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U.S. - JAPAN COORDINATED PROGRAM FOR MASONRY BUILDING RESEARCH

REPORT NO. 3.2 (b2)

THE TRANSVERSE RESPONSE OF CLAY MASONRY WALLS SUBJECTED TO STRONG MOTION EARTHQUAKES

Summary of Dynamic Test Results
Volume 1: General Information

by

Marcial Blondet
Ronald L. Mayes

APRIL 1991

supported by:

NATIONAL SCIENCE FOUNDATION
GRANT NO. CES-8518700

COMPUTECH ENGINEERING SERVICES, INCORPORATED

CES

This report presents the results of a research project which was part of the U.S. Coordinated Program for Masonry Building Research. The program constitutes the United States part of the United States - Japan Coordinated Masonry Research Program conducted under the auspices of the Panel on Wind and Seismic Effects of the U.S.-Japan Natural Resources Development Program (UJNR).

This material is based on work supported by the National Science Foundation under the direction of Program Director, Dr. S.C. Liu.

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ABSTRACT

This report presents summary information derived from a test program on the out-of-plane response of nine, reinforced, clay brick masonry walls subjected to simulated earthquake loading.

The project was developed by Computech Engineering Services (CES), as part of the US/Japan Coordinated Program for Masonry Building Research (TCCMAR). Its main objective was to evaluate the influence of the amount of vertical reinforcement, vertical ledger load, height-to-thickness (H/t) ratio, rebar splicing, and extent of grouting on the out-of-plane response of the walls.

Testing was performed at the Earthquake Engineering Research Center (EERC), University of California, Berkeley. The walls were 20 and 25 feet high, with a nominal thickness of 6 inches; the vertical reinforcement consisted of two #5 or three #7 rebar with steel ratios of $0.16\rho_b$ and $0.50\rho_b$, respectively. Simulated earthquake motions were applied at the base and the top of each wall. The base motions corresponded to the seismic ground excitation; the top motions represented the response, at the diaphragm level, of a typical warehouse structure. Both stiff and flexible diaphragm conditions were considered. The seismic inputs were generated by scaling recorded ground motions in the time or frequency domains, to attain specified intensities of 0.1, 0.2, 0.4, and 0.8 EPA (Effective Peak Acceleration) for a rock site. The first three EPA levels corresponded, respectively, to the lower, medium and highest seismic zones of the United States. The 0.8 EPA motions represented events of twice the intensity specified by the SEAOC requirements for a soil type 1 site (S1), although the longer period part of these spectra are similar to the 0.4 EPA soil type 3 spectra.

This report provides detailed descriptions of the experimental setup, input signal characteristics, data processing techniques, and summary data derived from the dynamic tests.

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1 INTRODUCTION

1.1 Background

The design of masonry structures enclosing large open spaces and with large story heights, such as single story warehouses and athletic facilities, is generally governed by the transverse, or out-of-plane, response of their tall, slender walls. Only within the last decade, however, have efforts been made to study the seismic transverse response of slender masonry walls.

A significant experimental program involving the testing of thirty full size slender reinforced concrete and masonry panels was conducted by a joint ACI-SEAOSC Task Committee [1]. As a result, an ultimate strength design procedure was developed and subsequently adopted by the 1985 Uniform Building Code [2]. The major limitation of the test program was that wall loading was quasi-static and monotonic, whereas seismic forces are dynamic and cyclic in nature. To enhance and broaden the applicability of the results from these studies, it was therefore necessary to test similar walls under realistic earthquake loads.

1.2 Scope

This program, Task 3.2 (b2) of the TCCMAR project, was devised to perform dynamic tests on slender masonry walls, to evaluate the influence of parameters such as vertical reinforcement ratio, vertical ledger load, H/t ratio, splicing configuration, and extent of grouting on the out-of-plane earthquake response of the walls. Eleven full scale clay block masonry walls were tested, following the test matrix shown in Table 1.1. Two of the walls were subjected to quasi-static tests, to determine the mechanical properties of masonry under pure bending; the remaining nine walls were tested under simulated earthquake loading.

1.3 Report Organization

This report presents summary results obtained from walls 3 through 11, which were tested under dynamic conditions. The information presented here is organized in four volumes. Brief descriptions of the test setup, experimental procedures, data processing techniques, and material properties, are given in Volume 1 (this volume). Summary data obtained from the dynamic tests are presented in Volumes 2 through 4. These volumes address only presentation of results, with no evaluation or interpretation. Preliminary evaluations have been performed [3] and a final report from this Task will present a full evaluation of the performance of clay block walls and the effects of the various parameters included in this program.

TABLE 1.1: TCCMAR Test Matrix - Cyclic and Dynamic Tests

Wall No.	Test Type	Vertical Reinforcement	Superimposed Dead Load	Nominal H/t	Lap Splices	Grouting	Wall Height
1	Cyclic	2#5	300 lb./ft.	40	No	Full	20'
2	Cyclic	2#3	50 lb./ft.	40	No	Full	20'
3	Dynamic	3#7	800 lb./ft.	50	No	Full	25'
4	Dynamic	2#5	50 lb./ft.	40	No	Full	20'
5	Dynamic	3#7	800 lb./ft.	50	No	Full	25'
6	Dynamic	2#5	300 lb./ft.	40	No	Full	20'
7	Dynamic	3#7	300 lb./ft.	50	No	Full	25'
8	Dynamic	3#7	300 lb./ft.	50	No	Partial	25'
9	Dynamic	2#5	300 lb./ft.	50	Yes	Partial	25'
10	Dynamic	3#7	300 lb./ft.	50	Yes	Partial	25'
11	Dynamic	3#7	300 lb./ft.	50	No	Partial	25'

Note: 2#3 corresponds to 0.07 ρ_b, 2#5 to 0.16ρ_b, 3#7 to 0.50ρ_b

2 TEST SETUP, INSTRUMENTATION & DATA ACQUISITION SYSTEM

2.1 Test Setup

All tests were performed at the structural laboratories of the Earthquake Engineering Research Center (EERC), University of California at Berkeley.

The walls were mounted on a "shake table", specially designed to test full scale masonry specimens. The system consists of a 8 by 4 feet platform resting on low friction bearings which restrict the motion to a single horizontal degree of freedom. Loading is provided by two actuators, one connected to the base of the shake table, the other to the top of the specimen. The load from both actuators is resisted by four steel reaction A-frames. The actuator connections to the frames, wall specimen, and shake table are hinged. The test specimens were connected to the table through a low friction pin, and were installed normal to the axis of table motion and therefore subjected only to out-of-plane excitations. Schematics of the dynamic test setup are presented in Fig. 2.1.

Wide-flange, steel beams, attached to the top of the test specimens, were used as spreader beams, to distribute the horizontal load from the top dynamic actuator, and to carry the superimposed vertical ledger load. The vertical load consisted of lead bricks and part of the weight of the actuator (approximately 200 lbs). Fig. 2.2 shows a detail of the ledger beams.

The dynamic actuators are capable of developing a maximum dynamic load of 75 kips; their maximum stroke is 12 inches peak to peak, the maximum piston velocity is 30 in/sec. The actuators were displacement controlled throughout these tests, i.e., they were programmed to follow the supplied earthquake displacement time histories, within the capabilities of displacement, velocity and force listed above.

2.2 Instrumentation

A wide array of instruments were used to monitor the dynamic input and the response of the walls on both the global and local (joint) levels. A brief description of the instrumentation used and the data acquisition system follows. Detailed technical specifications can be found in Appendix A. As an illustration, the instrumentation setup of Wall 10 is shown in Fig. 2.3.

Wire potentiometers and accelerometers were used to measure absolute displacement and absolute acceleration, simultaneously, at various locations up the wall height. The input motions were recorded by displacement transducers (LVDT's) built into the actuators, and by accelerometers connected to the table and to the spreader beam at the top of the walls. The information recorded by all these instruments was used to describe wall response at the global level. The absolute displacement and relative deflection patterns of the wall were

derived from the displacement measurements; the distribution of inertia forces and bending moments acting on the wall was obtained from the accelerometer measurements.

The response at the local level was described by measurements of rebar strain and joint deformation. Weldable strain gages, operational up to at least 2% strain, were used to measure strain levels at selected rebar locations. Most gages were placed in the central region of the walls, where the largest deformations were expected to occur. Gages were also placed near the rebar splices and within the center clay masonry block unit. The deformation of selected joints was studied by installing displacement transducers (DCDT's) across the joint at both sides of the wall. These instruments thus measured the relative motion of adjacent blocks; their output was used to estimate the extent of joint opening near the rebar and at the faceshell, as well as the compressive strain at the outside edge of the faceshell. The relative rotation between blocks was used as a measure of wall curvature.

2.3 Data Acquisition System

All instruments were calibrated through careful measurements of known quantities. The transducers were then connected to signal conditioners, which included lowpass analog filters set at 100 Hz to inhibit recording spurious high frequency noise. The output from the signal conditioners was fed to the data acquisition system — a high speed analog-to-digital scanner and digitizer.

The sampling frequency for each channel was set at 250 samples per second (time between samples: 0.004 sec). Therefore, the folding frequency was 125 Hz, high enough to avoid aliasing of the AC current (60 Hz) component. High frequency components were later eliminated from the signals via numerical filtering.

After each test, the acquired data was stored on magnetic tapes in digital format for subsequent processing and reduction.

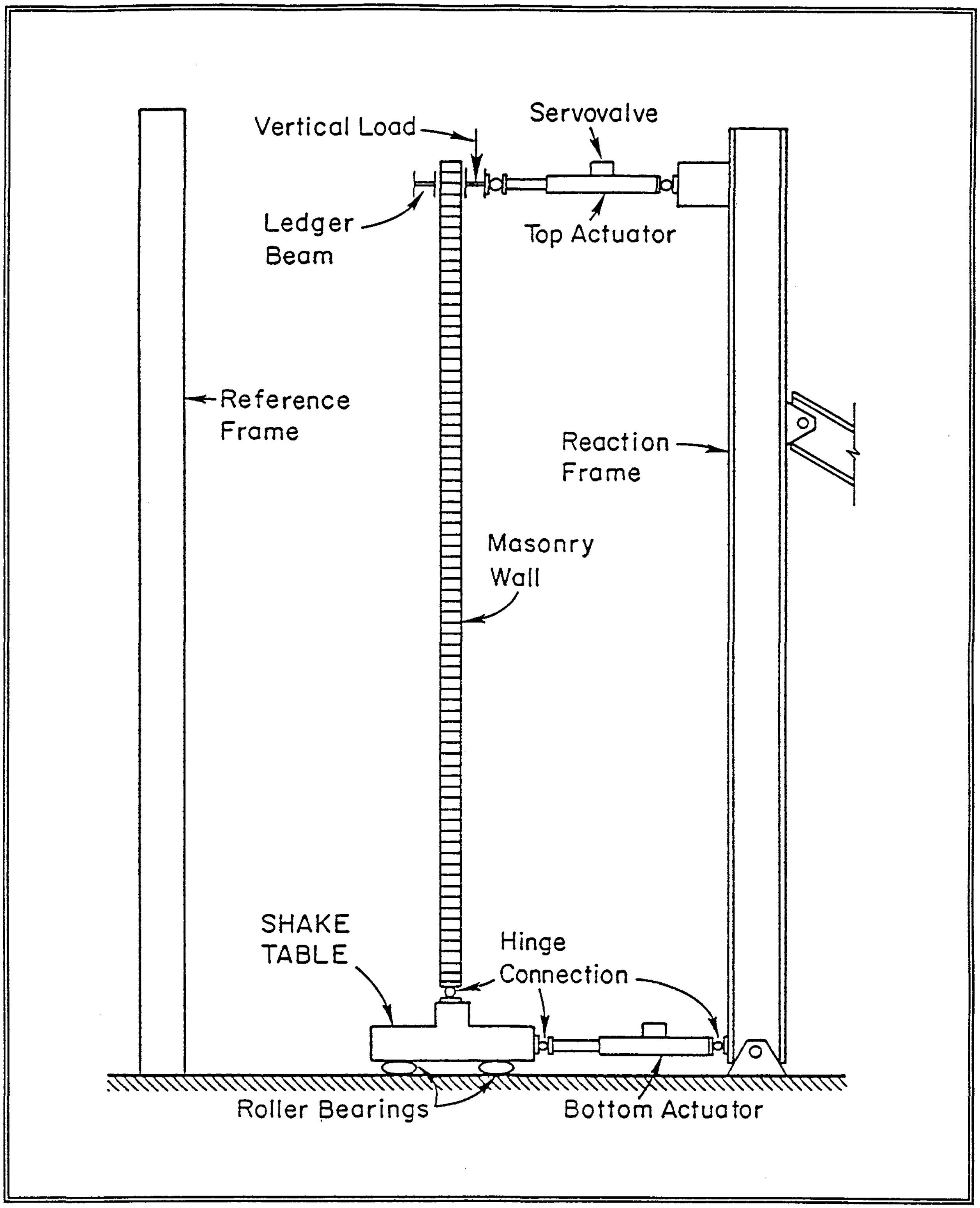


FIGURE 2.1: Test Setup for Dynamic Tests

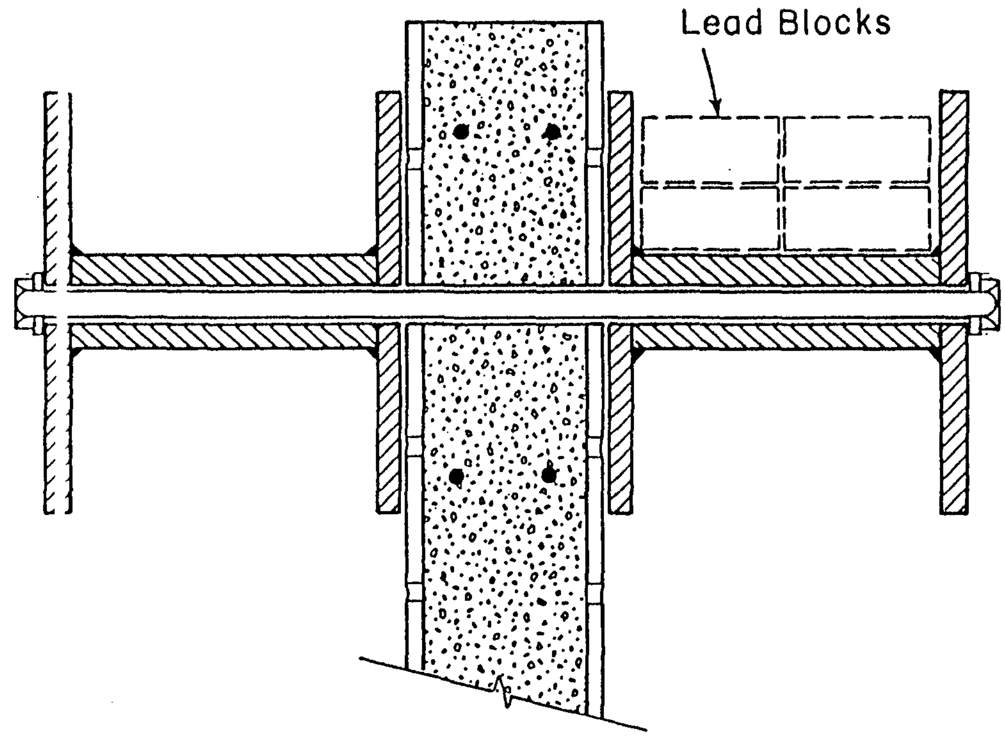
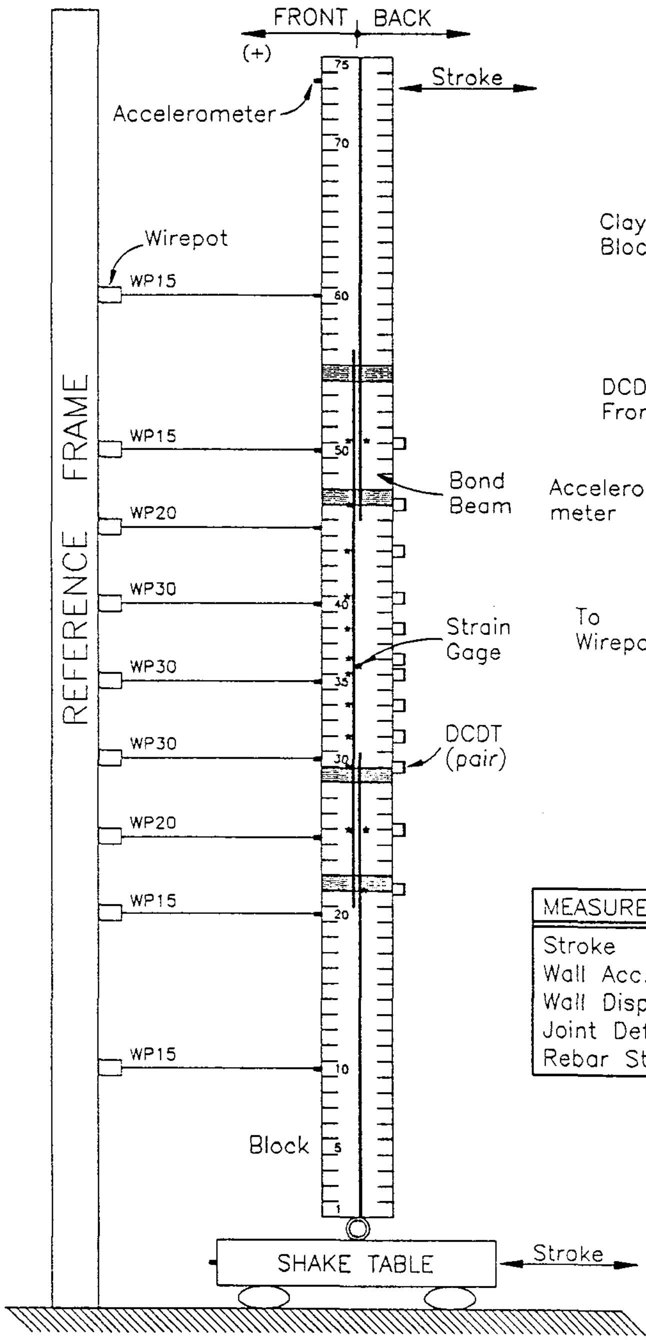
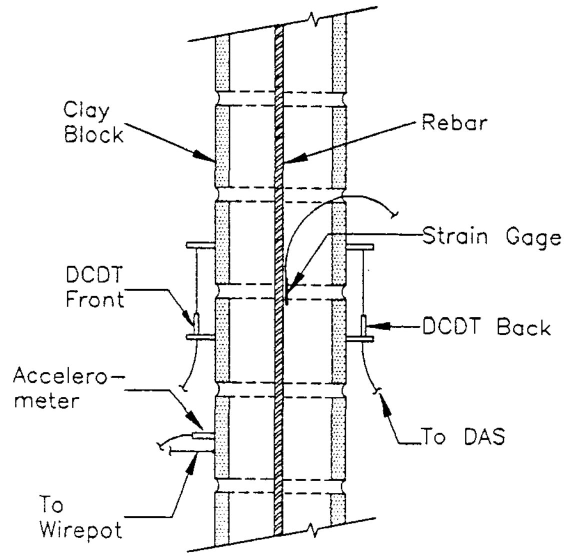


FIGURE 2.2: Top of Wall Attachment and Ledger Beam Details





TYPICAL SECTION

MEASUREMENT	#	INSTRUMENT	RANGE
Stroke	2	LVDT's	± 6 in
Wall Acc.	11	Acc's	± 4 g's
Wall Displ.	9	WP NN	± NN in
Joint Def.	12	DCDT pairs	± 0.5 in
Rebar Strain	15	SG's	± 0.2 in/in

SPECIFICATIONS

FIGURE 2.3: Wall 10 Instrumentation Schematics

3 TEST SPECIMENS & MATERIAL PROPERTIES

3.1 Test Specimens

The masonry walls were constructed in three groups: Group 1, consisting of Walls 1, 2, 4, and 6, was built in January-February 1987; Walls 8, 9, 10, and 11, built in December 1987, form Group 2; the remaining walls (3, 5, and 7) were built in February-March 1988; they constitute Group 3. All walls were constructed by D.A. Sullivan Company, a masonry contractor with years of experience in constructing specimens for the different masonry test programs conducted at EERC. Construction was supervised by CES engineers and samples of all construction materials were tested for quality control.

The main physical characteristics of the walls are schematically presented in Fig 3.1. Detailed construction drawings for each specimen are given in Volumes 2, 3, and 4 of this report. As a typical example, Fig. 3.2 shows the construction drawings which correspond to Wall 10.

Group 1 walls were 20 feet high; the remaining walls were 25 feet high. All specimens were 4 feet wide and nominally 6 inches thick. Nominal 16 ×6 ×4 inch (actual 15.5 ×5.5 ×3.5 inch) hollow, clay block masonry units were used, joined by 0.5 inch thick mortar joints. The nominal height-to-thickness ratio (h/t) was therefore 40 for the 20 feet high walls and 50 for the 25 feet high walls (actual h/t ratios: 54.5 and 43.6). All walls in Group 2 were partially grouted, i.e. only the cells containing the vertical rebars were grouted. The bottom and top three courses were always fully grouted. The walls of Groups 1 and 3 were fully grouted.

The main reinforcement of Walls 4, 6, and 9 consisted of two #5 vertical rebars; their reinforcement ratio, based on realistic material properties, was 16% of the balanced ratio. The remaining walls had three #7 bars, corresponding to 50% of the balanced ratio. Bond beams were provided for all walls of Group 2. They consisted of two #3 horizontal rebars laying on either side of the vertical rebar within a fully grouted block course. Vertical reinforcement was lap spliced in Walls 9 and 10. Walls 8 and 11 had top welded segments. Grade 60 steel was used for all reinforcement.

Vertical load was applied eccentrically at the ledger beam. These loads were 50 lb./ft. for Wall 4 and 300 lb./ft. for the remaining walls, except Walls 3 and 5, which were loaded with 800 lb./ft.

3.2 Material Properties

The walls were built in 5 feet high sections, using the specified material properties given in Table 3.1. Representative material samples were gathered near the completion of each section for quality control testing. Mortar specimens consisted of cubes 2 inches in size, and

cylinders 4 inches high with a 2 inch diameter. Grout samples were prisms 4 inches high and 2 inches wide (UBC test). Additional grout samples were prepared by filling some masonry block cells with grout, from which cores 4 inches high by 2 inches in diameter were taken. Mortar and grout samples were tested in compression after [at least] 28 days. These tests conformed to ASTM C91 and ASTM C109-75.

Masonry prisms were built to determine the compressive strength and modulus of rupture of the masonry. These prisms corresponded to the previously sampled groups of grout and mortar in terms of materials and locations within the wall. These specimens were tested at the EERC under supervision of engineers from CES and conformed to ASTM E 447-74, ASTM C 140-75 and ASTM C 1072-86.

The high strength of the clay units relative to the capacity of the EERC test machine prevented the testing of a full block unit in compression. Consequently, smaller (1.5 ×1.5 inch cross section) samples of block were cut and tested. Tests performed by TCCMAR Task 1.2(b) support the results reported from these smaller scale tests [4].

Rebar specimens were also tested in tension, to determine stress and strain at the yield, ultimate and rupture conditions.

The material tests are summarized in Table 3.2. Detailed material test data are presented in Appendix B.

TABLE 3.1: Material Specifications

BLOCKS:	15.5" ×5.5"x3.5" fired clay hollow blocks. Openings: Two 4.5"x2.75", one 1"x2.75". Manufactured by Interstate Block Company, West Jordan, Utah.
CEMENT:	Type I or Type II ASTM Portland Cement.
LIME:	Type S Hydrated non-air entraining line.
MORTAR:	1.0-0.5-4.5. 100% flow. Mixing time: 3 to 5 min.
GROUT:	1.0-3.0-2.0 Portland Cement and aggregate (3/8" max. size). Type II Grout Aid (Sika Corp.)
REINFORCEMENT:	Grade 60, #7 structural steel bars.

TABLE 3.2 a): Material Properties of Masonry

MASONRY	Group 1	Group 2	Group 3	Average	Cross Section
<u>COMPRESSIVE STRENGTH</u>					
BLOCK (psi)	NA	15050	15480	15270	1.5" ×1.5"
GROUT (psi)					
cylinder core	5580	2880*	5350	5470	2" dia.
prism UBC	4650	4410	5320	4790	2" ×2"
MORTAR (psi)					
cube	3060	3290	3490	3280	2" ×2"
cylinder	4090	2860	3390	3450	2" dia.
MASONRY prism (psi) $f'm$	5370	4900	4540	4940	5.5" ×7.5"
<u>MODULUS OF RUPTURE</u>					
MASONRY prism (psi)	NA	297	276	290	16" ×5.5"
(fraction of $\sqrt{}$ (f'_m)		4.14	4.09	4.12	

(*) Sample not representative. Most cores were badly damaged, probably due to poor manufacturing quality. Value not average.

TABLE 3.2 b): Material Properties of Reinforcement

STEEL REBARS	# 3	# 5	# 7
YIELD			
strain	0.0024	NA	0.0022
stress (ksi)	72.1	70.9	62.8
ULTIMATE			
strain	0.12	0.11	0.12
stress (ksi)	113	116	106
RUPTURE			
strain	0.21	0.21	0.27
stress (ksi)	82	97	86

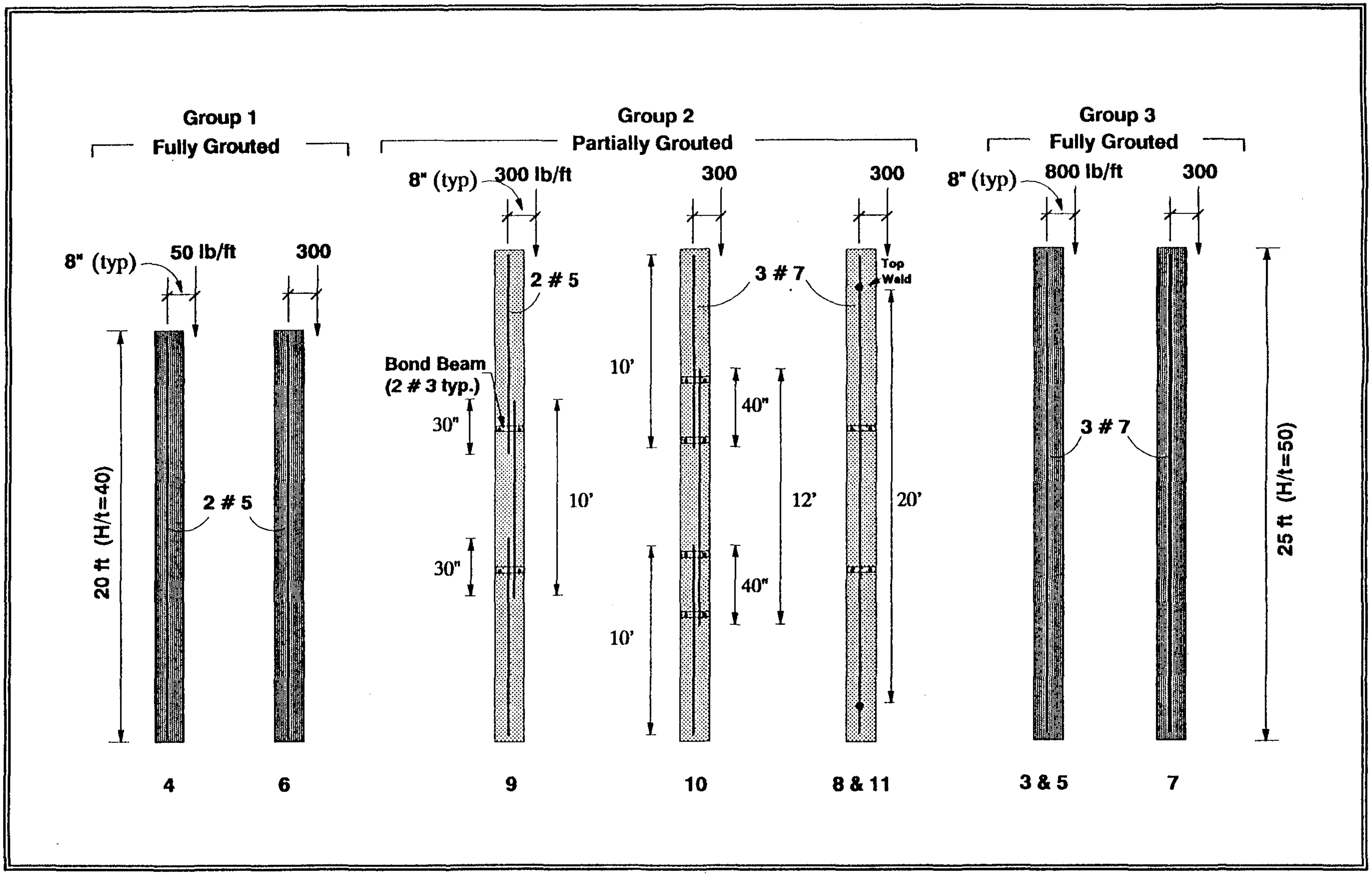


FIGURE 3.1: Characteristics of Walls

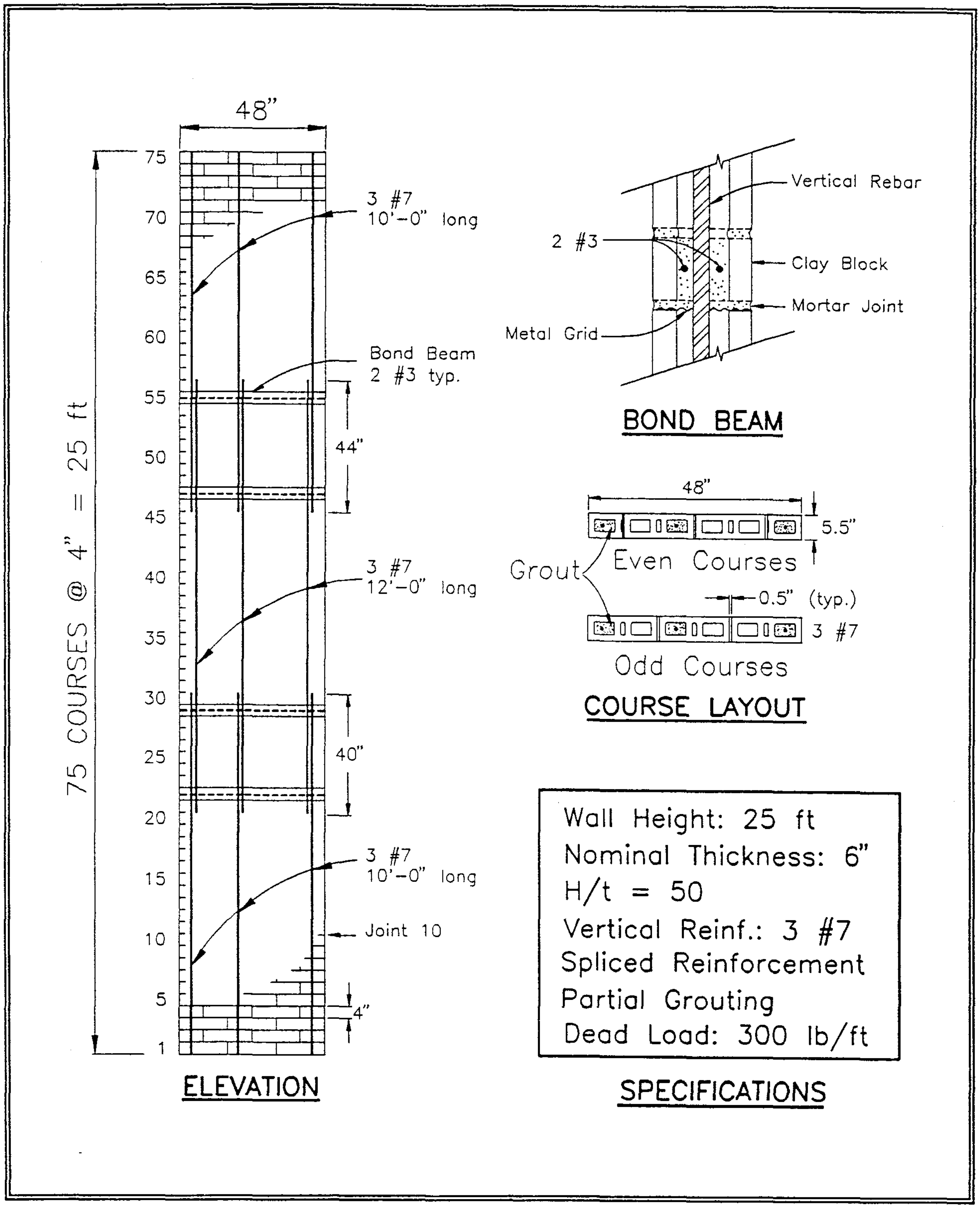


FIGURE 3.2: Wall 10 Construction Drawings

4 GROUND MOTION INPUT

4.1 Generation of Input Signals

The main objective in the specification of the excitation signals for the dynamic tests was to achieve realistic seismic input. Accordingly, the motion at the base of the walls was representative of earthquake induced ground motions, and the corresponding motion at the top simulated the response at roof level of typical masonry warehouse structures or athletic facilities subjected to the same ground motion. Flexible and stiff diaphragm conditions were investigated.

The intensity of the input signals was selected to be representative of rock sites for the different seismic zones of the USA. Ground motion intensity in zones of low, medium and highest seismicity is characterized by Effective Peak Acceleration (EPA) levels of 0.1, 0.2 and 0.4. Thus, command signals for each of these levels were generated.

The base input signals were created from measured earthquake acceleration records. Two procedures were used: direct amplitude scaling in the time domain to attain the target EPA levels, and iterative amplitude scaling in the frequency domain to match the ATC-S1 response spectral shape for the desired EPA level. Kariotis and Associates analytically developed the top input signals corresponding to each ground motion signal, by subjecting a model of a single story warehouse structure to the ground motions, and computing the resulting structural response at the diaphragm or roof level.

To illustrate the spectral matching procedure for input signal generation, the base input response spectrum for the Bonds Corner signal (BONDC) and the spectra corresponding to the top input signals for flexible and stiff diaphragms are shown in Fig. 4.1, along with the target ATC spectrum (ATC3-S1). Good correlation was reached for the base command signal. The top input spectra show amplification of response at periods of about 1.0 sec for a structure with a flexible diaphragm and at 0.2 sec for the structure with a stiff diaphragm.

4.3 Generated Command Signals

Fourteen sets of command signals were generated. Table 4.1 indicates the earthquake record, the scaling method used to generate the base input, the target EPA level, and the diaphragm conditions assumed to derive the top motion.

After the acceleration time histories for the bottom and top of the walls were generated, the corresponding velocity and displacement signals were computed by integration in the frequency domain via Fast Fourier Transforms. The displacement (command) signals were then baseline corrected and high pass filtered at 0.2 Hz to eliminate linear trends and

undesirable long period components. Finally, all input signals were tested in situ, with unattached actuators, to verify the accuracy of motion reproduction.

Fig. 4.2 shows: a) time histories and amplitude frequency spectra of measured bottom and top input displacements; b) similar graphs for the corresponding acceleration inputs; and c) acceleration and velocity response spectra calculated from the measured input time histories, for 5% damping. Appendix C contains similar information for all input signal sets.

During the first dynamic testing (Wall 4) the command amplitudes to the actuators for signal TAFT1 were inadvertently set to the values for the ELC1 signals. This resulted in an actual EPA level of 0.07 for TAFT1 and 0.15 for ELC1 instead of the scheduled 0.1 level. For consistency, these input levels were preserved for the remaining tests.

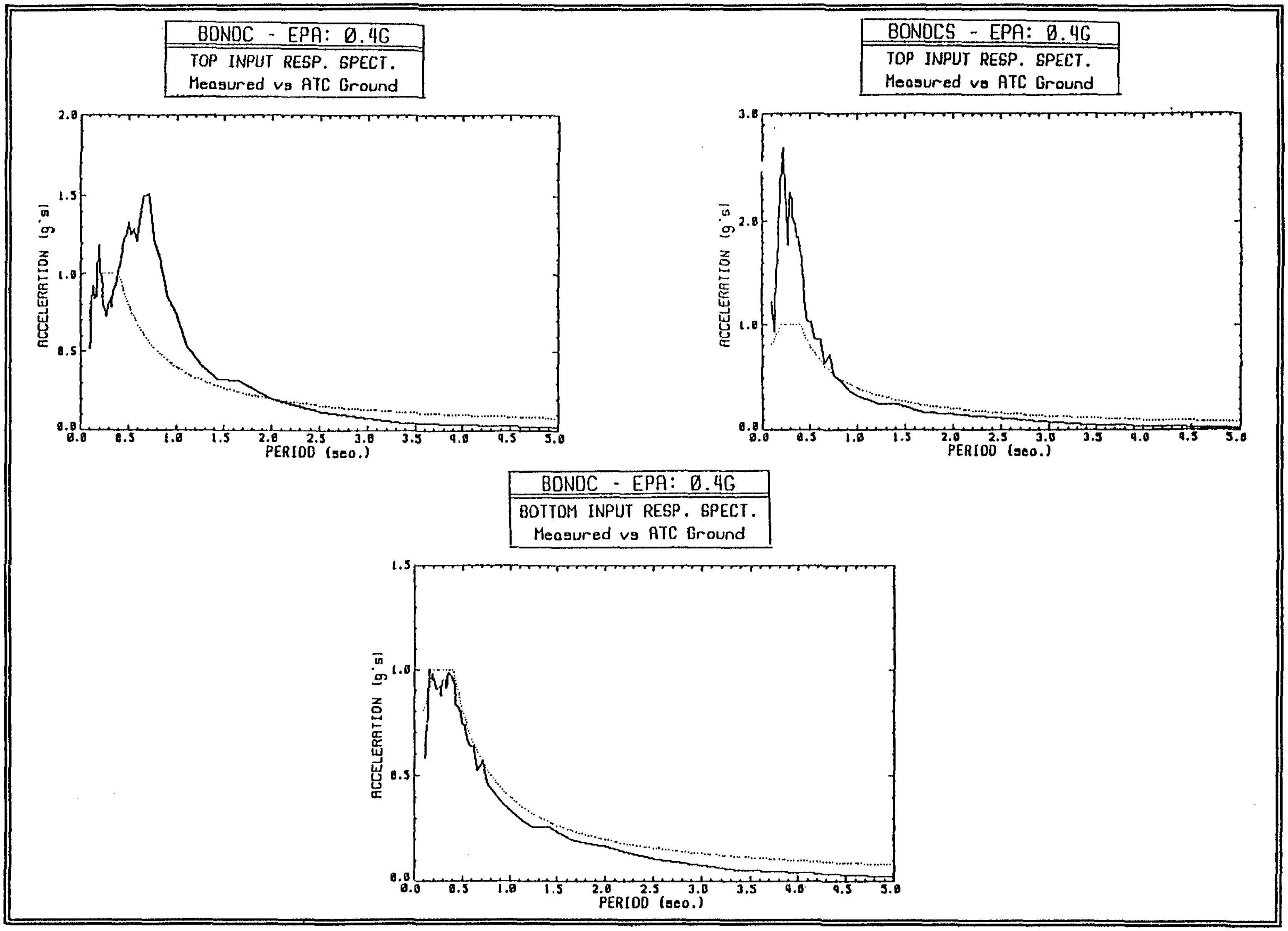


FIGURE 4.1: Spectral Matching Procedure for Input Generation
Top Left: Flexible Diaphragm   Top Right: Rigid Diaphragm
Bottom: Base Motion

TABLE 4.1: Input Time Histories

EPA (g)	SIGNAL			DIAPHRAGM TOP INPUT
	ID	ORIGIN	SCALING	
0.1	MS1	Hollister-Glorietta warehouse Morgan Hill, 1984	1.12	Flexible
0.1	MS2	Saratoga W. Valley College Gym, Morgan Hill, 1984	0.78	Stiff
0.1	TAFT1	Lincoln School Tunnel Taft, 1952	ATC-3 S1	Flexible
0.1	ELC1	El Centro, 1940	ATC-3 S1	Stiff
0.2	TAFT2	Lincoln School Tunnel Taft, 1952	ATC-3 S1	Flexible
0.2	MS3	El Centro, 1940	0.625	Flexible
0.2	ELC2	El Centro, 1940	ATC-3 S1	Stiff
0.4	MS5	El Centro, 1940	1.25	Flexible
0.4	ELC	El Centro, 1940	ATC-3 S1	Flexible
0.4	BONDC	Bonds Corner, 1979	ATC-3 S1	Flexible
0.4	TAFTS	Lincoln School Tunnel Taft, 1952	ATC-3 S1	Stiff
0.4	BONDCS	Bonds Corner, 1979	ATC-3 S1	Stiff
0.8	BONDCH	Bonds Corner, 1979	ATC-3 S1	Flexible
0.8	BONDCSH	Bonds Corner, 1979	ATC-3 S1	Stiff

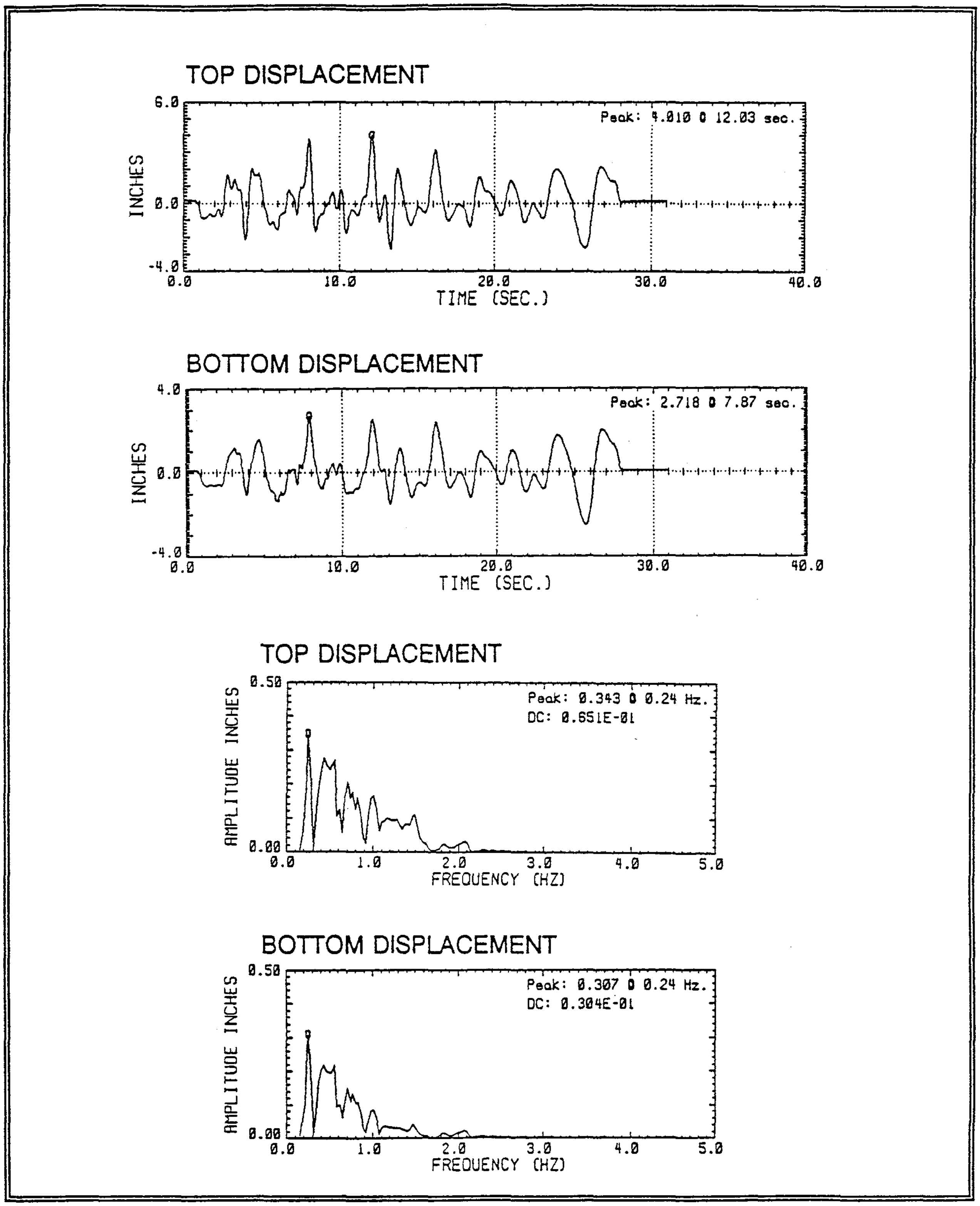


FIGURE 4.2a: BONDC - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra

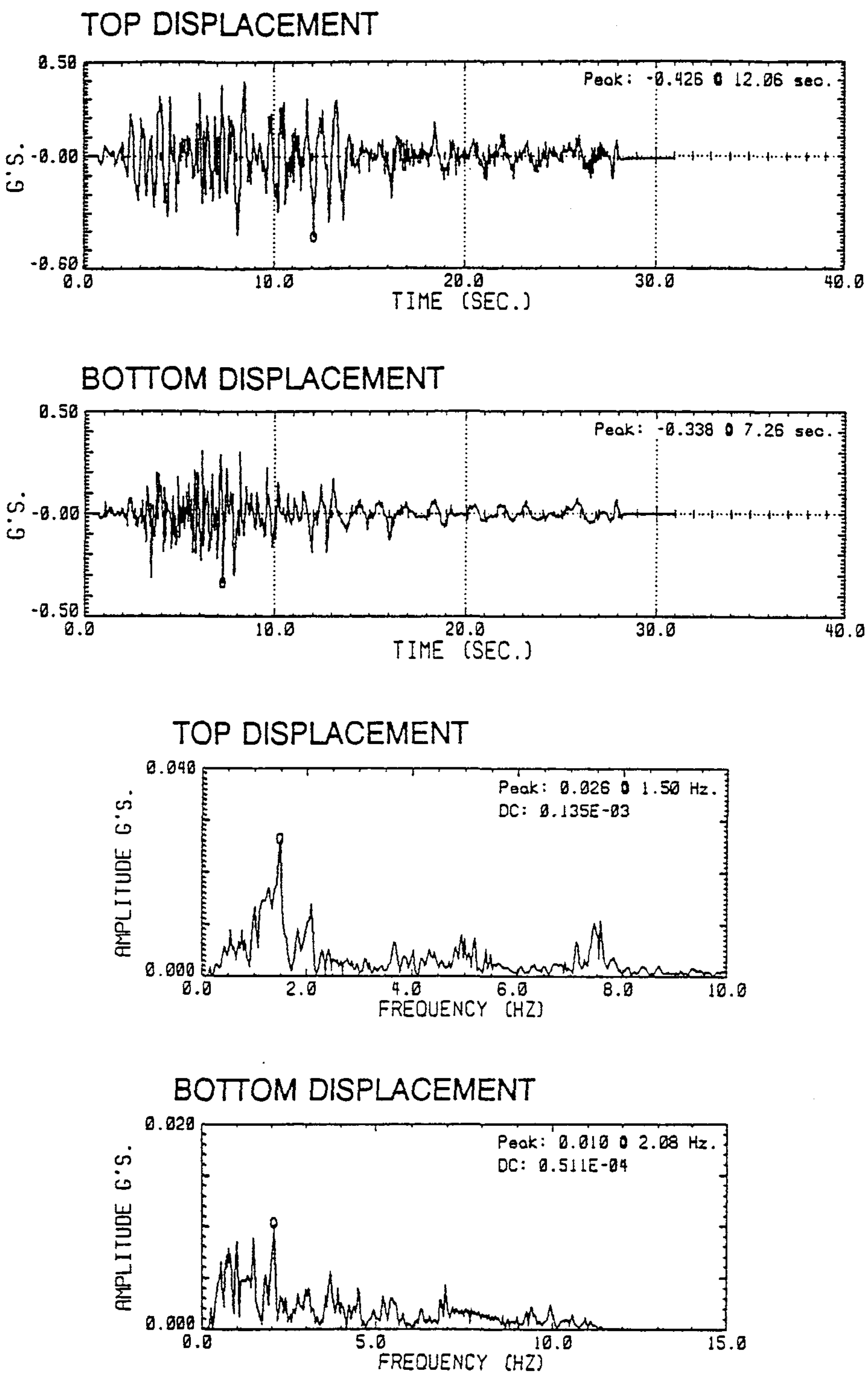


FIGURE 4.2b: BONDC - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra

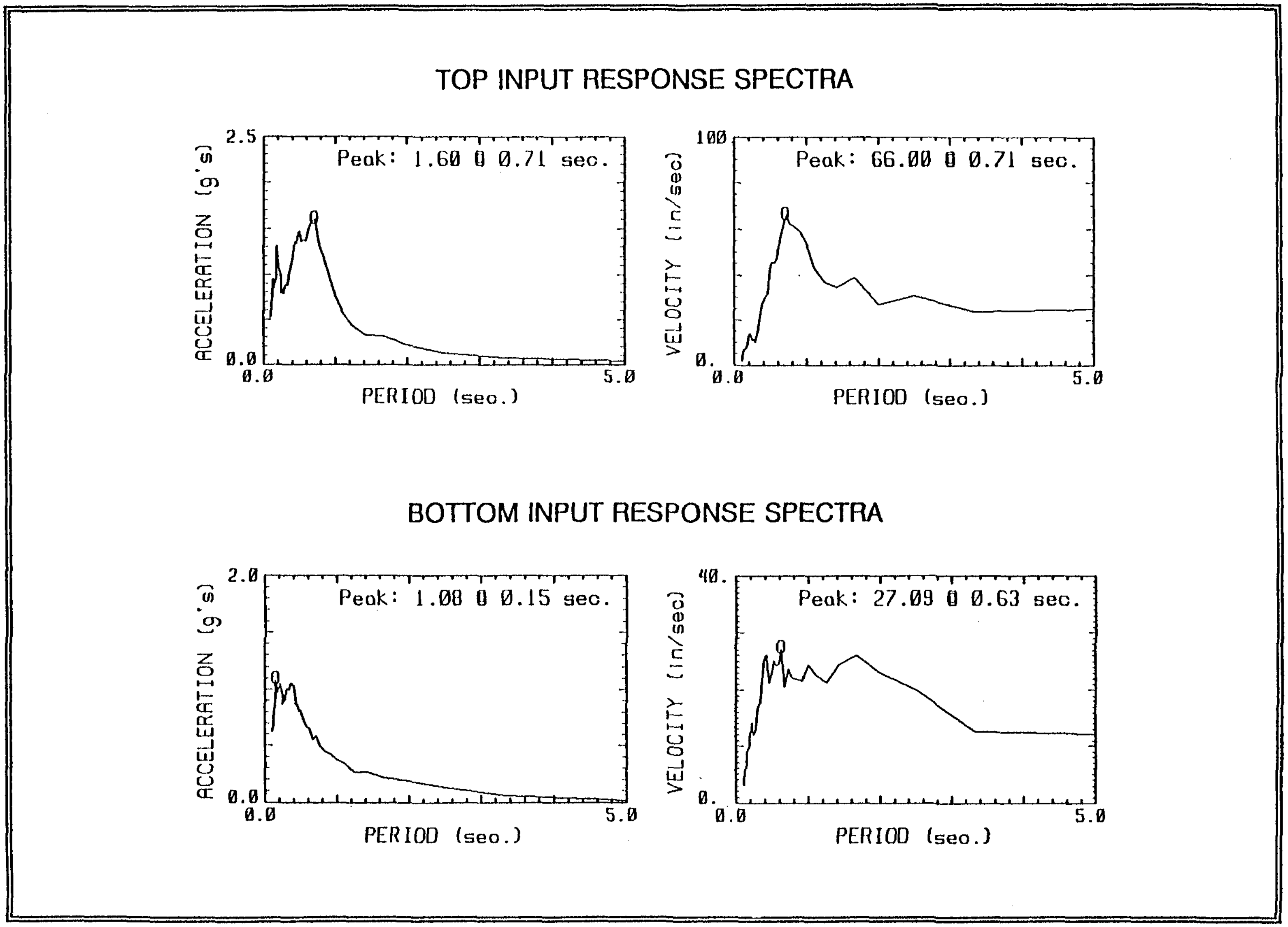


FIGURE 4.2c: BONDC - 0.4EPA: Input at Top and Bottom Actuators Acceleration and Velocity Response Spectra (5% damping)

5 TEST EXECUTION & DATA REDUCTION

5.1 Testing Procedure

All walls were tested at about the same age, 28 days after construction. Each wall was tested under the first, low intensity signal (MS1) a day earlier than the remainder of the tests to allow overnight verification of the operability of the test setup and instrumentation. The following day, testing of the wall progressed from the 0.1 EPA (MS2) through to the 0.8 EPA (BONDCSH) signals, according to a predetermined schedule. Not all signals were applied to all wall specimens. The test sequence specific to each specimen is detailed in the corresponding volume.

Each test (also called a "run") was videotaped. After each run, the wall was inspected and recorded data from several channels were plotted and evaluated. This included a check on whether or not yielding of the rebar had occurred near the wall center.

5.2 Sign Convention and Nomenclature

To avoid ambiguity in the data processing and interpretation of the results, it was decided to denote the wall surface facing away from the actuators as the front face; the opposite surface was therefore the back face.

Throughout this report, the terms "displacement" and "acceleration" mean absolute displacement and absolute acceleration, respectively, and the term "deflection" refers to relative wall deflection with respect to the chord connecting the top and bottom actuators.

The following sign convention was used: all displacements and accelerations toward the front were considered positive. Extension of strain gages and DCDT's were also positive. The sign of derived quantities was consistent with the above convention. Fig. 5.1 summarizes the terminology and sign convention.

5.3 Data Reduction

All data reduction was done at CES, using the processing scheme described below.

<u>a) Channel Data</u>

Separate files containing individual channel measurements were initially generated from the sequentially multiplexed raw data. The initial offset of each signal was then set, equal to the average value measured during the last second of the previous test, if any. This was necessary, since sometimes all signal offsets were set to zero between runs to avoid channel

saturation, thus making it more difficult to keep track of plastic rebar strains and permanent wall deformations.

Due to the massive amount of data gathered (about half a million values for a typical run), it was decided to reduce the number of data points per signal without losing the information contained in the 0 to 10 Hz frequency band. This was accomplished by reducing, in the frequency domain, the number of data points by a factor of eight, thus increasing the time step between datapoints from 0.004 seconds to 0.032 seconds.

Finally, all signals were low pass filtered at 10 Hz, and a constant baseline correction was performed on the acceleration signals. Tables with extreme values of processed channel data were then generated for all runs.

b) Input Excitation and Wall Global Response

The characteristics of the input excitation at the bottom and top of the wall were studied with plots of time history, Fourier amplitude frequency spectra, and acceleration response spectra.

The global descriptor of wall deformation was the relative deflection of the wall with respect to its chord. The excitation was characterized by the total inertia force imposed upon the wall and the distribution of bending moment throughout the wall height. These force quantities were computed by assigning a tributary mass to each acceleration transducer and integrating the resulting inertia forces over the wall height.

Effective or equivalent quantities were defined and calculated to characterize the input motions and the wall mechanical properties, as illustrated in Fig. 5.2. An equivalent load, equal to the uniformly distributed force required to produce the maximum calculated bending moment, was used as an indicator of the force acting on the test specimens. A seismic coefficient (C), was then defined as this equivalent load divided by the weight of the wall. The seismic coefficient can be described as the uniform lateral acceleration -in g's- required to produce the peak bending moment. The equivalent flexural stiffness (EI_{eqv}) was estimated as the uniform stiffness needed for the wall to obtain the measured deflection when subjected to the equivalent load. A measure of the change in wall stiffness as shaking progressed was given as the ratio (EmI_g/EI_{eqv}), where Em is the reference elastic modulus as specified by the UBC Code (750 f'mt), and I_g is the gross moment of inertia of the wall section.

Another measure of wall stiffness was provided by the dominant vibration frequency of the wall during each test. The dominant frequency was estimated from the transfer function between top and base input and midheight response accelerations. Typical transfer functions are shown in Fig. 5.3; it is apparent that, since the wall properties change during shaking (cracks open and close, mortar joints crush microscopically, etc.), the fundamental frequency

is not always well defined. In those cases, the Fourier spectrum of the acceleration response was used to assist in the estimation of the dominant frequency.

c) Joint Response Data

The information recorded by the DCDT's at both faces of the wall across selected joints was used to generate a detailed description of the deformation of the joints: average joint openings were computed at the faceshell and at the assumed rebar location; the compressive strain at the faceshell was estimated using the distance between DCDT anchors as the gage length; and finally, a measure of wall curvature was derived from the relative rotation between blocks. The procedure used to evaluate these parameters is sketched in Fig. 5.4.

The mechanical properties of the walls at the joint level were described through moment-curvature relationships. Moment-curvature plots were accordingly used to estimate the characteristic wall strength values (cracking and yield moments). In addition, an independent estimation of the wall stiffness (EI) was obtained for the cracked and uncracked joint conditions. These values were then used to validate the estimated wall equivalent stiffness.

5.4 Output Data

The amount of information obtained during the dynamic tests was staggering. For instance, the number of raw data points for an average run is: 64 data channels $\times$250 samples/ channel/sec $\times$30 seconds = 480000 datapoints. After processing all data, about seven pages of tables and eighty plots were generated per dynamic input.

Typical reduced output consisted of tables of extreme values of processed channel data and all calculated responses, and a great diversity of plots: time histories and Fourier amplitude spectra of most signals; response spectra of top and base input; and, force versus deformation graphs at the global (force versus deflection or moment versus deflection) and local (moment versus curvature) levels. Time histories of joint response consisting of average joint opening, rebar strain, faceshell strain and faceshell opening were also plotted for all instrumented joints. Finally, profiles, distributions and envelopes of all quantities were plotted in time windows of 5 or 10 seconds, to observe evolution of wall response. Appendix D presents this information for a single run of Wall 5. Reduced data for all tests performed on each wall is available at CES.

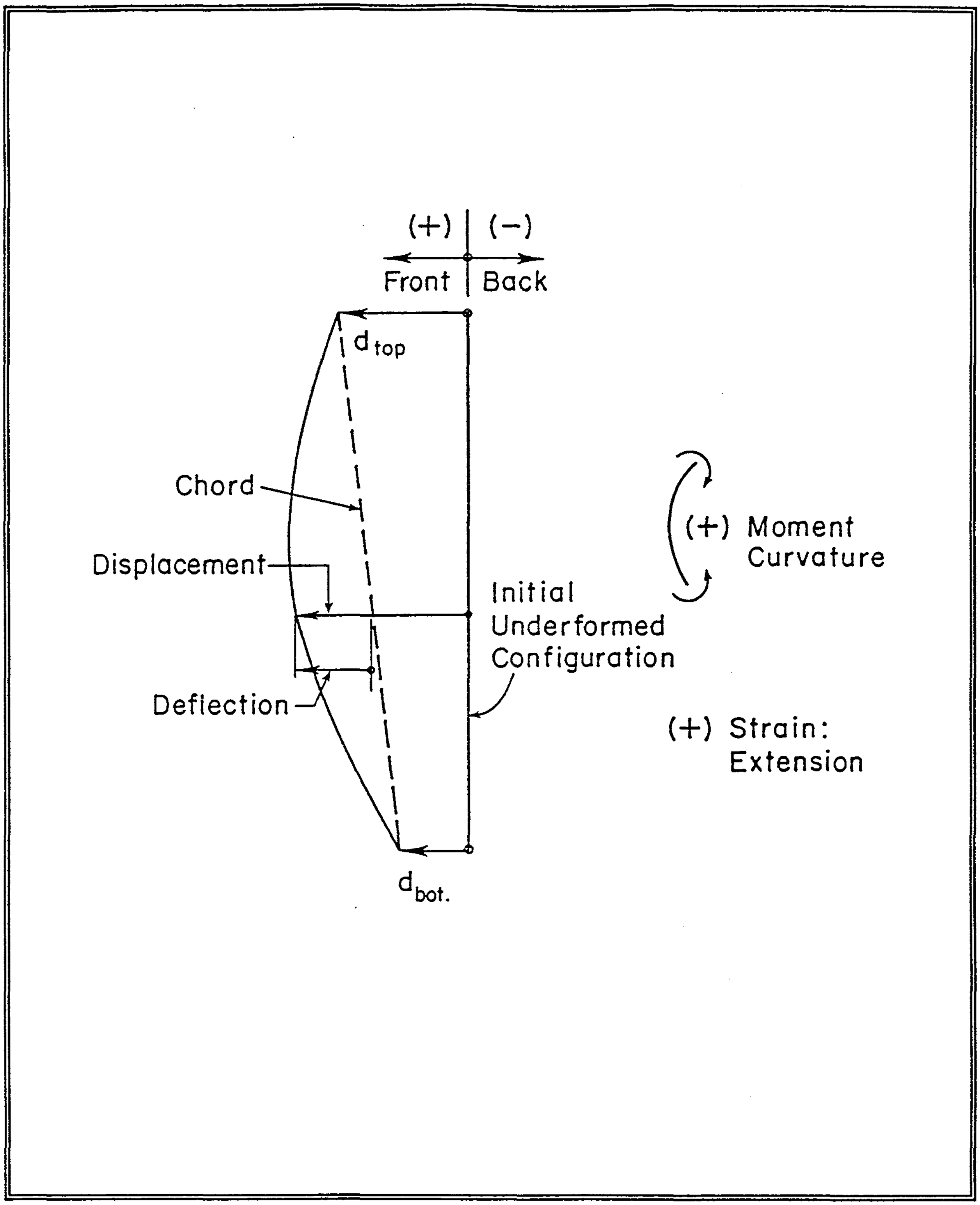
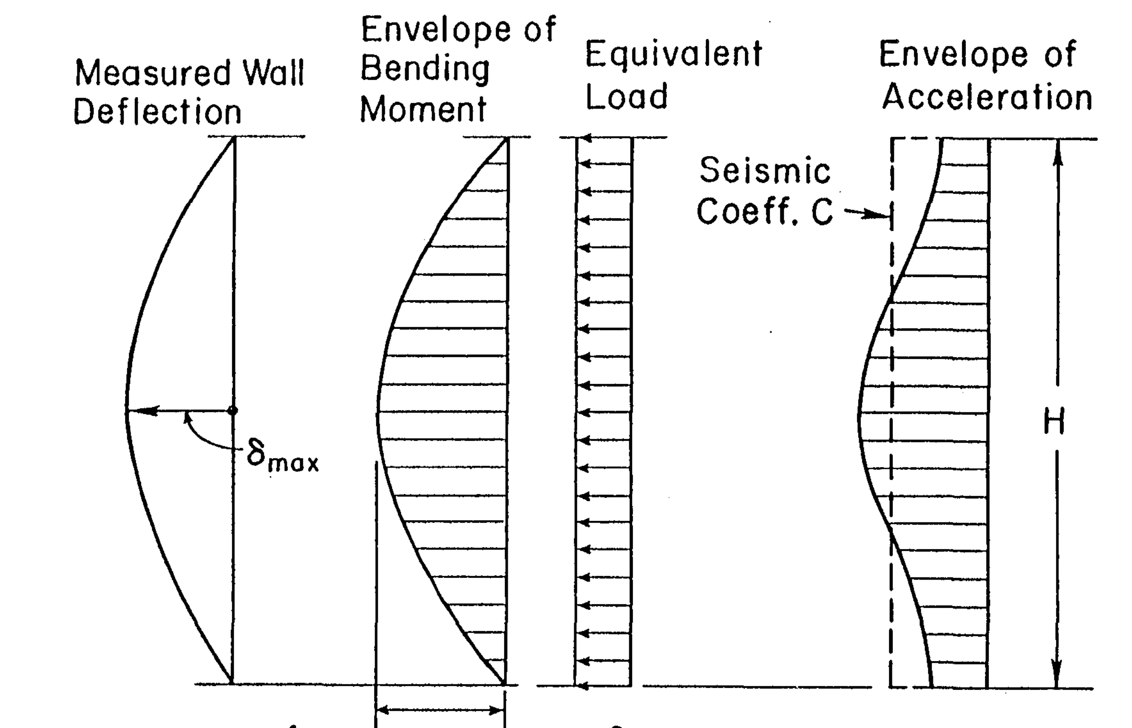


FIGURE 5.1: Sign Convention and Terminology



$$\delta_{max} = \frac{5\,\omega_{eq}\,H^4}{384\,EI_{eq}} \qquad M_{max} = \frac{\omega_{eq}\,H^2}{8} \qquad C = \frac{\text{Lateral Force}}{\text{Weight}}$$

$$EI_{eq} = \frac{5\,M_{max}\,H^2}{48\,\delta_{max}} \qquad \omega_{eq} = \frac{8\,M_{max}}{H^2} \qquad C = \frac{\omega_{eq}\,H}{\text{Weight}}$$

FIGURE 5.2: **Definition of Equivalent Stiffness EI_{eq} and Seismic Coefficient C**

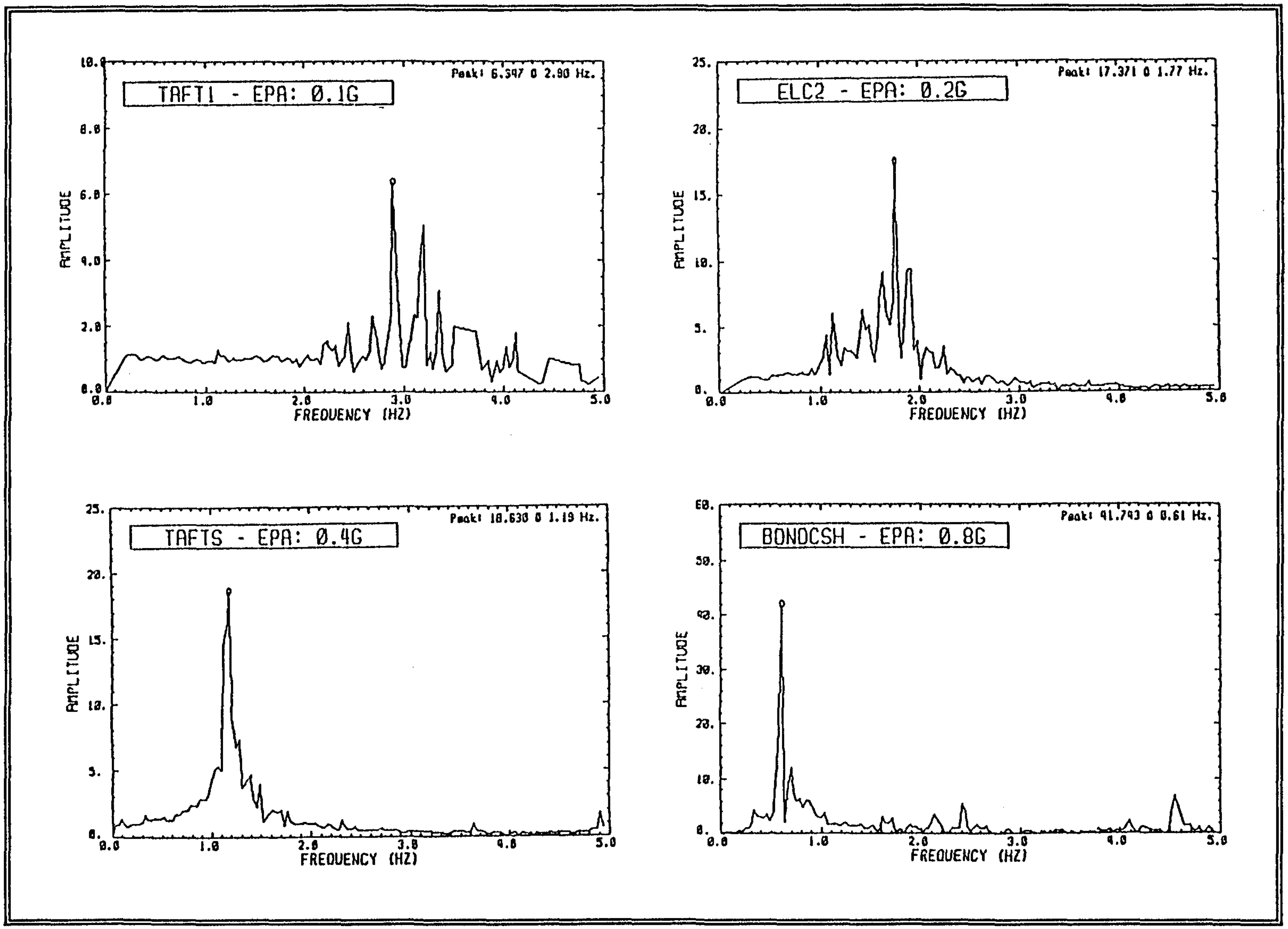


FIGURE 5.3: Samples of Acceleration Transfer Function

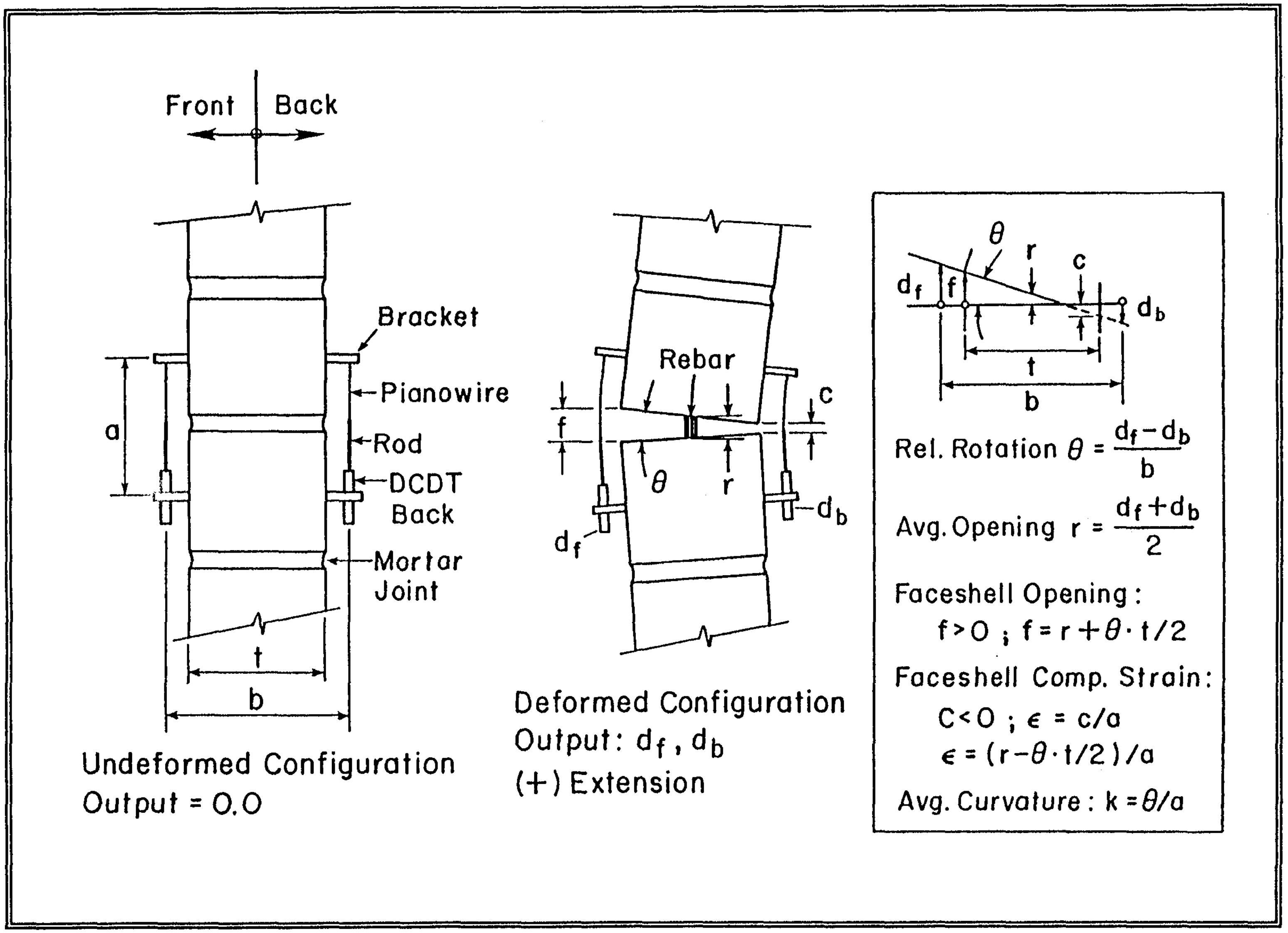


FIGURE 5.4: **Definition of Joint Deformation Quantities**

6 SUMMARY OF RESULTS

Summary results from the dynamic tests of each wall are presented in individual appendices. These are grouped in three separate volumes. Volume 2 contains the results of the first group of walls: Walls 4 and 6. Volume 3 contains the results from Group 2: Walls 8, 9, 10, and 11. Volume 4 contains the results from the third group: Walls 3, 5 and 7.

