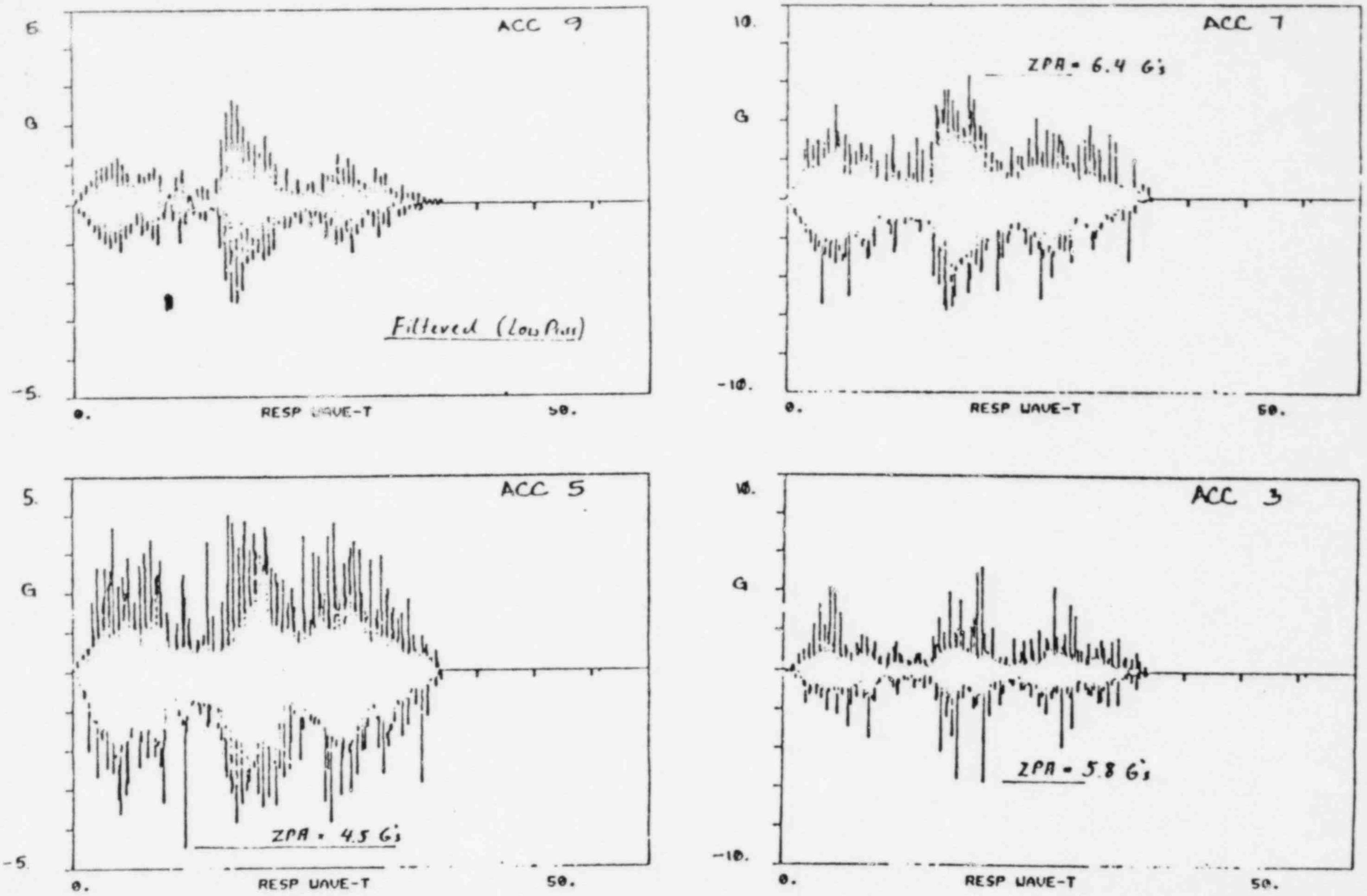


FIGURE 25 ACCELERATION TIME HISTORIES AT DIFFERENT SHROUD ELEVATIONS, OBE EVENT ORIENTATION 1

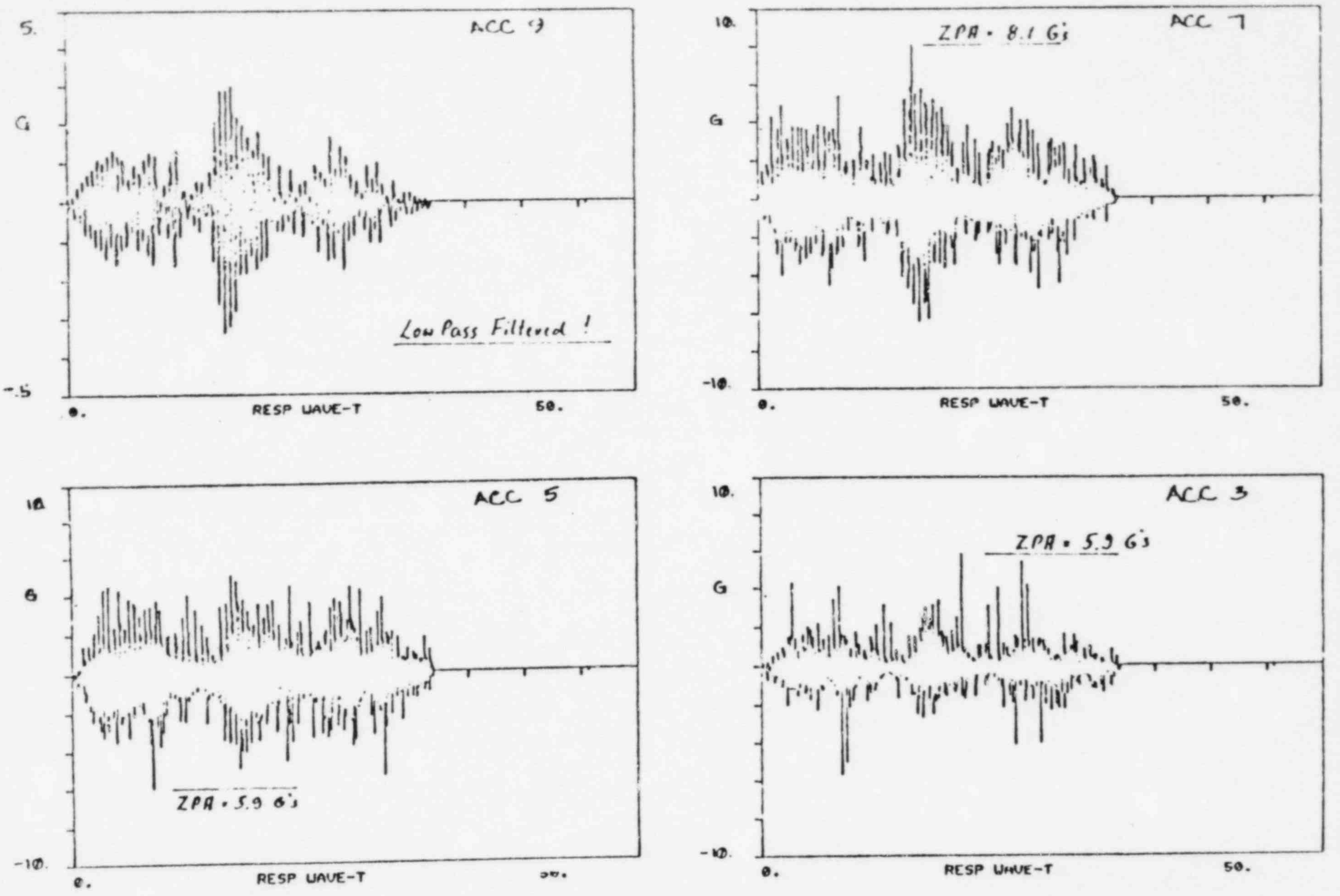


FIGURE 26 ACCELERATION TIME HISTORIES AT DIFFERENT SHROUD ELEVATIONS, SSE EVENT ORIENTATION 1

TABLE 1

SUMMARY OF RESULTS .02g EXCITATION SWEEPS
TEST FILE: RSSN02

MODAL STRAIN AMPLITUDES

		MODES			
		1	2	3	
STRAIN GAUGE (με)		2.3 Hz	- 9 Hz	-12 Hz	
S.G. 10		93.51	10.11	48.09	
S.G. 9				36.55	
S.G. 6		141.7			
S.G. 5					
S.G. 4		186.07	9.16	18.89	
S.G. 3		164.31	9.16	18.32	
S.G. 2		171.76	10.31	18.32	
S.G. 1		174.62	10.31	18.89	
MODAL TRANSFER FUNCTIONS (g/g)					FIRST MODE DAMPING (%)
ACC 9		59.39	6.90	6.70	2.7
ACC 8		50.0	4.58	9.06	
ACC 7		39.79	2.19	12.40	2.6
ACC 6		33.87	.95	15.08	
ACC 5		23.38	2.19	15.46	2.4
ACC 4			3.05	13.36	
ACC 3		8.87	3.45	9.77	
ACC 2		6.32	3.07	6.86	
ACC 1		3.54	2.20	3.80	

TABLE 2

SUMMARY OF RESULTS .05g EXCITATION SWEEPS
TEST FILE: RSSN05

MODAL TRANSFER FUNCTION AMPLITUDES

MODE	ACC 1	ACC 2	ACC 3	ACC 4	ACC 5	ACC 6	ACC 7	ACC 8	ACC 9
1	2.8	4.6	7.0	—	17.4	25.5	30.1	38.8	43.3
2	2.9	4.9	5.3	—	4.8	.5	6.3	7.7	18.9
3	2.3	3.9	5.4	—	9.2	9.1	8.8	7.5	6.7

