SEISMIC EVENT EVALUATION REPORT FOR THE

MARCH 15, 1992 Mc = 3.5 EARTHQUAKE

PERRY NUCLEAR PLANT

DOCKET NOS. 50-440; 50-441

THE CLEVELAND ELECTRIC ILLUMINATING COMPANY

MARCH 1992

Approved By: Steven F. Kinisch
Director, PNED

Approved By: [signature]
General Manager, PNPPD

Approved By: Frank R. Stead
Director, PNSD

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1.0 INTRODUCTION AND CONCLUSIONS

The purpose and scope of this report is to provide the results of The Cleveland Electric Illuminating (CEI) Company's seismic event evaluation of the March 15, 1992 earthquake pursuant to Perry Nuclear Plant Technical Specification 4.3.7.2.2. This evaluation report addresses the key issues related to the March 15 earthquake including the immediate response to the event, the plant status and impact assessments following the earthquake, evaluations of the seismological aspects of this event, and an analysis of the plant seismic design basis capabilities compared to recorded plant data.

The discussions contained herein provide the basis for CEI's conclusions that the March 15, 1992 Mc = 3.5 earthquake in the vicinity of the Perry site in Lake Erie:

1) did not adversely effect the plant structures, systems or components,

2) was within the Operating Basis Earthquake (OBE) of the Perry Nuclear Plant,

3) does not change the licensing basis or conclusions regarding the site geology, seismology or design basis earthquake, and

4) is further evidence that the Electric Power Research Institute (EPRI) recommendations on OBE exceedance should be implemented.

2.0 SEISMIC EVENT OVERVIEW

2.1 EVENT

An earthquake, with an approximate magnitude of 3.5 Mc, was recorded by the CEI seismic monitoring network (stations located in Lake and Geauga Counties) on Sunday, March 15, 1992 around 01:14 EST. The epicenter of the earthquake was located in Lake Erie about four (4) miles northwest of the Perry Nuclear Plant located in Perry, Lake County, Ohio. Figure 2.1 shows the epicentral location of this event. This event was followed by eight (8) aftershocks which were all substantially smaller than the main shock. From newspaper and police report accounts, the event was felt by the local population, mainly in the towns along the lake shore from Painesville to Geneva, Ohio. This earthquake was recorded by the seismic monitoring systems operated by CEI (Autostar) and John Carroll University. Plant staff began analyzing the Autostar records within one hour of the event and provided preliminary information to control room operators and local officials. The data was also evaluated by Weston Geophysical Corporation and these results are provided in Section 3.0 and Appendix C of this report.

2.2 PLANT RESPONSE

At the time of the event, the plant was operating at 99% power. This local earthquake (magnitude M = 3.5) was felt by Plant Operations personnel at the Plant and was recorded by in-plant strong motion seismic instruments. The Plant seismic instruments provided information which indicated that motions experienced by the Plant were significantly below the design or safe shutdown earthquake (SSE) and well below the operating basis earthquake (OBE). The SSE zero period acceleration (ZPA) is .15g and the OBE ZPA is .075g.

Control Room indications provided immediate information that the earthquake had occurred and that the recorded motion was below 2/3 of the OBE at the containment foundation. See Section 4.0 of this report.

At 01:43 EST the Plant declared an Unusual Event (UE), the lowest emergency action level, and Operations personnel immediately commenced a Plant walkdown to investigate for any Plant damage which could be earthquake related, and found none. The Plant remained at 99% power. Additionally, Plant technical support personnel were called into the Plant for further evaluations of the event. These personnel were needed to gather information from a seismic monitoring network located in the Lake/Geauga counties and to recommend further Plant actions. Also, PNPP Instrumentation and Control (I&C) technicians were called into the plant for strong motion earthquake records retrieval.

The seismic monitoring network provided data on size and location of the earthquake, which was provided to the Control Room personnel. Seismic specialists examined this field data and again reviewed the in-plant monitors, and consulted with Operations on results of Plant walkdowns which included the reactor containment building. At approximately 04:40 EST the Unusual Event was declared over as there were no safety concerns identified and all indications were that the OBE had not been exceeded.

2.3 EARTHQUAKE ANALYSIS

This is the first event since the 1/31/86 Leroy Earthquake (magnitude Mb = 5.0) that was felt and recorded at the Plant. This was a non-damaging small event, several times smaller than that of 1/31/86 event and below the OBE design of the Plant. The occurrence of the 3/15/92 earthquake and its aftershocks is typical of the periodic low level seismicity of the region and does not alter the conclusions of local and regional seismicity previously docketed by CEI in the following references:

- Perry USAR, Section 2.5, Revision 4, March, 1992.

- 18th Quarterly Seismic Monitoring Report (PY-CEI/NRR-0144L, dated 2/27/92).

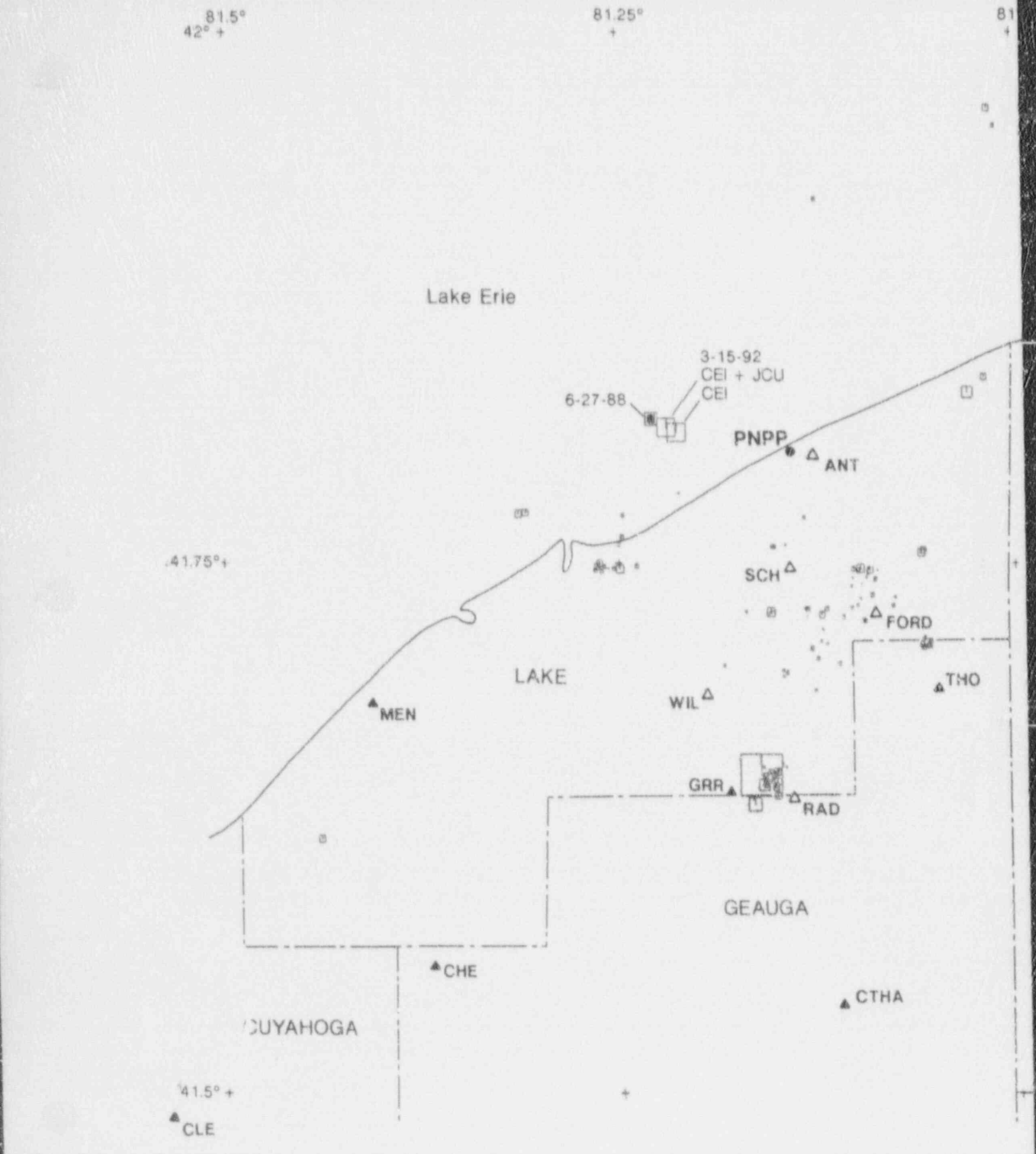
- SSER No.9 Confirmatory Activities Close Out: Geological and Geophysical Studies (PY-CEI/NRR-0486L, dated 6/24/86).

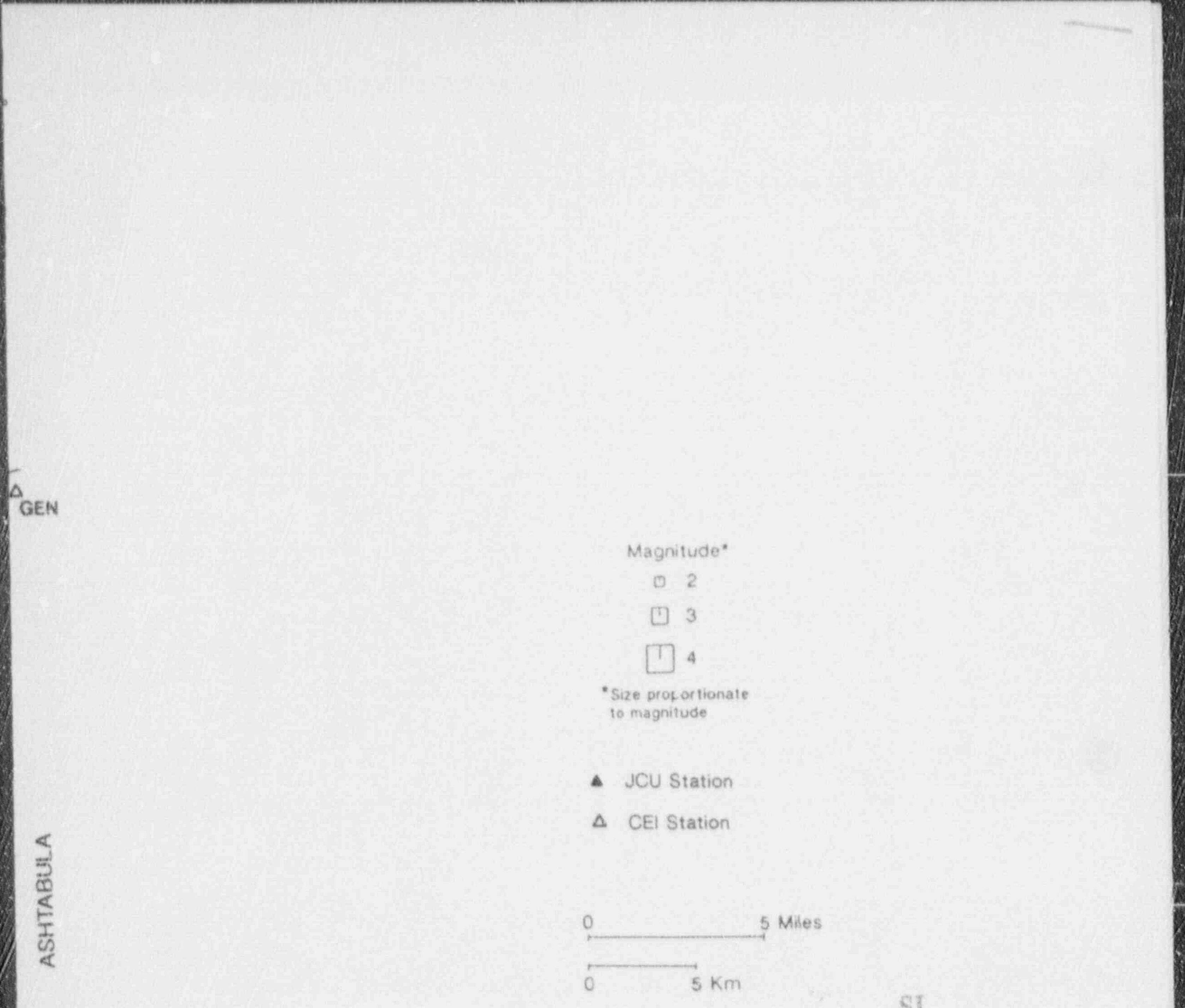
2.4 SEISMIC DESIGN EVALUATION

Results of the immediate inspections on 3/15/92 indicated that the peak ground acceleration at the Auxiliary Building foundation on Engdahl Peak Recorders was .038g and subsequent analysis of Kinemetrics time history data indicated a similar peak acceleration of .038g at the Containment Building foundation.

Acceleration data taken from the in-plant seismic recorders showed recorded floor response spectra were within the OBE design spectra. Similar to the 1986 earthquake response, the instrumentation located at elevation 686' of containment recorded the highest accelerations. This is an expected result as motions input to the foundation mat will be amplified as they are transmitted up through the structure. Design floor response spectra consider this amplification when they are developed for above grade elevations.

CEI analysis shows the high frequency accelerations involved are of a very short duration and the velocities and displacements are well below those which could cause damage even to non-engineered structures. The total energy associated with these high frequency accelerations is small, and therefore has no adverse impact on plant structures and equipment. Th... the high frequency accelerations have no engineering significance and the effects of the earthquake experienced at Perry are well within the seismic capability of the plant. This latest event is further evidence that the proposals provided by the Electric Power Research Institute (EPRI) on OBE exceedance should be implemented, and the application of Cumulative Absolute Velocity (CAV) would allow faster and more accurate plant assessments of potential damage. See Section 5.0 and Appendix C of this Report.


81.5°
42°
81.25°
81
Lake Erie
3-15-92
CEI + JCU
CEI
6-27-88
PNPP
ANT
41.75°
SCH
FORD
LAKE
THO
WIL
MEN
GRR
RAD
GEAUGA
CHE
CTHA
CUYAHOGA
41.5°
CLE



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PERRY NUCLEAR POWER PLANT
THE CLEVELAND ELECTRIC
ILLUMINATING COMPANY

Epicentral Location
03/15/92 Earthquake

FIGURE 2.1

3.0 EARTHQUAKE ANALYSIS

3.1 Introduction

In addition to the strong motion instrumentation installed at different locations inside the Perry Nuclear Plant, CEI still operates a small aperture telemetered seismic monitoring network, named AUTOSTAR. This AUTOmated Seismic Telemetering and Recording system has five 3-component stations and a 1-component analog station near Geneva, all of which are telemetered to a central receiving/processing station at the Plant. At the time of the earthquake, CEI was also testing a PDAS-100 instrument at the Antioch station of the Autostar network. In addition, John Carroll University (JCU) operates a small regional network centered around the epicenter of the January 31, 1986 earthquake. This section provides a preliminary summary review and analysis of all the data collected by the CEI and JCU stations. Appendix C provides a review of the PDAS-100 data and calculates a Cumulative Absolute Velocity (CAV) measurement for this event.

3.2 Hypocentral Determination

On March 15, 1992, at 6h 13m 56.8s UT, a small earthquake with a coda magnitude of 3.5, occurred offshore the town of Painesville, Ohio. The epicenter was located in Lake Erie approximately at 41.9N and 81.3W, about seven kilometers northwest of the Perry Nuclear Plant. Because of the short epicenter distance, some of the strong motion instrumentation at the Plant were triggered by the arrival of the shear and surface waves.

The hypocentral solution was calculated using all arrival times from the stations of both CEI and JCU networks. Table 3.1 presents the details of the hypocentral solution obtained with the "Hypoellipse" locationing computer program.

Because the event is outside the aperture of the two networks and far enough in Lake Erie, the focal depth estimate carries a large uncertainty. Other arrival times at more distant stations, e.g. from the Lamont-Doherty Observatory, the Canadian National Network and from the University of Western Ontario were obtained, but not used since they clearly contaminate the excellent data provided by the two local networks. Figure 2.1 shows the epicentral location of the event. The sensitivity of the location is illustrated by showing the difference obtained when only the CEI data are used and when the JCU data are added. JCU has stations west of the epicenter, while the CEI stations are all located to the east. Figure 3.1 shows the earthquake as recorded by the CEI Autostar system. Figure 3.2 provides a 20 second trace of the earthquake along with selected P and S wave arrival times. Figure 3.3 shows a "zoom" earthquake trace for the Antioch station which is located about 1 mile east of PNPP.

The small earthquake was felt in towns along the lake shore, mainly from Painesville to Geneva, Ohio. Although no formal intensity survey was conducted, the most common description as learned from police stations and local media reports corresponds to intensity (MM) III and IV levels, typical for events with similar magnitude. The event was clearly felt at the plant for a brief duration. From the recordings collected, one can assume that the perception of the tremor must not have lasted more than a few seconds.

Several aftershocks were detected by the two networks, at least eight over the next 60 hours. Table 3.2 presents the details of the entire sequence. The slight differences in epicentral location between the main shock and the aftershocks are not considered to be significant, and most probably reflect the bias introduced by processing weaker events with different station configurations and reading accuracies.

It should be noted that previously on June 27, 1988, a similar sequence consisting of a microearthquake with a magnitude Mc 2.7 and five small aftershocks ranging from -0.1 to 1.7 was detected and placed in the very same location, i.e. 41.81 and 81.229W. These events were documented in Quarterly Seismic Monitoring Report No. 7 (Ref. PY-CEI/NRR-0905L, dated 8/26/88).

3.3 FAULT PLANE SOLUTION

An attempt was made to obtain a fault plane solution. Unfortunately, all the CEI stations and most of the JCU stations are grouped in the same azimuthal quadrant. Additional data provided by other network operators are clearly inconsistent, thus suggesting that first arrivals are not truly read. This is to be expected beyond 100 km. Because of this a fault plane solution could not be obtained.

3.4 DISCUSSION

The small earthquake was not strong enough to cause any damage, but it was clearly felt by those awake at this early time of the night, within several tens of kilometers, particularly along the lakeshore where soil amplification is common. The instrumental data set is good enough to support a reliable epicenter, and possibly an indication that the depth was shallow. Occasional occurrences of magnitude 3 to 3.5 events are in agreement with the historical record of the region. Previous studies have established that the Northeastern Ohio seismicity is relatively low compared to other regions of the Northeast.

The examination of available accelerograms suggests that the largest peak ground acceleration observed at Antioch was associated with a very short duration wave, one or two cycles, at about 11 Hz. This seismic motion is well below any damage threshold. The CAV values obtained are low and consistent with several other observed magnitude 3 to 4 events with MM intensity III. See Appendix C.

Hypocentral Solution
03/15/92 Earthquake

TABLE 3.1

23-MAR-92 12:27:00 for the program ELLIPSE

###########

#7674 OFFSHORE PAINSVILLE, OH, MAINSHOCK

+++
Input filename....: MAR1592A.INP
+++

CRUSTAL MODEL 1

LAYER	VELOCITY KM/SEC	DEPTH KM	THICKNESS KM	VP/VS
1	4.250	0.000	2.000	1.78
2	6.500	2.000	33.000	1.78
3	8.100	35.000	1000.000	1.78

RESULTS OF EACH ITERATION:

I	LAT	LONG	DEPTH	RMS	DLAT	DLONG	DZ
1	45.0	15.0	2.00	0.68	6.76	-1.01	-0.16
2	48.6	14.3	1.82	0.17	1.20	-0.89	1.55
3	49.3	13.6	3.37	0.10	-0.93	-0.66	-1.68
4	48.8	13.6	1.68	0.09	-0.20	-0.70	0.00
5	48.7	13.1	1.68	0.06	1.07	0.68	1.67
5	49.3	13.6	3.35	0.09	-1.07	-0.68	-1.67
6	48.7	13.1	1.68	0.06	1.06	0.68	1.66
5	49.3	13.6	3.34	0.09	-1.06	-0.68	-1.66
6	48.7	13.1	1.68	0.06	0.52	0.36	0.95
7	49.0	13.3	2.63	0.06	-0.24	-0.21	-0.28
8	48.8	13.2	2.35	0.05	-0.08	0.01	-0.14
8	48.8	13.2	2.21	0.05	0.08	-0.01	0.14
9	48.8	13.2	2.35	0.05	0.00	0.00	0.00
9	48.8	13.2	2.35	0.05	0.00	0.00	0.00

########### HYPOELLIPSE LOCATION RESULTS ###########

HORIZONTAL(2DOF) VERTICAL

SE = 0.26 SE = 0.29 SE = 4.70 QUALITY = C

AZ = 44. AZ = -46.

DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	RMS	ERH	ERZ	SQD
920315	613 56.80	41N48.84	81W13.19	2.3	3.5	16	235	0.05	0.2	4.7	C D
		41.8139	81.2199								

(---STATION DATA---)(-----P WAVE DATA------)(-----S WAVE DATA------)(MAG DATA)

STA	DIST	AZM	ADP	PSEC	PRMK	PRES	PWT	SSEC	SRMK	SRES	SWT	FMP	FMAG
ANT	7.9	102	93	58.38	IPc0	-0.02	1.22	59.56	SS 0	-0.08	0.92		
SCH	9.7	139	92	58.71	IPC0	0.03	1.22	60.14	ES 0	-0.01	0.92		
WIL	14.3	172	92	59.45	IPC0	0.06	1.22	61.34	ES 0	-0.08	0.92		
FORD	14.6	132	92	59.51	IPC0	0.06	1.22	61.49	ES 0	-0.03	0.92		
GRR	19.4	170	91	60.20	IPC1	0.00	0.92					220	3.5
GEN	19.4	79	91	60.00	IPC4	-0.17	0.00						
THO	19.7	133	91	60.32	IPC1	0.06	0.92						
RAD	20.5	161	91	0.41	IPC0	0.03	1.22	3.15	ES 1	-0.02	0.69		
MEN	21.0	227	91	60.32	IPD1	-0.10	0.92					210	3.4
CHE	30.5	203	91	61.86	IP 1	-0.04	0.92						
CTHA	31.5	163	91	62.14	IP 1	0.08	0.92						
CLE	44.5	216	90	64.06	IPC1	0.01	0.92					210	3.4
BEAV	121.1	35	90	79.00	IP 4	3.15	0.00					260	3.6

QUALITY BASED ON FOCAL SPHERE: A

TABLE 3.2

MARCH 15, 1992 MAINSHOCK AND ASSOCIATED AFTERSHOCK PARAMETERS

	YEARMODY	HRMISEC	LATITUDE	LONGITUDE	DEPTH	NP	GAP	RMS	ERH	ERZ	Mc	Trigger #
1.	*19920315	61356.80	41N48.84	81W13.19	2.3	16	235	.05	.2	4.7	3.5	7674
2.	19920315	628 6.61	41N48.61	81W12.94	2.1	10	236	.03	.3	13.7	1.8	7675
3.	19920315	950 9.92	41N48.81	81W13.00	2.3	10	239	.08	.8	19.4	0.5	7677
4.	19920315	11 9 7.60	41N48.78	81W12.56	2.2	8	237	.04	.2	5.8	0.2	7678
5.	19920315	144939.81	41N48.67	81W12.65	2.2	10	235	.04	.3	9.3	2.2	7679
6.	19920316	22936.80	41N48.65	81W12.9[illegible]	2.1	10	236	.03	.2	9.7	1.1	7680
7.	19920316	458 0.56	41N48.73	81W12.21	2.2	9	235	.03	.3	10.9	0.2	7681
8.	19920316	122414.98	41N48.61	81W12.44	1.9	10	234	.04	.3	.2	1.6	7682
9.	19920316	141519.	No Trigger on Digital Network								-0.3	

Vp1=4.25 km/s Thickness = 2 km
Vp2=6.5 km/s Thickness = 33
Vp/Vs=1.78

MAR. 1992

* Indicates Mainshock

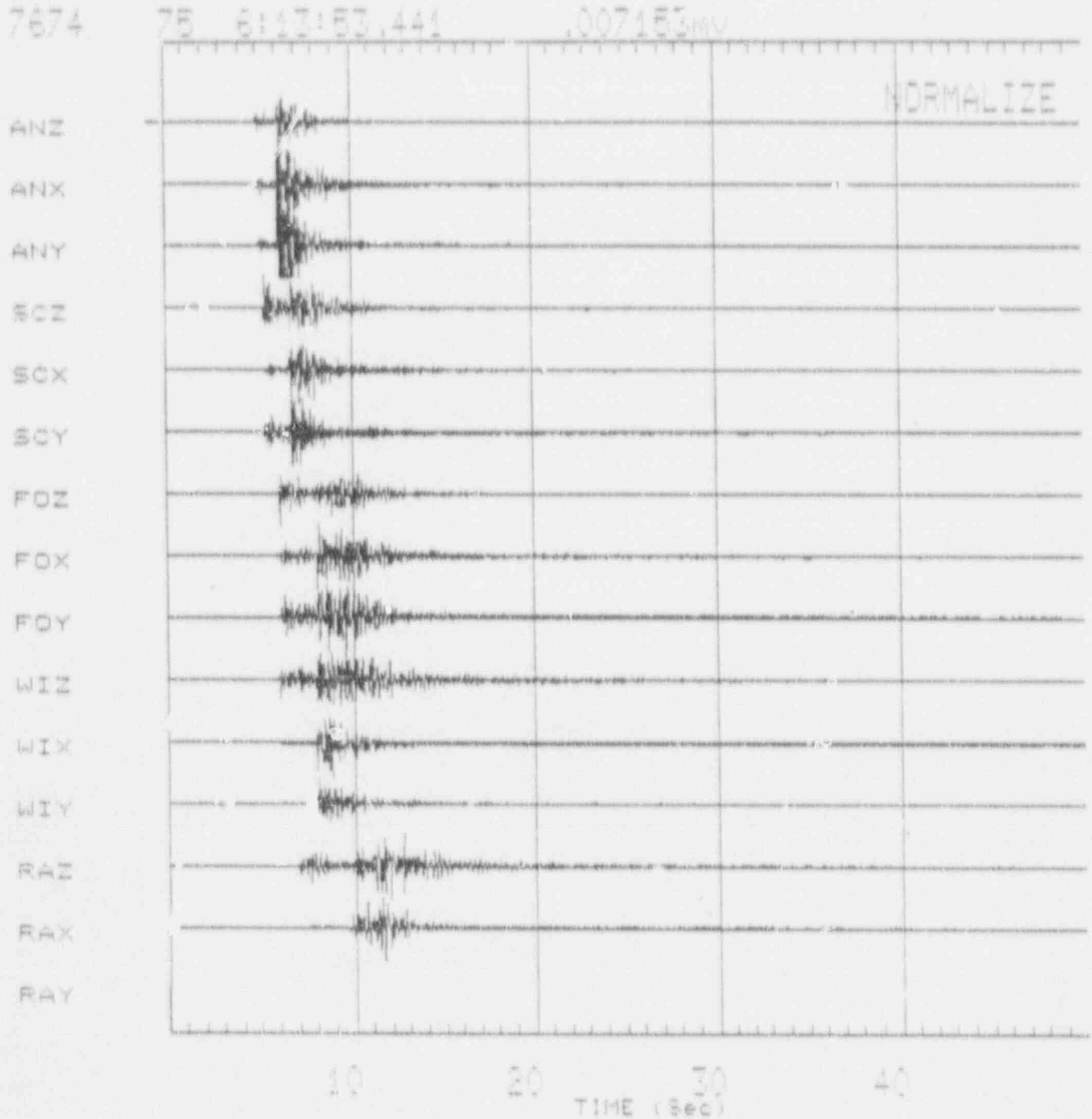


FIGURE 3.1 CEI Autostar Record
03/15/92 Earthquake
All stations - 50 seconds

NOTES: 1. Each signal is normalized to its peak amplitude for display.