Each appendix is organized as follows: First, a set of figures with construction drawings and test setup and instrumentation schematics is presented. This is followed by a table with test sequence and peak displacement, acceleration measured at the bottom, center and top of each wall, as well as measured peak rebar strain. For each run, a summary table is given indicating: a) peak values of input and global response (i.e., displacements and accelerations at the top, center and bottom of the wall, peak deflection, peak inertia force and bending moment, and seismic coefficient); b) summary of mechanical properties, average stiffness EI_{eqv}, compared to code reference value E_mI_g, and the average vibration frequency observed during the run; and c) local response, characterized by peak values of rebar strain, joint opening (near rebar), and faceshell compression strain and opening. Since these do not generally occur in the same joint, a joint near the center is selected, and the corresponding quantities recorded.

For each run, envelopes and representative patterns of wall displacement, relative deflection, and absolute acceleration and bending moment, followed by the distribution of rebar strain, joint opening (near the rebar location), and faceshell compressive strain and opening are given. Then, for the first run of each EPA level, or for each run where significant difference in input or response occurs, the following force deformation plots are included: total inertia force versus center deflection, center moment versus center deflection, and moment versus curvature at center joint.

REFERENCES

[1] ACI-SEAOSC Task Committee on Slender Walls, "Test Report on Slender Walls", February 1980 - September 1982, Los Angeles California.

[2] International Conference of Building Officials, Uniform Building Code, 1985 edition. Whittier, California.

[3] Sveinsson, B.I., M. Blondet, and R. L. Mayes, "The Transverse Response of Clay Masonry Walls Subjected to Strong Motion Earthquakes - Report on the testing of Wall No. 10", TCCMAR Report No. 3.2 (b2)-10, Computech Engineering Services, Inc., Berkeley, December 1988.

[4] Young, J. M and R. H. Brown, "Compressive Stress Distribution of Grouted Hollow Clay Masonry under Strain Gradient", TCCMAR Report No. 1.2 (b)-1, Department of Civil Engineering, Clemson University, Clemson, South Carolina, May 1988.

APPENDIX A

TEST EQUIPMENT, INSTRUMENTATION & DATA ACQUISITION SYSTEM FOR DYNAMIC TESTS

A.1 TEST EQUIPMENT

A.1.1 Test Setup

The general test setup consisted of a wall specimen mounted on top of a unidirectional shaking table. Table motion was normal to the plane of the walls to induce mainly out of plane loading. The dynamic input was provided by two MTS electrohydraulic actuators attached to the table and to spreader beams at the top of the wall, and to four massive reaction A-frames. All connections were hinged. The characteristics of the different components of the testing hardware are presented in the following sections.

A.1.2 Shake Table

The test walls were placed on top of a specially constructed "shake table" made up of a 1" thick steel plate 8' by 4' in plan. The plate rested on four Thomson Dual Roundway Bearings, sliding on top of hardened steel rods, allowing unidirectional motion with minimal friction force (friction coefficient equal to 0.007). These four main bearings carried the gravity load of the test specimens. A second set of Thomson Bearings was located such that they prevented uplift of the base of the walls. Spreader beams were attached to the test specimen at the top of the wall. The top actuator was attached to these beams to provide horizontal motions normal to the specimen.

A.1.3 Actuators

The actuators used to supply the required excitation are high performance equipment. They are capable of developing a maximum dynamic load of 75 kips using a hydraulic pressure of 3,000 psi for a relatively short time. Normal use of the hydraulic system requires a hydraulic pressure of 2,500 psi, thus reducing the dynamic load to 62.5 kips. The maximum stroke of the actuators is 12 inches peak to peak, the maximum piston velocity is 30 in/sec and the flow capacity of the servovalves is 200 gal/min.

A.1.4 Control System

The actuators were controlled by a displacement pattern which could be any earthquake time history, sine wave, step function, etc. The only restriction was that the above listed capabilities of displacement, velocity or force were not exceeded.

The displacement command signals for both actuators were stored in digital format on floppy disks. After appropriate normalization and conversion to an (analog) continuous voltage waveform, they were simultaneously sent to the MTS controller. The amplitude of the actual actuator displacement was controlled by the span settings on the control panel.

A.2 MEASUREMENT INSTRUMENTS

A.2.1 LVDT's

The displacement (stroke) of the hydraulic actuators were measured by built in Linear Variable Differential Transformer (LVDT), conditioned by an MTS controller. An LVDT is a transformer with a movable ferromagnetic core, one primary winding and two secondary windings, arranged so that movement of the core from its center position causes the voltage in one secondary winding to increase and the voltage in the other to decrease. This difference in voltage is translated by a phase-sensitive demodulator into a DC voltage proportional to the core displacement. At zero displacement, the voltage in both windings is equal and the output from the demodulator is zero.

A.2.2 Wire Potentiometers

The displacements at various points on the wall were measured with Celesto Wire Potentiometers. A Wire Potentiometer is a highly accurate, multiturn helical potentiometer which is attached to a spool which is rotated by a cable attached to the specimen. The spool is returned to one extreme position by a constant force spring motor which maintains tension on the cable. Intermediate positions are read from the variable voltage in the wiper of the potentiometer.

The Wire Potentiometers were calibrated using a jig with notches machined every three inches with 0.001" accuracy in a bar. The jig allows the cable to be extended to any notch and left there while a reading is taken.

A.2.3 Accelerometers

Two types of Accelerometers are available at the EERC laboratory, Statham (now made by ITE-Gould) and Setra. Both kinds were used in these tests.

The Setra Model 141 is a variable capacitance type Accelerometer. It is excited with direct current, and a built in oscillator converts the supply current to a 20 MHz internal operating frequency which is applied to two, fixed insulated electrodes. A thin, stiff, metal disk mounted on flexures between the electrodes is deflected proportionally to acceleration, and the change in capacitance is converted by built in circuitry to a direct current output. The movable element is highly damped (0.7 of critical) by an air-film damping mechanism.

The Statham's are strain gage type accelerometers. Four resistances within the accelerometer are connected in a Wheatstone bridge, and changing acceleration changes the resistance of the strain gage elements, resulting in a change in the output voltage.

The Accelerometers were calibrated by placing them on a level surface in two positions to obtain 1 g and -1 g, and on a vertical surface to obtain 0 g. The frequency range of both

accelerometers is down to 0.0 Hz, and they also have very low response to transverse acceleration, so a horizontal orientation of the accelerometer is an excellent approximation of 0 g.

A.2.4 DCDT's

The opening of joints on the specimens was determined by measuring the change in distance between the center of one block to the next (spanning over a joint). This measurement was made with Hewlett Packard Series 7 Direct Current Displacement Transducers (DCDTs). The DCDT is an LVDT, packaged in an assembly that contains an integral carrier oscillator and a phase sensitive demodulator. Hence, the operation is the same as that of an LVDT, but both the input and output are direct current.

The DCDTs were calibrated in a jig which permitted insertion of blocks of various thickness under the DCDT rod. The thickness of various machined steel blocks was measured using a micrometer, then the thickness of various stacks of the blocks were measured to account for any inaccuracies which might result from stacking them. One suitable set of blocks was chosen and used in calibrating all DCDTs.

A.2.5 Strain Gages

Strain in the reinforcing bar was measured with Ailtech weldable strain gages welded directly to the rebar. These gages were specified to be operational up to strain levels of 2%. Strain measurement is based on the principle that the resistance of the gage changes in direct proportion to the strain. The leads from the gage are brought outside the specimen to a terminal block mounted on the specimen as close as practical to the gage. From this point, another shielded cable connects the strain gage to a second terminal block on the back of the signal conditioner, where the leads from the strain gage are placed in series with a 220 ohm 0.05% resistor across the excitation voltage forming a two-arm bridge. Strain is then read as a change in voltage at the midpoint of the bridge.

Calibration was accomplished by shunting the strain gage with a 3317 ohm resistor and entering the calculated equivalent strain into the data acquisition system. (The resistor used was a 3.32 K-ohm 1% resistor, the actual resistance of which was determined by a highly accurate laboratory DVM).

A.3 DATA ACQUISITION SYSTEM

A.3.1 Instrument Calibration

The Data Acquisition System contains a calibration program. With all the instrumentation connected to its signal conditioning and to the Data Acquisition System, a channel is selected for calibration. A measurement of a known value is made with the appropriate instrument,

and the known valued is entered on the Data Acquisition System terminal. The terminal CRT then displays the voltage measured and the value entered, in adjacent columns, and simultaneously displays a graphical representation of each calibration point. The graphic display provides a quick, visual check for linearity and reproducibility.

When satisfactory calibration data have been obtained, they are entered in the Data Acquisition System, which then computes the slope (units/volts) of a least-squares line for those calibration points. This slope is then the calibration value and is stored permanently in the calibration file.

A.3.2 Analog to Digital Converter

The Data Acquisition System is a system that digitizes analog voltage signals in accordance with a predetermined schedule and at a selected frequency. The paragraphs below describe the analog-to-digital (A/D) process and some general principles that apply to ensure acquisition of valid data.

In general, the instruments (Accelerometers, DCDTs, Wirepots and Strain Gages) generate a voltage signal when subjected to motion compatible with their function. Accelerometers measure absolute accelerations on the moving wall, the Wirepots measure relative displacements between a fixed point and the moving wall, and the DCDTs measure relative displacements between two points on the wall across a bedjoint. The Strain Gages measure elongation of themselves (by changing their resistance) normalized to a strain value over the fixed length of the Strain Gage.

The voltage signals generated are usually not directly compatible with the analog-to-digital converter of a data acquisition system, in that the signal strength is too low to be properly defined by the 12 bit A/D converter most commonly used. Therefore, signal amplifiers are inserted into the circuit to amplify the voltage signal to a level suitable for the A/D converter. To do so, one must anticipate what the maximum response (acceleration, displacement, strain, etc) will be and set the amplification such that the anticipated maximum voltage signal equals the maximum voltage level. The drawback of this system is that if the anticipated maximum is exceeded, an overflow situation will be created in the A/D converter and the real maximum will not be properly recorded.

In addition to voltage amplification, the signal conditioning equipment used in the tests provided the capability of low pass filtering of measurements. This is an essential feature, since most of the signals contain some degree of high frequency noise. If this high frequency noise is not removed before digitization, it will appear in the digitized signal aliased as a lower frequency component, thus contaminating and distorting the data. For the dynamic tests, the cutoff frequency of the low pass filters was set at 100 Hz.

The A/D converter, which is an integral part of the Data Acquisition System, is capable of digitizing at the rate of approximately 90,000 values/sec. The converter is connected to a

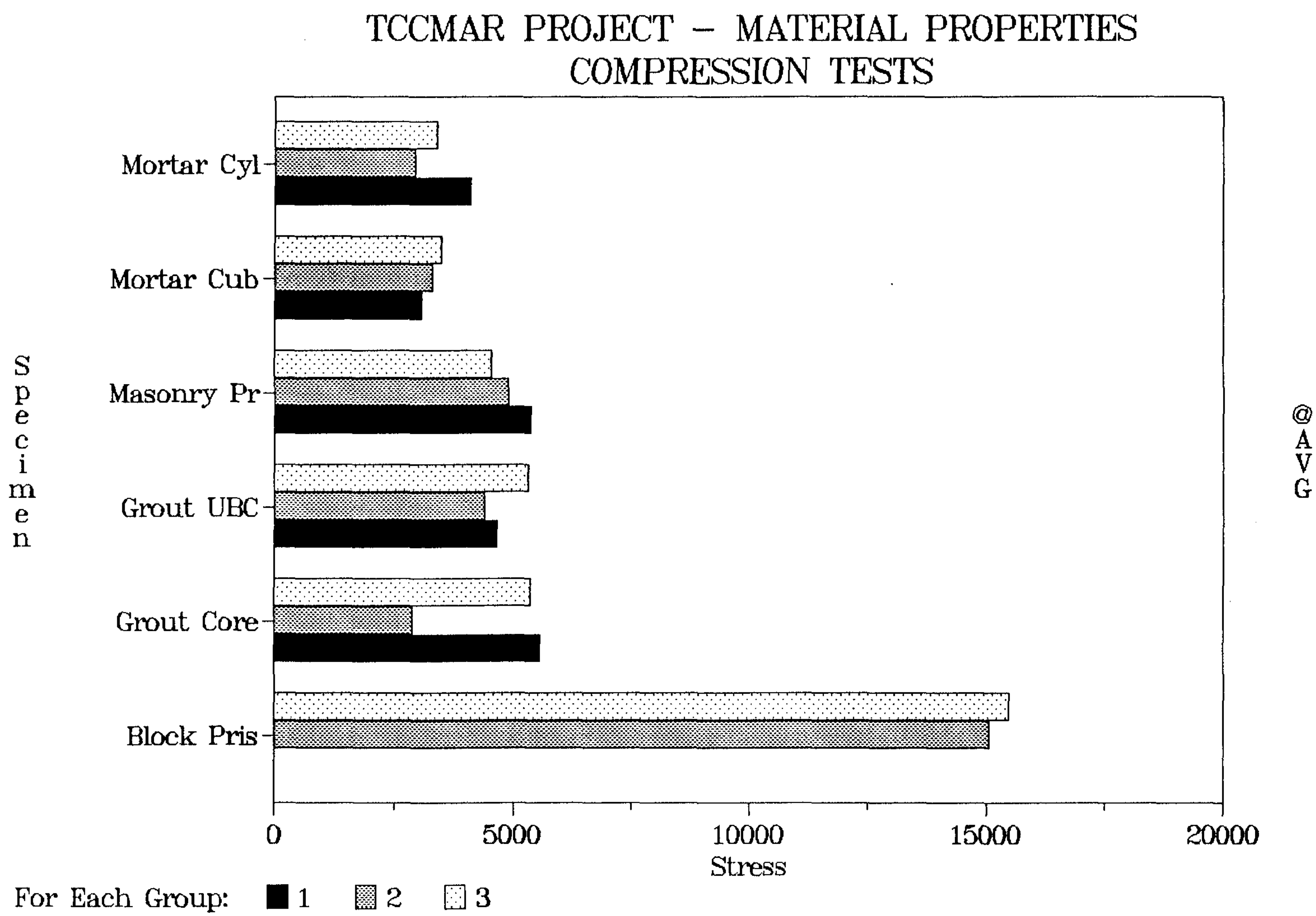
high-speed scanner, which can scan up to 64 channels (inputs) according to a schedule which is computer controlled. The combined system can, thus, technically accommodate 64 channels of data at the rate of approximately 1,400 readings/sec/channel. However, to preserve the phase relationship between the first and last channels of a sampling (scanning) schedule (important in a dynamic test), the digitization rate should not exceed 500 points/sec/channel if all 64 channels are sampled. This gives approximately a 2 to 1 ratio between the inactive periods of the A/D converter.

A.3.3 Data Storage

The sampled data (using the 12 bit A/D converter) is stored on the permanent storage device of an LSI-11 computer. After the tests were completed, all measurements were stored on magnetic tape in Vax compatible format. The filename of each run is YYMMDD.NN where YYMMDD indicates the test date and NN is the run number.

APPENDIX B

RESULTS FROM MATERIAL TESTS


TCCMAR PROJECT – MATERIAL PROPERTIES
COMPRESSION TESTS
Specimen
Mortar Cyl
Mortar Cub
Masonry Pr
Grout UBC
Grout Core
Block Pris
0
5000
10000
15000
20000
Stress
@AVG
For Each Group: 1 2 3

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 2

Specimen: Block Prism

Date Made	Date Tested	Age days	Stress psi
5/27/88	5/27/88	1	14880
5/27/88	5/27/88	1	14800
5/27/88	5/27/88	1	15340
5/27/88	5/27/88	1	15170
		Average:	15050

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 3

Specimen: Block Prism

Date Made	Date Tested	Age days	Stress psi
5/27/88	5/27/88	1	15540
5/27/88	5/27/88	1	15300
5/27/88	5/27/88	1	15270
5/27/88	5/27/88	1	15800
		Average:	15480

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 1

Specimen: Grout Core

Date Made	Date Tested	Age days	Stress psi
2/02/87	3/10/87	36	4710
2/02/87	3/11/87	37	5660
2/02/87	3/11/87	37	6480
2/02/87	3/11/87	37	6430
1/30/87	3/09/87	38	4760
1/29/87	3/09/87	39	5480
1/28/87	3/09/87	40	5190
1/29/87	3/10/87	40	5720
1/30/87	3/11/87	40	5130
1/28/87	3/10/87	41	6210
1/29/87	3/11/87	41	6050
1/28/87	3/11/87	42	5170
		Average:	5580

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 2

Specimen: Grout Core

Date Made	Date Tested	Age days	Stress psi
12/08/87	2/03/88	57	2750
12/08/87	2/03/88	57	3150
12/08/87	2/03/88	57	2510
12/09/87	3/01/88	83	3780
12/09/87	3/01/88	83	3580
12/07/87	3/01/88	85	2610
12/07/87	3/01/88	85	2750
12/07/87	3/01/88	85	2060
12/11/87	3/10/88	90	3480
12/11/87	3/10/88	90	2610
12/11/87	3/10/88	90	3620
12/10/87	3/10/88	91	1610
		Average:	2880

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 3

Specimen: Grout Core

Date Made	Date Tested	Age days	Stress psi
3/04/88	5/26/88	83	4780
3/04/88	5/26/88	83	4180
3/04/88	5/26/88	83	4100
3/03/88	5/26/88	84	5280
3/03/88	5/26/88	84	5410
3/03/88	5/26/88	84	5020
3/02/88	5/26/88	85	6260
3/02/88	5/26/88	85	5770
3/02/88	5/26/88	85	5850
3/01/88	5/26/88	86	7190
3/01/88	5/26/88	86	6330
2/29/88	5/26/88	87	4540
2/29/88	5/26/88	87	5140
2/29/88	5/26/88	87	5120
		Average:	5360

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 1

Specimen: Grout UBC

Date Made	Date Tested	Age days	Stress psi
2/02/87	4/24/87	81	4580
2/02/87	4/25/87	82	5770
2/02/87	4/25/87	82	5850
2/02/87	4/25/87	82	5660
1/28/87	4/22/87	84	4600
1/28/87	4/22/87	84	2700
1/28/87	4/22/87	84	4830
1/29/87	4/23/87	84	4230
1/29/87	4/23/87	84	4920
1/29/87	4/23/87	84	4700
1/30/87	4/24/87	84	4010
1/30/87	4/24/87	84	3980
		Average:	4650

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 2

Specimen: Grout UBC

Date Made	Date Tested	Age days	Stress psi
12/11/87	3/03/88	83	5040
12/11/87	3/03/88	83	4090
12/11/87	3/03/88	83	5800
12/11/87	3/03/88	83	5060
12/11/87	3/03/88	83	4680
12/11/87	3/03/88	83	5240
12/10/87	3/03/88	84	4690
12/10/87	3/08/88	84	4630
12/10/87	3/08/88	84	4590
12/09/87	3/03/88	85	5420
12/09/87	3/03/88	85	4630
12/09/87	3/03/88	85	4370
12/08/87	3/03/88	86	3810
12/08/87	3/03/88	86	4190
12/08/87	3/08/88	91	3850
12/07/87	3/08/88	92	3250
12/07/87	3/08/88	92	2900
12/07/87	3/08/88	92	3060
		Average:	4410

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 3

Specimen: Grout UBC

Date Made	Date Tested	Age days	Stress psi
3/04/88	5/24/88	81	4550
3/04/88	5/24/88	81	4640
3/03/88	5/24/88	82	5170
3/03/88	5/24/88	82	4550
3/03/88	5/24/88	82	4630
3/02/88	5/24/88	83	4410
3/02/88	5/24/88	83	5760
3/02/88	5/24/88	83	6000
3/04/88	5/26/88	83	4600
3/01/88	5/24/88	84	5900
3/01/88	5/24/88	84	6430
3/01/88	5/24/88	84	7050
2/29/88	5/24/88	85	5750
2/29/88	5/24/88	85	5450
2/29/88	5/24/88	85	4880
		Average:	5320

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 1

Specimen: Masonry Prism

Date Made	Date Tested	Age days	Stress psi
2/02/87	4/20/87	77	5920
2/02/87	4/21/87	78	6390
2/02/87	4/22/87	79	5200
1/30/87	4/20/87	80	4840
2/02/87	4/23/87	80	5830
1/29/87	4/20/87	81	4950
1/30/87	4/21/87	81	5030
2/02/87	4/24/87	81	5420
2/02/87	4/24/87	81	6060
1/28/87	4/20/87	82	4980
1/29/87	4/21/87	82	5750
1/30/87	4/22/87	82	5220
1/28/87	4/21/87	83	5150
1/29/87	4/22/87	83	5240
1/30/87	4/23/87	83	5190
1/28/87	4/22/87	84	4700
1/29/87	4/23/87	84	5990
1/30/87	4/24/87	84	4940
1/28/87	4/23/87	85	5530
1/29/87	4/24/87	85	6360
1/29/87	4/24/87	85	5290
1/28/87	4/24/87	86	4350
1/28/87	4/24/87	86	5290
		Average:	5370

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 2

Specimen: Masonry Prism

Date Made	Date Tested	Age days	Stress psi
12/12/87	3/25/88	104	4840
12/11/87	3/25/88	105	5540
12/11/87	3/25/88	105	5080
12/10/87	3/25/88	106	4300
12/10/87	3/25/88	106	4900
12/09/87	3/25/88	107	5280
12/09/87	3/28/88	107	4970
12/11/87	3/28/88	108	4900
12/11/87	3/28/88	108	5350
12/12/87	3/28/88	108	5300
12/12/87	3/28/88	108	5210
12/09/87	3/28/88	110	4850
12/09/87	3/28/88	110	4690
12/10/87	3/29/88	110	5030
12/10/87	3/29/88	110	5400
12/08/87	3/28/88	111	4130
12/08/87	3/28/88	111	4280
12/08/87	3/28/88	111	4800
12/08/87	3/28/88	111	4280
		Average:	4900

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 3

Specimen: Masonry Prism

Date Made	Date Tested	Age days	Stress psi
3/04/88	5/04/88	61	5060
3/04/88	5/04/88	61	4970
3/04/88	5/05/88	62	5330
3/04/88	5/06/88	63	5470
3/01/88	5/04/88	64	4860
3/01/88	5/04/88	64	4750
3/02/88	5/05/88	64	4050
3/03/88	5/06/88	64	3740
3/03/88	5/06/88	64	3690
3/03/88	5/06/88	64	3910
3/01/88	5/05/88	65	4650
3/02/88	5/06/88	65	4600
3/02/88	5/06/88	65	4350
2/29/88	5/06/88	67	4560
2/29/88	5/06/88	67	4800
2/29/88	5/06/88	67	4820
3/03/88	5/09/88	67	4140
3/02/88	5/09/88	68	4430
2/29/88	5/09/88	69	4150
		Average:	4540

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 1

Specimen: Mortar Cube

Date Made	Date Tested	Age days	Stress psi
2/02/87	3/05/87	31	2800
1/30/87	3/05/87	34	3260
1/30/87	3/05/87	34	3210
1/30/87	3/05/87	34	3280
1/28/87	3/04/87	35	3890
1/29/87	3/05/87	35	2240
1/29/87	3/05/87	35	2500
1/29/87	3/05/87	35	2230
1/28/87	3/05/87	36	3660
1/28/87	3/05/87	36	3500
		Average:	3060

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 2

Specimen: Mortar Cube

Date Made	Date Tested	Age days	Stress psi
12/11/87	1/15/88	35	3540
12/11/87	1/15/88	35	3630
12/11/87	1/15/88	35	3580
12/10/87	1/15/88	36	3300
12/10/87	1/15/88	36	3140
12/10/87	1/15/88	36	3150
12/09/87	1/15/88	37	3100
12/09/87	1/15/88	37	3010
12/09/87	1/15/88	37	2930
12/08/87	1/15/88	38	3400
12/08/87	1/15/88	38	3180
12/08/87	1/15/88	38	3110
12/07/87	1/15/88	39	3400
12/07/87	1/15/88	39	3180
12/07/87	1/15/88	39	3760
		Average:	3290

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 3

Specimen: Mortar Cube

Date Made	Date Tested	Age days	Stress psi
3/04/88	4/18/88	45	3210
3/04/88	4/18/88	45	3350
3/04/88	4/18/88	45	3010
3/03/88	4/18/88	46	3590
3/03/88	4/18/88	46	3600
3/03/88	4/18/88	46	3110
3/02/88	4/18/88	47	3480
3/02/88	4/18/88	47	2900
3/02/88	4/18/88	47	3550
3/01/88	4/18/88	48	3430
3/01/88	4/18/88	48	3410
3/01/88	4/18/88	48	3480
2/29/88	4/18/88	49	3980
2/29/88	4/18/88	49	3860
2/29/88	4/18/88	49	4360
		Average:	3490

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 1

Specimen: Mortar Cyl.

Date Made	Date Tested	Age days	Stress psi
2/02/87	3/06/87	34	3420
2/02/87	3/06/87	34	4350
1/30/87	3/06/87	35	3940
1/30/87	3/06/87	35	3790
1/29/87	3/06/87	36	3500
1/29/87	3/06/87	36	3580
1/28/87	3/06/87	37	4300
1/28/87	3/06/87	37	4490
1/30/87	3/09/87	38	4380
1/29/87	3/09/87	39	4280
1/28/87	3/09/87	40	4920
		Average:	4090

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 2

Specimen: Mortar Cyl.

Date Made	Date Tested	Age days	Stress psi
12/10/87	1/04/88	25	2180
12/10/87	1/04/88	25	2900
12/10/87	1/04/88	25	3060
12/09/87	1/04/88	26	3130
12/09/87	1/04/88	26	2960
12/09/87	1/04/88	26	2990
12/08/87	1/04/88	27	3210
12/08/87	1/04/88	27	3360
12/08/87	1/04/88	27	3250
12/07/87	1/04/88	28	3740
12/07/87	1/04/88	28	3570
12/11/87	1/04/88	35	3050
12/11/87	1/04/88	35	3010
12/11/87	1/04/88	35	3100
12/11/87	1/04/88	35	2440
12/11/87	1/04/88	35	3120
12/11/87	1/04/88	35	2270
12/11/87	1/04/88	35	2630
12/11/87	1/04/88	35	2160
12/11/87	1/04/88	35	2500
12/11/87	1/04/88	35	2690
		Average:	2920

TCCMAR PROJECT - MATERIAL PROPERTIES

COMPRESSION TESTS

WALLS GROUP 3

Specimen: Mortar Cyl.

Date Made	Date Tested	Age days	Stress psi
3/01/88	4/12/88	42	2680
3/04/88	4/18/88	45	2380
3/04/88	4/18/88	45	2770
3/04/88	4/18/88	45	2810
3/03/88	4/18/88	46	3210
3/03/88	4/18/88	46	3420
3/02/88	4/18/88	47	3200
3/02/88	4/18/88	47	2970
3/02/88	4/18/88	47	3200
3/01/88	4/18/88	48	4470
3/01/88	4/18/88	48	3290
2/29/88	4/18/88	49	4170
2/29/88	4/18/88	49	4500
2/29/88	4/18/88	49	4330
		Average:	3390

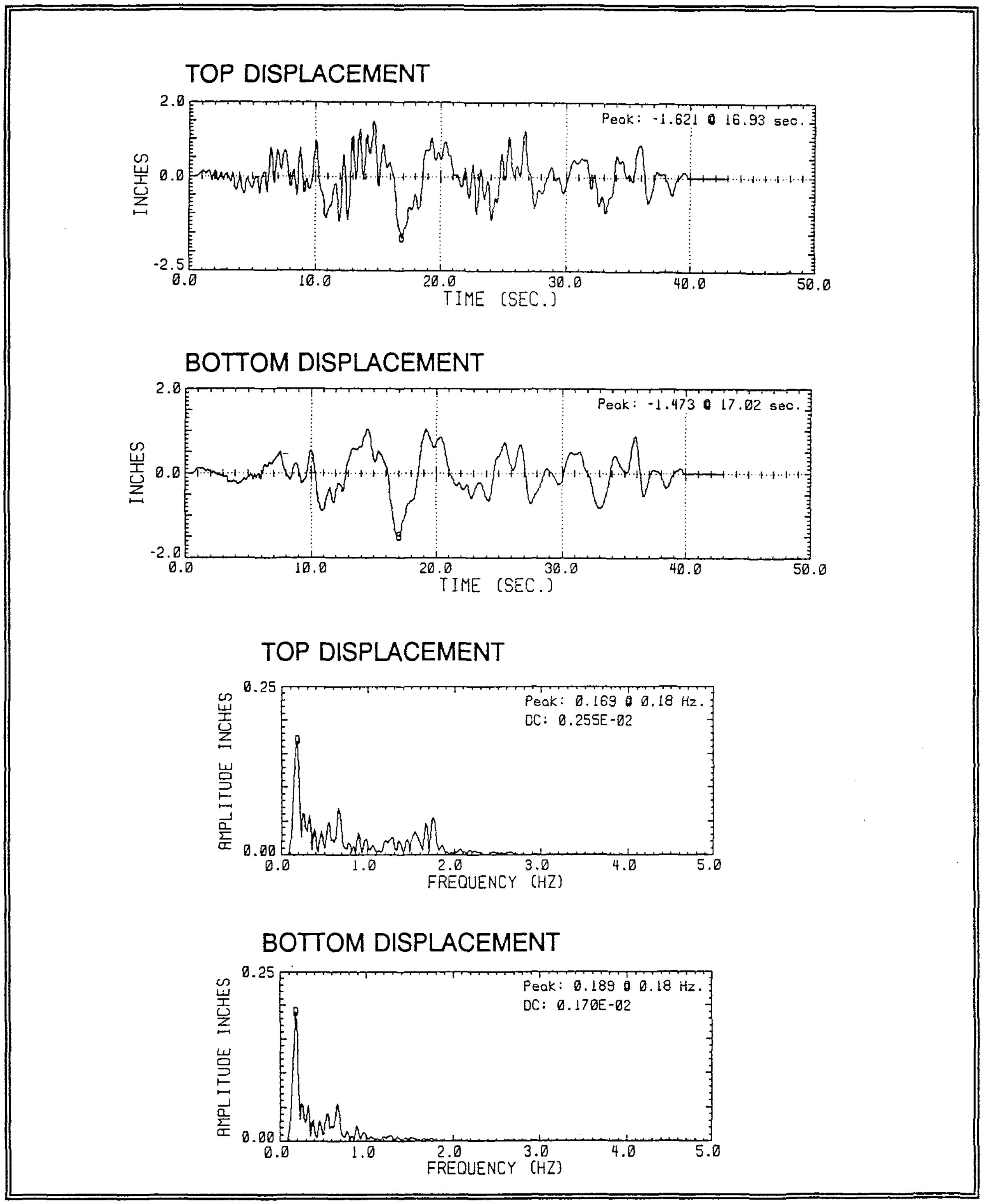
TCCMAR PROJECT - MATERIAL PROPERTIES

REINFORCEMENT TENSILE TEST RESULTS

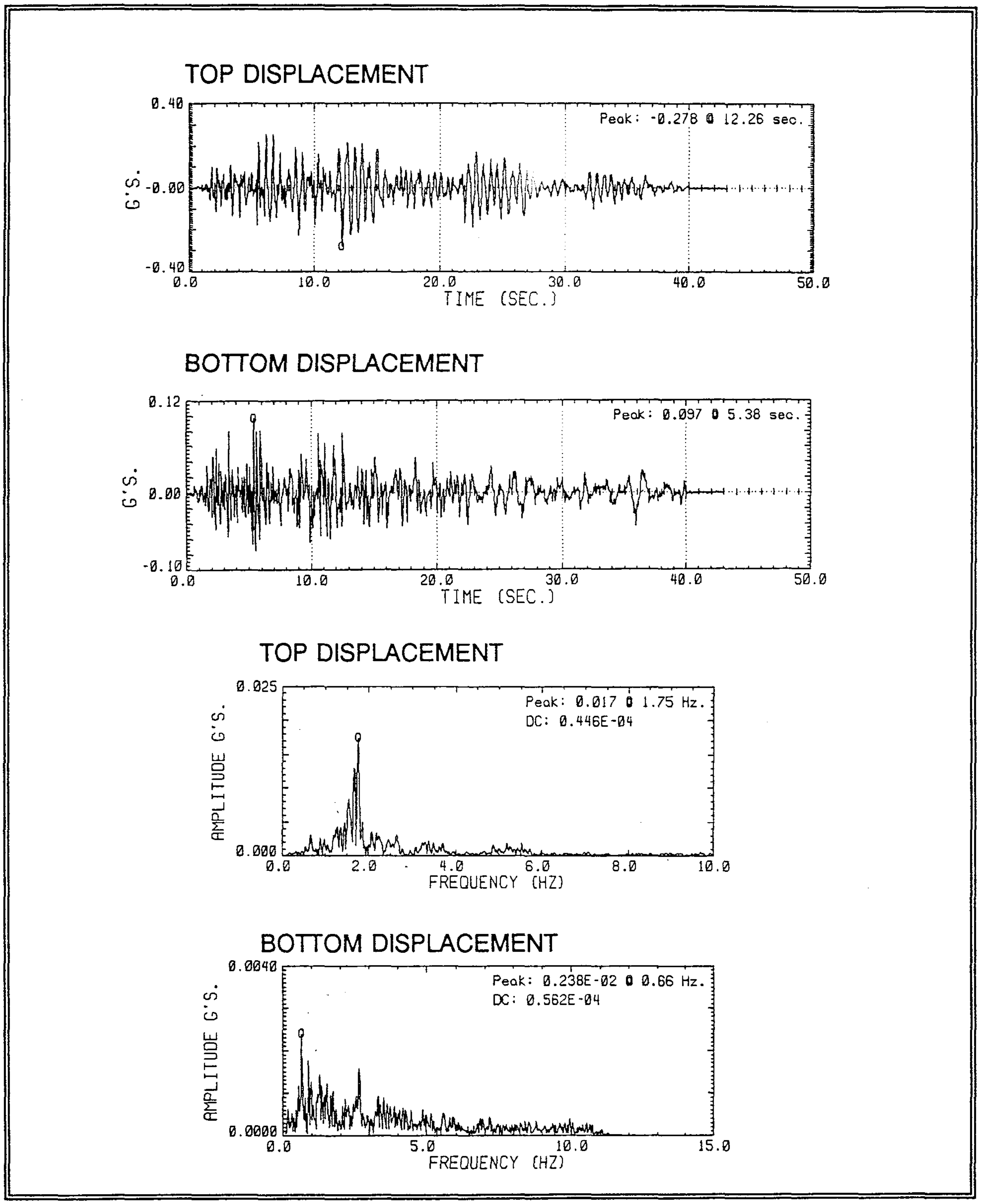
Bar Size	Test Date	Yield Strain in/in	Yield Stress ksi	Ultimate Strain in/in	Ultimate Stress ksi	Rupture Strain in/in	Rupture Stress ksi
3	11/16/87	0.0025	71.4	0.12	107	0.21	79
3	11/16/87	0.0022	70.3	0.10	131	0.15	85
3	11/16/87	0.0026	71.7	0.13	108	0.22	80
3	11/16/87	0.0022	72.6	0.12	110	0.26	84
3	11/16/87		74.5		109		
		======	====	====	===	====	====
	Average:	0.0024	72.1	0.12	113	0.21	82
5	11/16/87		70.6	0.10	116		
5	11/16/87		71.6	0.12	116	0.19	103
5	11/16/87		71.5	0.11	116	0.21	98
5	11/16/87		71.4	0.11	117	0.22	96
5	1/12/88		71.1	0.11	115	0.21	95
5	1/12/88		70.4	0.11	115	0.21	95
5	1/12/88		69.8	0.10	118		
		======	====	====	===	====	====
	Average:		70.9	0.11	116	0.21	97
7	1/12/88	0.0022	62.4	0.12	106		
7	1/12/88	0.0023	62.4	0.12	106		
7	1/12/88	0.0022	63.6	0.11	107	0.27	86
		======	====	====	===	====	====
	Average:	0.0022	62.8	0.12	106	0.27	86

APPENDIX C

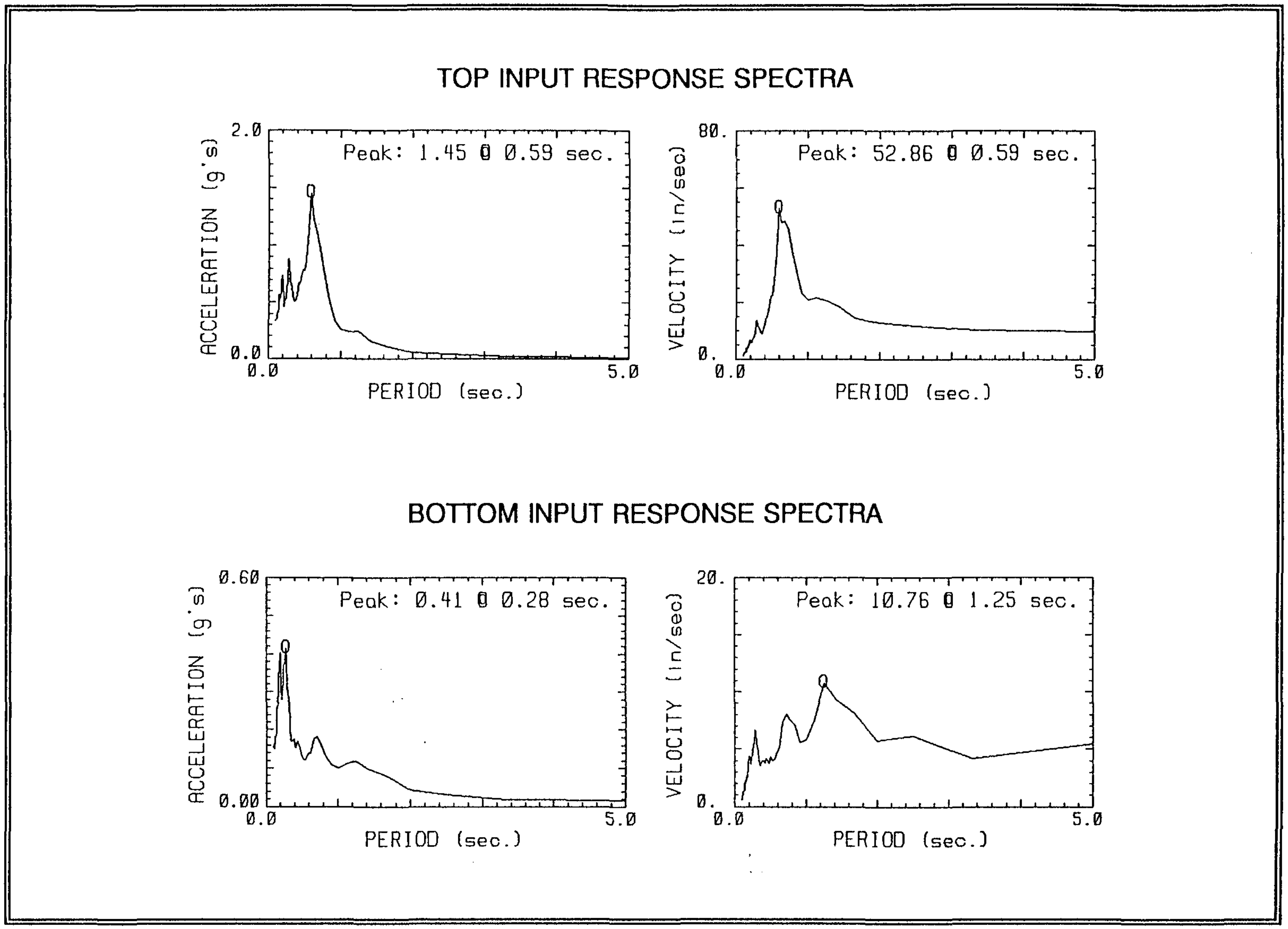
INPUT MOTIONS



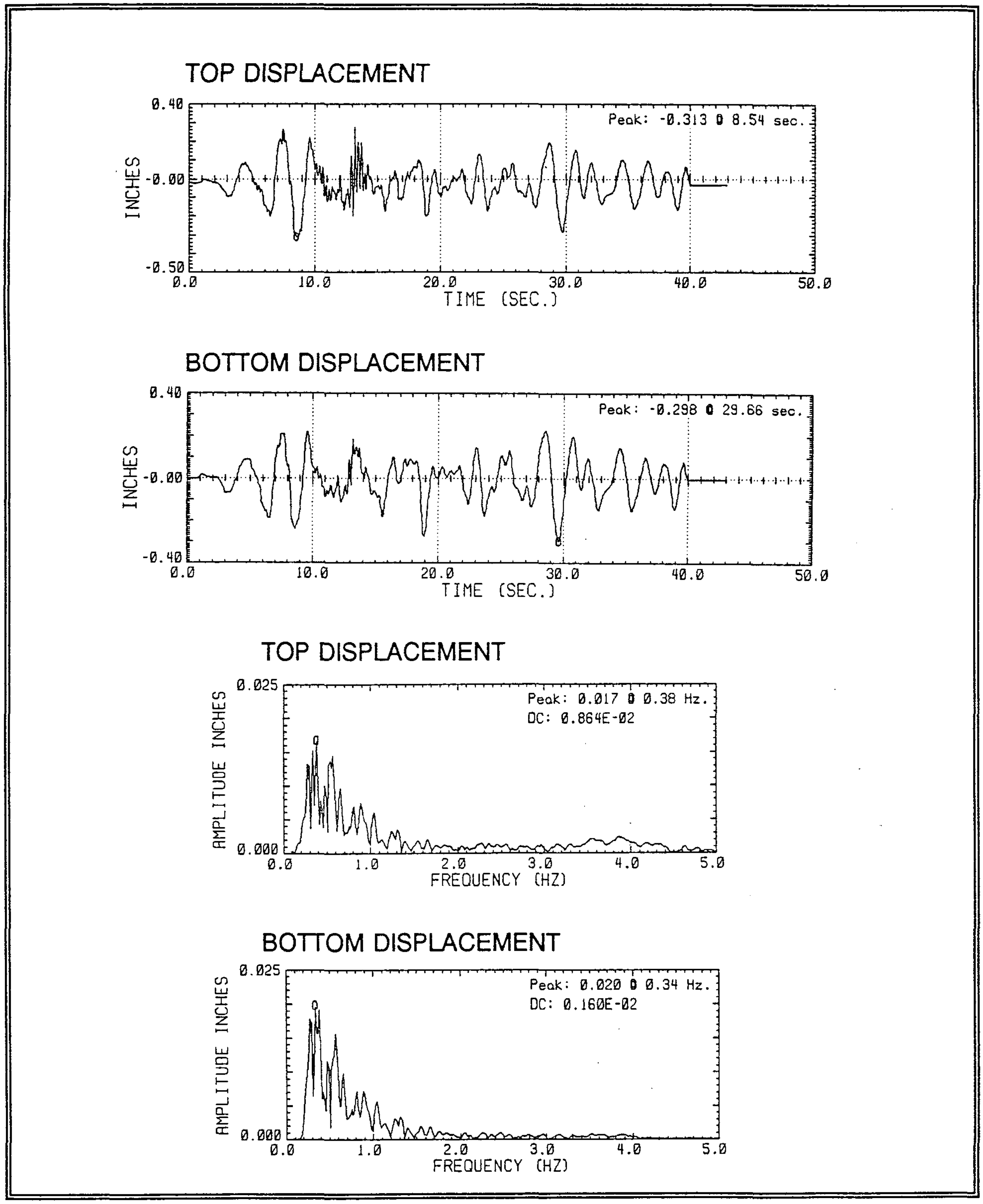
MS1 - 0.1EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



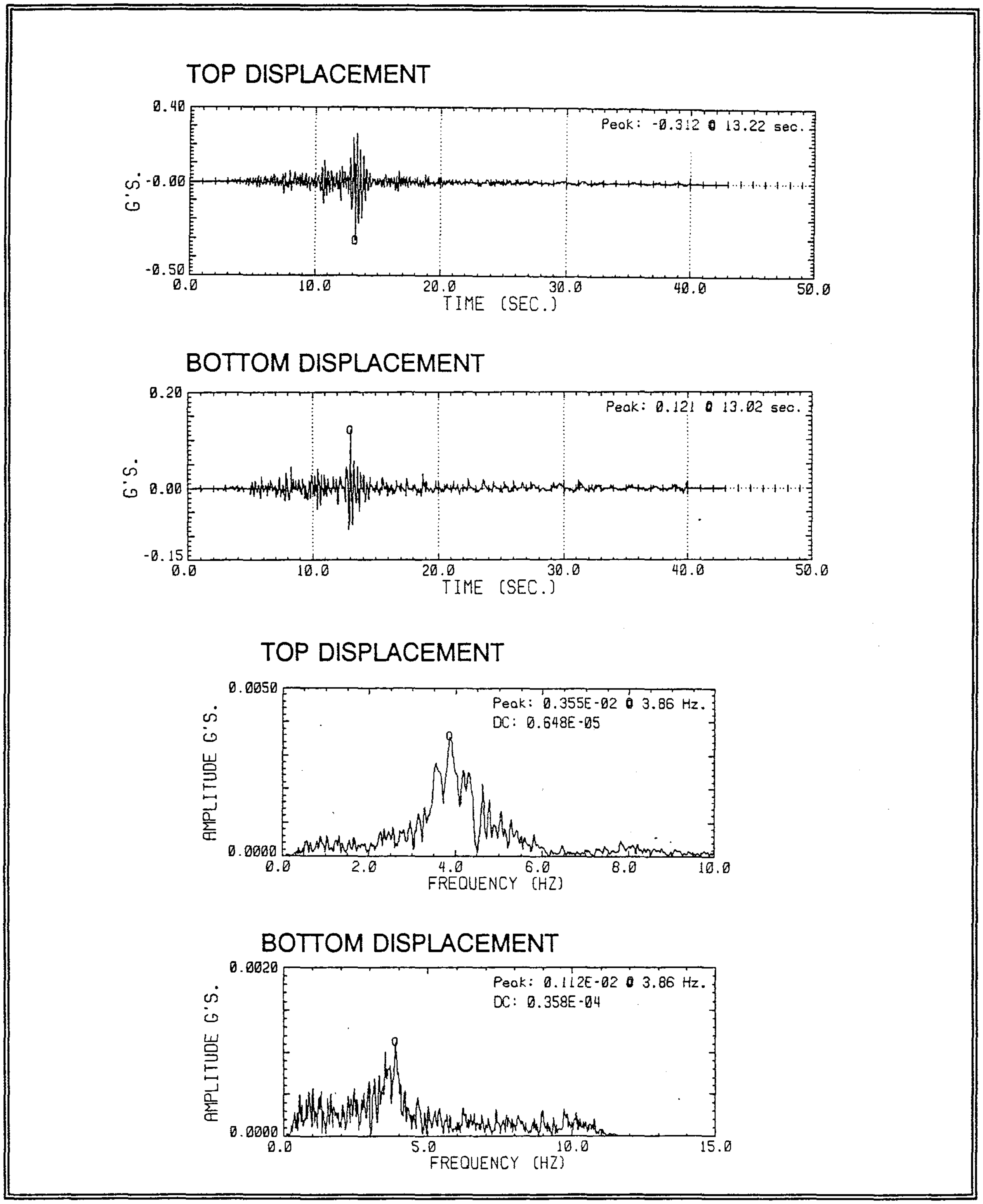
MS1 - 0.1EPA: Input Acceleration at Top and Bottom Actuators
Time Histories and Fourier Amplitude Spectra



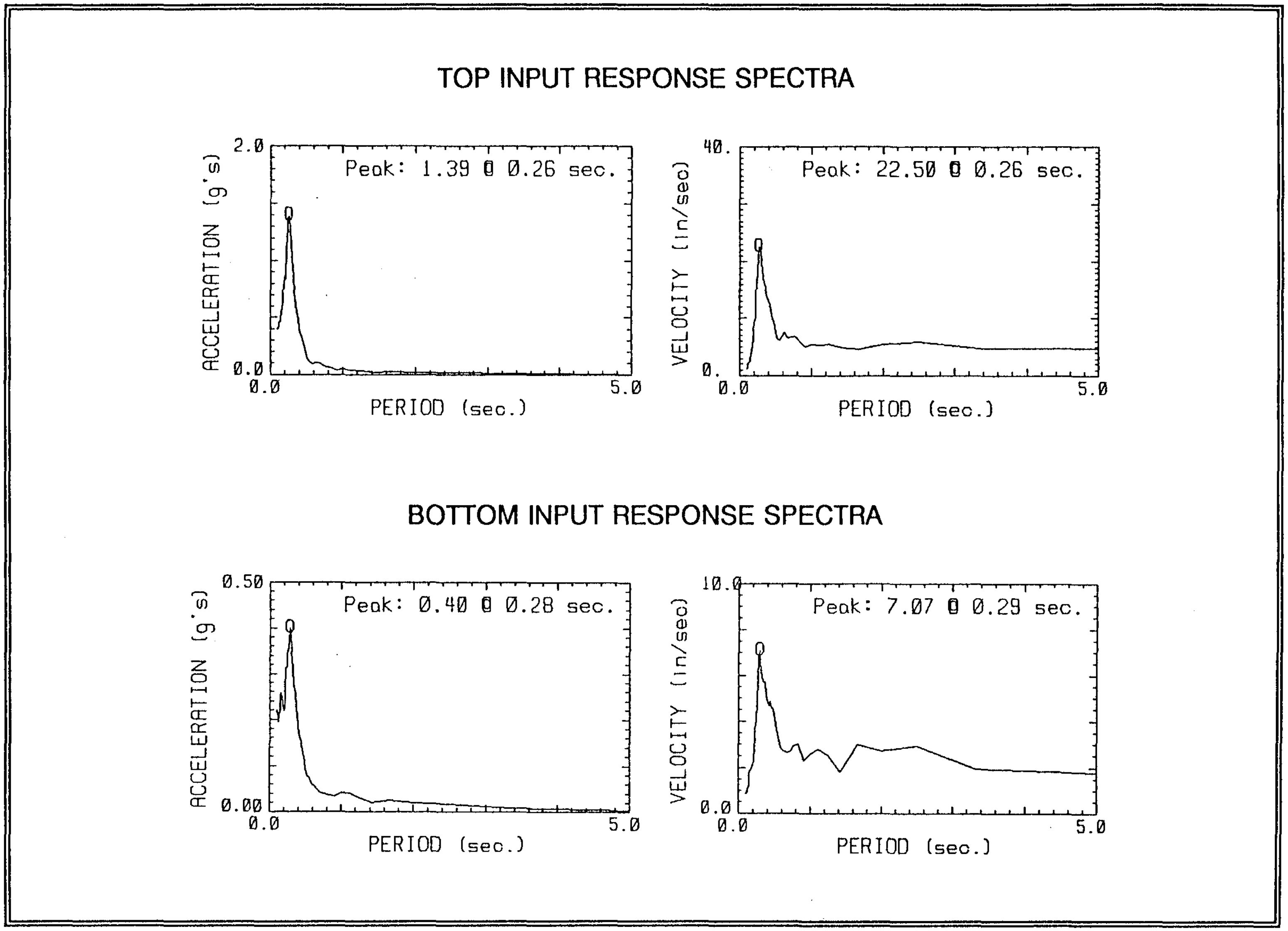
MS1 - 0.1EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



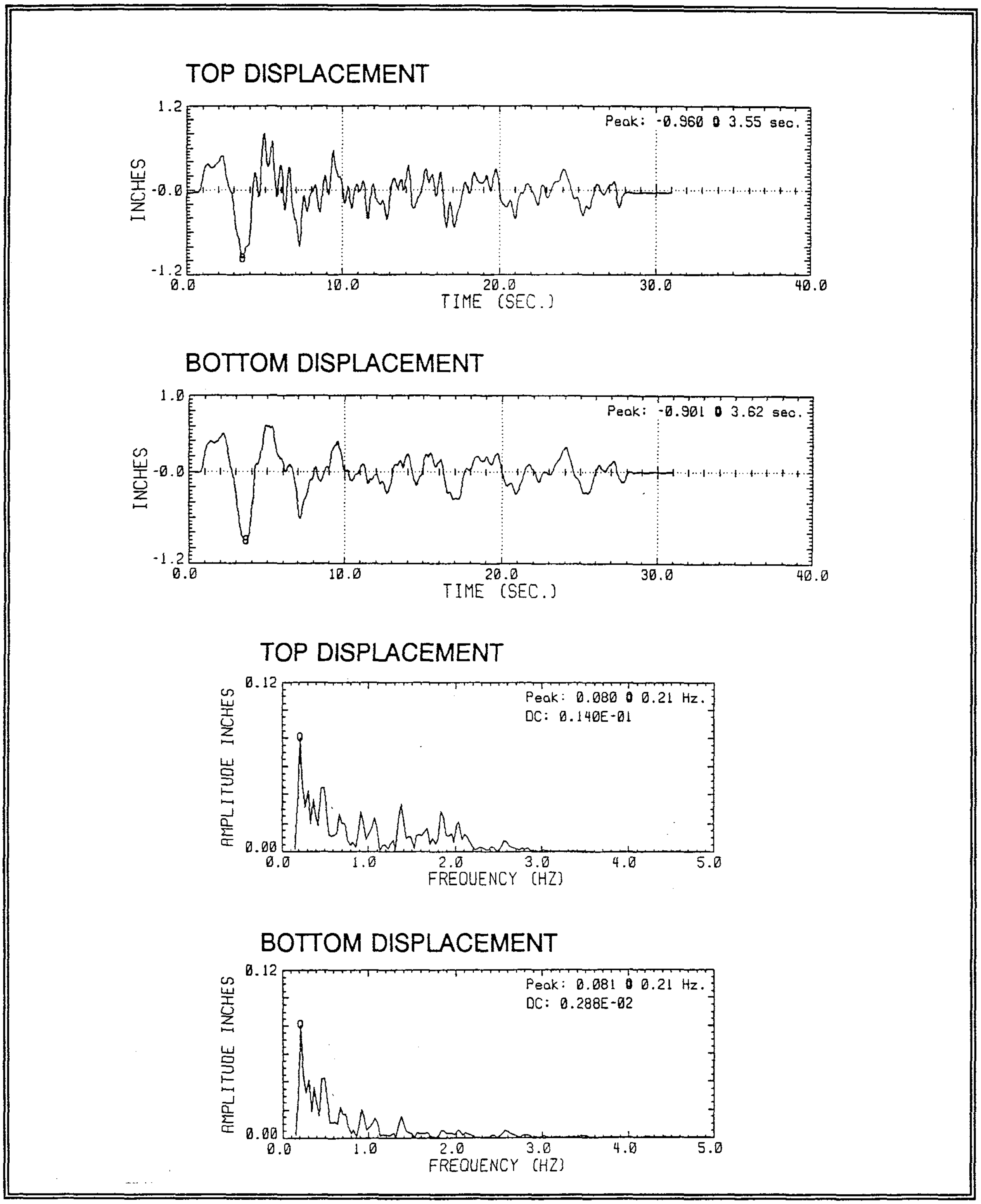
MS2 - 0.1EPA: Input Displacement at Top and Bottom Actuators
Time Histories and Fourier Amplitude Spectra



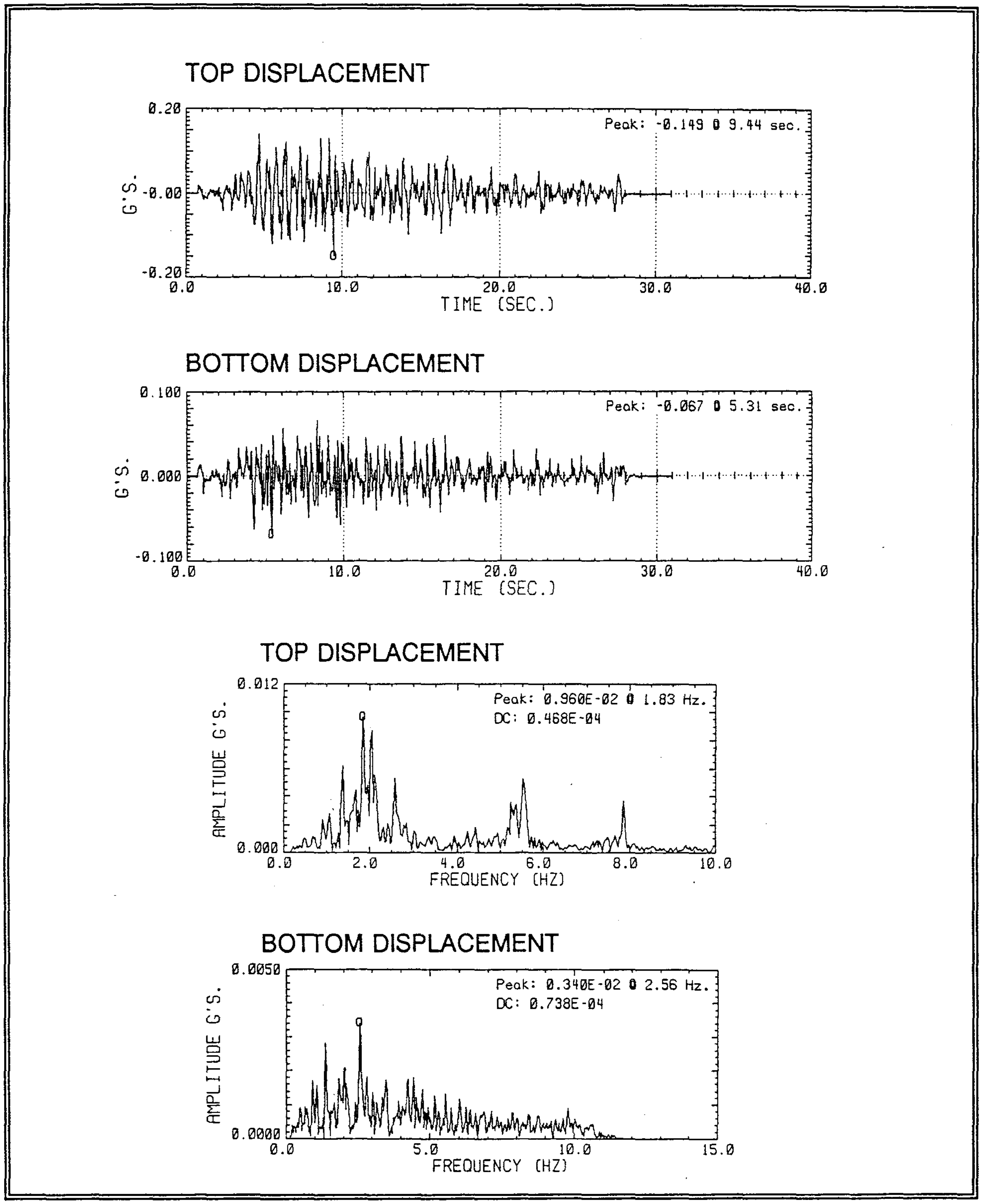
MS2 - 0.1EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