MODAL DAMPING VALUES

MODE	ACC 5	ACC 6	ACC 7	ACC 8	ACC 9	AVG.
1	2.54	2.69	2.54	2.65	2.61	2.61
2	3.86	-	2.76	4.04	3.39	3.51
3	1.95	2.11	2.51	-	-	2.19

MODAL STRAIN AMPLITUDES

MODE	S.G. 1	S.G. 2	S.G. 3	S.G. 4	S.G. 6	S.G. 9
1	360	367	347	377	293	61
2	37	43	37	40	-	-
3	23	23	23	23	-	25

TABLE 3

SUMMARY OF MODAL TRANSFER FUNCTIONS - SINE SWEEP TESTING

MODE	EXCITATION LEVEL (g)	ACC 1	ACC 2	ACC 3	ACC 4	ACC 5	ACC 6	ACC 7	ACC 8	ACC 9
1	.02	2.77	4.43	6.41	10.80	15.77	22.28	27.44	34.13	41.49
	.04	2.42	3.90	5.93	9.56	14.72	20.55	26.10	31.84	38.43
	.06	2.95	5.11	7.40	13.58	20.08	27.15	35.85	45.22	60.61
	.08					20.36		34.23		52.01
	.10					19.60		33.27		46.18
	.12					18.83		31.74		40.15
2	.05	2.87	4.33	5.0	4.04	2.31	1.25	3.81	8.10	11.35
	.10	3.44	5.48	6.53	5.69	3.72	.98	3.97	9.31	13.31
	.15	3.50	5.58	6.50	6.12	4.48	.86	4.52	9.29	15.16
	.20			5.77				3.81		12.88
	.25			5.66				3.37		11.73
3	.05	2.12	3.85	5.75	7.87	8.94	8.35	6.71	4.52	2.69
	.10	1.79	3.13	4.61	6.19	7.16	6.87	6.03	4.32	3.74
	.15	2.29	3.88	5.77	7.60	8.33	8.87	6.63	4.99	5.09
	.20			4.62				5.19		3.75
	.25			3.69				4.25		2.60

Note: The Transfer Functions are defined by the Ratio of Acceleration Levels of the monitored Accelerometer over the Horizontal Control Accelerometer.

TABLE 4

SUMMARY OF MODAL STRAIN LEVELS SINE SWEEP TESTING

MODE	EXCITATION LEVEL (g)	S.G. 1	S.G. 2	S.G. 3	S.G. 5	S.G. 6	S.G. 10
1	.02	132	136.5	127	117	101.7	76
	.04	236	241	228	212	183	149
	.06	472	492	460	427	366	283
	.08	640	660	600	560	480	350
	.10	790	810	740	690	580	420
	.12	910	920	860	790	660	480
2	.05	47	47	43	28	19	26
	.10	93	96	88	55	34	46
	.15	138	144	131	79	41	64
	.20	162	165	150	96	51	90
	.25	207	210	192	120	60	110
3	.05	29	29	26	15	9	69
	.10	42	44	40	27	15	121
	.15	74	75	70	43	21	203
	.20	87	90	81	48	27	240
	.25	96	99	84	51	27	230

Note: Strain values are listed in microinch/inch

TABLE 5

MODAL DAMPING PROPERTIES - SINE SWEEP TESTING

MODE	EXCITATION LEVEL (g)	ACC 1	ACC 2	ACC 3	ACC 4	ACC 5	ACC 6	ACC 7	ACC 8	ACC 9	AVERAGE
1	.02					3.15	3.05	3.10	3.05	3.12	3.09
	.04				2.93	2.80	2.94	2.73	2.72	2.77	2.82
	.06				2.32	2.32	2.38	2.14	2.07	1.97	2.20
	.08					2.43		2.41		2.34	2.39
	.10					2.32		2.48		2.74	2.51
	.12					2.52		2.48		3.14	2.71
2	.05	8.32	6.63	5.17	5.48	4.48			5.04		5.85
	.10										
	.15	4.93	4.82	5.09	4.86	5.05					4.95
	.20			5.96							5.96
	.25			5.65							5.65
3	.05		3.45	3.33	3.08	3.08	3.48				3.28
	.10		3.14	3.19	3.47	3.28	3.19	3.17			3.24
	.15	3.19		2.54	2.61	3.10	3.20	3.58			3.04
	.20			2.19							2.19
	.25			3.12							3.12

Damping values are listed in Percent of Critical

TABLE 6

STRAIN LEVELS AND RSPT ELECTRICAL PERFORMANCE
SEISMIC OBE AND SSE TESTING

			MEASURED STRAIN DATA-VISICORDER				ELECTRICAL PERFORMANCE	
TEST ORIEN.	TEST DESCRIPTION	TAPE RUN NO.	S.G. 1 με	S.G. 3 με	S.G. 5 με	S.G. 10 με	RSPT 1 S/N 604	RSPT 2 S/N 596
1	OBE 1	4	625	600	550	340	OK	OK
1	OBE 2	5	625	600	550	350	OK	OK
1	OBE 3	6	625	605	550	340	OK	OK
1	OBE 4	7	635	605	550	335	OK	OK
1	OBE 5	8	625	605	550	340	OK	OK
1	SSE 1	9	775	745	675	405	OK	OK
2	SSE 1	11	755	745	680	405	OK	OK
2	SSE 2	12	775	745	675	400	OK	OK
2	OBE 1	13	620	600	550	335	OK	OK
2	OBE 2	14	525	600	555	335	OK	OK
2	OBE 3	15	625	600	550	330	OK	OK
2	OBE 4	16	625	600	550	340	OK	OK
3	OBE 5	17	625	605	555	335	OK	OK
			S.G. 7 με	S.G. 8 με				
3	OBE 1	20	600	615			OK	OK
3	OBE 2	21	600	625			LOOSE	CABLE
3	OBE 3	22	610	635			OK	OK
3	OBE 4	23	620	630			OK	OK
3	OBE 5	24	615	630			OK	OK
3	OBE 6	25	615	630			OK	OK
3	SSE	26	755	740			OK	OK
4	OBE 1	27	760	740			OK	OK
4	OBE 2	28	760	750			OK	OK
4	OBE 3	29	765	760			OK	OK
4	OBE 4	30	770	760			OK	OK
4	OBE 5	31	770	750			OK	OK
4	OBE 6	32	770	750			OK	OK
4	SSE	33	765	750			OK	OK

Note: OBE Events for Test Orientation 4 inadvertently were run at SSE Intensity.

TABLE 7

LIST OF EQUIPMENT AND INSTRUMENTATION

Instrument	Manufacturer	Model Number	Serial Number	Calibration Requirements	
Seismic Shaker Table	M/Rad	—		--	
Hydraulic Shaker	MTS	204.63	299	—	
Shaker Controller	MTS	406.11B	1094	—	
Shaker Control Unit	MTS	436.11AB	463	—	
Digital Vibration	—	P/N 2931-973	Unit C-E	QA Verification of software used	
Control System	Time Data Corp.	TDV-25P			
Control Accelerometers	Unholtz Dickie	100-PA	492/493	Per Manufacturer	Check calibrated within last 12 months
Response Accelerometers	Unholtz Dickie	75 D2/PA	156/104-117	Per Manufacturer	
Response Accelerometers	Endevco	7701-100	AA15, AA16	Per Manufacturer	
Signal Conditioners	Unholtz Dickie	2216x	145/146	Performance Check	
Charge Amplifiers	Unholtz Dickie	D-22 H Type	2024-2027	Performance Check	
Charge/Voltage Amps	Unholtz Dickie	D-22 R Type	2048-2053	Performance Check	
Oscilloscope	Tektronix	5000 Series	B117232	Performance Check	
Strain Gauges	Micro Measurement	WK-06-125AD-350	—	—	
Visicorder	Honeywell	1858-07906	1704DH77	Signal Calibration	
Power Supply	Power Mate or equal	QRD15-1	IL-113	—	
Tape Recorder	Racal Store 7D	D7 690/S		Signal Calibration	

APPENDIX A

ELECTRICAL AND FUNCTIONAL INSPECTION SHEETS

Electrical Inspection Sheet

S.N. 576

ected by: John Falkowski

Date: 7/25/81

Ref. Para.	Pins	Measured Resistance (ohms) & Remarks									
7.1.2.1	A-B	3092				After Switch Aging					
7.1.2.2	A-C	1000	1110	1220	1330	1504	1614	1724	1844	1961	2075
		1010	1120	1230	1340	1514	1625	1735	1855	1965	2085
		1022	1130	1240	1350	1524	1634	1744	1865	1975	2094
		1029	1140	1250	1361	1534	1644	1754	1875	1985	2105
		1040	1144	1260	1370	1544	1656	1764	1885	1996	2114
		1050	1160	1270	1380	1554	1664	1775	1895	2006	
		1059	1169	1280	1391	1569	1675	1785	1906	2017	
		1069	1180	1290	1402	1574	1684	1795	1919	2027	
		1079	1189	1300	1411	1584	1694	1805	1925	2044	
		1091	1202	1311	1420	1594	1705	1815	1935	2055	
		1100	1210	1320	1433	1605	178	1825	1945	2064	
		Bottom to Top									
7.1.2.3	A-C	2114	1996	1885	1764	1656	1534	1361	1240	1130	1031
		2104	1985	1875	1756	1644	1524	1350	1230	1109	1012
		2094	1975	1865	1745	1634	1514	1340	1220	1099	1000
		2084	1965	1855	1735	1625	1504	1330	1210	1090	
		2074	1959	1845	1724	1614	1432	1320	1200	1079	
		2064	1945	1825	1715	1604	1420	1310	1190	1069	
		2054	1935	1815	1705	1594	1410	1290	1180	1059	
		2044	1925	1805	1694	1584	1401	1280	1161	1050	
		2037	1916	1795	1684	1574	1390	1270	1149	1042	
		2017	1906	1785	1674	1566	1380	1260	1140	1029	
		2006	1895	1775	1664	1554	1370	1250	1129	1022	
		Top to Bottom									
8.1.2.4	D-E F-H J-K	0.001 0.001 0.001									
8.1.2.5	A thru K	Satisfactory									