2. R[illegible] [illegible] station horizontal component (RAY) is out of service.

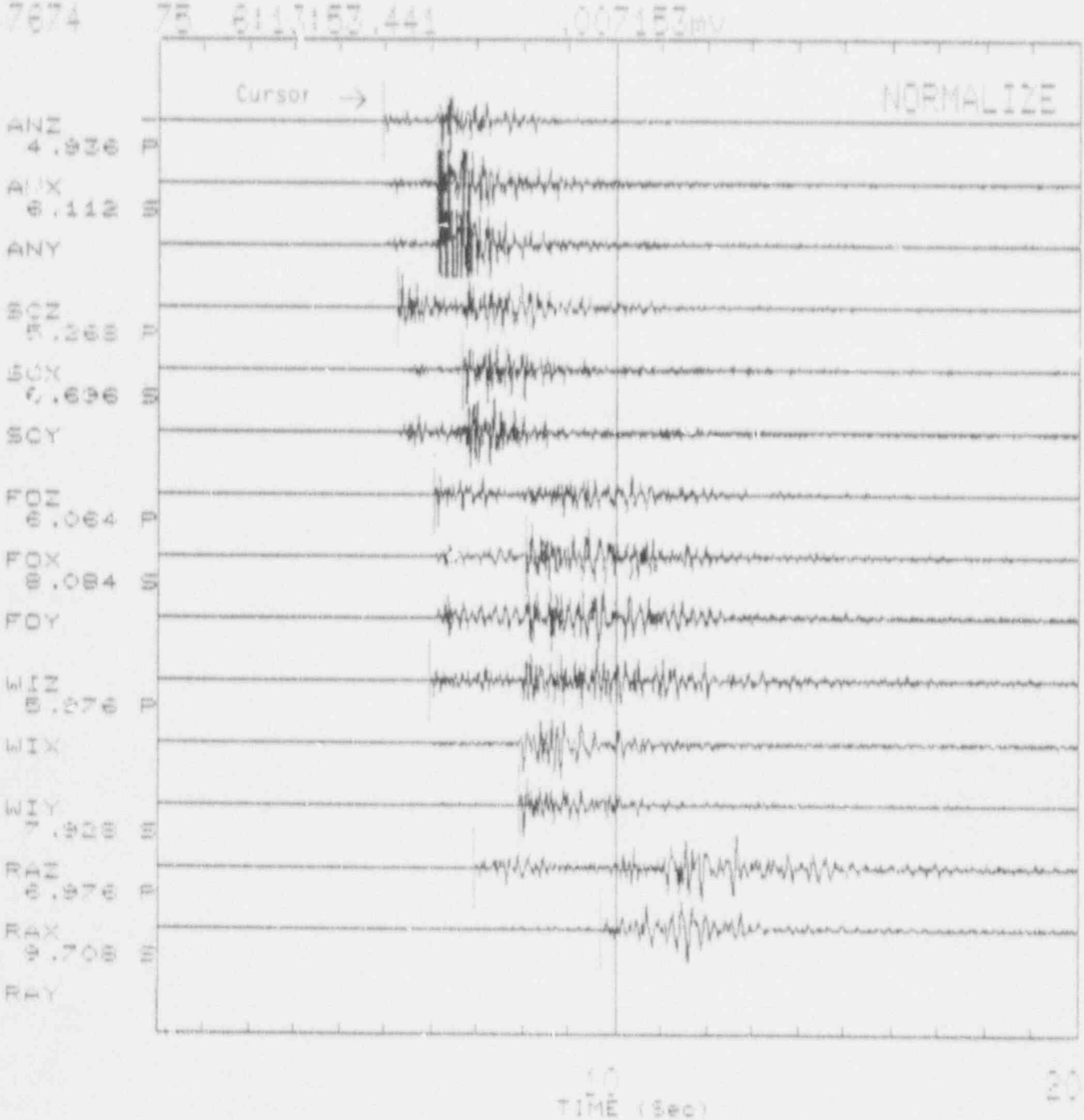


FIGURE 3.2 CEI Autostar Record
03/15/92 Earthquake
All stations - 20 seconds
(P and S wave arrival time picks displayed)

NOTES: 1. Each signal is normalized to its peak amplitude for display.

2. Radcliff station horizontal component (RAY) is out of service.

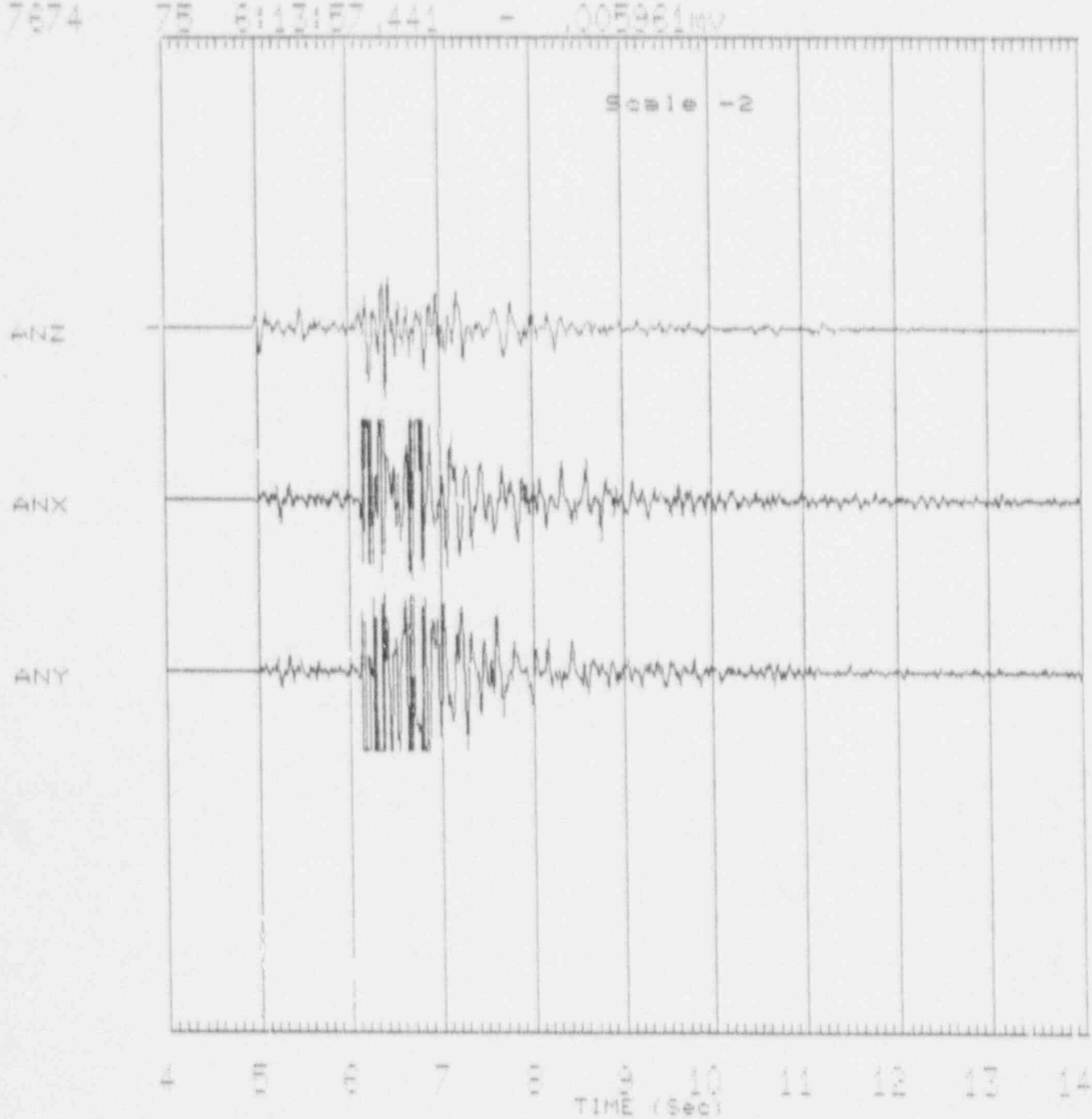


FIGURE 3.3 CEI Autostar Record
03/15/92 Earthquake
Antioch Station - 10 seconds

NOTE: Signal Amplitudes are scaled down twice for display.

4.0 SEISMIC INSTRUMENTATION AND RECORDS RETRIEVAL

4.1 INSTRUMENTATION

Three different types of in-plant seismic strong motion monitoring instrumentation were used to record the March 15, 1992 Mc 3.5 earthquake located near PNPP in Lake Erie. Table 4.1 and Figure 4.1 delineate the specific instrument number, type and location. PNPP is a fully instrumented Regulatory Guide 1.12 facility.

One type of instrument used is the Kinemetrics Model SMA-3 strong motion triaxial time-history accelerograph. This system detects and records three mutual perpendicular components of acceleration over the entire duration (recording starts within 200ms of measuring .005g) of the earthquake onto cassette magnetic tape. Power to the unit is supplied by internal rechargeable batteries which are kept in a charged state by 120 VAC line power. Two instruments of this type were used, one was located on the Reactor Building Foundation Mat at an elevation of approximately 575 feet, and the second on the containment shell at elevation 686 feet.

The second type of instrumentation used is the Engdahl PSR 1200-H/V response spectrum recorder. This total mechanical system records three mutually perpendicular components of acceleration, at selected frequencies. The instrument has twelve reeds fabricated of varying lengths, one for each frequency ranging from approximately 2 Hz to 25 Hz, and a diamond-tipped stylus at the free end of each reed to inscribe a permanent record on one of twelve record plates. Four instruments of this type are provided, two on the Auxiliary Building Foundation Mat, one at the Reactor Building Foundation Mat, and one in the Reactor Building located on the Bioshield Wall.

The third type of instrument is the Engdahl PAR 400 peak accelerograph.

This totally mechanical system records three mutually perpendicular components of peak local acceleration (i.e., the zero period acceleration). A diamond tipped scriber at the end of an amplifier arm records a permanent mark on a record plate. Again, this system is totally self-contained and requires no outside power source. Three instruments of this type are used and are located on the Auxiliary Building Foundation Mat, on a Reactor Recirculation Pump, and a third instrument on High Pressure Core Spray (HPCS) piping in the Reactor Building.

4.2 PLANT INSPECTIONS FOLLOWING EVENT

Prior to the earthquake that occurred on March 15, 1992, numerous testing, calibration and work completion activities were being conducted in preparation for the Third Refueling Outage. The plant had just completed a power reduction to 99% at Systems Operating Center (SOC) request.

On March 15, 1992 @ 0116 the Control Room received a Seismic Trouble Alarm, heard a large thud and felt the building shake. The plant supervision entered Off Normal Instruction (ONI) D51.

In support of the ongoing testing and surveillance activities, a significant number of systems were in operation. In addition, numerous other systems were energized and in the standby mode. All of the operating safety-related and non-safety systems continued to operate through the event. None of the systems in the standby mode experienced any spurious initiations.

In addition to the emergency plan action previously discussed, immediately following the event plant operators performed a plant walkdown. Areas of visual inspection include the Diesels Rooms, Control Complex 620', Auxiliary Boilers, Intermediate, Auxiliary, Fuel Handling, Turbine Heater Bay Buildings and the accessible areas of the Reactor Building. The plant outer structures including the Cooling Tower, Circulating Water Pump House, Emergency Service and Service Water Buildings were inspected. The reports to the Control Room indicated that the areas were found in satisfactory condition with no damage. An existing crack in the west stairway to the Heaterbay Building was noted as possibly disturbed, and was the only noted observation during the walkdown.

4.3 RECORDS RETRIEVAL

As part of CEI's response to the earthquake, the data collected from active and passive seismic recorders has been evaluated. The tapes from the Kinemetrics Strong Motion Acceleration system were sent to the vendor for further data reduction and analysis. See Appendix A of this report. Record plates were removed from the Engdahl Strong Motion monitors for the Auxiliary and Reactor Buildings and the High Pressure Core Spray Pump base. The records were analyzed and data interpreted by the System engineer, see Appendix B of this report.

One set of Engdahl records (vertical component) from the D51-R190 instrument located on the Auxiliary Building foundation were discovered damaged upon inspection and will be forwarded to the vendor for further analysis.

Peak accelerations recorded from instruments were as follows:

Instrument	Location	Acceleration
D51-N101	R.B. Foundation	0.038g ZPA (uncorrected)
D51-N111	Containment Vessel	0.03g @ 12 Hz (2% damped)
D51-R120	Reactor Recirc Pump	to be examined
D51-R130	HPCS Piping	to be examined
D51-R140	A.B. Foundation, HPCS Room	0.038g ZPA
D51-R160	R.B. Foundation	0.0625g @ 25.6 Hz (2% damped)
D51-R170	Bioshield Wall	to be examined
D51-R180	A.B. Foundation, HPCS Room	out-of-service
D51-R190	A.B. Foundation, RCIC Room	to be examined

Immediately following the event, preliminary indications were provided to the control room operators that this earthquake was not safety significant because:

1. Engdahl Panel H13-P969 indicated there were no recorded accelerations above the OBE or above 2/3 OBE at the 12 frequencies monitored at the containment foundation.
2. Kinemetrics Panel H51-P021 "seismic switch" indicated that the OBE had not been exceeded at the containment foundation.
3. There were no plant damage reports suggesting equipment may malfunction.
4. There were no unusual plant system reactions to the earthquake.
5. The location and magnitude of the event provided by the off-site monitoring network indicated the event was non-damaging.

In the early morning hours of 3/15/92, records were examined from instruments D51-N101, D51-R140 and D51-R190 to determine further the significance of the event, and to determine the need for additional records examination. Based on those initial three instrument readings, it was decided to continue records retrieval on a phased schedule with the refueling outage (RFO3) which commenced 3/20/92.

Off Normal Instruction (ONI) D51 requires removal and analysis of earthquake records following an event of this nature which is felt by PNPP personnel and triggers (.005g) on the Kinemetrics recording unit. Technical Specification 4.3.7.2.2 requires submittal of a Special Report to the Nuclear Regulatory Commission if any of the above instruments record accelerations greater than .03g.

PERRY NUCLEAR POWER PLANT UNIT NO. 1
SEISMIC MONITORING INSTRUMENTATION

TABLE 4.1

Instrument Number	Type	Manufacturer / Model Number	Location	3/15/92 Status
D51-N101	(1)	Kinemetrics / SMA-3	Reactor Building Foundation Mat Elevation 575'–10" Azimuth 175°	Operable
D51-N111	(1)	Kinemetrics / SMA-3	Reactor Building Containment Vessel Elevation 686'–0" Azimuth 174°	Operable
D51-R120	(2)	Engdahl / PAR-400	Reactor Recirculation Pump (Inside Drywell, Reactor Building) Elevation 605'–0" (Approximately) Azimuth 145°	Operable
D51-R130	(2)	Engdahl / PAR-400	Reactor Building HPCS Piping Elevation 631'-1"	Operable
D51-R140	(2)	Engdahl / PAR-400	Auxiliary Building Foundation Mat (HPCS Pump Room) Elevation 568'–4"	Operable

1. Triaxial Time-History Accelerograph
2. Triaxial Peak Accelerograph
3. Triaxial Response Spectrum Recorder

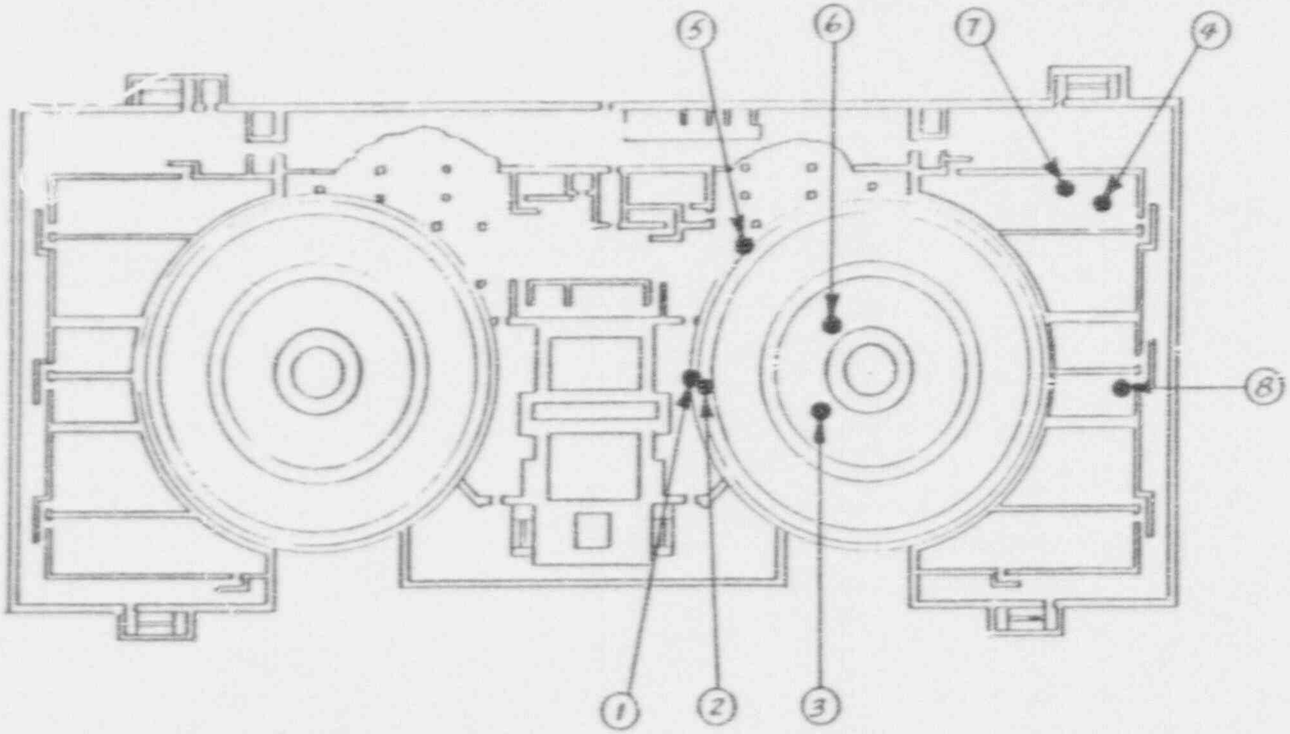
PERRY NUCLEAR POWER PLANT UNIT NO. 1
SEISMIC MONITORING INSTRUMENTATION

TABLE 4.1

Instrument Number	Type	Manufacturer / Model Number	Location	3/15/92 Status
D51-R160	(3)	Engdahl / PSR-1200-H / V-12A	Reactor Building Foundation Mat Elevation 574'-10" Azimuth 225°	Operable
D51-R170	(3)	Engdahl / PSR-1200-H / V	Reactor Building (Inside Drywell) Biological Shield Wall Elevation 636'-6" Azimuth 238°	Operable
D51-R180	(3)	Engdahl / PSR-1200-H / V	Auxiliary Building Foundation Mat (HPCS Pump Room) Elevation 568'-4"	Out-of-Service
D51-R190	(3)	Engdahl / PSR-1200-H / V	Auxiliary Building Foundation Mat (RCIC Pump Room) Elevation 568'-4"	Operable

1. Triaxial Time-History Accelerograph
2. Triaxial Peak Accelerograph
3. Triaxial Response Spectrum Recorder

Figure 4.1
Sheet 1

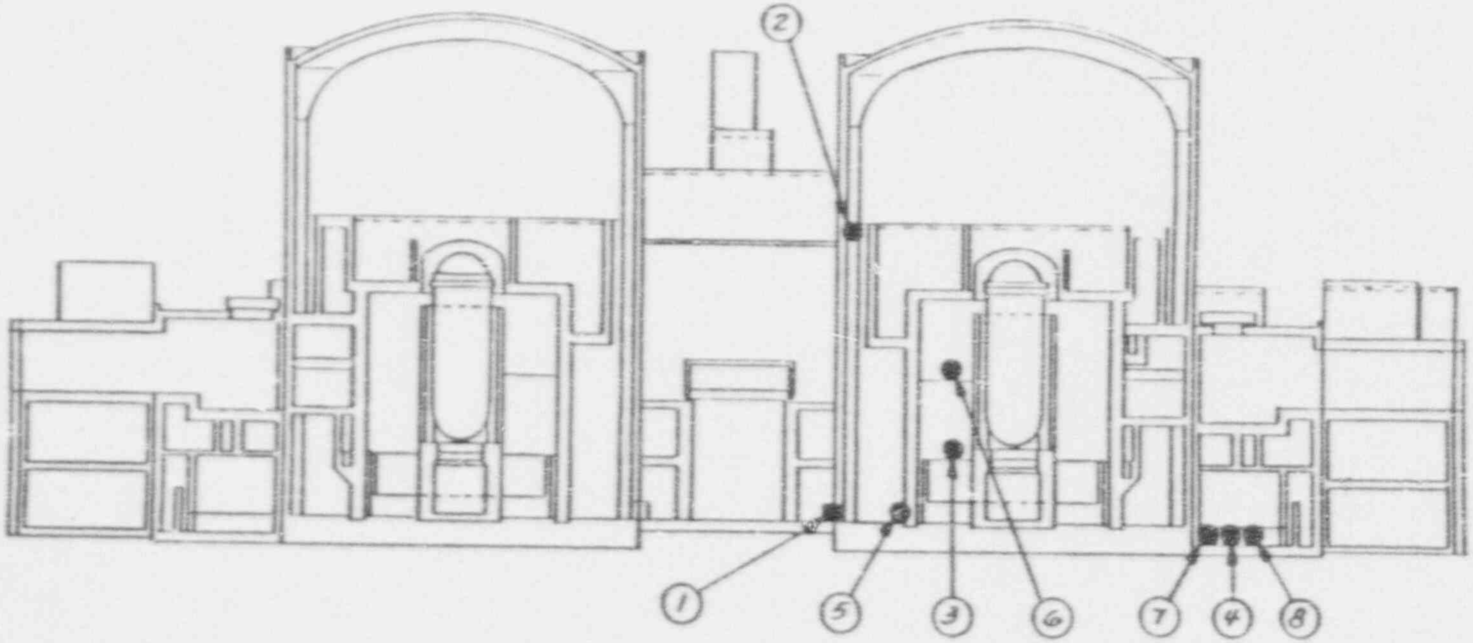


KEY:

1. Instrument #D51-N101
2. Instrument #D51-N111
3. Instrument #D51-R120
4. Instrument #D51-R140
5. Instrument #D51-R160
6. Instrument #D51-R170
7. Instrument #D51-R180
8. Instrument #D51-R190

FIGURE 4.1 - PERRY POWER PLANT INSTRUMENT LOCATIONS, PLAN VIEW

Figure 4.1
Sheet 2



KEY:

1. #D51-N101 R/B Foundation Mat, El. 575', Az. 175°
2. #D51-N111 R/B Containment Vessel, El. 686', Az. 174°
3. #D51-R120 Reactor Recirc Pump, El. 605', Az. 145°
4. #D51-R140 A/B Foundation Mat, El. 568'
5. #D51-R160 R/B Foundation Mat, El. 574', Az. 225°
6. #D51-R170 R/B Platform, El. 630', Az. 238°
7. #D51-R180 A/B Foundation Mat, El. 568'
8. #D51-R190 A/B Foundation Mat, El. 568'

FIGURE 4.1 - PERRY POWER PLANT INSTRUMENT LOCATIONS, ELEVATION VIEW

5.0 SEISMIC EVALUATION OF RECORDED EVENT

Seismic Design Background

The seismic design basis for the Perry Nuclear Power Plant is established by requirements in 10CFR Part 100, Appendix A and NRC Regulatory Guide 1.60. These regulations require nuclear plant structures and safety class systems and components to be designed to withstand loads induced by a "Safe Shutdown Earthquake" (SSE) for the particular site. The SSE is the strongest earthquake in terms of magnitude of vibratory ground motion that is expected to occur at a particular site. The SSE is the design basis earthquake considered for plant licensing. A second seismic event also considered in designing nuclear plants is the "Operating Basis Earthquake" (OBE). The OBE is the strongest earthquake considered likely to occur at a particular site during a plant lifetime, and is at least one-half of the SSE. Operations may resume following an earthquake which exceeds the OBE after demonstrating that no functional damage has occurred to safety-related plant features. (10CFR Part 100, Appendix A, III(c), V(a)).