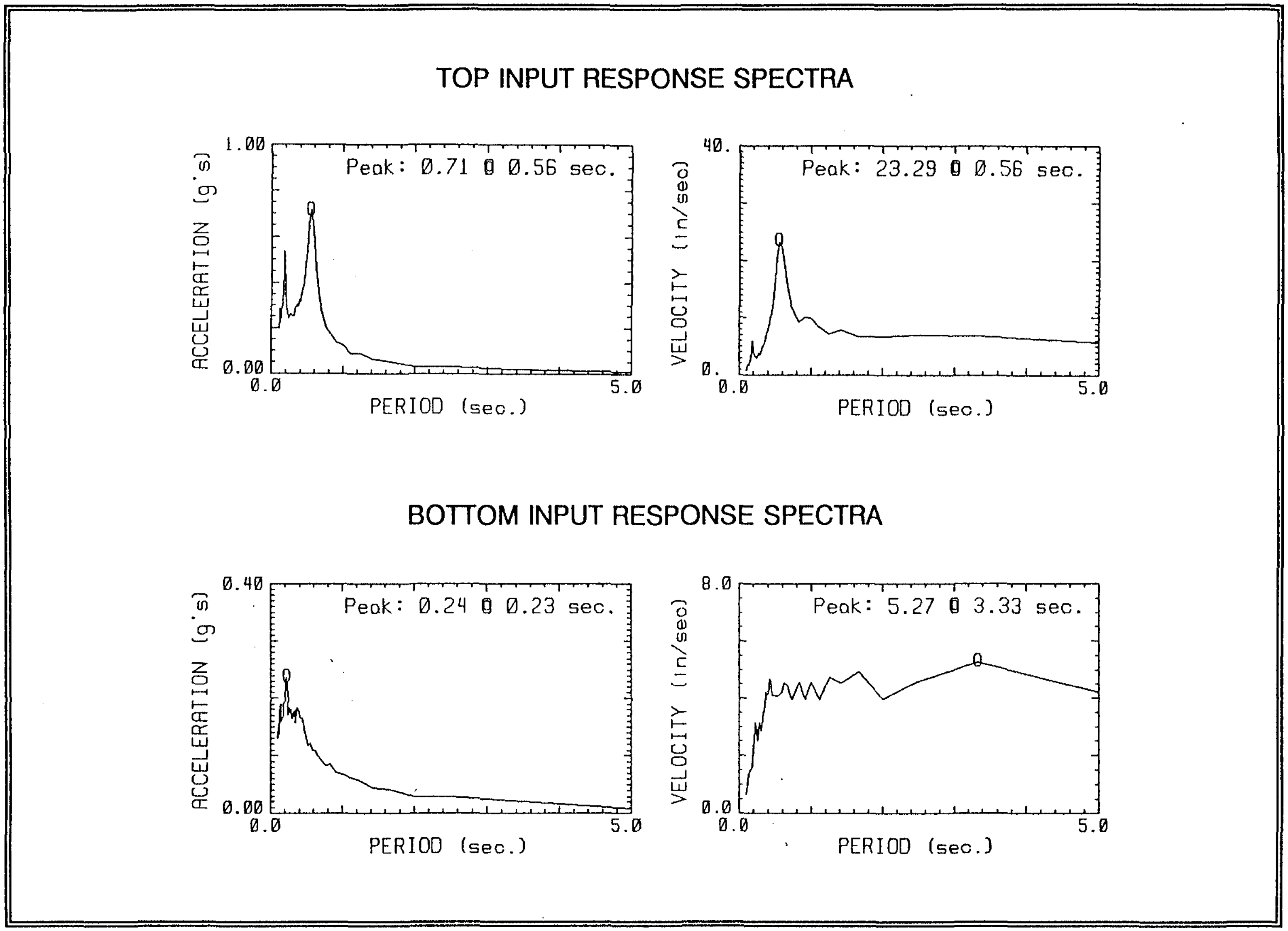
MS2 - 0.1EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



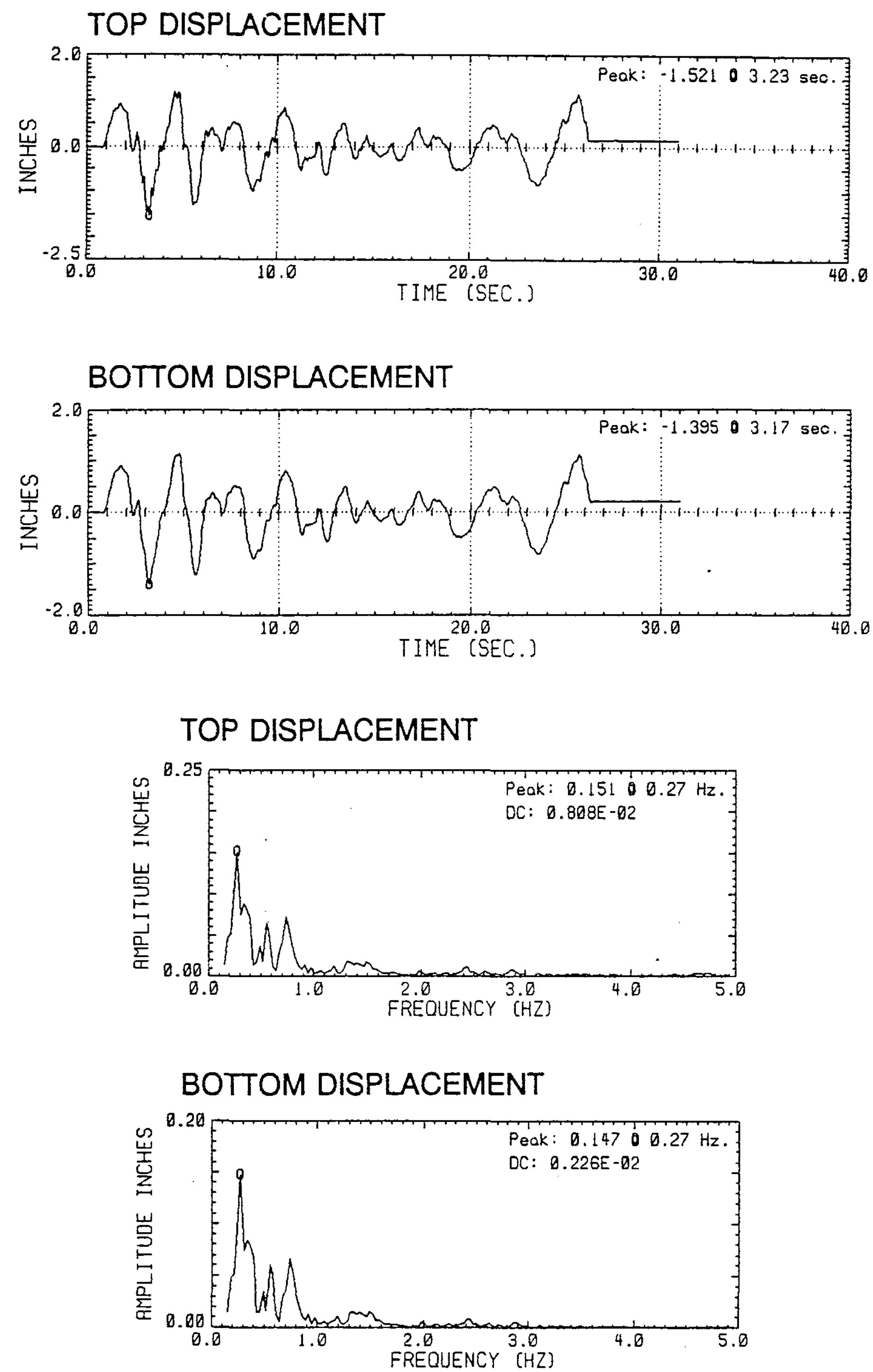
TAFT1 - 0.1EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



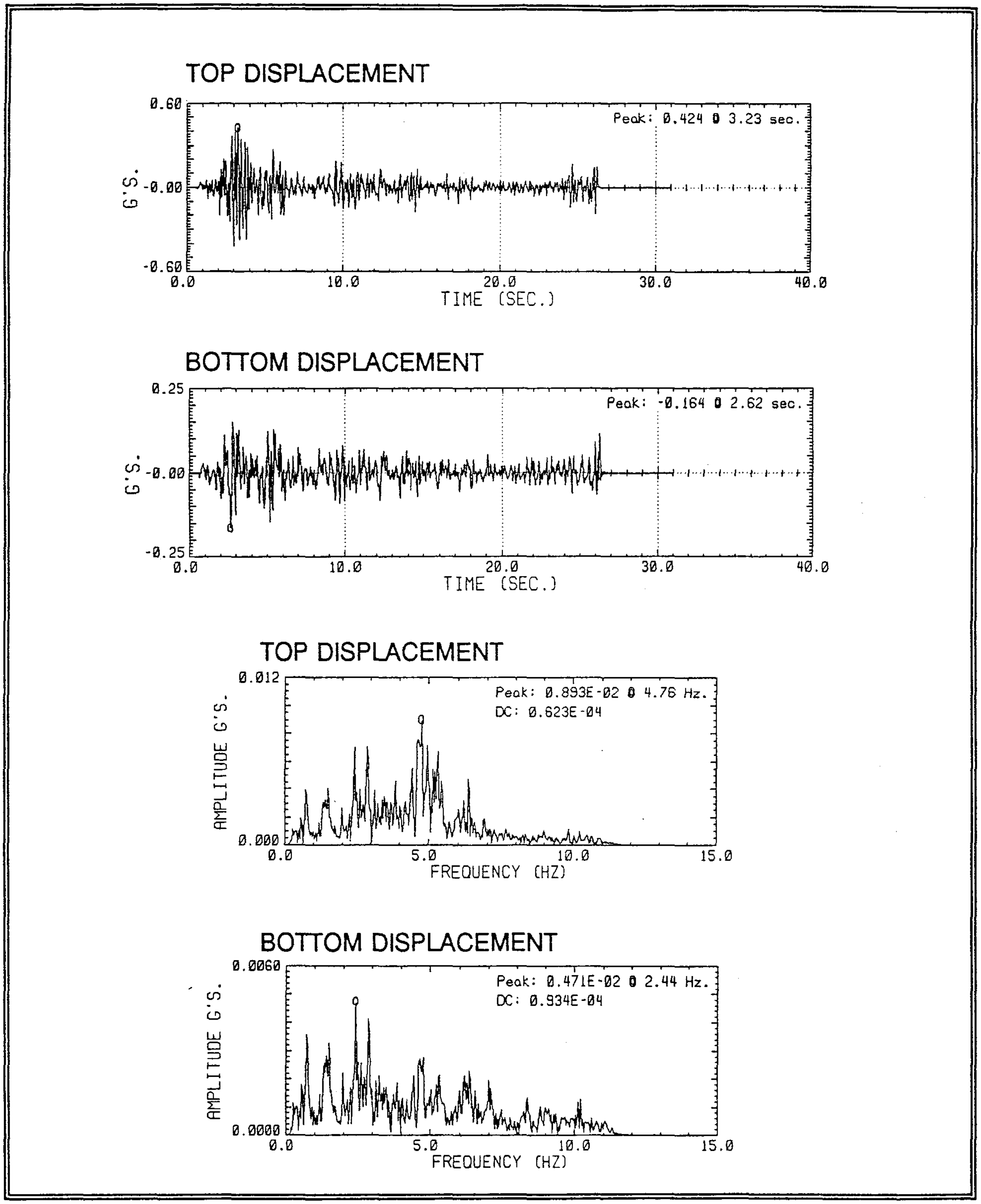
TAFT1 - 0.1EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



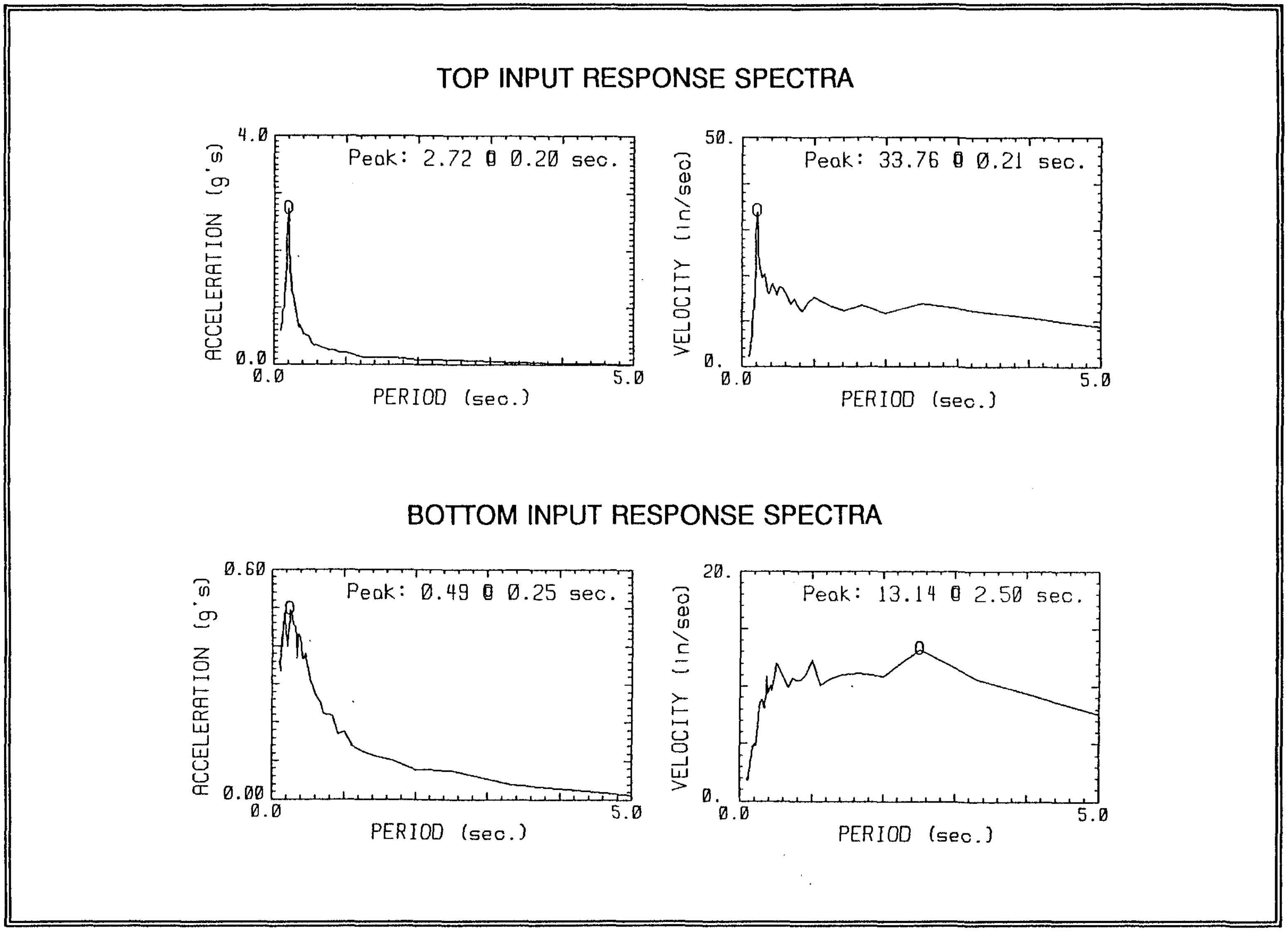
TAFT1 - 0.1EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



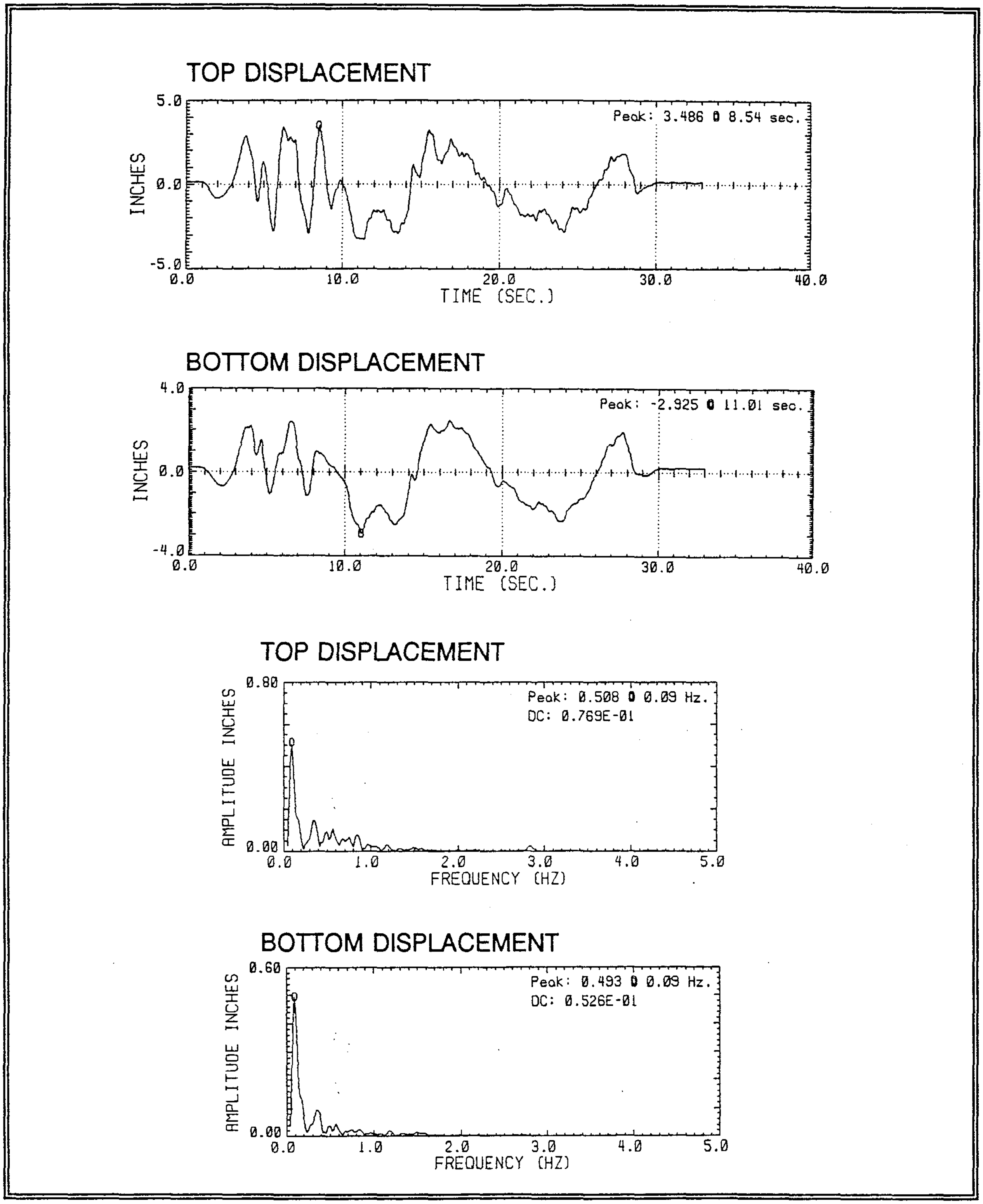
ELC1 - 0.1EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



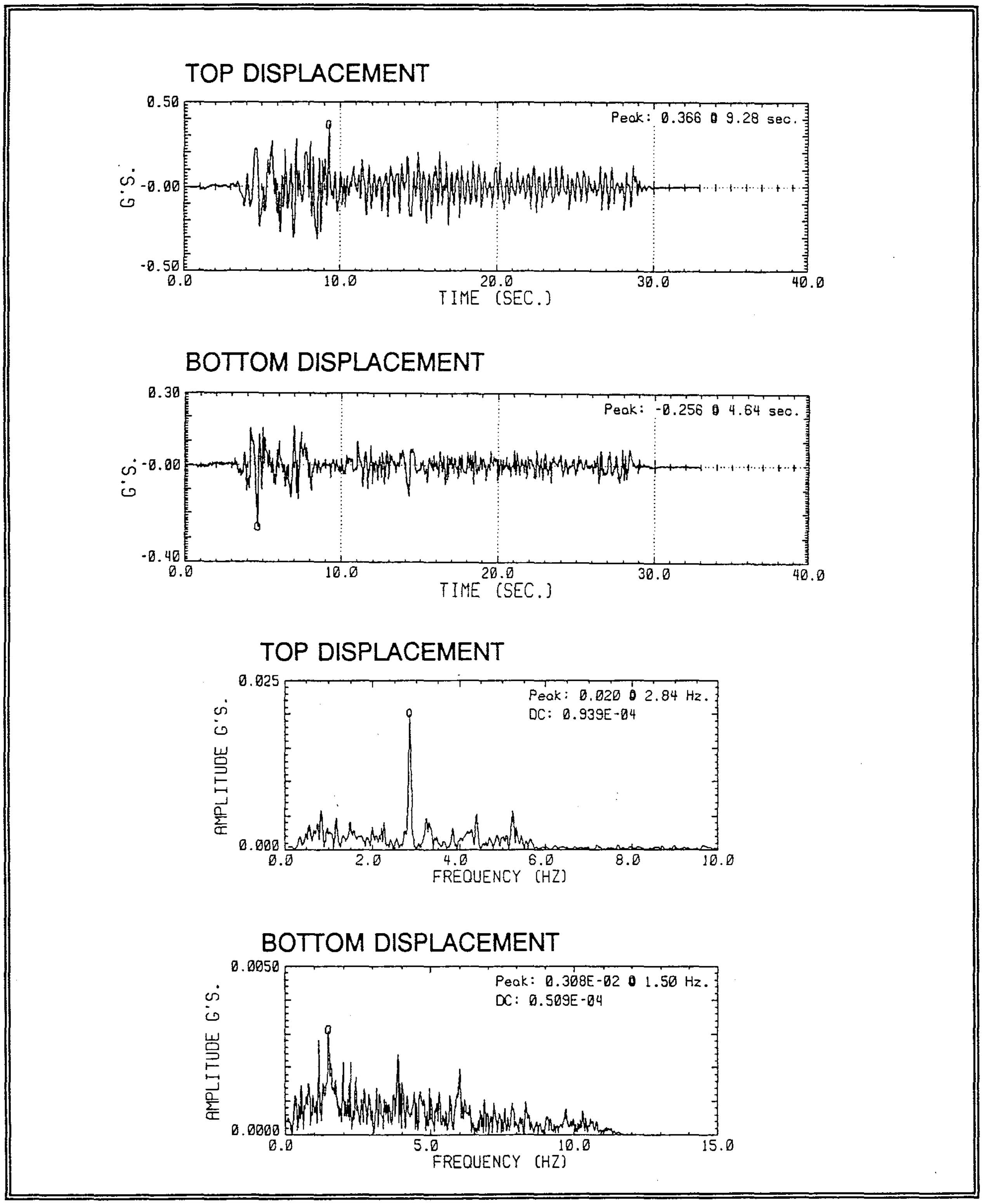
ELC1 - 0.1EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



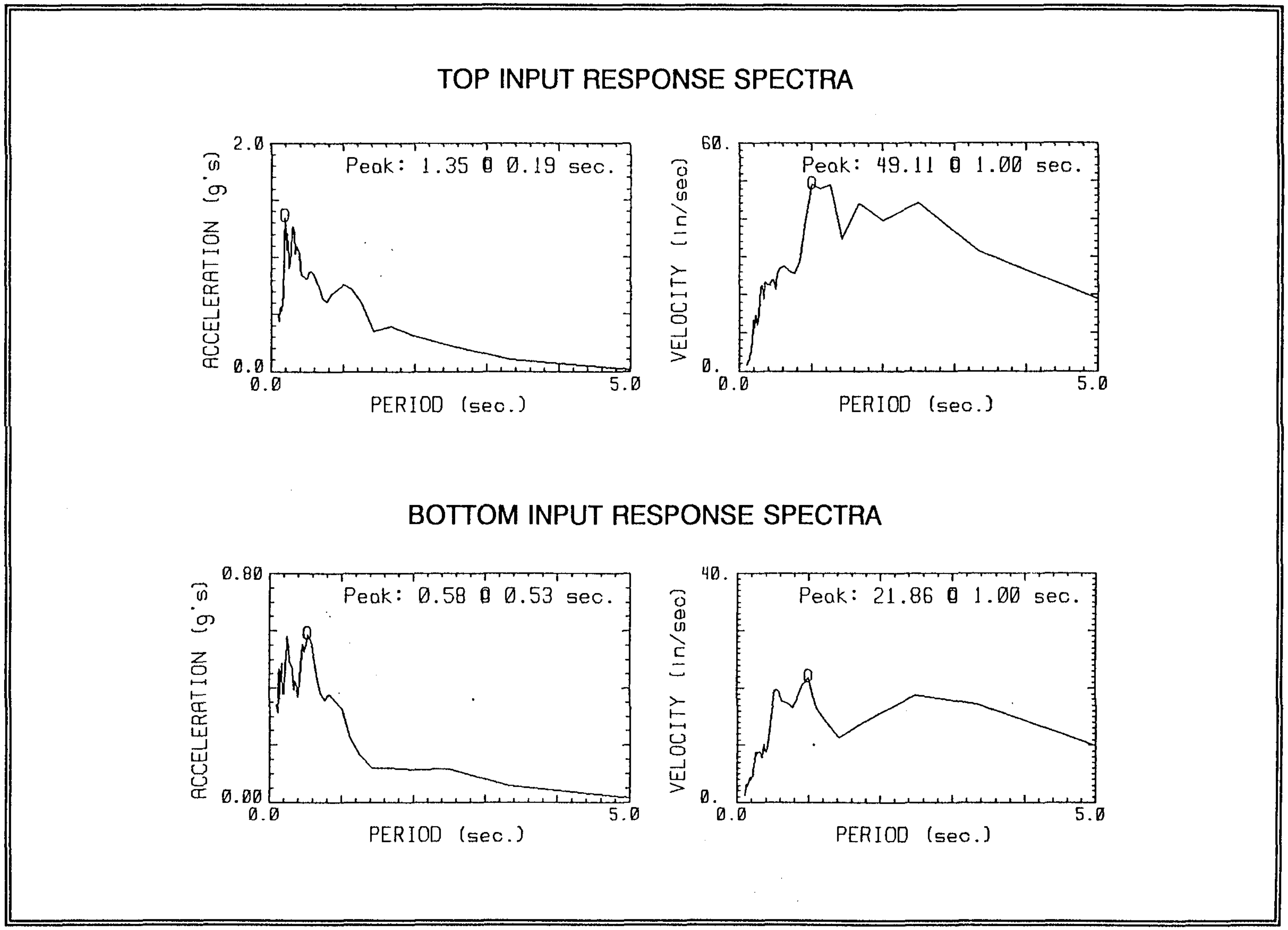
ELC1 - 0.1EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



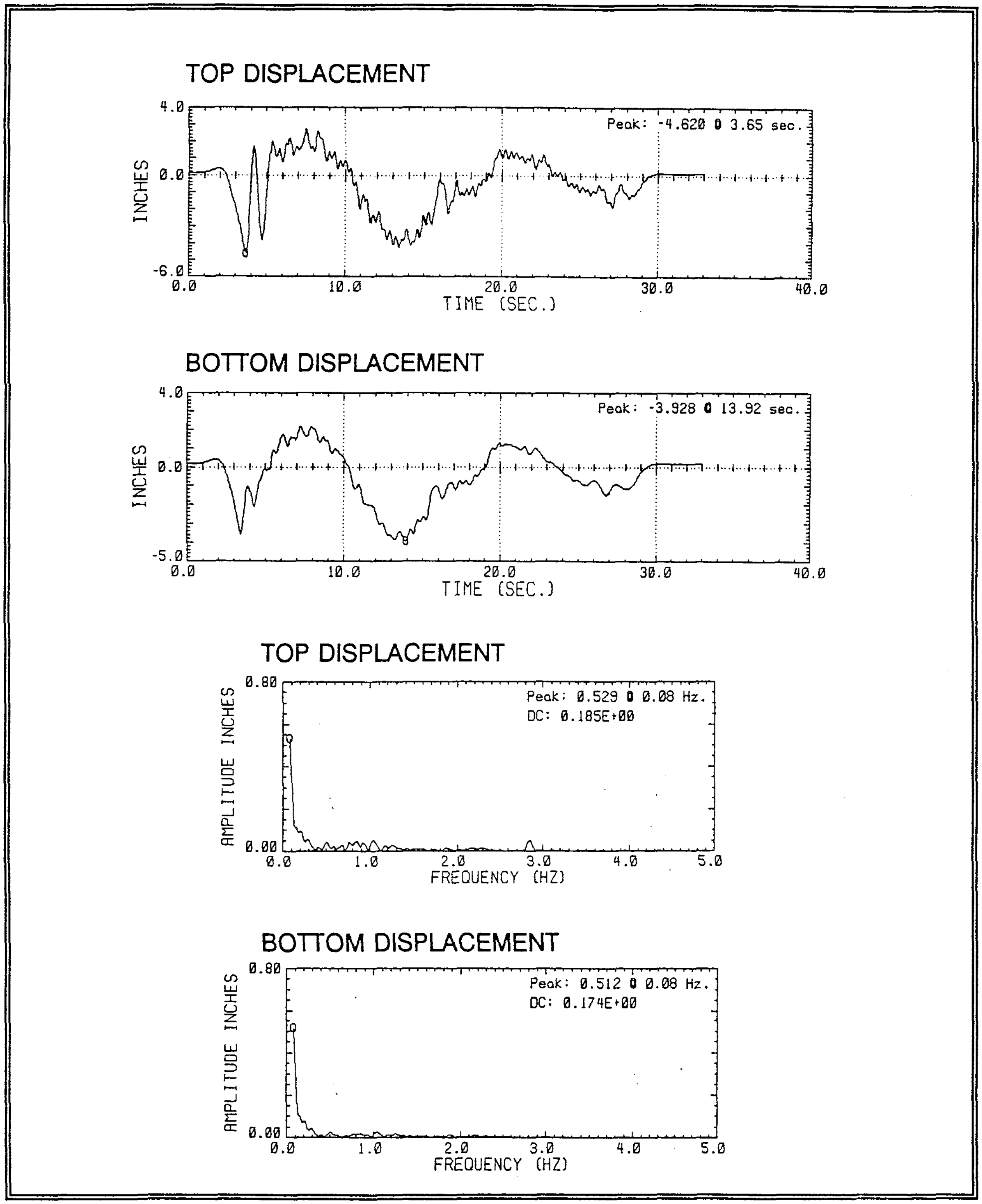
MS3 - 0.2EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



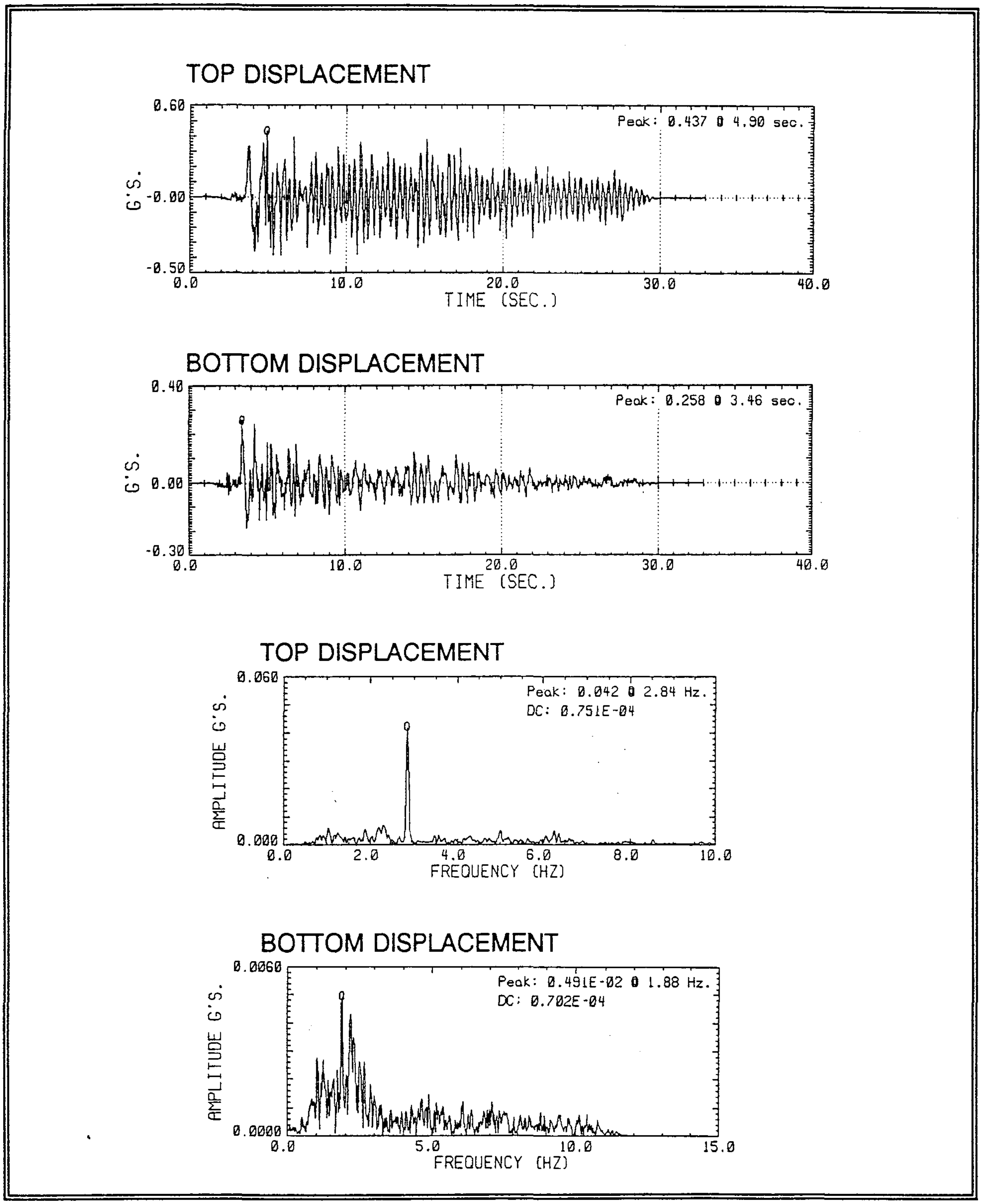
MS3 - 0.2EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



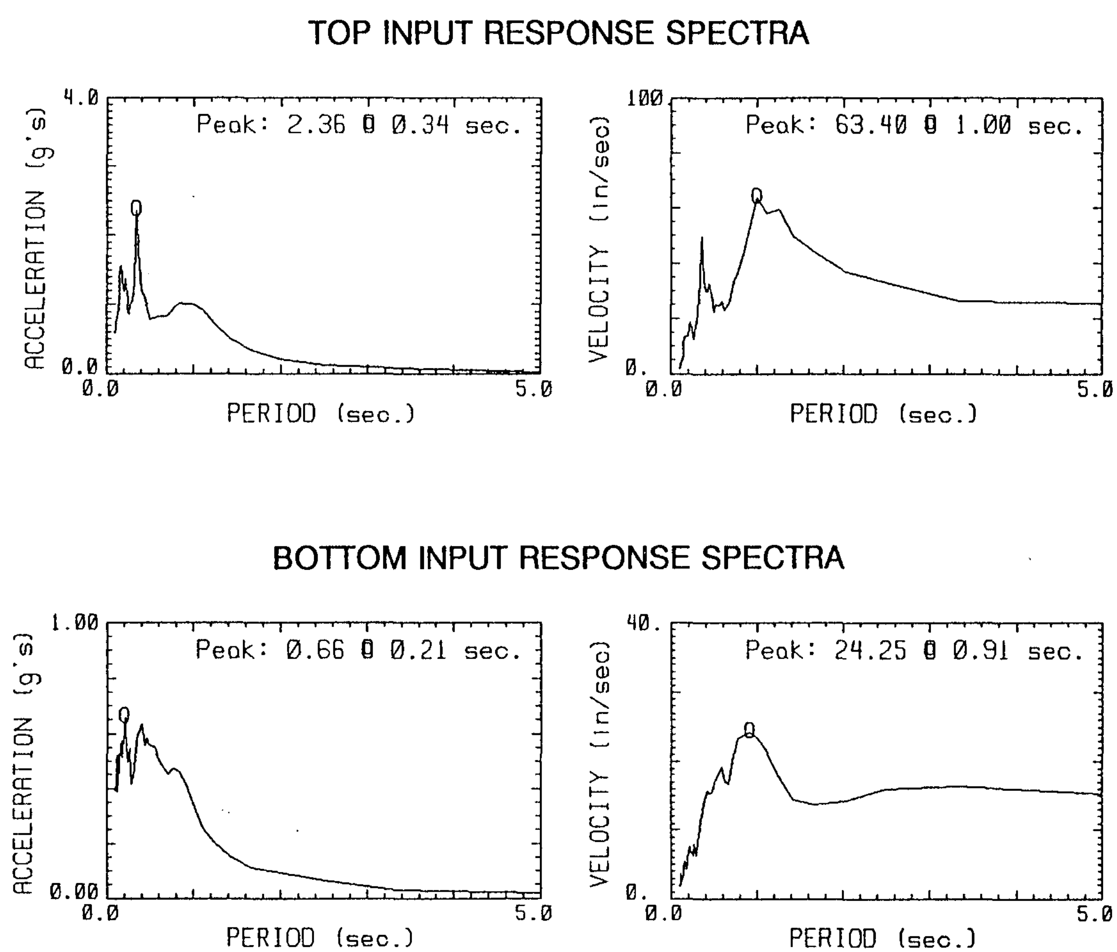
MS3 - 0.2EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



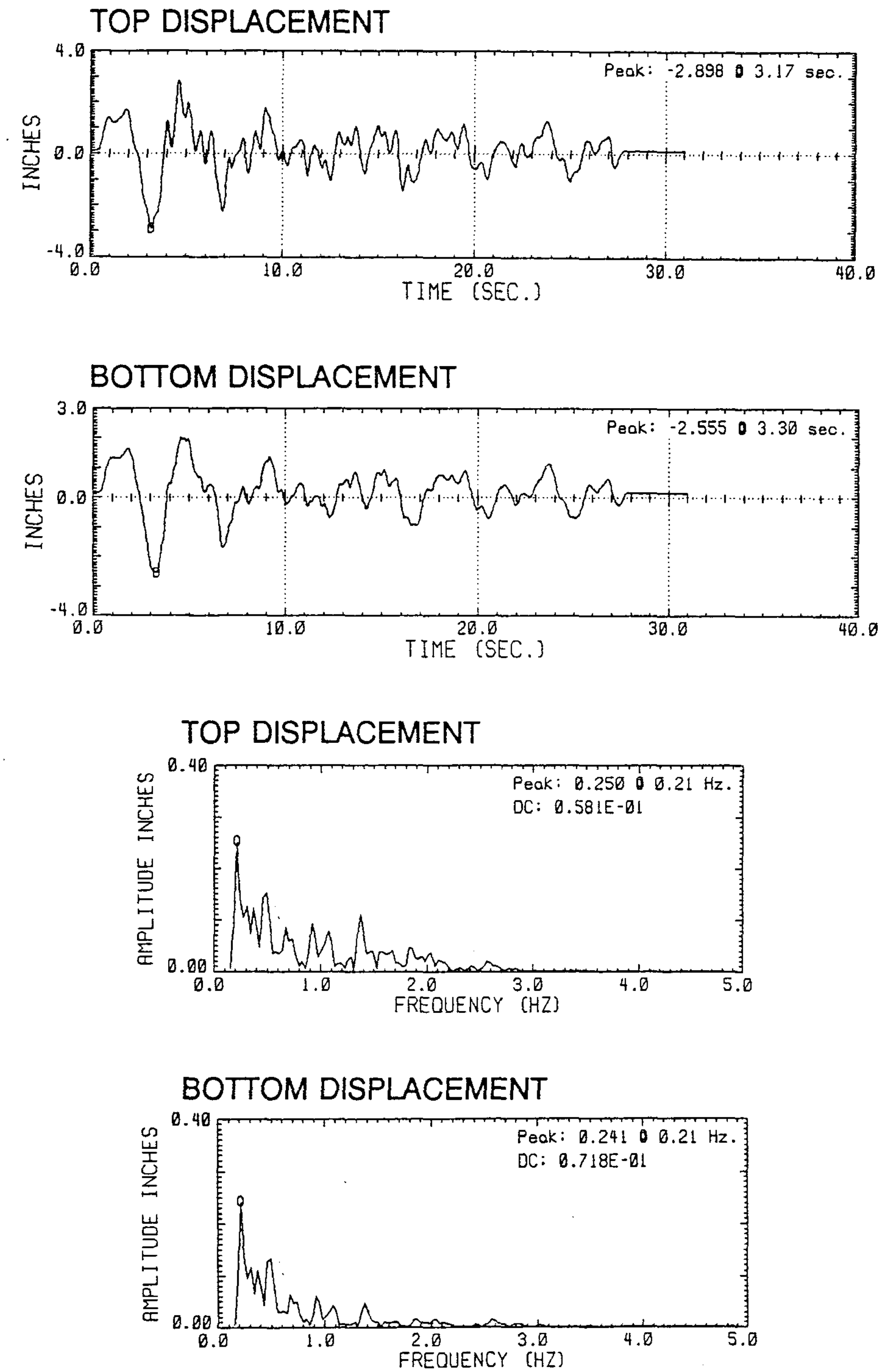
MS4 - 0.2EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



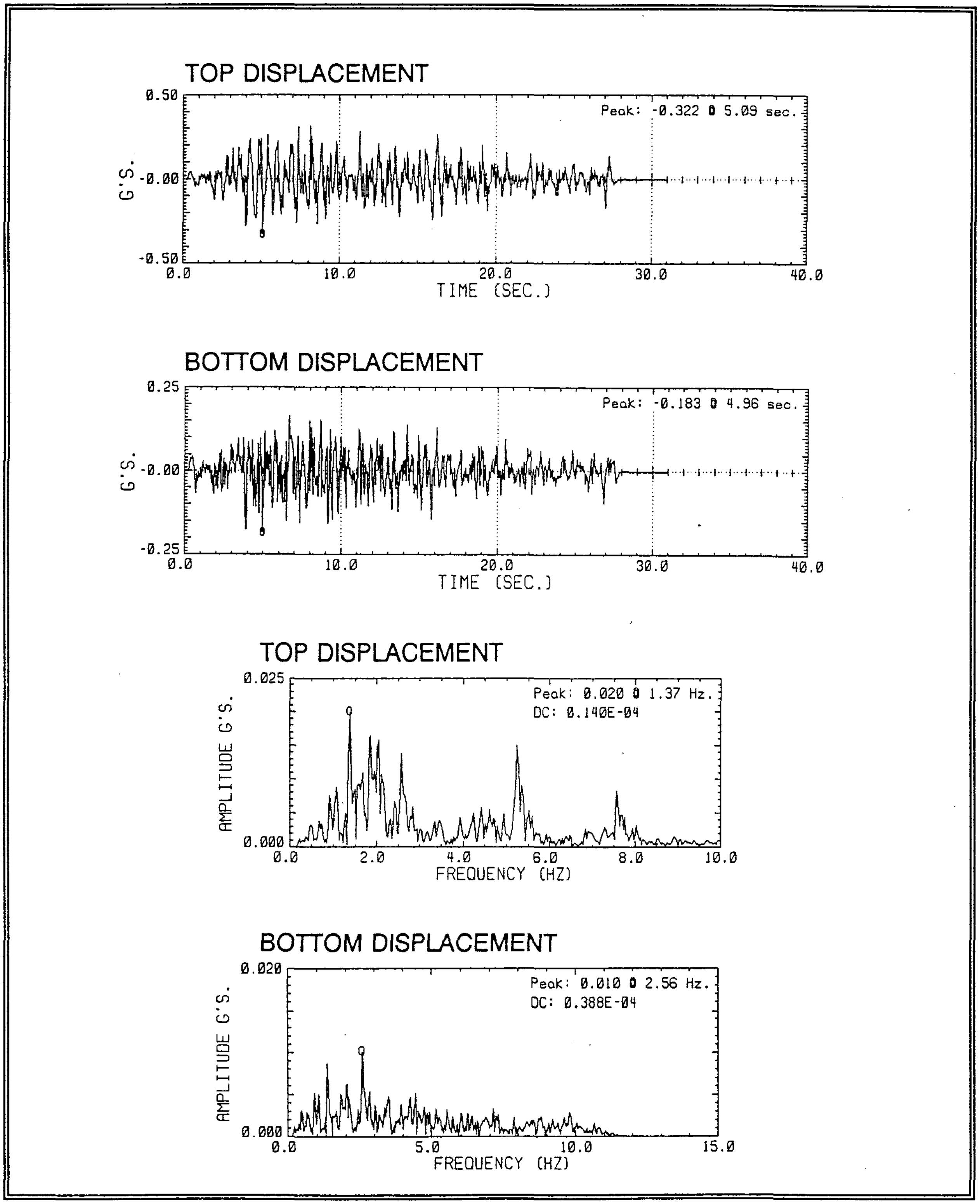
MS4 - 0.2EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



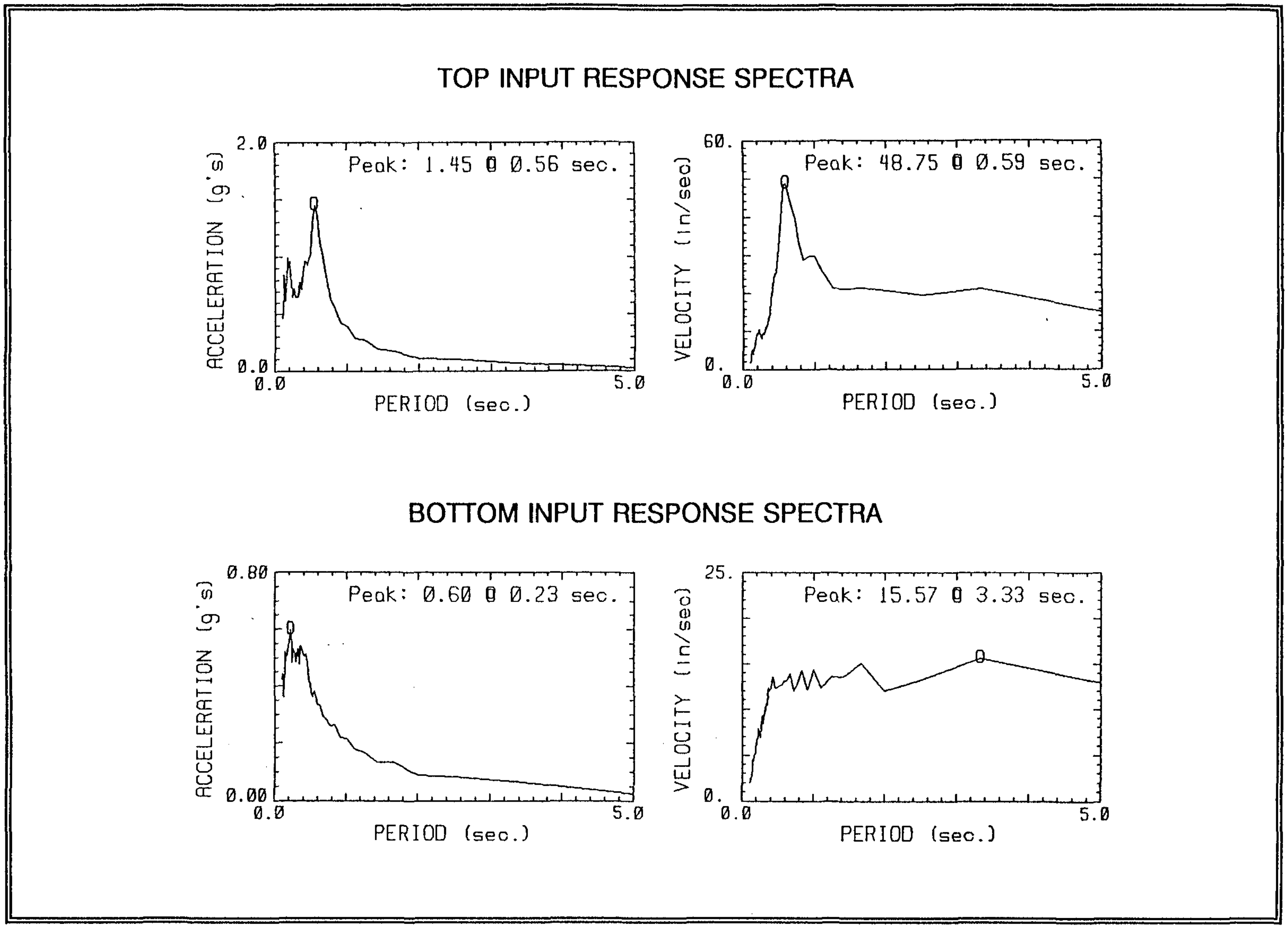
MS4 - 0.2EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



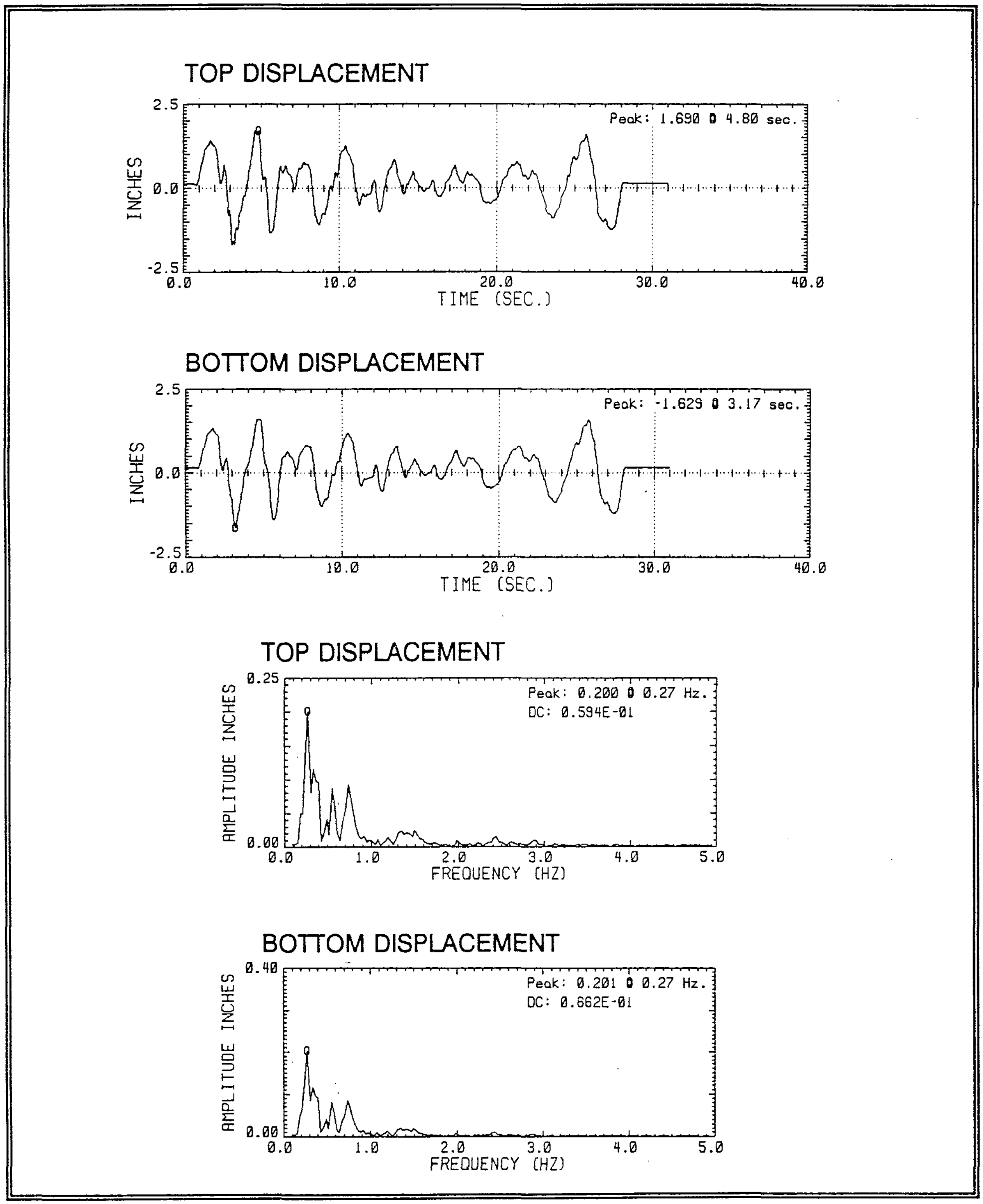
TAFT2 - 0.2EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



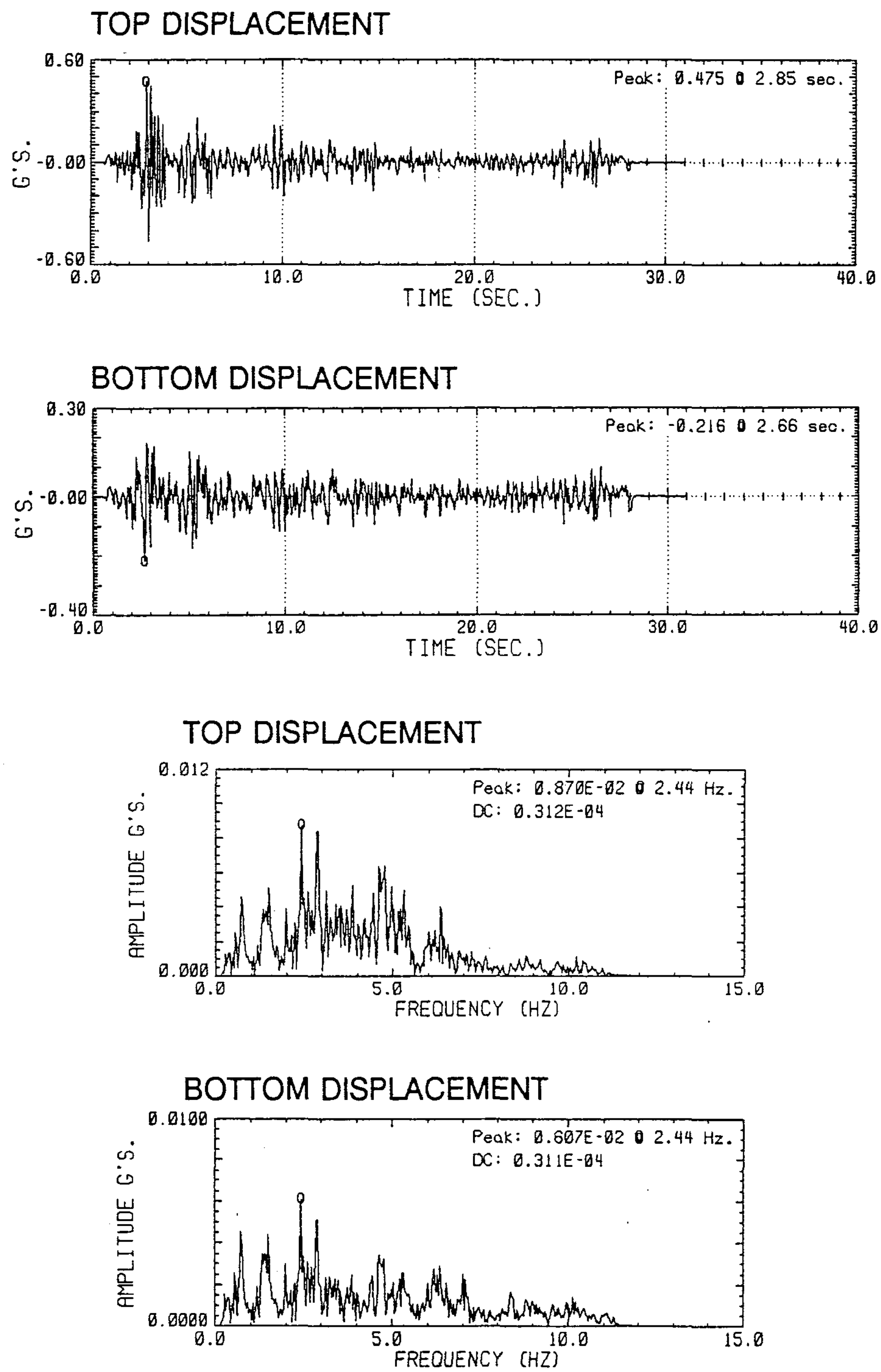
TAFT2 - 0.2EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



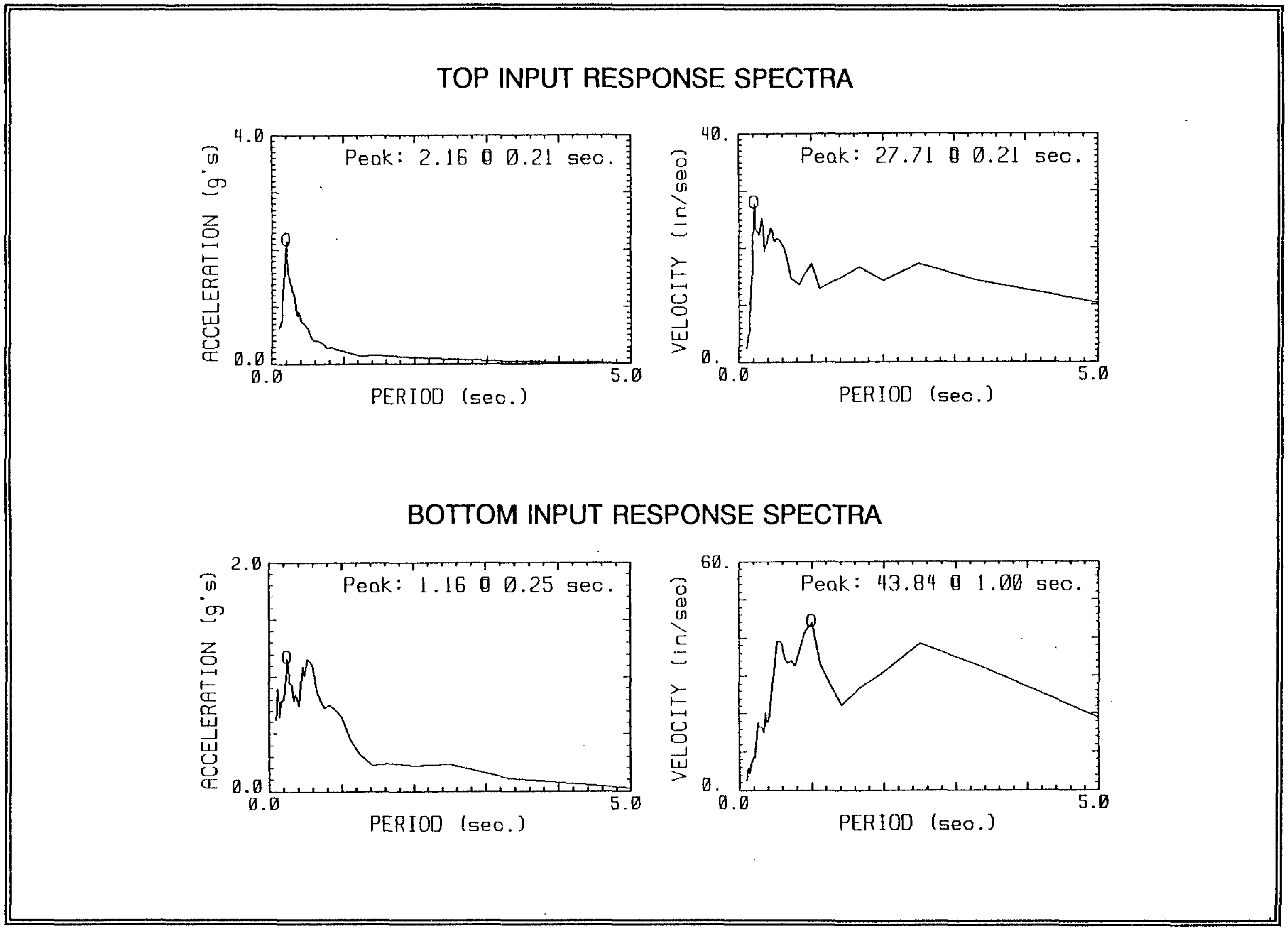
TAFT2 - 0.2EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



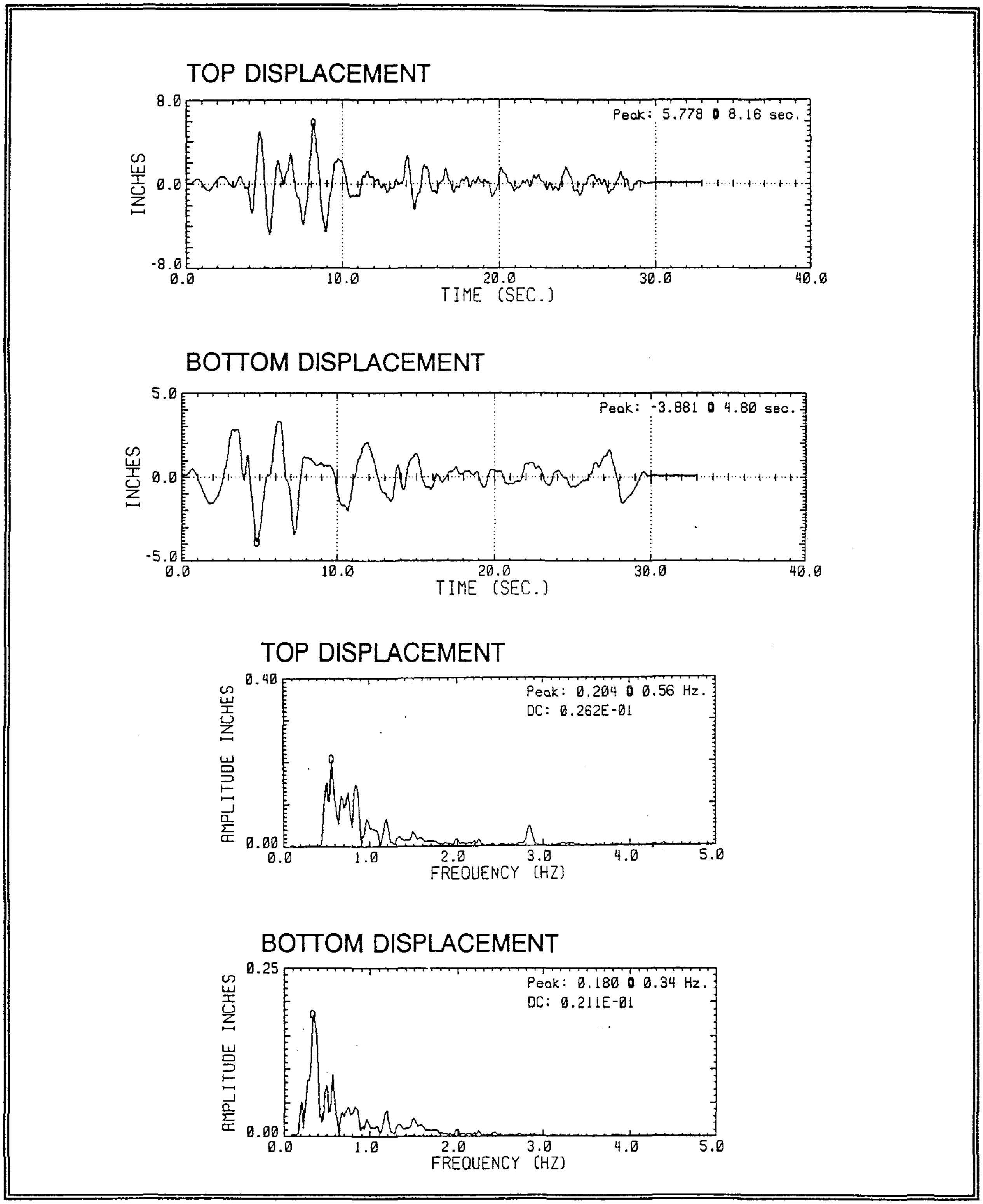
ELC2 - 0.2EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



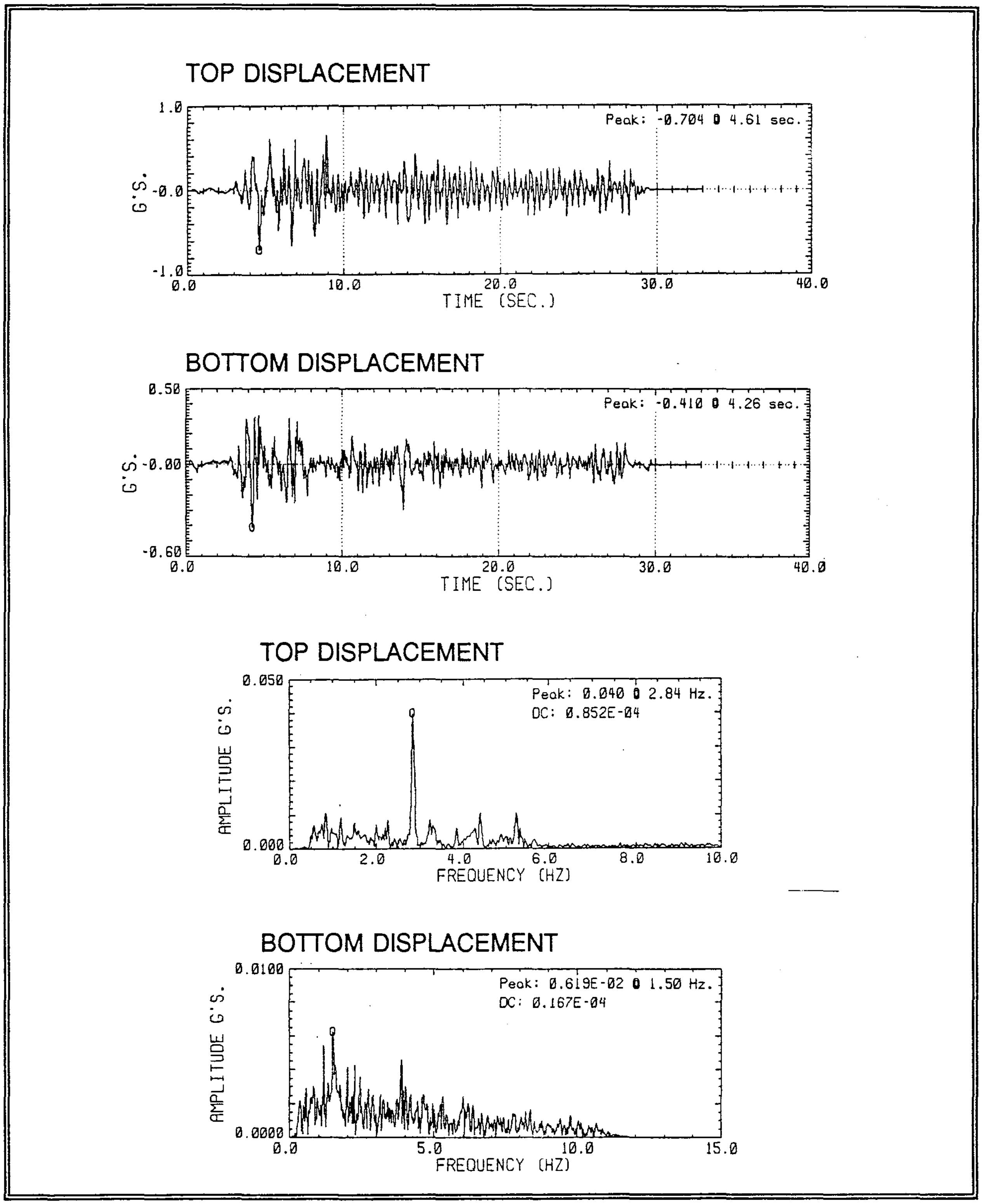
ELC2 - 0.2EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



