UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Appeal Board

In the Matter of	)	
	)	
THE CLEVELAND ELECTRIC ILLUMINATING COMPANY, ET AL.	)	Docket Nos. 50-440 50-441
	)	
(Perry Nuclear Power Plant, Units 1 and 2)	)	

AFFIDAVIT OF KALMAN LEE BENUSKA

County of Los Angeles)
: ss:
State of California)

Kalman Lee Benuska, being duly sworn, deposes and says as follows:

1. I, Kalman Lee Benuska, am Vice President and a Director of Kinemetrics, Inc. and General Manager of the Kinemetrics/Systems operating division ("Kinemetrics"). My business address is 222 Vista Avenue, Pasadena, California 91107. Kinemetrics, founded in 1969, designs and manufactures instrumentation for seismology and earthquake engineering. Kinemetrics' instrumentation is installed in power plants, large dams, bridges, offshore structures, buildings, and other engineered structures in over 80 countries world-wide.

2. A copy of my professional qualifications is attached hereto as Exhibit "A." As indicated therein, my professional qualifications include a M.S. in Engineering from the University of California. I am a licensed Structural Engineer in the State of California and have over 16 years of experience in ground motion measurements, structural vibration measurements, data analysis and their interpretation. I have personal knowledge of the matters set forth in this Affidavit and in the accompanying Exhibits, and believe the information set forth to be true and correct to the best of my knowledge and belief.

3. In addition to the qualifications discussed in Exhibit A, I was a member of the Working Group ANS-2.2 of the Standards Committee of the American Nuclear Society, which wrote the American National Standard ("Earthquake Instrumentation Criteria for Nuclear Power Plants"), ANSI/ANS-2.2-1978. I was also a member of the Working Group ANS-2.10 of the Standards Committee of the American Nuclear Society which wrote the American National Standard ("Guidelines for Retrieval, Review, Processing and Evaluation of Records Obtained from Seismic Instrumentation"), ANSI/ANS-2.10-1979.

4. On January 31, 1986, at the time of the earthquake that occurred in the vicinity of the Perry Nuclear Power Plant, there was a Kinemetrics time history accelerograph (Model SMA-3) with two triaxial sensors, installed and operational in the Perry Plant. This accelerograph measured the time-history of the Reactor Building motion during the earthquake at two

separate locations. Kinemetrics' time-history accelerographs, similar to the accelerograph installed at Perry, are installed in about 80 domestic nuclear plants and 120 nuclear plants world-wide. Kinemetrics Model SMA-3 accelerographs, including those installed in the Perry Plant, conform to the requirements of ANSI/ANS-2.2-1978 (Earthquake Instrumentation Criteria For Nuclear Power Plants") and to NRC Regulatory Guide 1.12 ("Nuclear Power Plant Instrumentation for Earthquakes, Rev. 1").

5. Following the January 31, 1986 earthquake, Perry Plant personnel retrieved two analog magnetic tape cassette records from the Kinemetrics accelerograph installed at Perry and provided the records to Kinemetrics for data reduction. Kinemetrics' personnel working under my supervision digitized the analog data, prepared acceleration time-histories, calculated velocity and displacement time-histories, and then calculated response spectra for the two sensor locations. Exhibit "B" attached hereto, entitled "Strong-Motion Data Report for the M_L 5.0 Earthquake of 1147 EST, January 31, 1986, Perry Ohio," dated February 4, 1986 (Revision 1, dated February 19, 1986), is complete and accurate report of the reduction of the January 31, 1986 earthquake data.

Kalman Lee Benuska

Kalman Lee Benuska

Subscribed and sworn to before me
this 24th day of February, 1986.

OFFICIAL SEAL
BRENDA L. ALVAREZ
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
My Comm. Expires March 25, 1988

Brenda L. Alvarez

Notary Public

My Commission Expires: March 25, 1988

EXHIBIT "A"

KALMAN LEE BENUSKA
YEAR OF BIRTH: 1937

EDUCATION: B.S., Engineering
University of California, Berkeley

M.S., Engineering
University of California, Berkeley

REGISTRATION: Civil Engineer, State of California

Structural Engineer, State of California

SUMMARY:

4 Years: General Management of an integrated company producing instrumentation, software, systems and services for seismology and earthquake engineering.

12 Years: Technical management of development and applications in instrumentation and analysis of civil construction.

2 Years: Technical management of a company engaged in design and manufacture of concrete modular housing.

6 Years: Associate in firm of consulting structural engineers with emphasis on structural safety applications.

Present: Mr. Benuska is a Vice President and Director of Kinemetrics, Inc. of Pasadena, California. He is General Manager of Kinemetrics Systems; with responsibility for sales, production, product design and service of instrumentation, software and systems used in seismology and earthquake engineering.

1972 to 1981: Mr. Benuska was Manager of the Services Department of Kinemetrics Systems; with responsibility for installation, maintenance, field measurement programs, analysis of seismic and structural vibration data, and structural integrity monitoring as a service to civil and structural engineers.

KINEMETRICS SYSTEMS

1969 - 1971: As Vice President of Engineering for Stressed Structures, Inc. of Denver, Colorado, Mr. Benuska was responsible for product development and design of a flexible housing module utilizing advanced concrete technology and factory assembly line fabrication techniques. He organized the company's engineering division and laboratory effort. The housing system, known as Uniment, was successfully brought through the design concept and prototype stages and into production. Mr. Benuska was Executive Vice President and Secretary of the Company when he resigned.

1967 - 1969: Mr. Benuska managed the engineering geophysics and structural dynamics activities of Earth Sciences, a Teledyne company, of Pasadena, California. He had technical and financial management responsibility for instrumentation development and sales, dynamic analysis services, field installation of instruments and monitoring of structural behavior, and geophysical surveys of foundations.

1961 - 1967: As an Associate in the firm of T.Y. Lin and Associates, consulting structural engineers, he managed the Special Projects Division.

As project manager and principal investigator, he managed research efforts such as the development of a computer program to analyze the dynamic response to nuclear blast of high-rise buildings; performed computer studies of the behavior of buildings during earthquakes, which led to a recommended earthquake design code for the Federal Housing Administration; and developed a computer program to analyze tall cylindrical towers subjected to nuclear blast for the Naval Facilities Engineering Command.

Mr. Benuska's professional design background includes various assignments in feasibility studies and preliminary design of construction projects. He has been responsible for the structural design, preparation of specifications and normal construction supervision of over $100 million of building construction. He has also served as earthquake design consultant for various multi-story apartment, office and hotel building.

PROFESSIONAL DATA: Mr. Benuska is a member of the American Society of Civil Engineers, the Structural Engineers Association of California, the Seismological Society of America, the United States Committee on Large Dams, and the Earthquake Engineering Research Institute. Mr. Benuska is a member of Phi Beta Kappa, Tau Bet Pi and Chi Epsilon.

PUBLICATIONS:

"A Computer Program to Analyze the Dynamic Response of High-Rise Buildings to Nuclear Blast Loading," Vols. I and II, with R.W. Clough, and E.L. Wilson, Office of Civil Defense, OCD-OS-63-172, January 1964.

"Reusability of Buildings After a Warfire," with G.E. Troxzell, J.G. Degenkolb Washington, D.C., OCD-OS63-172, January 1964.

"Inelastic Earthquake Response of Tall Buildings," with R.W. Clough and E.L. Wilson, Proceedings, Third World Conference on Earthquake Engineering, New Zealand, January 1965.

"Computer Analysis of Protective Structure for Protection from Nuclear Blast," Office of Civil Defense, OCD-PS-65-7, Washington, D.C., June 1965.

"Resistance of Tubular Structures to Dynamic Loading," with S.K. Takahashi and W.E. Gates, Technical Report R-463, U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, July 1966.

"FHA Study of Seismic Design Criteria for High-Rise Buildings," with R.W. Clough, U.S. Department of Housing and Urban Development, Federal Housing Administration, HUD TS-3, August 1966.

"A Computer Program for the Dynamic Response of Box-Type Structures," with I.R. Stubbs, OCD-PS-64-201, 1157B, Office of Civil Defense, Washington, D.C., December 1966.

"Nonlinear Earthquake Behavior of Tall Buildings," with R.W. Clough, Journal of the Engineering Mechanics Division, ASCE, Vol. 93, No. EM3, June 1967.

"Systems for Measuring the Earthquake Response of Civil Construction," with J.R. Stagner, presented at University of California at Berkeley, June 1968.

"Self-Stress Concrete for Precast Building Units," with V.V. Bertero and M. Polivka, Sixth Congress, Federation Internationale de la Precontrainte, Prague, June 1970.

"Dynamic Response of Tubular Towers to Simulated Ground Motion and Air Blast," with S.K. Takahashi and W.E. Gates, Third Japan Earthquake Engineering Symposium, Tokyo, November 1970.

"Dynamic Analysis of Building Failures," with R.W. Clough, The Great Alaska Earthquake of 1964, Engineering Volume, National Academy of Sciences, 1973, pp 283-307.