Electrical and Functional
Inspection Sheet

is. ted By: D.A. STORY D.A. Story Date: 8/7/91

RSPT S/N 596

ef. Para.	Pins	After Seismic Testing Measured Resistance (Ohms) & Remarks									
4.3.1	A-B	3,132 Ω				*			*.		
4.3.2	A-C	1000	1110	1221	1331	1543	1654	1764	1884	1995	2103
		1010	1121	1231	1341	1554	1664	1774	1885	2006	2113
		1020	1131	1241	1351	1564	1674	1784	1895	2006	2123
		1030	1141	1251	1361	1574	1684	1795	1905	2016	2133
		1043	1151	1261	1371	1584	1694	1804	1915	2026	2143
		1052	1161	1271	1381	1594	1704	1814	1925	2036	2153
		1060	1171	1281	1391	1604	1714	1824	1935	2046	
		1070	1191	1291	1401	1614	1724	1834	1945	2056	
		1080	1191	1301	1411	1624	1734	1844	1958	2066	
		1090	1202	1311	1421	1634	1744	1855	1965	2083	
		1100	1211	1321	1431	1644	1755	1865	1975	2093	
4.3.3	A-C	2153	2036	1935	1824	1714	1604	1391	1291	1171	1060
		2143	2026	1925	1814	1704	1594	1381	1271	1161	1051
		2133	2016	1415	1804	1694	1584	1371	1261	1151	1042
		2123	2006	1905	1796	1684	1574	1361	1251	1141	1030
		2113	2000	1895	1784	1674	1564	1351	1241	1131	1020
		2103	1996	1885	1774	1664	1554	1341	1231	1122	1010
		2093	1985	1880	1764	1654	1544	1331	1221	1110	1000
		2083	1975	1865	1754	1644	1431	1321	1211	1100	
		2066	1965	1855	1744	1634	1421	1311	1201	1090	
		2056	1956	1845	1734	1624	1411	1301	1191	1080	
		2046	1945	1834	1724	1614	1401	1291	1181	1070	
3.4	D-E	0.9 Ω									
	F-H	1.0 Ω									
	J-K	0.6 Ω									
4.3.5	A thru K	} INFINITY									

Electrical Inspection Sheet

SN 604

ected by: WJ Slater John Falkowski Date: 7/24/8

Ref. Para.	Pins	Measured Resistance (ohms) & Remarks									
7.1.2.1	A-B	3018			After Switch Aging						
7.1.2.2	A-C	0.997	1108	1219	1328	1428	1538	1648	1758	1868	1977
		1.008	1135	1228	1337	1438	1547	1658	1768	1878	1987
		1018	1129	1240	1342	1448	1559	1669	1779	1888	1997
		1028	1138	1249	1348	1458	1568	1678	1788	1897	2009
		1038	1149	1258	1358	1468	1578	1688	1798	1908	2019
		1048	1158	1268	1369	1478	1609	1698	1808	1918	2028
		1058	1169	1278	1378	1561	1599	1707	1818	1929	2038
		1068	1180	1289	1388	1499	1609	1718	1828	1937	
		1078	1188	1298	1398	1507	1618	1728	1837	1950	
		1088	1198	1309	1408	1518	1628	1739	1848	1959	
		1098	1208	1318	1418	1526	1638	1748	1858	1968	
							Bottom to Top R				
7.1.2.3	A-C	2038	1929	1818	1708	1598	1488	1379	1268	1158	1059
		2029	1918	1808	1698	1608	1478	1369	1258	1150	1048
		2019	1908	1798	1688	1578	1468	1358	1248	1139	1039
		2009	1898	1788	1678	1568	1458	1348	1240	1129	1028
		2000	1888	1779	1668	1558	1449	1339	1228	1125	1019
		1988	1878	1768	1658	1547	1438	1328	1219	1122	1008
		1978	1868	1758	1648	1539	1428	1318	1208	1108	1000
		1968	1858	1748	1638	1528	1418	1309	1198	1099	997
		1957	1848	1739	1629	1518	1409	1298	1188	1088	
		1948	1838	1728	1618	1508	1399	1288	1182	1078	
		1938	1828	1718	1609	1499	1388	1278	1169	1068	
							Top to Bottom S				
8.1.2.4	D-E F-H J-K	0.000 0.000 0.000									
8.1.2.5	A thru K	Satisfactory									

DATA SHEET NO. 1

Electrical and Functional

Inspection Sheet

ted By: D.A. STORY D.A. Story   Date: 8/7/81

RSPT   S/N 604

After Seismic Testing

Ref. Para.	Pins	Measured Resistance (Ohms) & Remarks									
4.3.1	A-B	3019Ω									
4.3.2	A-C	1000	1109	1219	1329	1439	1547	1659	1768	1877	198
		1009	1120	1229	1339	1449	1559	1669	1779	1884	2000
		19	1129	1241	1349	1459	1569	1679	1784	1898	2009
		29	1139	1250	1359	1469	1579	1689	1799	1904	2019
		39	1151	1254	1369	1479	1594	1699	1809	1918	2039
		49	1159	1269	1379	1490	1599	1709	1819	1928	
		59	1169	1279	1389	1499	1609	1719	1829	1938	
		69	1183	1289	1399	1509	1619	1729	1839	1949	
		79	1189	1299	1409	1519	1629	1739	1849	1959	
		89	1199	1309	1419	1529	1639	1749	1859	1968	
		99	1209	1319	1429	1539	1649	1759	1868	1978	
4.3.3	A-C	2039	1929	1819	1709	1599	1490	1379	1269	1150	1039
		2029	1917	1809	1699	1589	1479	1370	1259	1134	1029
		2019	1909	1799	1689	1574	1469	1354	1250	1129	1019
		2009	1898	1784	1679	1569	1454	1344	1241	1120	1009
		2000	1888	17[illegible]	1669	1559	1449	1339	1230	1109	1000
		1988	1879	1764	1659	1549	1439	1329	1219	1100	
		1978	1869	1754	1649	1539	1429	1319	1209	1089	
		1968	1854	1744	1639	1529	1419	1310	1200	1074	
		1954	1844	1739	1629	1519	1404	1300	1189	1064	
		1947	1839	1729	1619	1509	1400	1289	1181	1059	
		1938	1829	1719	1609	1499	1389	1279	1164	1049	
3.4	D-E	1.1Ω									
	F-H	1.0Ω									
	J-K	0.5Ω									
4.3.5	A thru	INFINITY									

APPENDIX B

LOG SHEETS

TAPE DATA LOG SHEET

LOG SHEET NO. 01

TEST ANPP RSPT SEIS. QUAL

HOOKUP SHEET NO.

DATE 7/31/81

RECORD SPEED 3 3/4

RECORDED BY S. K

RECORD BAND WB I

REEL NO.	RUN NO.	FOOTAGE	ATTENUATOR/AMP. SETTING							COMMENTS
			1	2	3	4	5	6	7	
S-01	# TAPE FT.	—	H.C	V.C.	Acc 9	Acc 7	Acc 5	Acc 3	Trigger	Transducer:
		—	10V 1G	10V	10V	10V	10V	10V	10V	[illegible]
	1	50								~~OBE~~ 0V SHORTED INPUTS CAL
	2	65	#1 only: 9v pk 100 Hz [CAL ONLY]							ALL INPUTS F. S. CAL SIGNAL 2-6: 10v pk 100 Hz 7:
	3	90	10v	10v	10v	10v	10v	10v	~5v NOM	ALL INPUTS F. S. CAL 10 v PK. 100 Hz
	4	108								ORIENTATION 1: OBE 1
	5	124								ORT 1 OBE 2
	6	141								ORT 1 OBE 3
	7	161								ORT 1 OBE 4
	8	179								ORT 1 OBE 5
	9	199								ORT 1 SSE 1
	10	226								~~ORT 2~~ ABORT ~~SSE 1~~
	11	238								ORT 2: SSE 1
	12	259								ORT 2 SSE 1, 2nd run
	13	278								OBE 1 ORT 2

TAPE DATA LOG SHEET

TEST ANPP RSPT SEIS. QUAL
DATE 7/31/81
RECORDED BY S.K.