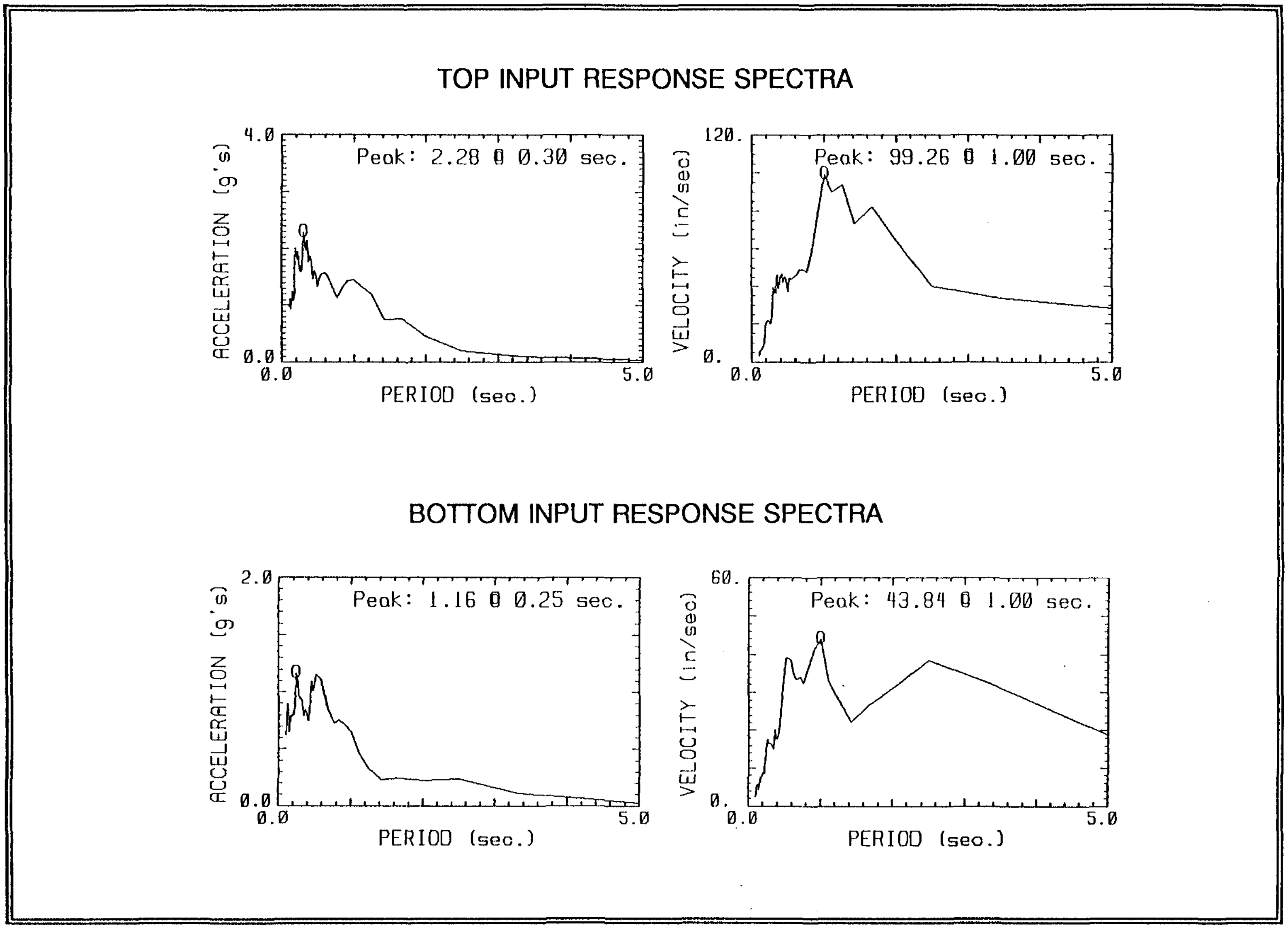
ELC2 - 0.2EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



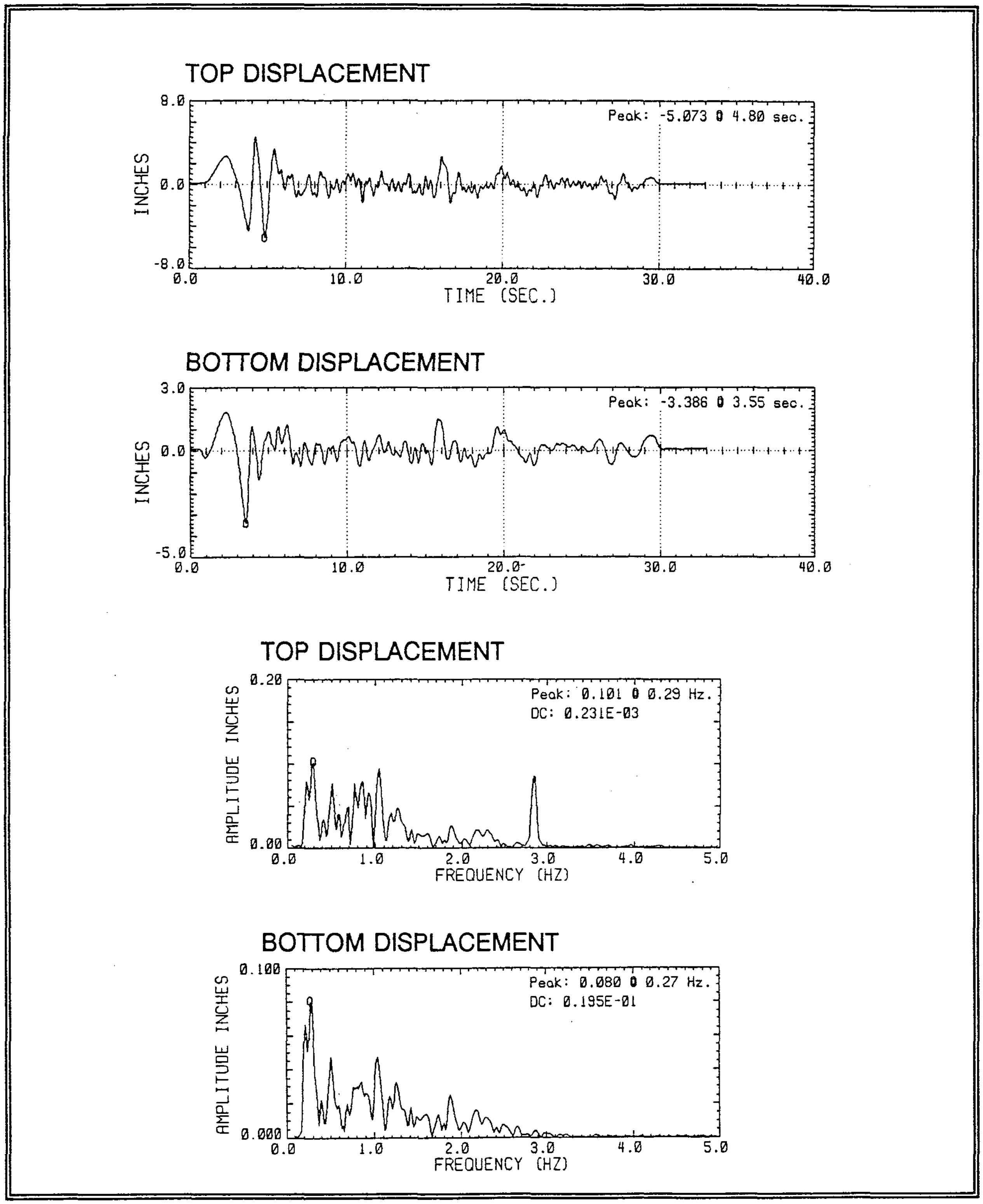
MS5 - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



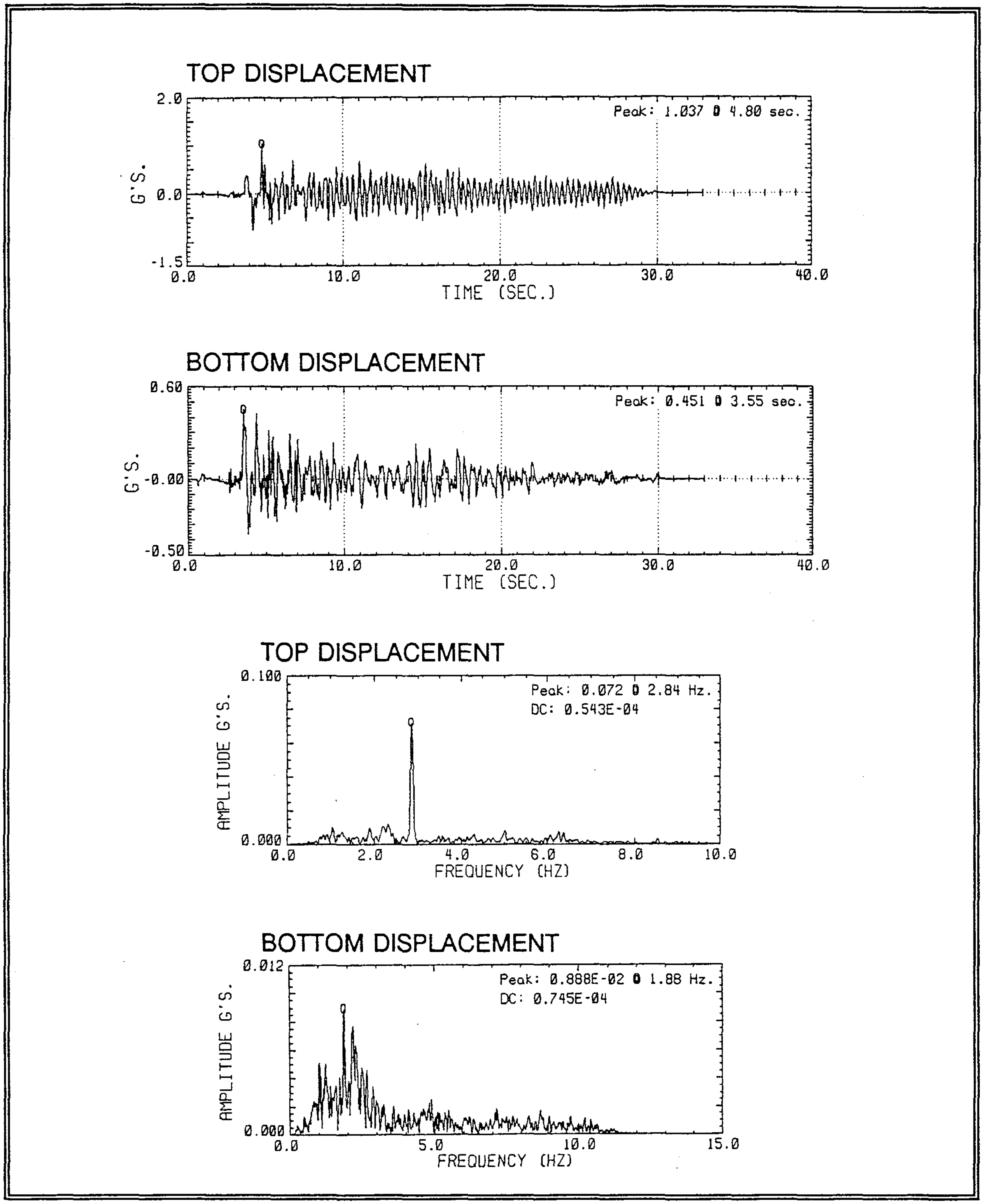
MS5 - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



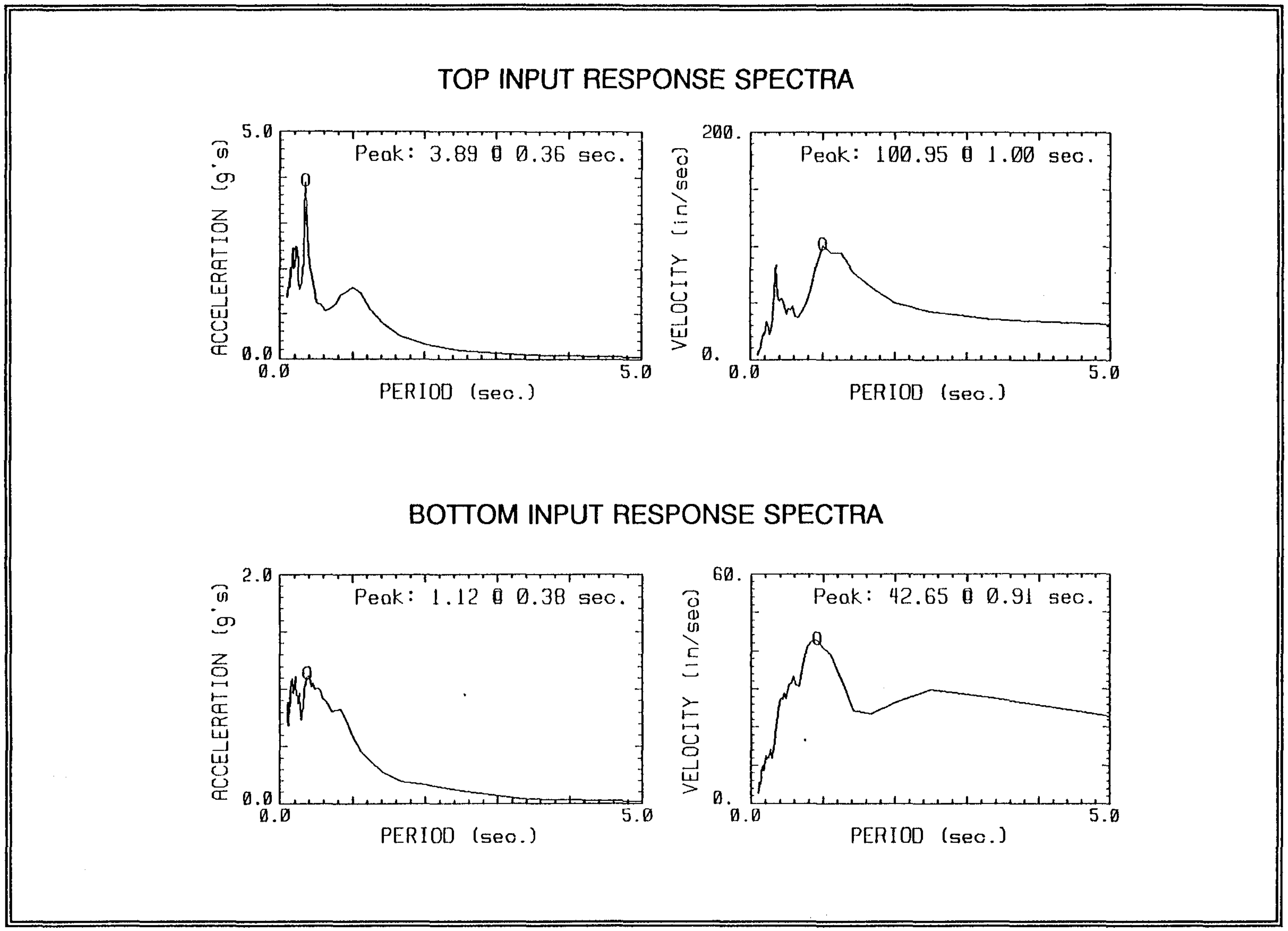
MS5 - 0.4EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



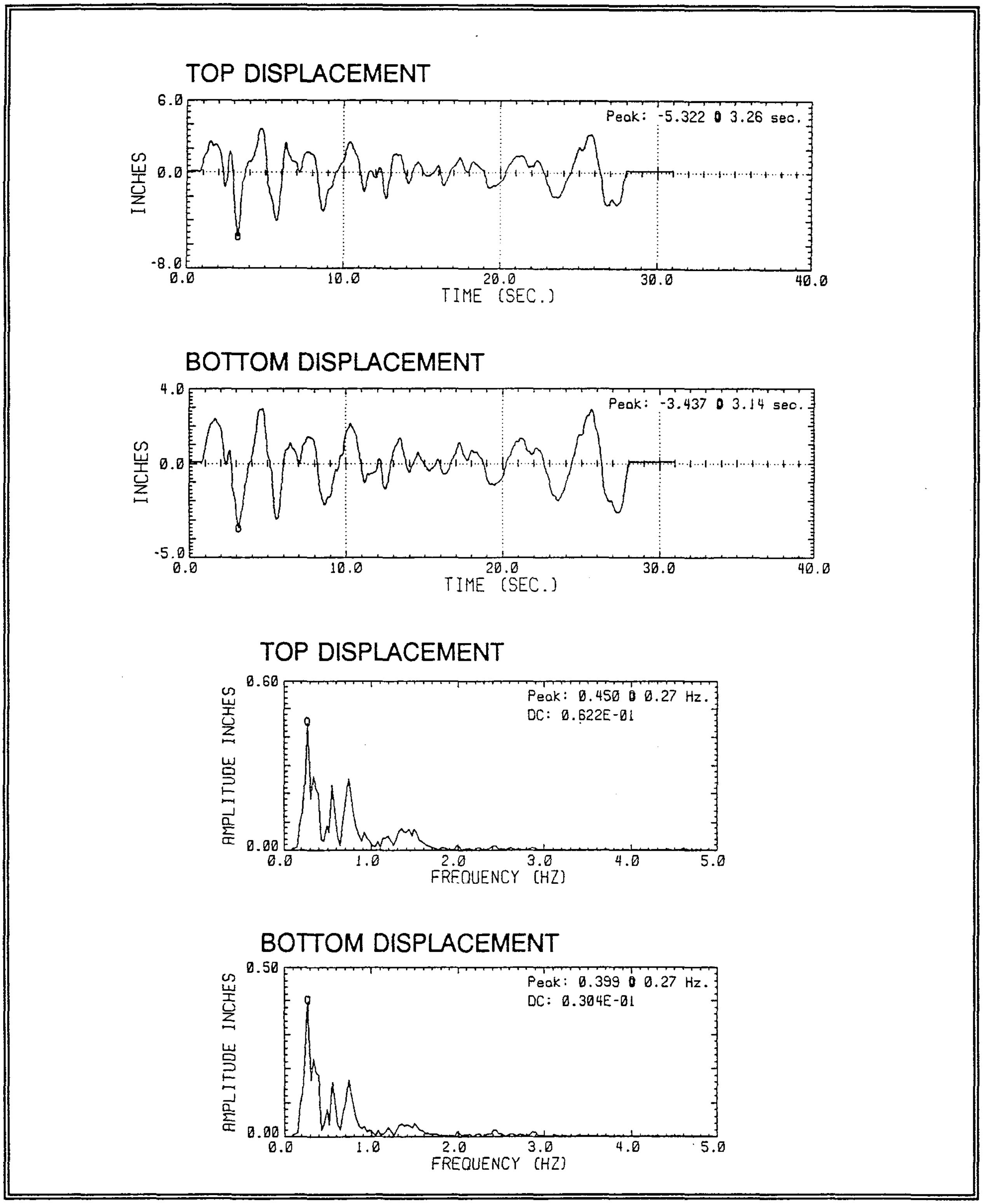
MS6 - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



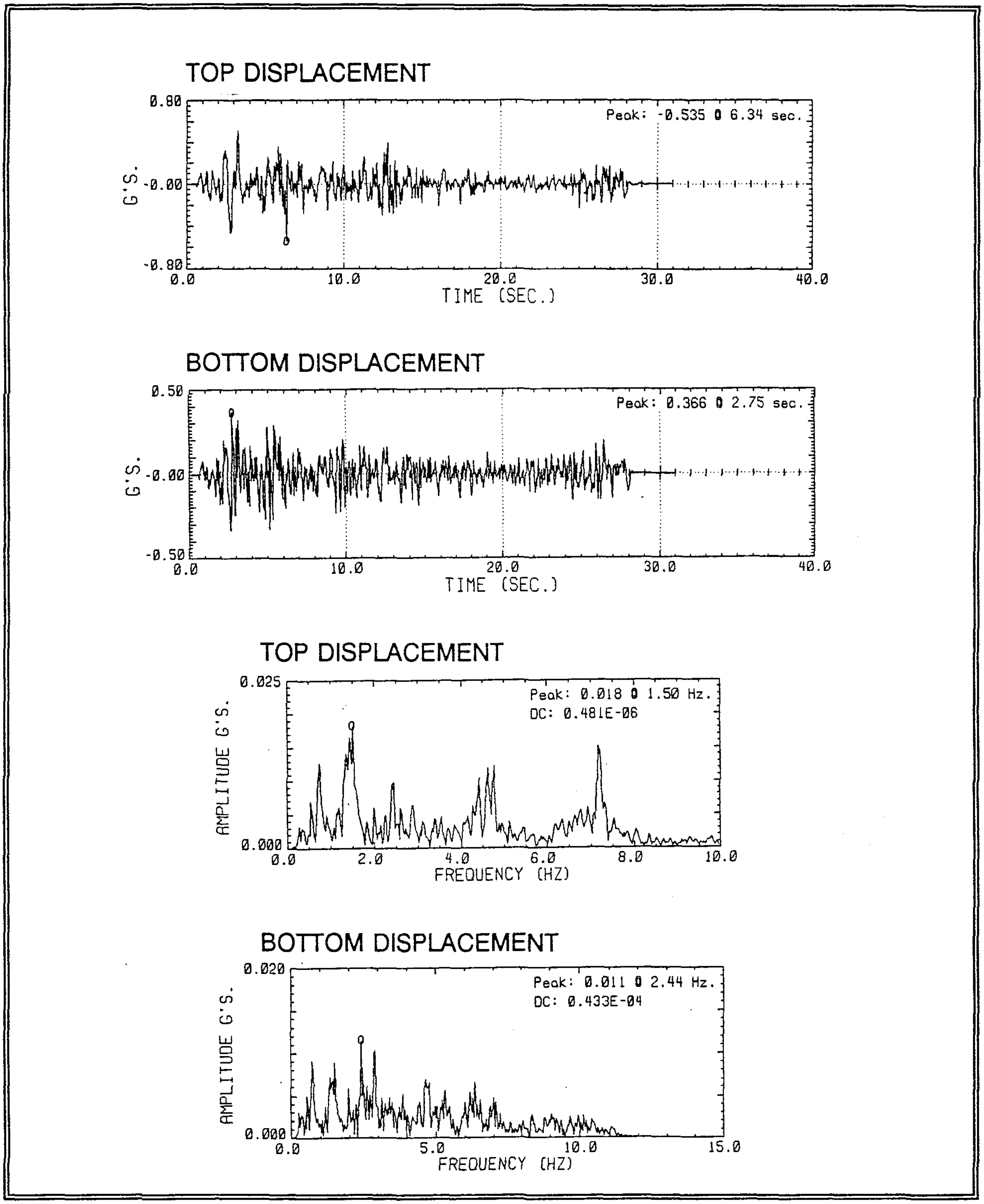
MS6 - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



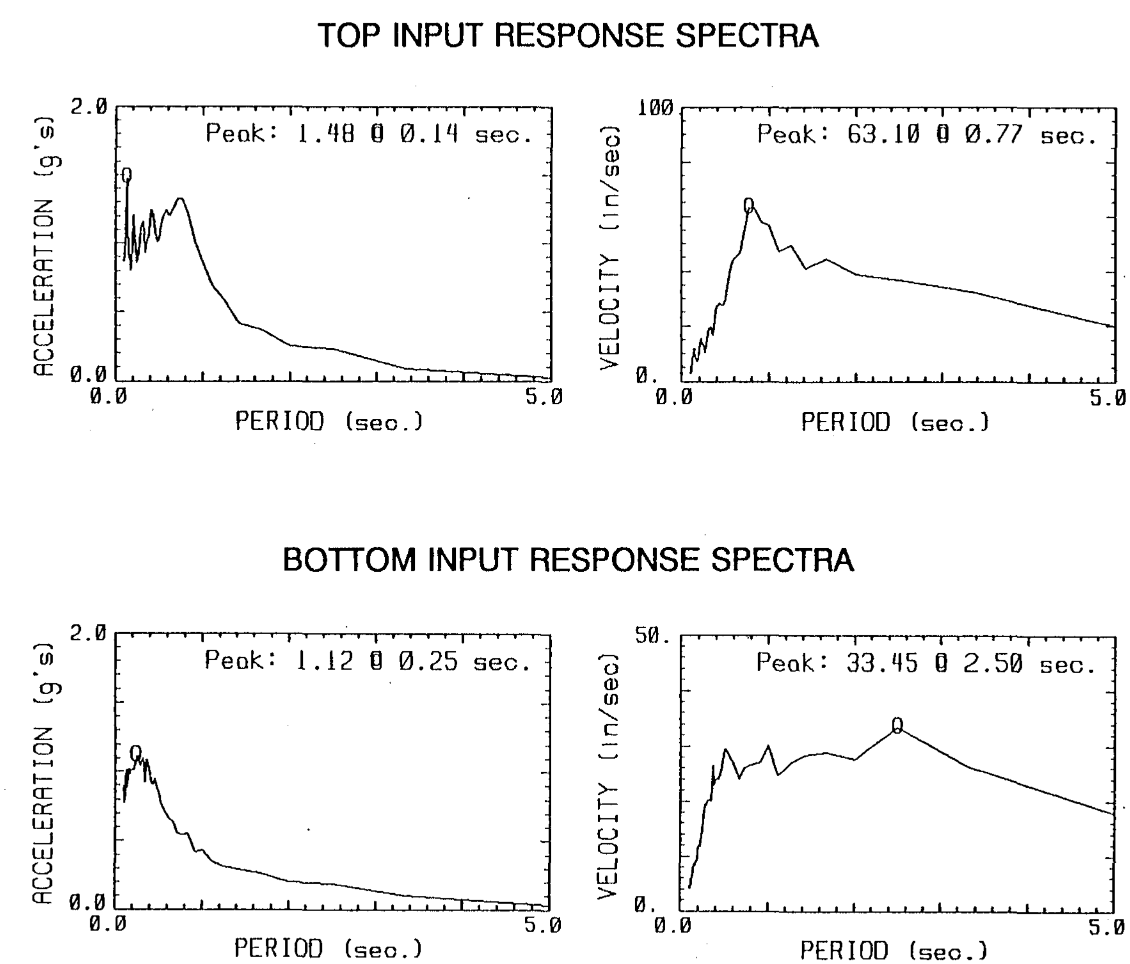
MS6 - 0.4EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



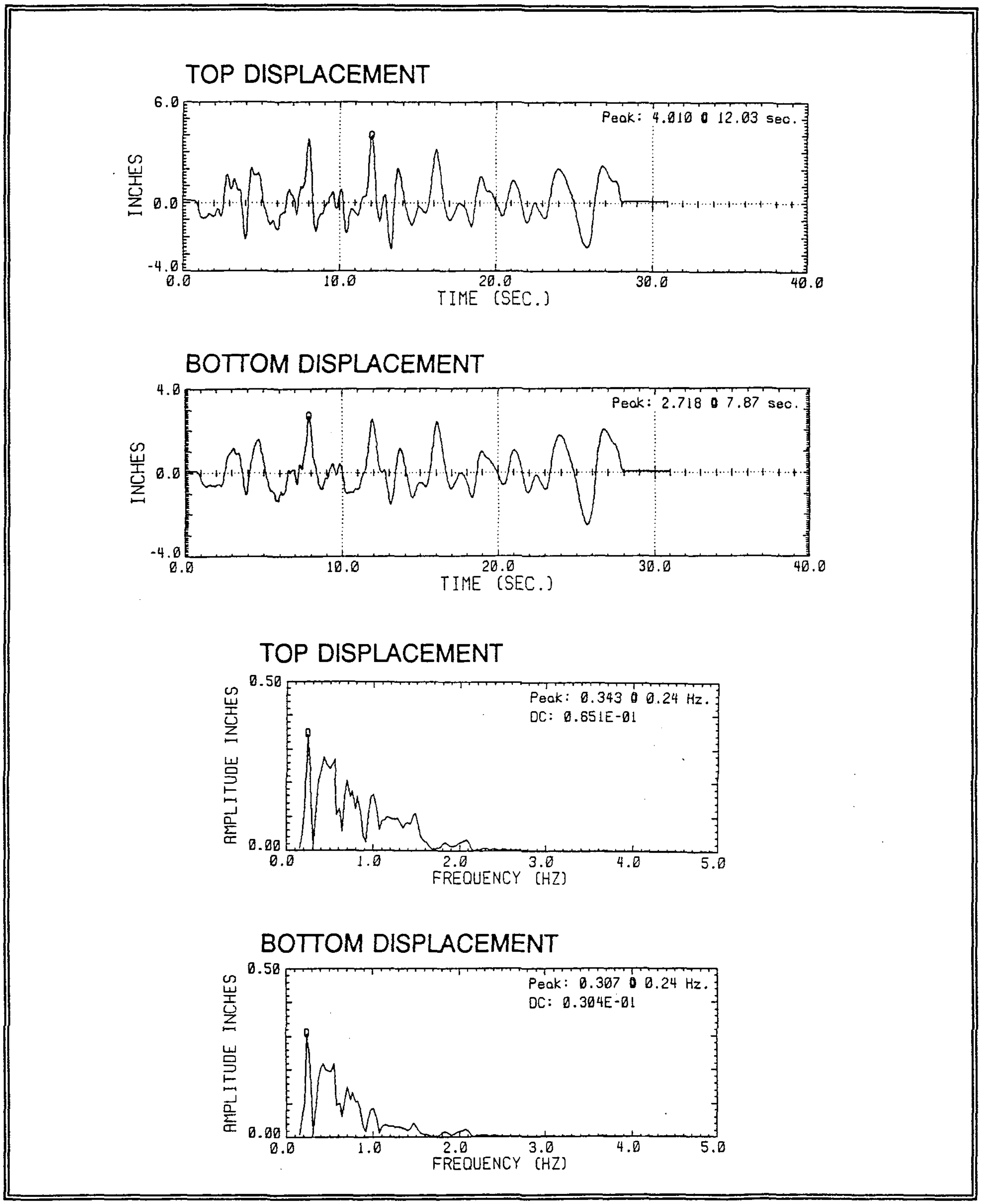
ELC - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



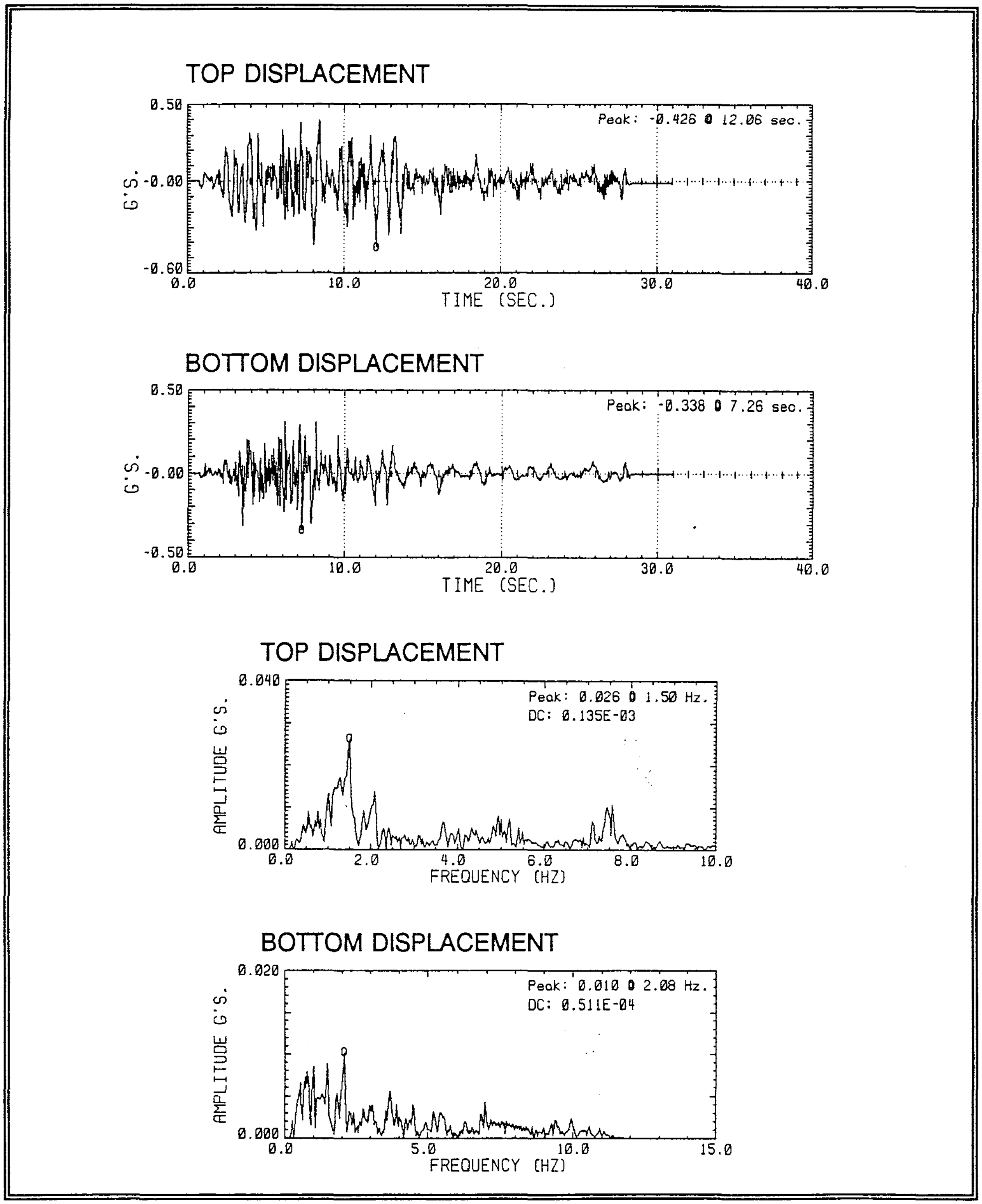
ELC - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



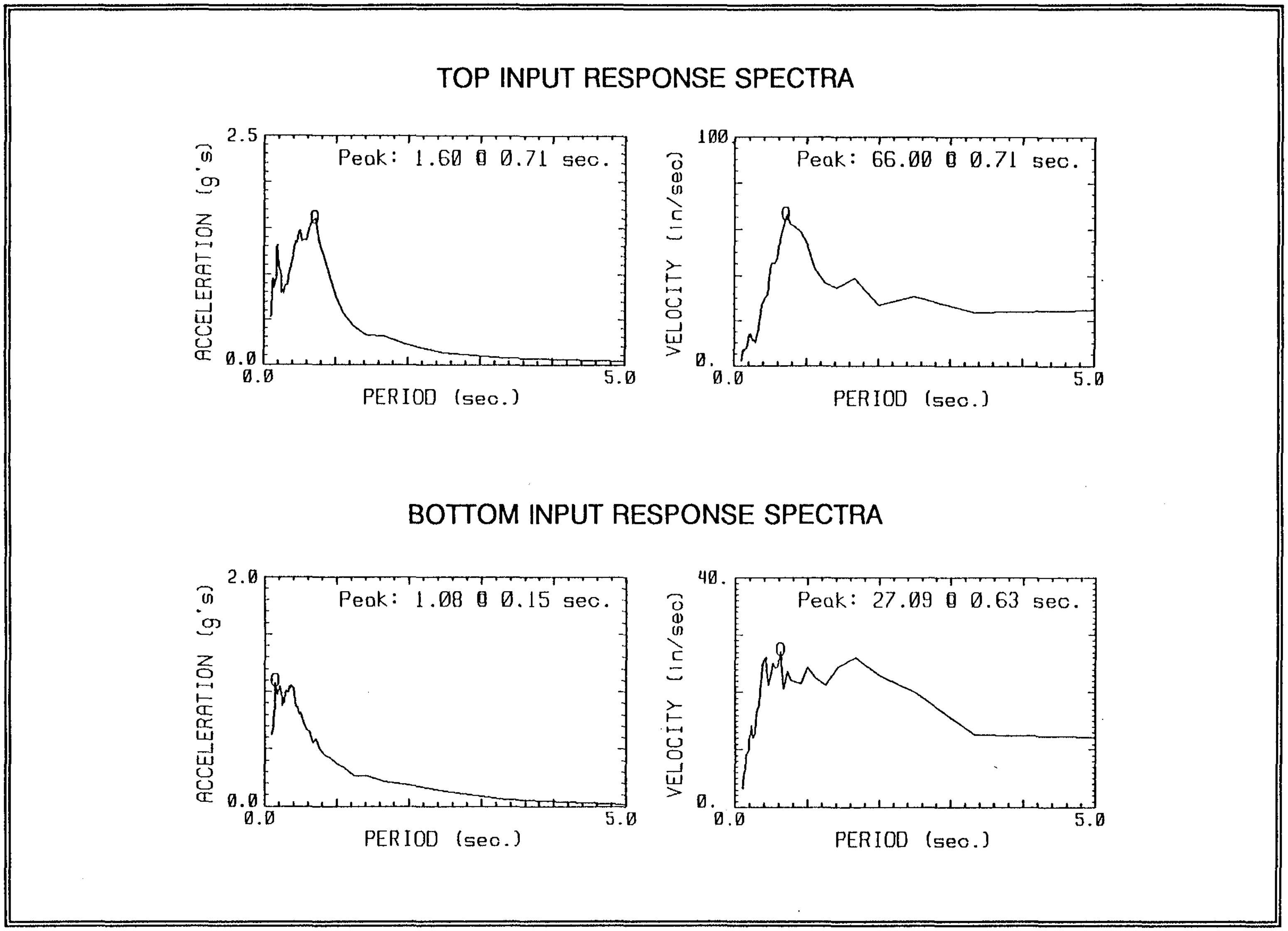
ELC - 0.4EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



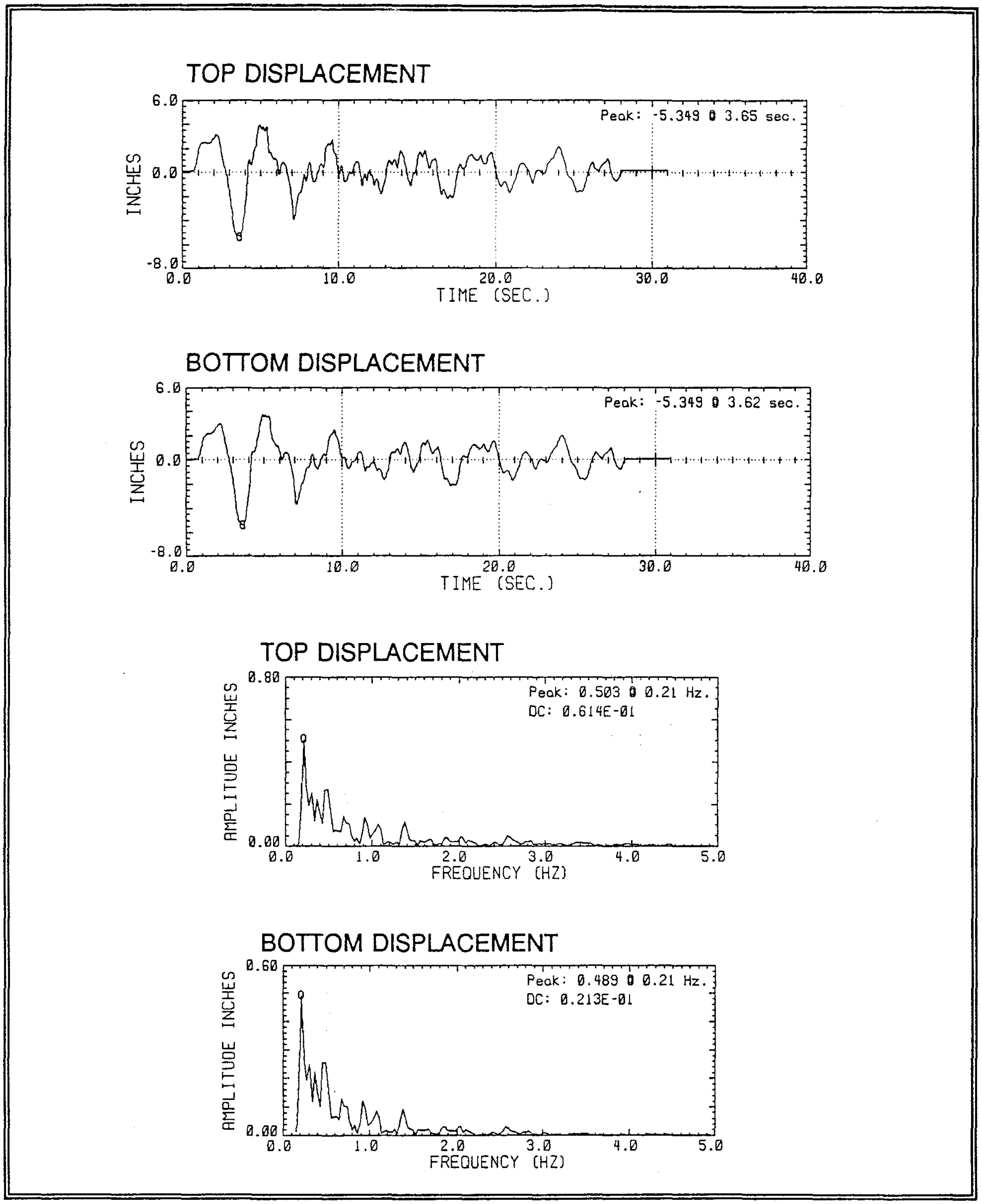
BONDC - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



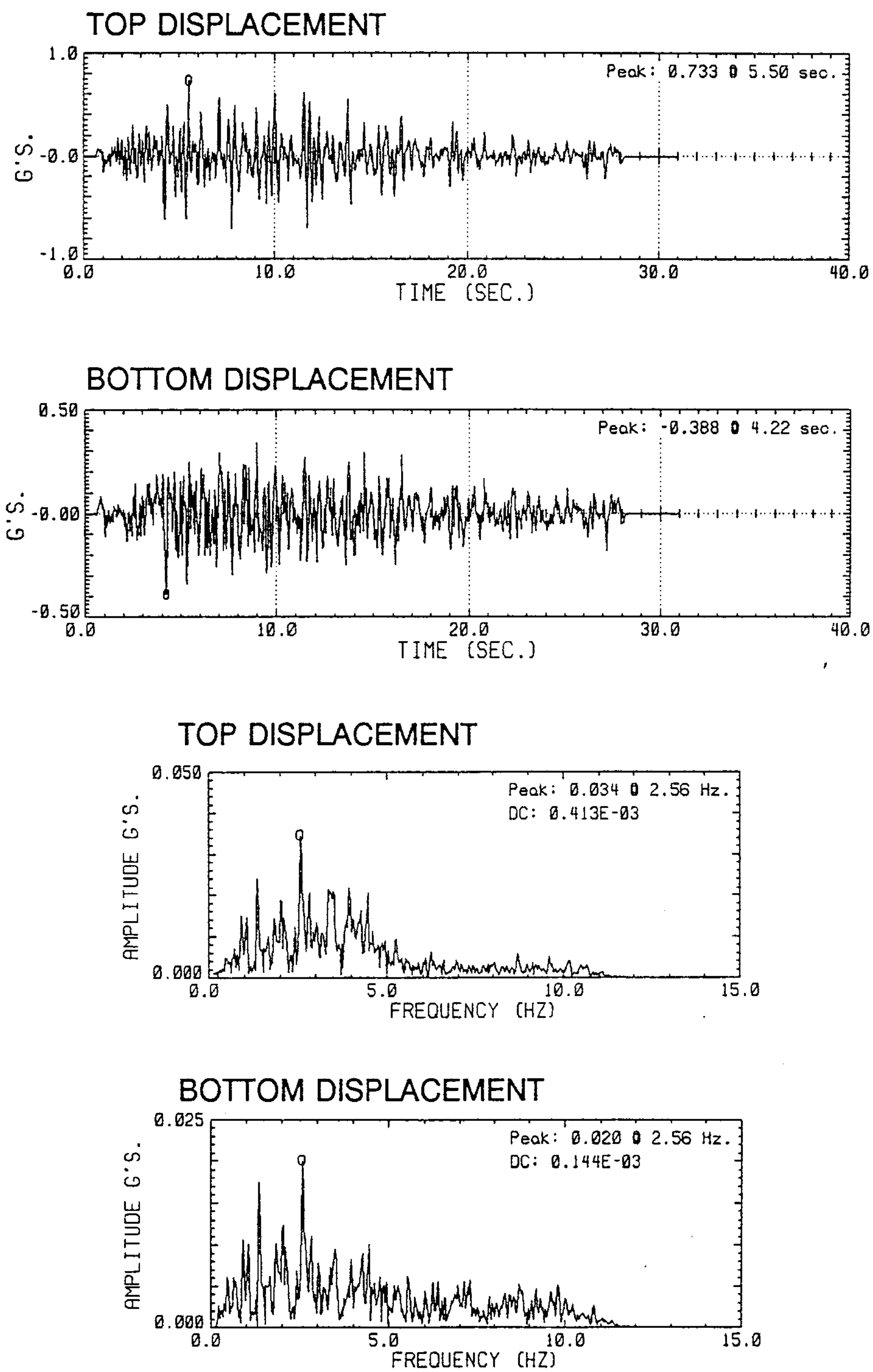
BONDC - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



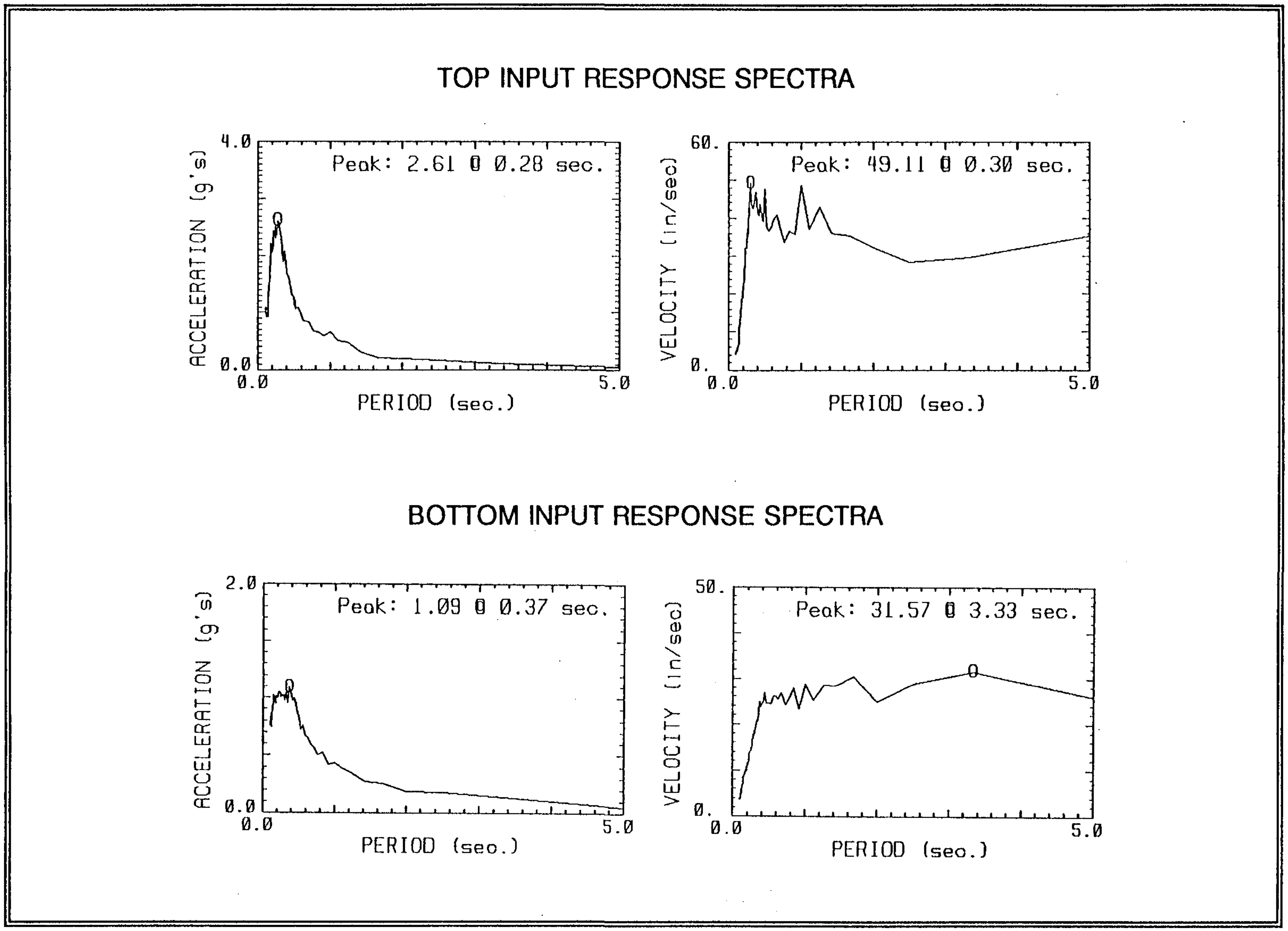
BONDC - 0.4EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



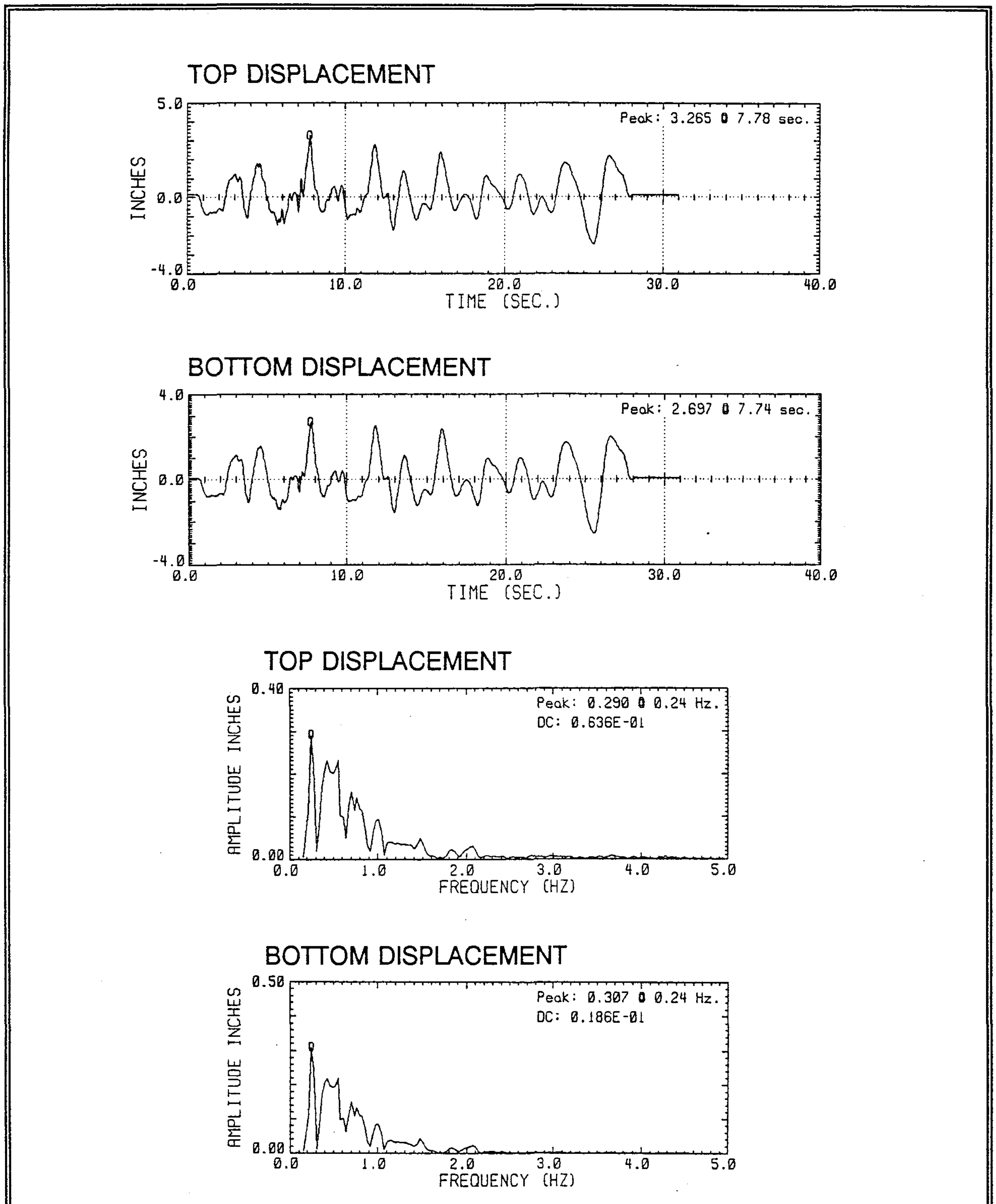
TAFTS - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



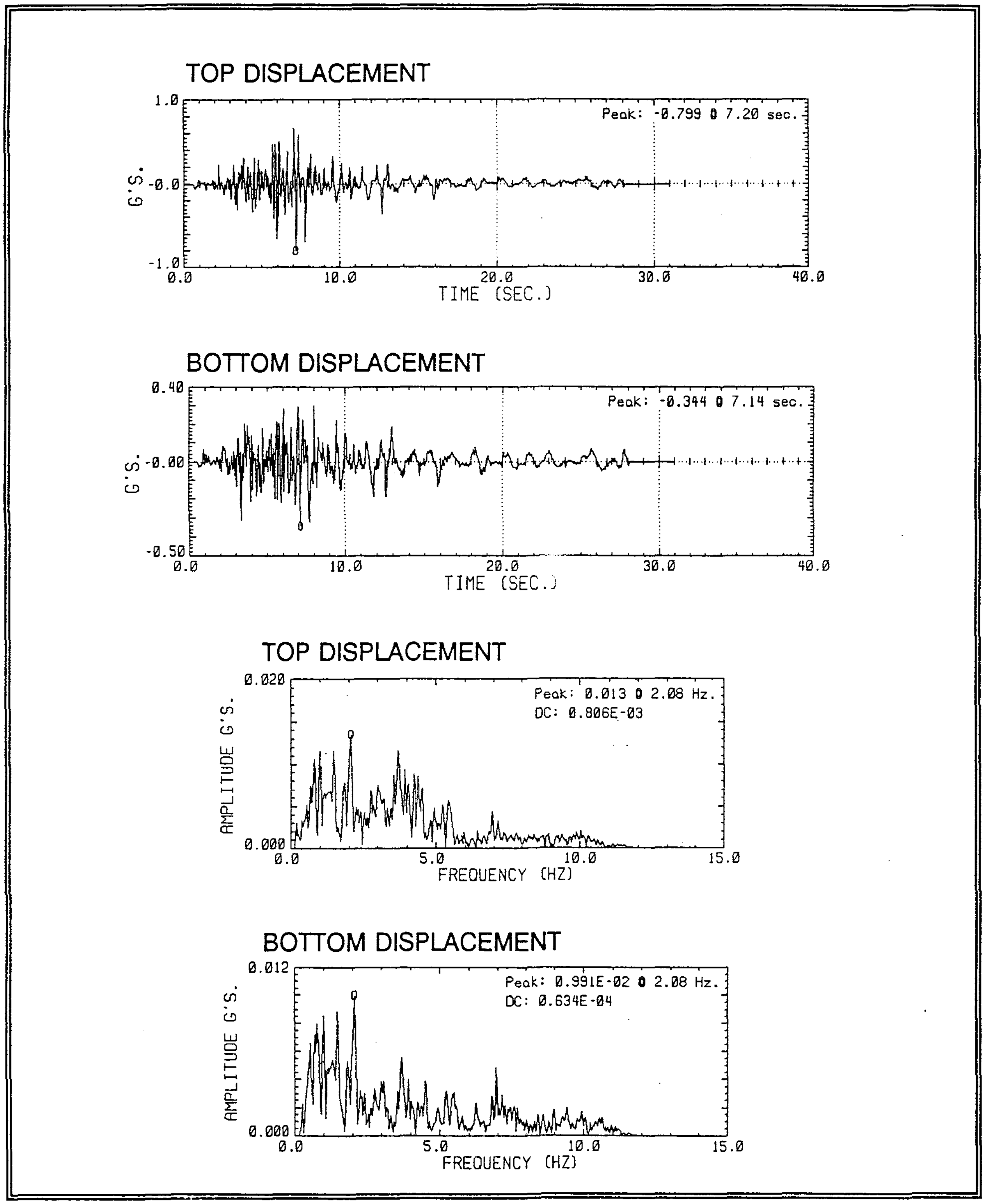
TAFTS - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



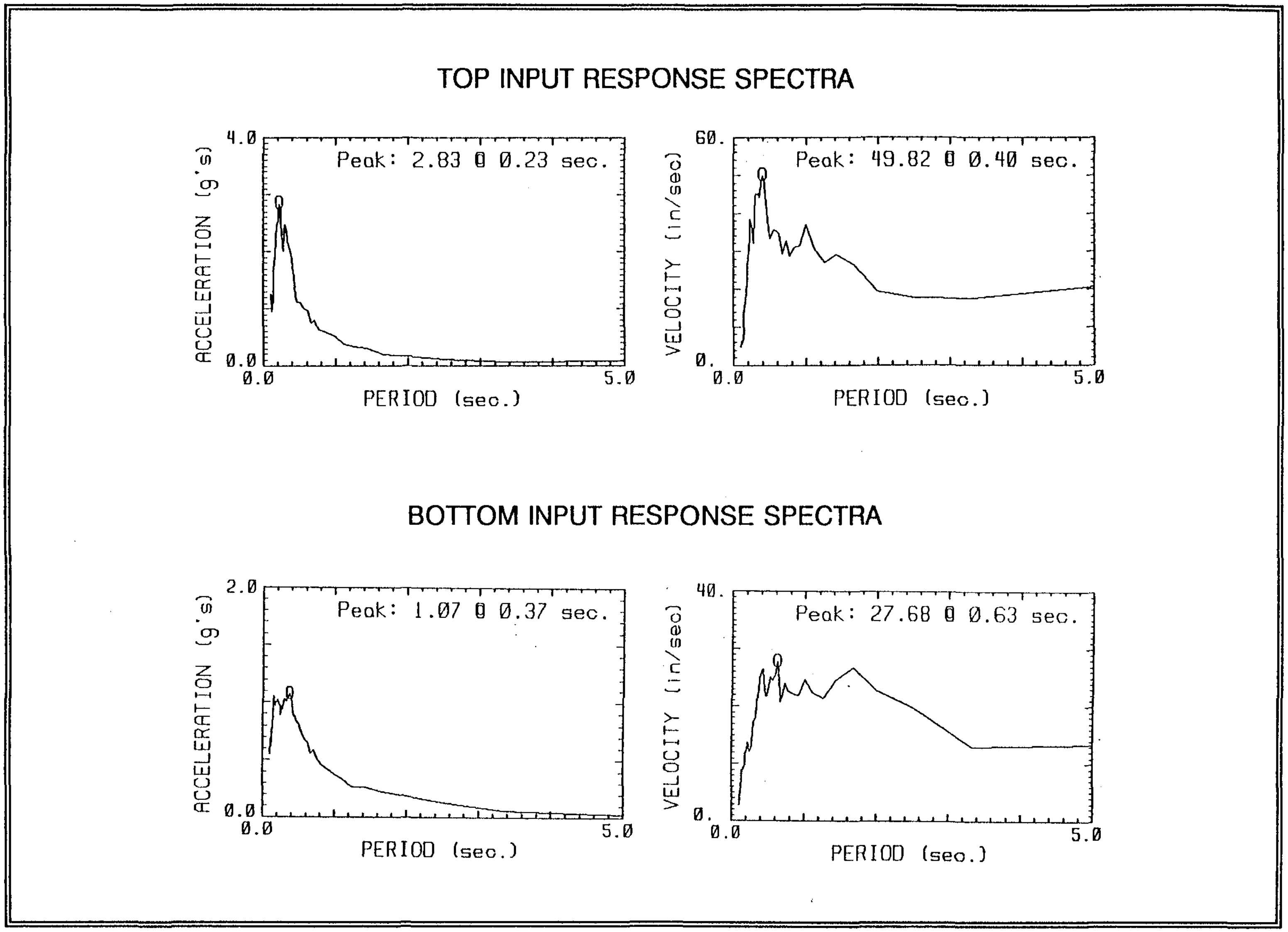
TAFTS - 0.4EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



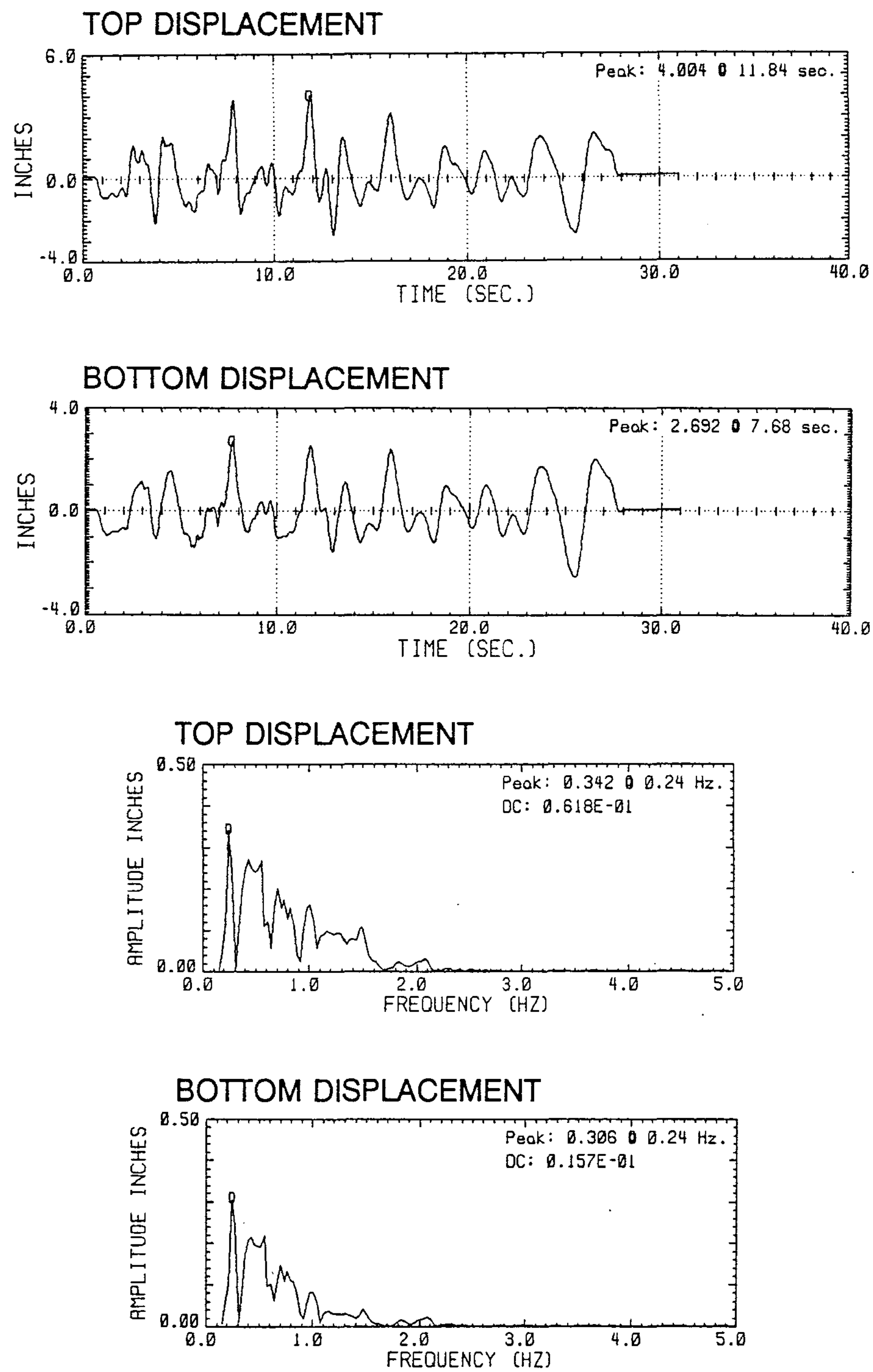
BONDCS - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



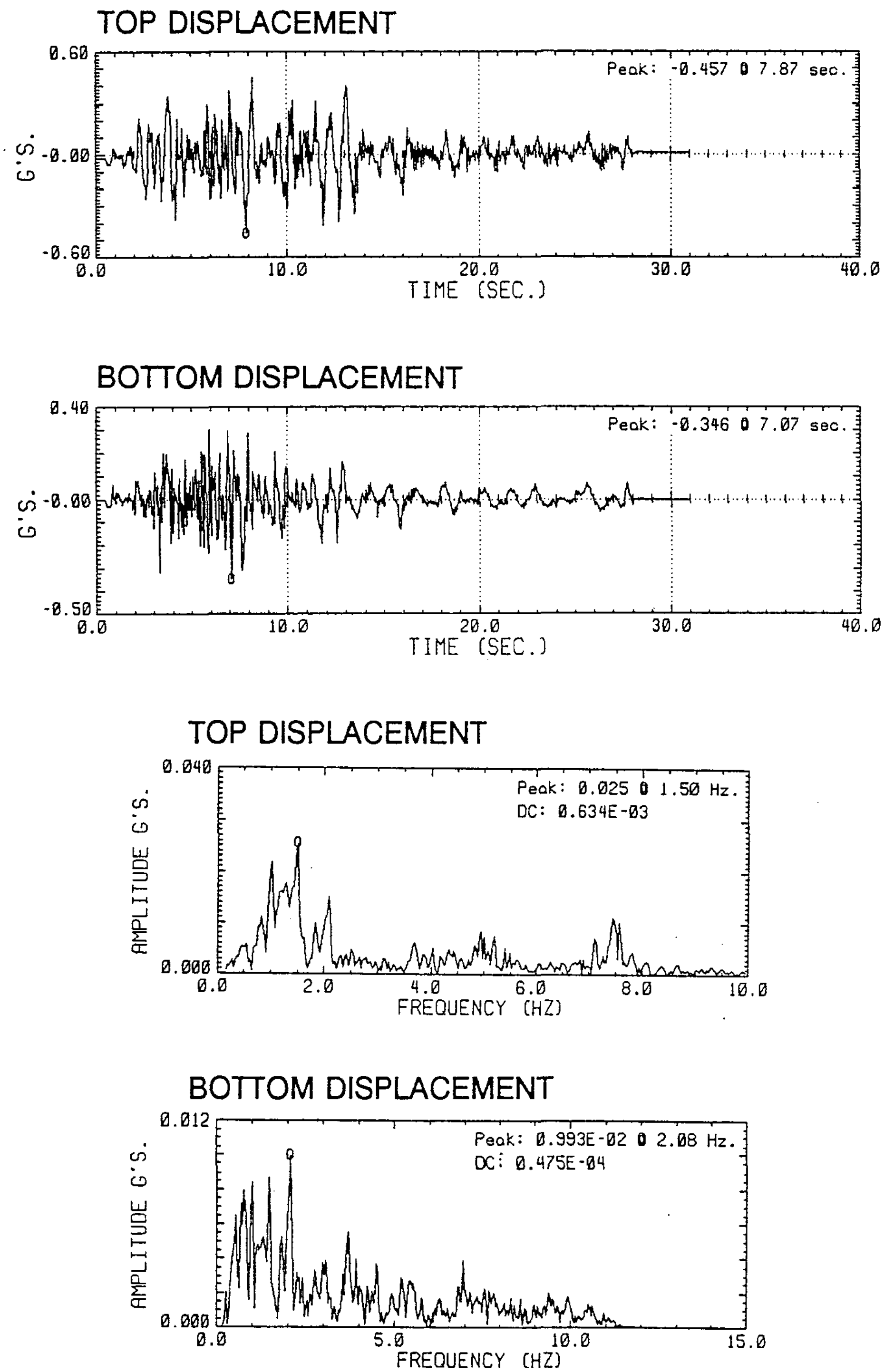
BONDCS - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