The Perry SSE design response spectra were derived by using the standard response spectra of Reg. Guide 1.60 scaled to a zero period acceleration (ZPA) of 0.15g determined for the Perry site. These spectra served as the design response spectra at the foundation elevations for use in designing the plant buildings. The corresponding OBE design response spectra are scaled to a ZPA of 0.075g.

For more details concerning Perry's design response spectra, including significant inherent conservatisms within its development, refer to Section 6.0 of Reference 1 or USAR Chapter 3.

5.2 Overview of March 15, 1992 Earthquake

The March 15, 1992 event was determined to be of an approximate 3.5 Mc magnitude, with an epicenteral location about four (4) miles northwest of the operating Perry Nuclear Plant. This event is of substantially lower magnitude and total energy than the earthquake for which the Perry Plant was designed. Comparison of recorded time-history accelerations (Figure A-1 of Appendix A) at the foundation mat (el. 574'-10") of the Reactor Building (RB) with the corresponding OBE time-history acceleration used for design has revealed the minor nature of this event with respect to its overall duration, time of strong motion and energy content. In fact, as stated in Section 4.0 of Appendix A, the recorded data at this location was of such low magnitude that response spectrum analysis could not be performed by the vendor due to a low signal to noise ratio.

The overall minor nature of the event, as recorded by the Kinemetrics SMA-3 instrument at the R/B foundation, is further collaborated by the following seismic data:

- Engdahl PSR-1200 readings (at the same general R/B location) indicate very low acceleration values. See Table B-4 of Appendix B.

- Engdahl PAR-400 readings (at Auxiliary Building (AB) foundation, El. 568'-4") indicate a ZPA horizontal acceleration of 0.038g. See Table B-5 of Appendix 3. This compares favorably to the SMA-3 data of the R/B foundation, which also is approximately 0.038g (uncorrected) horizontal acceleration. See Figure A-1 of Appendix A for the latter data.

- Horizontal PSR-1200 readings (at A/B foundation, el. 568'-4") indicate a very low response spectra values. See Table B-7 of (el. 574'-10") Appendix B. The vertical readings utilized as the recordings (scratches) for this instrument are poor and appear to represent manmade disturbances, and are thus discounted.

5.3 Evaluation of Specific Recorded Data

To further evaluate the nature of this event, detailed response spectrum analyses were performed for the Kinemet ics SMA-3 data recorded at Elevation 686' on the Containment Vessel. This data is presented in Appendix A and the pertinent tripartite plots are repeated in Figures 5.1 through 5.3 (vertical, north-south and east-west, respectively) for convenience. Similar to the January 31, 1986 Leroy earthquake (Reference 1), this event is also characterized by high frequency content, with maximum recorded accelerations occurring above 10 Hz.

For purposes of comparison against the plant's design basis, the 2% damped OBE design spectra have been superimposed on these tripartite plots in Figures 5.4 through 5.6. As can be seen by comparison to the 2% recorded data, the OBE spectra have not been exceeded in any case. In the low frequency range (less than 10 Hz), there is substantial margin between the two. Again, similar to the 1986 event, it is not surprising that less margin is seen between the plots in the high frequency range (above 10 Hz). For very similar reasons as discussed in Section 6.3 of Reference 1, these high frequency responses have negligible engineering significance due to associated low velocities and displacements. Subsequent work by EPRI (References 2 and 3) has also further demonstrated the relative engineering insignificance of small high frequency earthquakes in general.

5.4 Conclusions

The March 15, 1992 earthquake was a very low magnitude event which did not exceed the design basis of the Perry Plant. Similar to the January

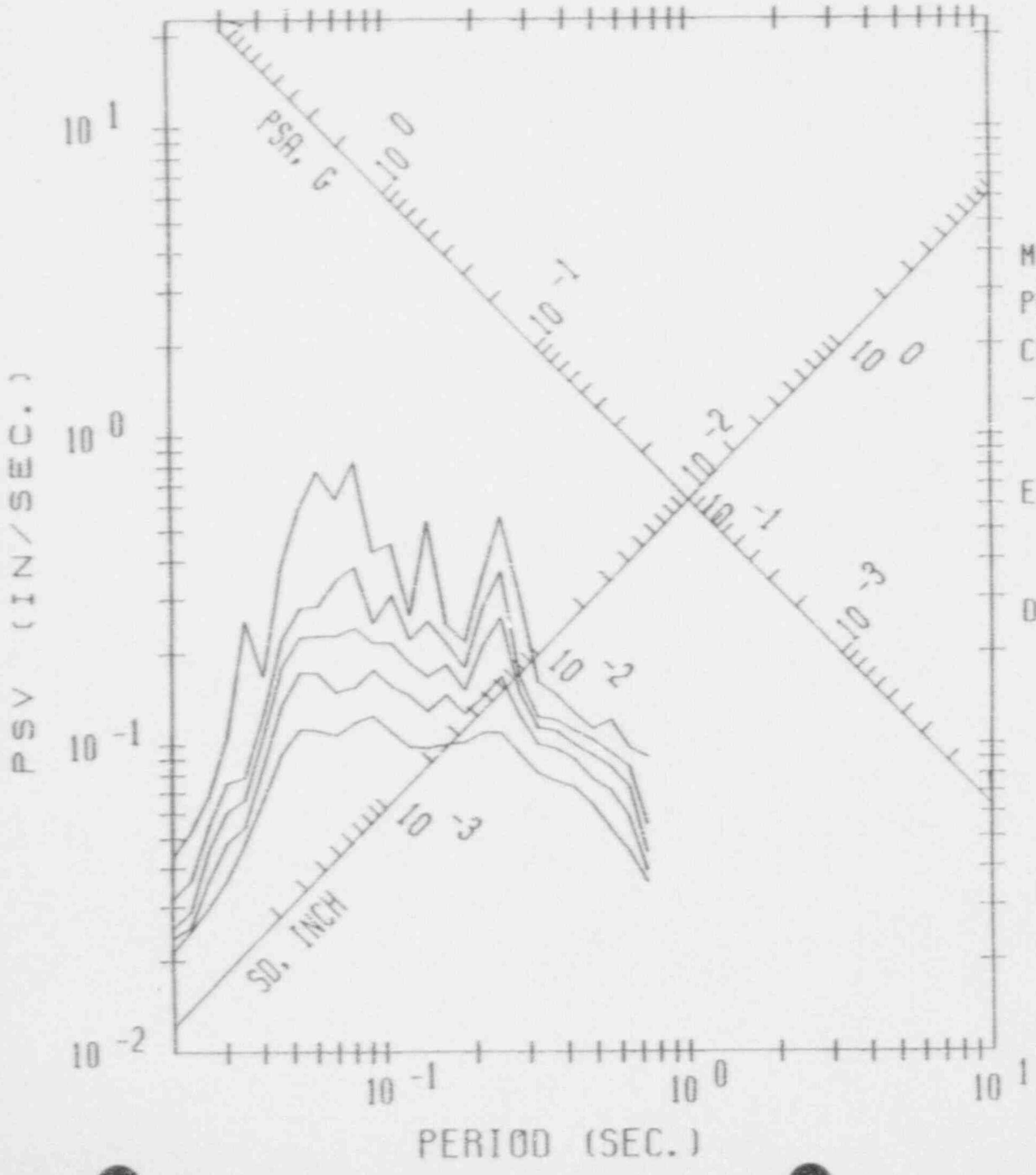
31, 1986 Leroy earthquake, the event was characterized by low energy, high frequency, short duration and small displacement. No further engineering evaluations for this event are considered necessary.

5.5 References

1. PY-CEI/NRR-0437L dated February 12, 1986, "Seismic Event Evaluation Report".

2. EPRI NP-5930 Final Report dated July, 1988, "A Criterion for Determining Exceedance of the Operating Basis Earthquake".

3. EPRI NP-6695 Final Report dated December, 1989, "Guidelines for Plant Response to an Earthquake".



KINEMETRICS

RESPONSE SPECTRUM

D51-N111 (VERTICAL)

MARCH 15, 1992 OHIO EARTHQUAKE

PERRY NPP, SMA-3 S/N 165-2

COMP 3

-V-

EQ112E.V3

DAMPING VALUES:

.00

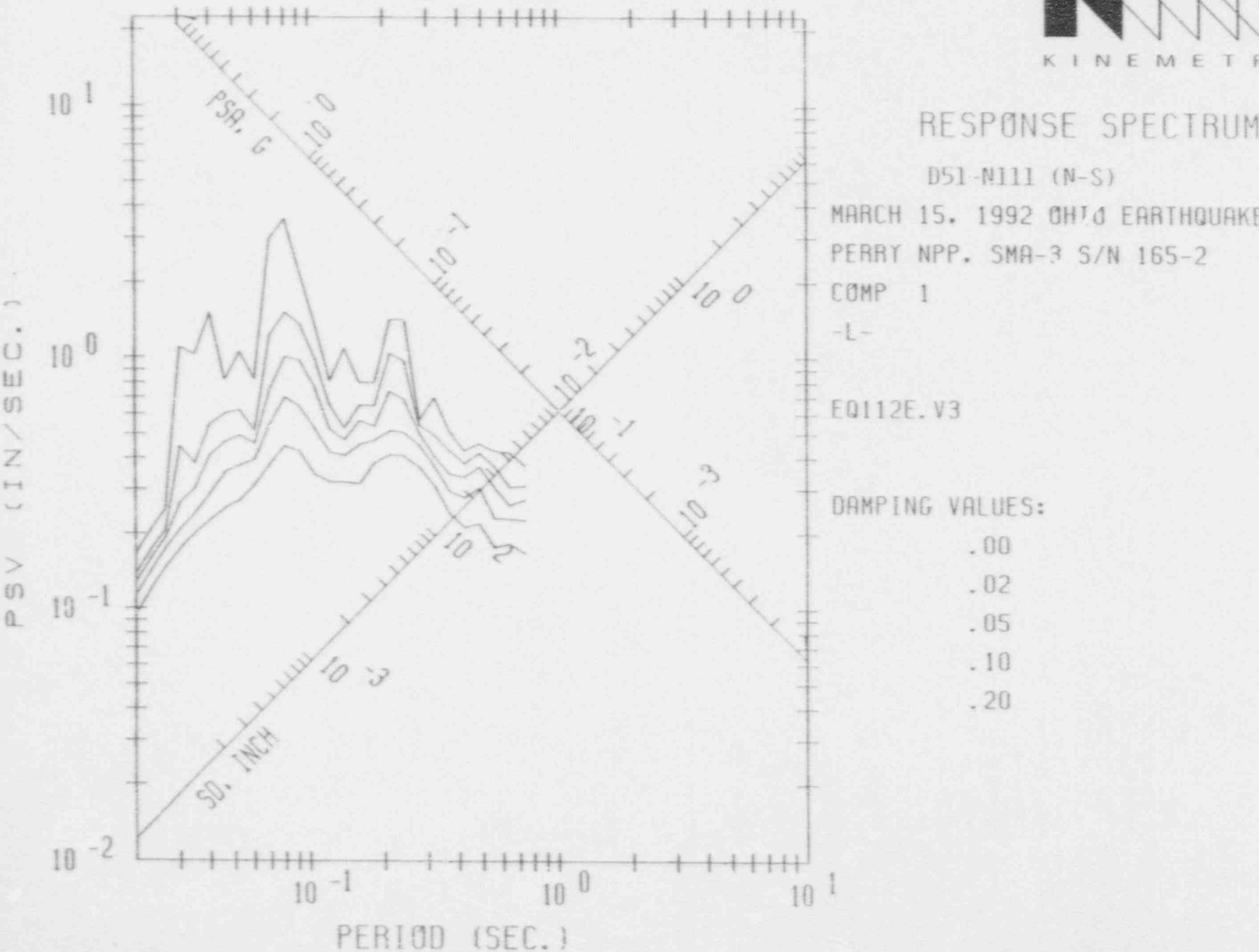
.02

.05

.10

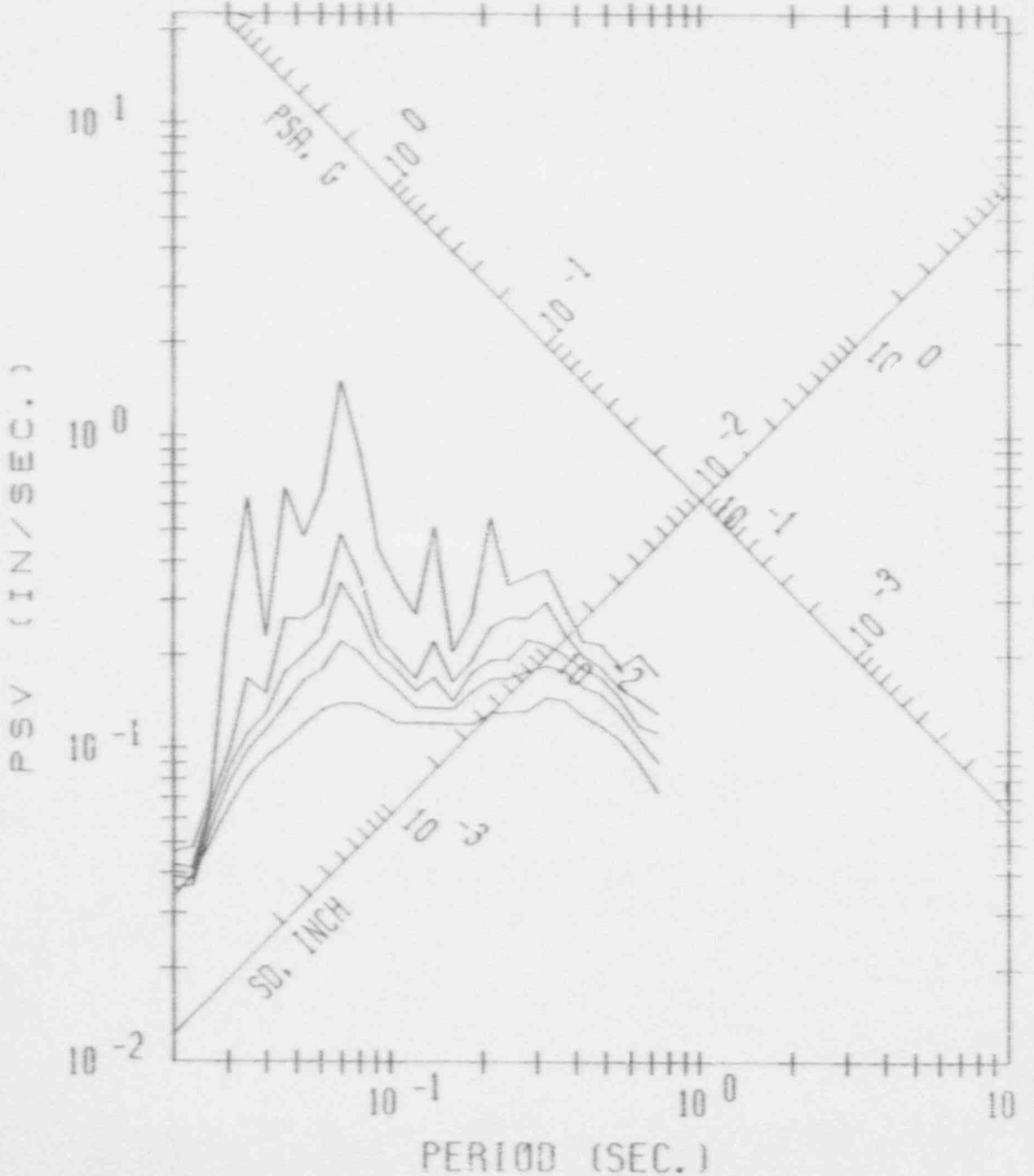
.20

FIGURE 5.1



KINEMETRICS

FIGURE 5.2



KINEMETRICS

RESPONSE SPECTRUM

D51-N111 (E-W)

MARCH 15. 1992 OHIO EARTHQUAKE

PERRY NPP. SMA-3 S/N 165-2

COMP 2

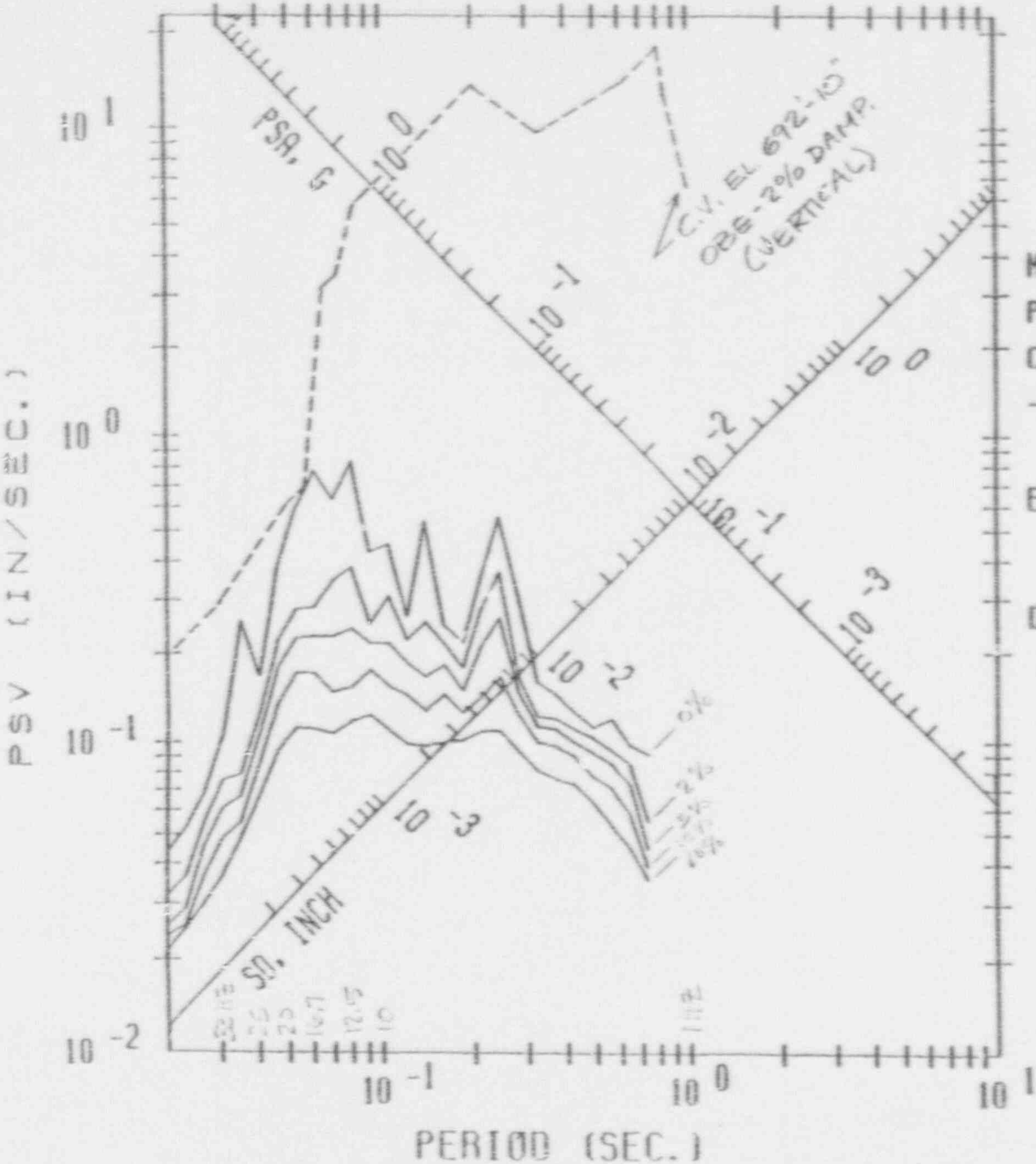
-T-

EQ112E.V3

DAMPING VALUES:

.00
.02
.05
.10
.20

FIGURE 5.3



RESPONSE SPECTRUM

D51-N111 (VERTICAL)