LOG SHEET NO. 02
HOOKUP SHEET NO.
RECORD SPEED 3 3/4
RECORD BAND WB1

REEL NO.	RUN NO.	FOOTAGE	ATTENUATOR/AMP. SETTING							COMMENTS
			1	2	3	4	5	6	7	
S-01		—	H.C	V.C	Acc 9	Acc 7	Acc 5	Acc 3	Trigr	~~OBE 2 2d RTN~~ ~~ORT 2~~
	—	—	10V	10V	10V	10V	10V	10V	10V	INPUT ATTEN
	14	298								OBE 2 2d RTN ORT. 2
	15	319								ORT 2 OBE RUN 3
	16	335								ORT 2 OBE RUN 4
	17	354								ORT 2 OBE RUN 5
8/5/81		INPUTS →	HC	VC	SG 7	SG 8	RSPT 1	RSPT 2	TC662	
		ATTEN →	10V	10V	1V	1V	0.2	0.2	10V	
	18	373								F.S. CAL CH 1, 2, 3, 4
	19	390								ORIENTATION 3 OBE 1 NG ABORT
	20	412								ORIENT. 3 OBE 1
	21	431								ORIENT 3 OBE 2 LOOSE CABLE
	22	448								ORIENT 3 OBE 3
	23	466								ORIENT 3 OBE 4

TAPE DATA LOG SHEET

LOG SHEET NO. 03

TEST ANPP CSDT SEISMIC QUAL.

HOOKUP SHEET NO. ____

DATE 8/5/81

RECORD SPEED 3 3/4

RECORDED BY ETN

RECORD BAND WB I

REEL NO.	RUN NO.	FOOTAGE	ATTENUATOR/AMP. SETTING							COMMENTS
			1	2	3	4	5	6	7	
8/5/81		—								
		—								ORIENT 3 OBE 5
S-01	24	484								ORIENT 3 OBE 5
	25	500								ORIENT 3 OBE 6
	26	517								ORIENT 3 SSE
	27	533								ORIENT 4 OBE 1
	28	549								ORIENT 4 OBE 2
	29	567		NG - MISSED DATA.						ORIENT 4 OBE 3
	30	571								ORIENT 4 OBE 4
	31	587								ORIENT 4 OBE 5
	32	604								ORIENT 4 OBE 6
	33	620								ORIENT 4 SSE
	34	637								

Test ID: M01S02 Data Sheet Sine Sweep Test Date: 7/29/81

Test Description: ANPP CEDM 1st Mode Sweeps .02g Observer: KUH. HM

Run No.	DVC System Channel A	B	C	D	Amplifier A	B	C	D	Transducer Sens. A	B	C	D	Comments
1	H.C.	Acc 9 ✓	Acc 7 ✓	Acc 5 ✓	H/C	14	15	16	1.	61.2	70.5	70.5	
2	"	Acc 8 ✓	Acc 6 ✓	Acc 3 ✓	H/C	"	"	"	1.0	69.5	70.5	70.1	
3	"	Acc 1 ✓	Acc 2	Acc 4	H/C	"	"	"	1.0	89.	89.6	70.9	
4													
5													
6													
7													
8													
9													

Amplifier No:	Control Horiz.	Control Vertical	1	2	3	4	5	6	13	14	15	16	17	
Full Scale Range Setting	1		300 SG. 1	300 2	300 3	300 5	300 6	100 10	3	3	3	3		

[illegible]

Test ID: M01S04 **Data Sheet Sine Sweep Test** Date: 7/29/91

Test Description: ANPP CE011 1st Mode .04g Observer: Skip Kraus K.H.

Run No.	DVC System Channel				Amplifier				Transducer Sen.				Comments
	A	B	C	D	A	B	C	D	A	B	C	D	
✓ 1	H.C	Acc 1	Acc 2	Acc 4	H/c	14	15	16	1	89	83	70.8	
✓ 2	H.C.	Acc 9	Acc 7	Acc 5	"	"	"	"	1	61.2	71.5	70.5	
✓ 3	H.C.	Acc 8	Acc .6	Acc 3	"	"	"	"	1	69.5	70.5	70.1	
4													
5													
6													
7													
8													
9													

Amplifier No:	Control Horiz.	Control Vertical	1	2	3	4	5	6	13	14	15	16	17	
Full Scale Range Setting														

Test ID: 1101506 **Data Sheet Sine Sweep Test** Date: 7/29/81

Test Description: ANPP CEAM 1ST MODE .06 g. Observer: S. KRAUSE

Run No.	DVC System Channel				Amplifier				Transducer Sens.				Comments
	A	B	C	D	A	B	C	D	A	B	C	D	
1	H.C	Acc 8	Acc 6	Acc 3	H/C	14	15	16	1	69.5	70.5	70.1	
2	H.C	Acc 1	Acc 2	Acc 4	H/C	"	"	"	1	89.0	89.6	70.8	
3	H.C	Acc 9	Acc 7	Acc 5	H/C	"	"	"	1	61.2	71.5	70.5	
4													
5													
6													
7													
8													
9													

Amplifier No:	Control Horiz.	Control Vertical	1	2	3	4	5	6	13	14	15	16	17
Full Scale Range Setting	1G		300	←			→	300		3G	3G	3G	

Test ID: M01S0XX Data Sheet Sine Sweep Test Date: 7/29/81

Test Description: ANPP CERM 1ST MODE Observer: S. Krause

Run No.	DVC System Channel A	B	C	D	Amplifier A	B	C	D	Transducer Sens. A	B	C	D	Comments
1✓	H.C	Acc 9	Acc 7	Acc 5	H/C	14	15	16	1	61.2	71.5	70.5	M01S08
2✓		Acc 9	Acc 7	Acc 5		"	"	"		"	"	"	M01S10
3✓		Acc 9	Acc 7	Acc 5									M01S12
4													~~M23S05~~
5													
6													
7													
8													
9													

Amplifier No:	Control Horiz.	Control Vertical	1	2	3	4	5	6	13	14	15	16	17	
Full Scale Range Setting	1		1000με ←				→	1000 με		10G	10G	10G		

2/13/78 VHF

Test ID: M23S XX   Data Sheet Sine Sweep Test   Date: 7/29/81

Test Description: ANPP CEDM 2ND MODE   Observer: ____________

Run No.	DVC System Channel A	B	C	D	Amplifier A	B	C	D	Transducer Sens. A	B	C	D	Comments
✓1	H.C.	Acc 9	Acc 7	Acc 5	H/C	14	15	16	1	61.2	71.5	70.5	M23S05.
-2	H.C.	8	6	3	"	"	"	"					
✓3	H.C	1	2	4	"	"	"	"		89.0	89.6	70.8	
4	H.C	1	2	4	"	"	"	"		89.0	89.6	70.8	M23S10
5	H.C	9	7	5	"	"	"	"		61.2	71.5	70.5	
6	H.C	8	6	3	"	"	"	"		69.6	70.5	70.1	
7	H.C	8	6	3	"	"	"	"		69.5	70.5	70.1	M23S15
8	H.C	1	2	4	"	"	"	"		89.0	89.6	70.8	
9	H.C	9	7	5	"	"	"	"		61.2	71.5	70.5	

Amplifier No:	Control Horiz.	Control Vertical	1	2	3	4	5	6	13	14	15	16	17	
Full Scale Range Setting										10g	10g	10g		

11:179 VUE

Test ID: M235XX **Data Sheet Sine Sweep Test** Date: 7/29/81

Test Description: ANPP CEDM 2+3RD MODE Observer: ______

Run No.	DVC System Channel				Amplifier				Transducer Sens.				Comments
	A	B	C	D	A	B	C	D	A	B	C	D	
1	H/C	Acc 9	Acc 7	Acc 3	H/C	14	15	16	1	61.2	71.5	70.1	M23520
2	H/C	↓ 9	↓ 7	↓ 3	H/C	14	15	16	1	61.2	71.5	70.1	M23525
3													
4													
5													
6													
7													
8													
9													

Amplifier No:	Control Horiz.	Control Vertical	1	2	3	4	5	6	13	14	15	16	17	
Full Scale Range in Units														

2/23/78 KHE

Test ID: RSSN05 **Data Sheet Sine Sweep Test** Date: 7/28/29/81

Test Description: Sine Sweep .05g Input. Observer: W.K/M.M KAV

Run No.	DVC System Channel A	DVC System Channel B	DVC System Channel C	DVC System Channel D	Amplifier A	Amplifier B	Amplifier C	Amplifier D	Transducer Sen. A	Transducer Sen. B	Transducer Sen. C	Transducer Sen. D	Comments
1 ✓	H.C	Acc 5	Acc 7	Acc 9	H.C.	14	15	16	1.0	70.5	71.5	61.2	
2 ✓		Acc 4	Acc 6	Acc 8	H.C	"	"	"		70.8	70.5	69.5	Abuk. 1
3 ✓		"	"	"	H.C	"	"	"					
4 ✓		ACC 1	ACC 2	ACC 3	H.C	"	"	"		89.00	89.63	70.1	
5 ✓		S.G. 1	S.G. 2	S.G. 3	H.C	1	2	3		72.5	72.5	72.5	INCORRECT SENSITIVITY SETTINGS RERUN. ABORT
6 ✓		S.G. 1	S.G. 2	S.G. 3	"	"	"	"		"	"	"	
7		S.G. 4	S.G. 5	S.G. 6	H.C					72.5	72.5	72.5	
8		S.G. 7	S.G. 8	S.G. 9	H.C					72.5	72.5	72.5	
9		Acc 4	Acc 5	Acc 6	H. C	~~70.8~~ 14	~~70.5~~ 15	~~70.5~~ 16		70.8	70.5	70.5	REPLACE ACC CABLE #4

Amplifier No.:	Control Horiz.	Control Vertical	1	2	3	4	5	6	13	14	15	16	17	
Full Scale Range Setting	1 G									3G	3G	3G		

APPENDIX C

RESULTS: STATIC LOAD DEFLECTION TESTS AND FIRST MODE DYNAMIC TEST

Static Deflection Tests

Using a pull wire arrangement (connected to the CEDM top), the CEDM was deflected incrementally up to 5 inch total displacement. The deflection at the CEDM top was measured by an LVDT with ± 5 inch travel. The strain gauges (Nos. 7 and 8) were connected to a balance box and measured by a digital readout unit. The results from the static load deflection tests are summarized on page C-3. A linear deflection characteristic was observed with a strain to deflection ratio of about 111 με/in, whereby the strain was measured 4 inches above the base plate and the deflection at the CEDM top.