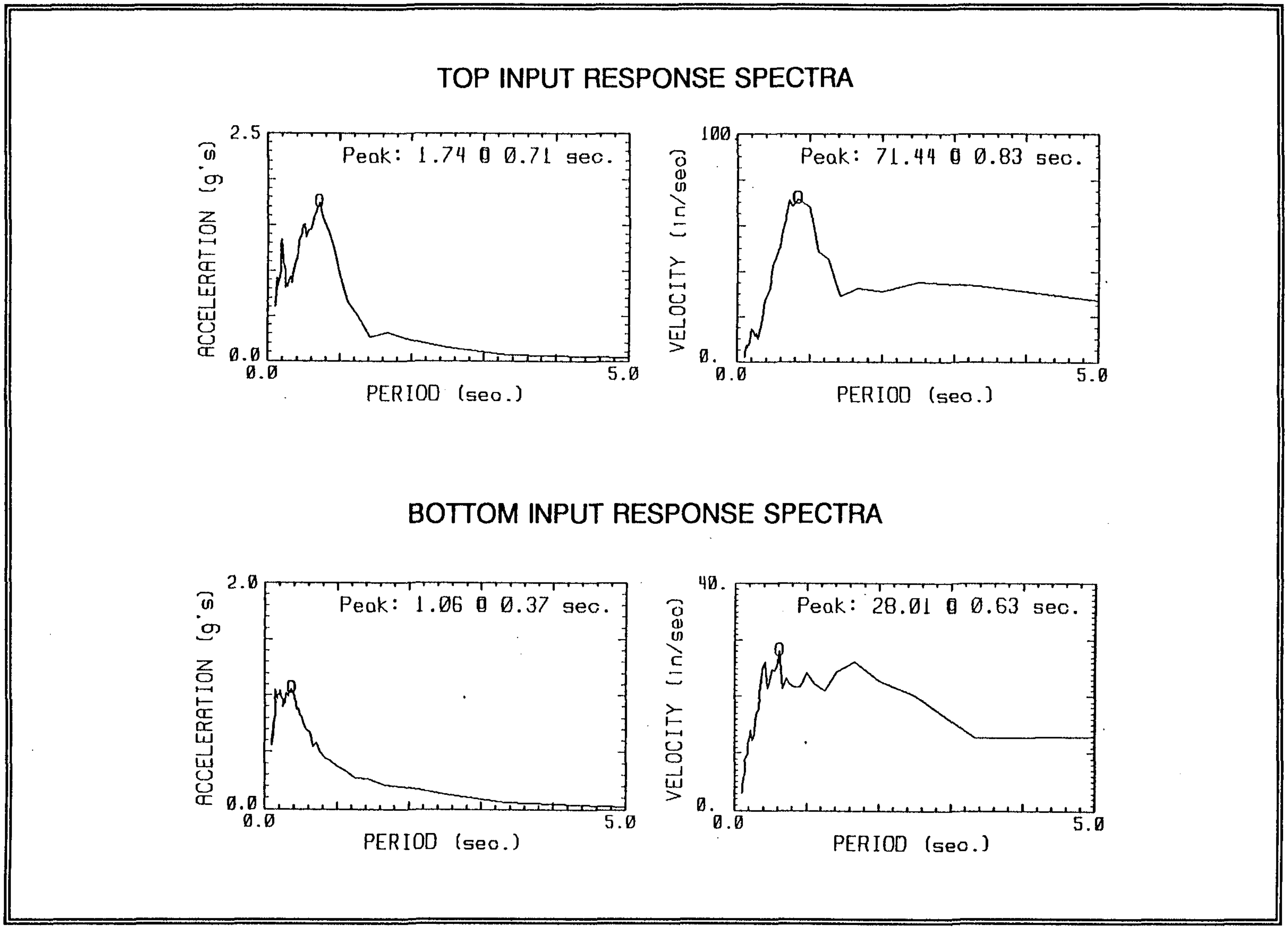
BONDCS - 0.4EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



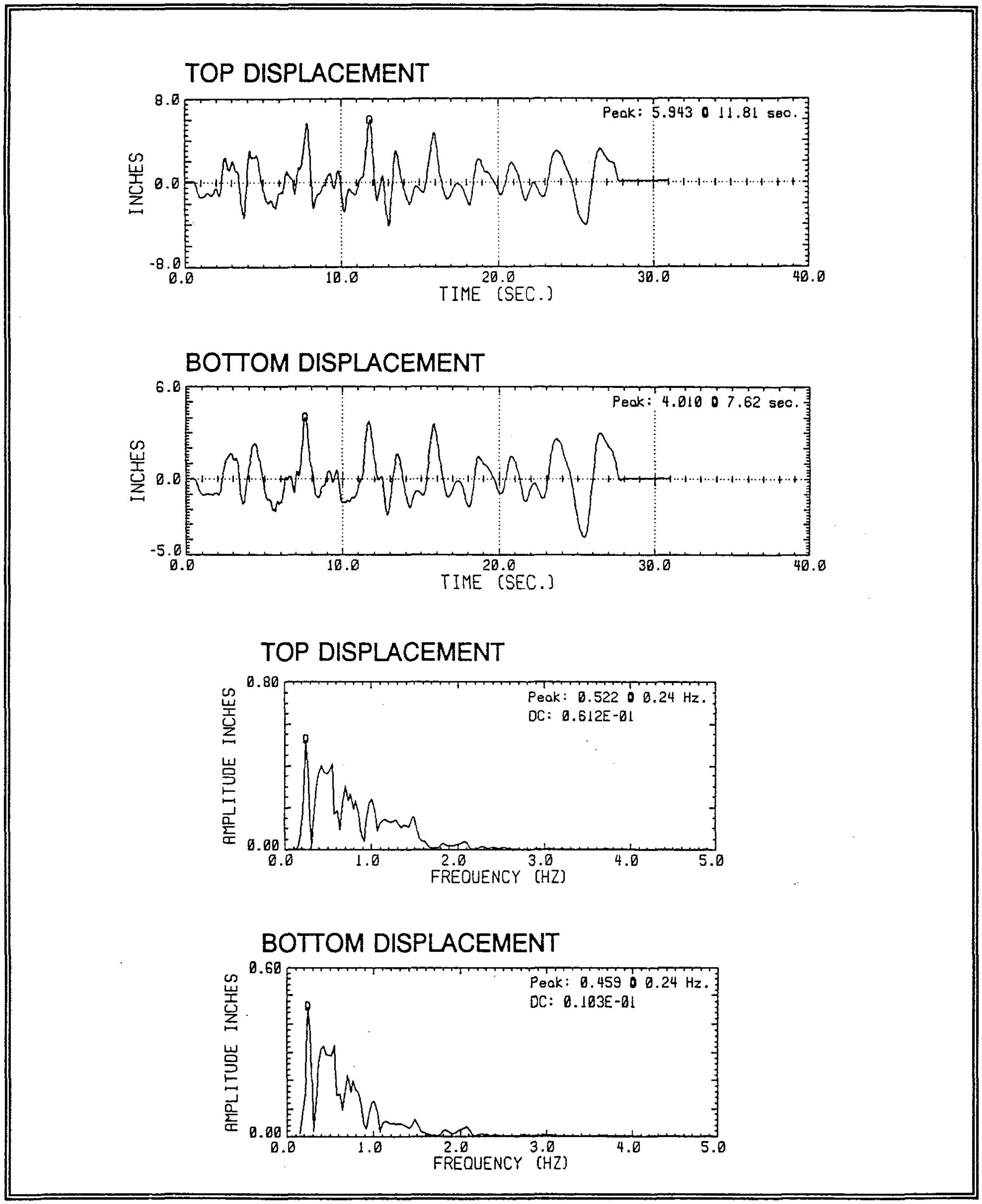
BONDCV1 - 0.4EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



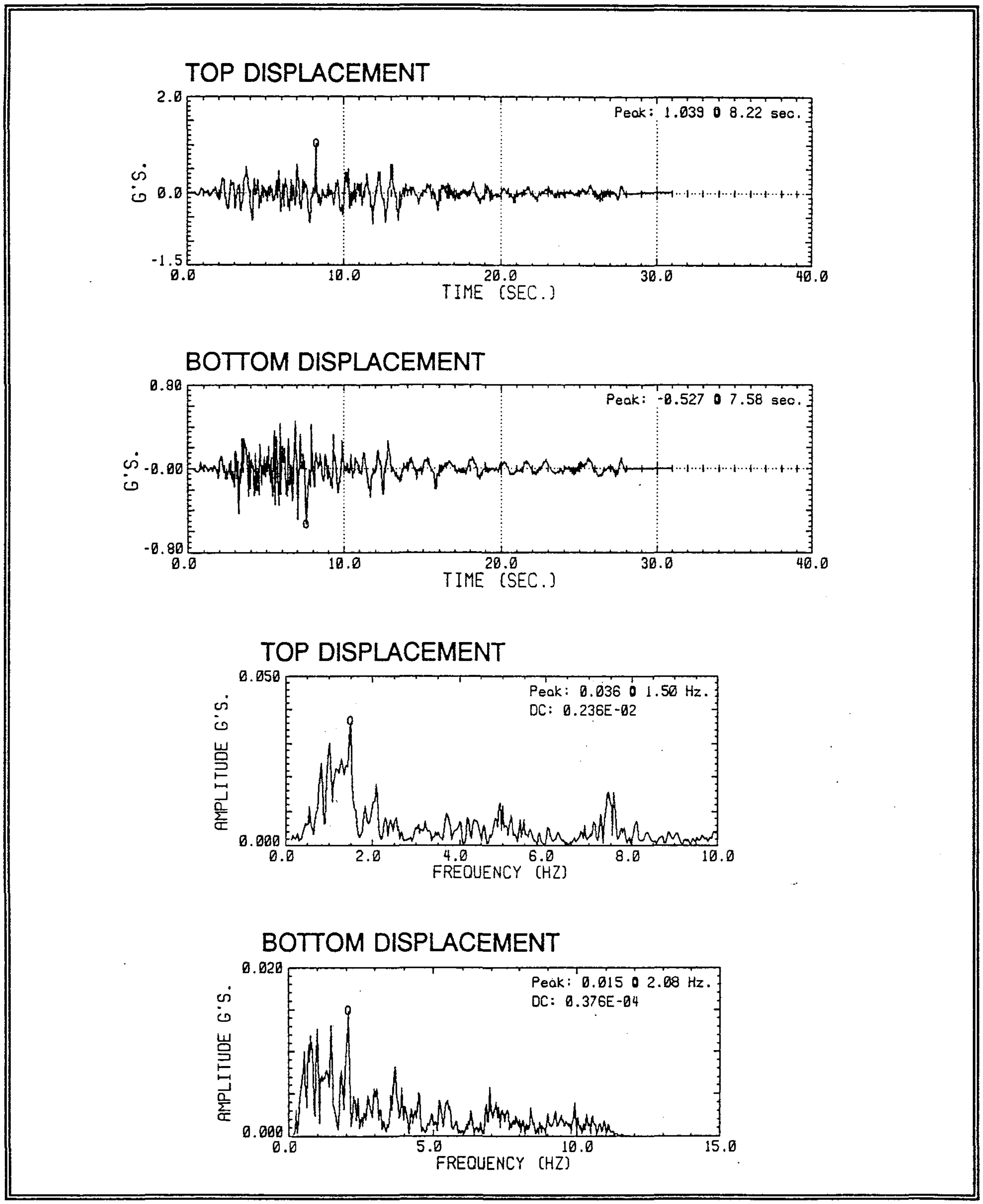
BONDCV1 - 0.4EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



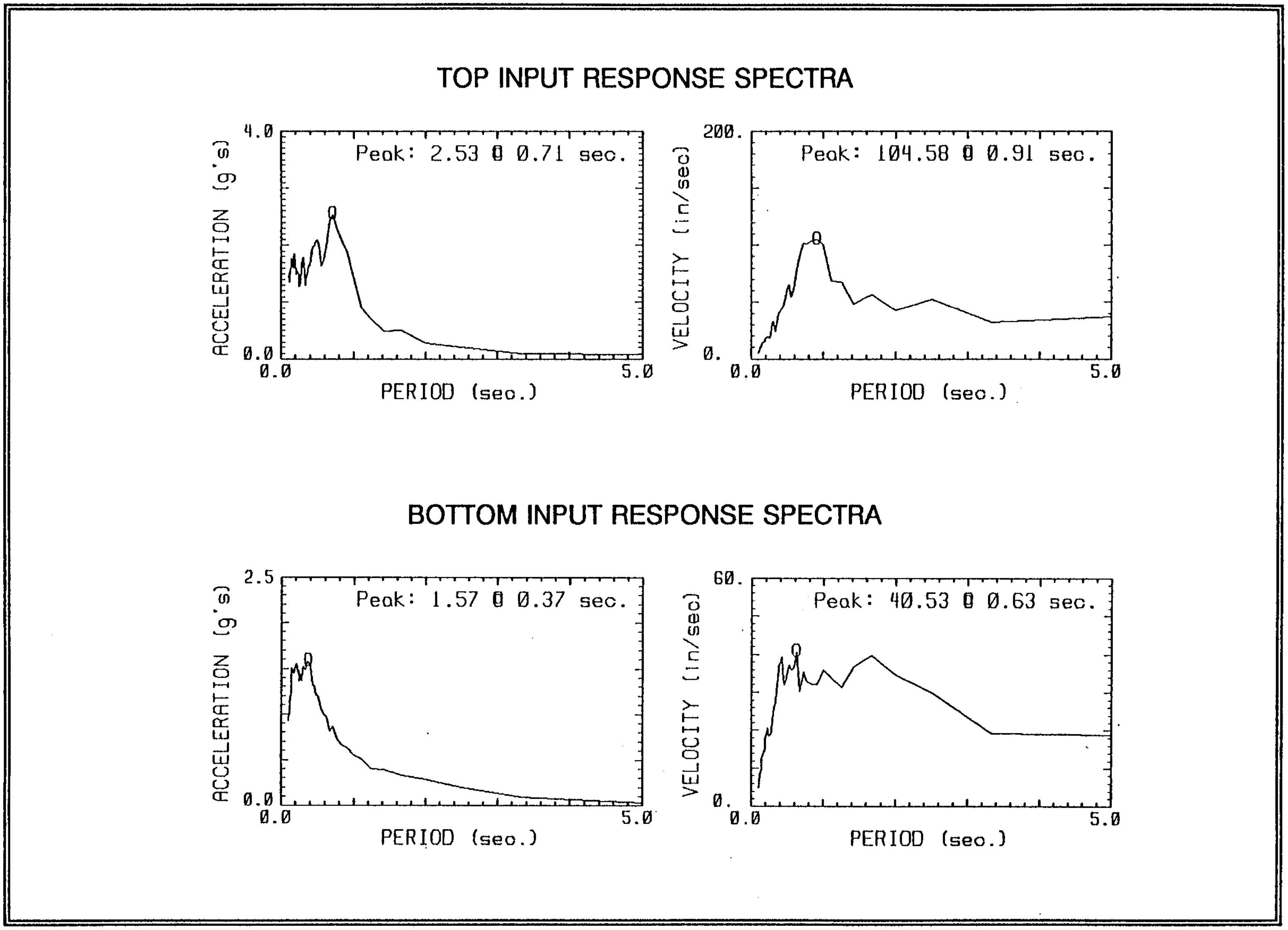
BONDCV1 - 0.4EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



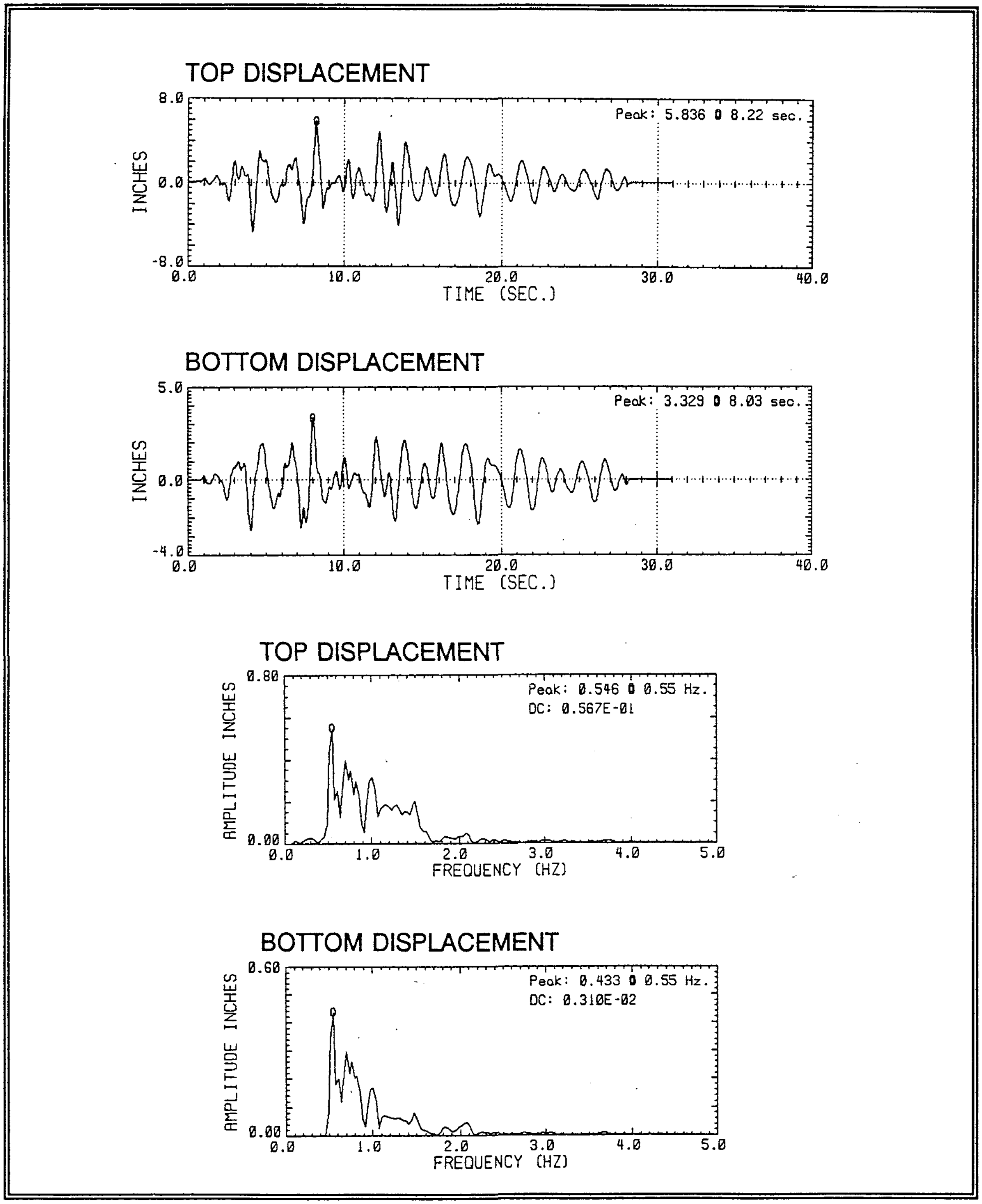
BONDCV2 - 0.5EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



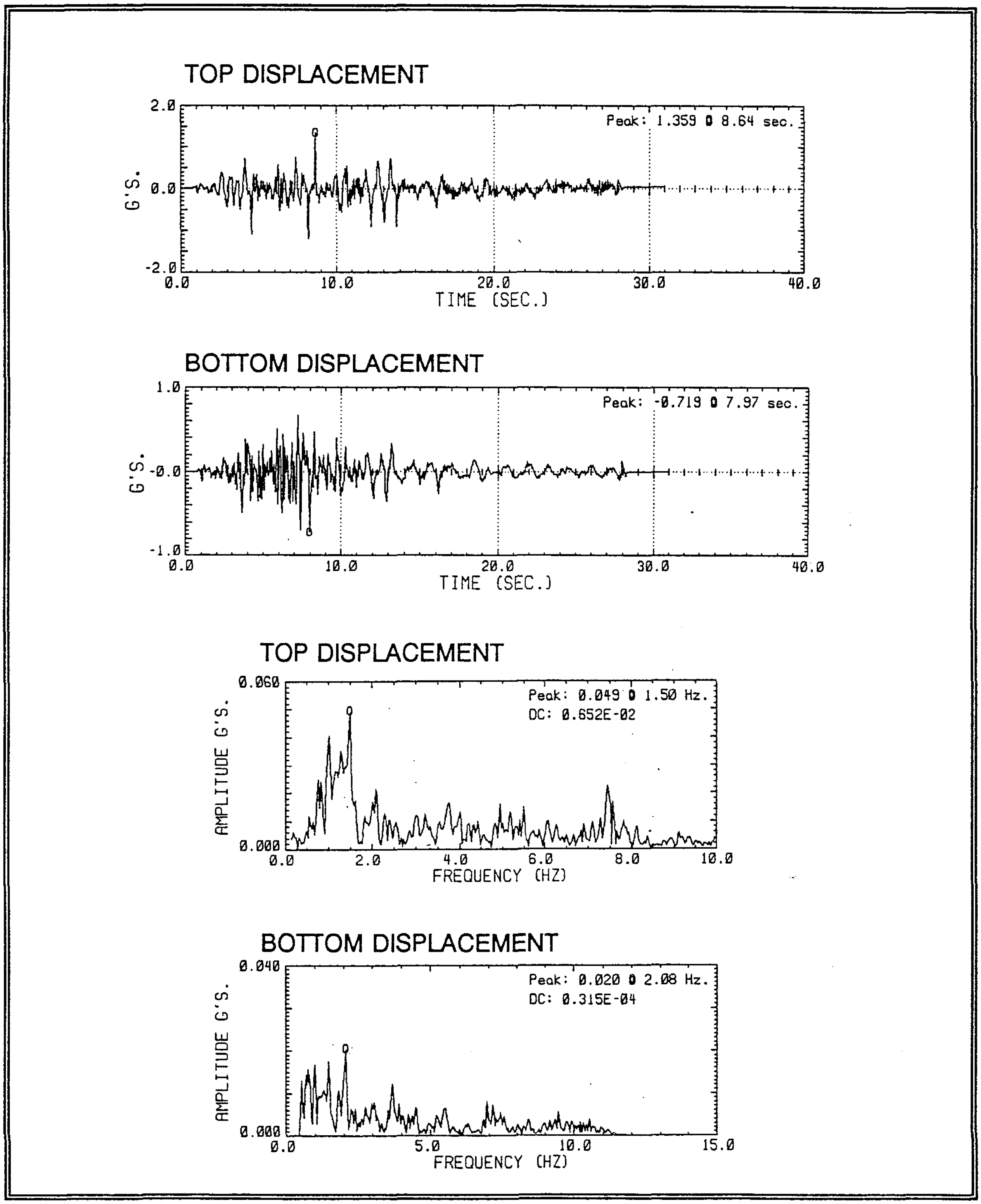
BONDCV2 - 0.5EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



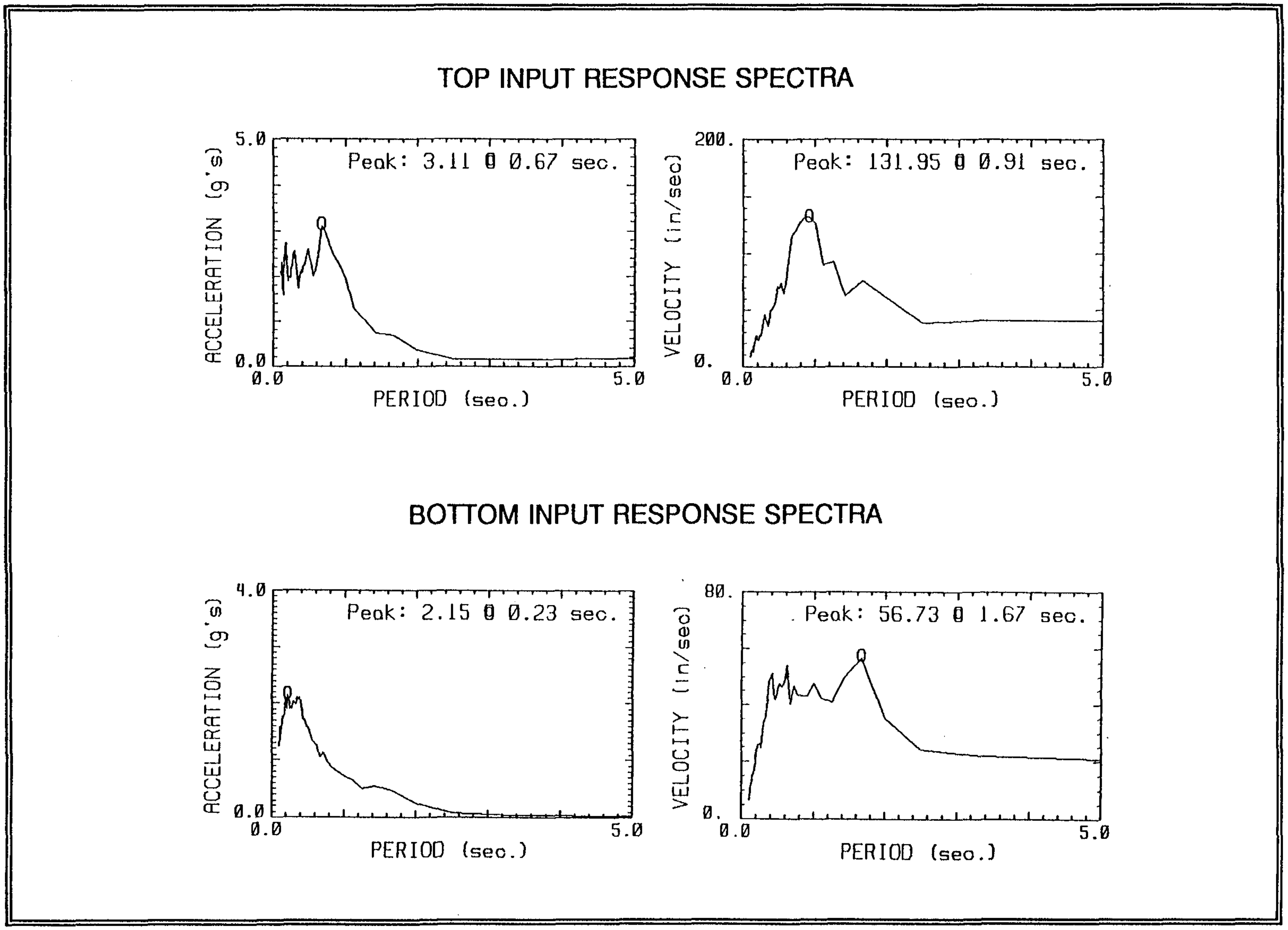
BONDCV2 - 0.5EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



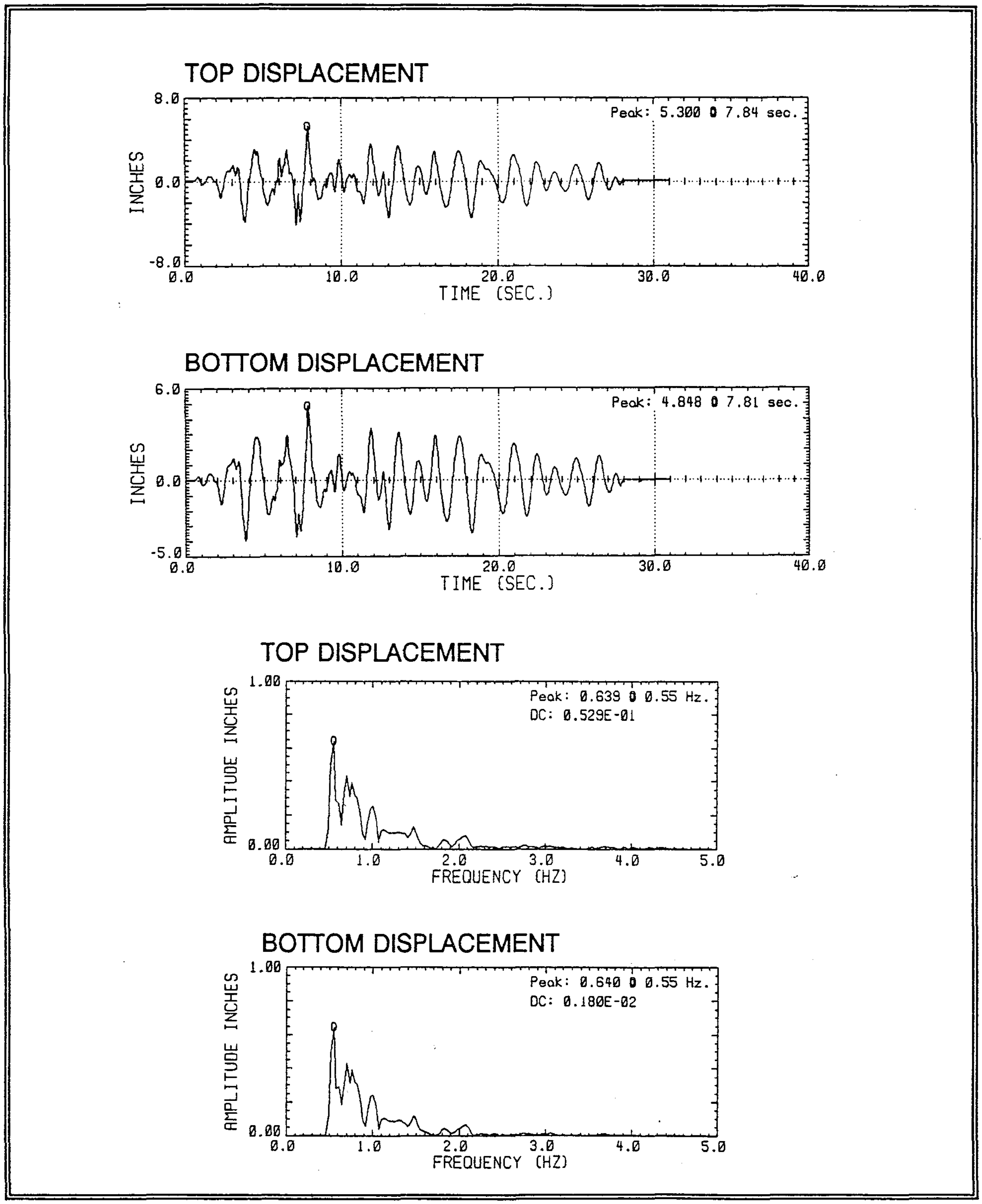
BONDCH - 0.8EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



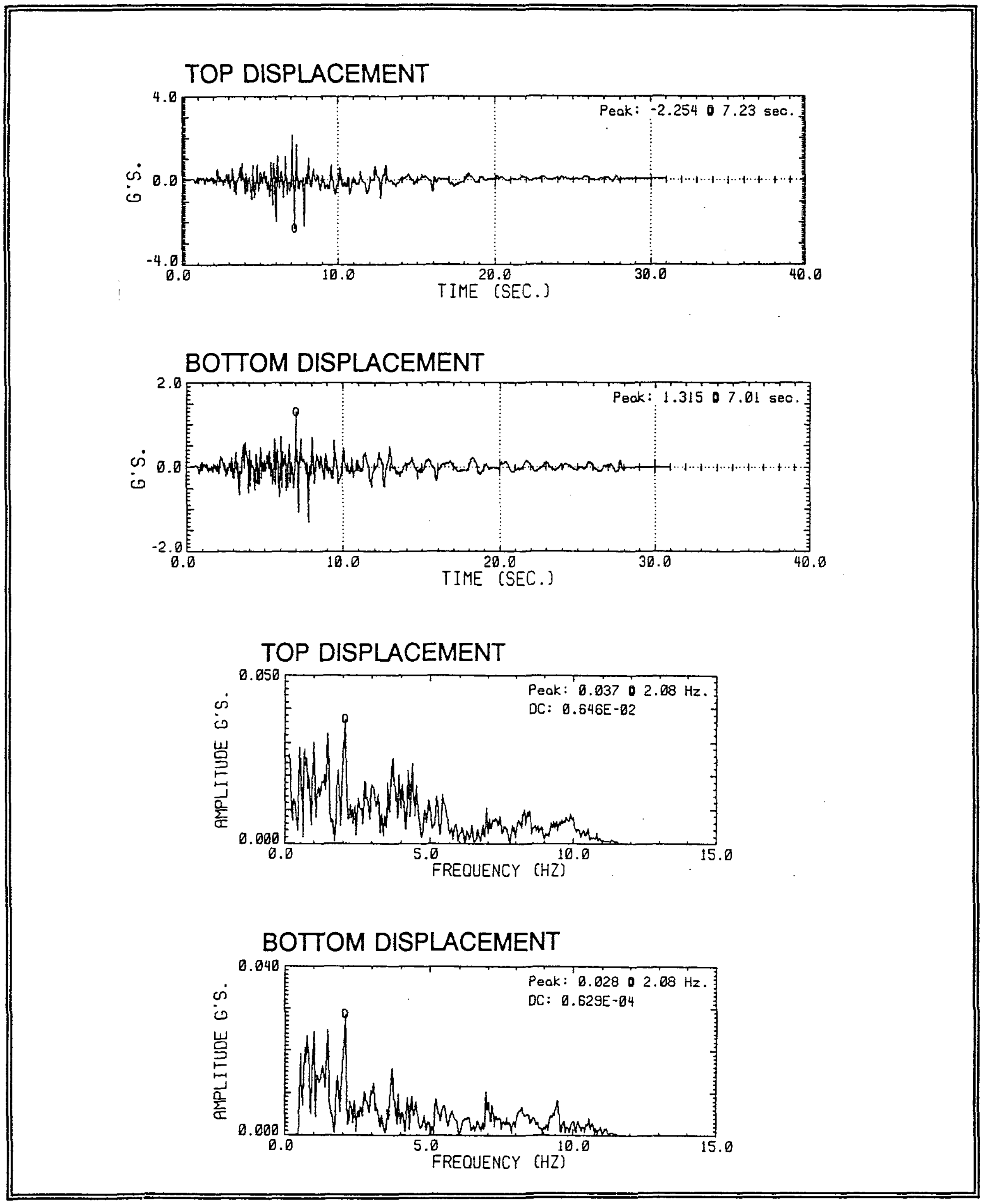
BONDCH - 0.8EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



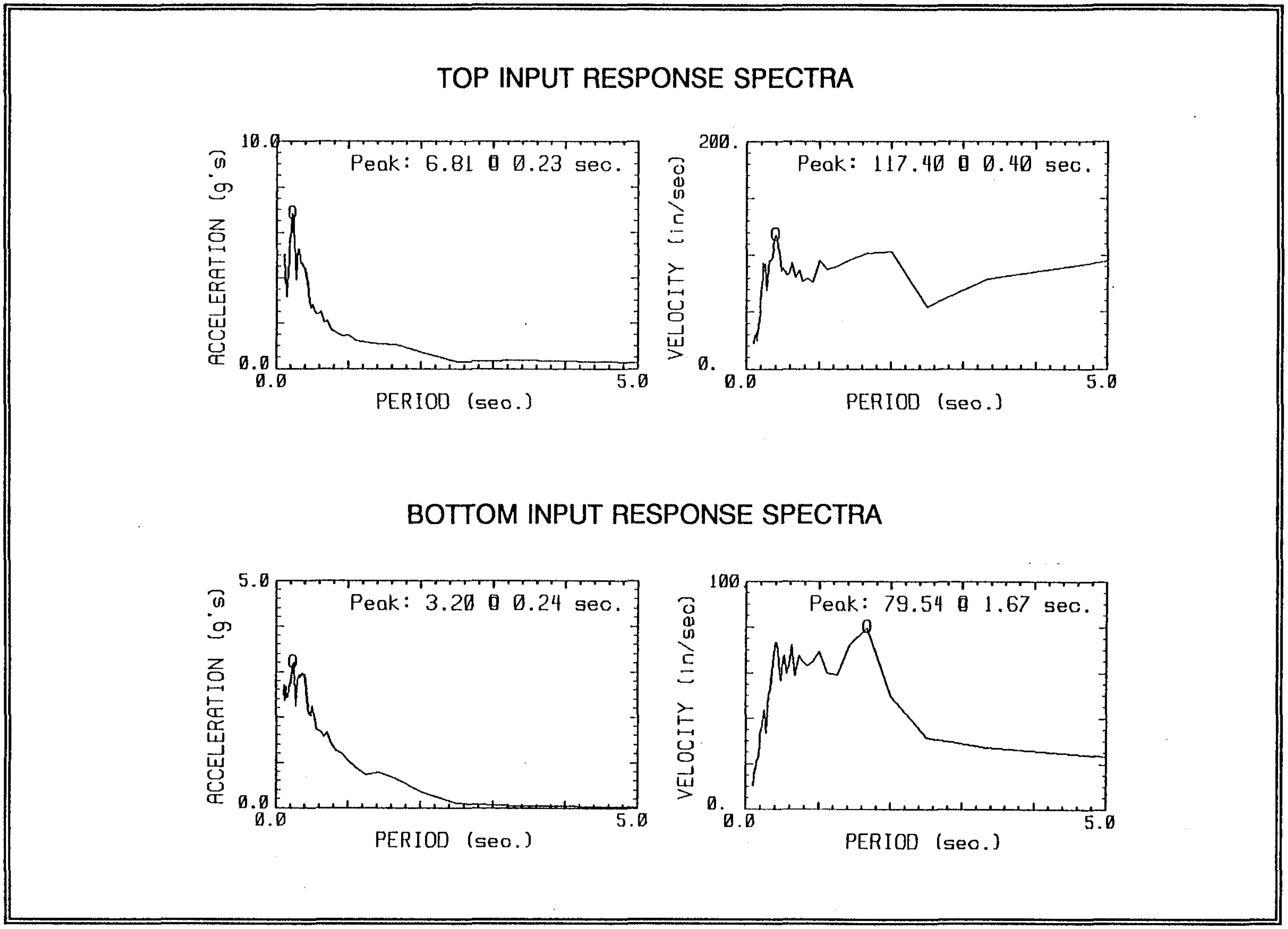
BONDCH - 0.8EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)



BONDCSH - 0.8EPA: Input Displacement at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



BONDCSH - 0.8EPA: Input Acceleration at Top and Bottom Actuators Time Histories and Fourier Amplitude Spectra



BONDCSH - 0.8EPA: Input at Top and Bottom Actuators
Acceleration and Velocity Response Spectra (5%damping)

APPENDIX D

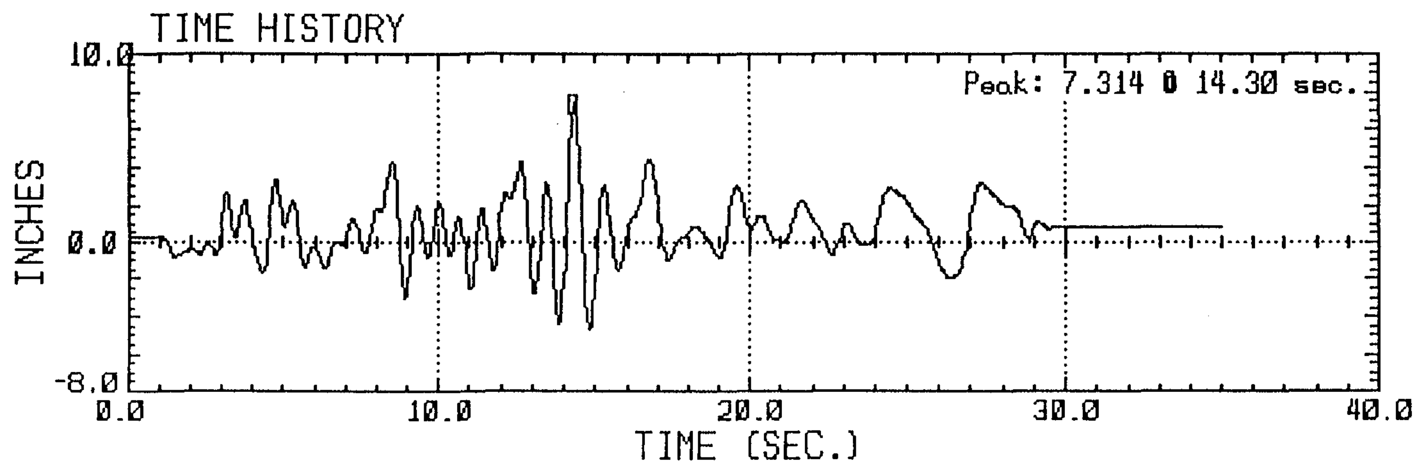
TYPICAL PROCESSED DATA

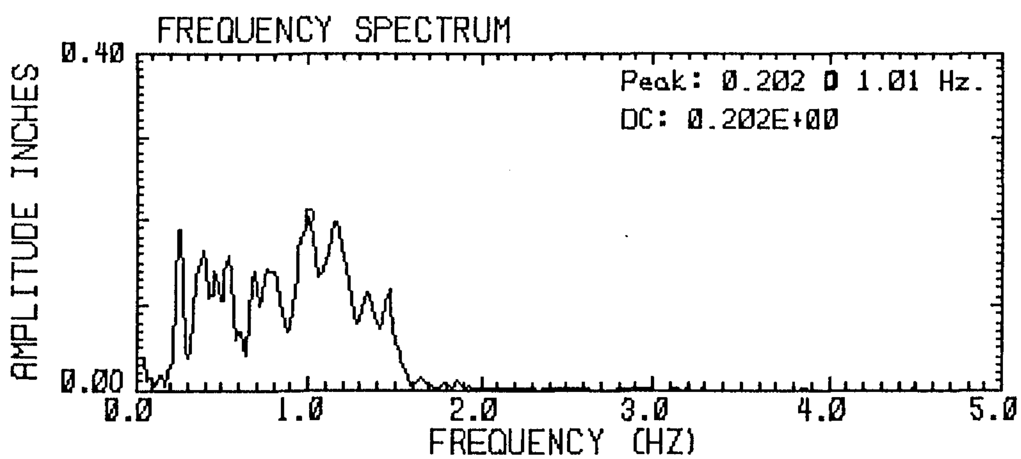
WALL 5, RUN BONDC (0.4 EPA)

WALL # 5 DYNAMIC TEST | BONDC - EPA: Ø.4G

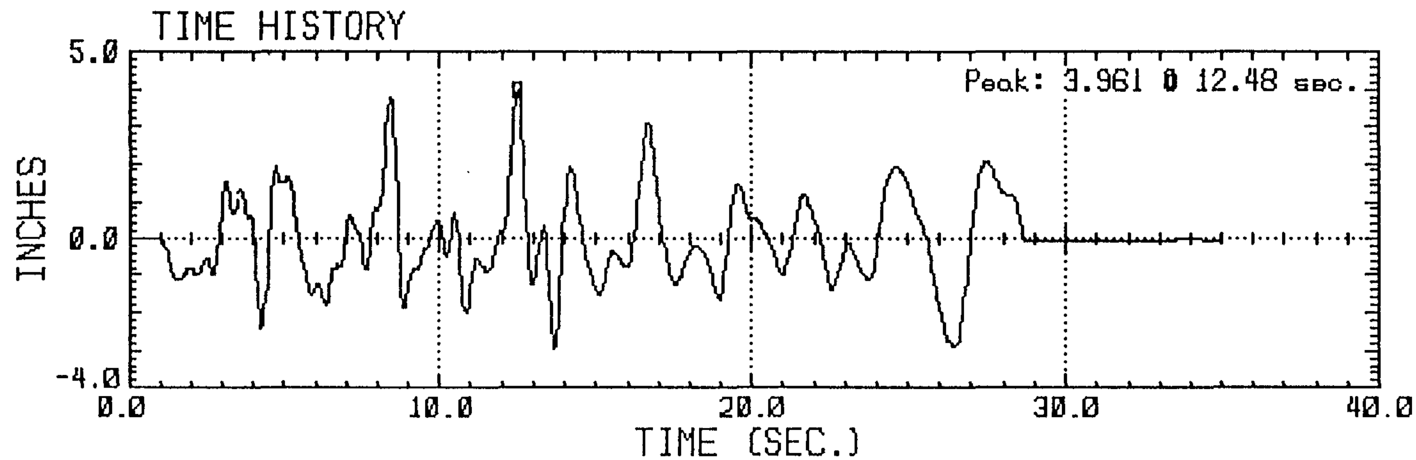
WALL HEIGHT: 25 ft H/T RATIO: 5Ø
VERT. REINF: 3 # 7 GROUTING : FULL
DEAD LOAD : 8ØØ lb/ft SPLICES : NO

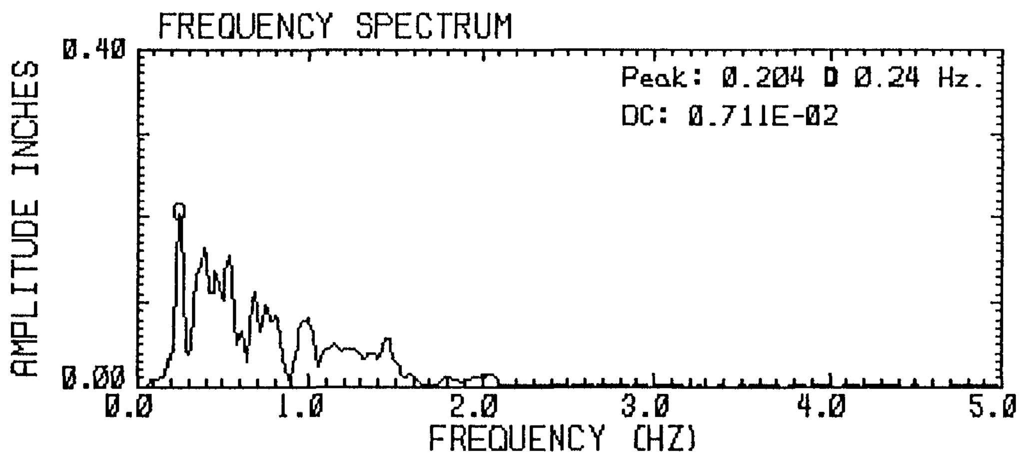
CENTER DISPLACEMENT
LPF: Ø - 1Ø Hz

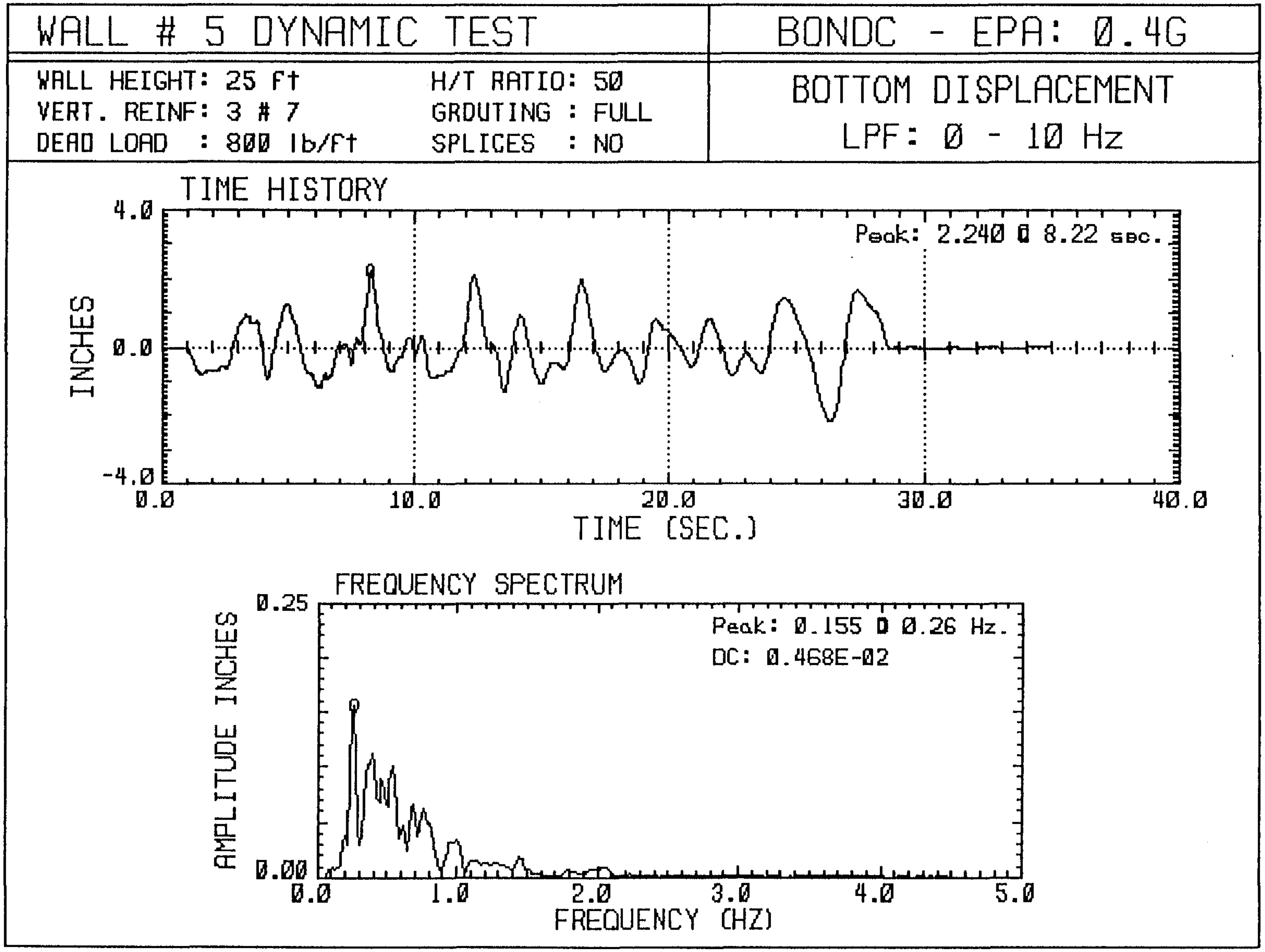




WALL # 5 DYNAMIC TEST		BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	TOP DISPLACEMENT LPF: Ø - 1Ø Hz



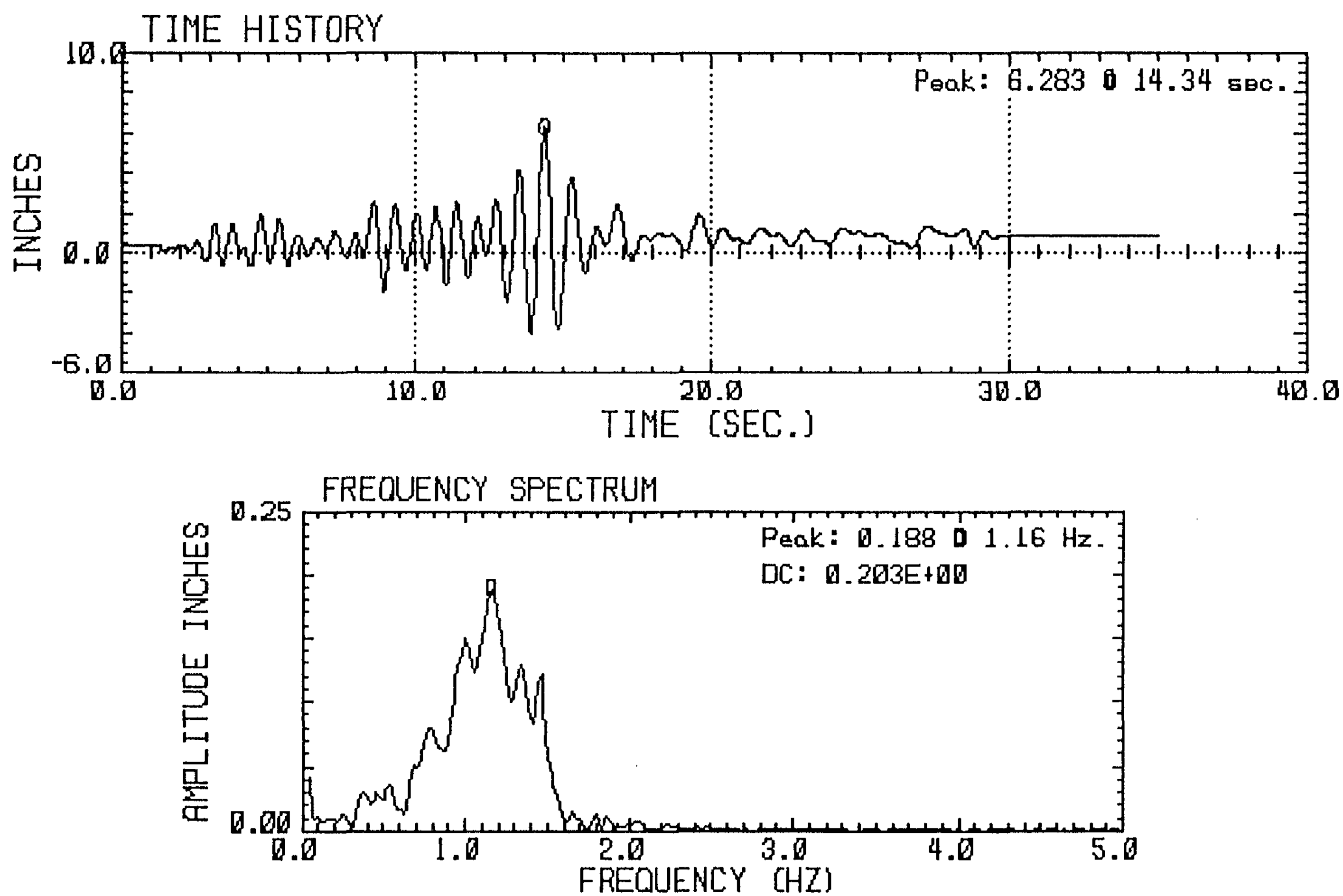



WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
BOTTOM DISPLACEMENT
LPF: 0 - 10 Hz
TIME HISTORY
INCHES
4.0
0.0
-4.0
Peak: 2.240 @ 8.22 sec.
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
FREQUENCY SPECTRUM
AMPLITUDE INCHES
0.25
0.00
Peak: 0.155 @ 0.26 Hz.
DC: 0.468E-02
0.0
1.0
2.0
3.0
4.0
5.0
FREQUENCY (HZ)

WALL # 5 DYNAMIC TEST | BONDC - EPA: 0.4G

WALL HEIGHT: 25 ft | H/T RATIO: 50
VERT. REINF: 3 # 7 | GROUTING : FULL
DEAD LOAD : 800 lb/ft | SPLICES : NO

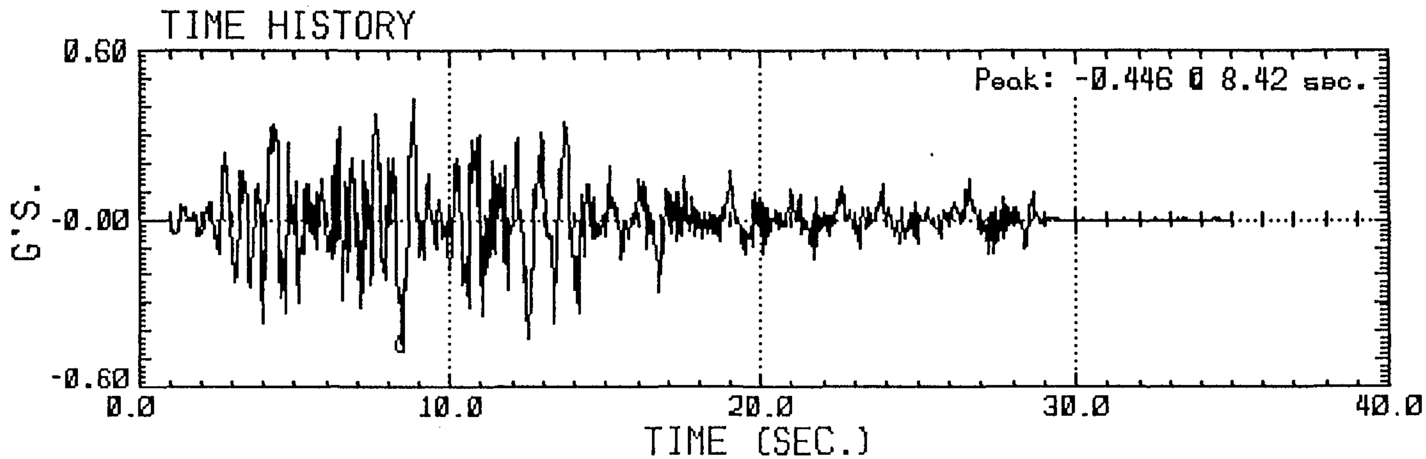
CENTER REL. DEFLECTION
LPF: 0 - 10 Hz

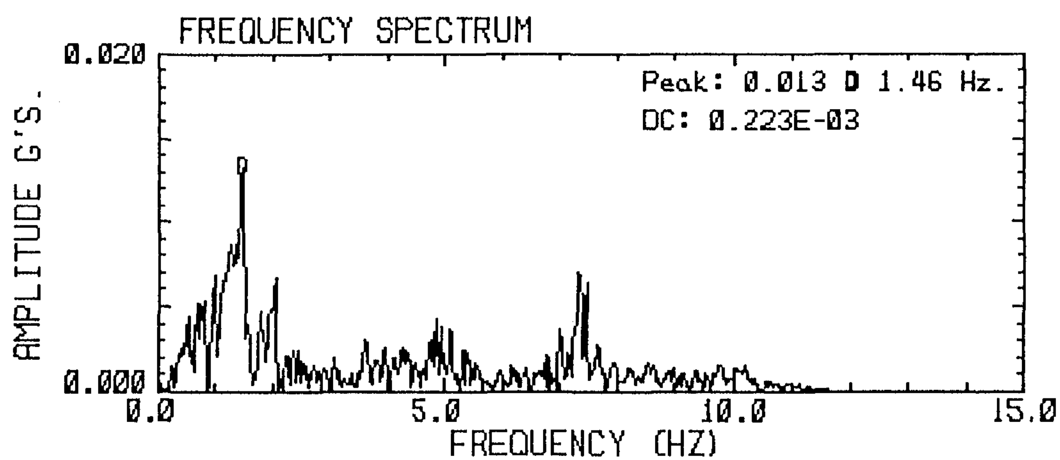


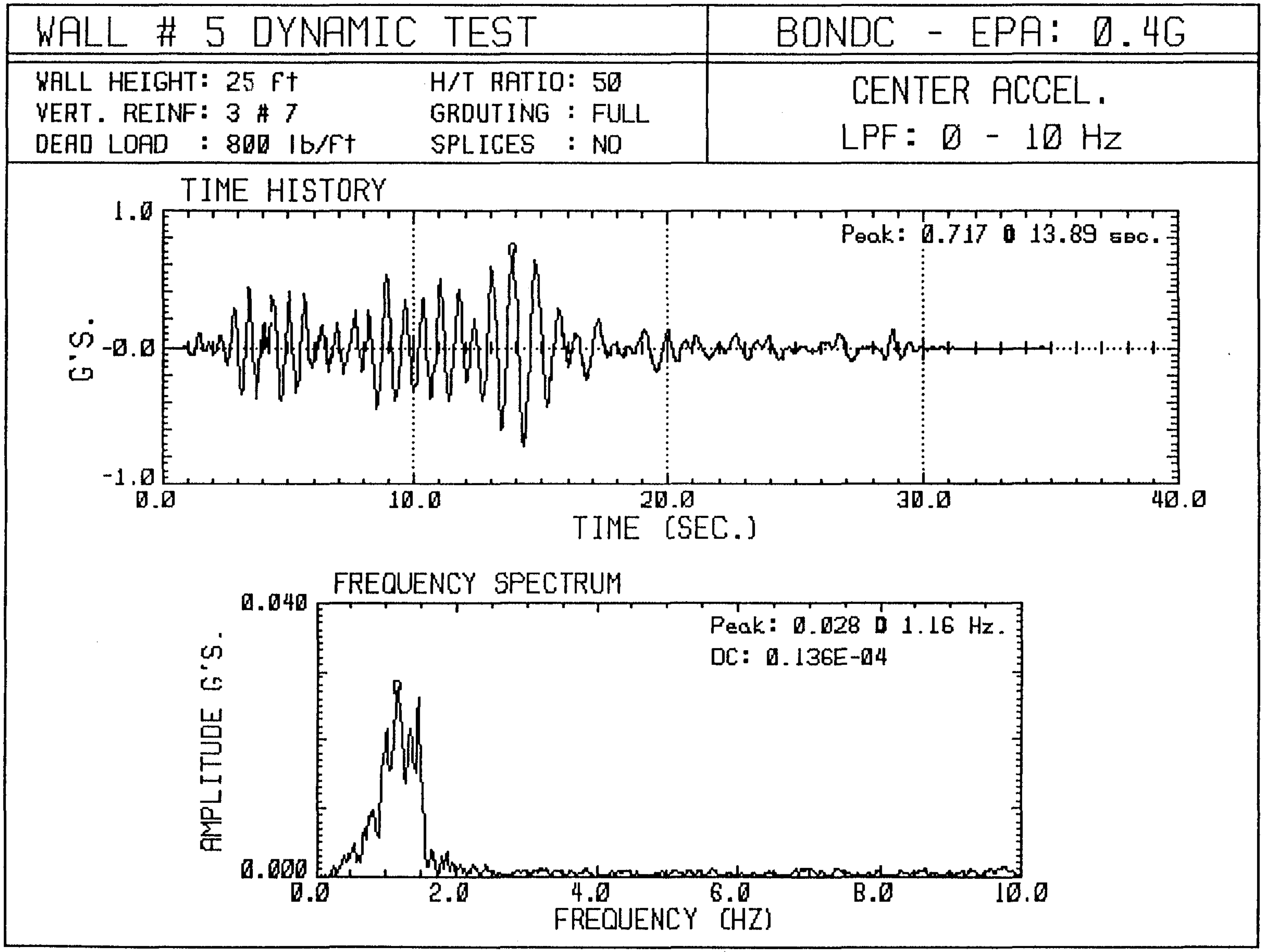
WALL # 5 DYNAMIC TEST | BONDC - EPA: Ø.4G