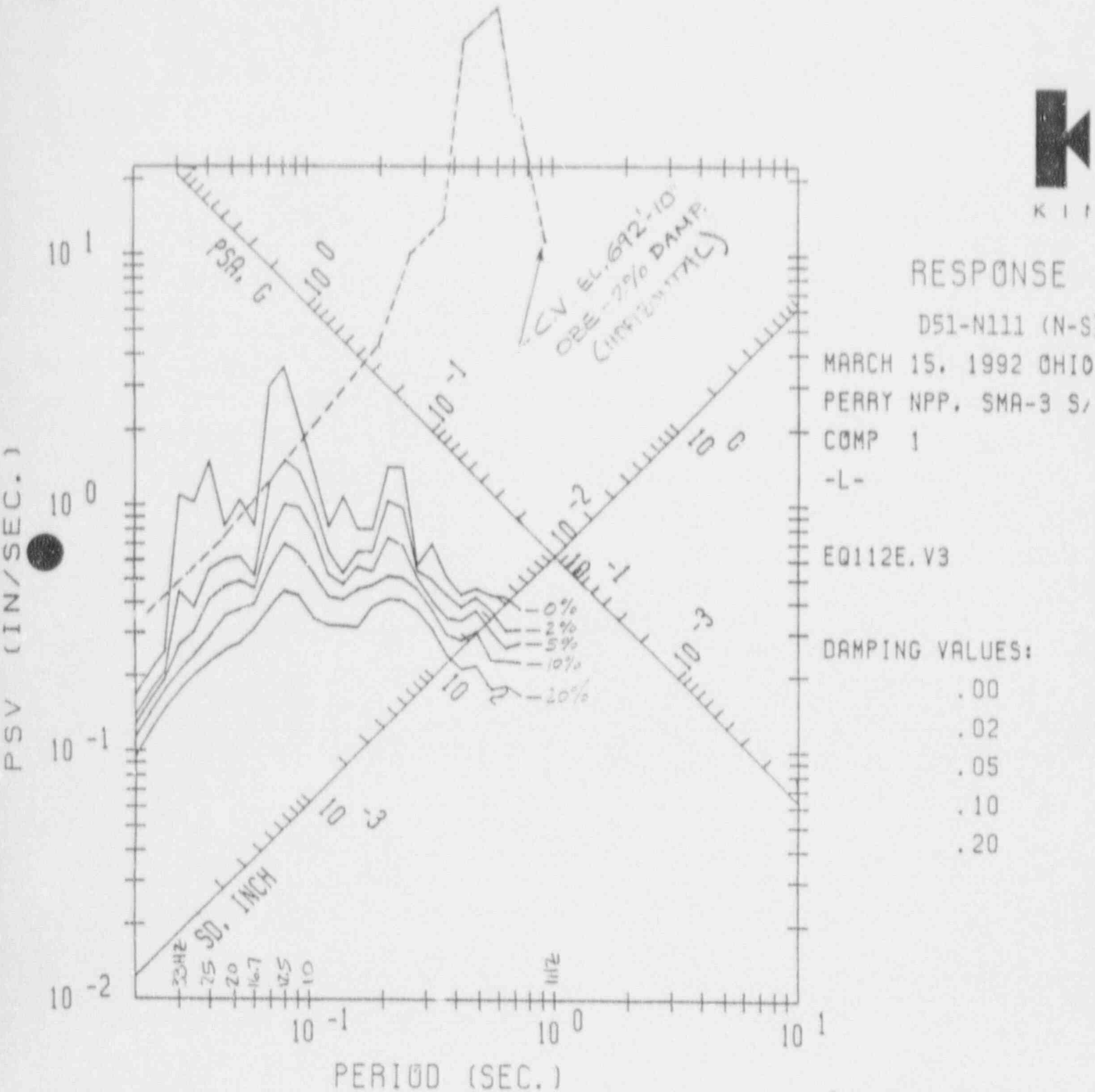
MARCH 15. 1992 OHIO EARTHQUAKE
PERRY NPP. SMA-3 S/N 165-2
COMP 3
-V-

EQ112E.V3

DAMPING VALUES:
.00
.02
.05
.10
.20

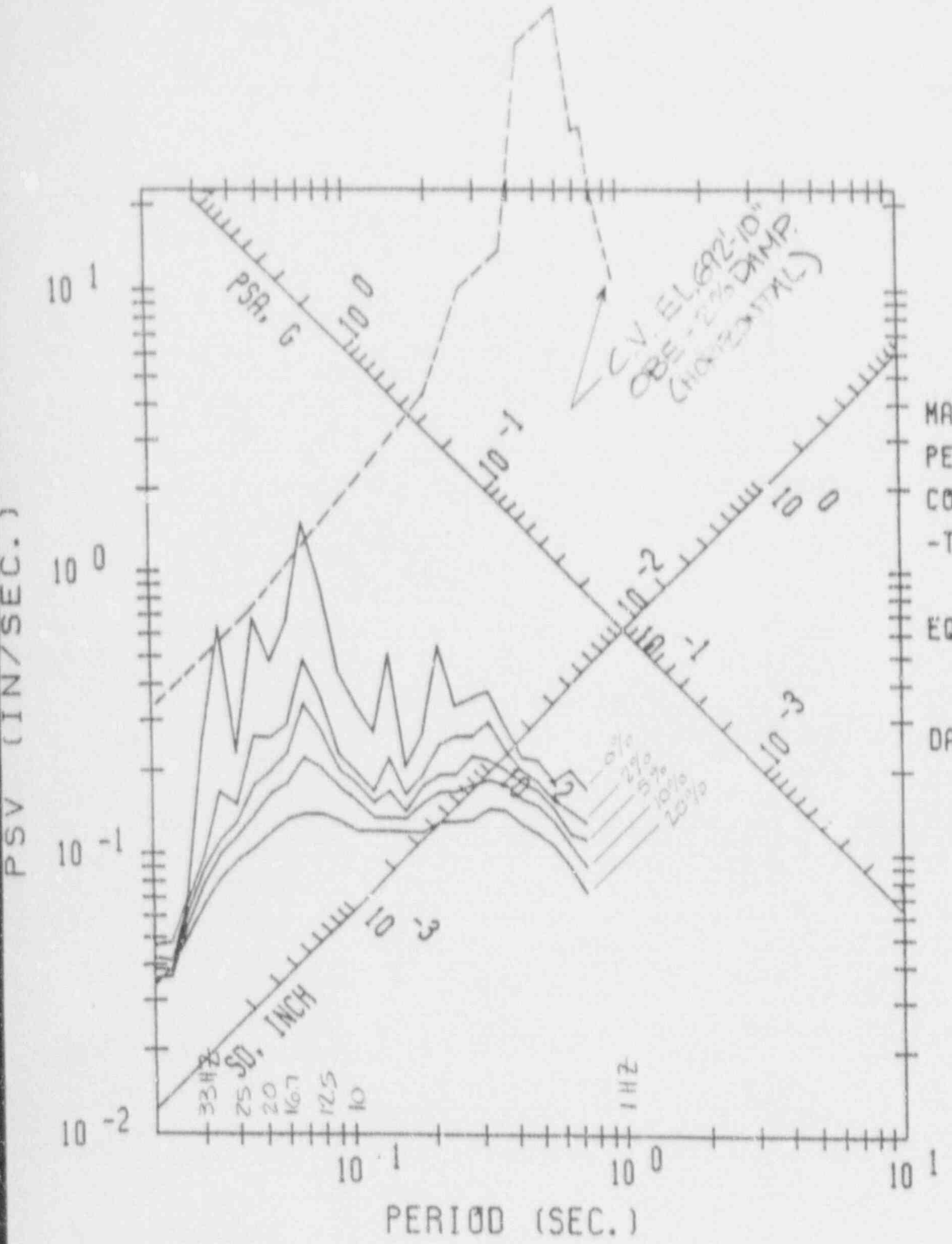
Containment Vessel
Vertical Component
Elevation 692'-10"

FIGURE 5.4



Containment Vessel
North-South Component
Elevation 692'-10"

FIGURE 5.5



RESPONSE

D51-N111 (E-W)

MARCH 15, 1992 OHIO
PERRY NPP, SMA-3 S,
COMP 2
-T-

EQ112E.V3

DAMPING VALUES:
.00
.02
.05
.10
.20

Containment Vessel
East-West Component
Elevation 692'-10"

FIGURE 5.6

APPENDIX A

TO

SEISMIC EVENT EVALUATION

FOR THE

MARCH 15, 1992 Mc = 3.5 EARTHQUAKE

PERRY NUCLEAR PLANT

KINEMETRICS STRONG-MOTION DATA

ML 3.5 EARTHQUAKE

MARCH 15, 1992

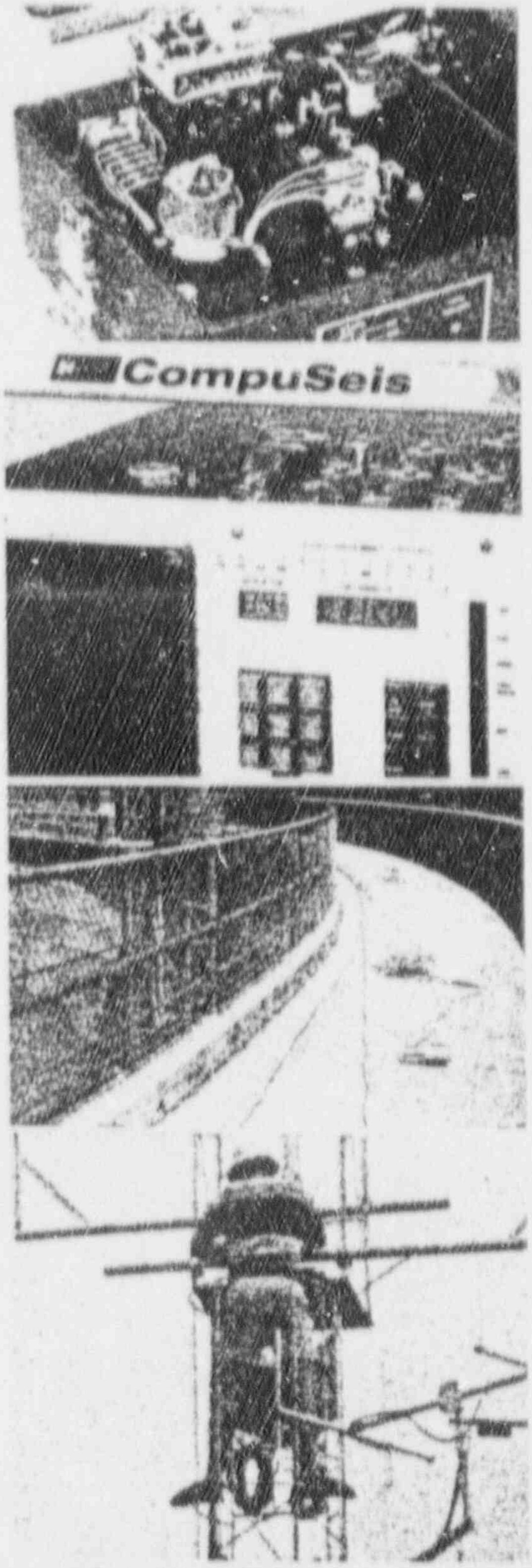
STRONG-MOTION DATA

FROM THE

PERRY NUCLEAR POWER PLANT

SEISMIC INSTRUMENTATION

MARCH 19, 1992



KINEMETRICS

STRONG MOTION DATA REPORT

for the

M_L 3.5 EART. `KE

of

0614 GMT, MARCH 15, 1992

at

41.9° North, 81.3° West

near

PERRY, OHIO

RECORDED ON THE

PERRY NUCLEAR POWER PLANT

STRONG MOTION ACCELEROGRAPHS

for

Cleveland Electric Illuminating Company

Requisition No. C901454

by

Kinemetrics/Systems
222 Vista Avenue
Pasadena, CA 91107

Sales Order C-K2082

March 18, 1992

TABLE OF CONTENTS

DATA PLOTS

APPENDICES

1.0 INTRODUCTION

On March 15, 1992, a (M_L 3.5) local earthquake was recorded by the strong motion instrumentation at Perry Nuclear Power Plant, Perry, Ohio. The FM analog magnetic tape cassette records from two Kinemetrics Model SMA-3 accelerographs were retrieved from the instruments and provided to Kinemetrics for analysis.

This report describes the processing of these strong motion records and presents the results. Included are the uncorrected accelerograms, corrected acceleration, velocity and displacement time series for the containment vessel (elevation 686') and response spectra for the containment vessel annulus. Data correction was not performed and response spectra plots were not made for the reactor building foundation mat location since the recorded earthquake signals are very small; representing a signal to noise ratio of less than 1.

2.0 INSTRUMENTATION

2.1 Model SMA-3 Accelerograph

The SMA-3 is a multi-channel, centralized recording, FM analog magnetic tape accelerograph system designed to detect and record strong local earthquakes and record the three orthogonal acceleration signals on cassette tape. The SMA-3 remains in a standby mode until its vertical trigger detects an earthquake. The trigger then actuates recording in less than 0.10 seconds.

The force balance accelerometers in the SMA-3 have a nominal natural frequency of 50 Hz and damping of 65% critical, providing flat (-3dB) response from DC to 50 Hz. The nominal sensitivity of each of the three channels is 2.5 volts/g with a full scale response of 1.0 g. The dynamic range of the accelerograph is nominally 40 dB, giving it a resolution of approximately 0.01g.

The trigger in the SMA-3 has a flat (-3dB) response from 1 to 10 Hz and a nominal trigger level of 0.01g. For Perry Nuclear Power Plant the threshold is lowered to 0.005g.

Power is supplied to the SMA-3 by internal rechargeable batteries. These batteries are kept in a charged state by 120 Vac line power.

2.2 Calibration Data

The two accelerometers connected to the Model SMA-3 accelerograph system which recorded the event were calibrated for sensitivity by Perry NPP personnel. Natural frequency and damping characteristics for the sensors were derived from most recent calibration data available to Kinemetrics.

Sensor characteristics provided by CEI and used to correct the data are given in Table 1 below.

Table 1. Most recent accelerometer calibration data

Ser. No.	Channel	Sens., v/g	Nat. Freq., Hz	Damping % Crtcl
165-1	long	2.46	50.8	0.65
(D51-N111)	tran	2.48	51.4	0.62
	vert	2.53	51.8	0.63
165-2	long	2.47	53.6	[illegible]
(D51-N101)	tran	2.49	51.1	0.63
	vert	2.46	52.4	0.65

3.0 DATA PROCESSING

Data from the Model SMA-3 accelerographs were played back using a Kinemetrics Model SMP-1 Playback System through a Data Compensator, digitized using a Kinemetrics Model SSR-1 Solid State Recorder and processed as described in Kinemetrics' Application Note No. 7, "Conditioning and Correction of Strong Motion Data on Analog Magnetic Tapes" (appended to this report) with exceptions as noted in section 1.0 INTRODUCTION of this document.

3.1 Digitization

The magnetic tapes were digitized using the SSR-1 Solid State Recorder. The 1024 Hertz FM time reference recorded on channel 4 of the cassette is output from the SMP-1 and divided down by four (256 Hz ± deviation) and used as the timing signal for the digital conversion time interval. The multiplexed uncorrected time series are written into the SSR-1 digitizer's solid state memory for retention until retrieval with an IBM-PC or 100% compatible computer.

3.2 Conversion and Data Reduction

The binary file(s) retrieved from the SSR-1 recorder are converted to Kinemetrics' common data format for analysis. The time series data is edited to constrain the file to seismic information only.

3.3 VOL1 Processing

The digitized data were demultiplexed and scaled to acceleration units using specific sensor characteristics for damping and sensitivity. Calibration data from Table 1 is incorporated into the header information of the file for reference during VOL2 analysis. The mean was then subtracted from each acceleration time history. The new time histories were then written in a Kinemetrics' VOL1-format disk file.

The three uncorrected acceleration time histories from each SMA-3 record were then plotted; these plots are included in the data section of this report.

3.4 VOL2 Processing

The recorded accelerograms were then instrument and baseline corrected using Kinemetrics' VOL2 program. This program is based upon the VOL2 program developed at Caltech (Trifunac and Lee, 1973). No major modifications to the original VOL2 algorithms have been made.

The data were bandpass filtered using Ormsby filters. The low-pass filter had a cut-off frequency of 33 Hz and a termination frequency of 35 Hz. The high-pass filter had a cutoff frequency of 1.5 Hz and a termination frequency of 1.3 Hz.

Output of this program consists of a plot of corrected acceleration, velocity and displacement for each component of recorded data. Plots for the containment vessel are presented in the data section of this report. The small signal levels recorded for the reactor building foundation mat did not permit this type of analysis.

3.5 VOL3 Processing

Linear response spectra were calculated from the corrected acceleration time histories using the algorithms developed by Trifunac and Lee. Response spectra were calculated for damping ratios of 0, 2, 5, 10, and 20 percent.

The traditional tripartite log-log plots of pseudo-velocity vs. period were produced and are included in the data section of this report.

4.0 OBSERVATIONS

The resolution of the SMA-3 system is appoximately 0.01g. The earthquake data recorded at the containment vessel (elevation 686') were very small but, were of sufficient signal to noise ratio for response spectrum calculation. The earthquake data recorded at the reactor building foundation mat were not of sufficient signal to noise ratio to permit this analysis

Because of the low levels of motion associated with this event, the accelerograph system triggered on the arrival of the S-wave, not the P-wave. As such the initial earthquake motion was not recorded.

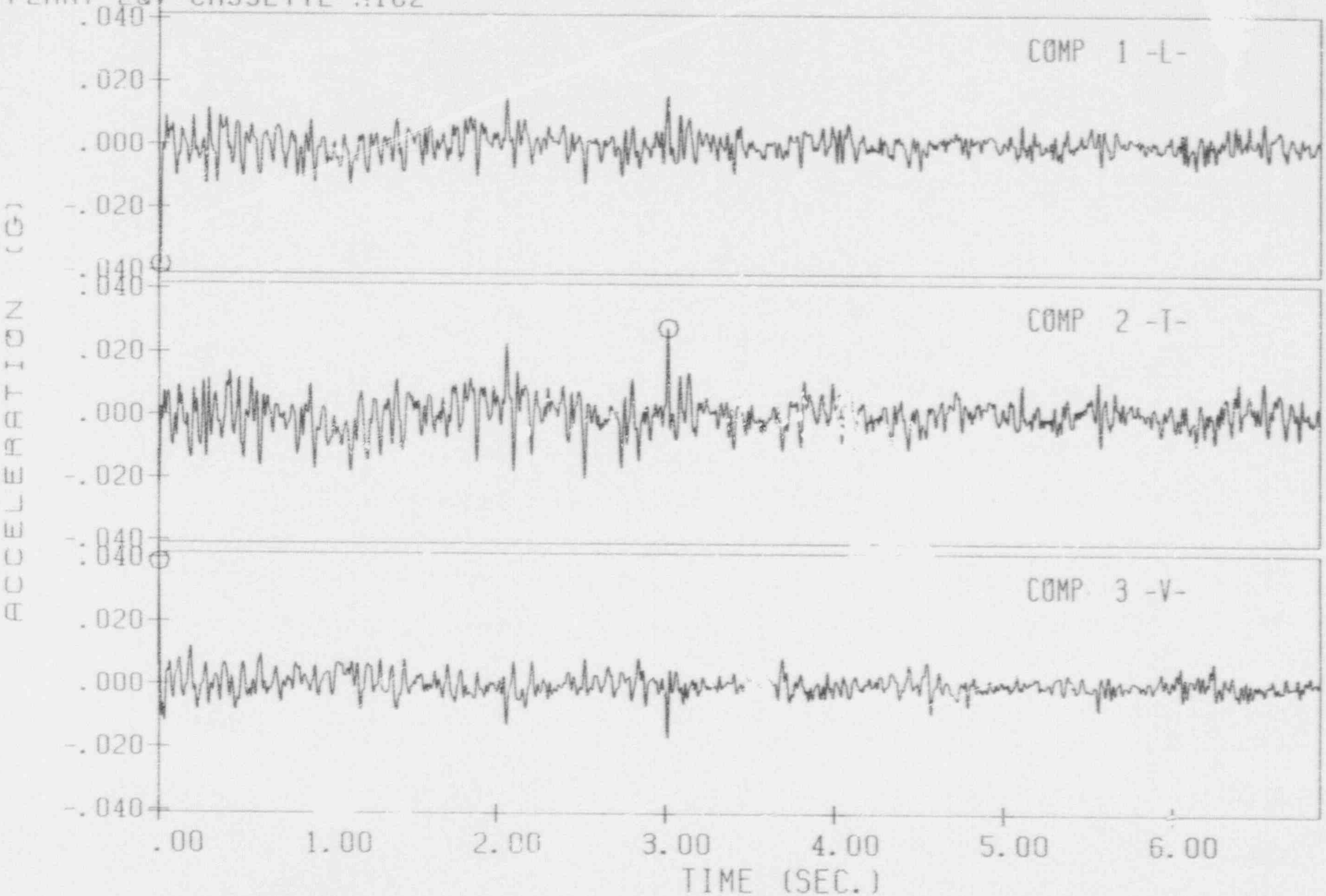
The start-up time for the SMA-3 accelerograph system is 0.1 seconds and is usually characterized by a large spike(s) at the beginning of the recorded event. Non-seismic data (i.e. spikes) within the 0.1 second start-up time were edited from the accelerogram prior to this analysis work.

Reactor Building Foundation Mat, Elevation 575 ft.

SMA-3 Serial Number 165-1
Tag Number D51-N101

Longitudinal Channel - South Orientation
Transverse Channel - West Orientation
Vertical Channel - Up Orientation

PEAKS(G):1:-.038 2: .028 3: .039
FILE: EQ102E.V1 MAR 17, 1992 16:47:11.953 [C]
PERRY EQ, CASSETTE R102



D51-N101 UNCORRECTED ACCELERATION TIME HISTORIES

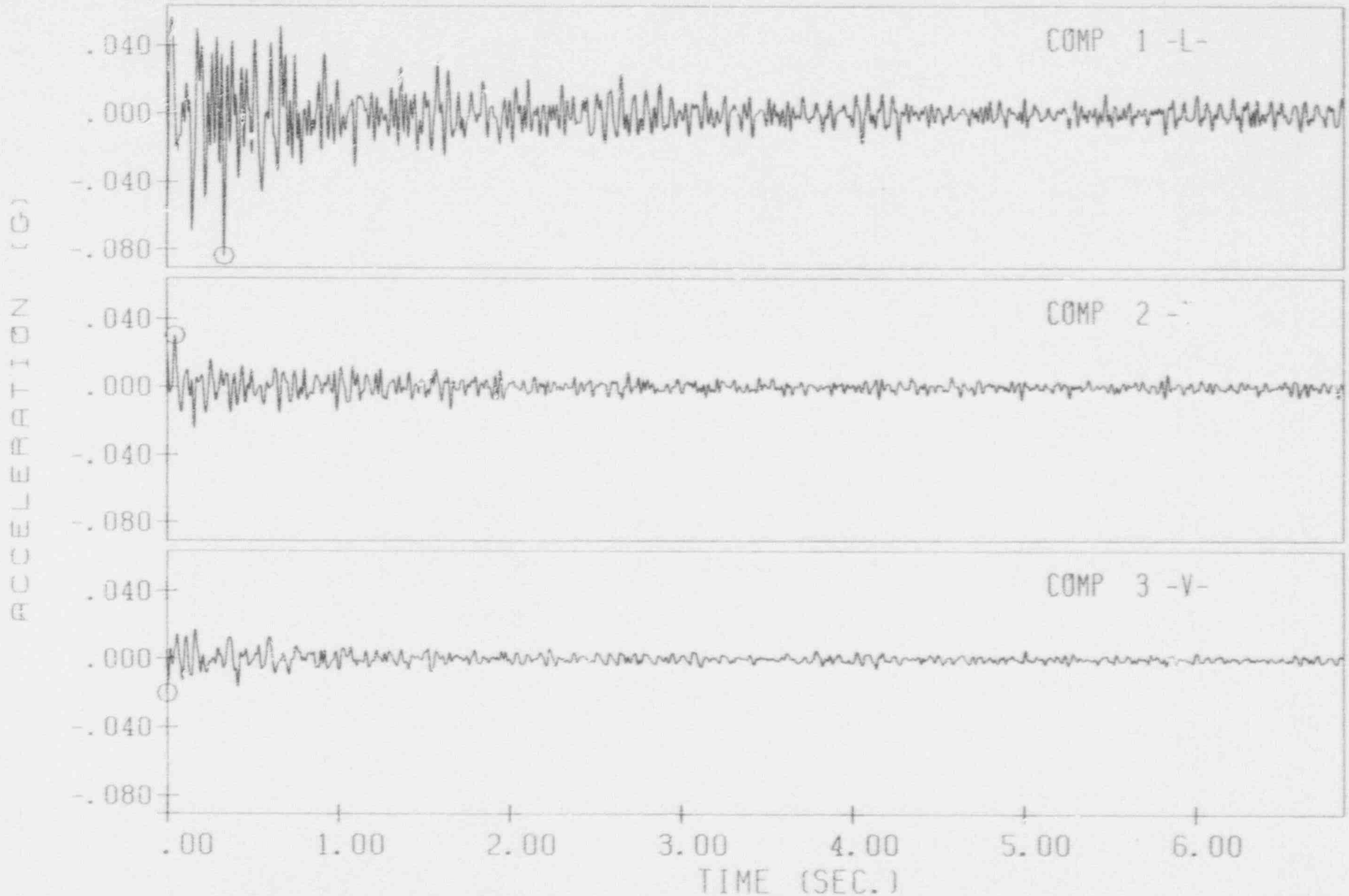
FIGURE A.1

Containment Vessel, Elevation 686 ft.