"Elevator Earthquake Safety Control," with S. Aroni and W. Schroll, Sixth World Conference on Earthquake Engineering, New Delhi, January 1977.

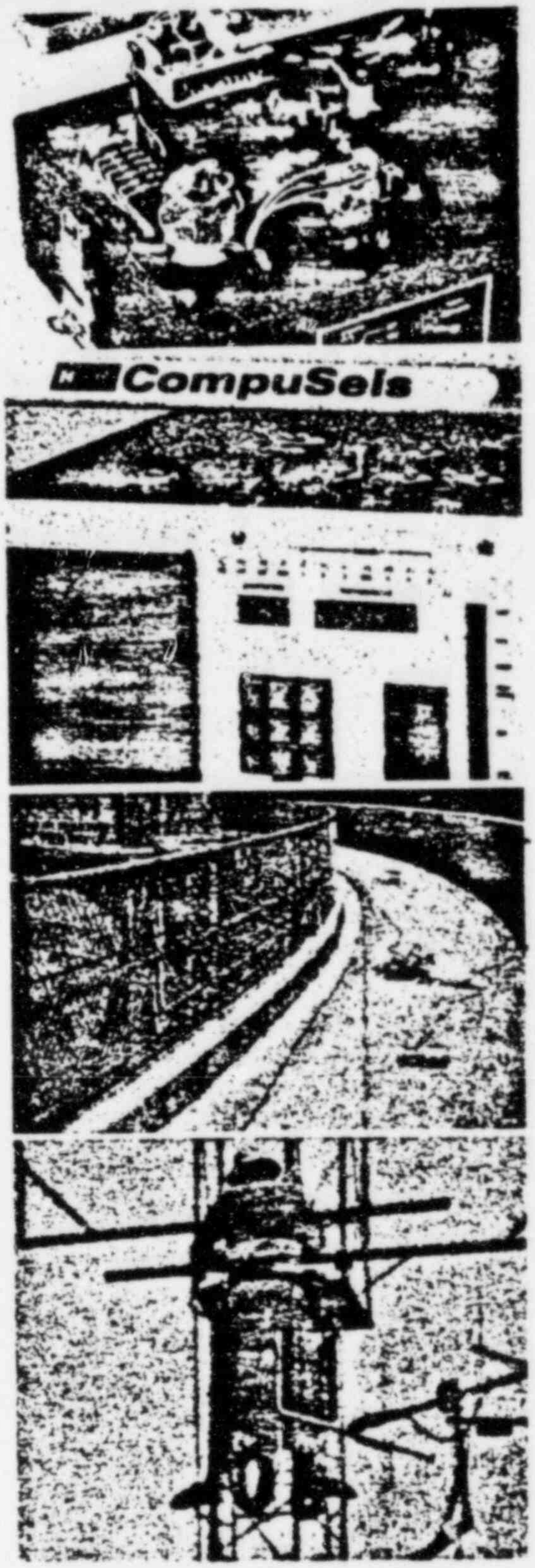
"Ambient Vibration of Structures," with G.C. Hart, Proceedings, Second Annual Engineering Mechanics Division Specialty Conference, Raleigh, North Carolina, May 1977.

"Dynamic Properties of an Arch Dam," with B. Hoerner and R. Van Orden, Proceedings, Second Annual Engineering Mechanics Division Specialty Conference, Raleigh, North Carolina, May 1977.

"Structural Characterization of Concrete Chimneys," with J.G. Diehl, Proceedings of the Second Specialty Conference on Dynamic Response of Structures, ASCE, Atlanta, Georgia, January 1981, pp 152-163.

"Strong Ground Motion Record the the 16 September 1978 Tabas, Iran, Earthquake," with D. Hadley and H. Hawkins, Bulletin of the Seismological Society of America, Vol. 73, No. 1, February 1983, pp 315-320.

EXHIBIT "B"



ML 5.0 EARTHQUAKE

JANUARY 31, 1986

STRONG-MOTION DATA

from the

PERRY NUCLEAR POWER PLANT

SEISMIC INSTRUMENTATION

February 3, 1986

KINEMETRICS

STRONG-MOTION DATA REPORT

for the

M_L 5.0 EARTHQUAKE

of

1147 EST, JANUARY 31,1986

PERRY, OHIO

RECORDED ON THE

PERRY NUCLEAR POWER PLANT

STRONG MOTION ACCELEROGRAPHS

for

Cleveland Electric Illuminating Company

Requisition No. NED-E-860006

by

Kinemetrics/Systems
222 Vista Ave.
Pasadena, CA 91107

Sales Order C-K6028

February 4, 1986

February 19, 1986, Revision 1

TABLE OF CONTENTS

1.0 INTRODUCTION

On January 31, 1986, a (M_L 5.0) 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, and response spectra.

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 triaxial trigger detects an earthquake. The trigger then actuates recording in less than .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 1.0g. The dynamic range of the accelerograph is nominally 40 dB, giving it a resolution of approximately .01g.

The trigger in the SMA-3 has a flat (-3dB) response from 1 to 10 Hz and a nominal trigger level of 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 three Model SMA-3 accelerographs which recorded the event were factory calibrated in January, 1985, and the sensors were recalibrated for sensitivity by the Perry NPP personnel in December of 1985. These most current calibration data are given in Table 1 below.

Ser. No.	Channel	Sens., v/g	Nat. Freq., Hz	Damping % critical
165-1	long	2.48	52.3	65
	tran	2.49	53.7	65
	vert	2.47	50.6	64
165-2	long	2.48	52.6	67
	tran	2.48	52.2	72
	vert	2.65	50.5	66

TABLE 1: Calibration Data

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 DDS-1105 Digital Data System 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.

3.1 Digitization

The magnetic tapes were digitized using the DDS-1105. 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 on 9-track computer-compatible tape at 256 samples per second.

3.2 VOL1 Processing

The digitized data were demultiplexed and scaled to acceleration units using the Table 1 calibration data. 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.

3.3 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 35 Hz and a termination frequency of 40 Hz. The high-pass filter had a cutoff frequency of 0.625 Hz and a termination frequency of 0.4 Hz.

Output of this program consists of a plot of corrected acceleration, velocity and displacement for each component of recorded data. These plots are presented in the data section of this report.

3.4 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, 1, 2, 4, and 7 percent. The period range of these spectra was 1.68 to 0.0283 seconds (0.59 to 35.4 Hz) with oscillator response calculated at 1/24 th octave intervals.

Two types of plots were produced and are included in the data section of this report. The first type is the traditional tripartite log-log plot of pseudo-velocity vs. period. The second is a linear plot of velocity response and Fourier spectrum vs. frequency.

Reactor Building Foundation, Elevation 575 Ft.