First Mode Dynamic Test

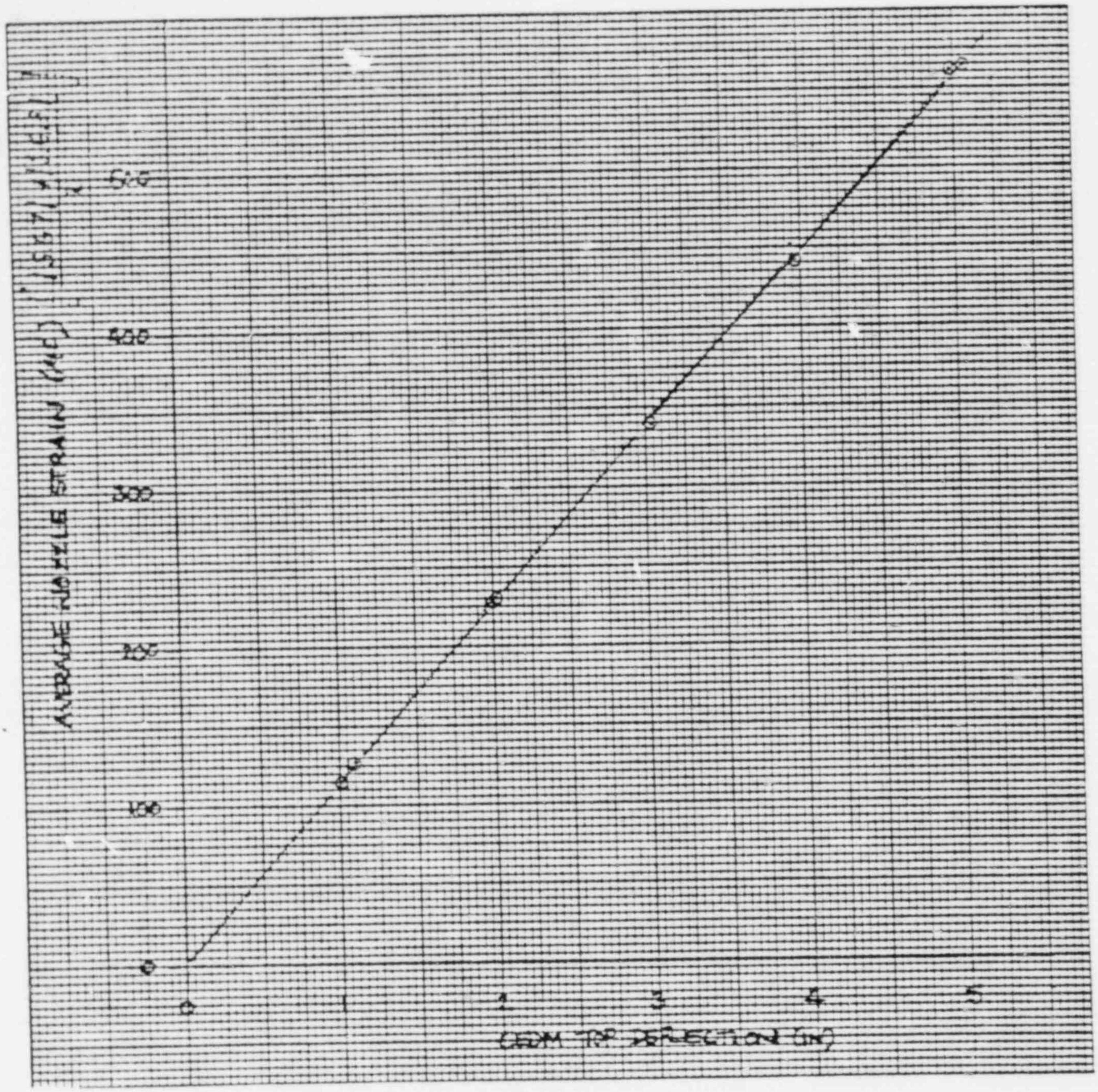
Strain gauges 7 and 8 were connected over two dynamic signal conditioning units (same as described in main report) to the visicorder readout device. The 5" stroke LVDT was displayed on a third visicorder channel. The CEDM was set into vibratory motion by exciting it manually above the coilstack. The resulting CEDM top motions, as well as the nozzle strain levels were then recorded on calibrated visicorder traces and converted into engineering units. The figure on page C-4 shows a typical visicorder trace and an average nozzle strain of about 240 με per 2.41 inch top deflection (or 100 με/in) is observed. This value is slightly higher than those recorded for strain gauges 1 through 4 of the shaker table tests. The differences may be explained by the fact that these two tests were run with the CEDM set-up in two different orientations and/or by some flexibility of the shaker table suspension system.

List of Test Equipment in addition to items listed in Table 7.

LVDT Schaevitz Model M/N 5000 HPD, S/N 192, Calibrated 1/16/80.

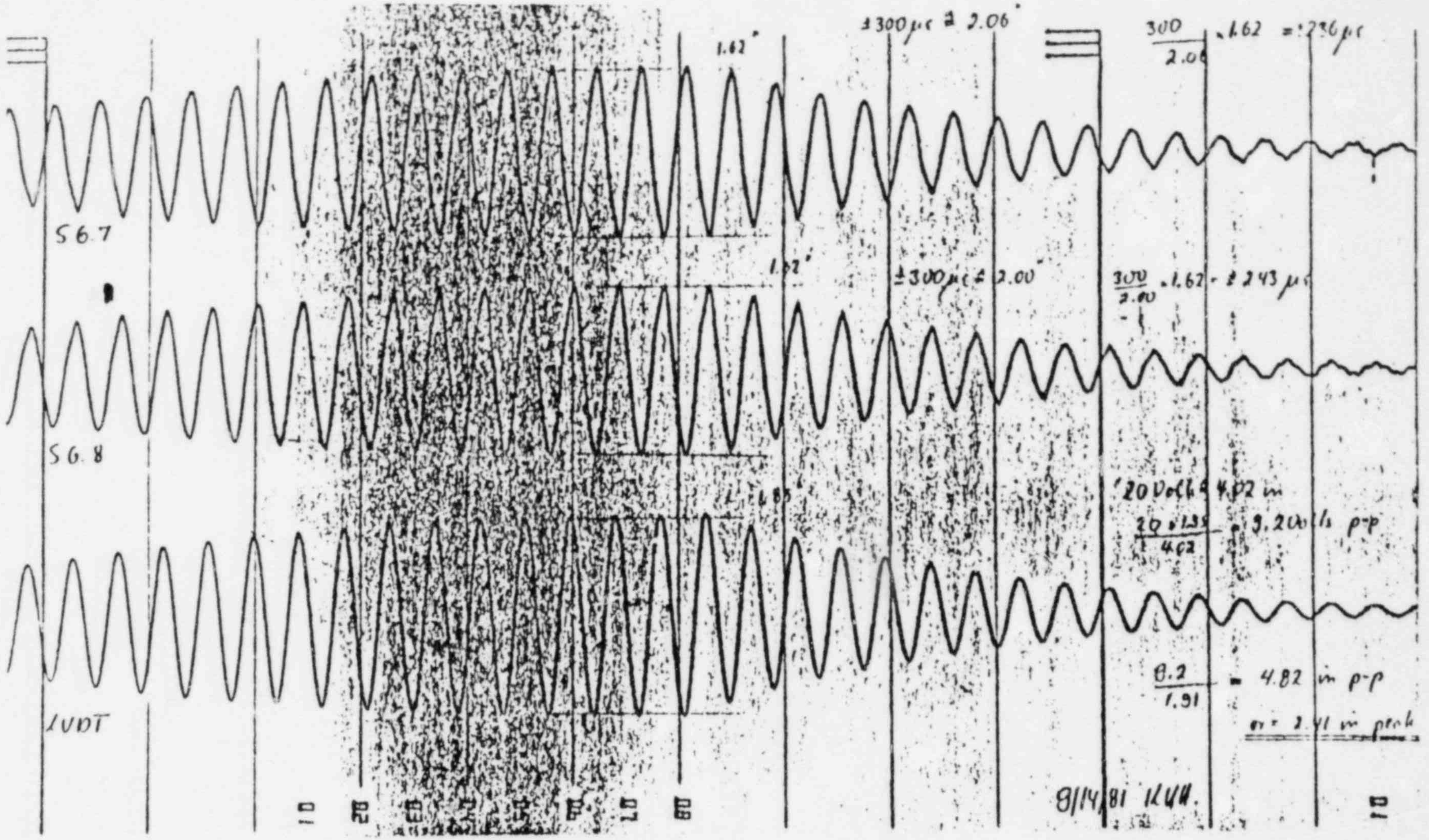
Digital Voltmeter MM200, C-E EL-259, Calibrated 2/10/81.

Strain Read-Out Unit Vishay VE-20A, S/N 25026, Performance Check 9/81.