SMA-3 Serial Number 165-2
Tag Number D51-N111

Longitudinal Channel - South Orientation
Transverse Channel - West Orientation
Vertical Channel - Up Orientation

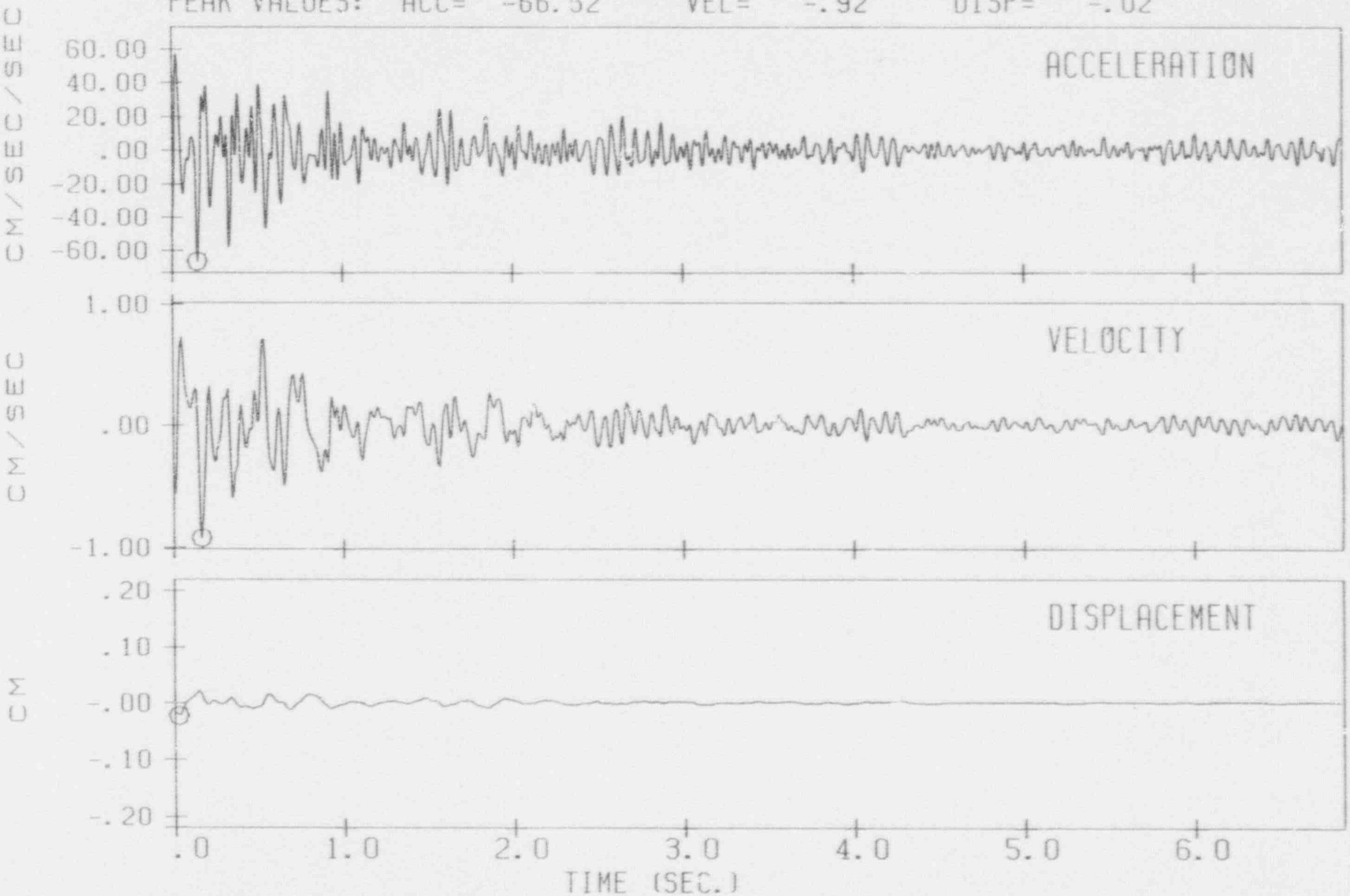
PEAKS(G):1:-.084   2: .030   3:-.020
FILE: EQ112E.V1 MAR 17, 1992 14:44:22.438 [C]
PERRY EQ, CASSETTE R112



D51-N111 UNCORRECTED ACCELERATION TIME HISTORIES

FIGURE A.2

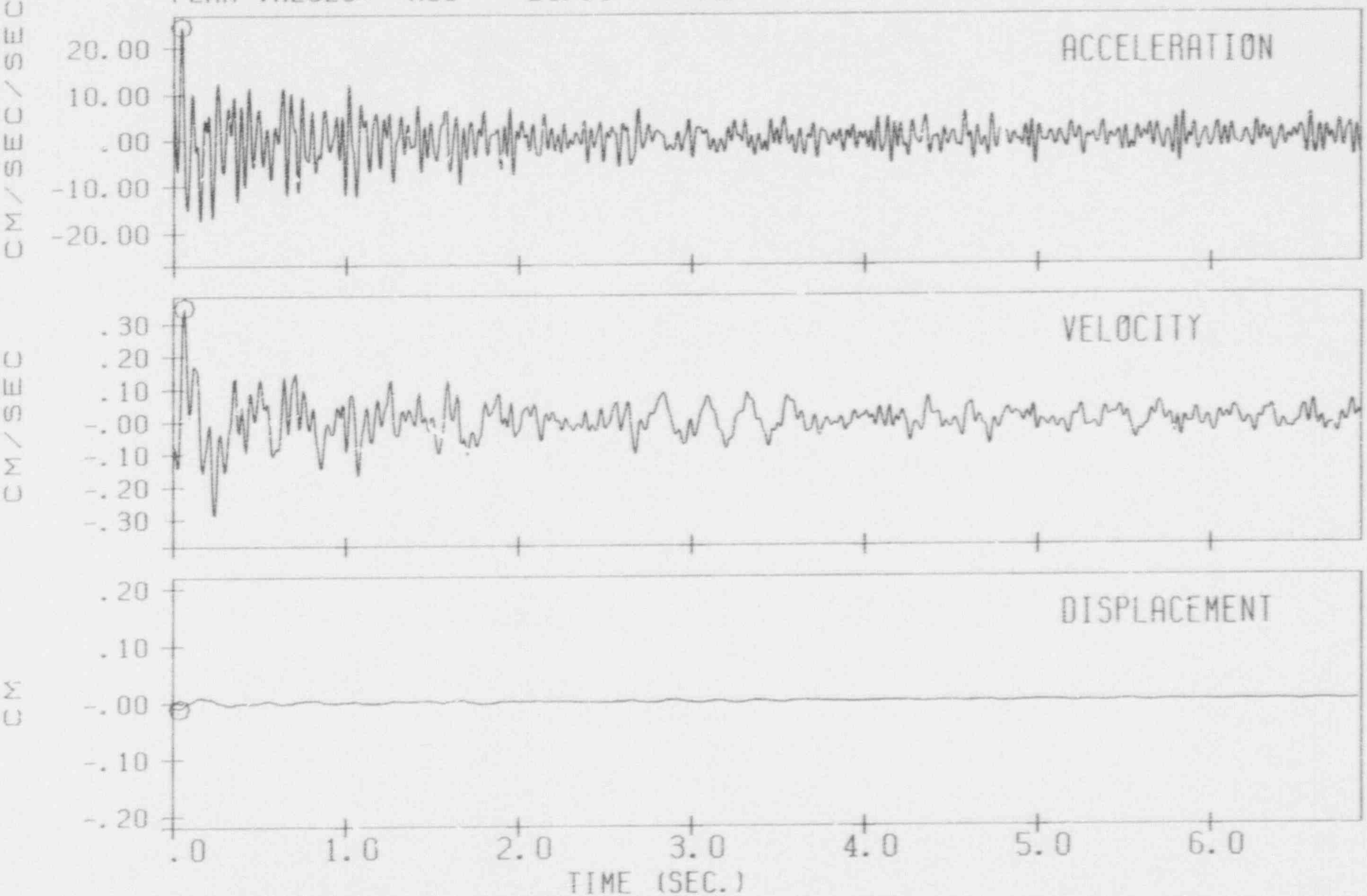
MARCH 15. 1992 OHIO EARTHQUAKE
PERRY NPP. SMA-3 S/N 165-2 COMP 1 -L- EQ112E.V2
BANDPASS FILTER LIMITS: 1.300-1.500 33.00-35.00
PEAK VALUES: ACC= -66.52 VEL= -.92 DISP= -.02



D51-N111 CORRECTED TIME HISTORIES (N-S)

FIGURE A.3

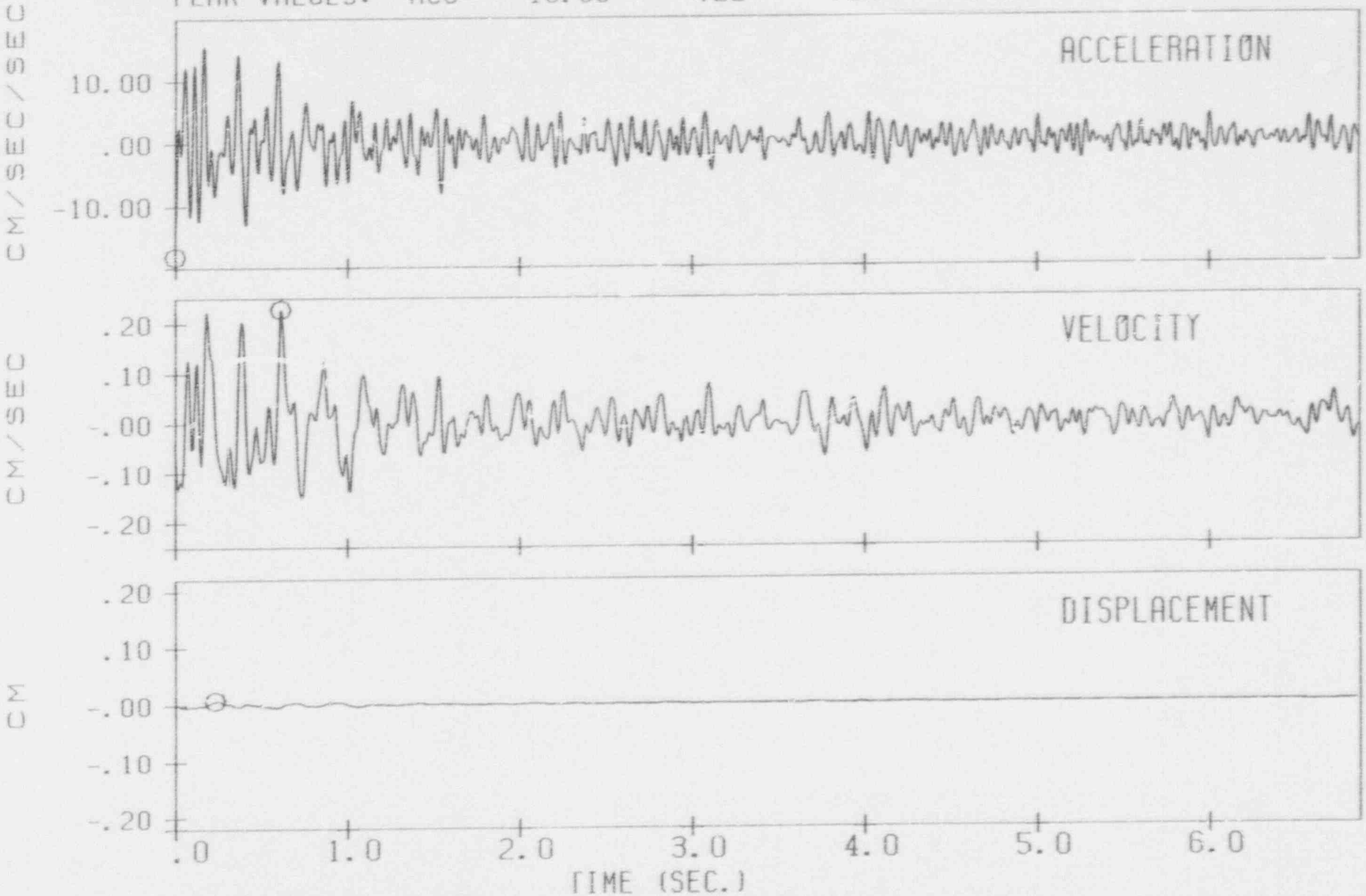
MARCH 15, 1992 OHIO EARTHQUAKE
PERRY NPP. SMA-3 S/N 165-2 COMP 2 -T- EQ112E.V2
BANDPASS FILTER LIMITS: 1.300-1.500 33.00-35.00
PEAK VALUES: ACC= 24.54 VEL= .35 DISP= -.01



D51-N111 CORRECTED TIME HISTORIES (E-W)

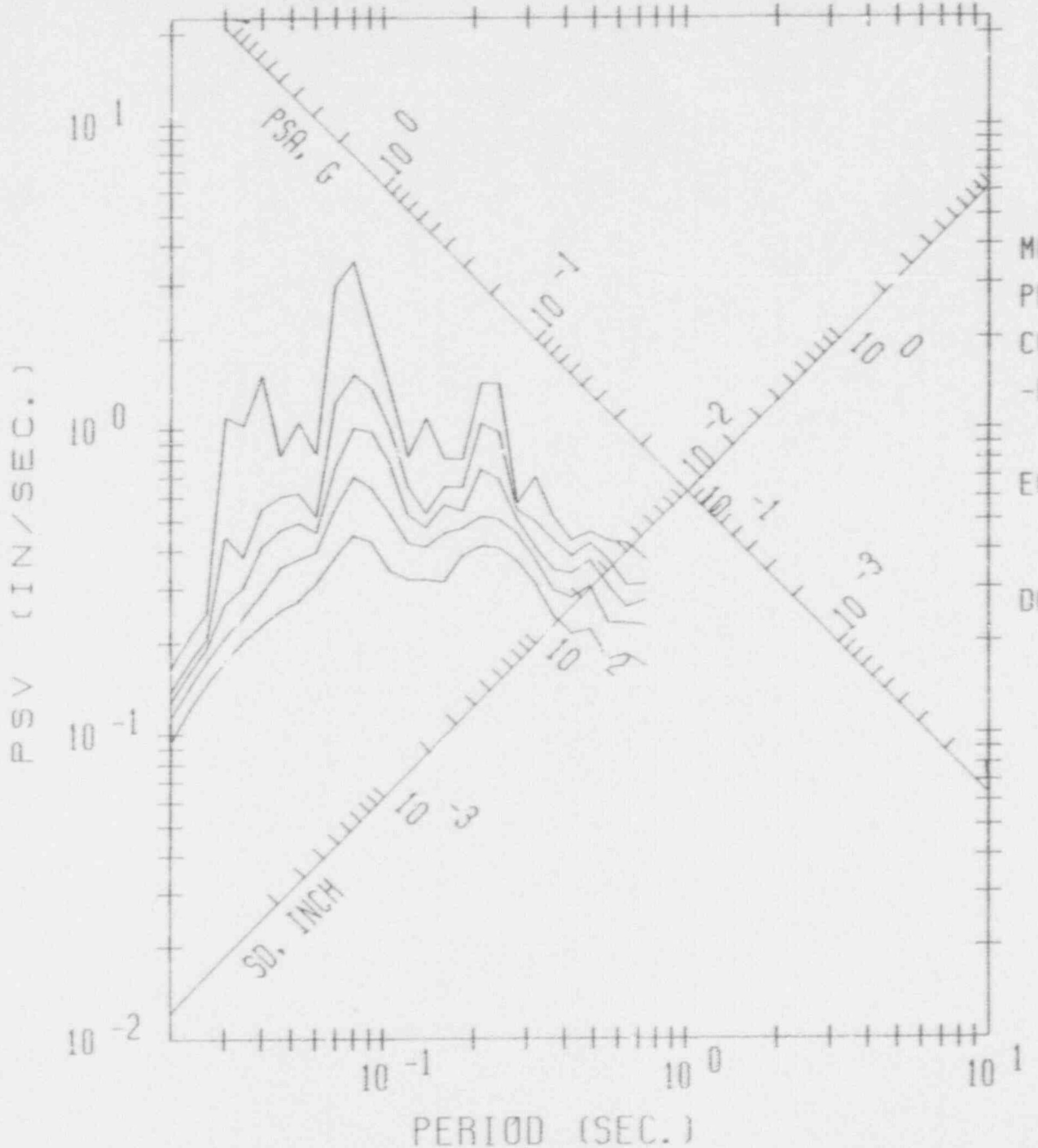
FIGURE A.4

MARCH 15, 1992 OHIO EARTHQUAKE
PERRY NPP, SMA-3 S/N 165-? COMP 3 -V- EQ112E.V2
BANDPASS FILTER LIMITS: 1.300-1.500 33.00-35.00
PEAK VALUES: ACC= -18.06 VEL= .23 DISP= .01



D51-N111 CORRECTED TIME HISTORIES (V)

FIGURE A.5



KINEMETRICS

RESPONSE SPECTRUM

D51-N111 (N-S)

MARCH 15, 1992 OHIO EARTHQUAKE

PERRY NPP, SMA-3 S/N 165-2

COMP 1

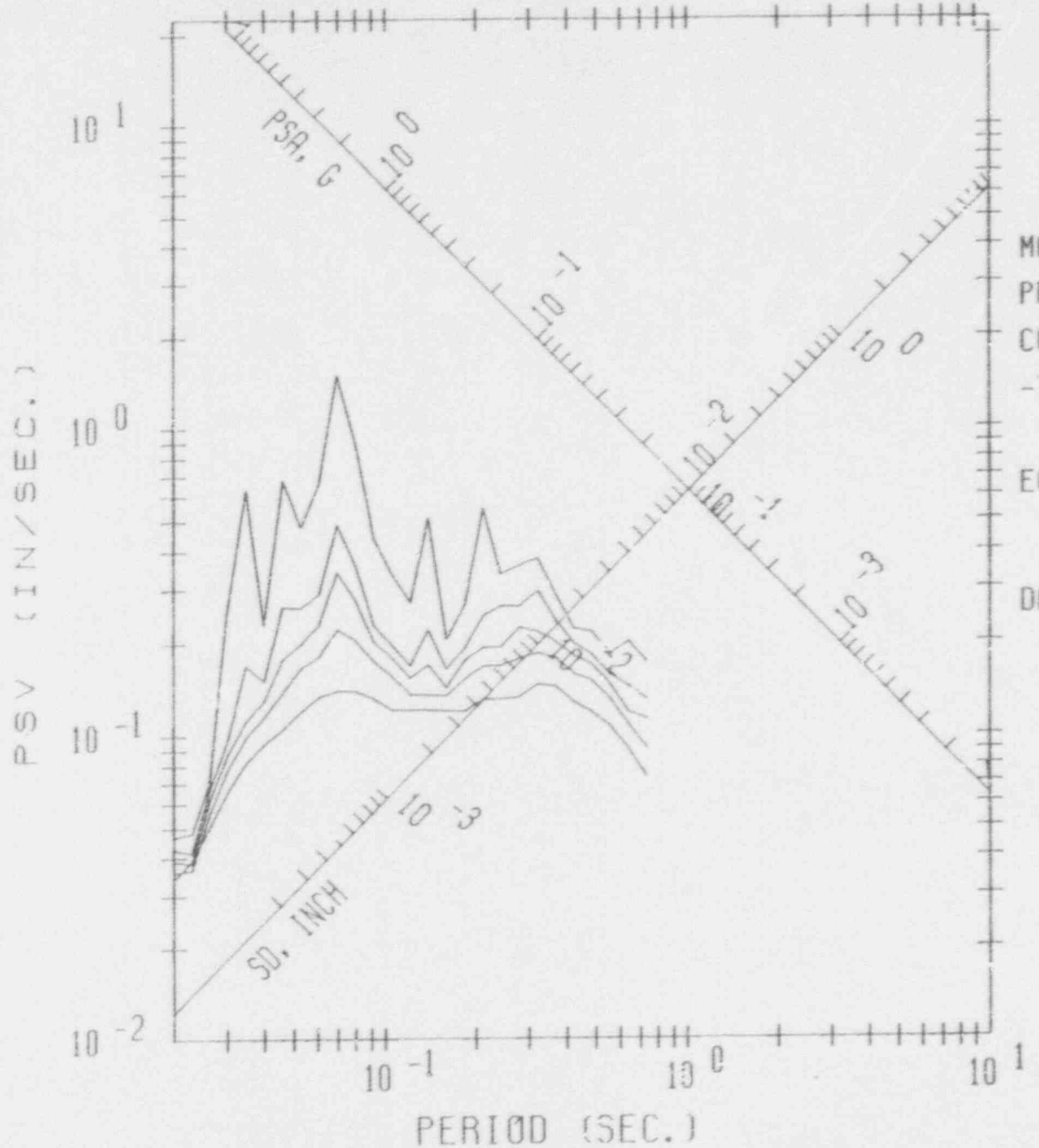
-L-

EQ112E.V3

DAMPING VALUES:

.00
.02
.05
.10
.20

FIGURE A.6



KINEMETRICS

RESPONSE SPECTRUM

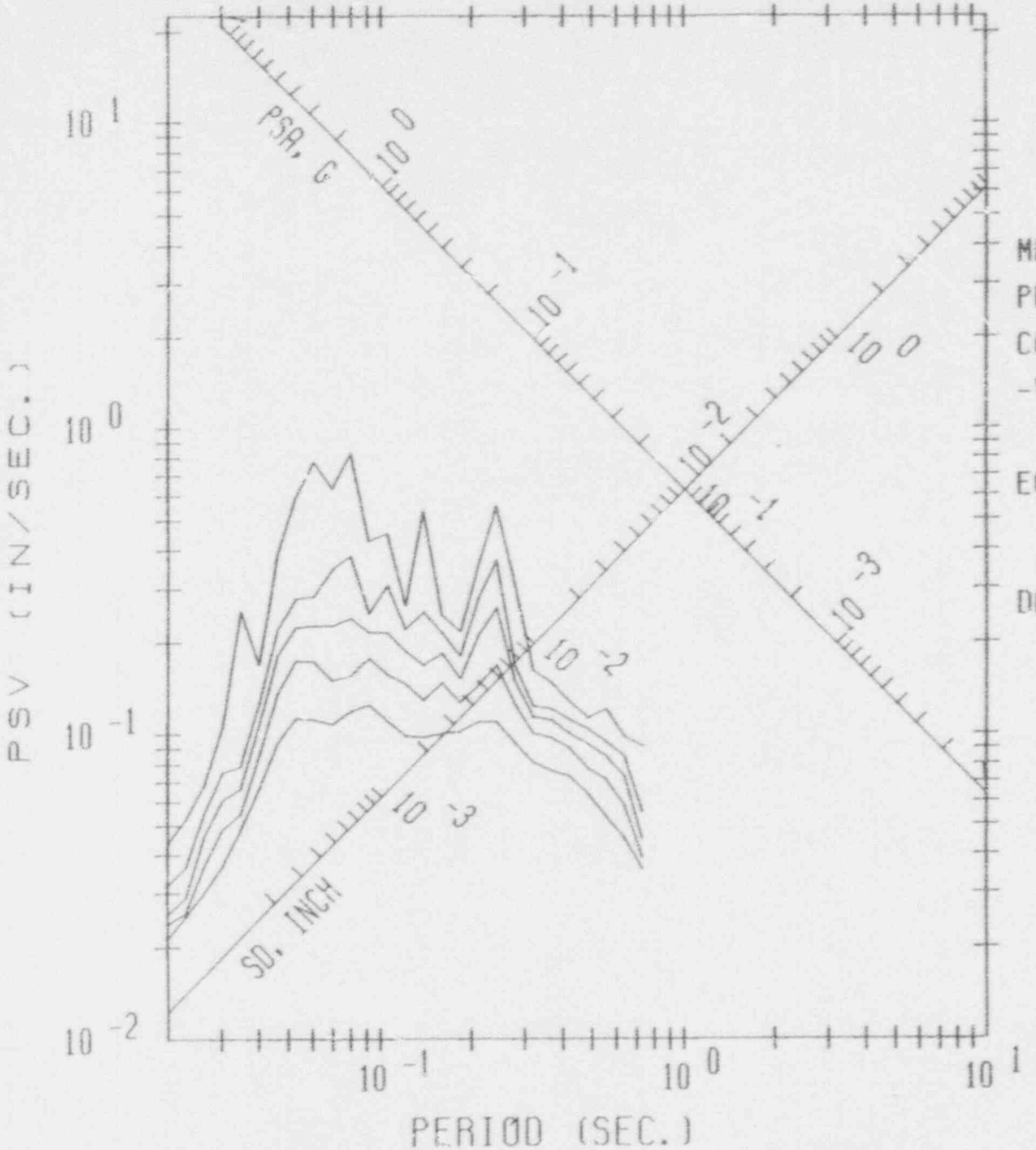
D51-N111 (E-W)

MARCH 15, 1992 OHIO EARTHQUAKE
PERRY NPP. SMA-3 S/N 165-2
COMP 2
-T-

EQ112E.V3

DAMPING VALUES:
.00
.02
.05
.10
.20

FIGURE A.7



KINEMETRICS

RESPONSE SPECTRUM

D51-N111 (VERTICAL)

MARCH 15, 1992 OHIO EARTHQUAKE
PERRY NPP. SMA-3 S/N 165-2
COMP 3
-V-

EQ112E.V3

DAMPING VALUES:
.00
.02
.05
.10
.20

FIGURE 4.8

KINEMETRICS

APPLICATION NOTE

Conditioning and Correction of Strong Motion Data on Analog Magnetic Tapes

No. 7

Kinemetrics has developed programs for routine computer processing of data recorded on the analog magnetic tape accelerographs, Models SMA-2 and SMA-3. The software from published research for film recording accelerographs (Trifunac & Lee, 1973) has been adapted to the analog magnetic tape recording instruments.