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Tag Number D51-N101
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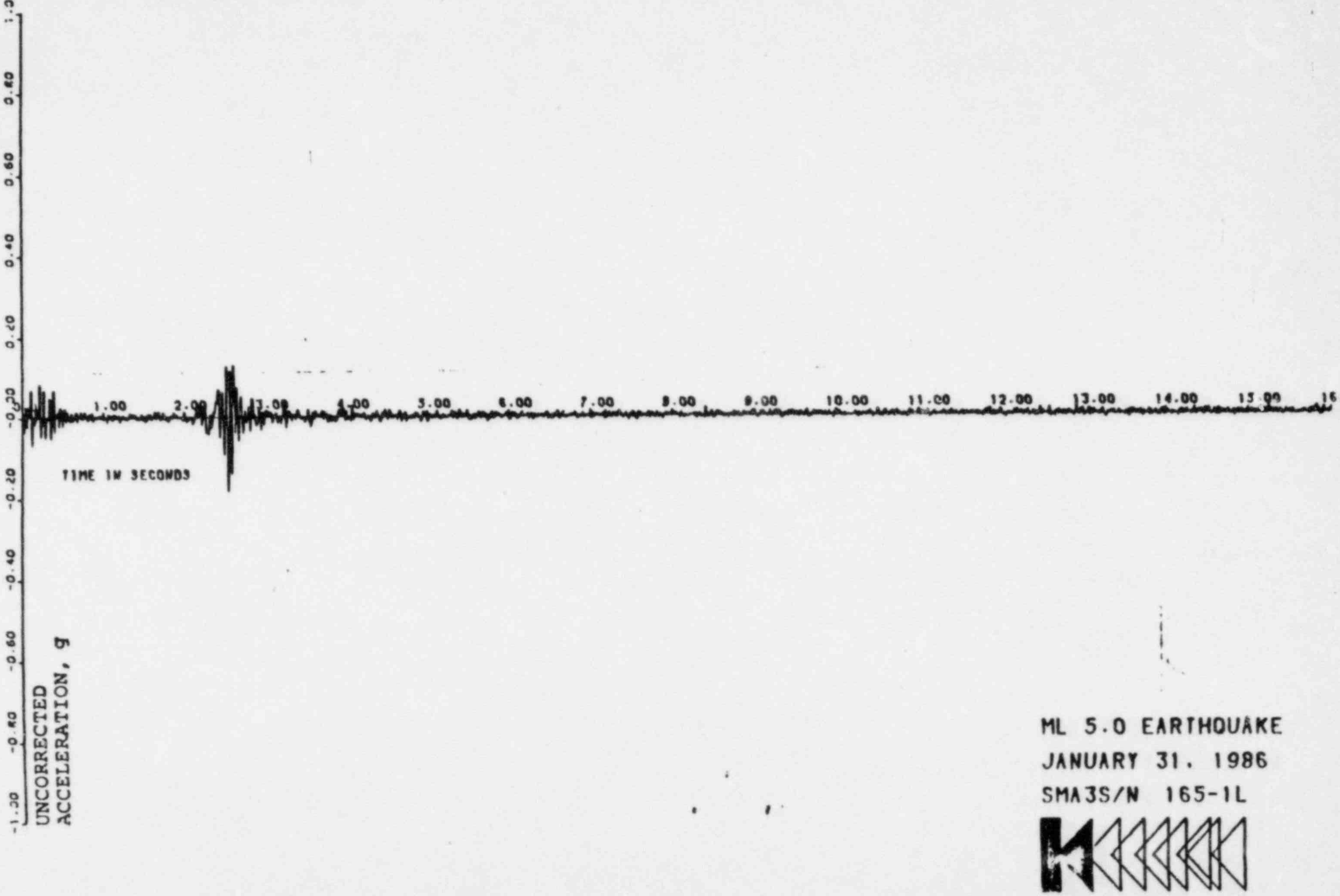
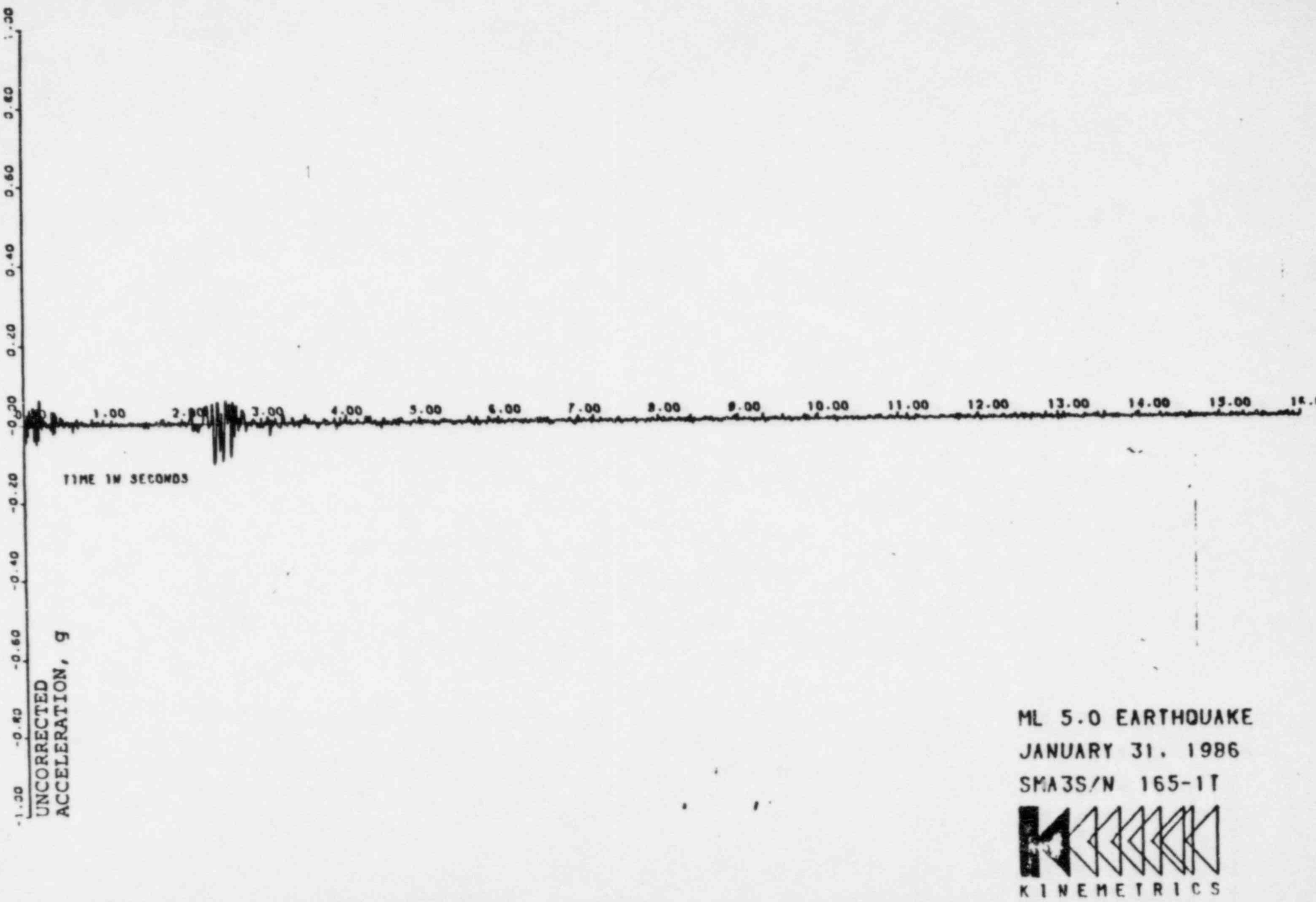
Transverse Channel - West Orientation
Vertical Channel - Up Orientation



ML 5.0 EARTHQUAKE
JANUARY 31, 1986
SMA3S/N 165-1L

KINEMETRICS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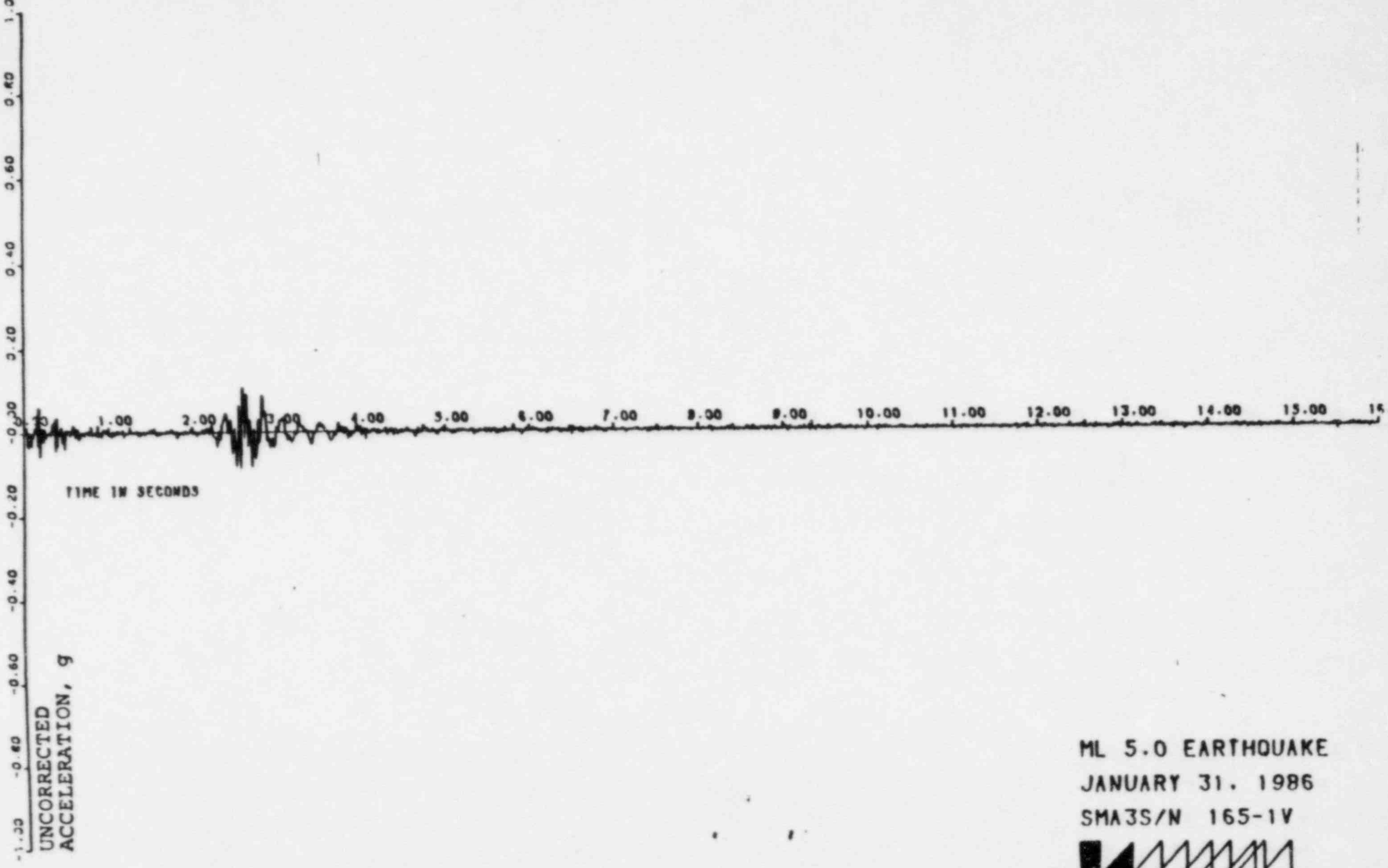
TIME IN SECONDS
ML 5.0 EARTHQUAKE
JANUARY 31, 1986
SMA3S/N 165-1T
KINEMETRICS