STATIC DEFLECTION TEST

NOZZLE STRAIN (4" ABOVE BASE PLATE)
VERSUS CEDM TOP DEFLECTION



STRAIN GAUGE AND CEDM TOP DISPLACEMENT TIME HISTORY TRACES

Attachment 3

APPENDIX O

AGE CONSIDERATIONS FOR
SEISMIC DESIGN
AND
SURVEILLANCE/MAINTENANCE
IN
MILD ENVIRONMENTS

FOREWORD

This Appendix treats two related aspects of equipment aging. For clarity the presentation is subdivided accordingly. Part 1 of this Appendix discusses the aspects of Age Considerations for Equipment Seismic Design. Part 2 of this Appendix covers the feasibility of Surveillance Maintenance as Basis for Equipment Qualification.

PART 1

AGE CONSIDERATIONS FOR EQUIPMENT SEISMIC DESIGN

1.0 INTRODUCTION

Special concern exists regarding the need for equipment preaging prior to seismic test. Much of this concern arises due to the often conflicting guidance provided by IEEE-323-1974, DOR Guidelines, NUREG-0588, and IEEE-344-1975. The purpose of this Appendix is to demonstrate the nonvalidity of the requirement to include preaging. As a rule, when formulating seismic testing programs, in order to prove the adequacy of the equipment to perform its safety-related design function.

2.0 POSITION

Available information and evidence does not justify that there will be any significant enhancement to the safety of nuclear power plants by including preaging as part of the testing program for qualification of safety-related equipment subject only to mild environments. Neither do experimental studies conducted (Refer to IEEE "Study of the Effect of Aging on the Operation of Switching Devices," 1980) to determine whether equipment aging affects the vulnerability of electric switching devices to malfunction caused by vibrational stresses in the range of seismic frequencies and acceleration amplitudes. For most devices tested, the fragility level was approximately the same before and after testing, in some cases the fragility level increased while in others it decreased. Overall the changes were not significantly different from the fragility levels variations observed for duplicate specimens under identical test conditions. The results of this test support the position that seismic qualification need not be conducted with aged specimens.

Based on above considerations and other equipment aged versus non-aged testing such as the Position Paper "Justification for Seismic Testing Un-Aged Sub-Vendor Qualified Items," tests results provided from such Sub-Vendors as: Amp Special Industries, Anaconda Ericson Inc, Brand Rex Co, Electroswitch Corp and General Electric Co, it is our position that the preaging requirement to seismic test (IEEE-323-74, Subsection 6.3.5) be waived in the Qualification Program of Safety-Related Equipment subjected only to Mild Environments and that only IEEE-344-75 requirements be considered for seismic testing in this Class 1E equipment.

3.0 DISCUSSION

3.1 Based on information submitted by the Industry, and in particular the data presented by the Atomic Industrial Forum, and in a meeting held with the NRC on August 12, 1981 we concluded that any requirement for preaging of equipment would have no meaningful consequence on the results of a seismic test program performed on unaged equipment.

This conclusion was documented with information supplied to NRC from the following sources:

i. Manufacturers Test Reports

Tests performed on aged and unaged equipment show results not supportive of a conclusion that aging effects play a consequential role in the ability of the equipment to function, even in the upper limits of seismic operability.

ii. Test Laboratory Reports

Tests performed in components illustrate that the aging - seismic combination is not significant in terms of component ability to function under seismic stress conditions.

iii. Historical Data

Reports evaluating equipment operation of aged equipment subjected to actual seismic events conclude that the electrical equipment performed its functions even where seismic design considerations were exceeded and when some of the devices were approaching end-of-life condition.

iv. Industry Standards

Performance requirements for nonnuclear stations for seismic considerations are based on standards which are also applicable to nuclear stations because equipment environmental conditions and seismic stresses are similar for nonnuclear and nuclear non harsh conditions. Pre-aging is not included in the seismic test neither is recommended.

v. Manufacturers Type and Rating Tests

These tests document the equipment's ability to reach an end of design life without degradation of structural, mechanical, or electrical integrity not affecting the equipment's capability to perform its safety functions during seismic conditions.

vi. Plant Surveillance and Testing Programs

These aspects of equipment aging are discussed in the latter part of this Appendix.

3.2 The IEEE members S P Carfagno, Franklin Research Center, and G Erich Herberlein, Jr, Gould Inc., conducted an experimental study in 1980 on twenty-four (24) different specimens consisting of duplicated pairs, except for starters, circuit breaker and current-limiting fuses, to determine pre-aging effects on the vulnerability of electric switching devices to malfunction caused by vibratory stress in the range of seismic frequencies and acceleration amplitudes.

The devices tested were: Circuit Breakers, Relays, Time-Delay Relays, Contactors, Starters, Current-Limiting Fuses and Fuse Blocks.

The experimental program consisted of:

a. Functional Test
b. Vibration Test
c. Functional Test
d. Gamma Radiation
e. Functional Test
f. Accelerated Thermal Aging (At High Relative Humidity)
g. Functional Test
h. Electrical/Mechanical Life Cycling
i. Functional Test
j. Accelerated Thermal Aging (Coils Only)
k. Functional Test
l. OBE Vibration
m. Repeat of Vibration Test
n. Functional Test

Description of these tests can be found in IEEE Paper F-80-259-2, IEEE Power Generation Committee, IEEE Power Engineering Society, February 3-8, 1980.

Results of the tests show that specimens 5B, 6B and 21B were removed from program after irradiation. These specimens correspond to devices Time-Delay Relay (5B, 6B) and Circuit Breaker (21B) because they failed to function after irradiation. All the other devices passed the environmental test and were afterwards submitted to the seismic test. In most cases, there was no difference between the fragility levels before and after aging; this includes the cases in which the fragility level exceeded the test limit.

Table 1 shows the specimen identification by number and function description. Table 2 shows the Cycles Accumulated During Electrical/Mechanical Life Tests.

The test results demonstrate that there is no significant difference between fragility levels before and after accelerated aging, including cases in which the fragility level exceeded the test limit.

The specimens passed inspections and functional tests conducted in accordance with the experimental program where minor exceptions occurred after gamma irradiation. Details of the exceptions are discussed in the IEEE Paper, Page 4 affecting mostly plastic material of some components. Since two time-delay relays (specimens 7B and 8B) did not function properly after irradiation, they were replaced by specimens 27B and 28B, added to the program, which functioned satisfactorily afterwards. All specimens passed the final vibration tests and all passed successfully the initial vibration test (Specimens 27B and 28B were not submitted to the initial vibration test due to lack of availability of test facility when the specimens were added to the program).

An analysis of the component seismic vulnerability was made to determine whether aging had produced a significant change in the fragility level (measure of the ability of the devices to withstand vibrations in the seismic range). An attempt was made to ascertain whether the changes observed were sufficiently large to be unlikely to have occurred by chance. A curve was plotted showing the significant reductions in fragility level after aging compared to the level before aging (aging effect on seismic capability), chance variations (small reductions in fragility level) and the normal distribution curve.

A thorough analysis of the Fragility Level Curve by the probability law was conducted. These anlayses again support the hypothesis that there is no statistically significant aging effect. Summary of the results is tabulated in Table 3.

From the test and study conducted, in which devices were submitted to vibration test consisted of shaking each device in the direction that was most likely to cause spurious opening or closing of contacts, at discrete frequencies between 1.0 and 32.0 Hertz at interval of 1/3 octave and maximum acceleration amplitudes increasing from 0.4g at 1 Hz to 6g at 12.7 Hz, it was concluded that aging does not have a significant effect on the seismic vulnerability of most of the types of contact devices tested.

3.3 Summarizing the documents, tests and analysis referred to in above Paragraphs 3.1 and 3.2 of this discussion confirm the statement of our position, Paragraph 2.0 that the pre-aging does not affect substantially the seismic capability of equipment when in mild environments such as Motor Control Center Rooms, Switchgear Rooms, Main Control Rooms, etc, therefore the pre-aging requirement for seismic testing in Class 1E equipment should not be included in the seismic reports.

It is no coincidence that the above testing demonstrates the insignificance of accelerated aging before seismic testing. Virtually all of the components used within mild environments are identical in design to their commercial grade components. In most cases the only parameter increased for the nuclear grade component is the price, the lead time and the volumes of documentation supplied by test labs attempting to reinvent the decades of experience of the international electrical industry.

The conclusion of the ITE Gould/Franklin Research test program demonstrating that equipment aging does not effect seismic withstand ability serves as testimony to the quality of industry in its design and manufacture of equipment. Industry, both in the U.S. and worldwide, has addressed the subject of equipment aging for the past 30 years and has designed their equipment accordingly.

Industry representations have developed many concensus standards to cover the area of equipment aging.

In particular, two ANSI standards apply to a vast majority of the equipment of concern. The first is the Standard for Industrial Control Equipment ANSI/UL-508 and the second is the Standard for Polymeric Materials, Long-Term Evaluations ANSI/UL-746B. Both these ANSI standards were adopted from the standards of Underwriters Laboratories. A review of ANSI/UL-746B standard identifies among its basis materials standards published by the IEEE. These include IEEE-1 and IEEE-101, the same standards which form the basis of Arrhenius methodology for NUREG-0588.

The point above is that the utilities already use industry standards developed over decades which reasonably addresses aging. Unfortunately, a mystique has been carried around the word "nuclear," requiring a reinvention of techniques adopted not only within the U.S. but worldwide (IEC 216, "Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Materials," IEC 493, "Guide for the Statistical Analysis of Aging Test Data," etc).

The entire issue regarding the aging of mild environment equipment before OBE and DBE goes away when analysis can point back to the industry standards. Moreover, the NASA, and MIL Standards are more stringent. These reflect vibration and require severe acceleration values for extended time periods much greater than 30 seconds at under 5g's (the typical nuclear plant numbers).