Magnetic tape is used where rapid playback and analysis of data are required. These accelerographs are normally located at large engineered facilities, such as nuclear power plants. Figure 1, "Kinemetrics Earthquake Data Reduction System Flow Diagram," illustrates the specialized services needed to prepare data immediately after an earthquake.

The purpose of this Note is to describe the standard data conditioning and correction used to prepare accelerograms for subsequent response spectrum or time-series analysis. On Figure 1 are references to the following paragraphs: 1.0--Data Playback, 2.0--Analog-to-Digital Conversion, 3.0--Data Conditioning, and 4.0--Data Correction.

There are two "tape speed" errors in all FM analog recording/playback systems. One "error" is a change in apparent amplitude due to unwanted tape speed changes. Correction of this error is called "amplitude compensation". This is shown in Figure 2 and described in Sections 1.0 and 3.0. The second "error" is a change in apparent length of the earthquake due to different tape speeds during recording and playback. Correction of this error is called "time base compensation". This is shown in Figure 3 and described in Section 2.0.

1.0 Data Playback

1.1 The playback system is a Model SMP-1 (Figure 4). If the SMP-1 is used to play out the SMA-2 or SMA-3 tapes, the signals which appear on the integral chart recorder are amplitude compensated.

1.2 The electrical outputs taken from the DEMODULATED OUTPUT jacks (Channels 1, 2, or 3 of Figure 4) are not amplitude compensated. However, Kinemetrics has an electronic Data Compensator which plugs into an SMP-1.

When the Data Compensator is used, the output signals are amplitude compensated by electronic subtraction of Channel 4 from Channels 1, 2, and 3. The electronic subtraction is accomplished by means of a unity-gain operational amplifier for each of the three data channels. The data channel (1, 2 or 3) drives one input to the op-amp and the time compensation channel (4) drives the other op-amp input. The op-amp output is the difference between the two inputs and provides the amplitude compensation (as shown in Figure 2).

The Data Compensator should be used if the signals are to be recorded on a three-channel strip-chart recorder for display. The signals are not time base compensated.

1.3 If the signals are to be processed on a computer, there are two options:

1.3.1 Use the Data Compensator for amplitude compensation and digitize channels 1, 2 and 3.

1.3.2 Without a Data Compensator, digitize channels 1, 2, 3 and 4, and have software perform amplitude compensation by subtracting channel 4 from each of the three data channels.

2.0 Analog-to-Digital Conversion

The following steps are taken at Kinemetrics using the SMP-1 connected to the Analog-to-Digital Converter, Model DDS-1105 or DataSeis®.

2.1 Three (3) analog outputs of the SMP-1 with Data Compensator are digitized simultaneously: longitudinal, transverse, and vertical (Channels 1, 2, 3 of Figure 4). A 12-bit analog-to-digital converter is used with normal full scale of ±5 volts.

2.2 The FM Time reference output (Channel 5 of Figure 4) is 1,024 Hz plus or minus tape speed error. This signal is divided down by four (256 Hz ± deviation) and used as the timing signal for the digital conversion time interval (see Figure 3). Thus, the accelerogram time base is corrected for tape speed error and the voltage values are equally spaced at 1/256 second. This is "time base compensation" and can be done on analog-to-digital converters other than DDS-1105 or DataSeis®.

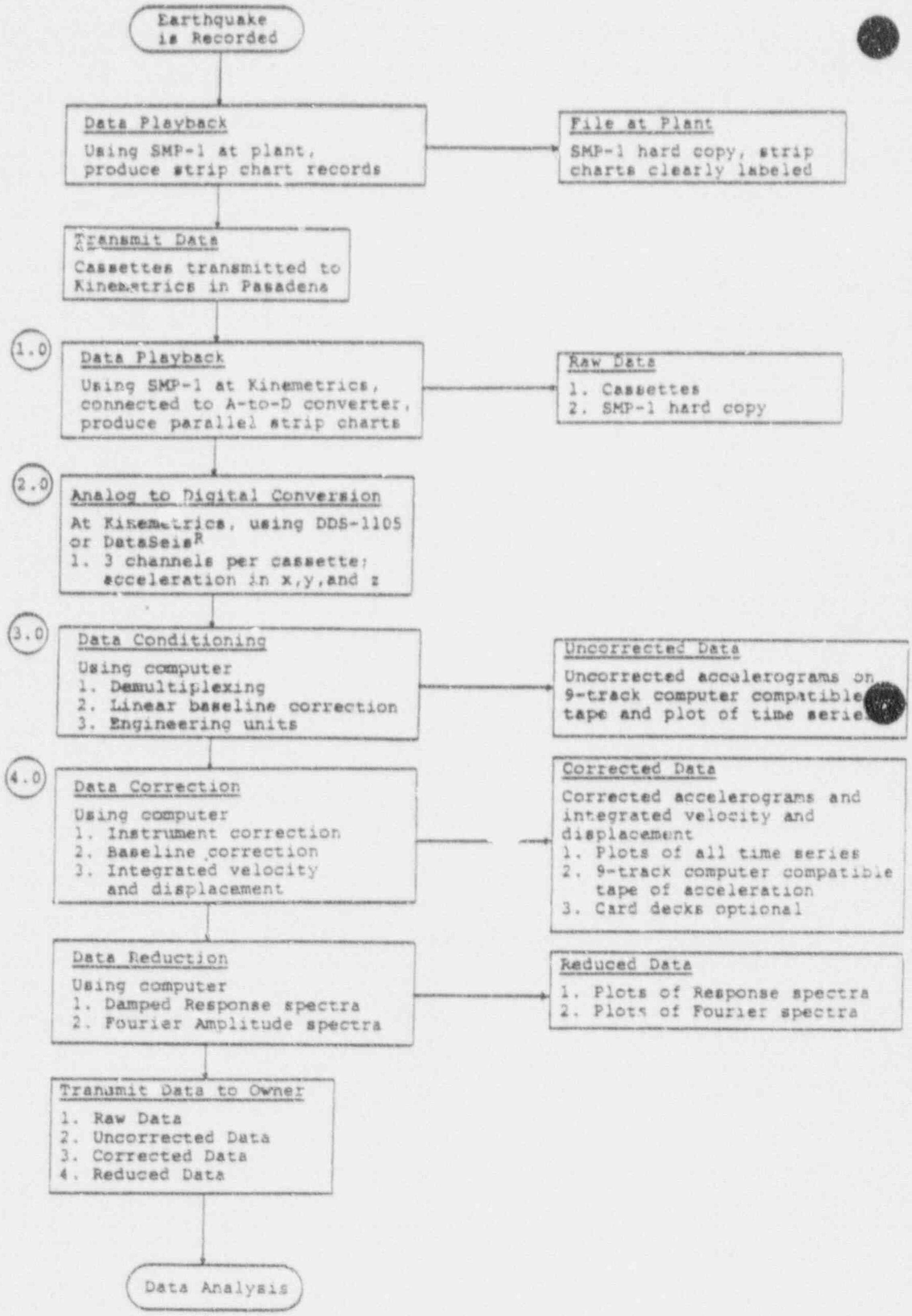


FIGURE 1 Flow Diagram for Kinemetrics E.D.R.S. (Earthquake Data Reduction Sequence)

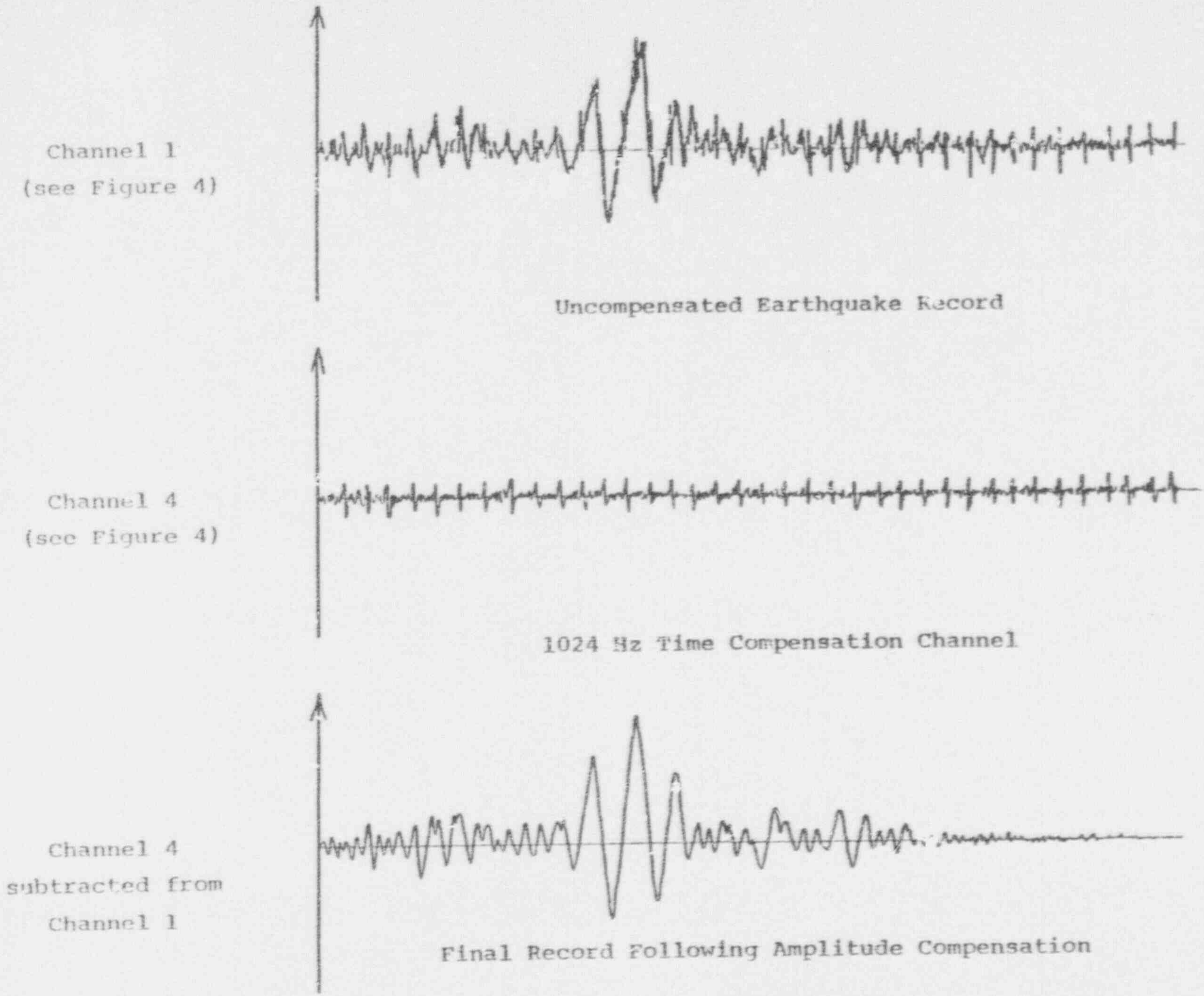


FIGURE 2 Amplitude Compensation

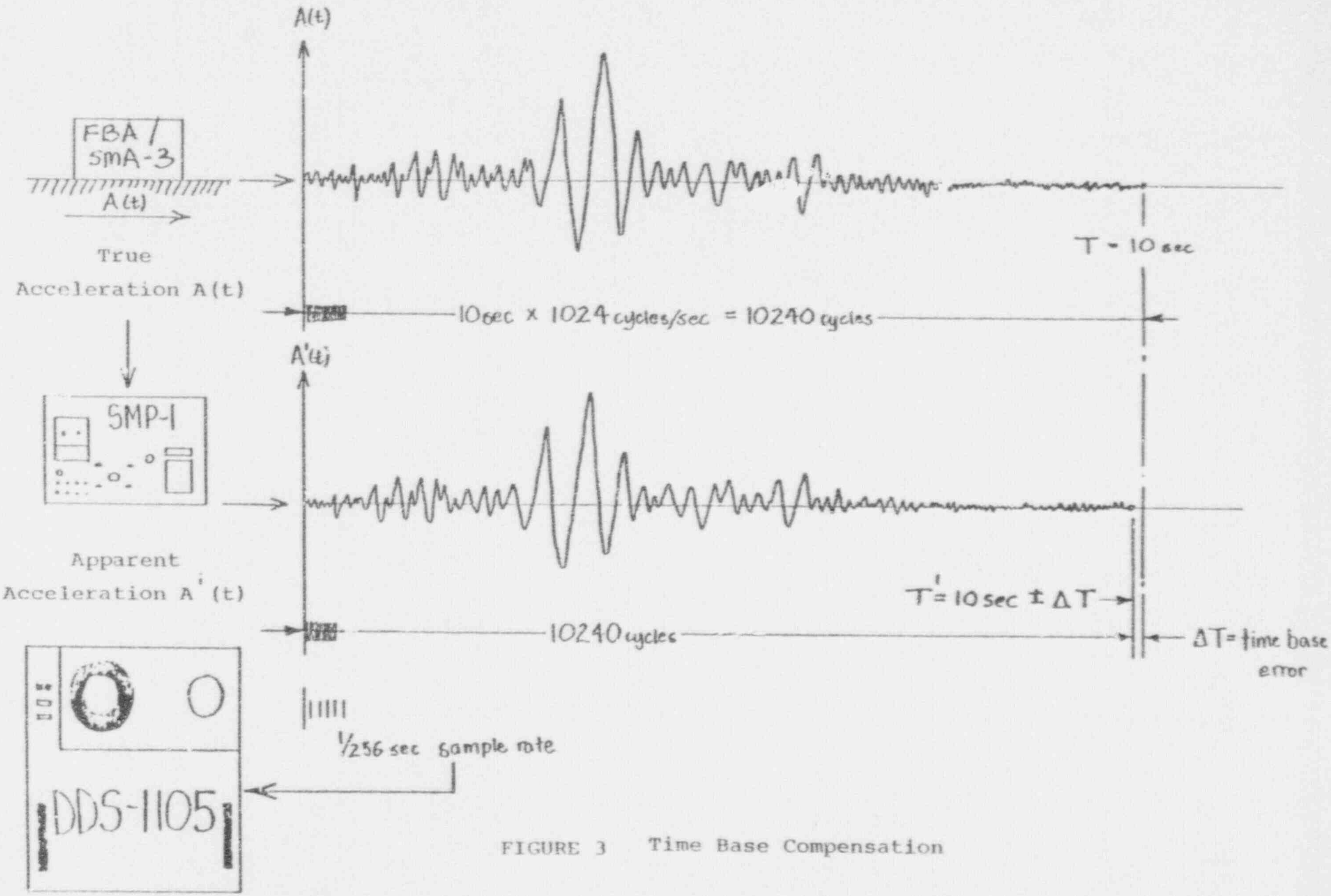


FIGURE 3 Time Base Compensation

2.3 The final uncorrected accelerograms are written on 9-track computer-compatible tape. The three channels are multiplexed (i.e., 1, 2, 3, 1, 2, 3, 1, 2,...), and are in a 16-bit, offset binary format.

3.0 Data Conditioning

Figure 5 illustrates the flow of the "Data Conditioning" software. Tape speed variations during recording and during playback of FM analog tape change the apparent time base and affect the analog amplitude. The time base has been compensated in the previous section (see Figure 3) by using the FM time reference output as the timing signal for the analog-to-digital converter. The amplitude has been compensated (see Figure 2) using the Data Compensator module.

The output accelerograms are uncorrected in the sense that no modifications have been introduced which involve any hypothesis of the ground motion character or of the instrument involved.

4.0 Data Correction

Figure 6 illustrates the flow of the "Data Correction" software. The purpose is to present corrected acceleration and integrated velocity and displacement time-histories in as accurate a form and over as wide a frequency range as is compatible with the original data. The corrected data are believed to be the most accurate form of input data feasible to produce from the original records. They are suitable input for structural response calculations and for response spectrum calculations.

A high-frequency instrument correction is introduced to compensate for the accelerometers' frequency response. The Caltech publication EERL 71-05 discusses the approach used. The low frequency baseline correction uses an Ormsby high-pass filter. The technique is explained in Caltech publication EERL 70-07.

Figure 7 contains a sample output plot of corrected data for one component of the Santa Barbara earthquake of 13 August 1978, recorded on a SMA-2 accelerograph.

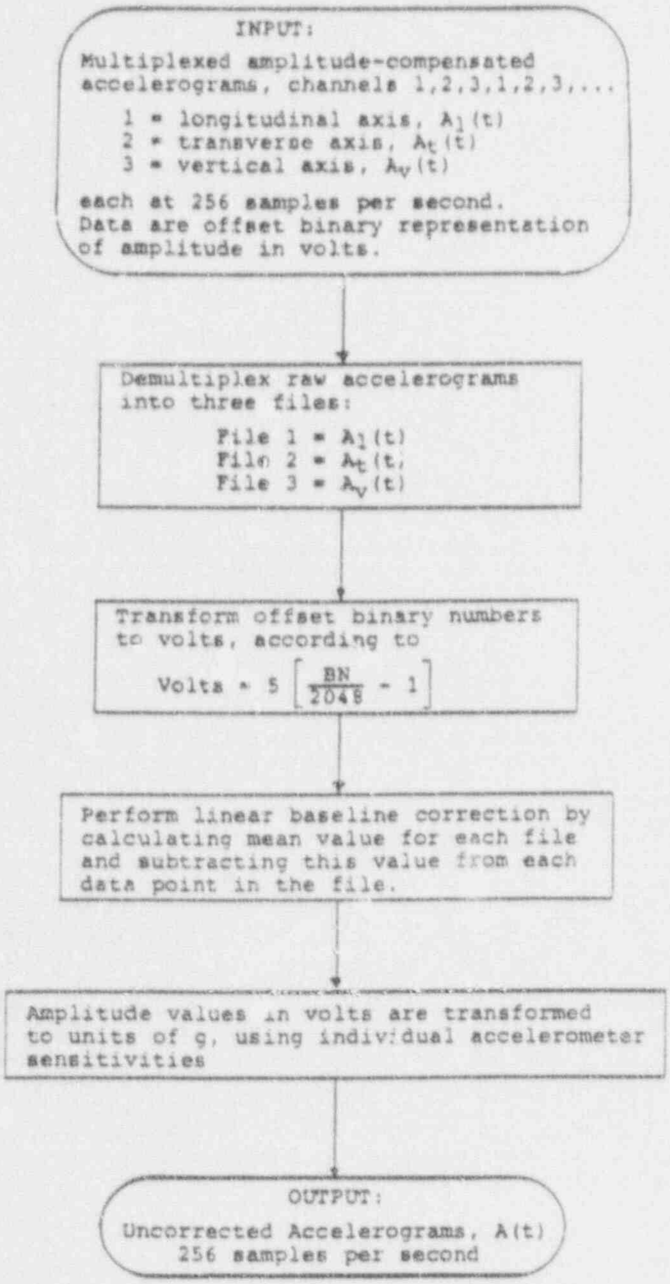


FIGURE 5

Data Conditioning, E.D.R.S.

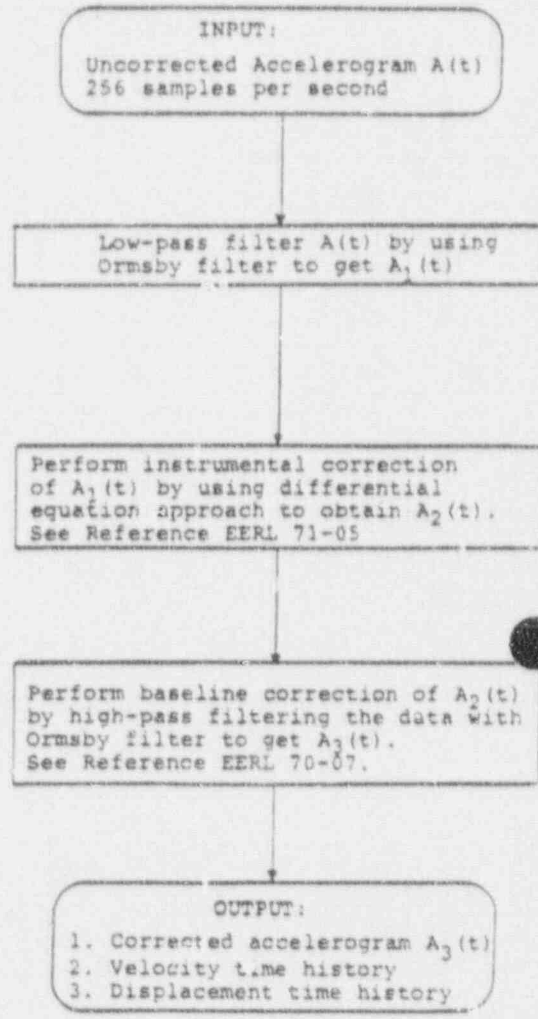
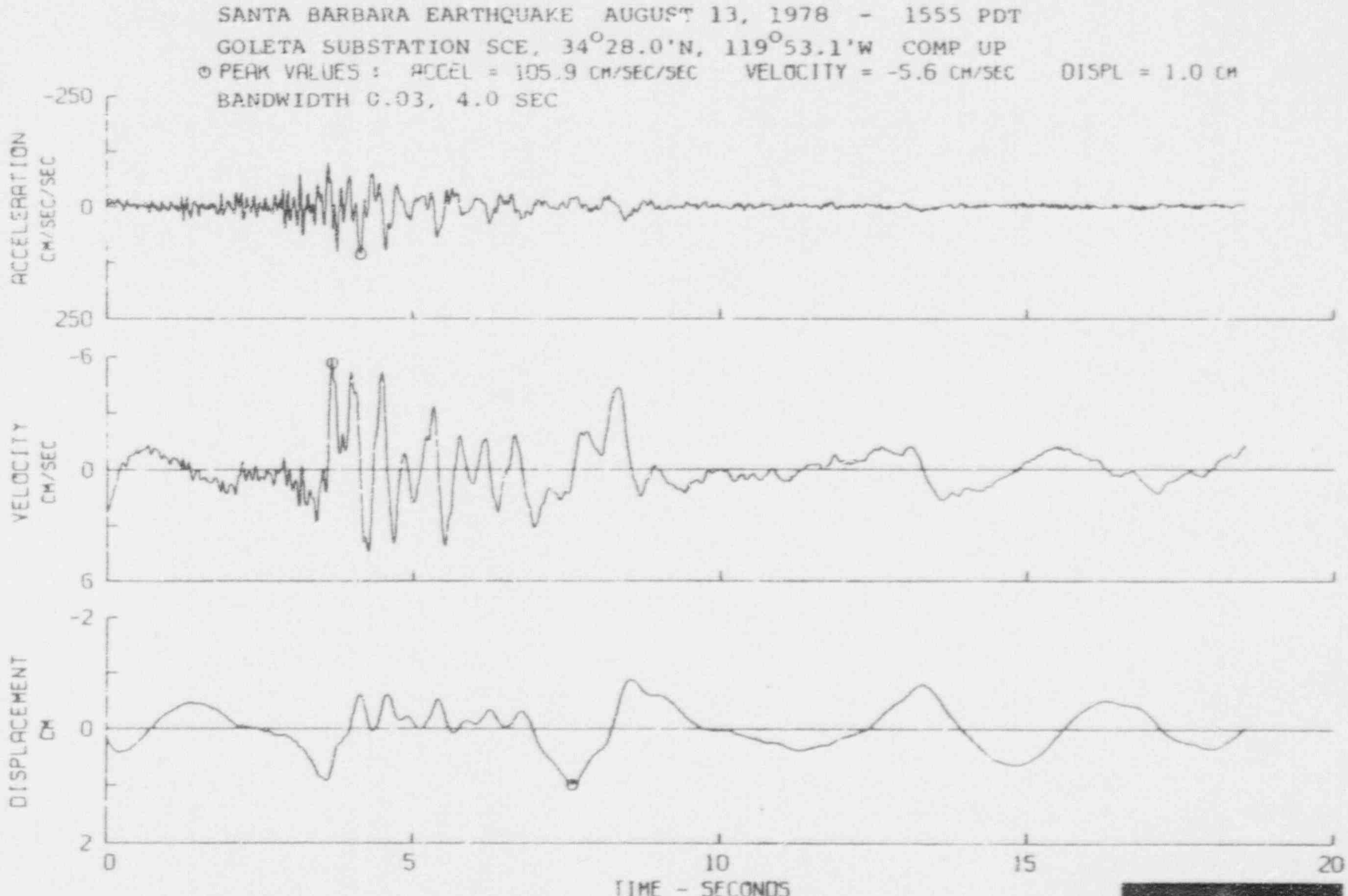


FIGURE 6

Data Correction, E.D.R.S.