WALL HEIGHT: 25 ft H/T RATIO: 5Ø
VERT. REINF: 3 # 7 GROUTING : FULL
DEAD LOAD : 8ØØ lb/ft SPLICES : NO

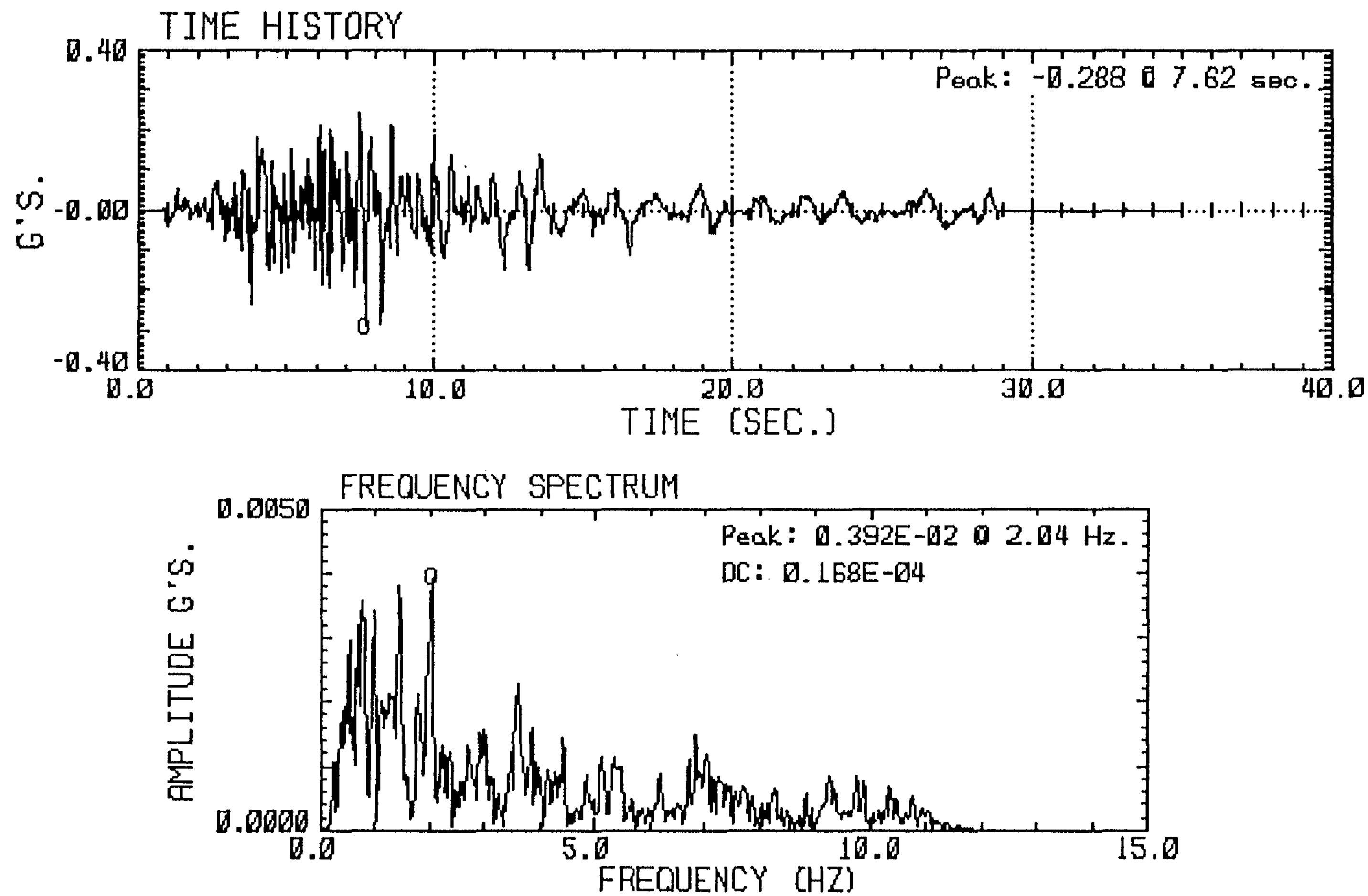
TOP INPUT ACCEL.
LPF: Ø - 1Ø Hz

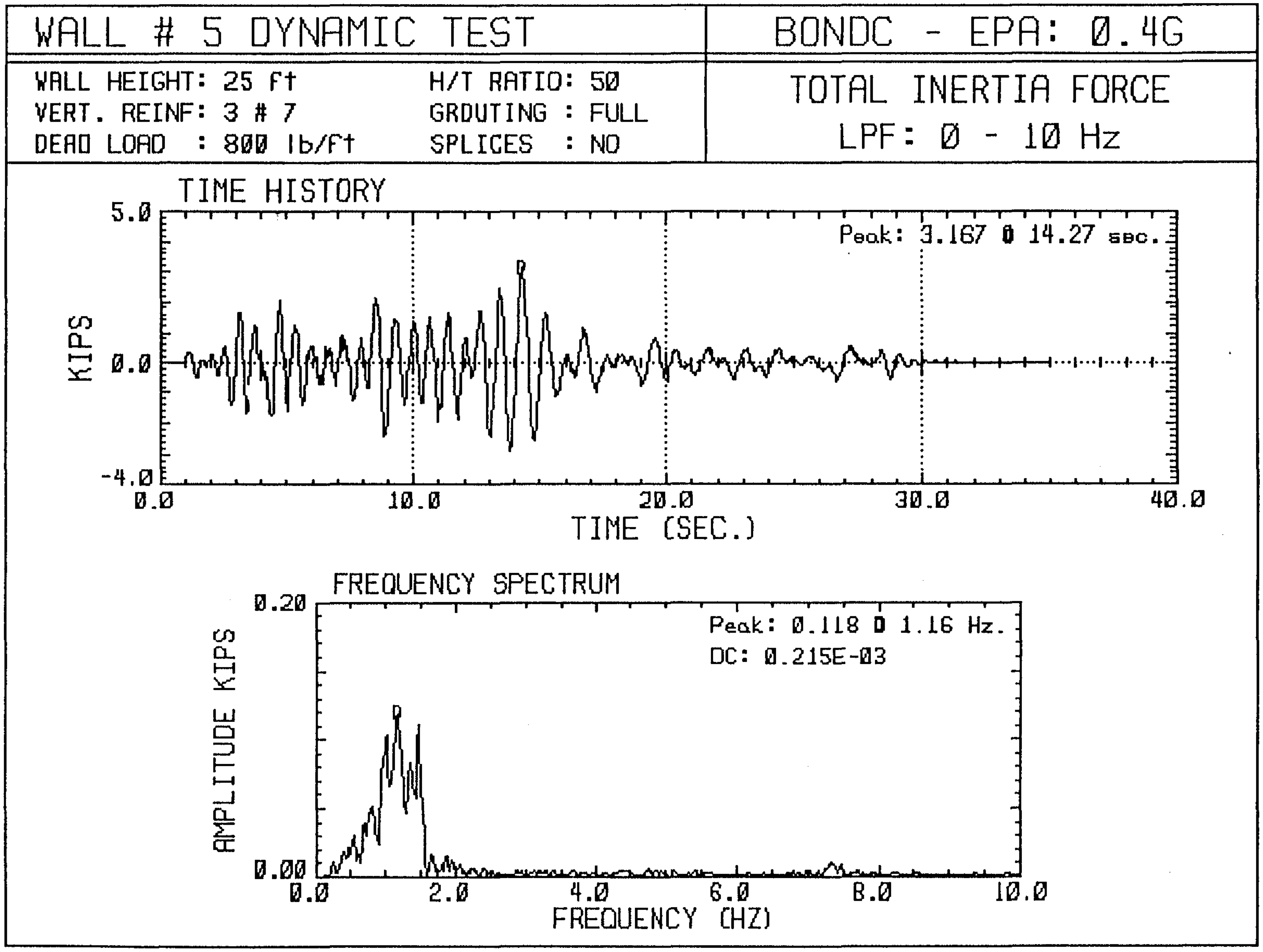


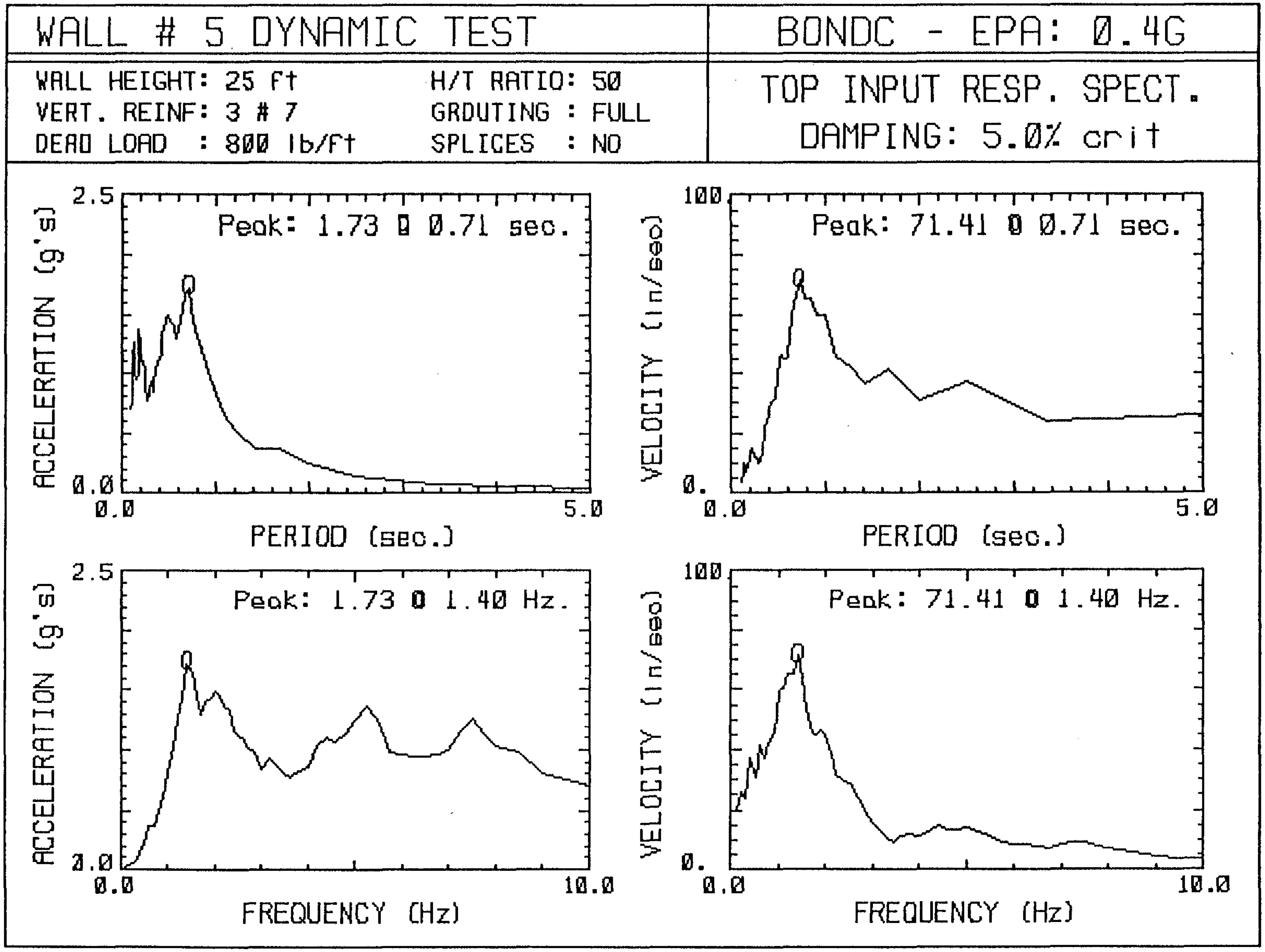



WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
CENTER ACCEL.
LPF: 0 - 10 Hz
TIME HISTORY
G'S.
1.0
-0.0
-1.0
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
Peak: 0.717 @ 13.89 sec.
FREQUENCY SPECTRUM
AMPLITUDE G'S.
0.040
0.000
0.0
2.0
4.0
6.0
8.0
10.0
FREQUENCY (HZ)
Peak: 0.028 @ 1.16 Hz.
DC: 0.136E-04

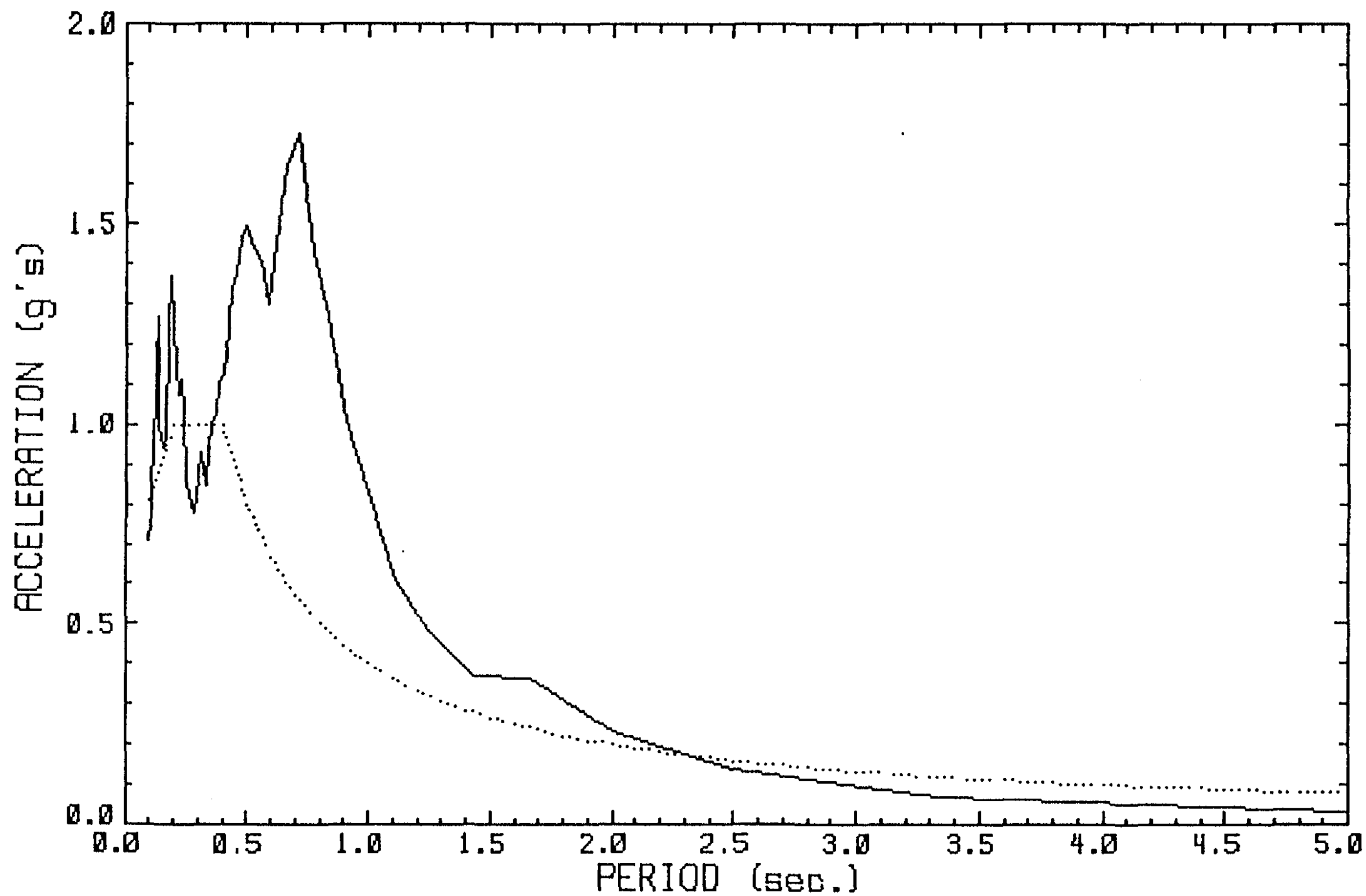
WALL # 5 DYNAMIC TEST		BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	BOTTOM INPUT ACCEL. LPF: 0 - 10 Hz

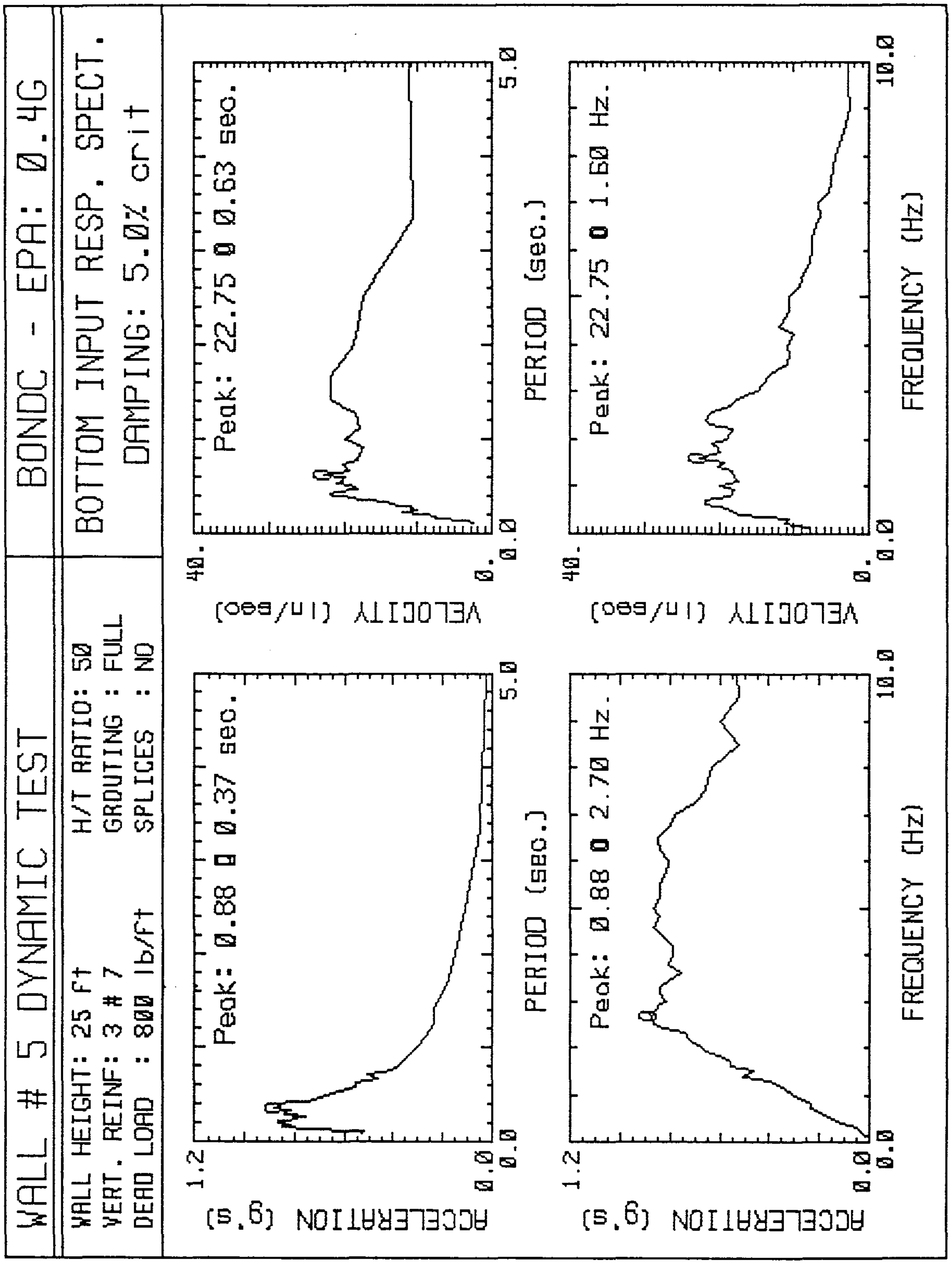


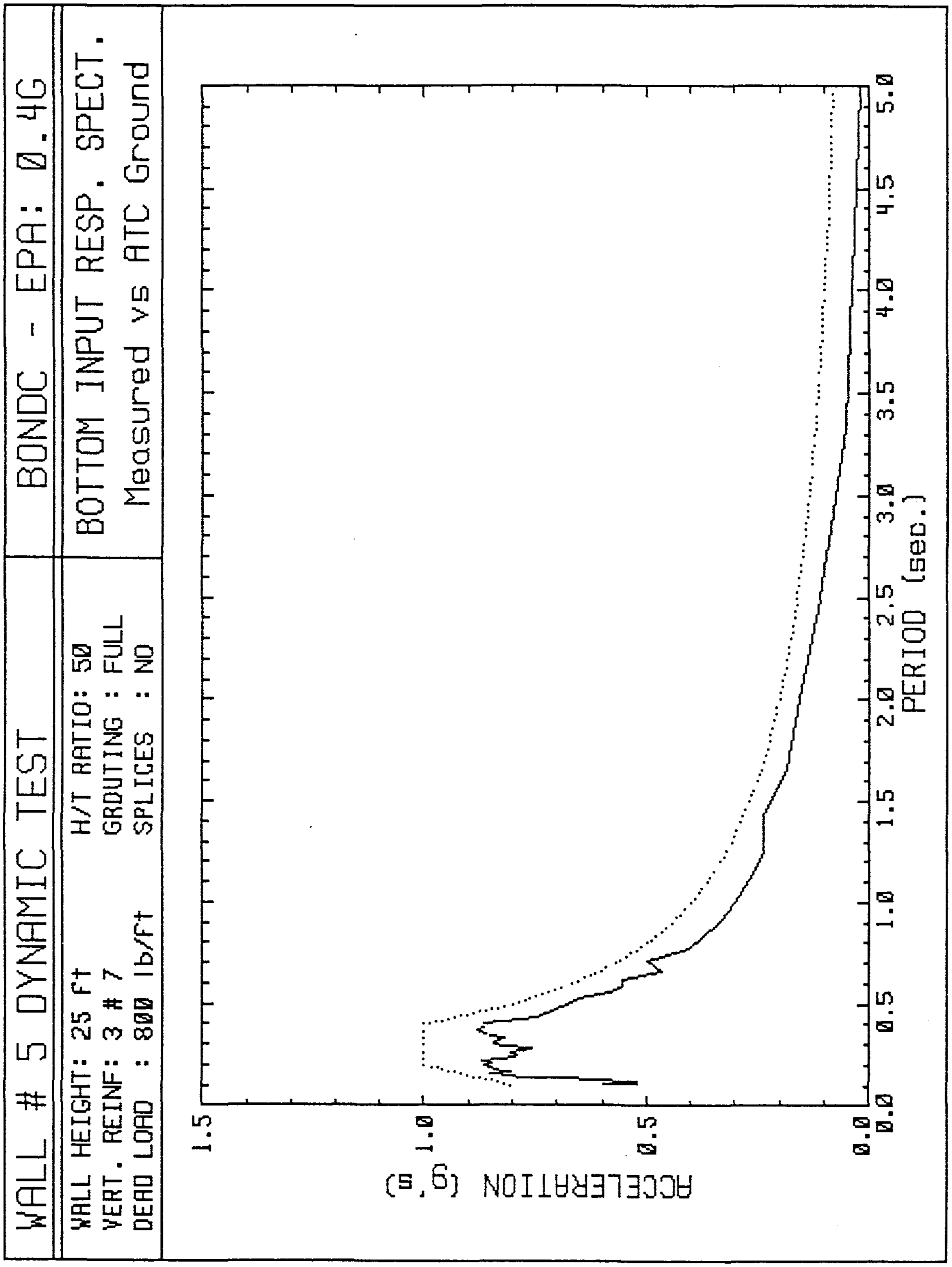

WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
TOTAL INERTIA FORCE
LPF: 0 - 10 Hz
TIME HISTORY
KIPS
5.0
0.0
-4.0
Peak: 3.167 @ 14.27 sec.
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
FREQUENCY SPECTRUM
AMPLITUDE KIPS
0.20
0.00
Peak: 0.118 @ 1.16 Hz.
DC: 0.215E-03
0.0
2.0
4.0
6.0
8.0
10.0
FREQUENCY (HZ)

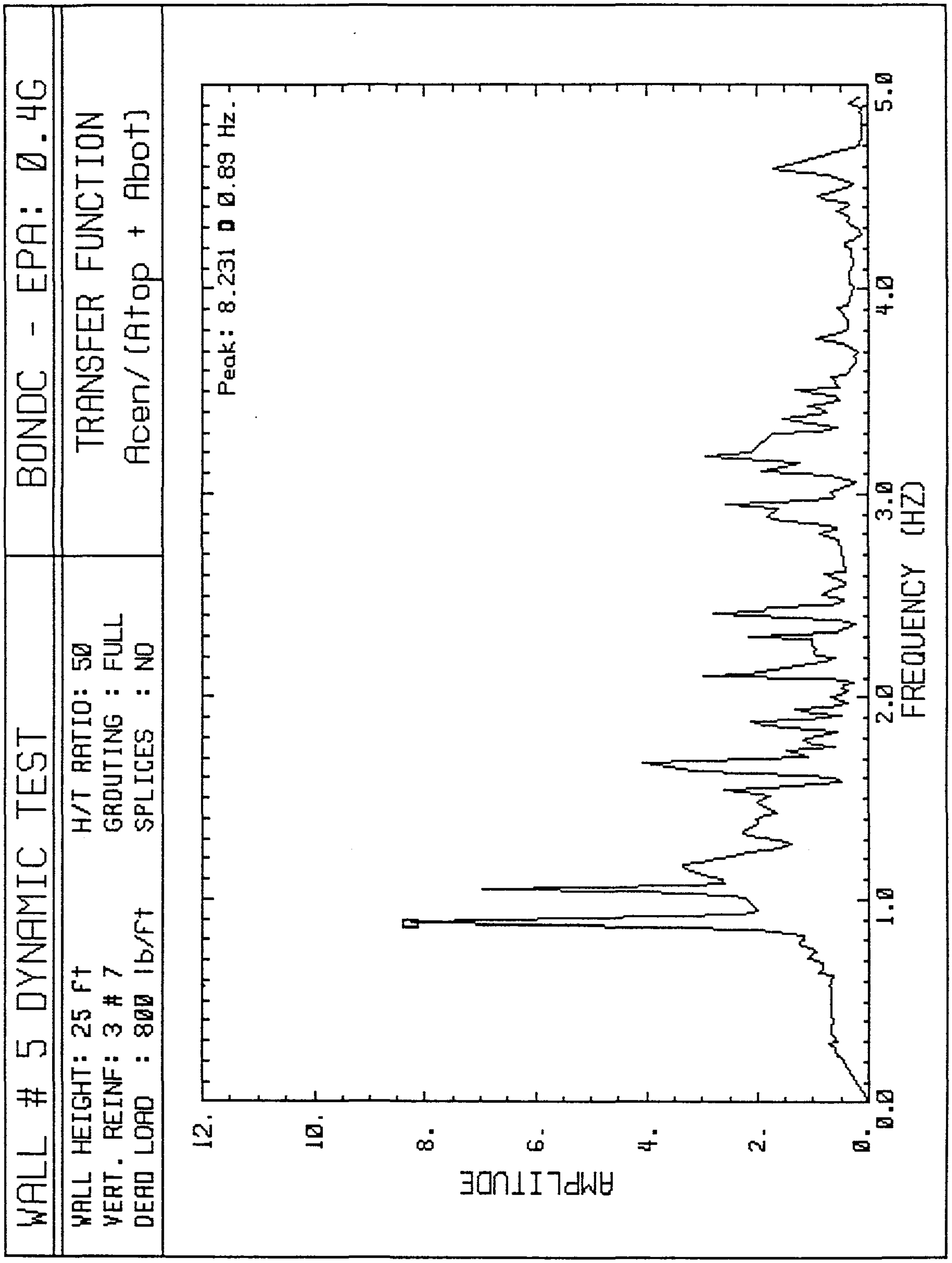

WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
TOP INPUT RESP. SPECT.
DAMPING: 5.0% crit
Peak: 1.73 @ 0.71 sec.
Peak: 71.41 @ 0.71 sec.
Peak: 1.73 @ 1.40 Hz.
Peak: 71.41 @ 1.40 Hz.
ACCELERATION (g's)
VELOCITY (in/sec)
PERIOD (sec.)
FREQUENCY (Hz)
2.5
0.0
100
0.
5.0
10.0

WALL # 5 DYNAMIC TEST		BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	TOP INPUT RESP. SPECT. Measured vs ATC Ground




WALL # 5 DYNAMIC TEST
BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft
H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO
BOTTOM INPUT RESP. SPECT.
DAMPING: 5.Ø% crit
Peak: Ø.88 @ Ø.37 sec.
ACCELERATION (g's)
PERIOD (sec.)
Peak: 22.75 @ Ø.63 sec.
VELOCITY (in/sec)
PERIOD (sec.)
Peak: Ø.88 @ 2.7Ø Hz.
ACCELERATION (g's)
FREQUENCY (Hz)
Peak: 22.75 @ 1.6Ø Hz.
VELOCITY (in/sec)
FREQUENCY (Hz)


WALL # 5 DYNAMIC TEST
BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft
H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO
BOTTOM INPUT RESP. SPECT.
Measured vs ATC Ground
ACCELERATION (g's)
1.5
1.Ø
Ø.5
Ø.Ø
Ø.Ø
Ø.5
1.Ø
1.5
2.Ø
2.5
3.Ø
3.5
4.Ø
4.5
5.Ø
PERIOD (sec.)


WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
TRANSFER FUNCTION
Acen/(Atop + Abot)
Peak: 8.231 @ 0.89 Hz.
AMPLITUDE
FREQUENCY (HZ)
0.
2.
4.
6.
8.
10.
12.
0.0
1.0
2.0
3.0
4.0
5.0

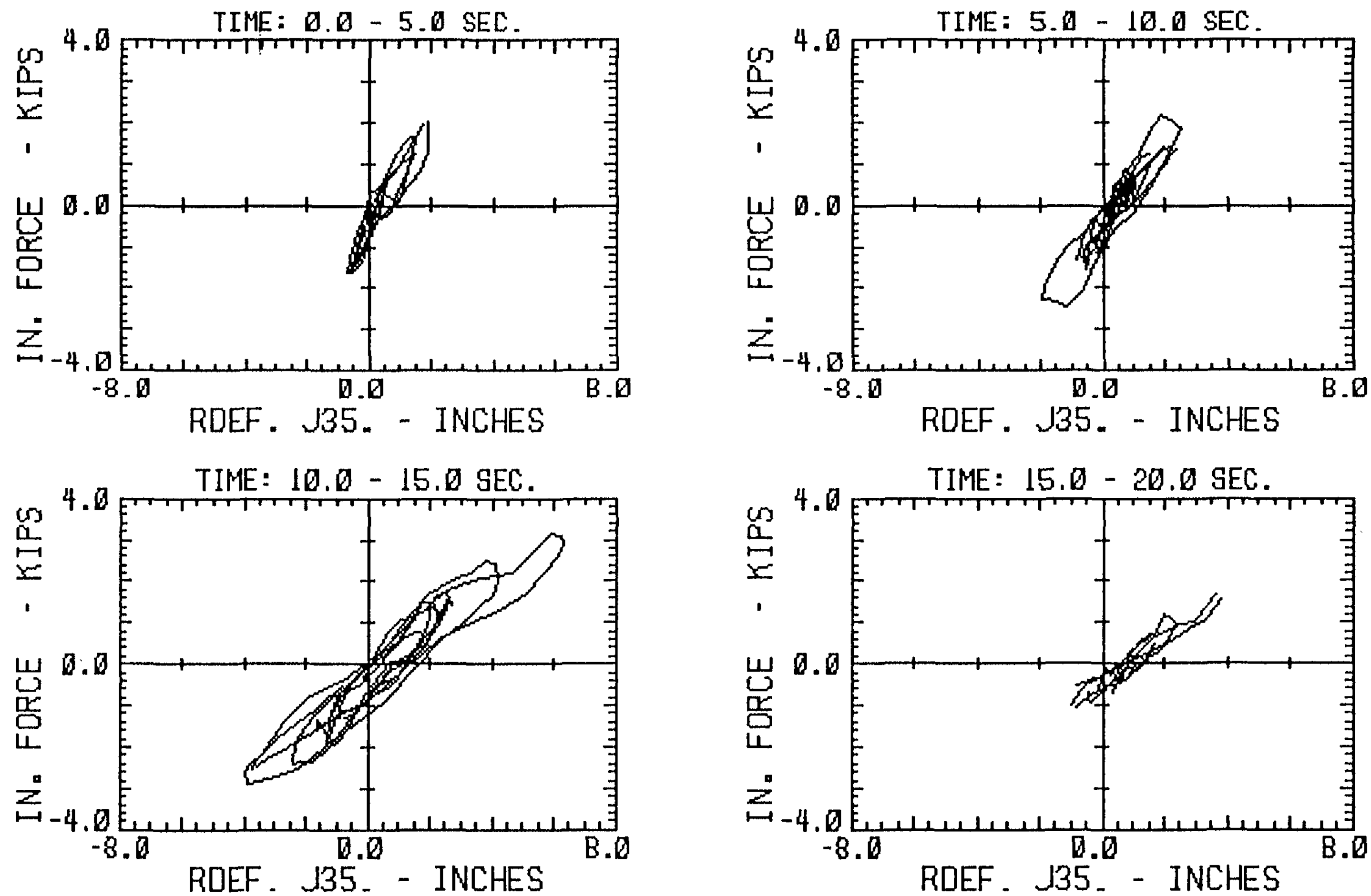
WALL # 5 DYNAMIC TEST

BONDC - EPA: 0.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

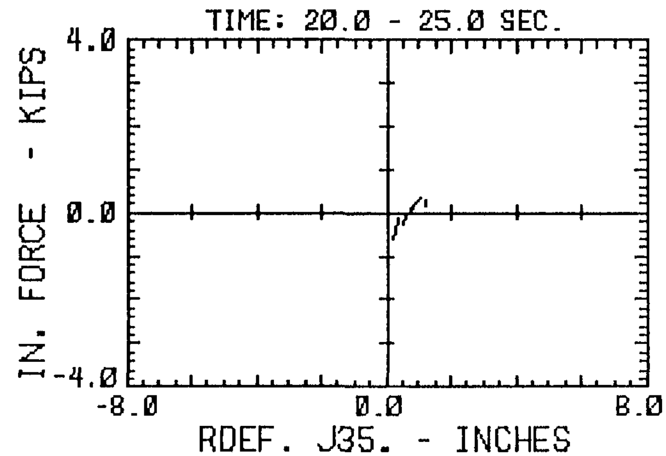
IN. FORCE vs REL. DEFL.
WALL CENTER

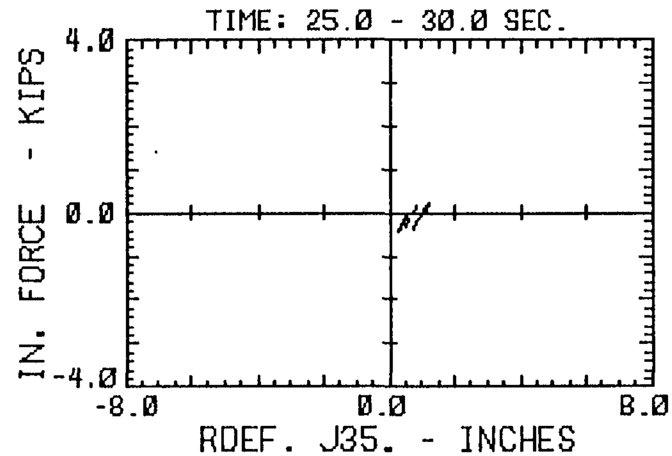


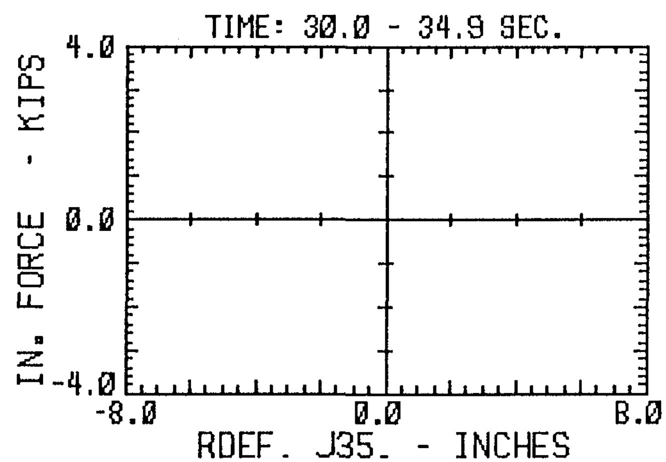
WALL # 5 DYNAMIC TEST | BONDC - EPA: 0.4G

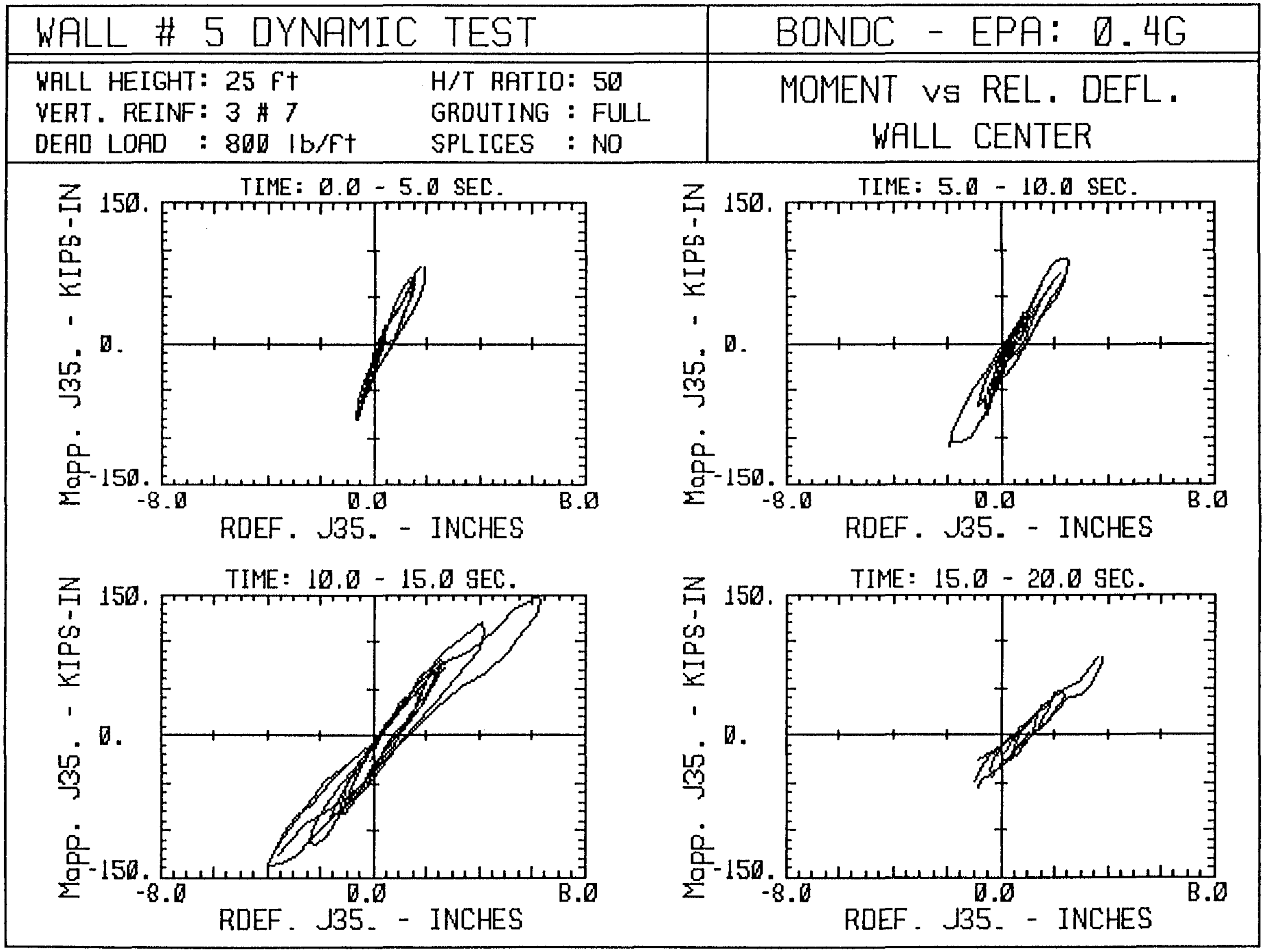
WALL HEIGHT: 25 ft H/T RATIO: 50
VERT. REINF: 3 # 7 GROUTING : FULL
DEAD LOAD : 800 lb/ft SPLICES : NO

IN. FORCE vs REL. DEFL.
WALL CENTER

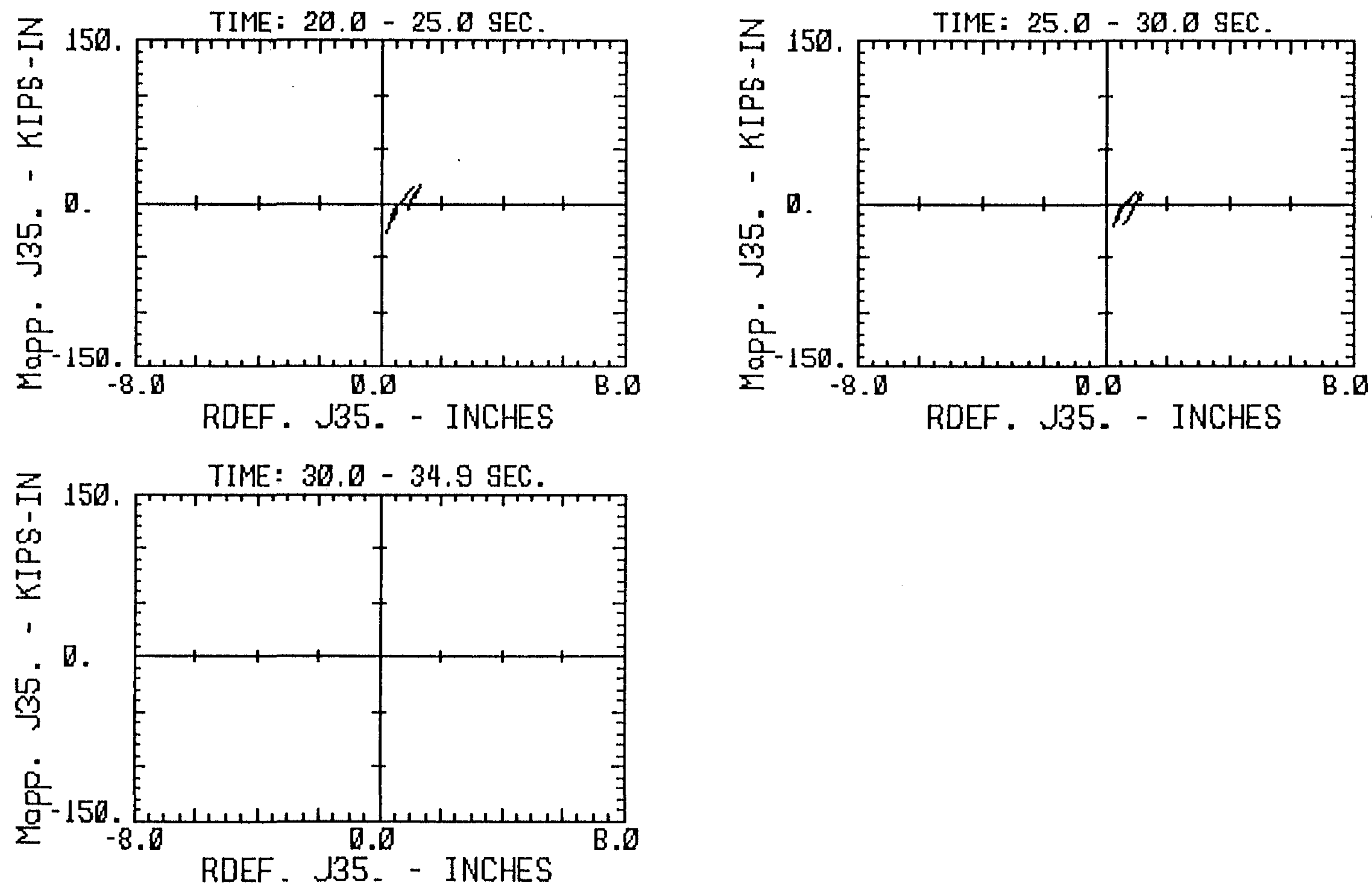


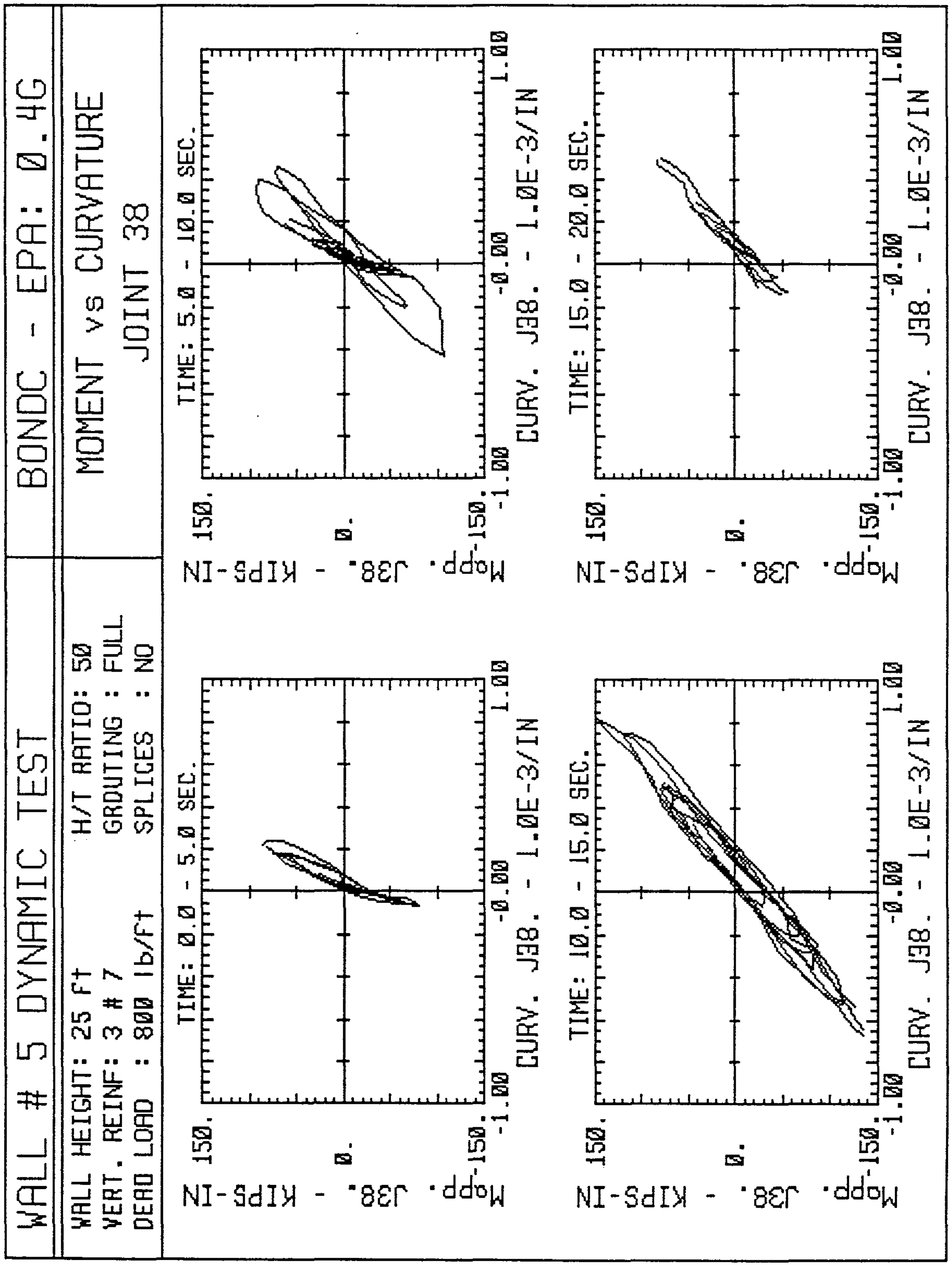




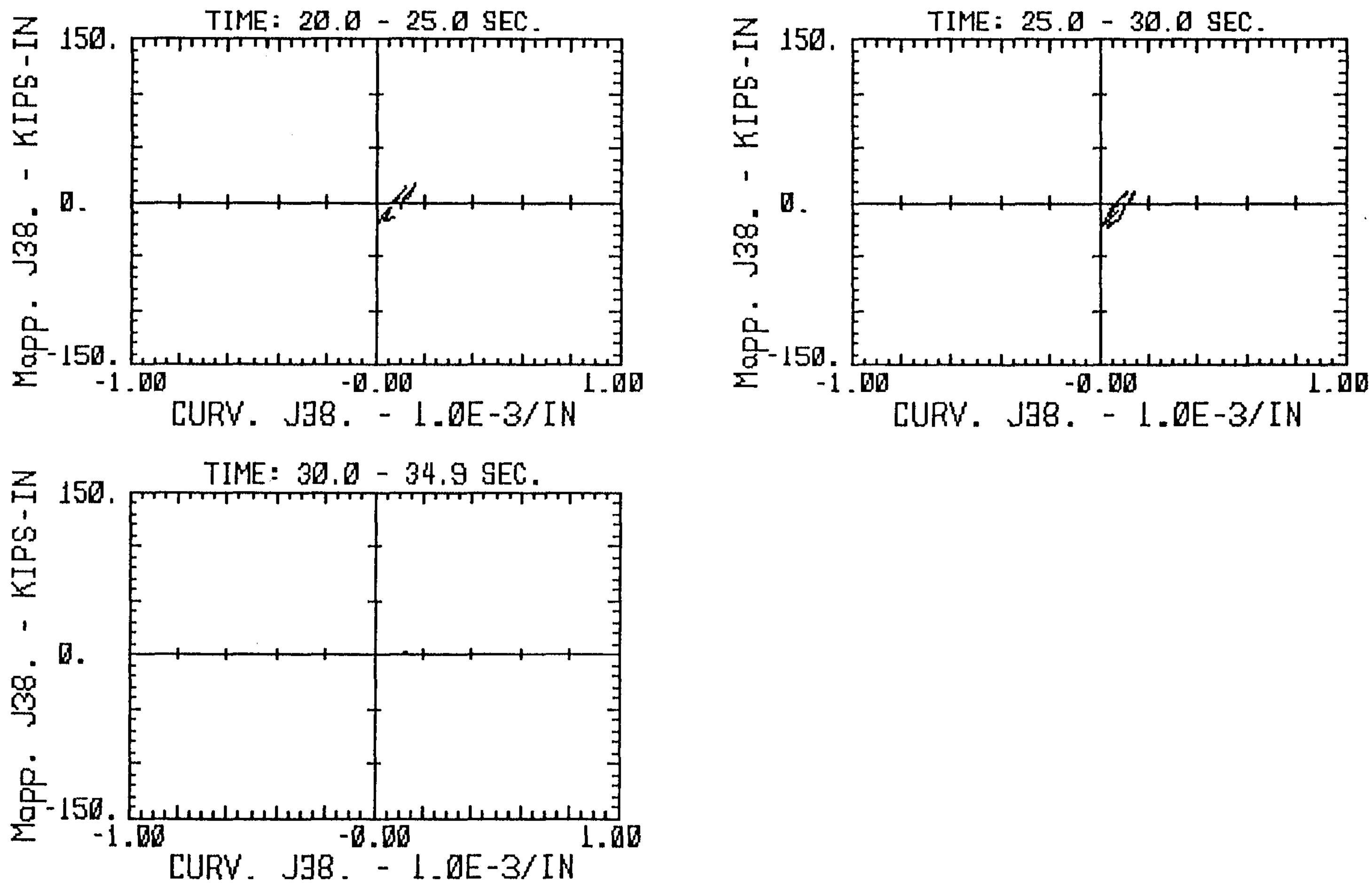

WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
MOMENT vs REL. DEFL.
WALL CENTER
TIME: 0.0 - 5.0 SEC.
TIME: 5.0 - 10.0 SEC.
TIME: 10.0 - 15.0 SEC.
TIME: 15.0 - 20.0 SEC.
Mapp. J35. - KIPS-IN
RDEF. J35. - INCHES
150.
0.
-150.
-8.0
0.0
8.0

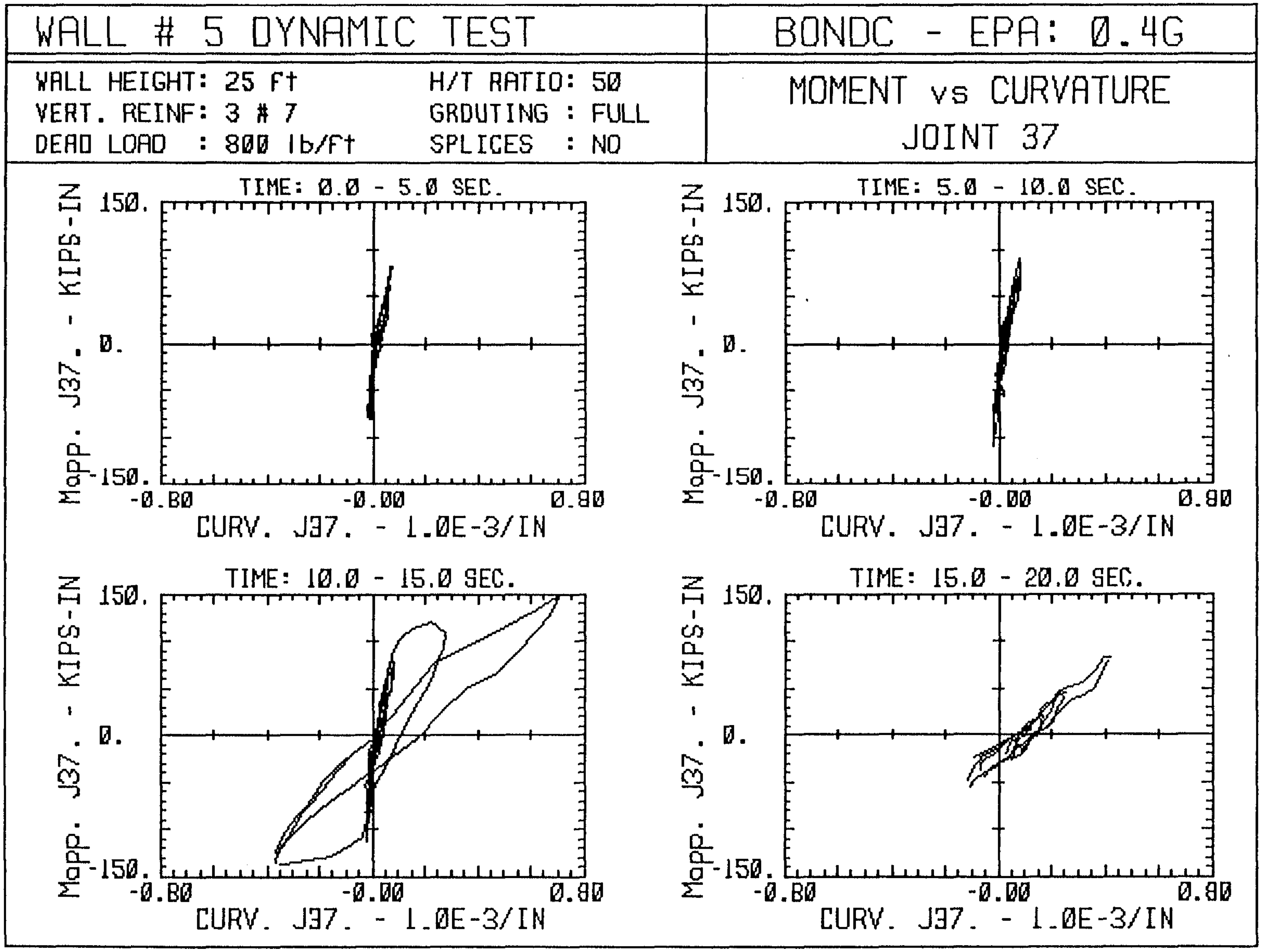
WALL # 5 DYNAMIC TEST		BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	MOMENT vs REL. DEFL. WALL CENTER

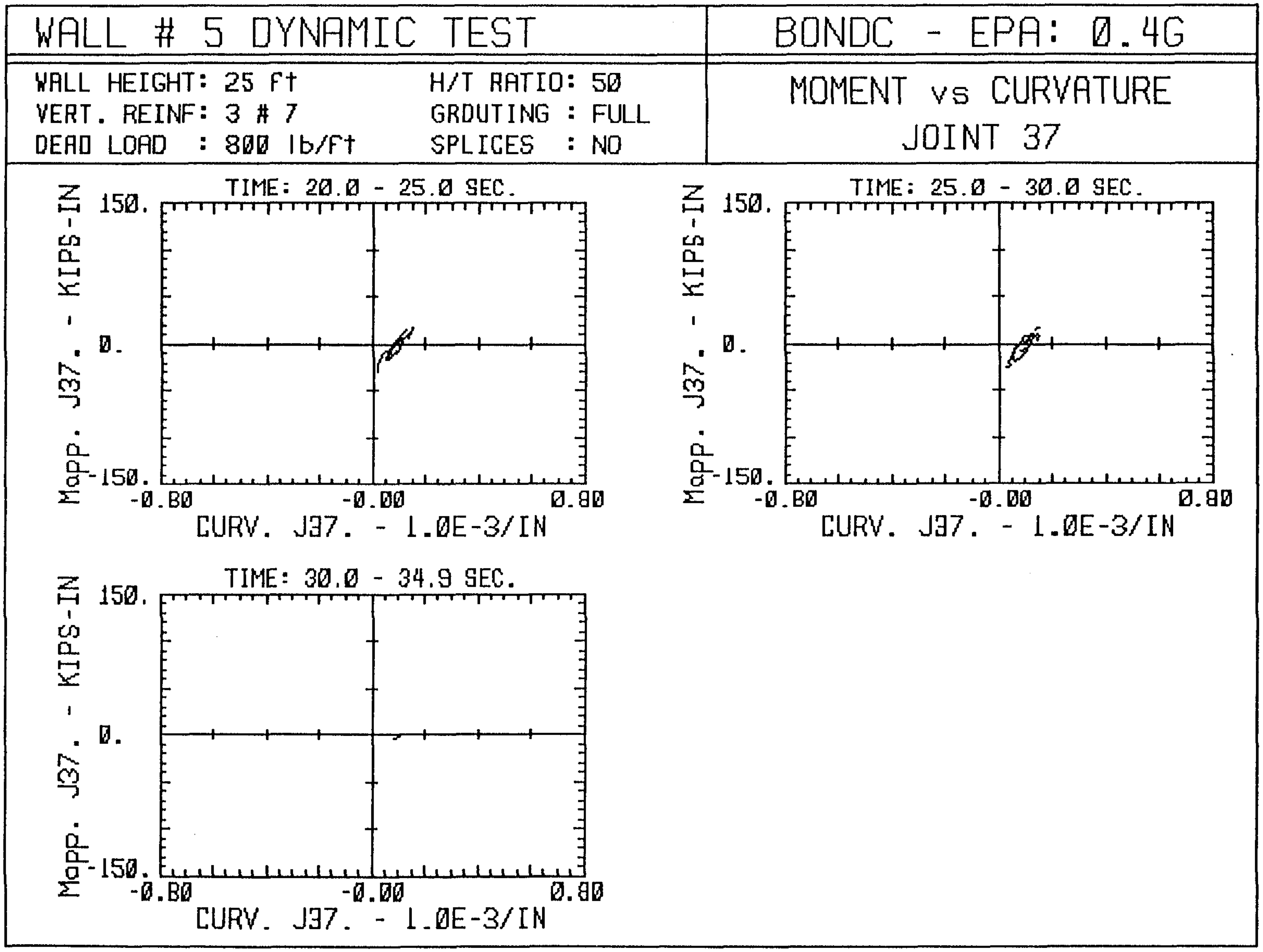


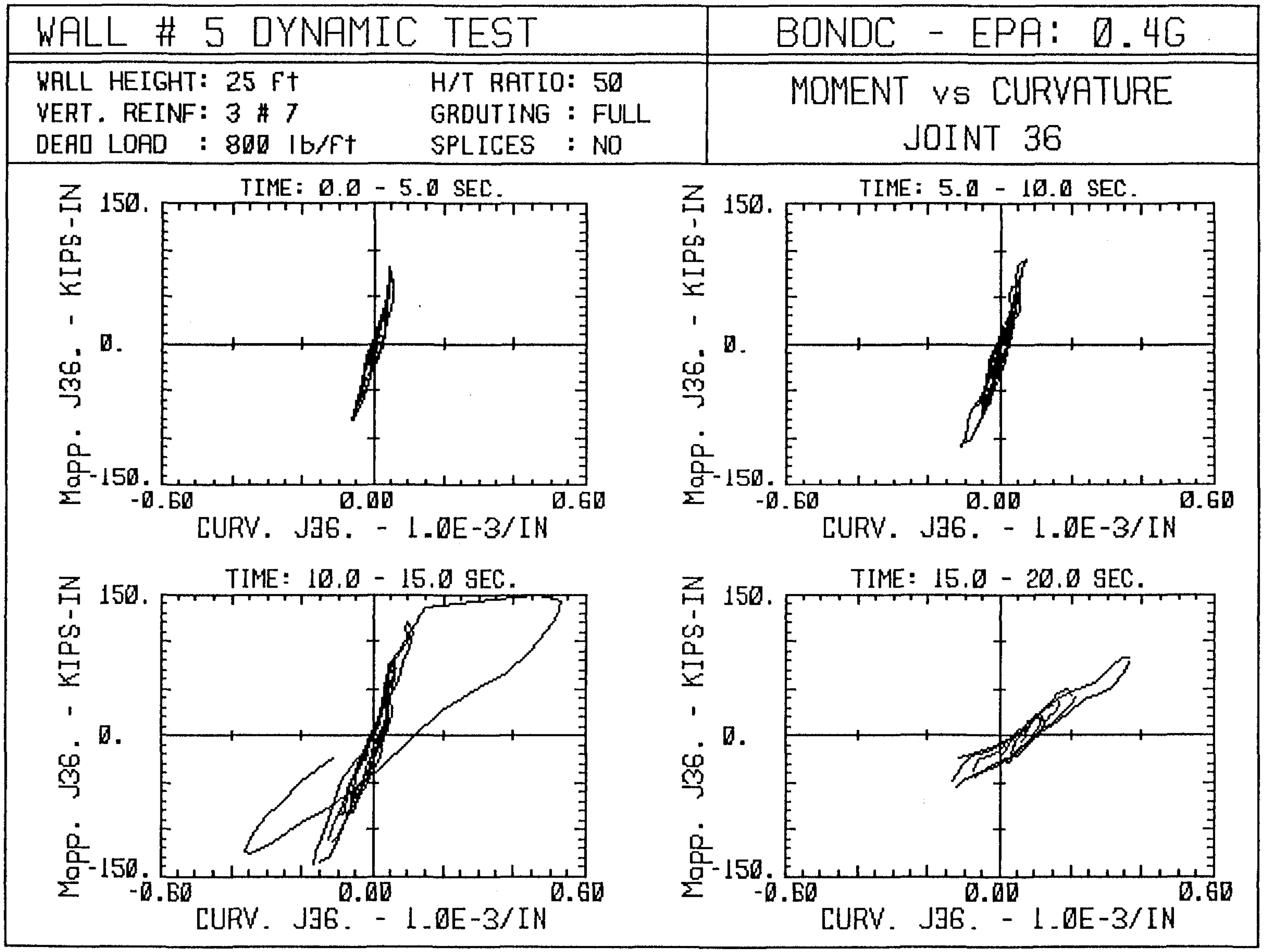

WALL # 5 DYNAMIC TEST
BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft
H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO
MOMENT vs CURVATURE
JOINT 38
TIME: Ø.Ø - 5.Ø SEC.
TIME: 5.Ø - 1Ø.Ø SEC.
TIME: 1Ø.Ø - 15.Ø SEC.
TIME: 15.Ø - 2Ø.Ø SEC.
Mopp. J38. - KIPS-IN
CURV. J38. - 1.ØE-3/IN
15Ø.
Ø.
-15Ø.
-1.ØØ
-Ø.ØØ
1.ØØ

WALL # 5 DYNAMIC TEST	BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft H/T RATIO: 50 VERT. REINF: 3 # 7 GROUTING : FULL DEAD LOAD : 800 lb/ft SPLICES : NO	MOMENT vs CURVATURE JOINT 38




WALL # 5 DYNAMIC TEST
BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft
H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO
MOMENT vs CURVATURE
JOINT 37
TIME: Ø.Ø - 5.Ø SEC.
TIME: 5.Ø - 1Ø.Ø SEC.
TIME: 1Ø.Ø - 15.Ø SEC.
TIME: 15.Ø - 2Ø.Ø SEC.
Mapp. J37. - KIPS-IN
150.
Ø.
-15Ø.
-Ø.8Ø
-Ø.ØØ
Ø.8Ø
CURV. J37. - 1.ØE-3/IN


WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
MOMENT vs CURVATURE
JOINT 37
TIME: 20.0 - 25.0 SEC.
TIME: 25.0 - 30.0 SEC.
TIME: 30.0 - 34.9 SEC.
Mapp. J37. - KIPS-IN
150.
0.
-150.
-0.80
-0.00
0.80
CURV. J37. - 1.0E-3/IN


WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
MOMENT vs CURVATURE
JOINT 36
TIME: 0.0 - 5.0 SEC.
TIME: 5.0 - 10.0 SEC.
TIME: 10.0 - 15.0 SEC.
TIME: 15.0 - 20.0 SEC.
Mapp. J36. - KIPS-IN
150.
0.
-150.
-0.60
0.00
0.60
CURV. J36. - 1.0E-3/IN

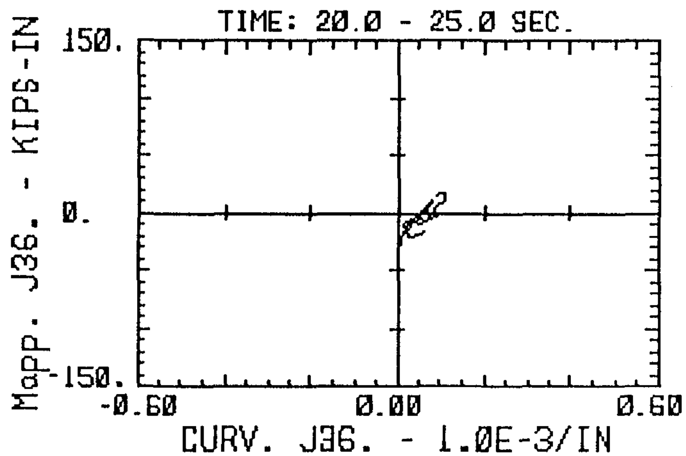
WALL # 5 DYNAMIC TEST

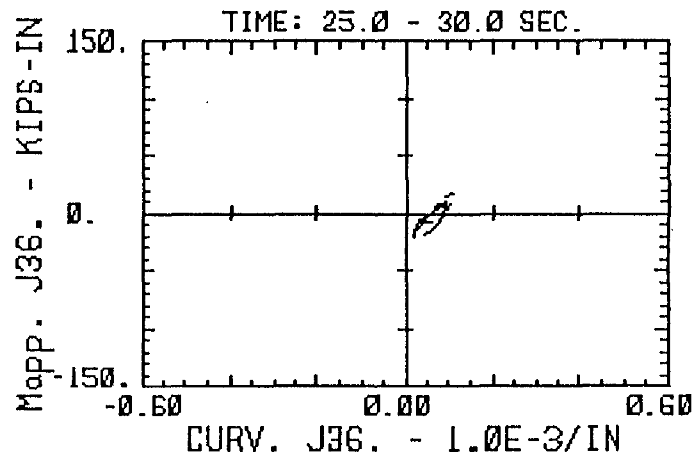
BONDC - EPA: Ø.4G

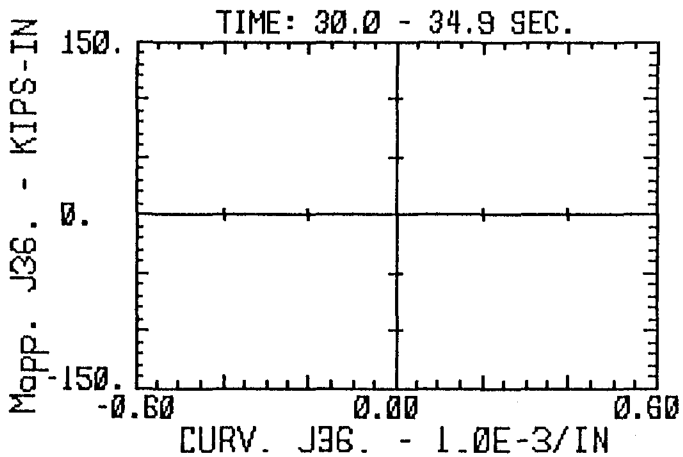
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft

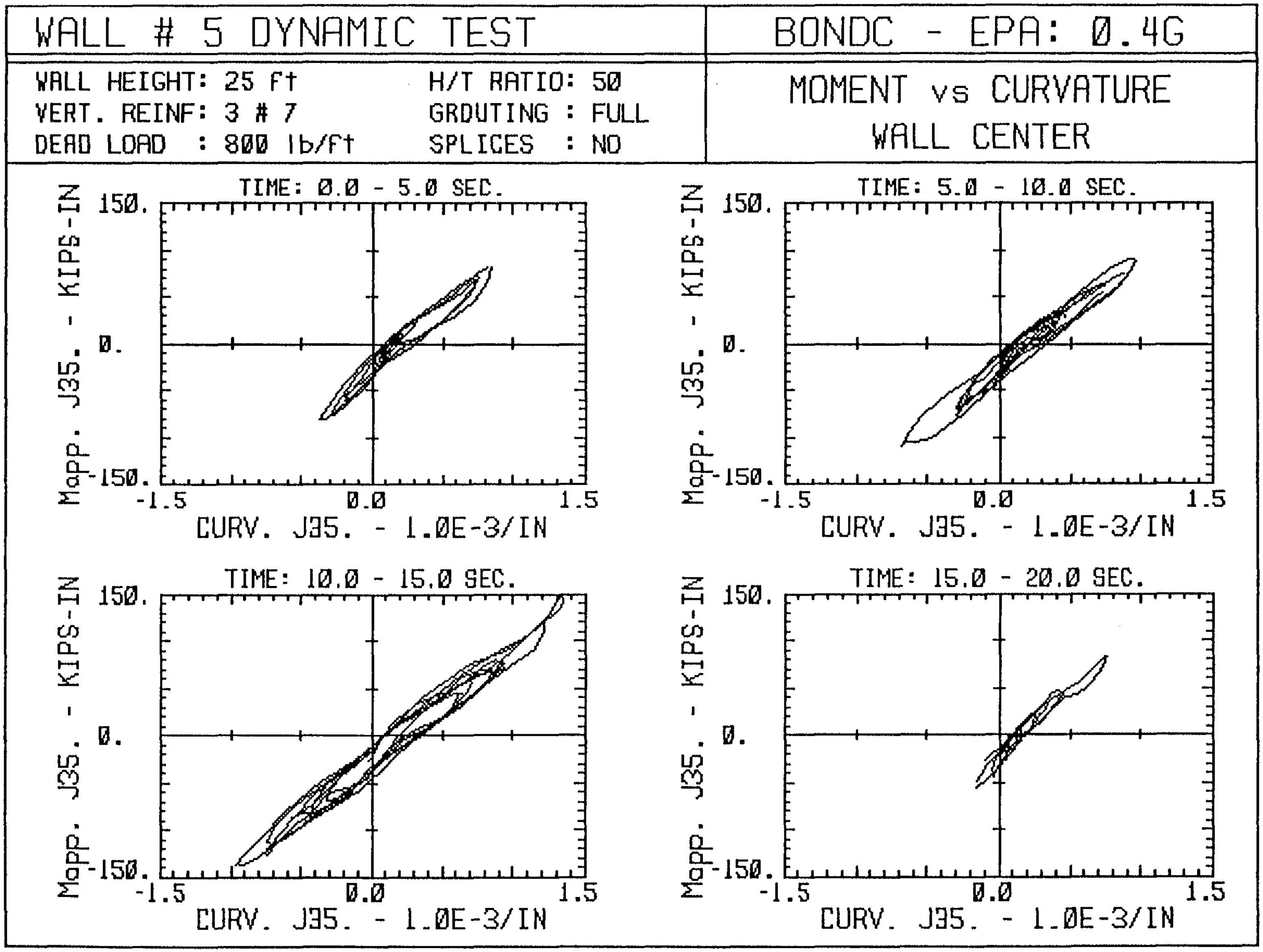
H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO

MOMENT vs CURVATURE
JOINT 36







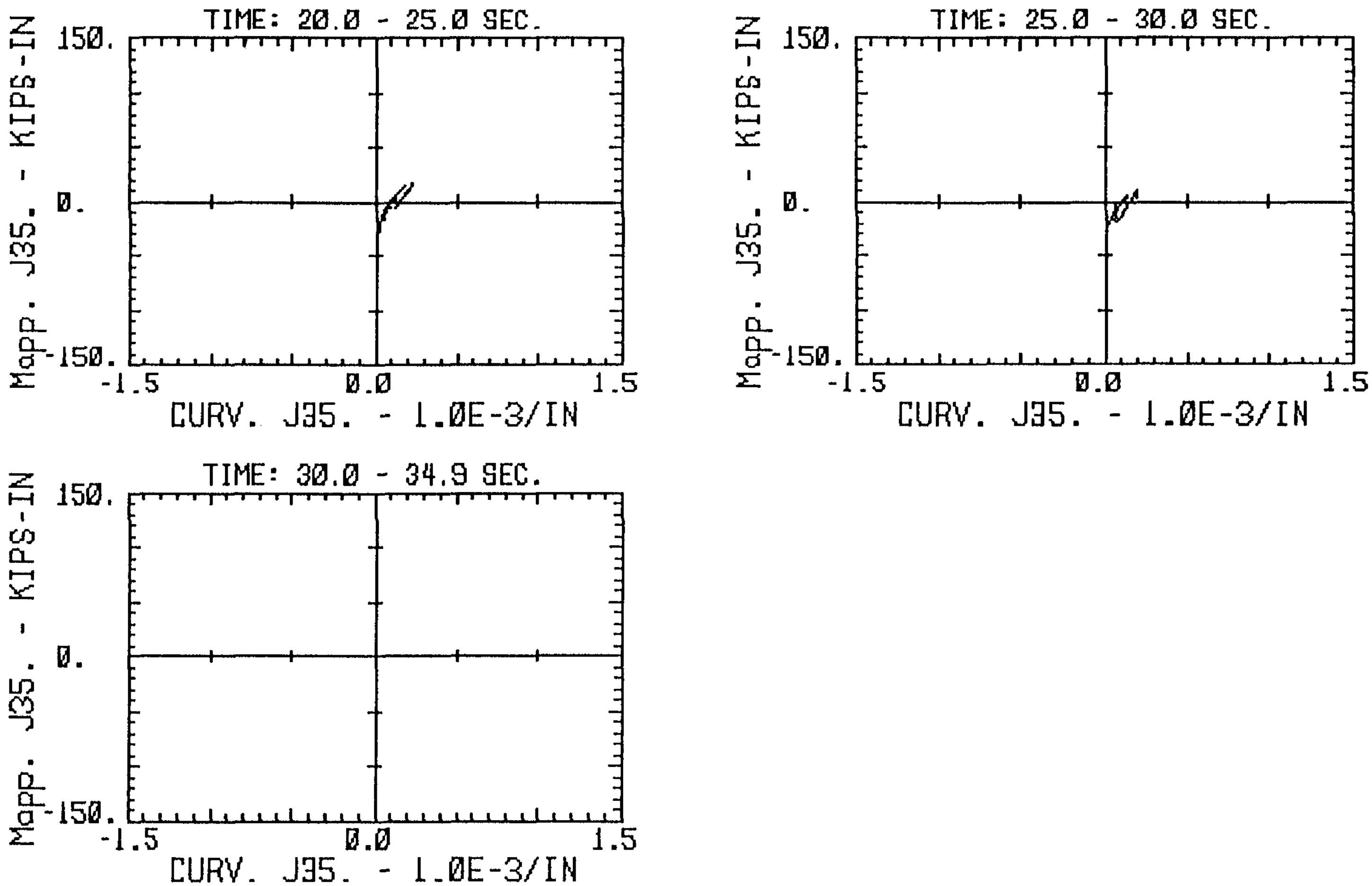

WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
MOMENT vs CURVATURE
WALL CENTER
TIME: 0.0 - 5.0 SEC.
TIME: 5.0 - 10.0 SEC.
TIME: 10.0 - 15.0 SEC.
TIME: 15.0 - 20.0 SEC.
Mapp. J35. - KIPS-IN
150.
0.
-150.
-1.5
0.0
1.5
CURV. J35. - 1.0E-3/IN

WALL # 5 DYNAMIC TEST | BONDC - EPA: Ø.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft

H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO

MOMENT vs CURVATURE
WALL CENTER



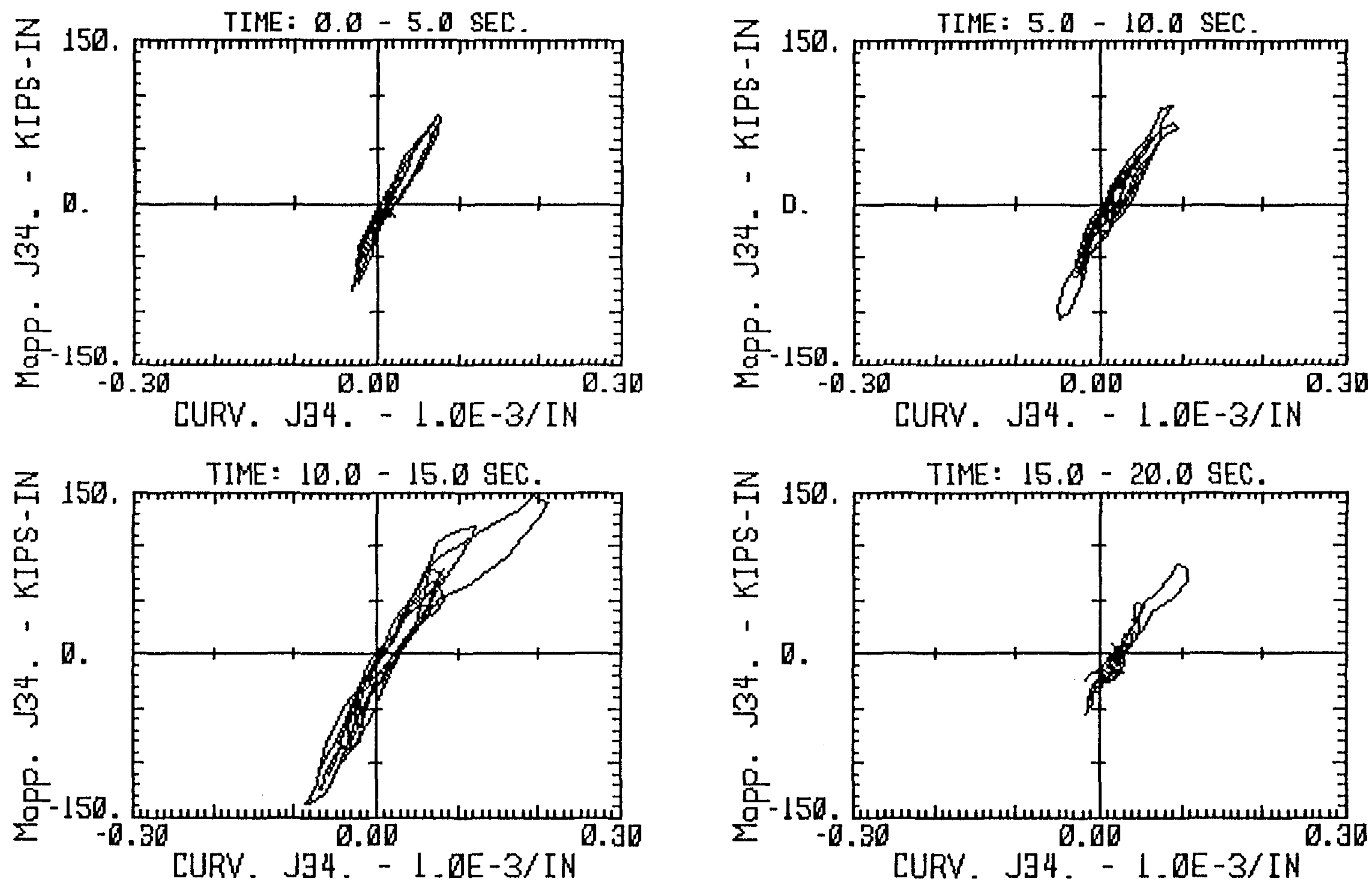
WALL # 5 DYNAMIC TEST

BONDC - EPA: 0.4G

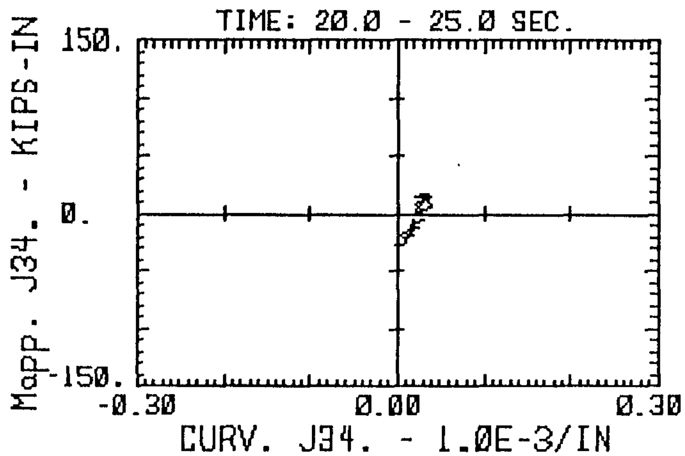
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

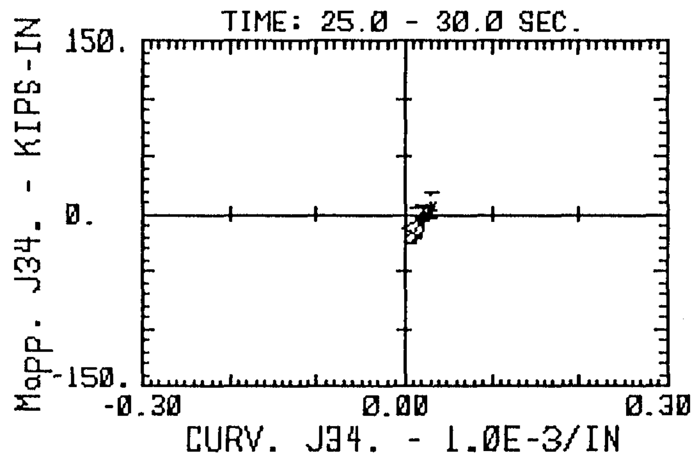
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

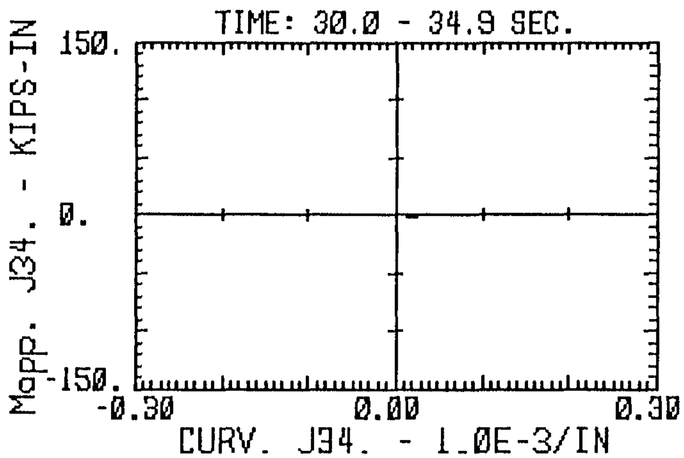
MOMENT vs CURVATURE
JOINT 34



WALL # 5 DYNAMIC TEST	BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft H/T RATIO: 5Ø VERT. REINF: 3 # 7 GROUTING : FULL DEAD LOAD : 8ØØ lb/ft SPLICES : NO	MOMENT vs CURVATURE JOINT 34







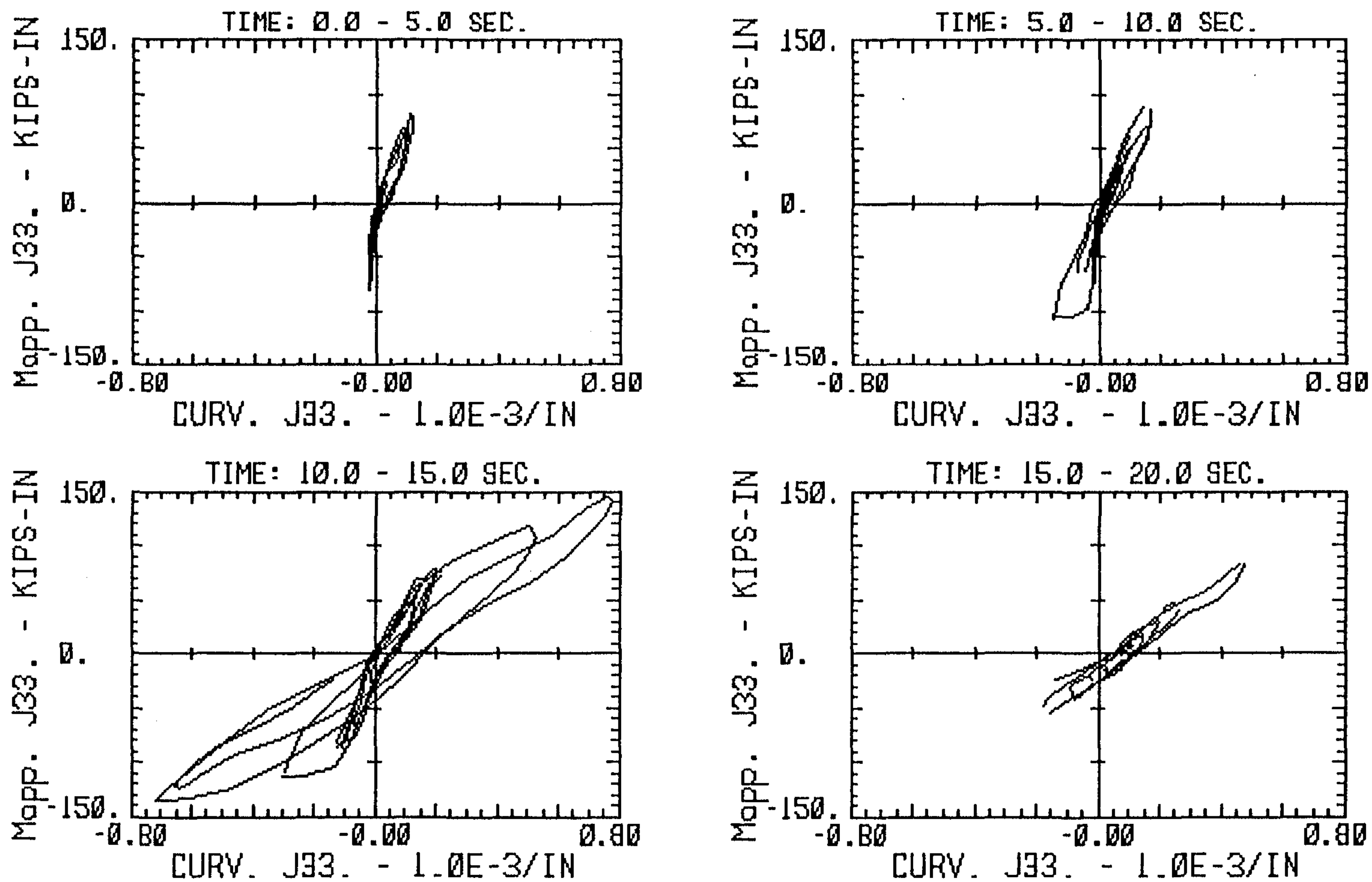
WALL # 5 DYNAMIC TEST

BONDC - EPA: Ø.4G

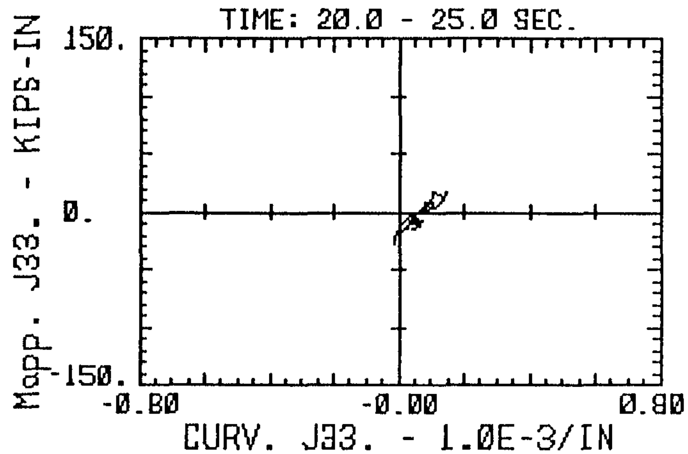
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft

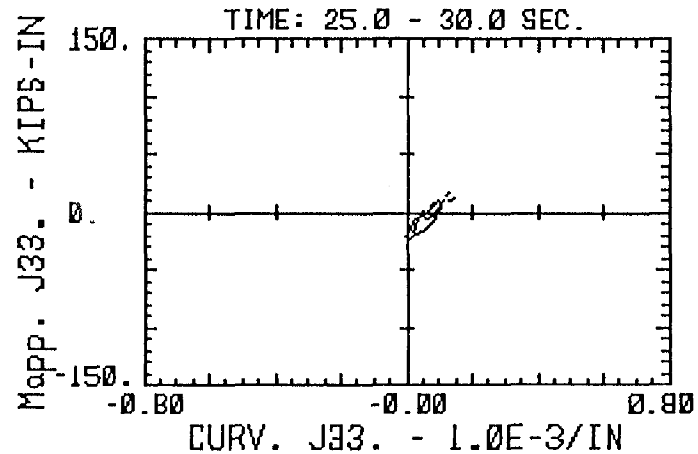
H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO

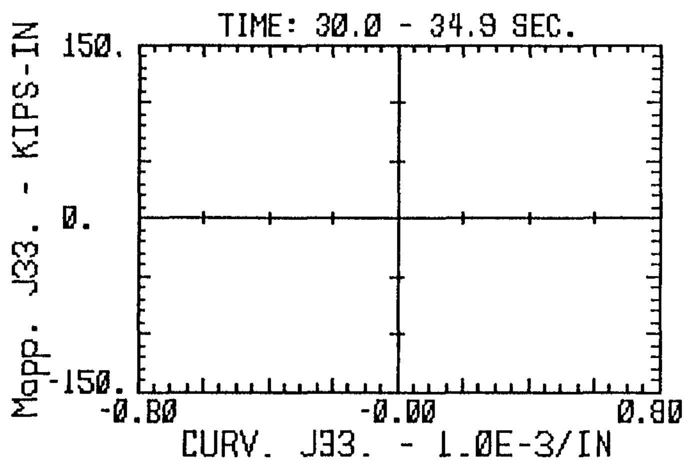
MOMENT vs CURVATURE
JOINT 33



WALL # 5 DYNAMIC TEST	BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft H/T RATIO: 50 VERT. REINF: 3 # 7 GROUTING : FULL DEAD LOAD : 800 lb/ft SPLICES : NO	MOMENT vs CURVATURE JOINT 33



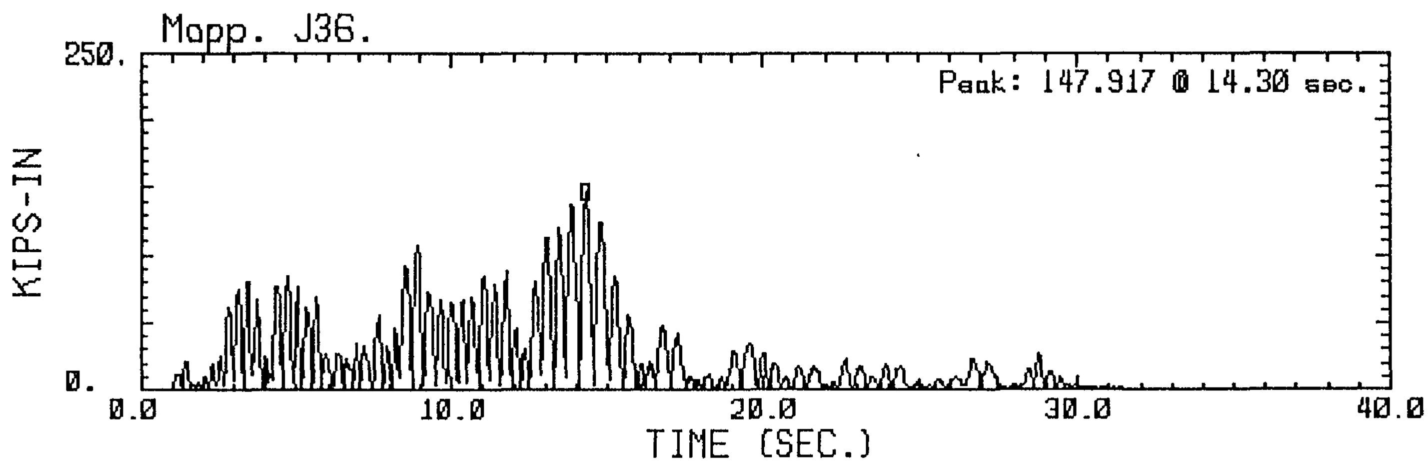


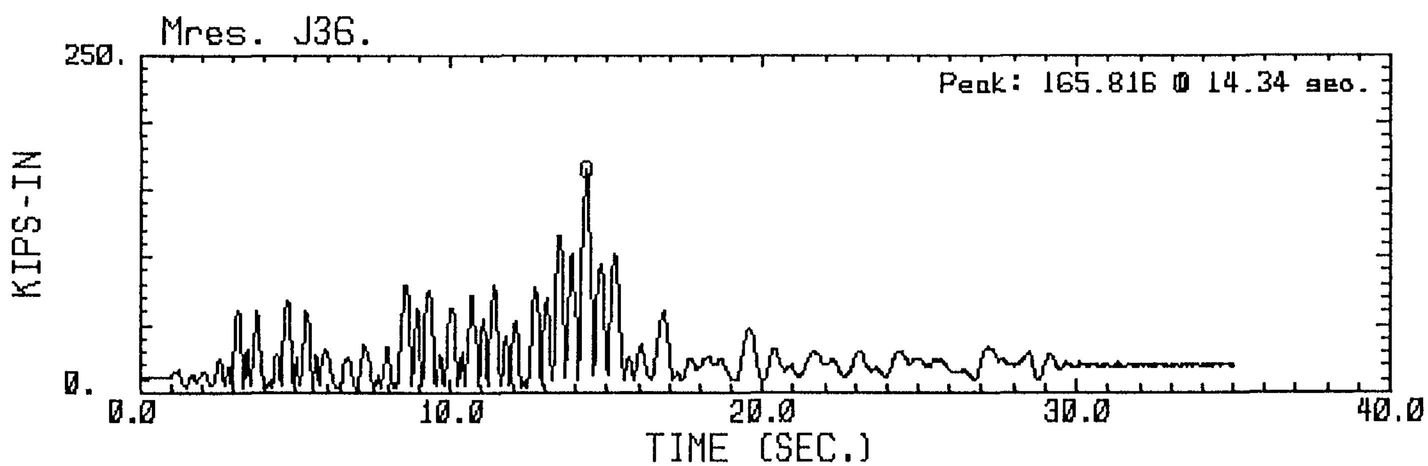


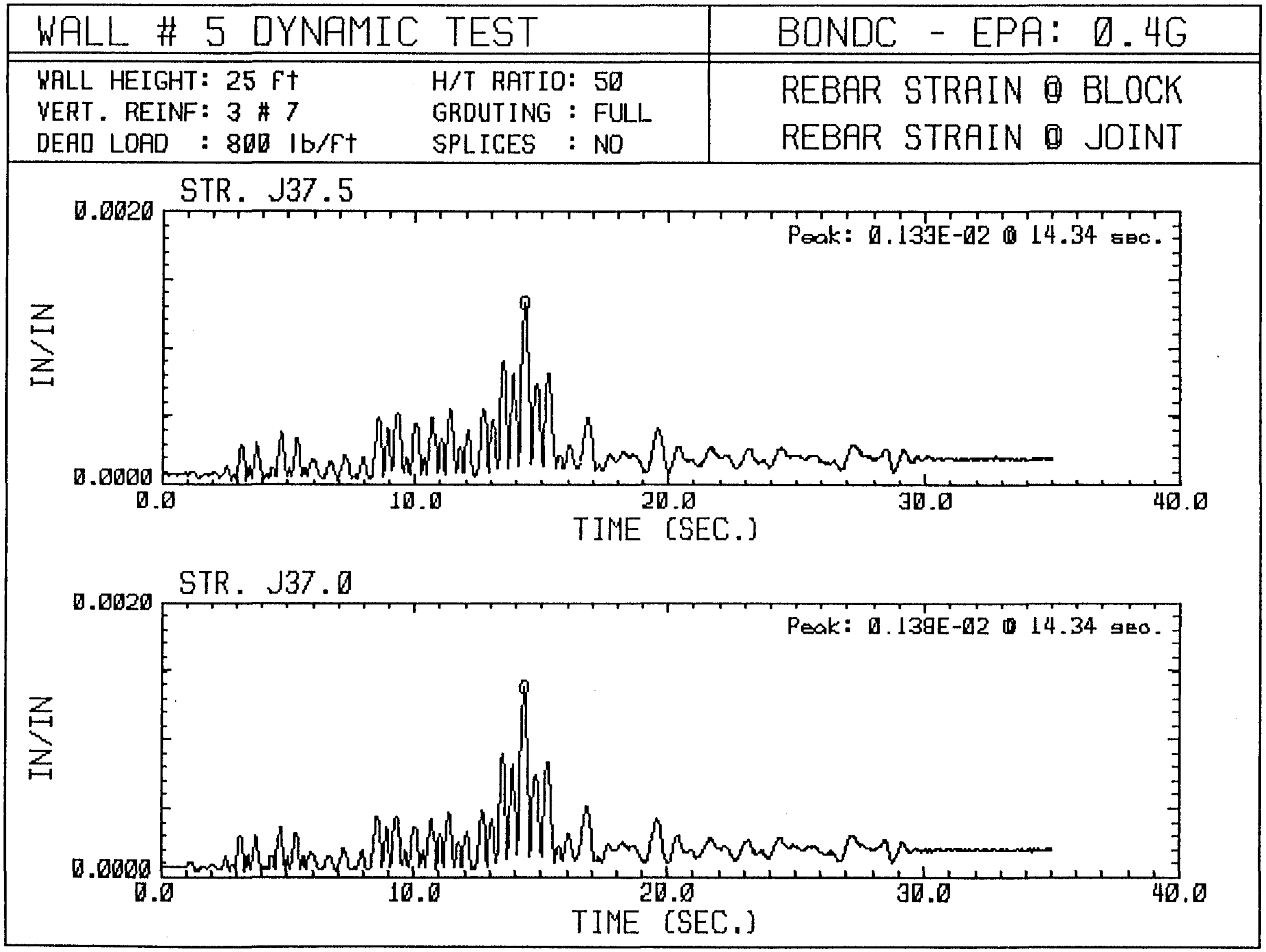
WALL # 5 DYNAMIC TEST | BONDC - EPA: 0.4G

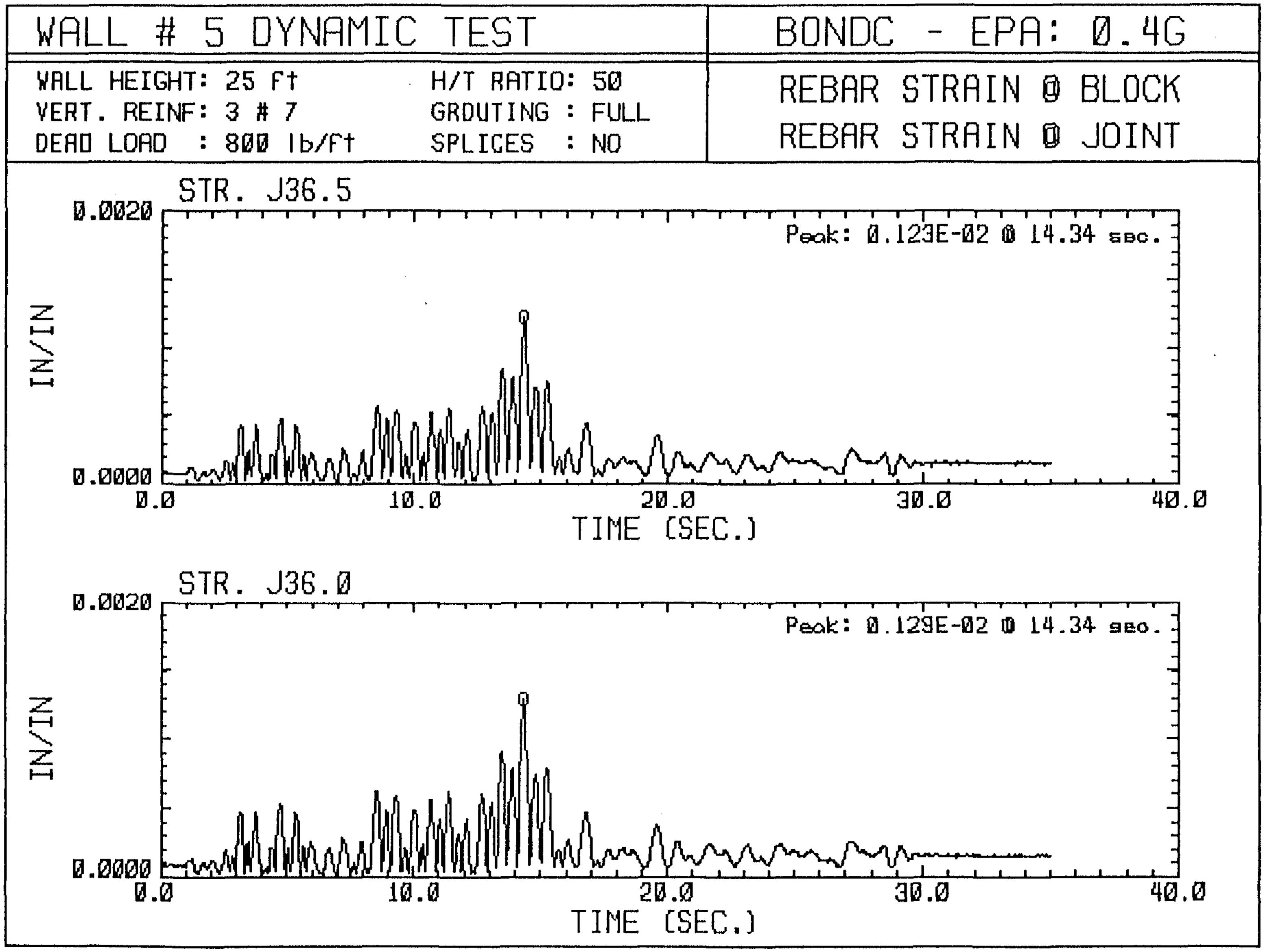
WALL HEIGHT: 25 ft   H/T RATIO: 50
VERT. REINF: 3 # 7   GROUTING : FULL
DEAD LOAD : 800 lb/ft   SPLICES : NO

APPLIED MOMENT
RESISTING MOMENT






WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
REBAR STRAIN @ BLOCK
REBAR STRAIN @ JOINT
STR. J37.5
IN/IN
0.0020
0.0000
Peak: 0.133E-02 @ 14.34 sec.
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
STR. J37.0
IN/IN
0.0020
0.0000
Peak: 0.138E-02 @ 14.34 sec.
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)



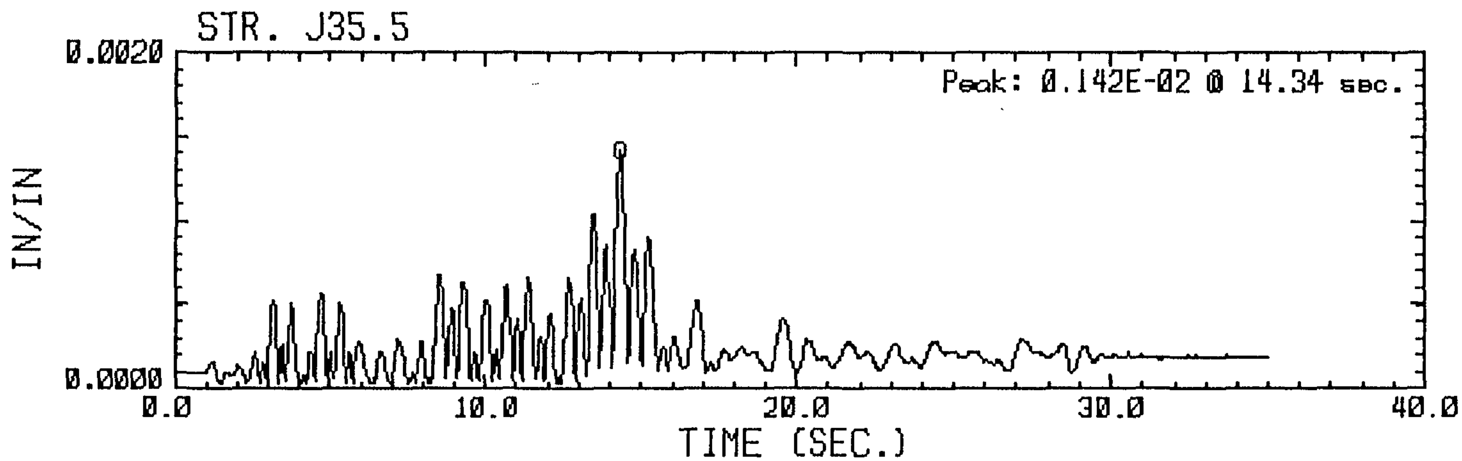
WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
REBAR STRAIN @ BLOCK
REBAR STRAIN @ JOINT
STR. J36.5
Peak: 0.123E-02 @ 14.34 sec.
IN/IN
0.0020
0.0000
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
STR. J36.0
Peak: 0.129E-02 @ 14.34 sec.
IN/IN
0.0020
0.0000
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)

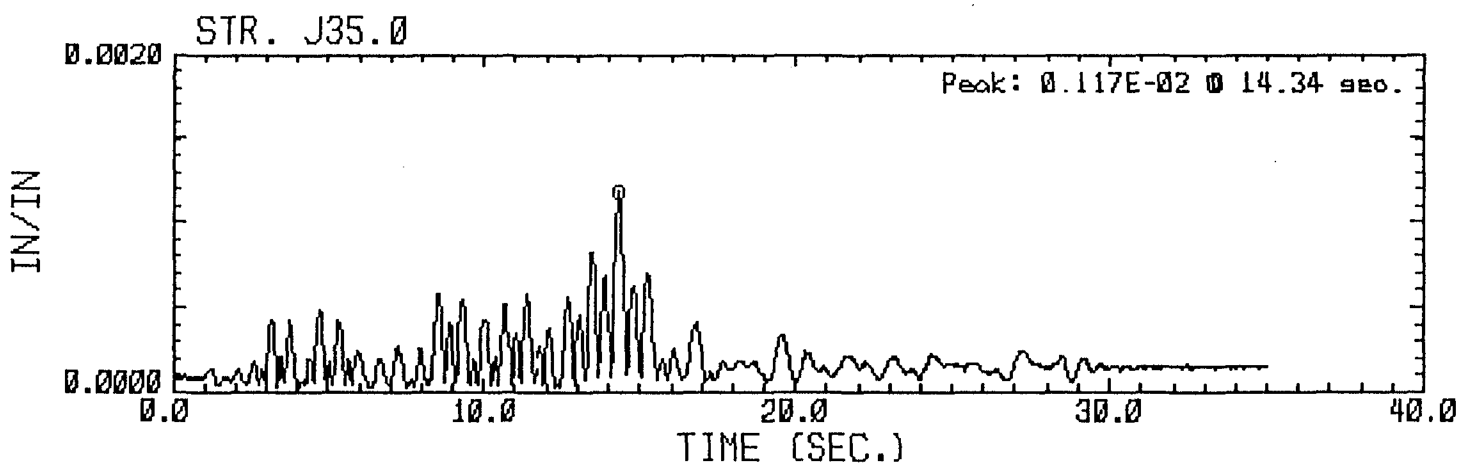
WALL # 5 DYNAMIC TEST | BONDC - EPA: 0.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

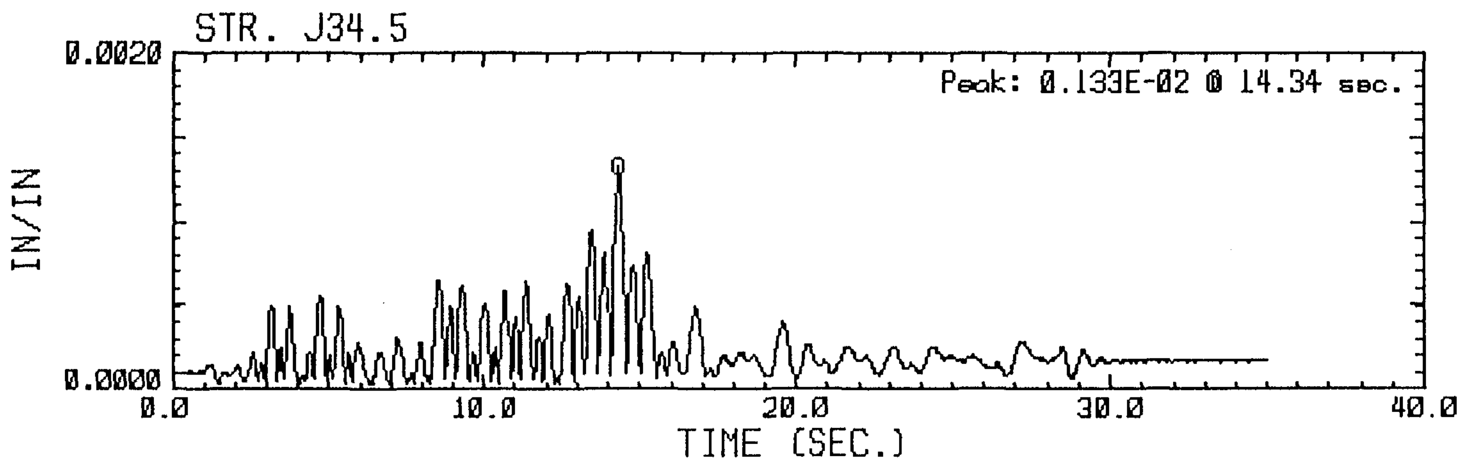
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

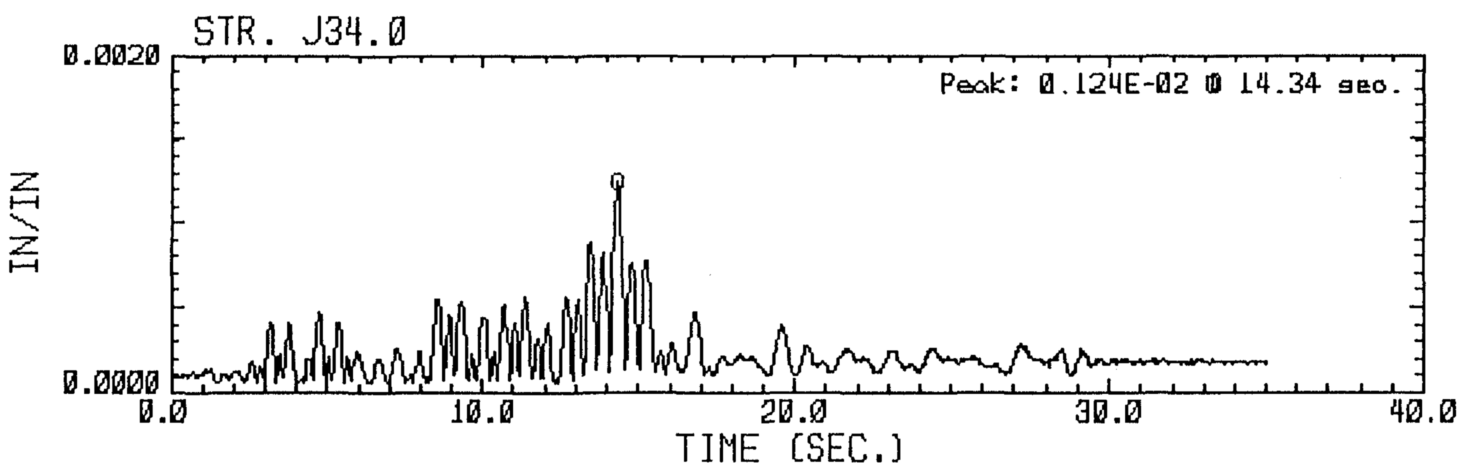
REBAR STRAIN @ BLOCK
REBAR STRAIN @ JOINT



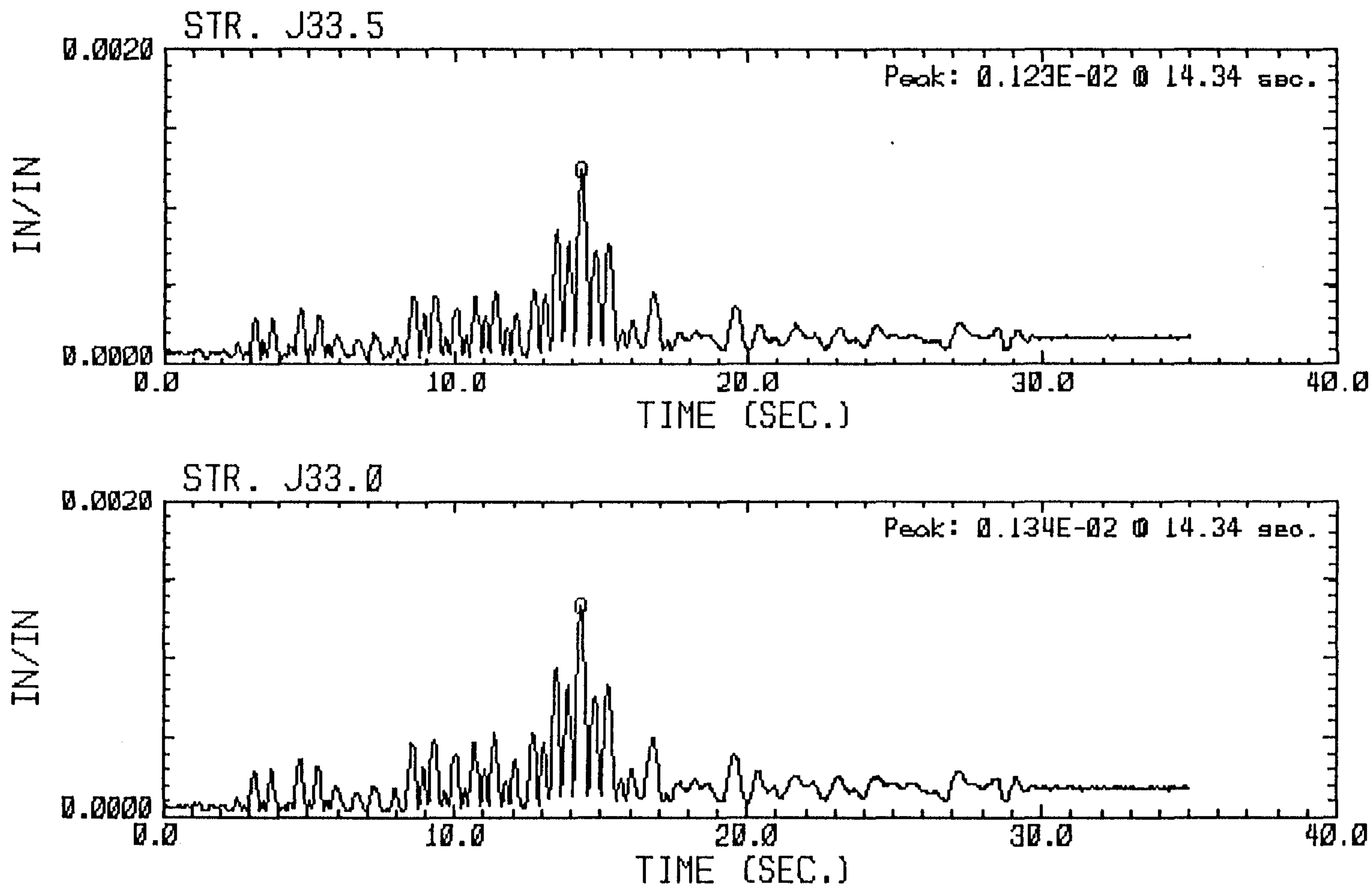


WALL # 5 DYNAMIC TEST		BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	REBAR STRAIN @ BLOCK REBAR STRAIN @ JOINT

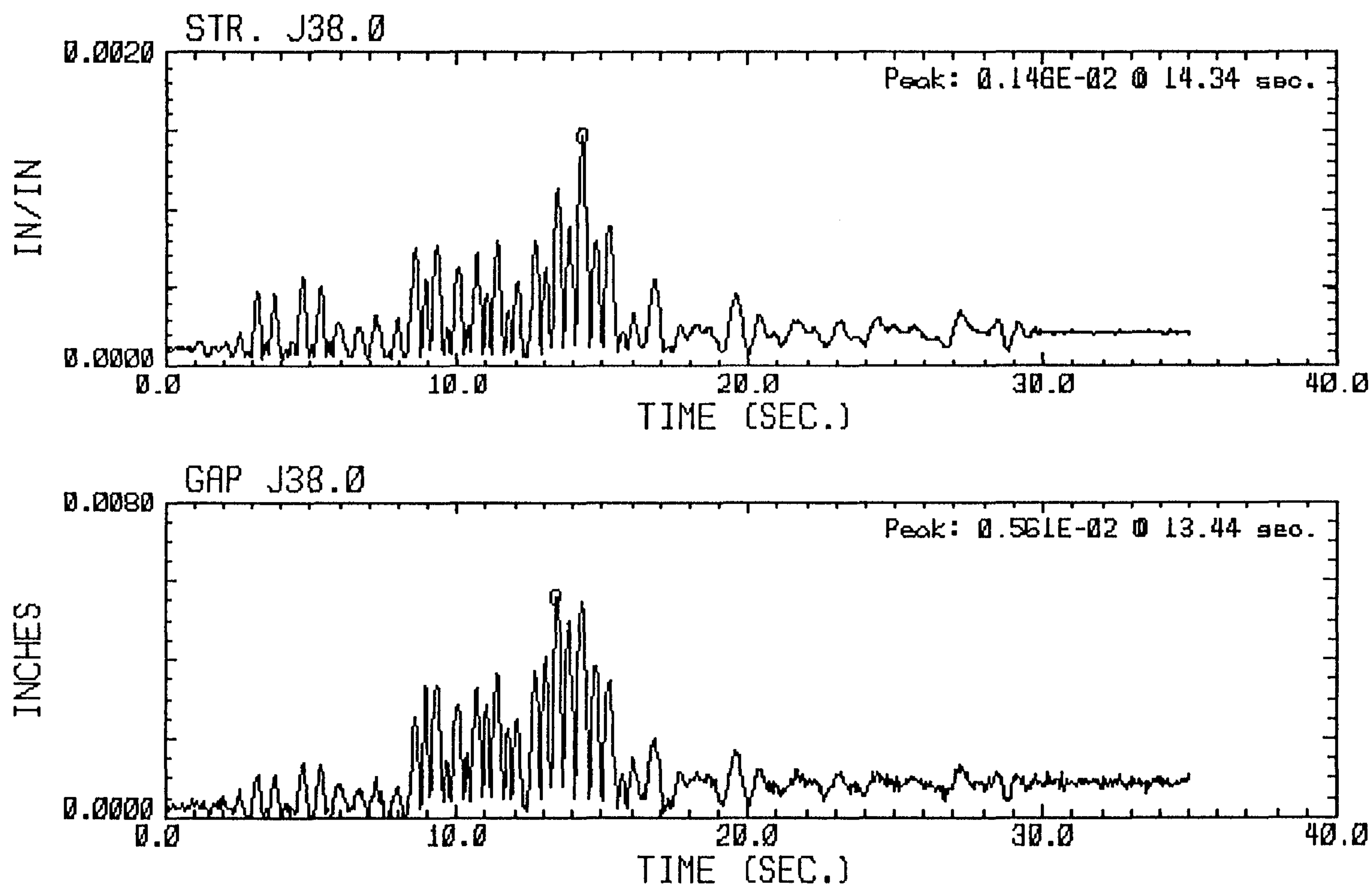




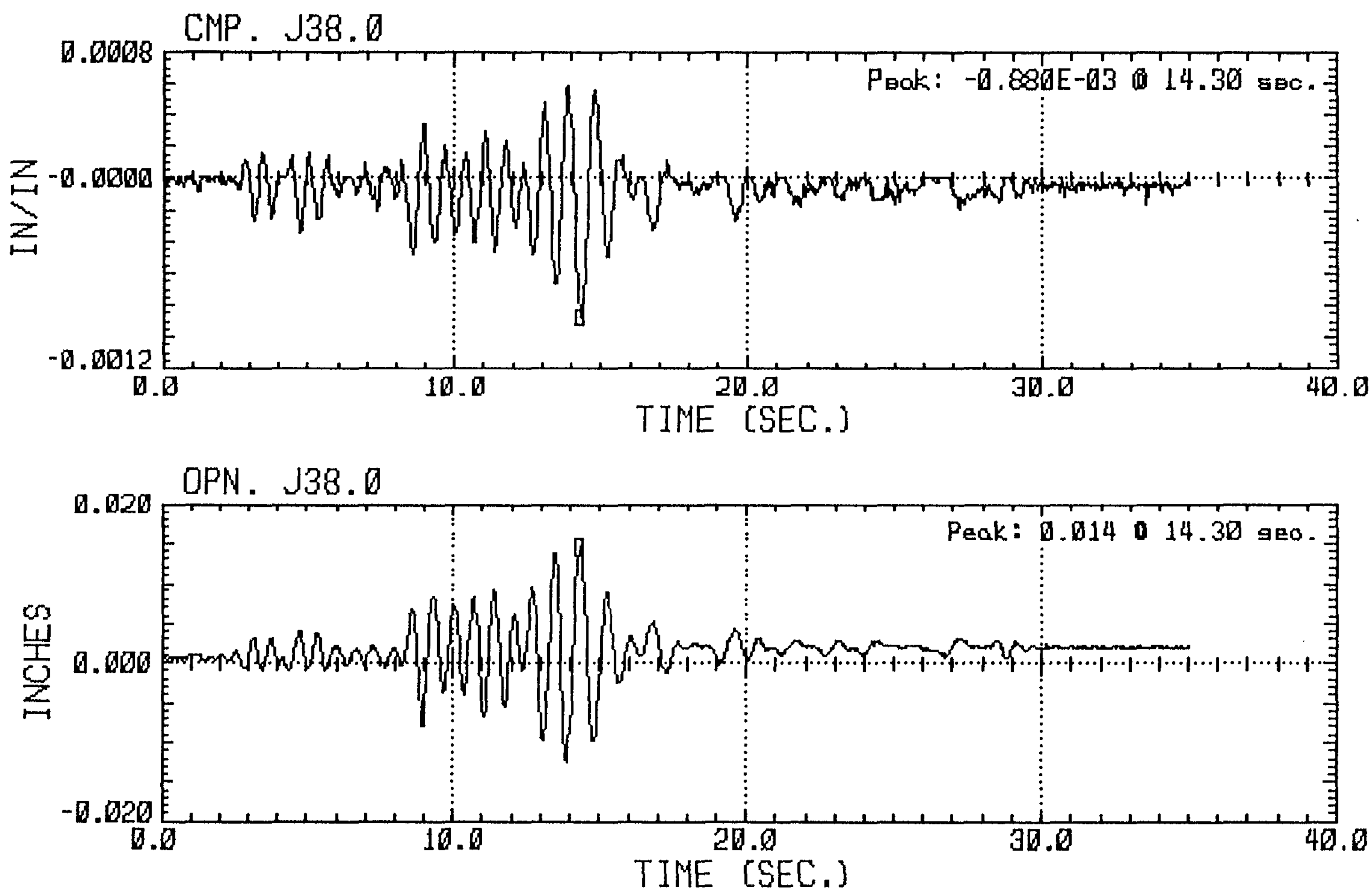
WALL # 5 DYNAMIC TEST	BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft H/T RATIO: 50 VERT. REINF: 3 # 7 GROUTING : FULL DEAD LOAD : 800 lb/ft SPLICES : NO	REBAR STRAIN @ BLOCK REBAR STRAIN @ JOINT

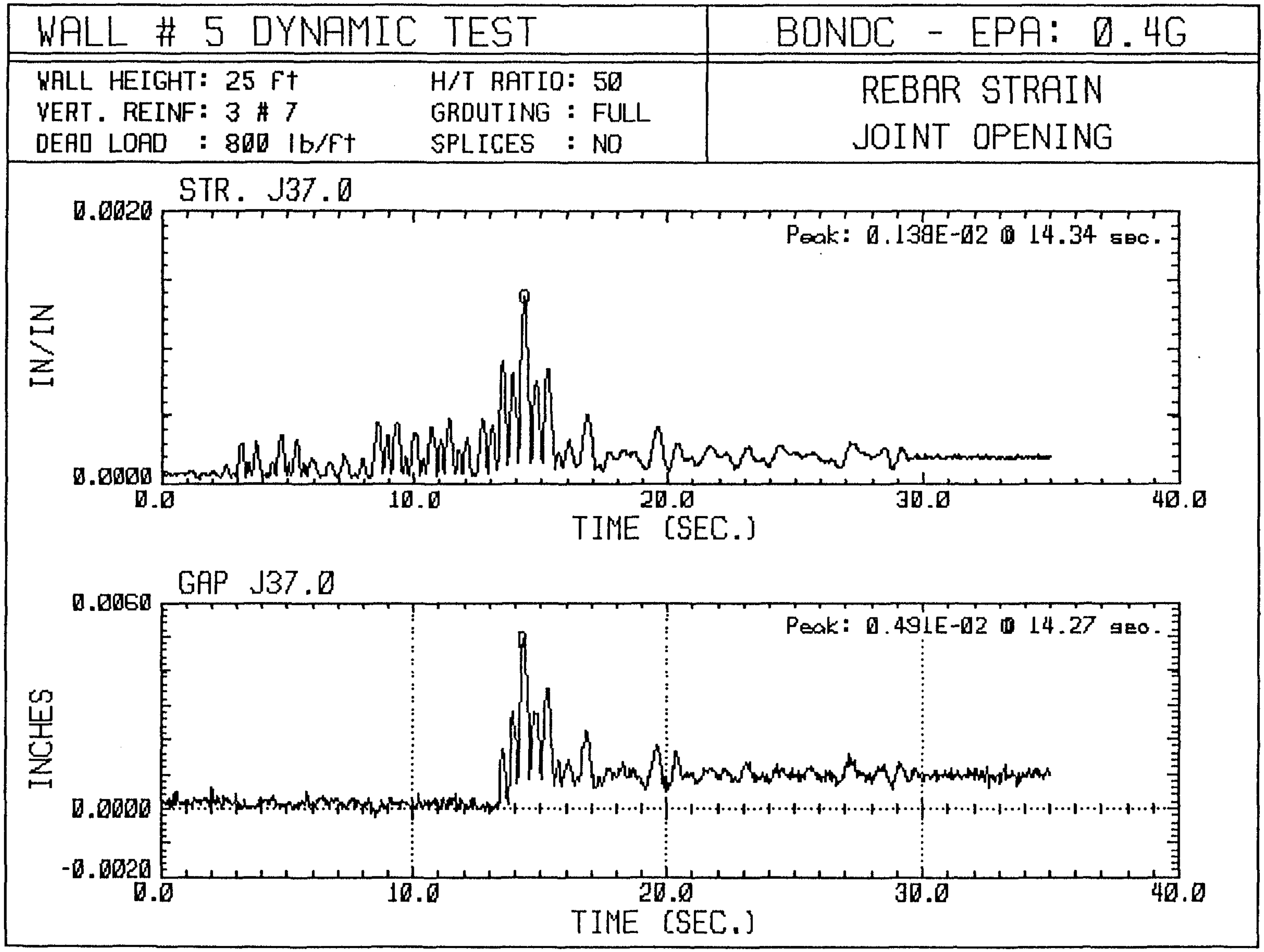


WALL # 5 DYNAMIC TEST		BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 8ØØ lb/ft	H/T RATIO: 5Ø GROUTING : FULL SPLICES : NO	REBAR STRAIN JOINT OPENING

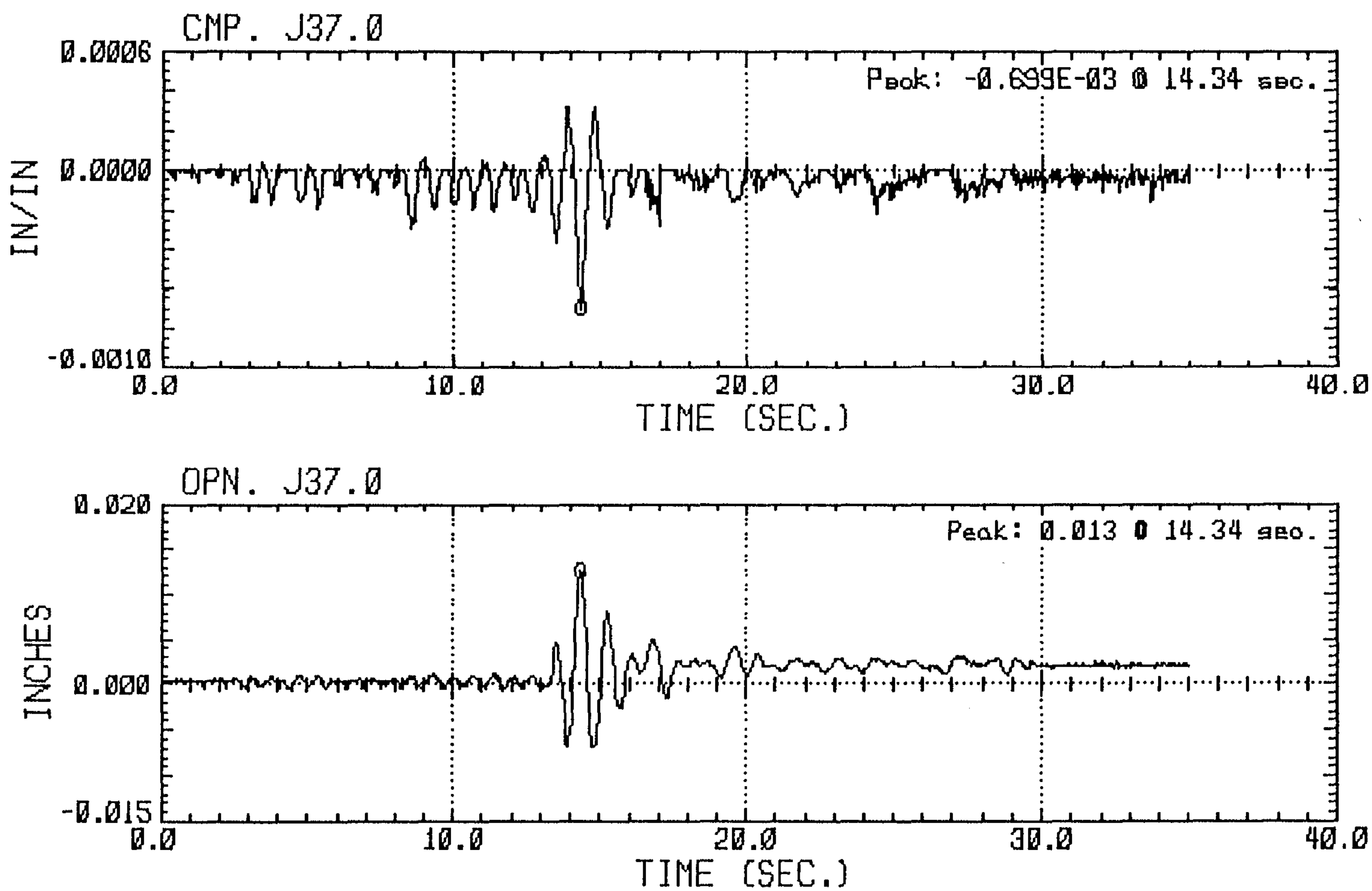


WALL # 5 DYNAMIC TEST		BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	FACESHELL COMP. STRAIN FACESHELL OPENING

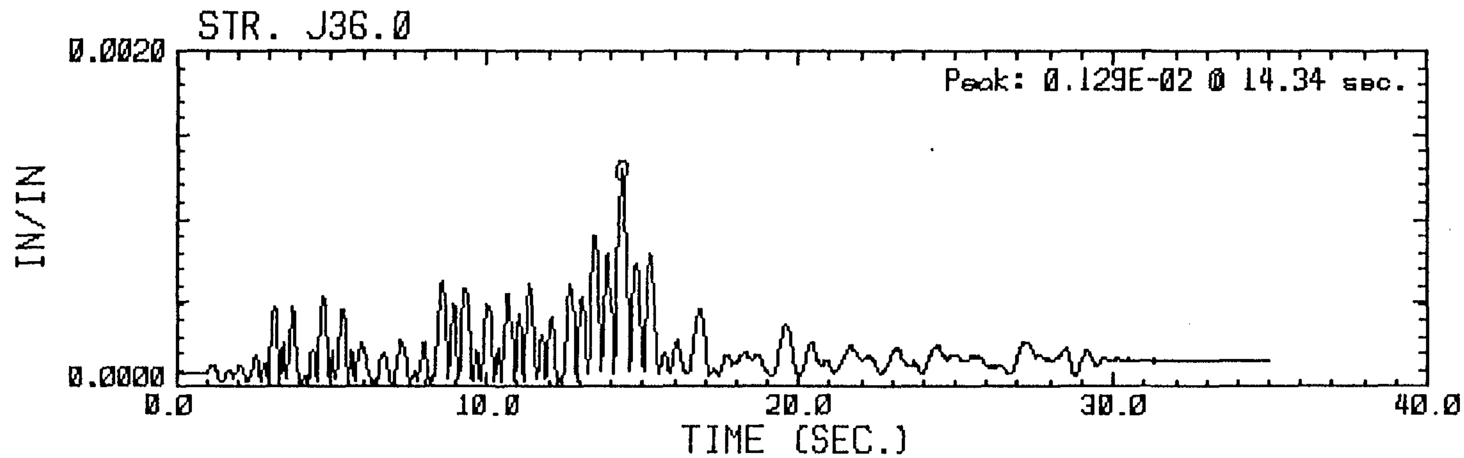


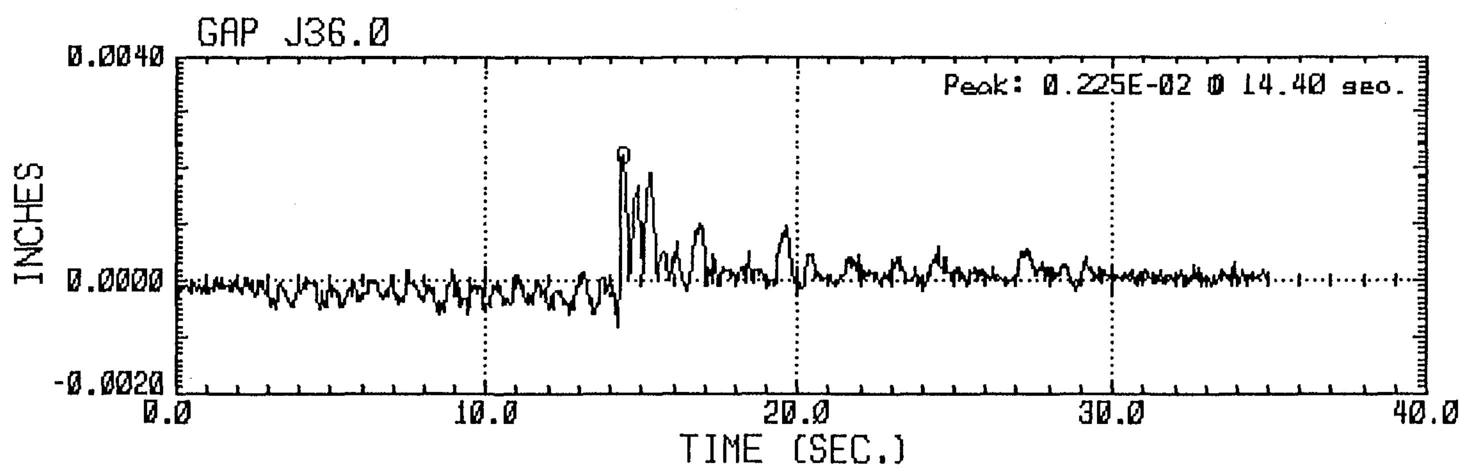

WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
REBAR STRAIN
JOINT OPENING
STR. J37.0
IN/IN
Peak: 0.138E-02 @ 14.34 sec.
0.0020
0.0000
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
GAP J37.0
INCHES
Peak: 0.491E-02 @ 14.27 sec.
0.0060
0.0000
-0.0020
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)