Another aspect of equipment aging addresses solid state component. As indicated within IEEE-650 solid state devices are generally considered not to possess age related failure mechanisms. This position is supported by reliability models such as the bathtub curve and the Unified Field Theory. The latter approach identifies a constantly decreasing failure rate with time when the equipment is under a continuous stress (i.e., aging, voltage, etc).

Use of the standard bathtub curve with its infant failure region of decreasing failure rate, the flat region of constant failure rate, and the hypothetical region of increasing failure rate demonstrates that equipment operating in the constant failure rate region does not significantly age, all failures being considered random. The recent evidence, Figure 0-1 more than supports the theory that aging to the deteriorated "end-of-life point" is not applicable for solid state components. The most failure prone time is the beginning of life, consequently supporting the industry practice of solid state component "burn-in."

There is however an immediate problem with these philosophies. Both models account only for a continuous level of equipment stress. The situation in a harsh environmental area of a nuclear plant is different. Here, the equipment appears to see a step function increase in the level of equipment stress (especially that equipment used only for and during accident mitigation). This apparent situation decreases confidence level regarding immunity to common-mode failures. Use of engineering analysis tools such as thermal inertia calculations, review of actual Arrhenius curves, etc can still be used to demonstrate acceptability. Moreover, component derating can be used to regain the reliability numbers during all adverse conditions.

PART 2

THE FEASIBILITY OF EQUIPMENT QUALIFICATION BY SURVEILLANCE MAINTENANCE

This is Part 2 of Appendix O which describes the Applicant's approach to determining the cost-effective feasibility of applying surveillance/maintenance as the basis for mild environment equipment qualification. At the time of issuance of this appendix there is no Class IE equipment dependent on surveillance/maintenance to establish qualification.

1. Introduction

NUREG-0588, paragraph 1.5(2) requires that, "Equipment located in general plant areas outside containment where equipment is not subjected to a design basis accident environment should be qualified to the normal and abnormal range of environmental conditions postulated to occur at the equipment location." Every nuclear plant receiving an operating license subsequent to May 23, 1980 (per NUREG-0588 Revision 1, Memorandum and Order CLI-80-21 and IEB 79-01B Supplement 2 Question/Answer 3) is required to meet NUREG-0588.

Earlier plants (those in operation prior to May 23, 1980) were to meet IEB 79-01B (Supplements 1-3) which did provide a specific limitation in scope of the formal submittal to the NRC for harsh environment located equipment, (refer to IEB 79-01B Supplement 1, Question/Answer 1). However, even these plants required "qualification" (IEB 79-01B enclosure 4, paragraphs 4.3.3 and 7), where significant aging degradation has been identified.

No official regulation (proposed 10CFR50.49) or regulatory guide (proposed RG 1.89, revision 1) exists on the issue of mild environment equipment. Literally thousands of pages of draft staff positions, ACRS/NRC meeting transcripts, etc. exist - but no official guidance to the industry.

What does exist is NUREG-0800 (Rev 2 - July 1981) Section 3.11 which is the NRC Standard Review Plan (SRP). Contained within that plan is the following:

Mild Environment

The environmental qualification of all electrical and mechanical equipment located in the mild environment is acceptable if the following procedure is followed:

> "The documentation required to demonstrate qualification of equipment in a mild environment are the "Design/Purchase" specifications. The specifications shall contain a description of the functional requirements for its specific environmental zone during normal and abnormal environmental conditions. A well supported maintenance/surveillance program in conjunction with a good preventive maintenance program will suffice to assure that equipment that meets the design/purchase specifications is qualified for the designed life."

> "Furthermore, the maintenance/surveillance program data and records shall be reviewed periodically (not more than 18 months) to ensure that the design qualified life has not suffered thermal and cyclic degradation resulting from the accumulated stresses triggered by the abnormal environmental conditions and the normal wear due to its service condition. Engineering judgment shall be used to modify the replacement program and/or replace the equipment as deemed necessary."

2. Definition

Replacement/Maintenance Internal

The replacement/maintenance interval is determined as the maximum cost effective period of time during which there is a high level of confidence that installed equipment can perform its necessary function up to, during and following a design basis event.

3. Evaluation of NRC SRP Position on Mild Environment Equipment and Its Potential Negative Impact

The key phrases in the NRC SRP position are "well supported maintenance/surveillance", "a good preventive maintenance program", and "maintenance/surveillance program data and records shall be reviewed periodically (not more than 18 months)."

These phrases and unofficial NRC discussions reflect very intensive surveillance/maintenance activities, perhaps at every refueling outage. Implementation of these activities necessitates a definition of meaningful degradation, determination of a surveillance/maintenance procedure to measure that degradation, initiation and maintenance of traceable surveillance/maintenance records for trending, and other very labor intensive and burdensome tasks.

The magnitude of the intensive effort must consider:

Labor Productivity

- a) Travel Time
- b) Waiting for tools and parts
- c) Unavailability of components

Workload and Workwindow

- a) Magnitude of craft personnel
- b) Time available to do work (e.g. refueling)

The impact on resources to establish "well supported" surveillance/maintenance both by the utility during plant life and by the design team appears to be more costly than qualifying equipment for mild environments.

For example, simply extending the surveillance/maintenance interval from a 2-4 year range to a 6-8 year range on 40-50 valve/damper operators results in a plant cost savings of some $350 - 400,000.00 on an engineering evaluated (present worth) basis. It is clear that excessive dependence on frequent surveillance/maintenance will run in the many millions of dollars.

4. Qualification Methods for Mild Environments

Significant data exists and/or can be completed to demonstrate that a significant percentage of equipment is qualified. Much of this analysis is based on the application of Military and Industry Standards. Appendix E contains much data which can be used to qualify equipment by analysis supported by "partial test data".

5. Industry

Frankly, some industry members want to close the mild environment issue in the short term and are presently willing to commit the industry to intensive surveillance/maintenance planning to "renew the fight at a later day". Other members want to face and resolve the entire issue now and recognize the qualification inherent in the standards now used for commercial grade items described in Appendix E.

6. Qualification Feasibility By Surveillance/Maintenance Decision Logic Tree

The attached logic tree (Figure O-2) may aid in determining if surveillance and maintenance, as a basis for mild environment equipment qualification is feasible and logical. Use of this logic tree quickly and directly leads to a "real world" determination if and when qualification based on surveillance/maintenance in lieu of qualification is prudent.

Leadership/Training

a) Quality of supervision and training

Availability of QC/QA Support

a) Magnitude of QA/QC personnel available to support work on Class IE items

Planning/Scheduling

a) Significant magnitude of planning/scheduling to support intensive efforts without impacting plant availability - Is it possib

Engineering Support

a) Evaluation of trending

Purchasing/Inventory Support

a) Level of inventory for seals, gaskets; service engineering to support maintenance.

Nuclear Records Management

a) Significant historical record keeping to verify maintenance performed, maintenance results and other pertinent information. The collected information can be handled manually on historical record cards or preferably by computer.

Surveillance/Maintenance Operating Review

a) Procedures (efforts) to identify deficiencies and problem areas

b) Factor (a) above into continuing program

To bring this into context review Guidebook Subsection 8.3.4 and Appendix E. We can easily demonstrate that most commercial grade items such as simple relays, precision switches (e.g. Microswitches) have a cycle life far in excess of the majority of plant requirements or alternatively we can check every relay contact for wear at every refueling. Likewise cables and motors can be qualified for the 40 year life, or alternatively the insulation resistance can be measured and dielectric tests can be conducted at each refueling or at a maximum of eighteen month intervals. For solid state components we can demonstrate that aging is insignificant and need not be considered prior to seismic testing (as described in part 1 of this appendix), or we can attempt to establish (if practical), meaningful surveillance/maintenance tests for solid state components.

TABLE 1

IDENTIFICATION OF TEST SPECIMENS

Note: All specimens consisted of duplicate pairs, except specimens 19B through 22B.

Specimen No.	Description
1B	Circuit Breaker
2B	Circuit Breaker
3B	Relay
4B	Relay
5B*	Time-Delay Relay
6B*	Time-Delay Relay
7B	Time-Delay Relay
8B	Time-Delay Relay
9B	Relay
10B	Relay
11B	Contactor
12B	Contactor
13B	Starter
14B	Starter
15B	Circuit Breaker
16B	Circuit Breaker
17B	Circuit Breaker
18B	Circuit Breaker
19B	Starter
20B	Starter
21B	Circuit Breaker
22B	Current-Limiting Fuses/Fuse Block Trip Indicator
27B	Time-Delay Relay
28B	Time-Delay Relay

*Failed functions test after irradiation

TABLE 2

CYCLES ACCUMULATED DURING ELECTRICAL/MECHANICAL LIFE TESTS

Specimen No.	No. of Cycles	Conditions
1B	6000	30 amp
	4000	No load
2B	6000	30 amp
	4000	No load
3B	2.0×10^6	5 amp
4B	2.0×10^6	5 amp
5B	Removed from program after irradiation	
6B	Removed from program after irradiation	
7B	1.0×10^6	Relay load
8B	1.0×10^6	Relay load
9B	2.0×10^6	5 amp
10B	2.0×10^6	5 amp
11B	2.5×10^6	30 amp
12B	2.5×10^6	30 amp
13B*	2.5×10^6	Note 1
14B*	2.5×10^6	Note 1
15B	6000	30 amp
	4000	No load
16B	6000	30 amp
	4000	No load
17B	6000	125 amp
	4000	No load
18B	6000	125 amp
	4000	No load
19B*	1.0×10^6	Note 2
20B*	1.0×10^6	Note 1
21B	Removed from program after irradiation	
22B	No operations required	-
27B	1.0×10^6	Relay load
28B	1.0×10^6	Relay load