ML 5.0 EARTHQUAKE
JANUARY 31. 1986
SMA3S/N 165-1V

KINEMETRICS

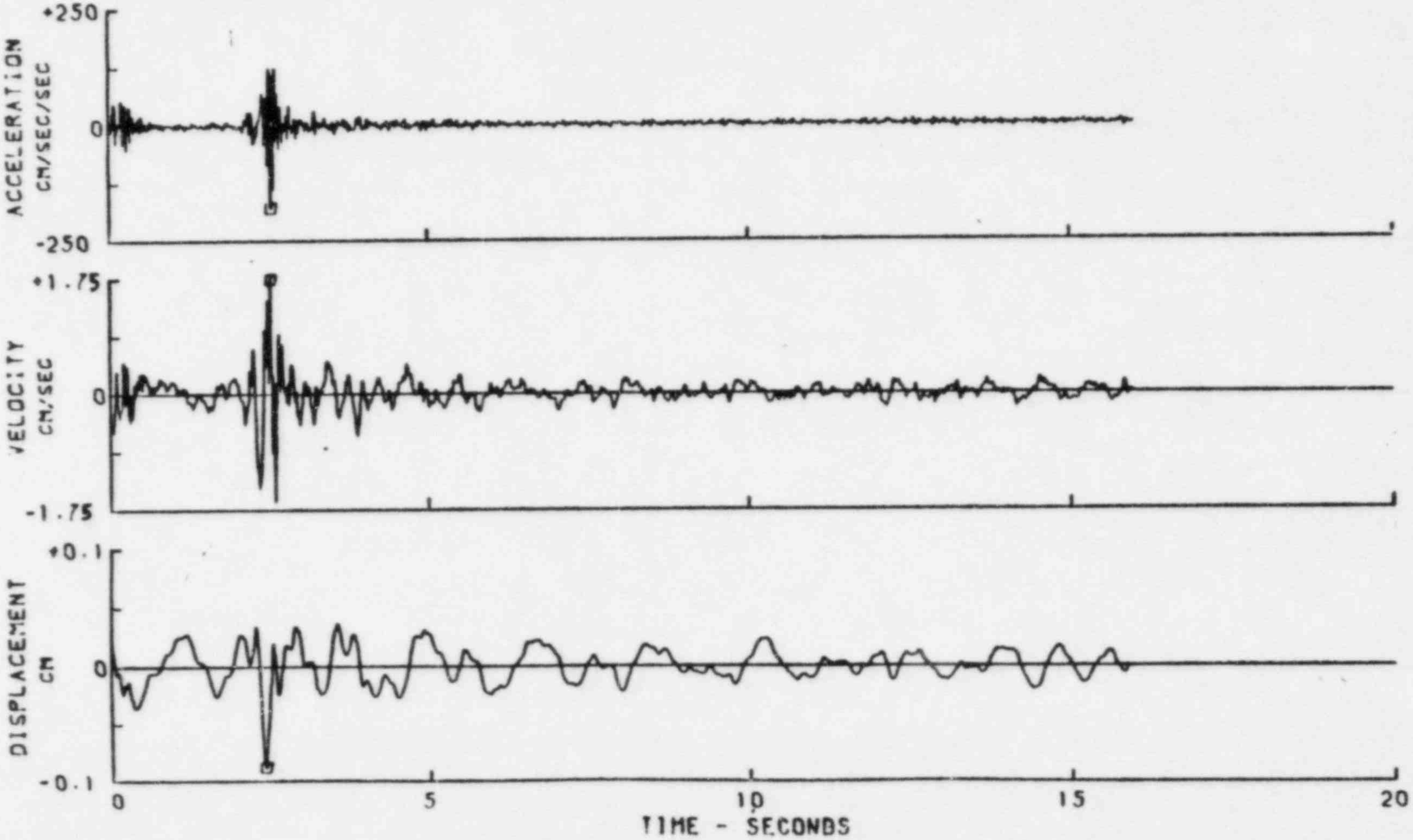
KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8001 PERRY NUCLEAR POWER PLANT COMP SOUTH SMA3S/N 165-1L

ACCELEROGRAM IS BAND-PASS FILTERED BETWEEN 0.400- 0.625 AND 35.00- 40.00 HERTZ

⊡ PEAK VALUES: ACCEL= -177.21 CM/SEC/SEC VEL= +1.74 CM/SEC DISPL=-0.09 CM



KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

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ACCELEROGRAM IS BAND-PASS FILTERED BETWEEN 0.400- 0.625 AND 35.00- 40.00 HERTZ

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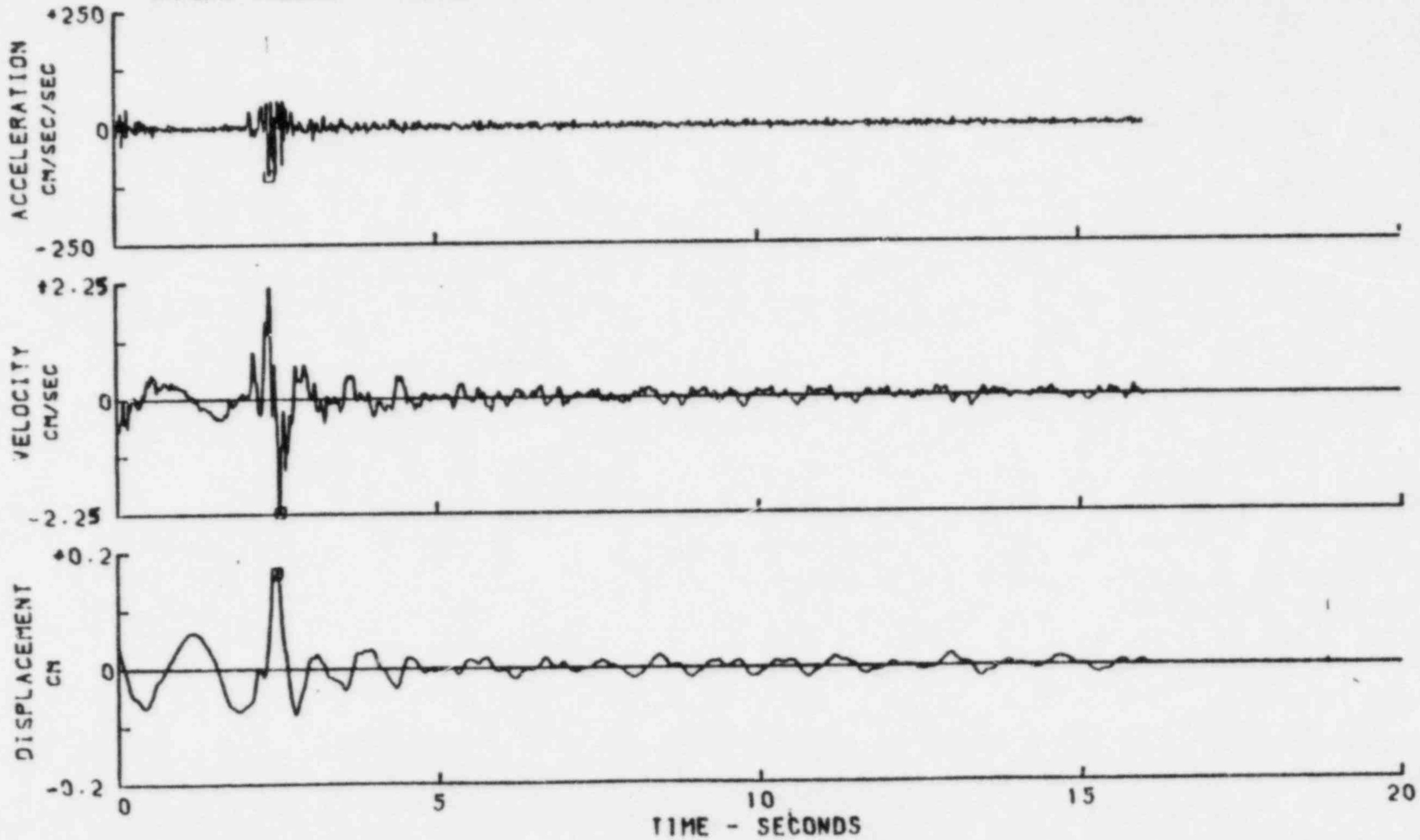

KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8001 PERRY NUCLEAR POWER PLANT COMP UP SMA3S/N 165-1V

ACCELEROGRAM IS BAND-PASS FILTERED BETWEEN 0.400- 0.625 AND 35.00- 40.00 HERTZ

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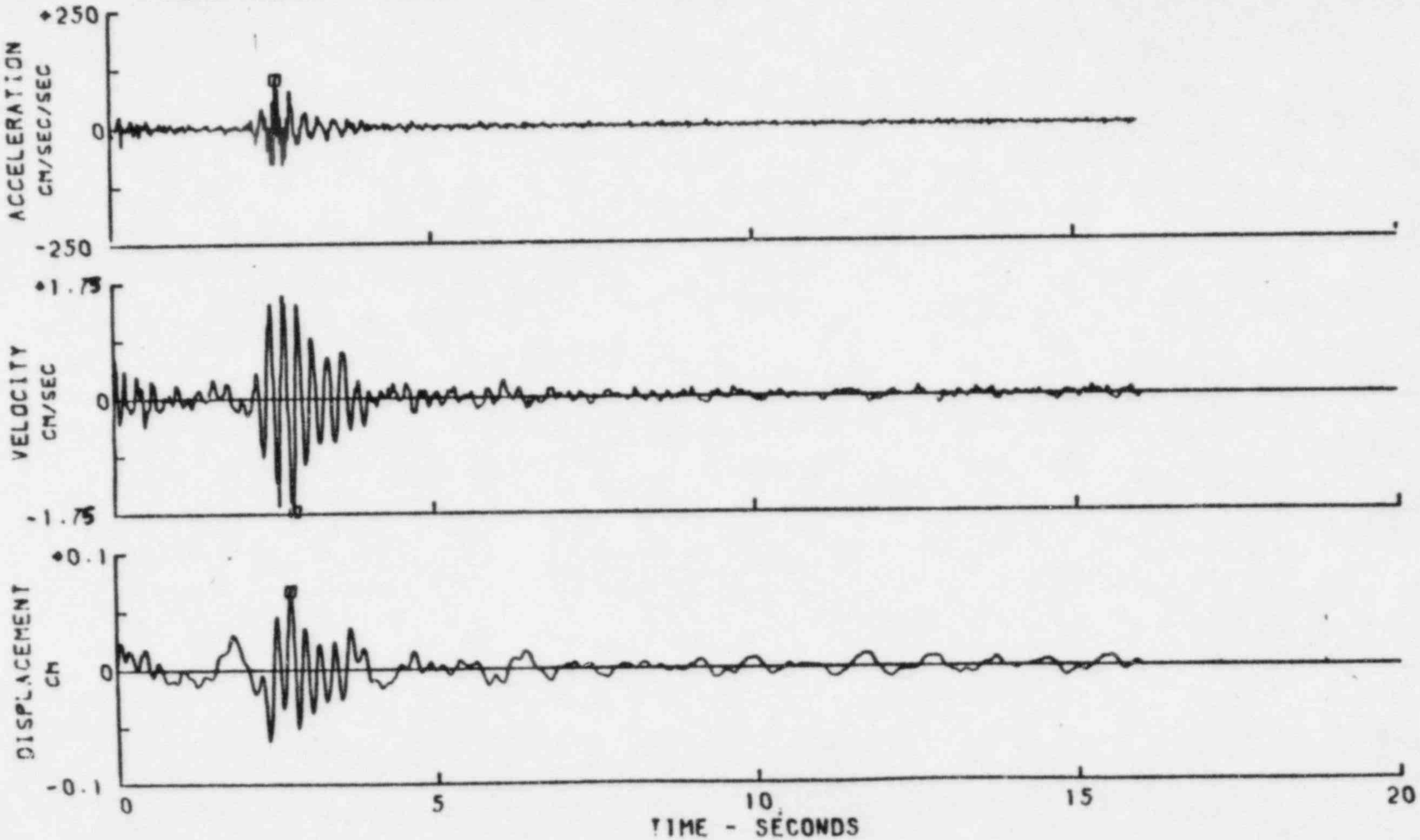

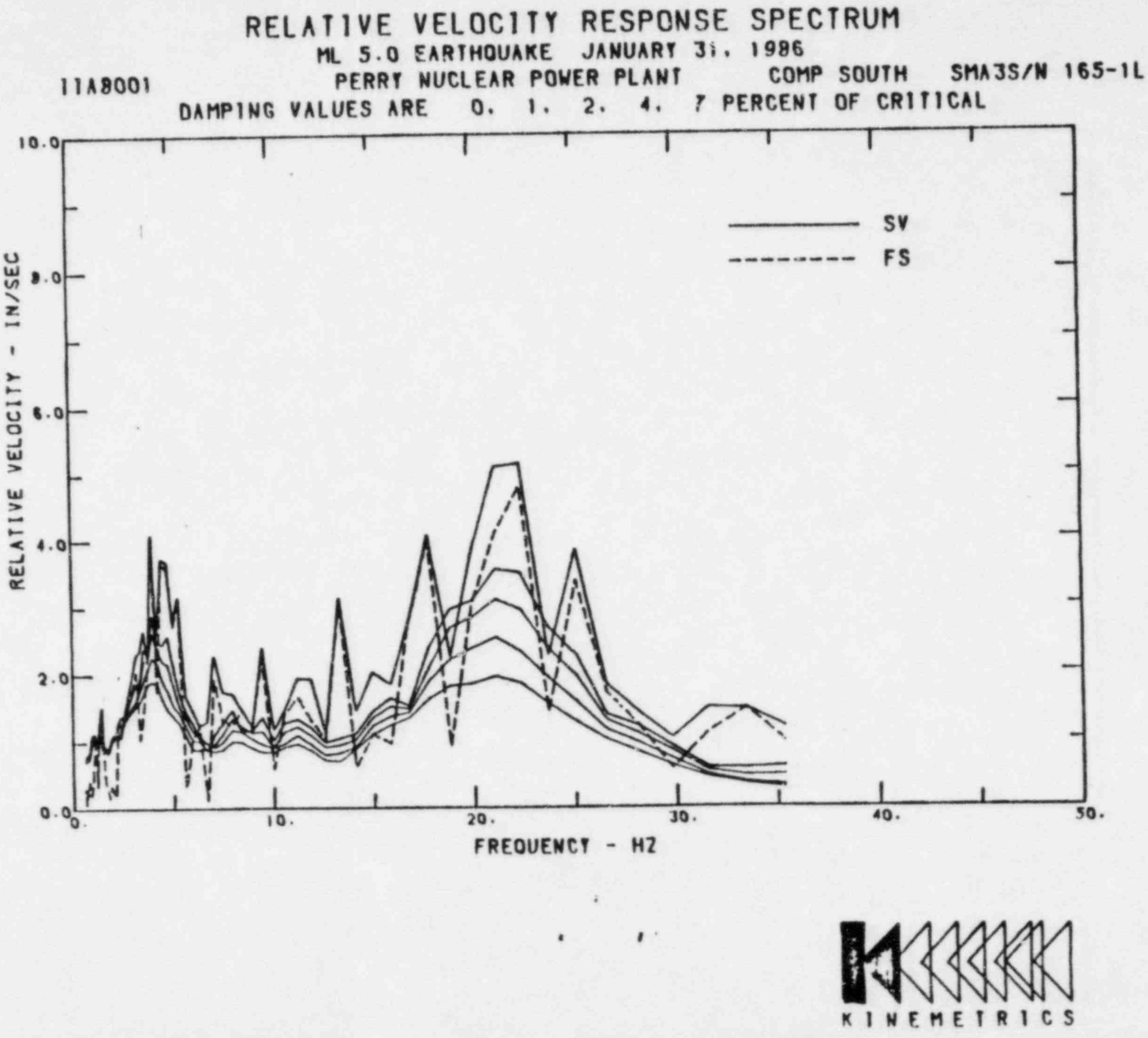
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DAMPING VALUES ARE 0. 1. 2. 4. 7 PERCENT OF CRITICAL
SV
FS
RELATIVE VELOCITY - IN/SEC
FREQUENCY - HZ
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2.0
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10.
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30.
40.
50.
KINEMETRICS