FIGURE 7



SANTA BARBARA EARTHQUAKE AUGUST 13, 1978 - 1555 PDT
GOLETA SUBSTATION SCE, 34°28.0'N, 119°53.1'W COMP UP
PEAK VALUES : ACCEL = 105.9 CM/SEC/SEC VELOCITY = -5.6 CM/SEC DISPL = 1.0 CM
BANDWIDTH 0.03, 4.0 SEC
ACCELERATION CM/SEC/SEC
-250
0
250
VELOCITY CM/SEC
-6
0
6
DISPLACEMENT CM
-2
0
2
0
5
10
15
20
TIME - SECONDS

REFERENCES

Trifunac, M. D. (1970). Low Frequency Digitization Errors and a New Method for Zero Baseline Correction of Strong-Motion Accelerograms, Earthquake Engineering Research Laboratory, EERL 70-07, pgs. 32-52, California Institute of Technology, Pasadena

Trifunac, M. D., F. E. Udwadia and A. G. Brady (1971). High Frequency Errors and Instrument Corrections of Strong-Motion Accelerograms, Earthquake Engineering Research Laboratory, EERL 71-05, pgs. 33-47, California Institute of Technology, Pasadena

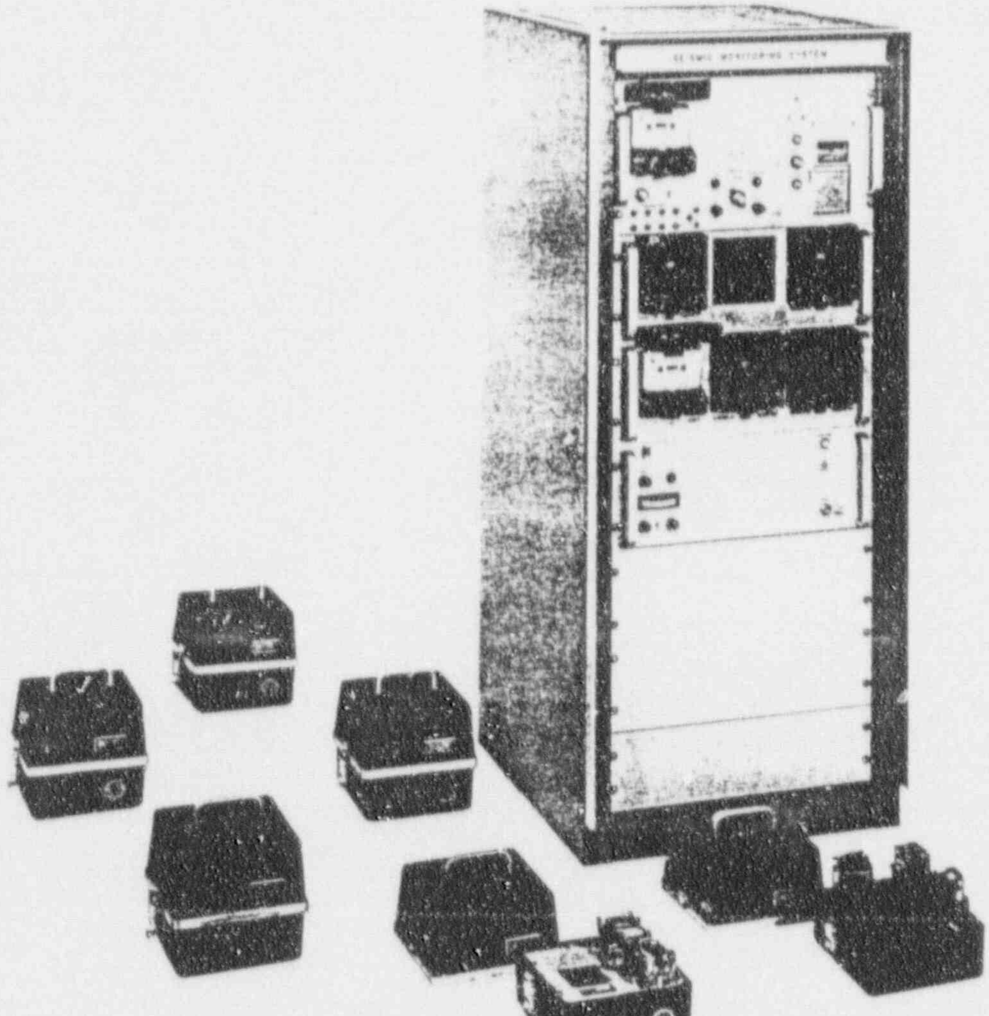
Trifunac, M. D. and V. Lee (1973). Routine Computer Processing of Strong-Motion Accelerograms, Earthquake Engineering Research Laboratory, EERL 73-03, California Institute of Technology, Pasadena

KINEMETRICS

EARTHQUAKE ENGINEERING INSTRUMENTS

SMA-3

Strong Motion Acceleration System



The SMA-3 is a multi-channel, centralized recording, magnetic tape accelerograph system designed to detect and record strong local earthquakes. Typical structural applications include nuclear power plants, tall buildings, dams, offshore platforms and bridges. The SMA-3, used with the companion SMP-1 Playback System, meets the requirements of U.S. NRC Regulatory Guide 1.12 and is being used at over 90 nuclear power plants around the world.

An SMA-3 can accommodate up to 27 channels of acceleration data, usually from triaxial force balance accelerometers, Model FBA-3. Downhole triaxial sensors (FBA-13DH) can be installed, and uniaxial and biaxial accelerometers may also be used. The sensors may be located up to 1500 feet from the central recorder. The TS-3 triaxial seismic trigger is standard with any SMA-3 system. The SMA-3 comes supplied with two cassettes per recording section, and all mounting hardware and mating connectors for the specified number of triggers and accelerometers.

USA - 222 VISTA AVE., PASADENA, CA 91107-TEL. (818) 795-2220, TELEX 67-5402 KMETRICS PSD • EUROPE - RUE DE LA VIGIE 3, 1003 LAUSANNE, SWITZERLAND-TEL. 201025, TELEX 455207

GENERAL DESCRIPTION

The SMA-3 is a versatile multi-channel acceleration recording system. It is self-actuating when a local earthquake exceeds a predetermined level of ground acceleration. When acceleration falls below the preset value, the SMA-3 automatically returns to the standby condition.

The standard FBA-3 triaxial accelerometer package is approximately a 20 centimeter cube. It contains three force-balance acceleration sensors. The accelerometer package accepts calibration commands for damping and natural frequency.

Each accelerometer signal is buffered, frequency modulated, and recorded on an assigned track of a four-track magnetic tape cassette. Three tracks are used for acceleration data and the fourth for a timing signal, which is common for all recording tape transports in the system.

TECHNICAL SPECIFICATIONS

SEISMIC TRIGGERS (Model TS-3)

Type: Triaxial acceleration trigger
Housing: Cast aluminum, waterproof
Set Point: 0.01g standard; field adjustable, 0.005g to 0.05g
Option: Adjustment range of 0.025g to 0.25g
Current Drain: 0.45 mA in standby; 60 mA operating

TRANSDUCERS (Model FBA-3)

Type: Force balance accelerometers
Housing: Cast aluminum, waterproof
Bandwidth: 0 to 50 Hz
Range: ± 1g full scale
Output: ± 2.5 V full scale
Damping: 70% of critical
Natural Frequency: 50 Hz
Calibration: Damping and natural frequency recorded by command
Temperature Range: −20° to 70° C (0° to 160° F)
Temperature Effects: ± 1.5% of full scale over operating range

RECORDING SYSTEM

Type: Frequency modulation
Tape: Four track magnetic tape cassette
Tape Speed: 1-7/8" per second
Recording Time: 30 minutes
Bandwidth: 0 to 50 Hz
Dynamic Range: 40 dB from 15° to 35° C (with SMP-1)
Modulation Frequency: 1000 Hz ± 50% modulation
Timing Frequency: 1024 Hz ± 0.2%
System Accuracy (with SMP-1): ± 5% at full scale, changing linearly to 1.5% of full scale at 0.01g
Start-up Time: Less than 0.1 seconds
Event Alarm: Normally open contacts, rated 1 amp @ 12 Vdc
Event Indicator: Electromagnetic visual display

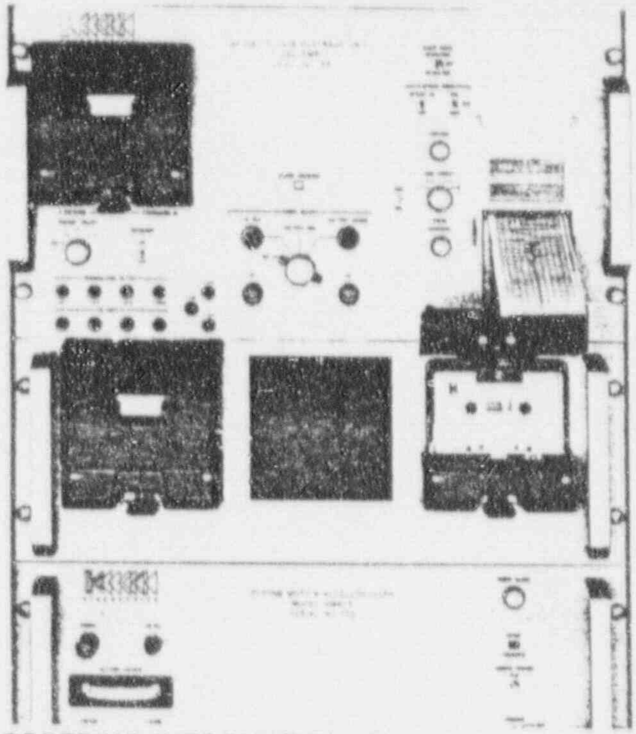
POWER SUPPLY

Two 12 V internal, rechargeable batteries. An internal battery charger, operating from 110 Vac, is supplied.

OPERATING ENVIRONMENT

Temperature: 0° to 55° C (30° to 130° F)
Humidity: Remote packages, 100% R.H.
Cabinet mounted panels, 80% R.H. non-condensing

KINEMETRICS — EARTHQUAKE ENGINEERING INSTRUMENTS



ORDERING INFORMATION, SMA-3

Kinemetrics Part Number: 101100
Strong Motion Acceleration System, including:

One triaxial seismic trigger, Model TS-3
Specify triggering threshold (0.01g standard)
Specify number of additional triggers if desired

Up to nine triaxial acceleration sensors, Model FBA-3; 1.0g full scale
Cost Option—Model FBA-11 uniaxial sensor
Cost Option—Model FBA-13DH downhole triaxial sensor
Option—Range 0.25g, 0.5g, 2.0g full scale
Specify number and type of sensors, up to 27 channels

Up to nine triaxial tape recording modules, with cassettes
Cost Option—Flame resistant wiring
Specify number of channels, up to twenty-seven

Control/Power Panel
Cost Option—Conversion to 220 Vac

Accessories:

Interconnecting Cables for seismic trigger(s)
Cost Option—Flame retardant cable
Specify lengths required, up to 1500' to each trigger

Interconnecting Cables for remote accelerometers
Cost Option—Flame retardant cable
Specify lengths required, up to 1500' to each sensor

19-inch Rack Mounting Cabinet
Cost Option—Seismically braced cabinet

Tape Playback, Model SMP-1 (see SMP-1 data sheet)

Spares and Supplies:
Magnetic Tape Cassettes, Part #700030
Desiccant Envelopes, Part #700049
12 V Batteries (pair), Part #103413

APPENDIX B

TO

SEISMIC EVENT EVALUATION

FOR THE

MARCH 15, 1992 Mc = 3.5 EARTHQUAKE

PERRY NUCLEAR PLANT

ENGDAHL STRONG-MOTION DATA

MPL NUMBER: D51-R120 *
LOCATION: REACTOR RECIRCULATION PUMP

SENSOR LOCATION	ACCELERATION (g)	
NORTH/SOUTH (L)		
EAST/WEST (T)		
VERTICAL		

*Information not available at preparation time of this report.

TABLE B-1
ENGDAHL RECORDED DATA
03/15/92 EARTHQUAKE

MPL NUMBER: D51-R130 *
LOCATION: HPCS INJECTION LINE

SENSOR LOCATION	ACCELERATION (g)	
NORTH/SOUTH (L)		
EAST/WEST (T)		
VERTICAL		

*Information not available at preparation time of this report.

TABLE B-2
ENGDAHL RECORDED DATA
03/15/92 EARTHQUAKE

MPL NUMBER: D51-R140
LOCATION: HPCS PUMP BASE MAT - 574'

SENSOR LOCATION	ACCELERATION (g)	
	LEFT	RIGHT
NORTH/SOUTH (L)	0.0	0.0
EAST/WEST (T)	0.038	0.019
VERTICAL	0.0	0.0

TABLE B-3
ENGDAHL RECORDED DATA
03/15/92 EARTHQUAKE

MPL NUMBER: D51-R160
LOCATION: REACTOR BUILDING FOUNDATION - 574'

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical	
		LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
1	2.00	0.0019g	0.0014	0.0023g	0.0000g	0.000g	0.000g
2	2.52	0.0021g	0.0041g	0.0020g	0.0013g	0.000g	0.000g
3	3.17	0.0032g	0.0054g	0.0045g	0.0000g	0.000g	0.000g
4	4.00	0.0000g	0.0080g	0.0000g	0.0000g	0.000g	0.000g
5	5.04	0.0000g	0.0196g	0.0048g	0.0000g	0.000g	0.000g
6	6.35	0.0078g	0.0197g	0.0000g	0.0000g	0.000g	0.000g
7	8.00	0.0000g	0.000g	0.0129g	0.0129g	0.000g	0.000g
8	10.1	0.0098g	0.0098g	0.0000g	0.0000g	0.000g	0.000g
9	12.7	0.0000g	0.0154g	0.0220g	0.0145g	0.000g	0.000g
10	16.0	0.0000g	0.0253g	0.0366g	0.0366g	0.000g	0.000g
11	20.2	0.0000g	0.0000g	0.0000g	0.0000g	0.000g	0.000g
12	25.4	0.0625g	0.0325g	0.0000g	0.0000g	0.000g	0.000g

TABLE 8-4
ENGDAHL RECORDED DATA
03/15/92 EARTHQUAKE

MPL NUMBER: D51-R170 *
LOCATION: REACTOR BUILDING BIOSHIELD WALL - DW 630', 240°

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical	
1	2.00						
2	2.52						
3	3.17						
4	4.00						
5	5.04						
6	6.35						
7	8.00						
8	10.1						
9	12.7						
10	16.0						
11	20.2						
12	25.4						

*Information not available at preparation time of this report.

TABLE B-5
ENGDAHL RECORDED DATA
03/15/92 EARTHQUAKE

MPL NUMBER: D51-R180 *
LOCATION: HPCS PUMP BASE MAT - 574'

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical*	
1	2.00						
2	2.52						
3	3.17						
4	4.00						
5	5.04						
6	6.35						
7	8.00						
8	10.1						
9	12.7						
10	16.0						
11	20.2						
12	25.4						

*D51-R180 was out-of-service for repair during the seismic event. No data available.

TABLE B-6
ENGDAHL RECORDED DATA
03/15/92 EARTHQUAKE

MPL NUMBER: D51-R190
LOCATION: RCIC PUMP BASE MAT - 574'

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical *	
		LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
1	2.00	0.006	0.00	0.00	0.004	NA	NA
2	2.52	0.007	0.00	0.003	0.002	NA	NA
3	3.17	0.008	0.00	0.004	0.00	NA	NA
4	4.00	0.00	0.00	0.004	0.004	NA	NA
5	5.04	0.00	0.020	0.00	0.00	NA	NA
6	6.35	0.00	0.00	0.00	0.00	NA	NA
7	8.00	0.00	0.025	0.019	[illegible]	NA	NA
8	10.1	0.00	0.00	0.00	0.00	NA	NA
9	12.7	0.00	0.00	0.00	0.00	NA	NA
10	16.0	0.00	0.00	0.00	0.00	NA	NA
11	20.2	0.00	0.00	0.00	0.00	NA	NA
12	25.4	0.00	0.00	0.00	0.00	NA	NA

*Recordings from the Vertical component were difficult to read, irregular, and thought to be non seismic scratches. These will be reviewed by our consultant, Engdahl.

TABLE B-7
ENGDAHL RECORDED DATA
03/15/92 EARTHQUAKE

APPENDIX C

TO

SEISMIC EVENT EVALUATION

FOR THE

MARCH 15, 1992 Mc = 3.5 EARTHQUAKE

PERRY NUCLEAR PLANT

PDAS-100 RECORDINGS AND CAV CALCULATIONS

C. Analysis of the PDAS-100 Data Records of the Earthquake of March 15, 1992 06:14 GMT

C.1 Introduction

The 3/15/92 earthquake event was recorded by a portable digital seismograph (PDAS-100) installed at the Antioch station of the CEI Autostar network. The Antioch station is located about 1 km ENE of the Perry Nuclear Plant and approximately 8 km from the epicenter of the March 15th earthquake.

At the time of the earthquake, the PDAS-100 was configured to record two vertical component channels and 1 horizontal component channel. The PDAS-100 was in this configuration to "base-line" the unit with the Autostar Network. All channels were enabled to record at 100 samples per second. The transducer for one of the vertical components is a PA20 accelerometer (Teledyne-Geotech). This accelerometer was installed at ground surface on a wood floor of a small shed which houses the telemetry of the Antioch seismic station. The second vertical component included an L-28 velocity transducer (Mark Products) with a natural frequency of 4.5 hertz. The horizontal component also included an L-28 velocity transducer. Both the vertical and horizontal L-28 velocity transducers are installed in a waterproof lexan box and installed outside the Autostar instrument shed. The lexan box and velocity transducers are buried at a depth of about 1 foot below ground surface. It should be noted that the Antioch site has a stratigraphic column of about 70 feet of overburden over Paleozoic bedrock. Thus, PDAS-100 ground surface records discussed below were recorded at a 'soil site'.

C.2 Recorded Ground Motion

The PA20 vertical component record was corrected for instrument sensitivity (i.e. 5 volts/g) to obtain the accelerogram shown at the top of Figure C.1. The peak acceleration for this record is 0.014g.

Fourier Amplitude Spectrum and Power Spectral Density plots shown on Figure C.1 illustrate the frequency composition of the PA20 vertical component accelerogram. Dominant frequencies are at 10.9 and 11.7 hertz. Other spectral peaks occur at 5, 7, 14.3, and 18.8 hertz. It is noted that the PA 20 record exhibited additional high frequency energy at frequencies of about 38 to 42 hertz. Similar amplitude high frequencies were not present in the L-28 vertical record buried in the ground near the small instrument shed. The high frequencies are attributed to resonance of the wooden shed. These high frequencies were filtered using a cut-off frequency of 30 hertz. The peak acceleration of the unfiltered record was slightly higher at -0.016g.

More extensive processing was required to generate acceleration time histories for the vertical and horizontal ground motions recorded by the L-28 velocity transducers. Ground velocities were computed using the published instrument sensitivities (i.e. 0.65 volts/inch/second). Next, the time derivative was taken of the velocity record to derive ground acceleration records. Shown on Figure C.2 is the vertical component L-28 derived accelerogram. The peak ground acceleration is 0.0095g. Spectral composition of this L-28 record is similar to that recorded by the PA20 accelerometer. Dominant spectral peaks are at about 10.6 and 11.8 hertz. Secondary peaks occur at 5, 7, 13.2 and 17.8 hertz.

Application of the same data processing stream to the L-28 horizontal component ground response record resulted in the accelerogram shown on Figure C.3. The peak acceleration of this record is 0.102g, about a factor of 10 larger than the corresponding L-28 vertical component acceleration time history. As can be seen in the time history, the peak acceleration is associated with one cycle of high amplitude S-wave motion. The dominant frequency of the lateral acceleration is at 11.5 hertz. Other peaks occur at 5.2 and 13.7 hertz.

C.3 Cumulative Absolute Velocity (CAV)

Cumulative absolute velocity (CAV) has been promoted as an alternative measure of ground motion intensity, which perhaps is better correlated to damage potential than is peak acceleration, especially if the peak acceleration is associated with high ground motion frequencies. The formulation used to calculate CAV values from the PDAS-100 data for the 3/15/92 event is defined in EPRI NP-5930, Project 2848-16, A Criterion for Determining Exceedance of the Operating Basis Earthquake, Final Report dated 7/88.

CAV can be computed for the entire duration of the recorded time history. It should be noted that approximately 70 seconds of coda were recorded by the PDAS for the March 15th earthquake. Figures C.4 thru C.6 show 10.24 seconds of the record beginning at the P-wave arrival. Although the entire records have a duration of about 70 seconds, highest accelerations are observed in the first 4 to 5 seconds after initial P-wave arrival. Amplitudes are relatively small at 10 seconds from the beginning of the event. CAV is thus computed for the 10.24 seconds of ground motion shown on Figures C.4 thru C.6 for the PA20 (vertical), L-28 (vertical), and L-28 (horizontal), respectively.

Resultant CAV's for these records are .012 g-sec, .0077 g-sec, and .026 g-sec, respectively. A comparison of the CAV of .026 g-sec computed for the L-28 horizontal component record with CAV's determined by the OBE Exceedance Working Panel (EPRI RP2843-16), suggests that the associated site intensity at the Antioch site for the March 15th earthquake was about III on the Modified Mercalli

Scale. Seven records with CAV's ranging from .021 to .027 g-sec are listed in the referenced EPRI OBE Exceedance report. Parameters of these events are listed below.

Record No.	Earthquake	Magnitude	Site Intensity	CAV
42	South Carolina	2.7	III (3.3)	.027
43	South Carolina	2.7	III (3.3)	.024
89	Oroville, CA	4.1	III (3.2)	.027
101	Oroville, CA	4.1	III (3.2)	.027
140	Oroville, CA	4.0	III (3.2)	.021
141	Oroville, CA	4.0	III (3.2)	.022
248	Ancona, Italy	3.5	III (3.7)	.027

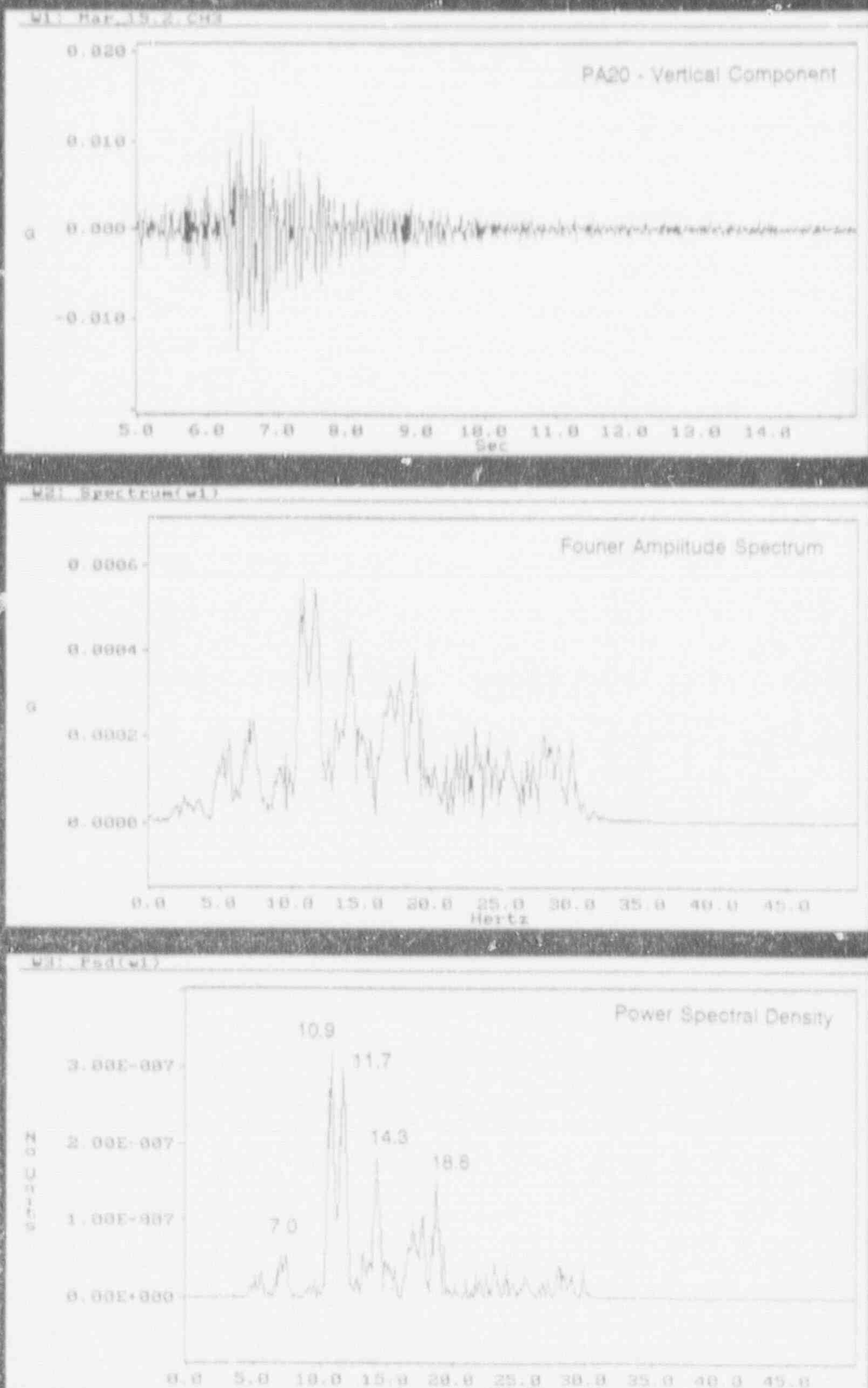
Comparison of the CAV's (and associated magnitudes and site intensities) with the CAV of .026 determined for the Antioch site confirms that the local intensity was low, on the order of about III (MMI scale). As noted above, the Antioch site is a 'soil site' and the records likely have some level of amplification relative to an adjacent bedrock site. Intensities and CAV's estimated for the nearby Perry Nuclear Plant, founded on bedrock, are at most, equivalent to but likely smaller than those observed at the Antioch seismograph site. It is concluded that although instrumentation at the plant was triggered by the March 15 event, ground motions were well below levels required to cause damage to structures or equipment.