*These devices were cycled without electrical loading. However, the contacts were replaced with contacts removed from identical devices previously subjected to electrical load cycles as follows:

Note 1. Make 84 A& 45% P.F., break 14 A& 90% P.F. and 480 V. 2.5×10^6 cycles at rate of 900/h

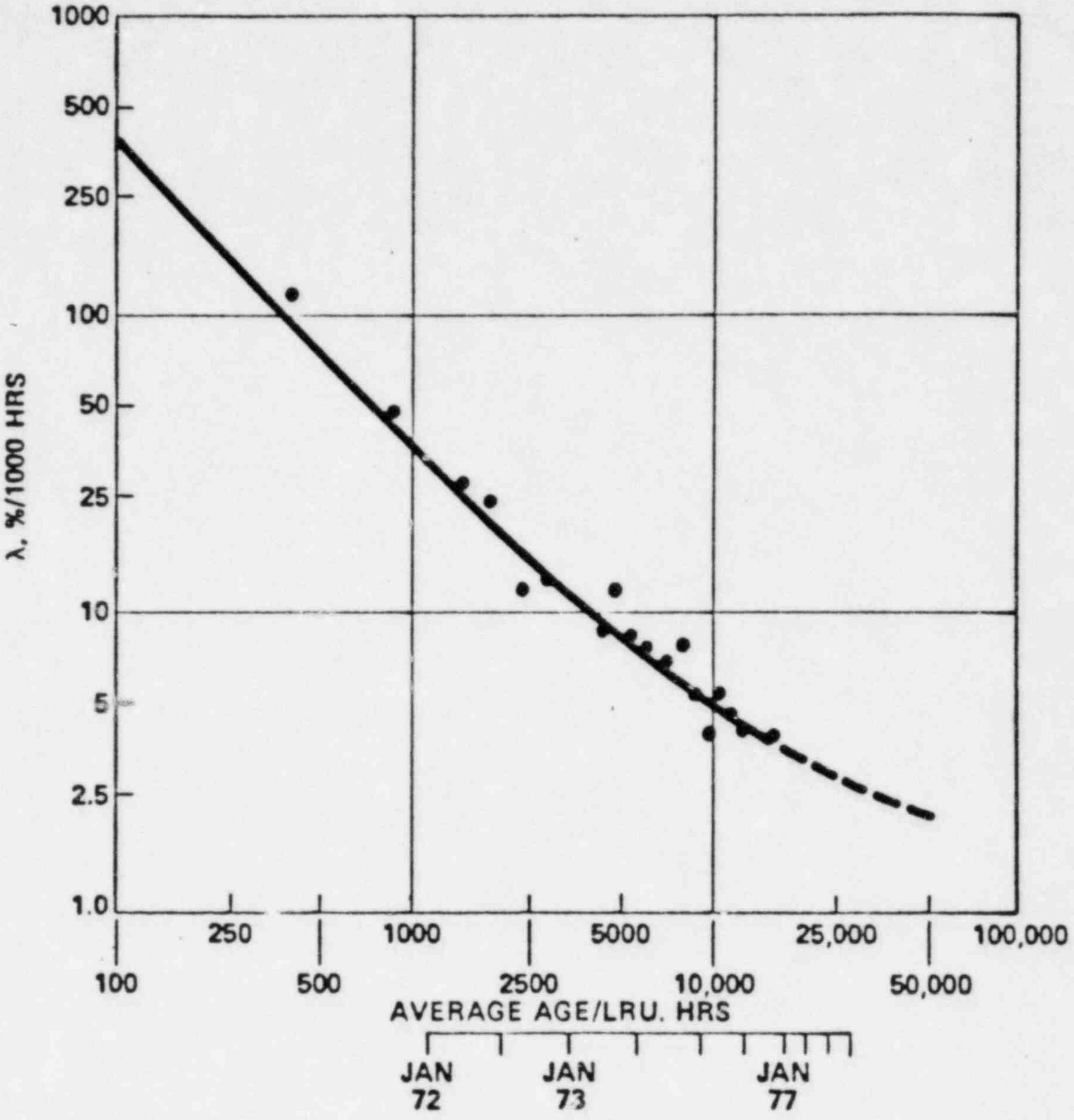
Note 2. Make 300 A& 45% P.F., break 50 A& 98% P.F. and 480V. 2.5×10^6 cycles at rate of 450/h

Special Note - A quantitative review and analysis of contact cycle life based upon electrical ratings is discussed within Appendix E of this Guidebook.

TABLE 3

SUMMARY OF OBSERVED CHANGES IN FRAGILITY LEVEL

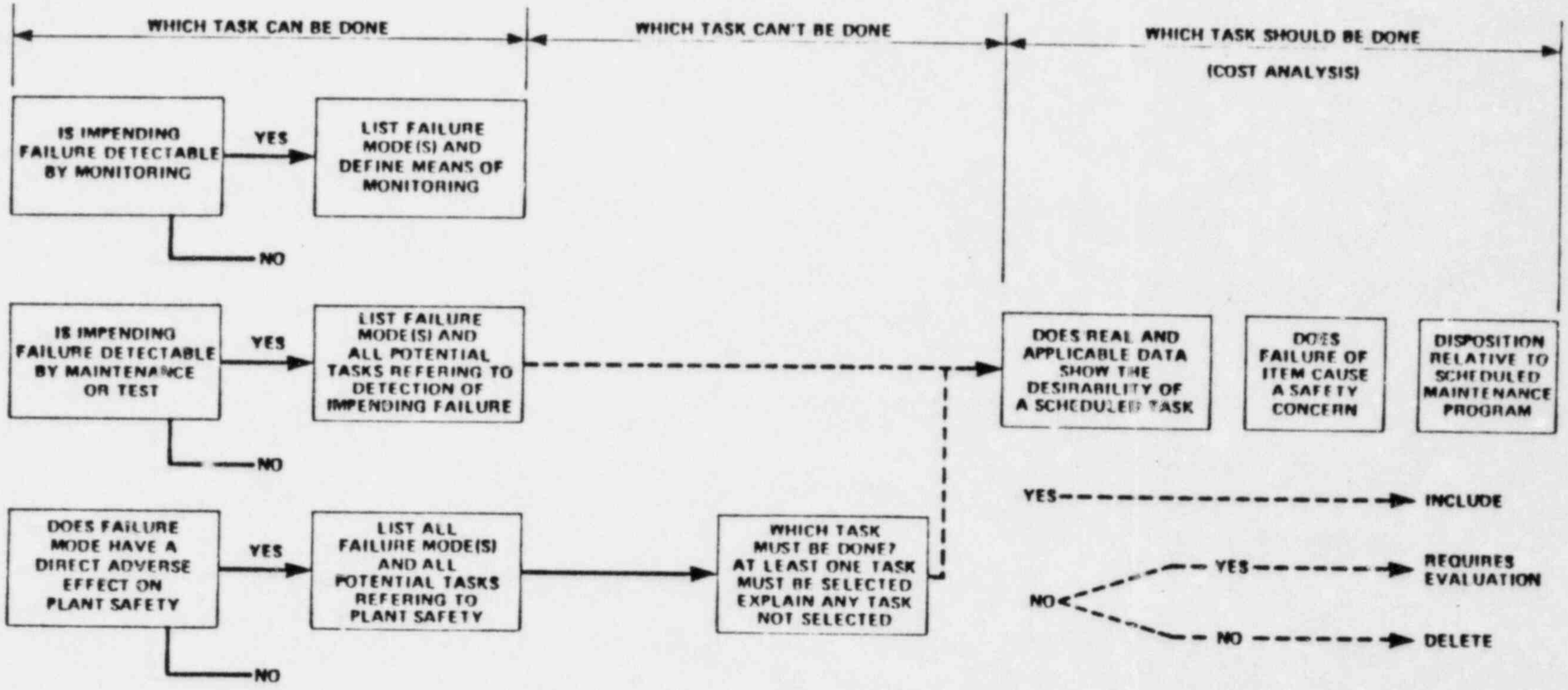
	Specimens 9B & 10B						Specimens 11B & 12B						Specimens 13B & 14B						Specimen 19B			Specimen 20B		
		Decrease		Increase				Decrease		Increase				Decrease		Increase								
(f) Hertz	None	Signif	Not Signif	None	Sign	Not Sign	None	Signif	Not Signif	None	Signif	Not Signif	None	Signif	Not Signif	None	Signif	Not Signif	None	Decrea	Increa	None	Decrea	Increa
1.0	x						x						x						x			x		
1.3	x						x						x						x			x		
1.5	x						x						x						x			x		
2.0	x						x						x						x			x		
2.5	x						x						x						x			x		
3.2			x				x						x						x			x		
4.0	x						x						x						x			x		
5.0				x			x						x						x			x		
5.3			x						x						x					x			x	
8.0						x	x						x							x			x	
10.1						x		x						x						x			x	
12.7			x						x						x						x		x	
16.0			x					x						x						x			x	
20.1			x							x						x				x			x	
25.4		x						x						x						x			x	
32.0		x							x						x					x			x	



LOUISIANA
POWER & LIGHT CO.
Waterford Steam
Electric Station

ELECTRONICS FAILURE RATE VERSUS
AVERAGE AGE IN HOURS

Figure
O-1



REV NO 1, (1/83)

LOUISIANA POWER & LIGHT CO.

Waterford Steam Electric Station

QUALIFICATION FEASIBILITY BY
SURVEILLANCE MAINTENANCE
DECISION LOGIC TREE

FIGURE O 2