RELATIVE VELOCITY RESPONSE SPECTRUM

ML 5.0 EARTHQUAKE JANUARY 31, 1986

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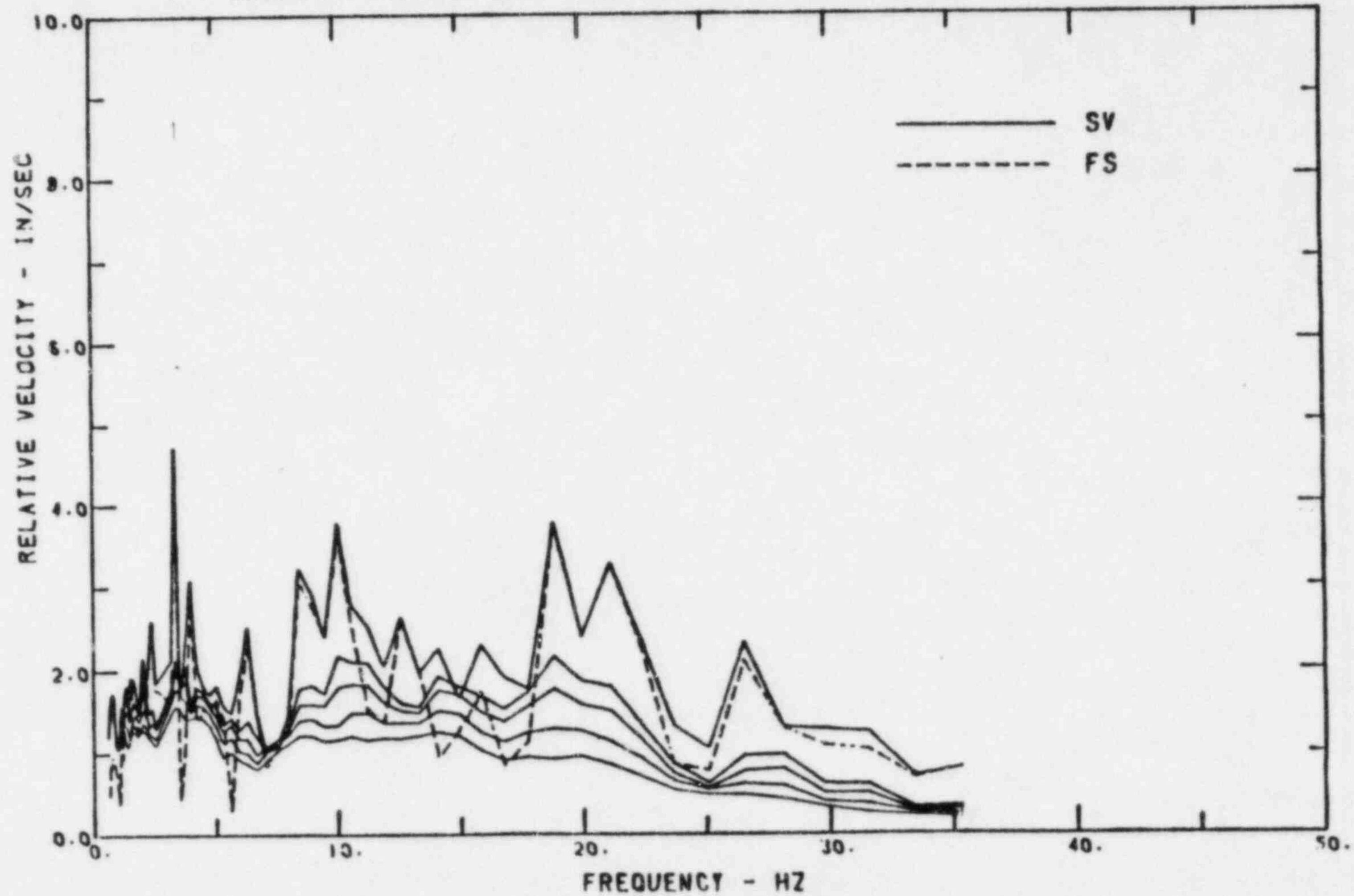

KINEMETRICS

RELATIVE VELOCITY RESPONSE SPECTRUM

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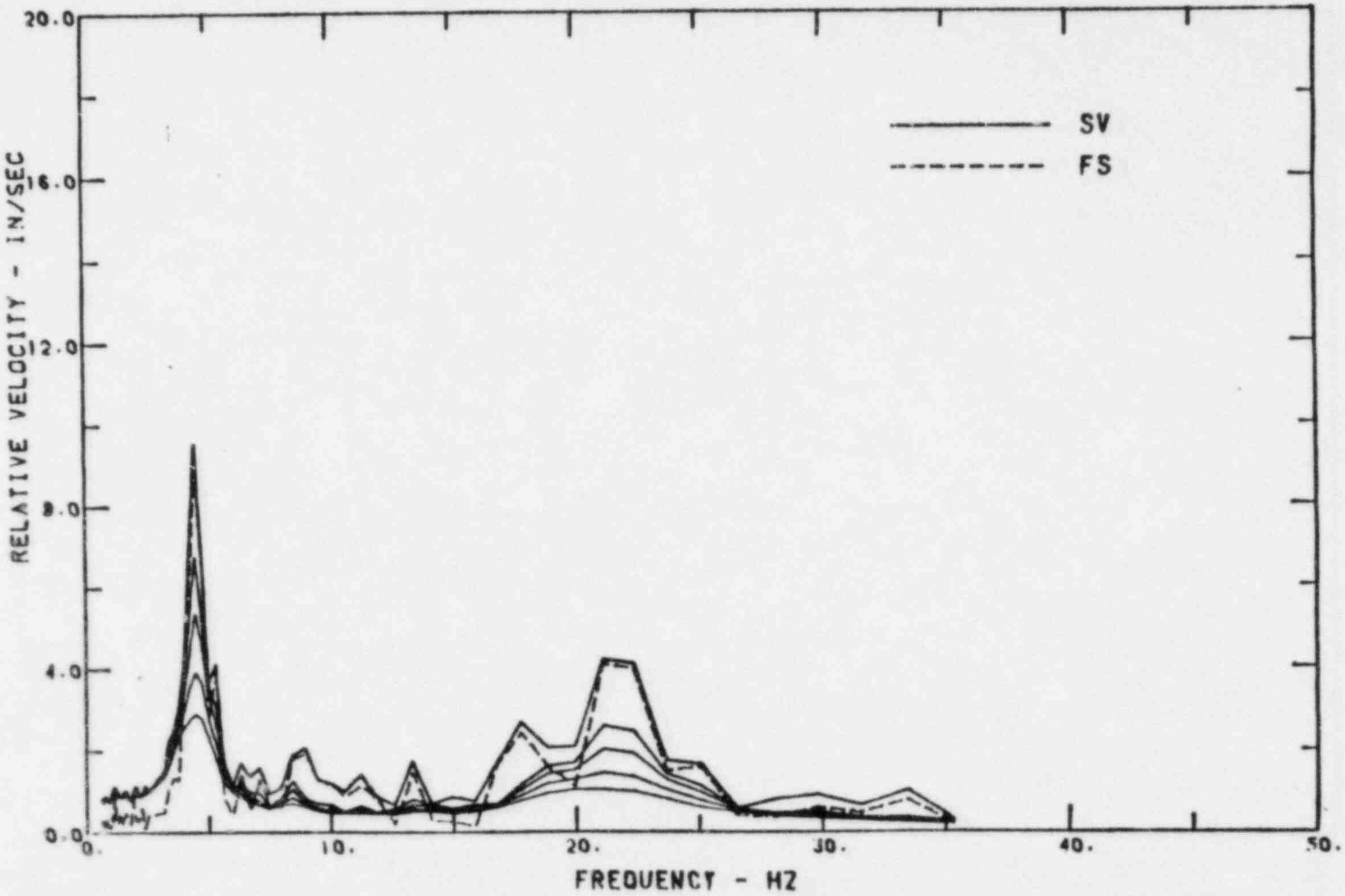

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ML 5.0 EARTHQUAKE JANUARY 31, 1986