CEI PDAS - 100
03/15/92
Earthquake

FIGURE C.1

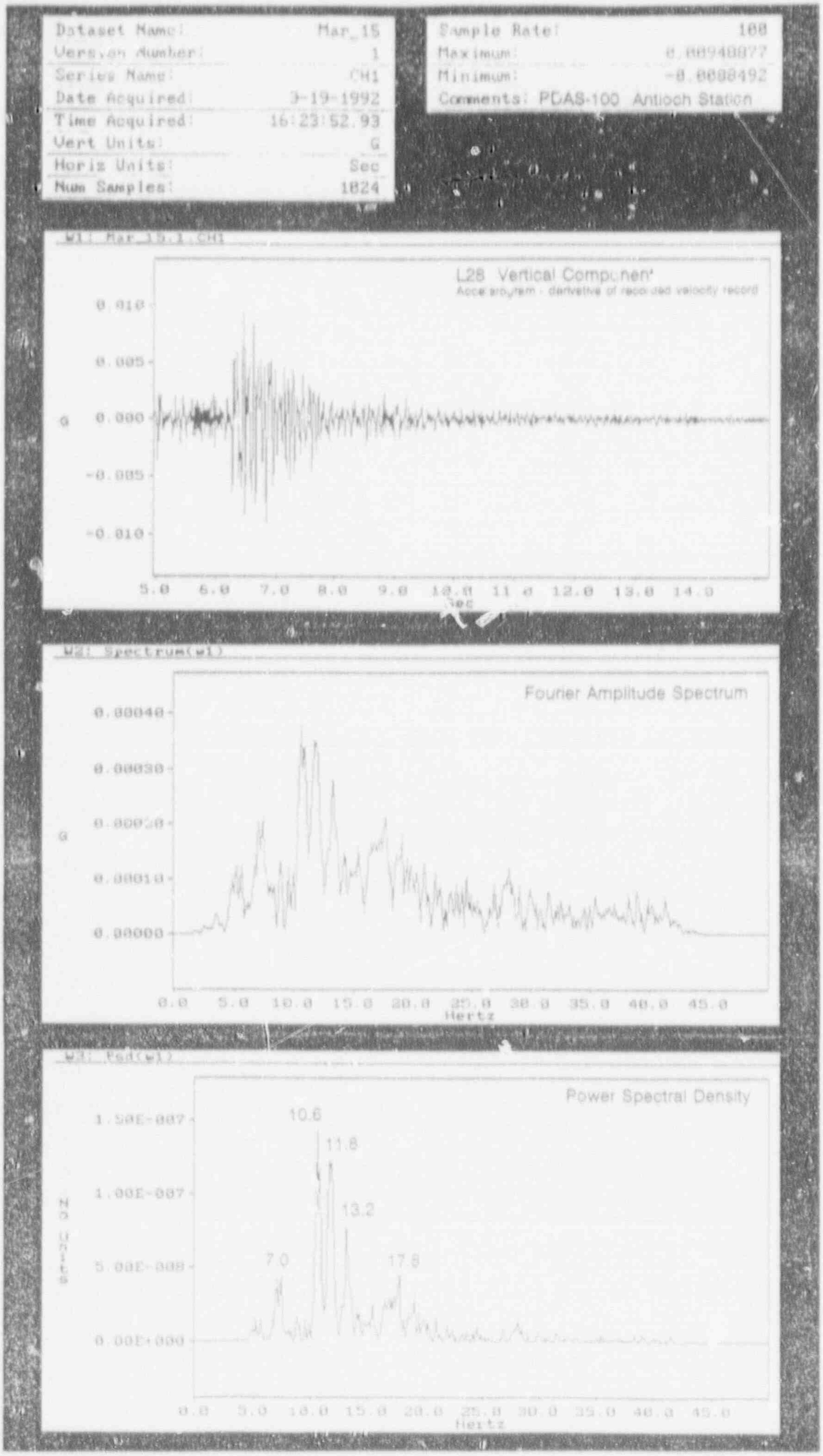
Dataset Name:	Mar_15
Version Number:	2
Series Name:	CH3
Date Acquired:	3-19-1992
Time Acquired:	16:43:07.41
Vert Units:	G
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.0140276
Minimum:	-0.0135216
Comments:	PDAS-100 Antioch Station



CEI PDAS - 100
03/15/92
Earthquake

FIGURE C.2

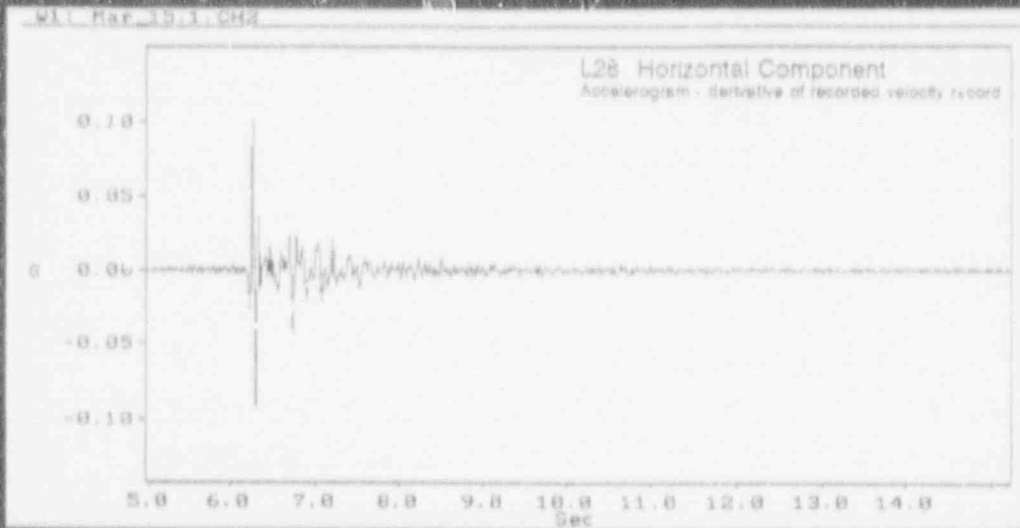


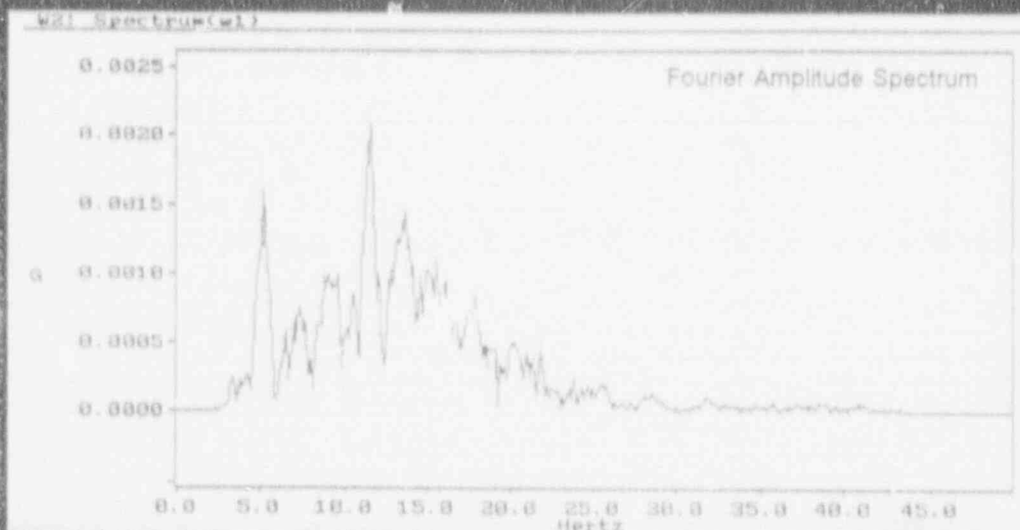
CEI PDAS - 100
03/15/92
Earthquake

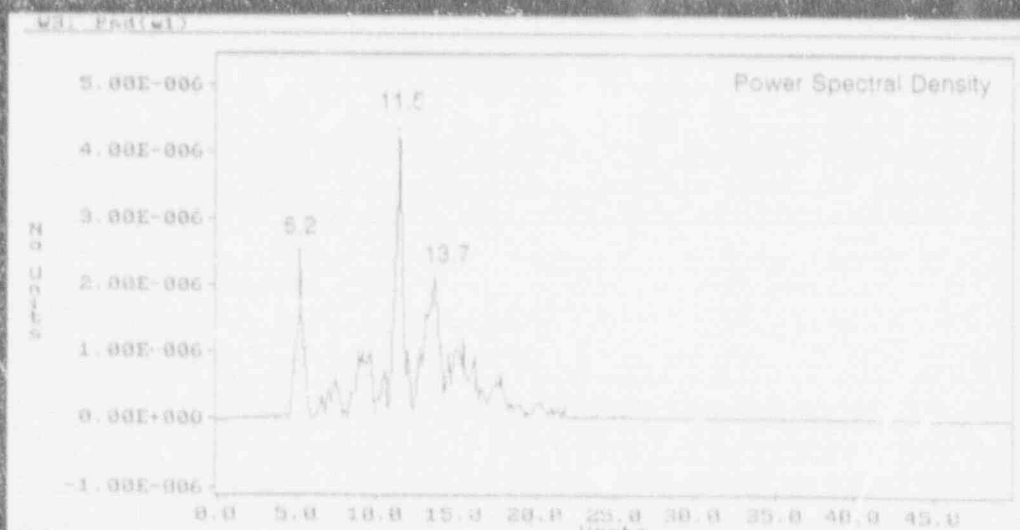
FIGURE C.3

Dataset Name:	Mar_15
Version Number:	1
Series Name:	CH2
Date Acquired:	3-19-1992
Time Acquired:	16:25:53.60
Vert Units:	G
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.101006
Minimum:	-0.0915660
Comments:	PDAS-100 Antioch Station





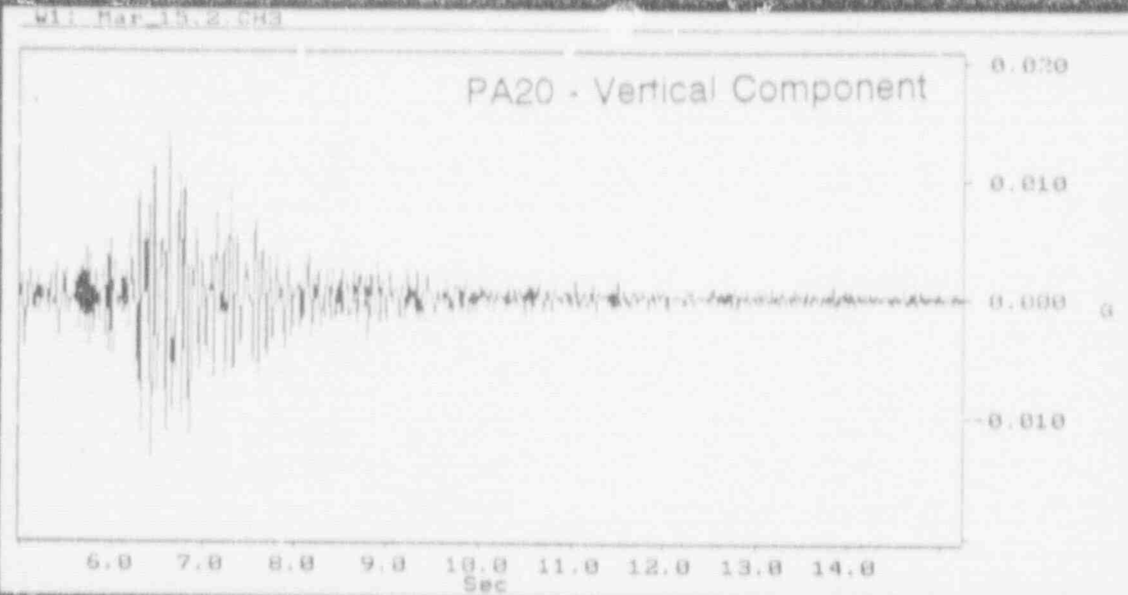


CEI PDAS - 100
03/15/92
Earthquake

FIGURE C.4

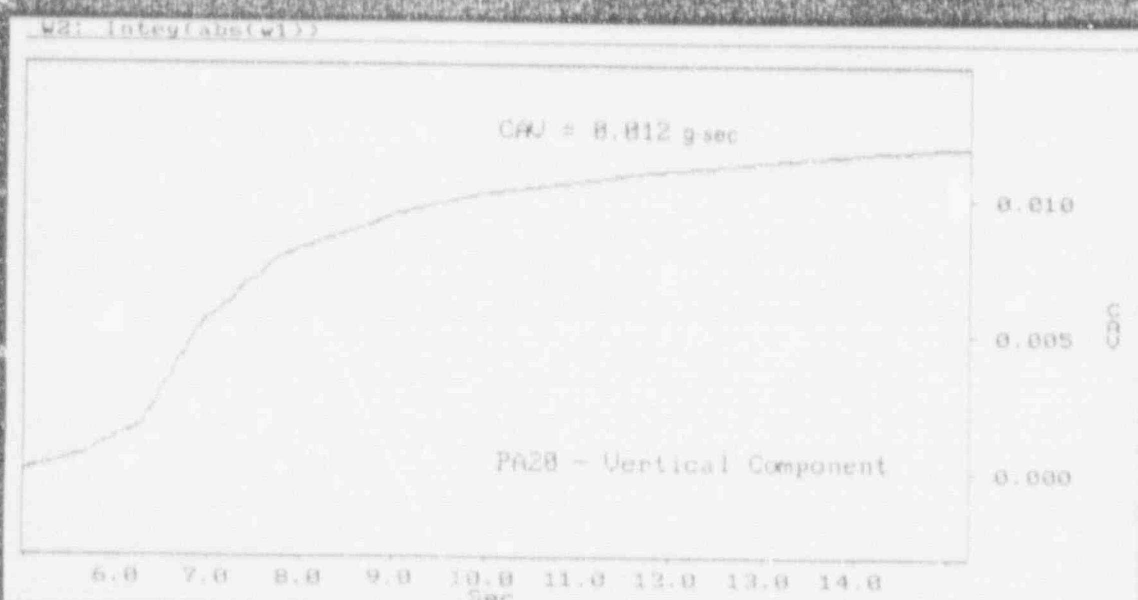
Dataset Name:	Mar_15
Version Number:	2
Series Name:	CH3
Date Acquired:	3-19-1992
Time Acquired:	16:43:07.41
Vert Units:	G
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.0140276
Minimum:	-0.0135216
Comments:	None



Dataset Name:	Unspecified
Version Number:	0
Series Name:	Unspecified
Date Acquired:	3-20-1992
Time Acquired:	13:18:57.37
Vert Units:	CAV
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.0119531
Minimum:	0
Comments:	None

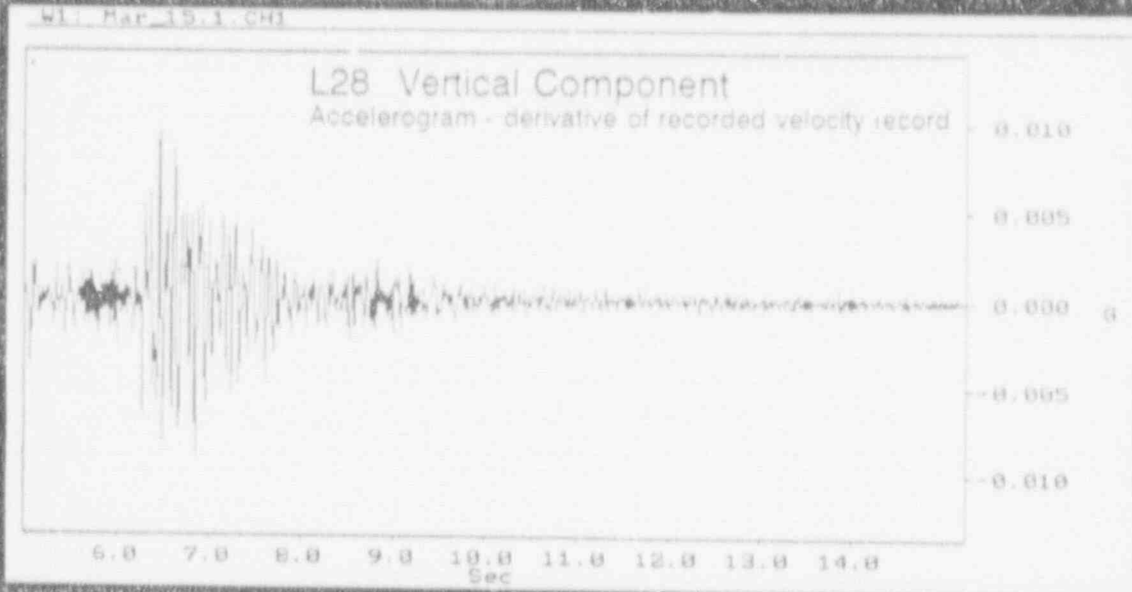


CEI PDAS - 100
03/19/92
Earthquake

FIGURE C.5

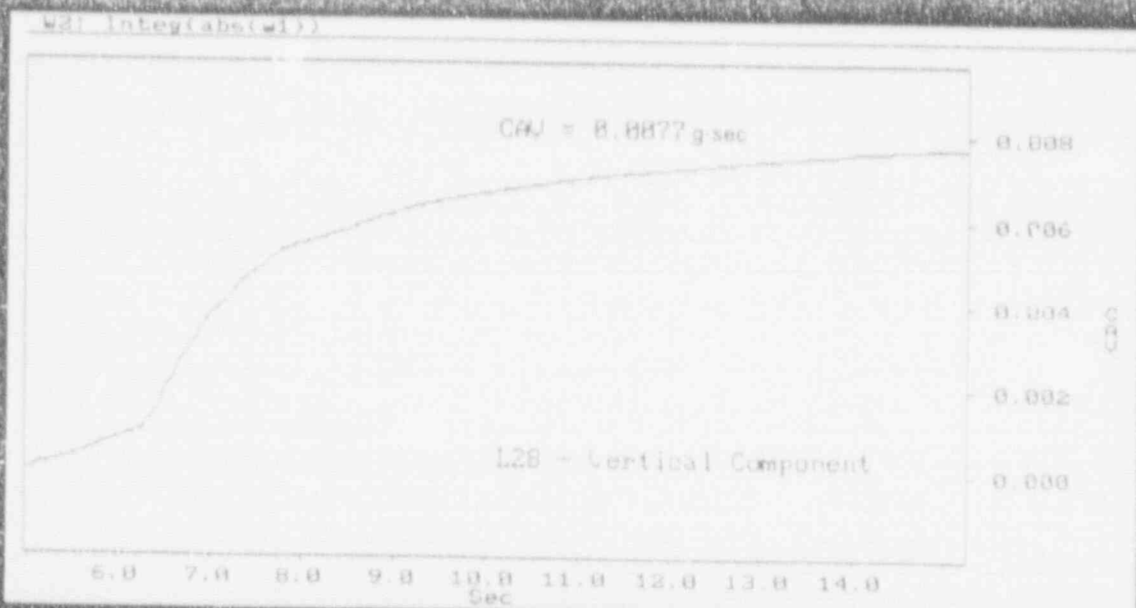
Dataset Name:	Mar_15
Version Number:	1
Series Name:	CH1
Date Acquired:	3-19-1992
Time Acquired:	16:23:52.93
Vert Units:	G
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.00948877
Minimum:	-0.0088492
Comments:	None



Dataset Name:	Unspecified
Version Number:	0
Series Name:	Unspecified
Date Acquired:	3-20-1992
Time Acquired:	12:51:56.58
Vert Units:	CAV
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.00774492
Minimum:	0
Comments:	None

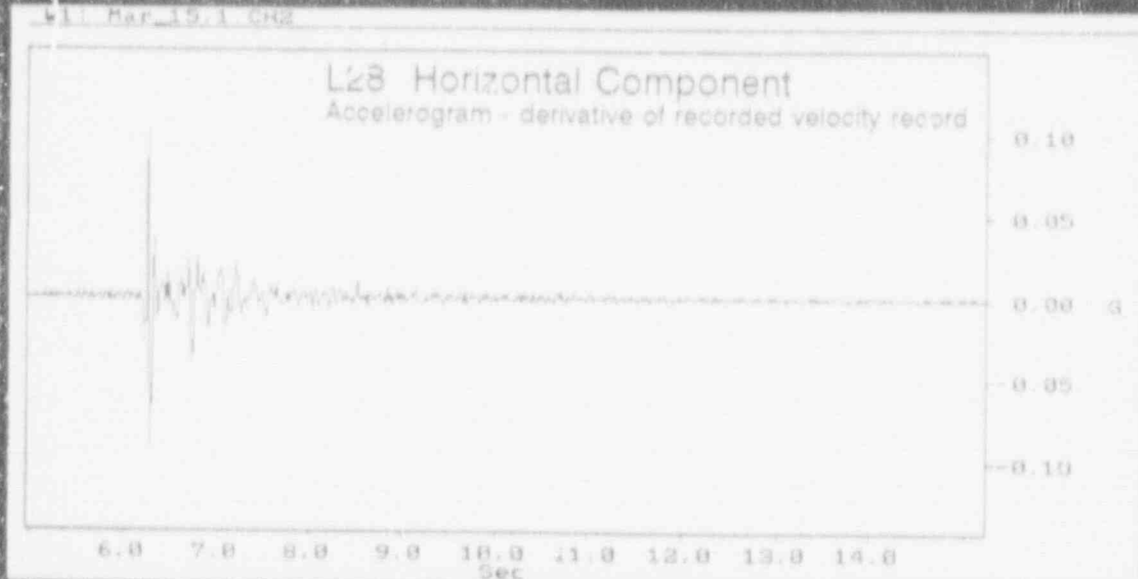


CEI PDAS - 100
03/15/92
Earthquake

FIGURE C.6

Dataset Name:	Mar_15
Version Number:	1
Series Name:	CHZ
Date Acquired:	3-19-1992
Time Acquired:	16:25:53.60
Vert Units:	G
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.101806
Minimum:	-0.0915668
Comments:	None



Dataset Name:	Unspecified
Version Number:	0
Series Name:	Unspecified
Date Acquired:	3-20-1992
Time Acquired:	13:05:50.07
Vert Units:	CAV
Horiz Units:	Sec
Num Samples:	1024

Sample Rate:	100
Maximum:	0.0260261
Minimum:	0
Comments:	None