WALL # 5 DYNAMIC TEST		BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	FACESHELL COMP. STRAIN FACESHELL OPENING

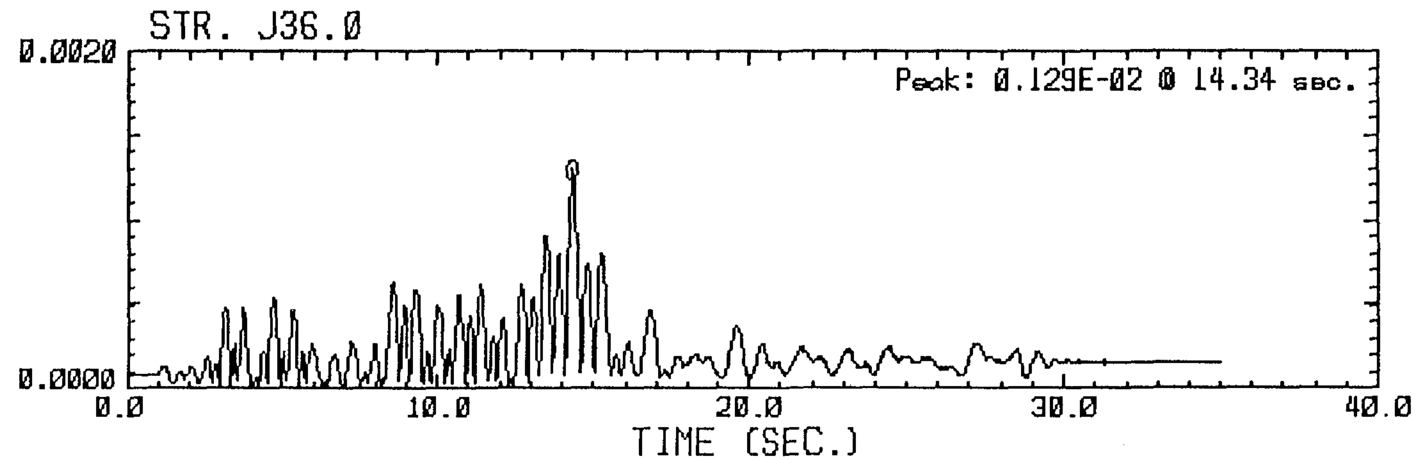


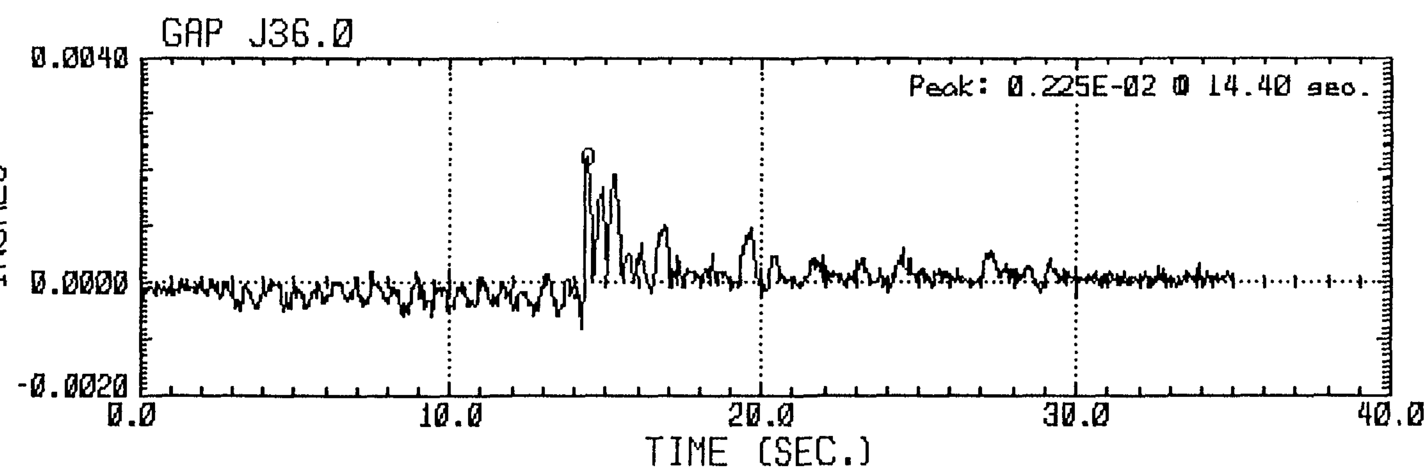
WALL # 5 DYNAMIC TEST		BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft VERT. REINF: 3 # 7 DEAD LOAD : 800 lb/ft	H/T RATIO: 50 GROUTING : FULL SPLICES : NO	REBAR STRAIN JOINT OPENING

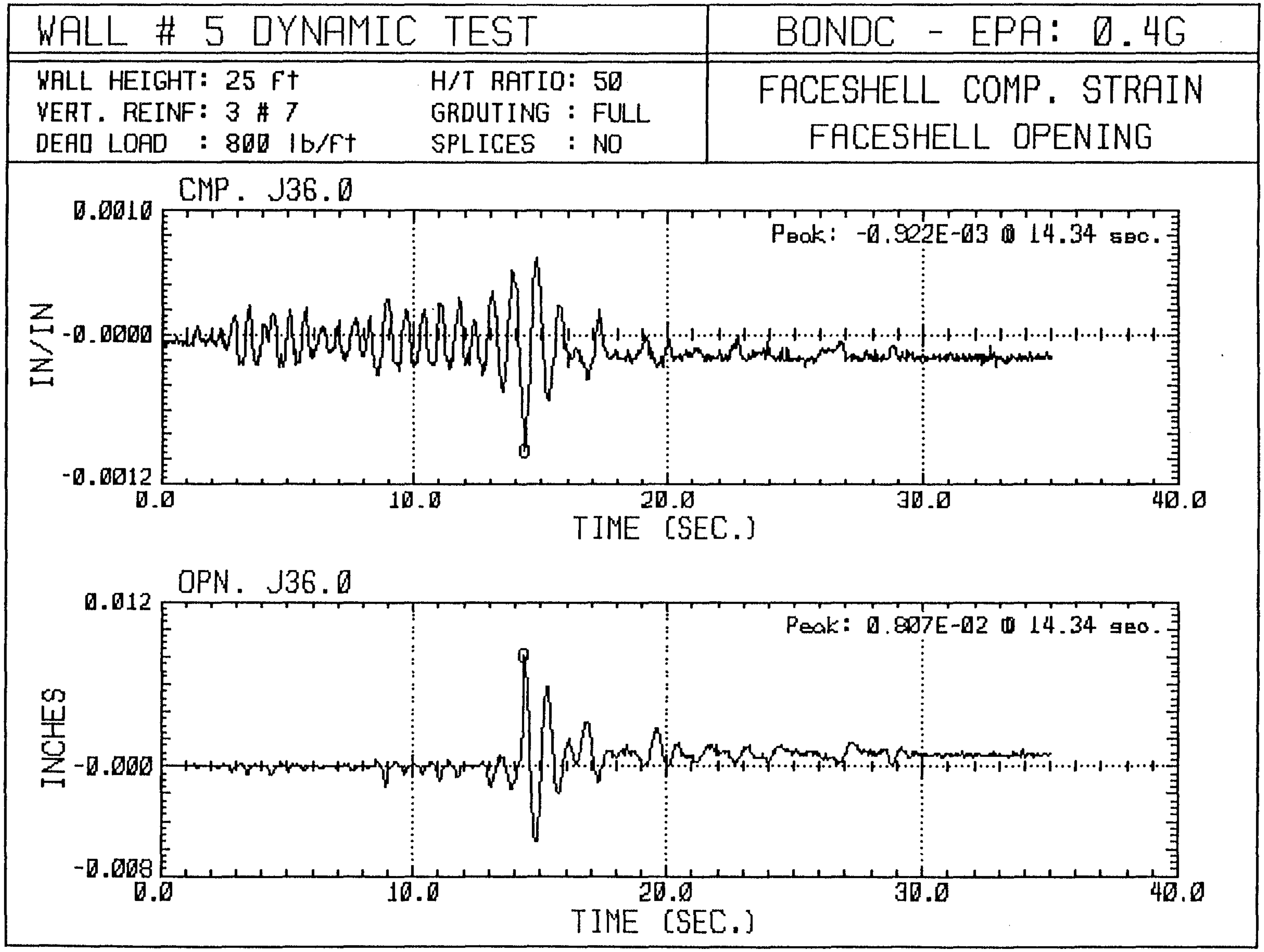




WALL # 5 DYNAMIC TEST	BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft H/T RATIO: 50 VERT. REINF: 3 # 7 GROUTING : FULL DEAD LOAD : 800 lb/ft SPLICES : NO	REBAR STRAIN JOINT OPENING





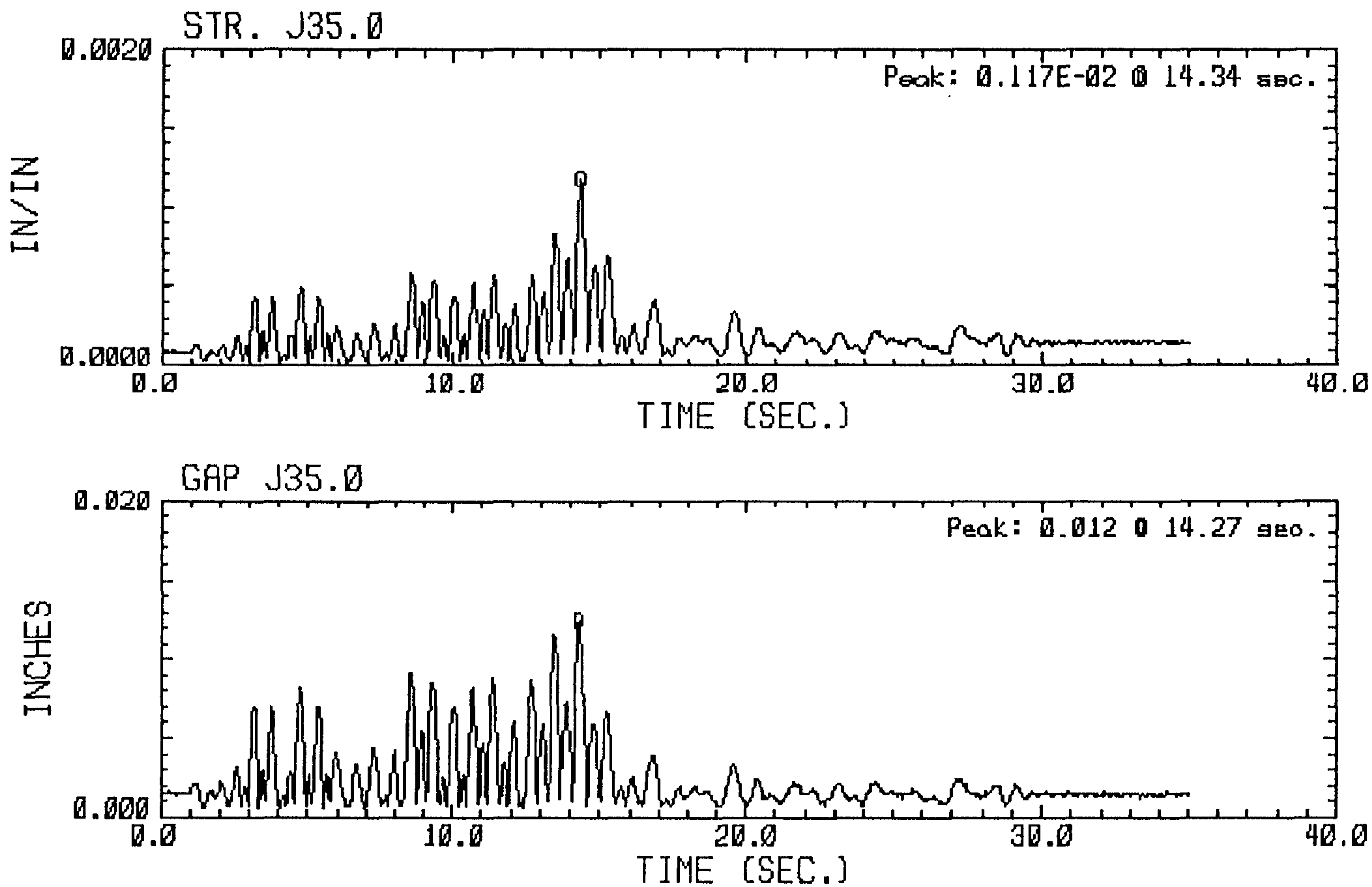

WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
FACESHELL COMP. STRAIN
FACESHELL OPENING
CMP. J36.0
IN/IN
0.0010
-0.0000
-0.0012
Peak: -0.922E-03 @ 14.34 sec.
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
OPN. J36.0
INCHES
0.012
-0.000
-0.008
Peak: 0.807E-02 @ 14.34 sec.
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)

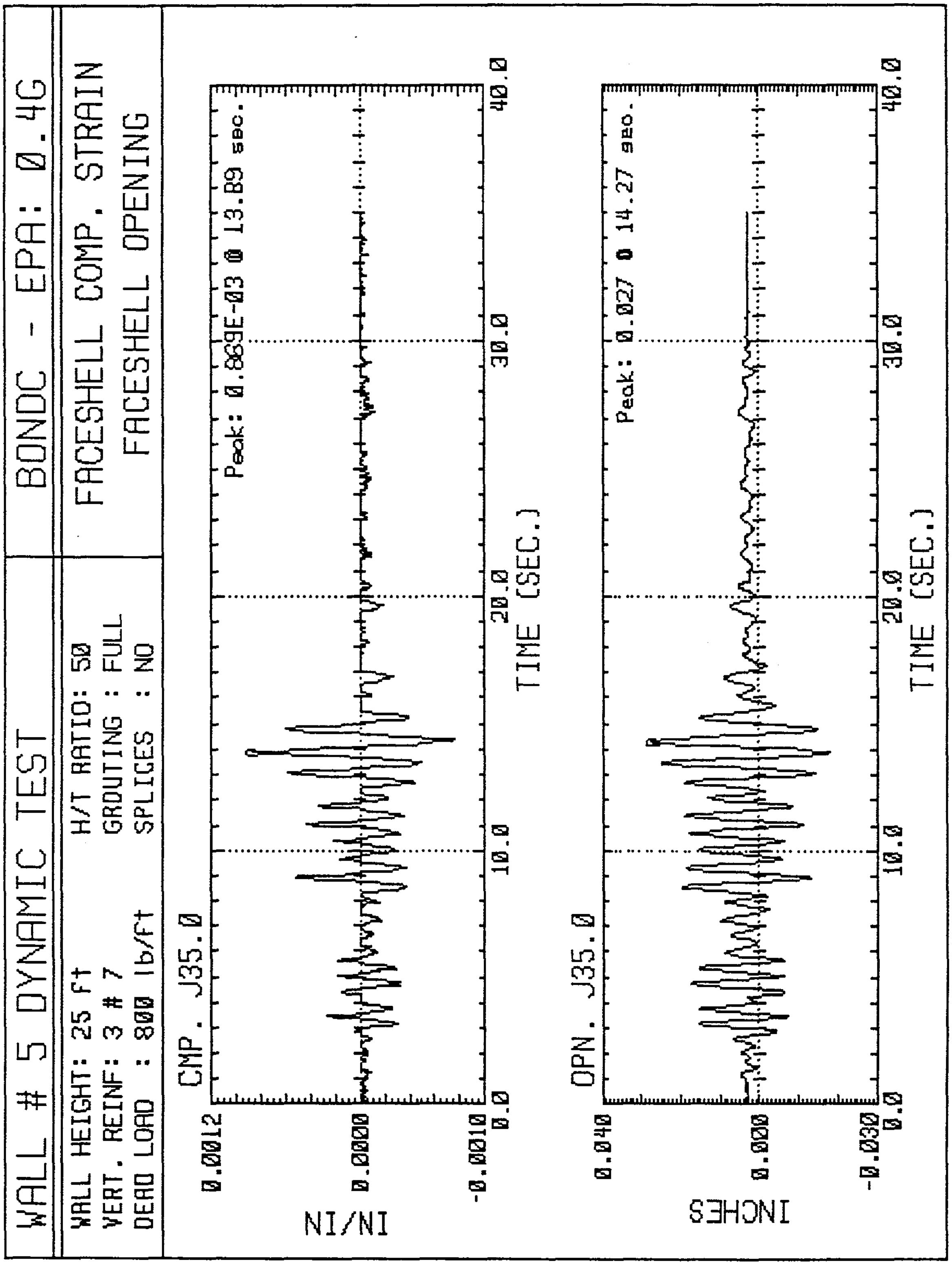
WALL # 5 DYNAMIC TEST | BONDC - EPA: 0.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

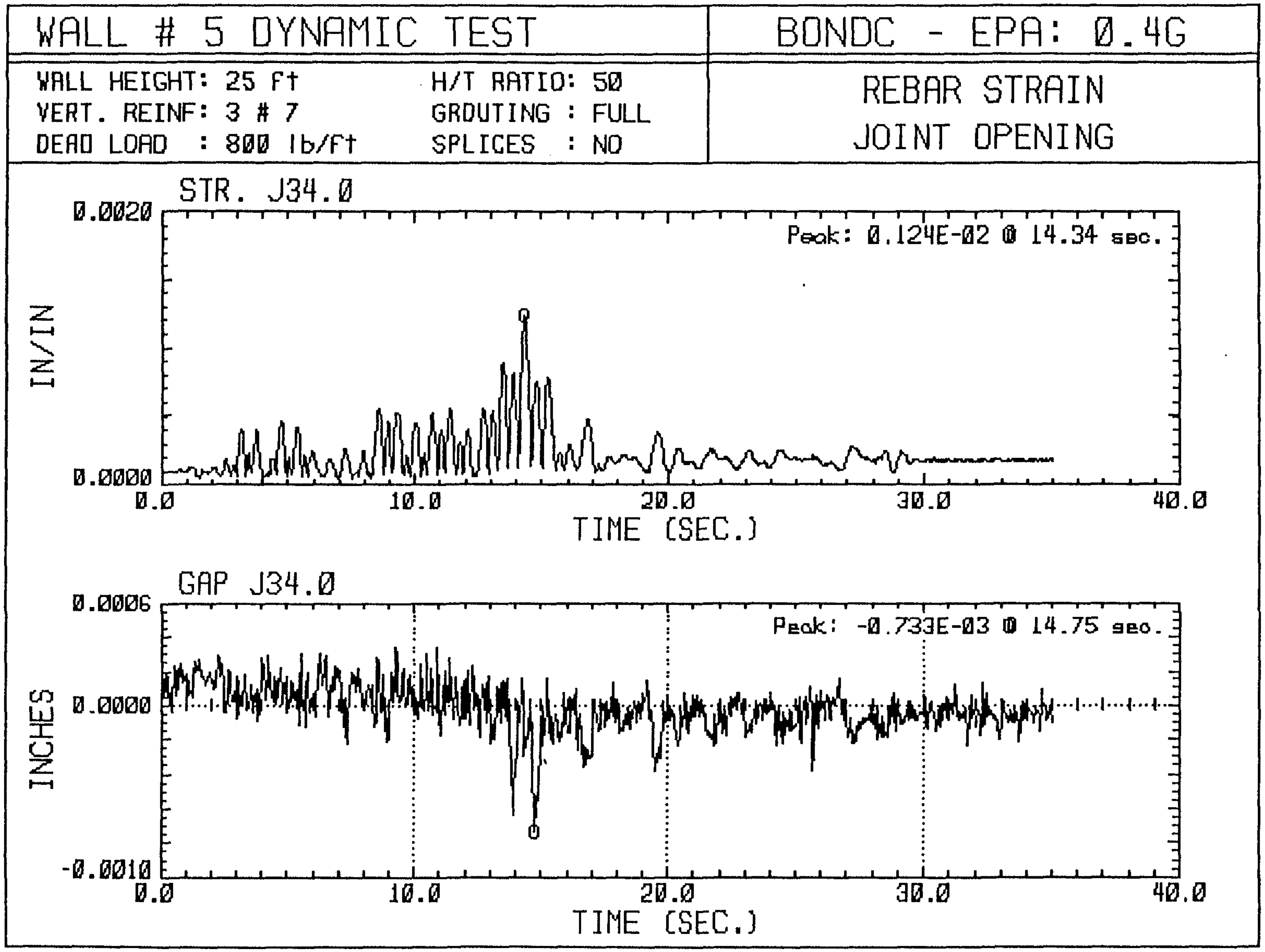
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

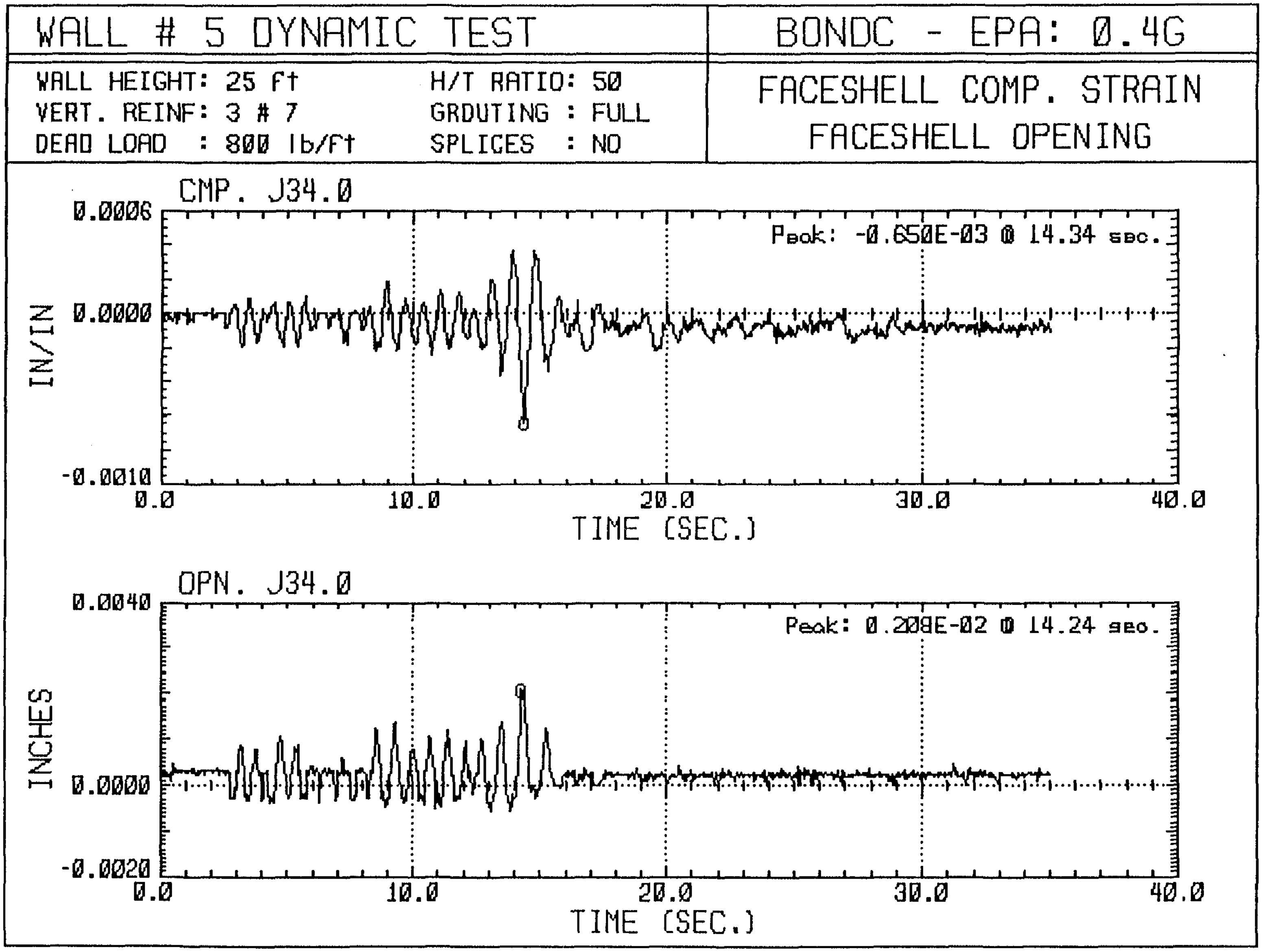
REBAR STRAIN
JOINT OPENING





WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
FACESHELL COMP. STRAIN
FACESHELL OPENING
CMP. J35.0
Peak: 0.869E-03 @ 13.89 sec.
IN/IN
0.0012
0.0000
-0.0010
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
OPN. J35.0
Peak: 0.027 @ 14.27 sec.
INCHES
0.040
0.000
-0.030
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)


WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
REBAR STRAIN
JOINT OPENING
STR. J34.0
Peak: 0.124E-02 @ 14.34 sec.
IN/IN
0.0020
0.0000
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
GAP J34.0
Peak: -0.733E-03 @ 14.75 sec.
INCHES
0.0006
0.0000
-0.0010
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)

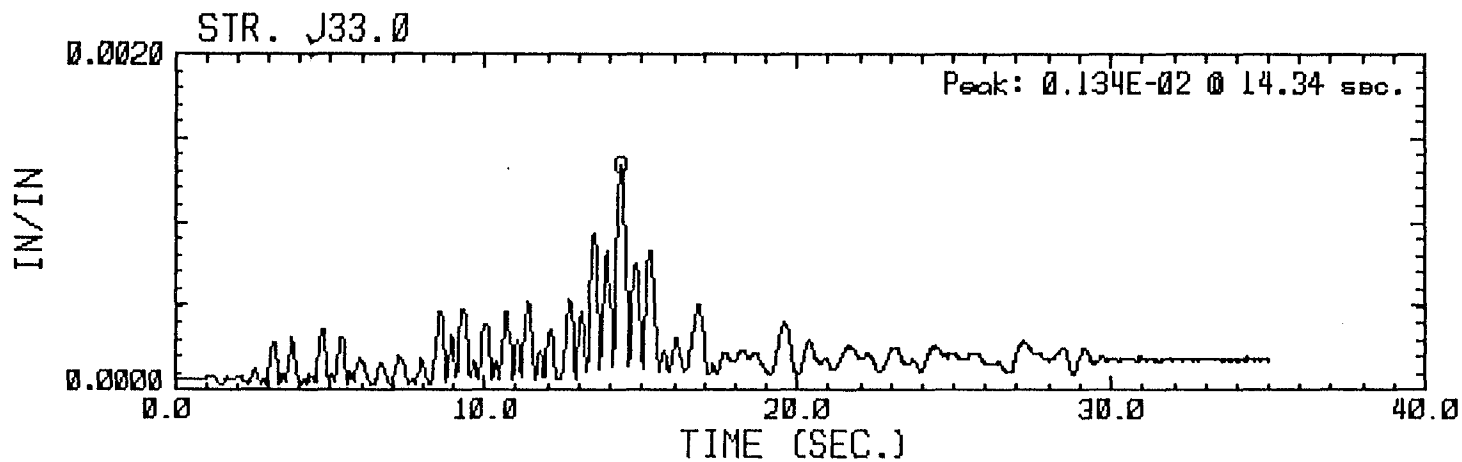


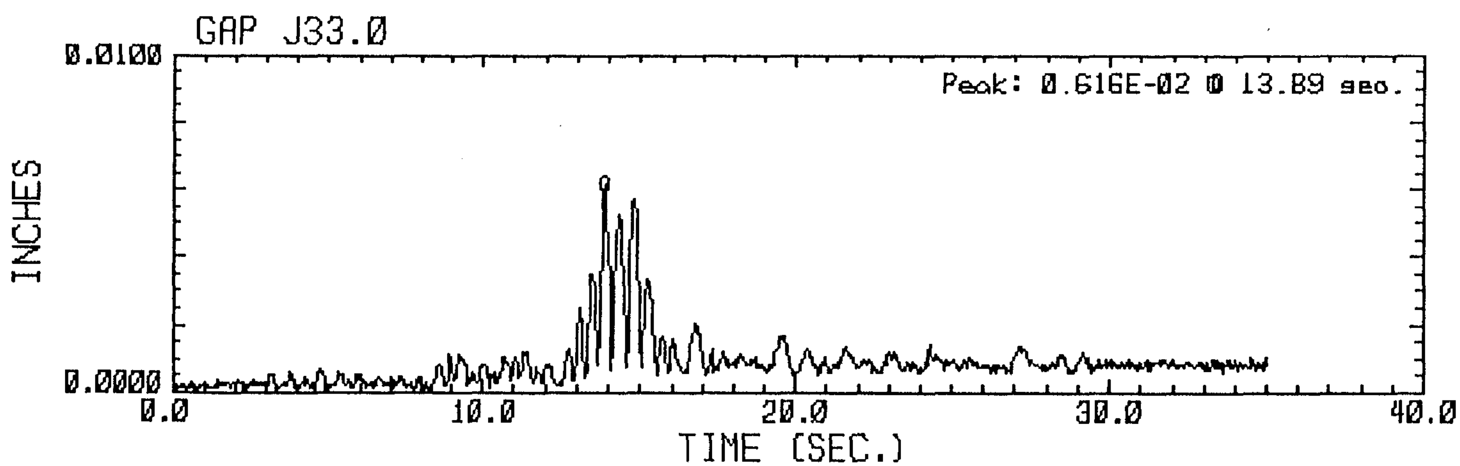
WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
FACESHELL COMP. STRAIN
FACESHELL OPENING
CMP. J34.0
Peak: -0.650E-03 @ 14.34 sec.
IN/IN
0.0006
0.0000
-0.0010
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
OPN. J34.0
Peak: 0.208E-02 @ 14.24 sec.
INCHES
0.0040
0.0000
-0.0020
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)

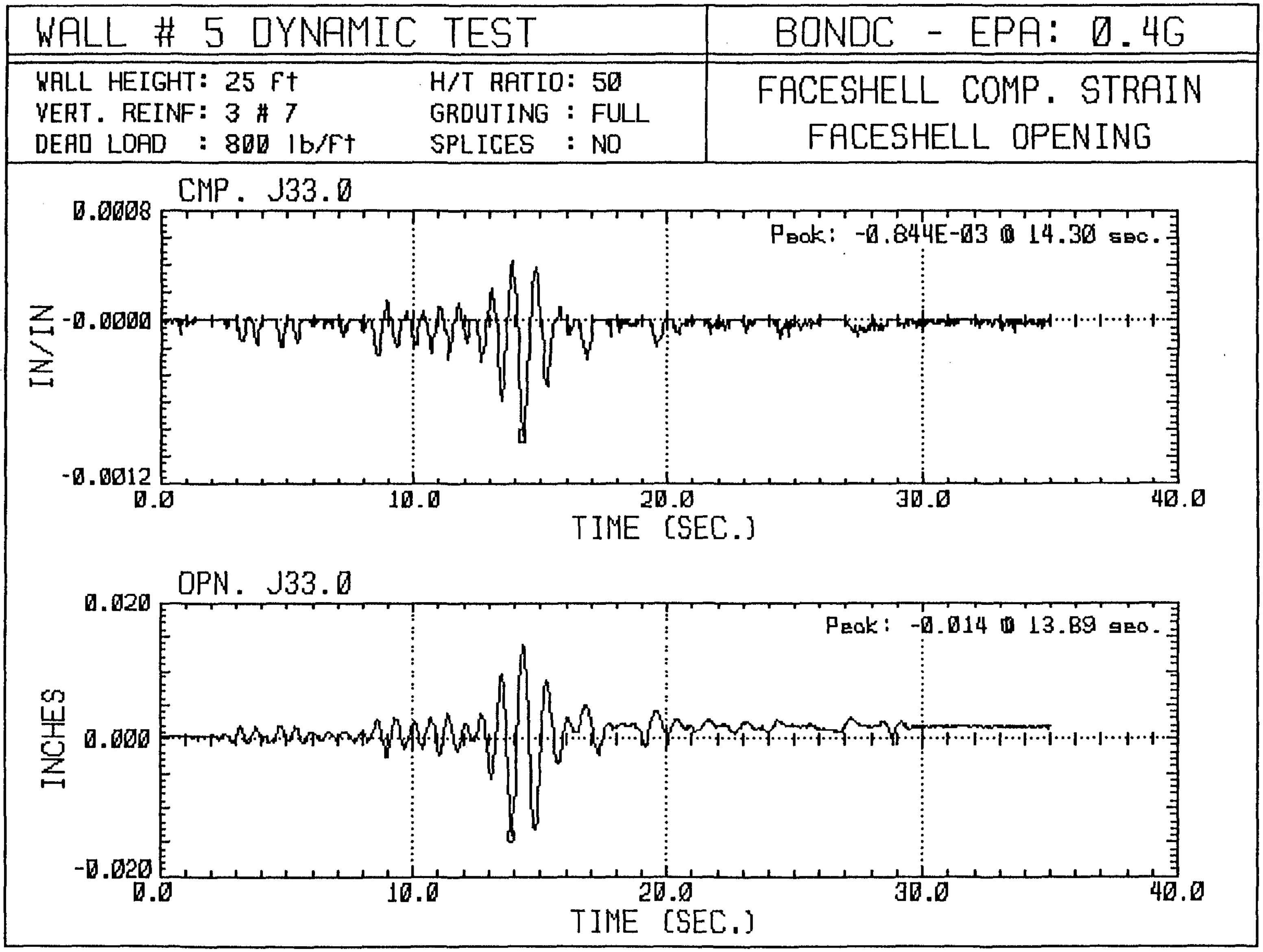
WALL # 5 DYNAMIC TEST — BONDC - EPA: 0.4G

WALL HEIGHT: 25 ft	H/T RATIO: 50
VERT. REINF: 3 # 7	GROUTING : FULL
DEAD LOAD : 800 lb/ft	SPLICES : NO

REBAR STRAIN
JOINT OPENING






WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
FACESHELL COMP. STRAIN
FACESHELL OPENING
CMP. J33.0
Peak: -0.844E-03 @ 14.30 sec.
IN/IN
0.0008
-0.0000
-0.0012
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)
OPN. J33.0
Peak: -0.014 @ 13.89 sec.
INCHES
0.020
0.000
-0.020
0.0
10.0
20.0
30.0
40.0
TIME (SEC.)

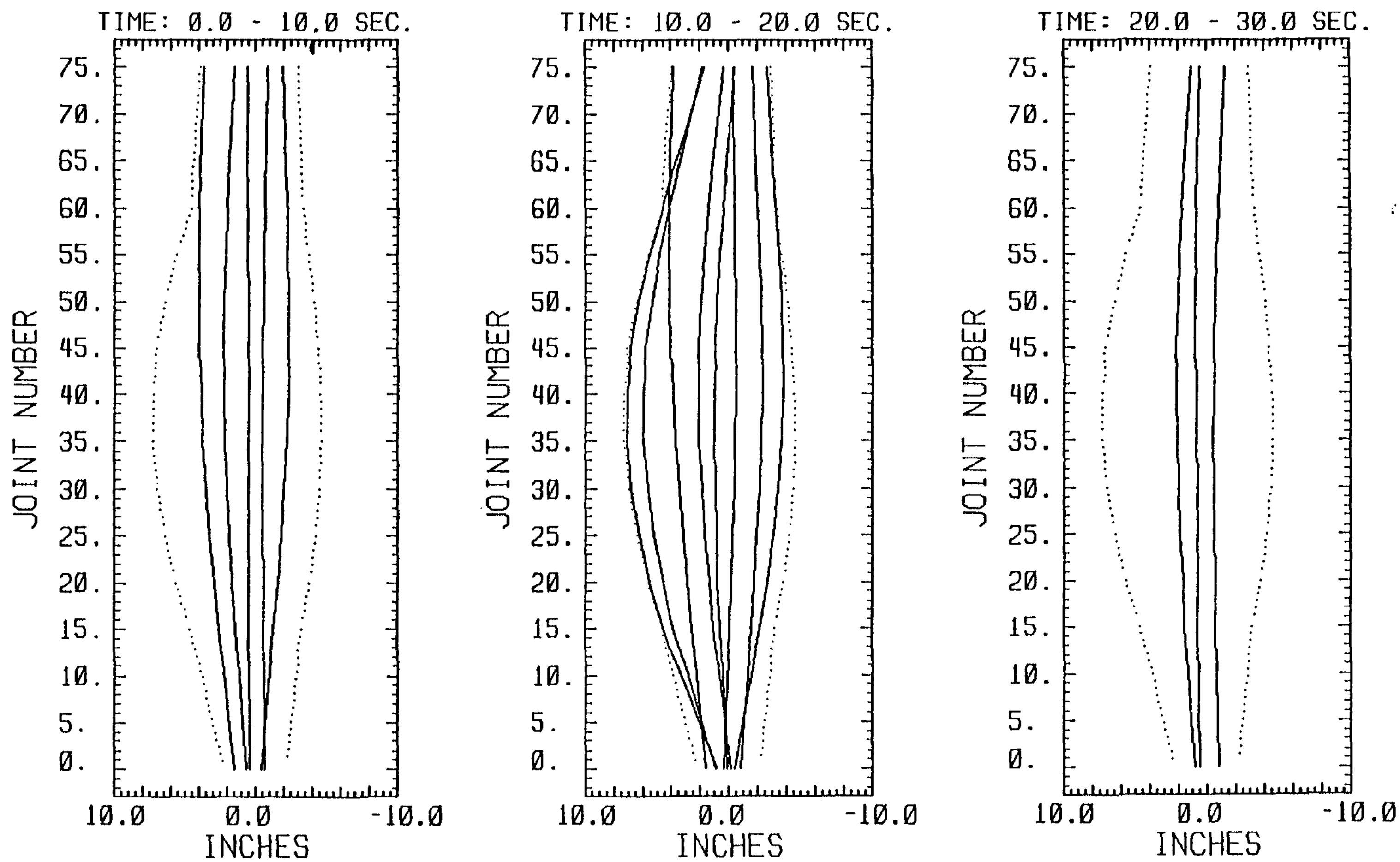
WALL # 5 DYNAMIC TEST

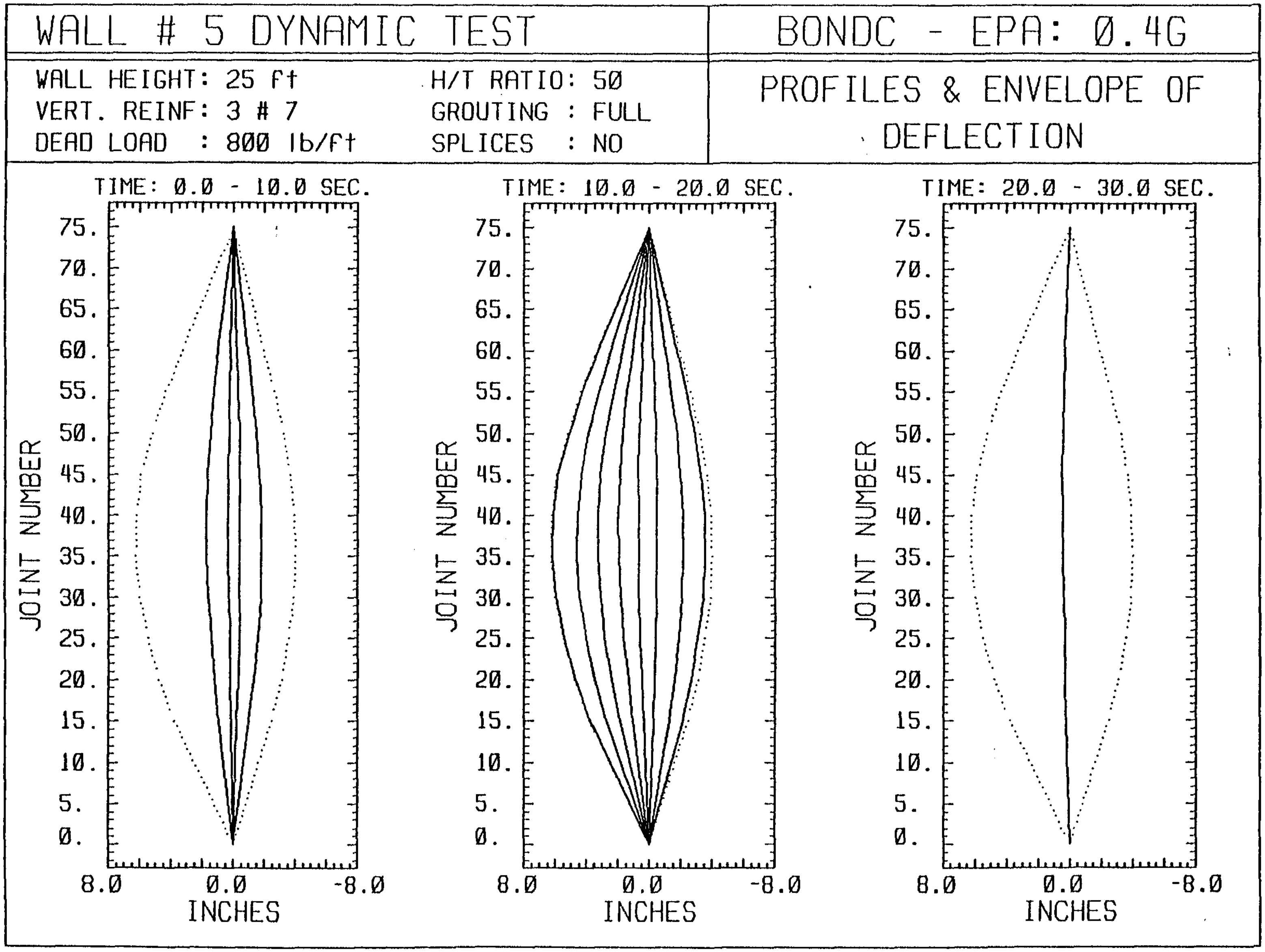
BONDC - EPA: 0.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

PROFILES & ENVELOPE OF DISPLACEMENT



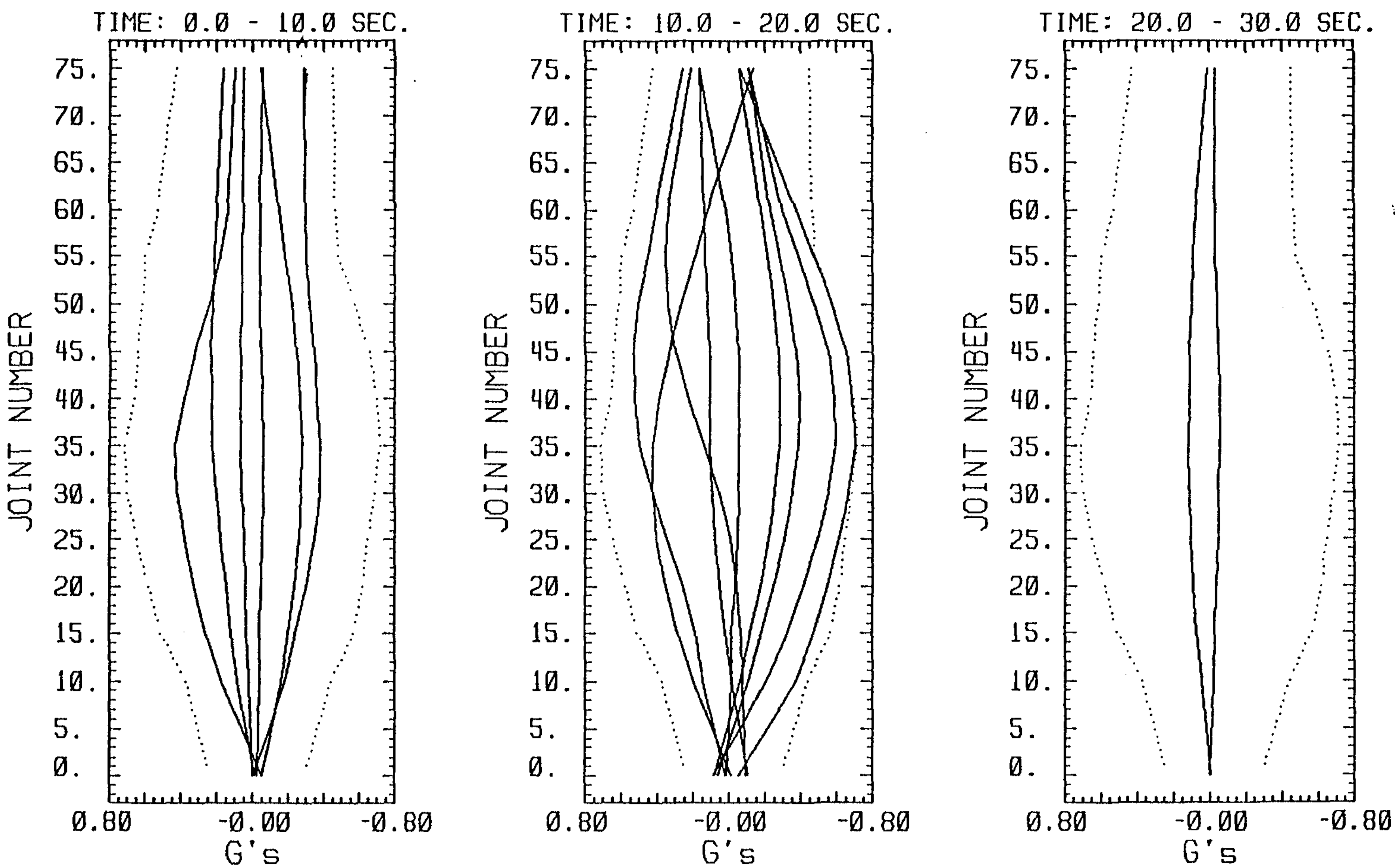

WALL # 5 DYNAMIC TEST
BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
PROFILES & ENVELOPE OF DEFLECTION
TIME: 0.0 - 10.0 SEC.
TIME: 10.0 - 20.0 SEC.
TIME: 20.0 - 30.0 SEC.
JOINT NUMBER
75. 70. 65. 60. 55. 50. 45. 40. 35. 30. 25. 20. 15. 10. 5. 0.
INCHES
8.0 0.0 -8.0

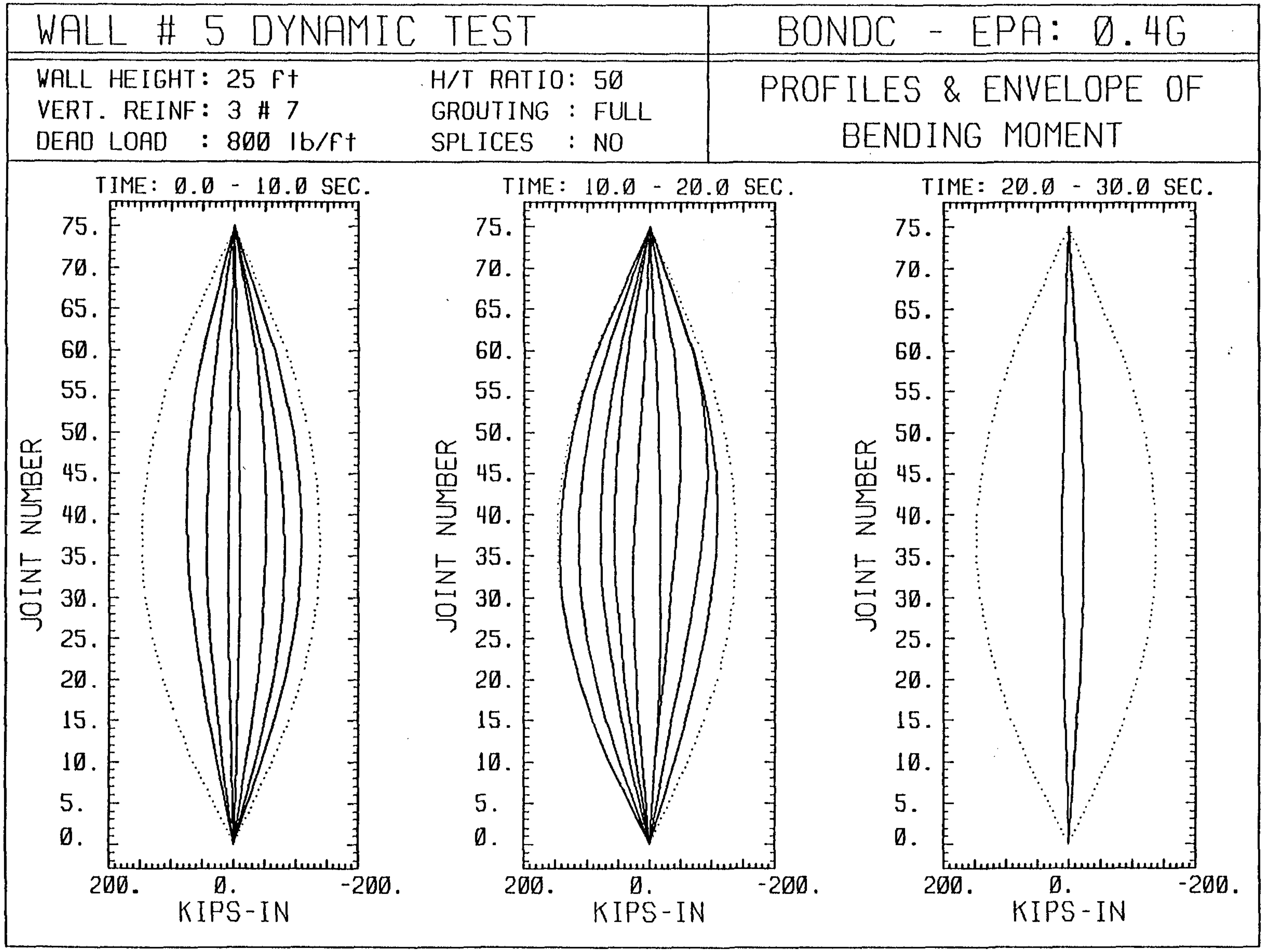
WALL # 5 DYNAMIC TEST | BONDC - EPA: 0.4G

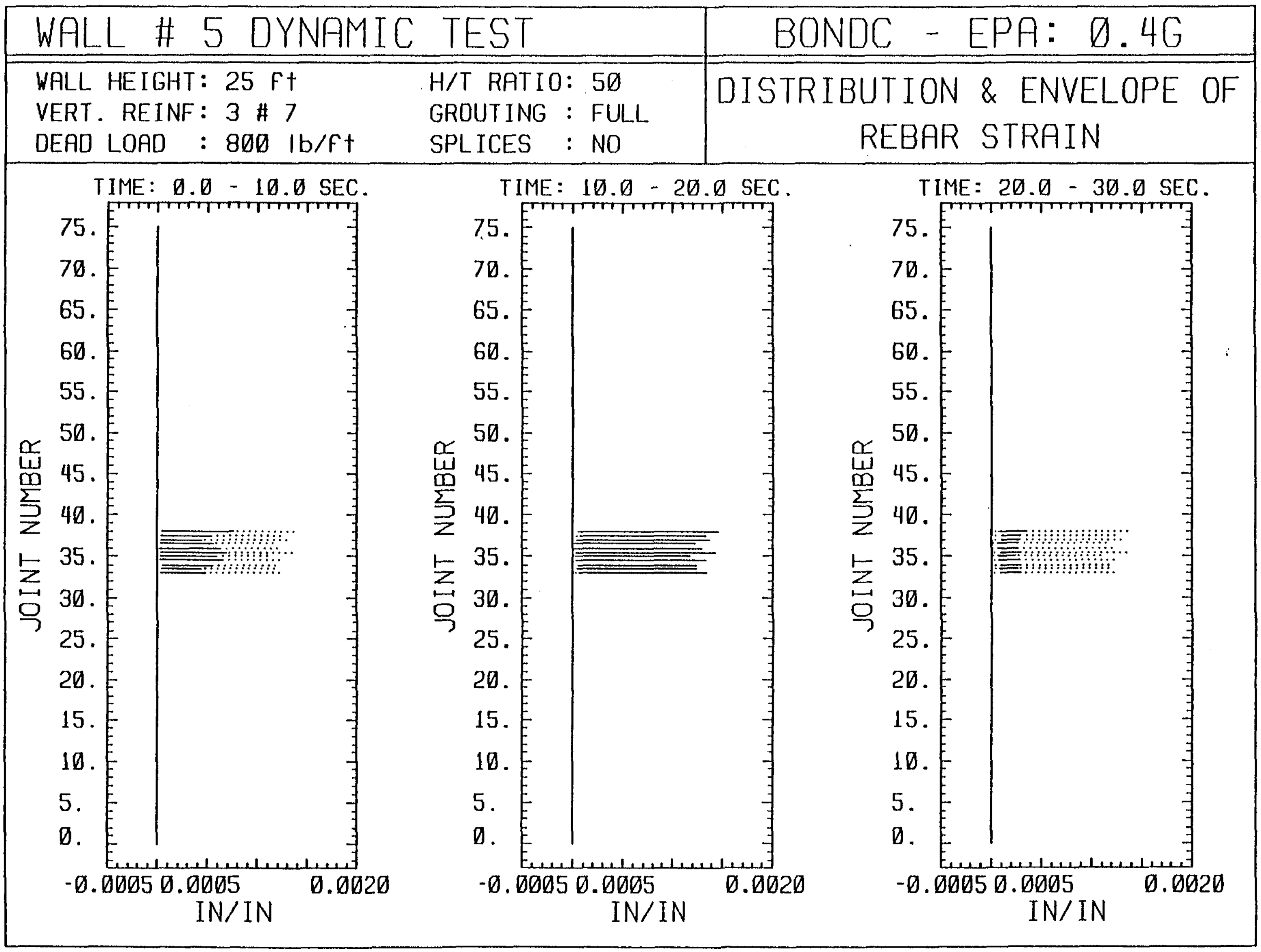
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

PROFILES & ENVELOPE OF ACCELERATION




WALL # 5 DYNAMIC TEST
BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
PROFILES & ENVELOPE OF BENDING MOMENT
TIME: 0.0 - 10.0 SEC.
TIME: 10.0 - 20.0 SEC.
TIME: 20.0 - 30.0 SEC.
JOINT NUMBER
KIPS-IN
75.
70.
65.
60.
55.
50.
45.
40.
35.
30.
25.
20.
15.
10.
5.
0.
200.
0.
-200.

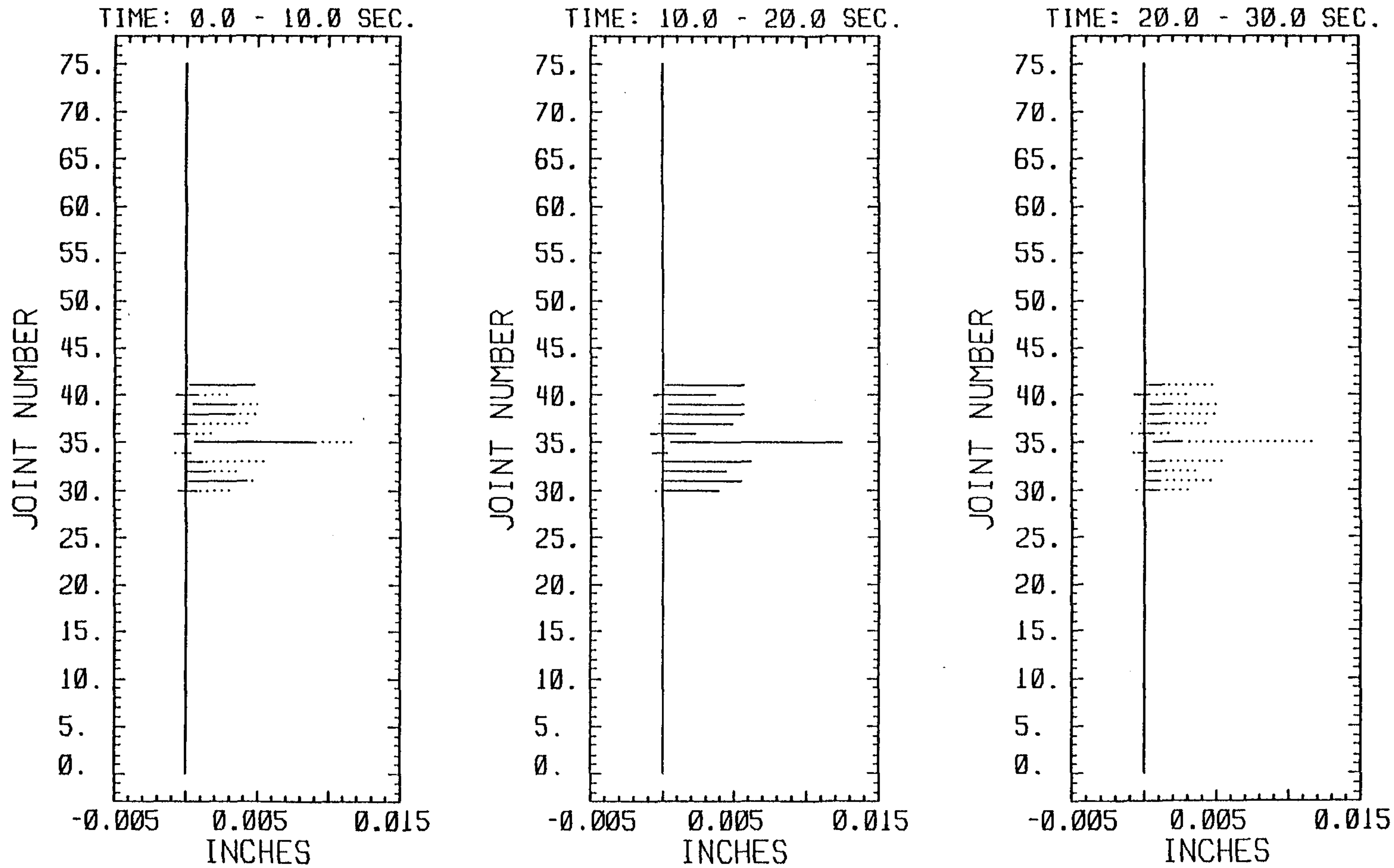

WALL # 5 DYNAMIC TEST
BONDC - EPA: Ø.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
DISTRIBUTION & ENVELOPE OF REBAR STRAIN
TIME: 0.0 - 10.0 SEC.
TIME: 10.0 - 20.0 SEC.
TIME: 20.0 - 30.0 SEC.
JOINT NUMBER
75. 70. 65. 60. 55. 50. 45. 40. 35. 30. 25. 20. 15. 10. 5. 0.
-0.0005 0.0005 0.0020
IN/IN

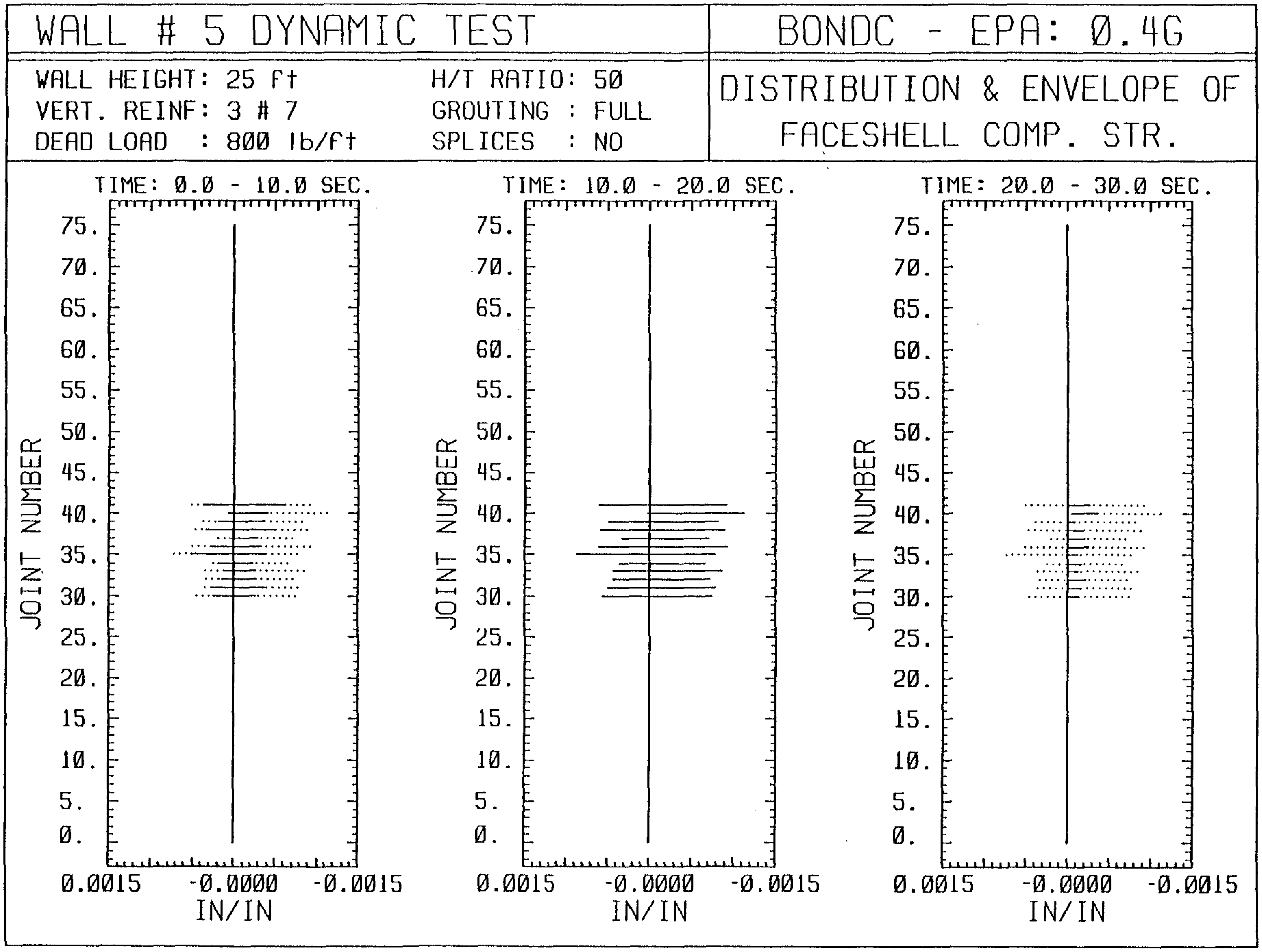
WALL # 5 DYNAMIC TEST | BONDC - EPA: Ø.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 8ØØ lb/ft

H/T RATIO: 5Ø
GROUTING : FULL
SPLICES : NO

DISTRIBUTION & ENVELOPE OF JOINT OPENING




WALL # 5 DYNAMIC TEST
BONDC - EPA: 0.4G
WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft
H/T RATIO: 50
GROUTING : FULL
SPLICES : NO
DISTRIBUTION & ENVELOPE OF
FACESHELL COMP. STR.
TIME: 0.0 - 10.0 SEC.
TIME: 10.0 - 20.0 SEC.
TIME: 20.0 - 30.0 SEC.
JOINT NUMBER
75. 70. 65. 60. 55. 50. 45. 40. 35. 30. 25. 20. 15. 10. 5. 0.
0.0015 -0.0000 -0.0015
IN/IN

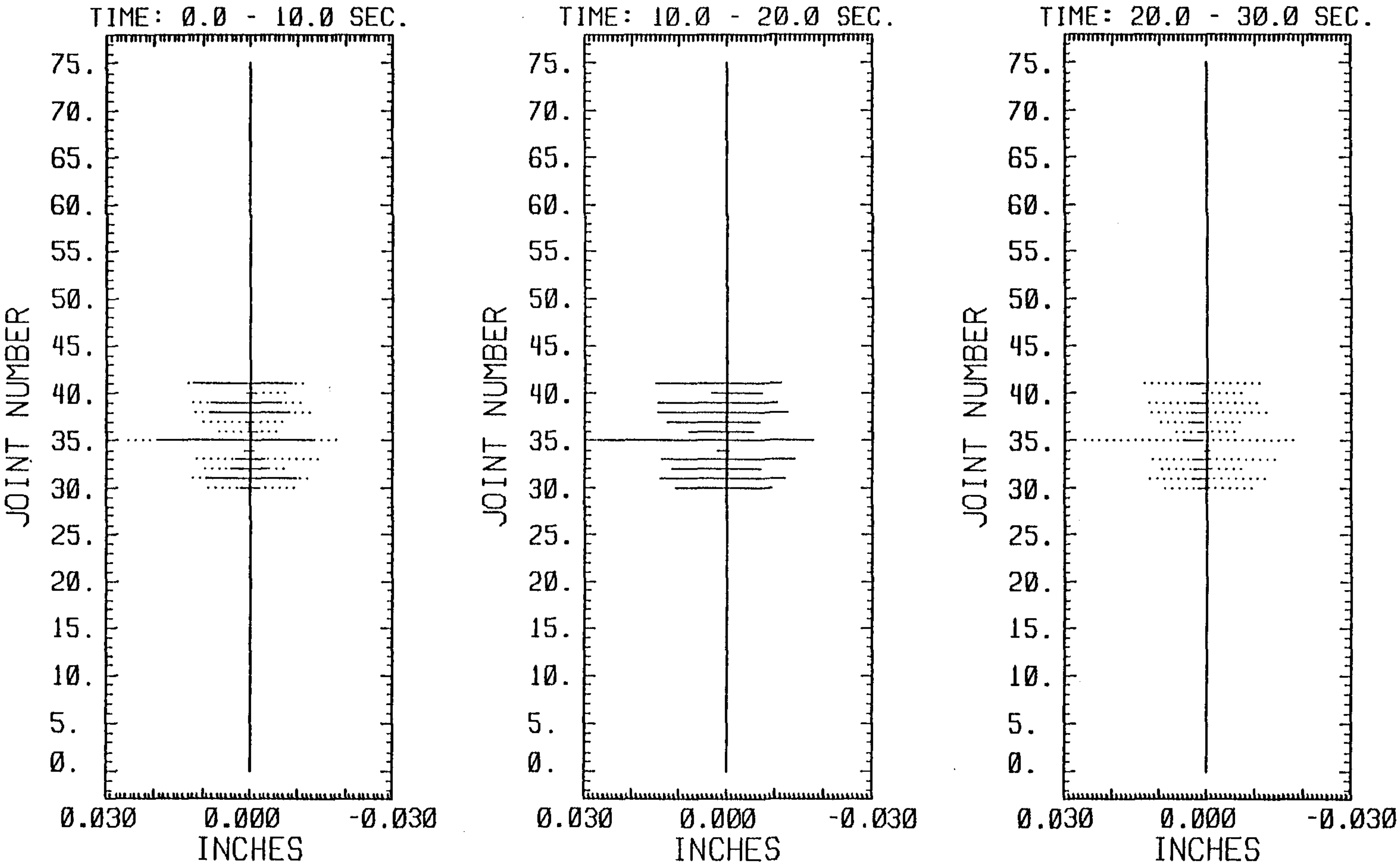
WALL # 5 DYNAMIC TEST

BONDC - EPA: Ø.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

DISTRIBUTION & ENVELOPE OF FACESHELL OPENING



WALL # 5 DYNAMIC TEST | BONDC - EPA: Ø.4G

WALL HEIGHT: 25 ft
VERT. REINF: 3 # 7
DEAD LOAD : 800 lb/ft

H/T RATIO: 50
GROUTING : FULL
SPLICES : NO

DISTRIBUTION & ENVELOPE OF CURVATURE