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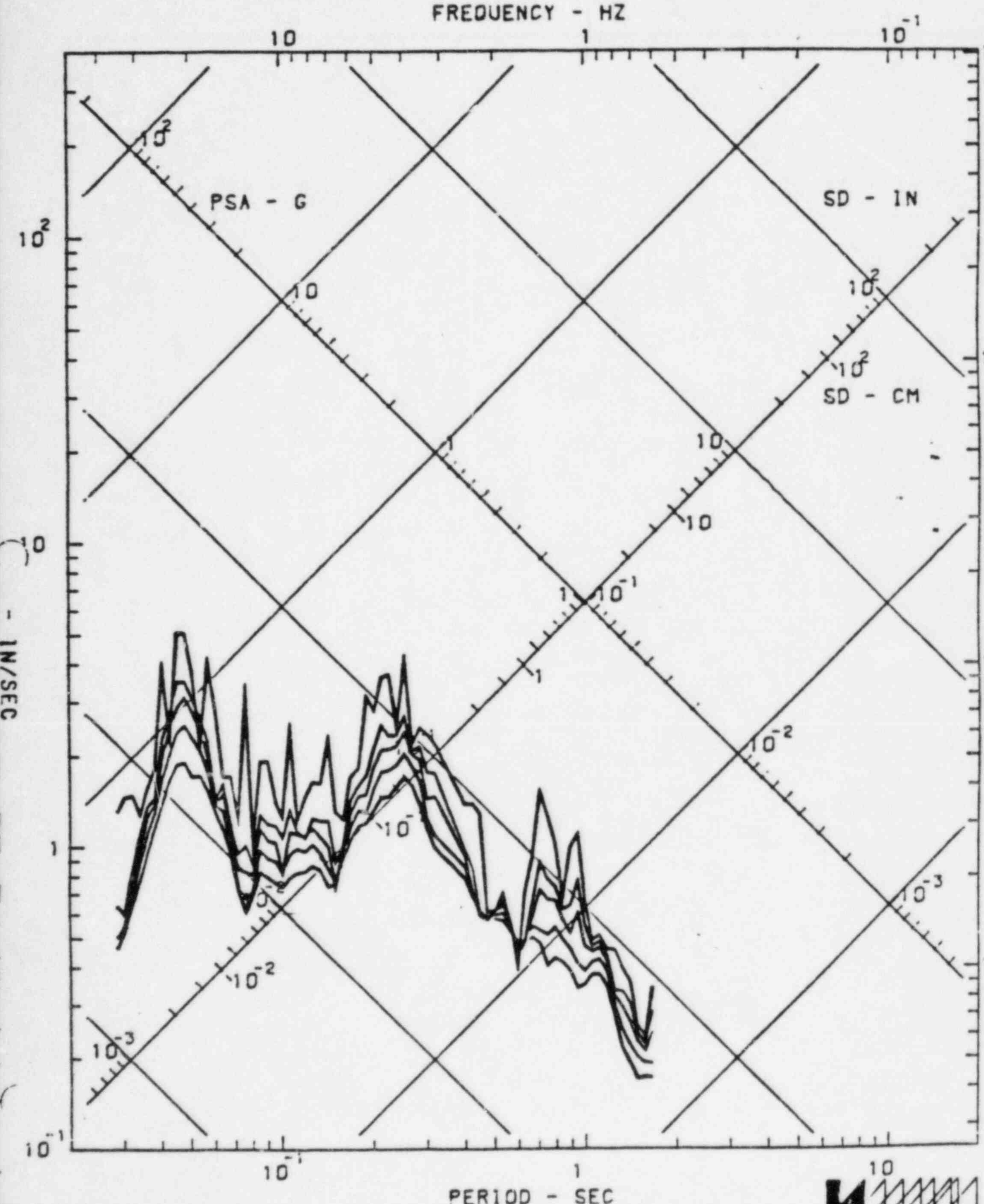

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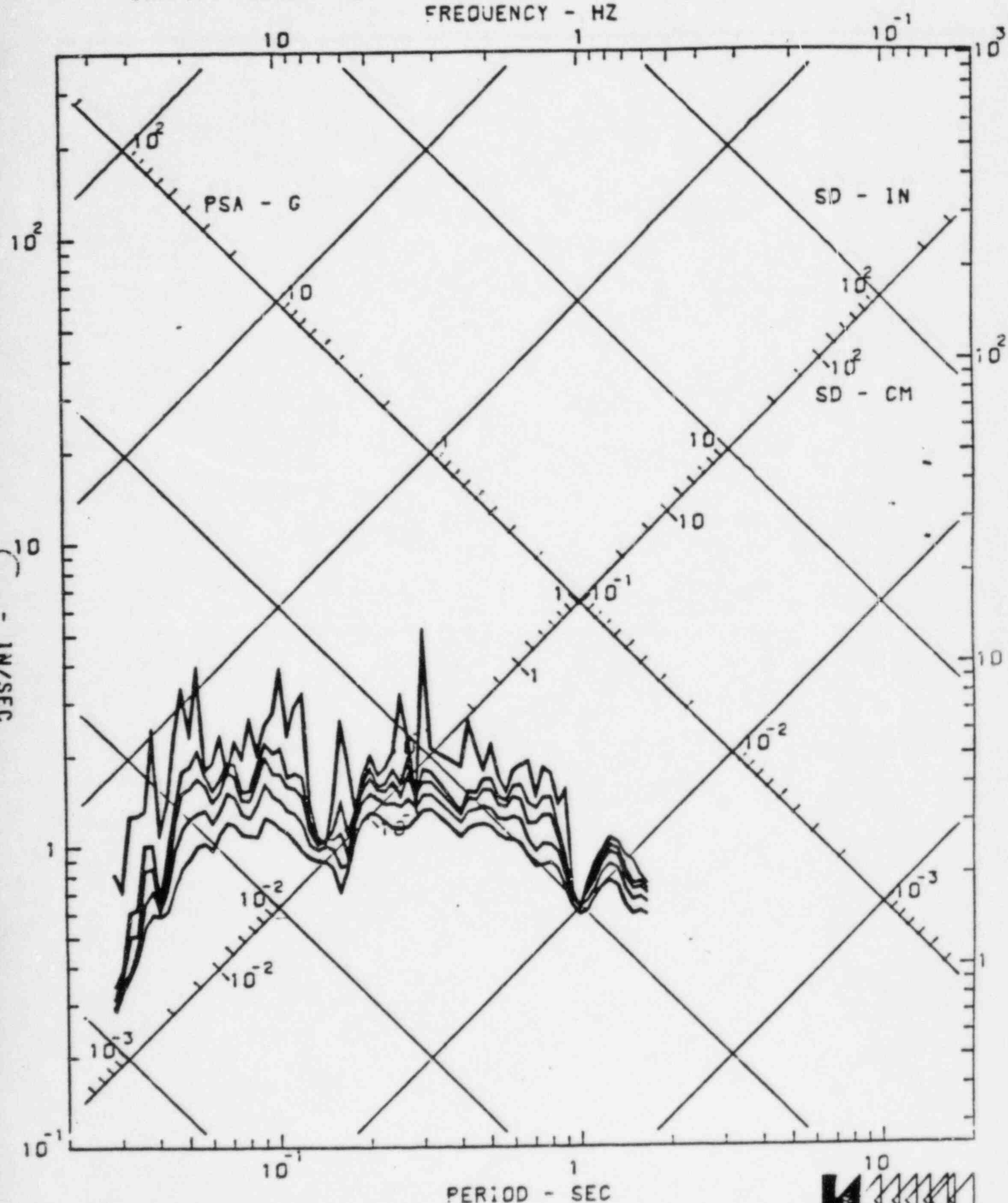

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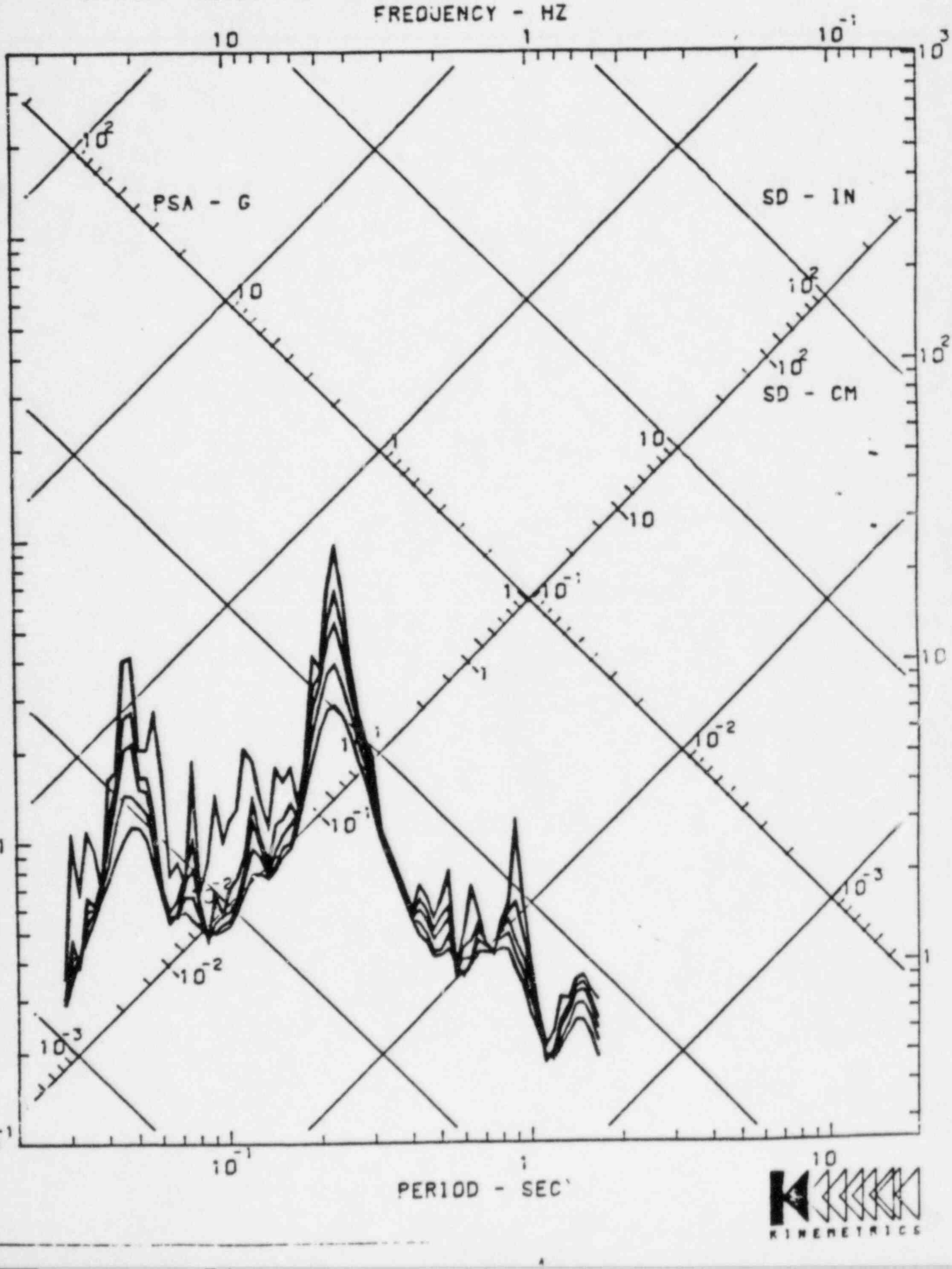

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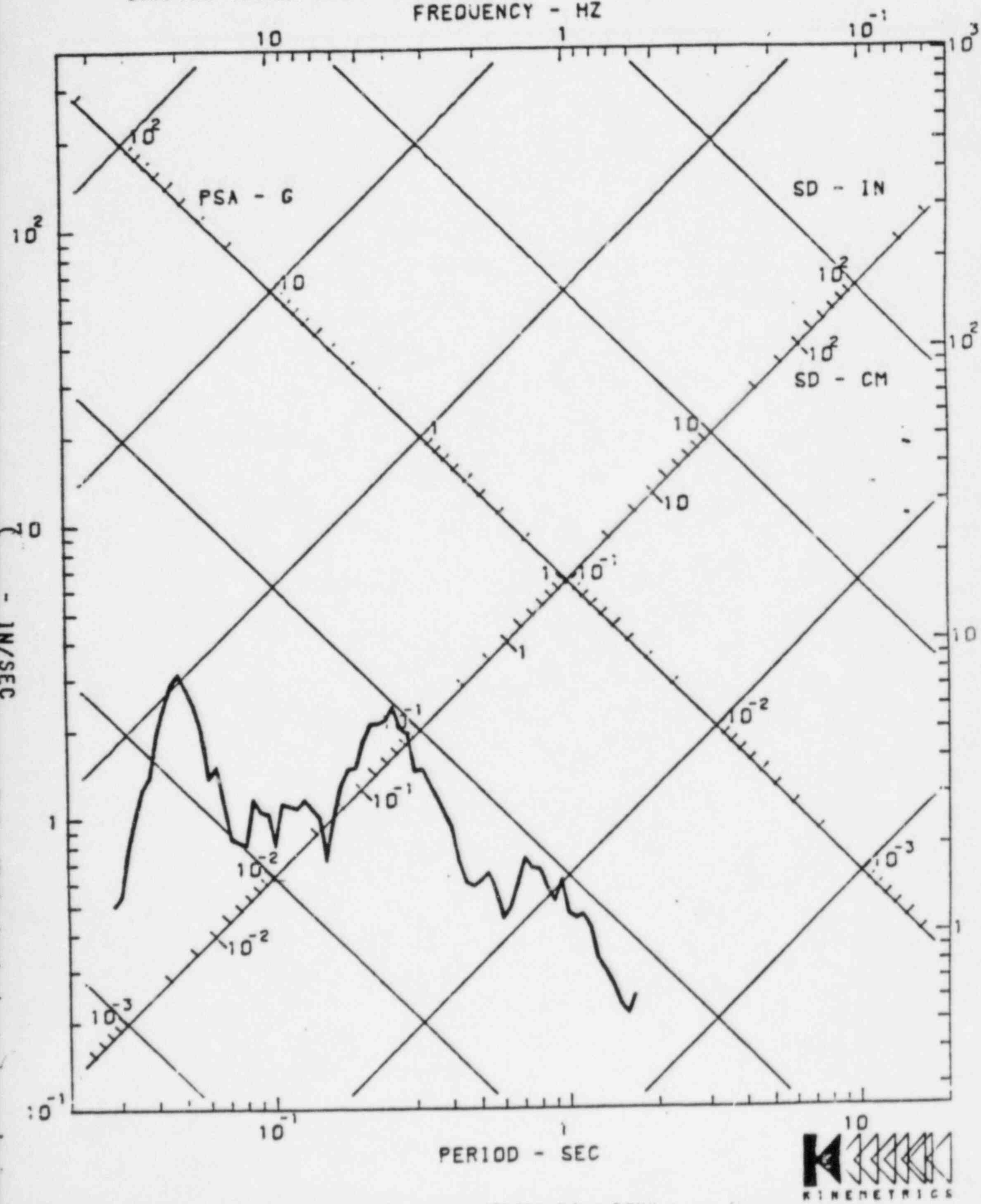

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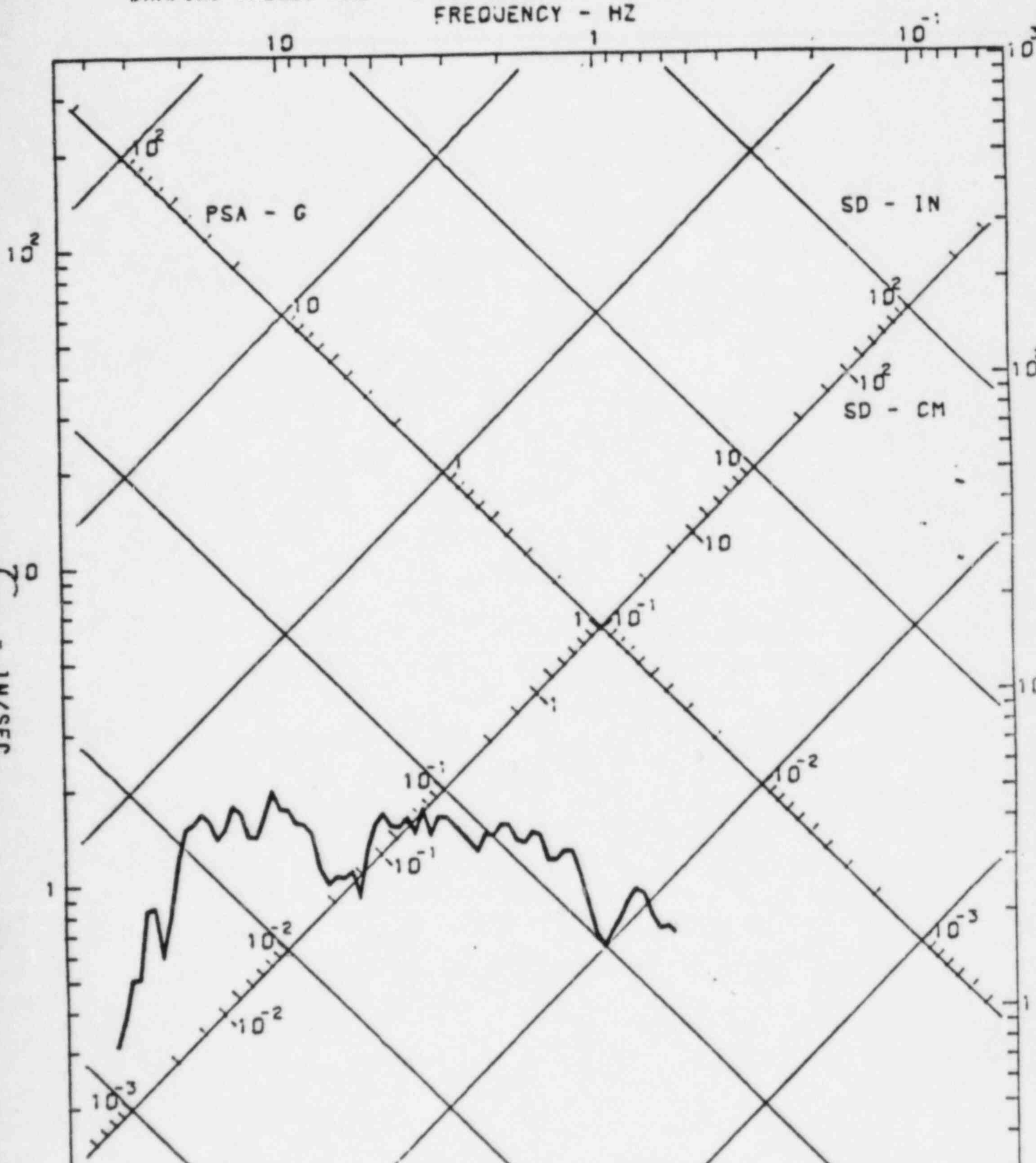

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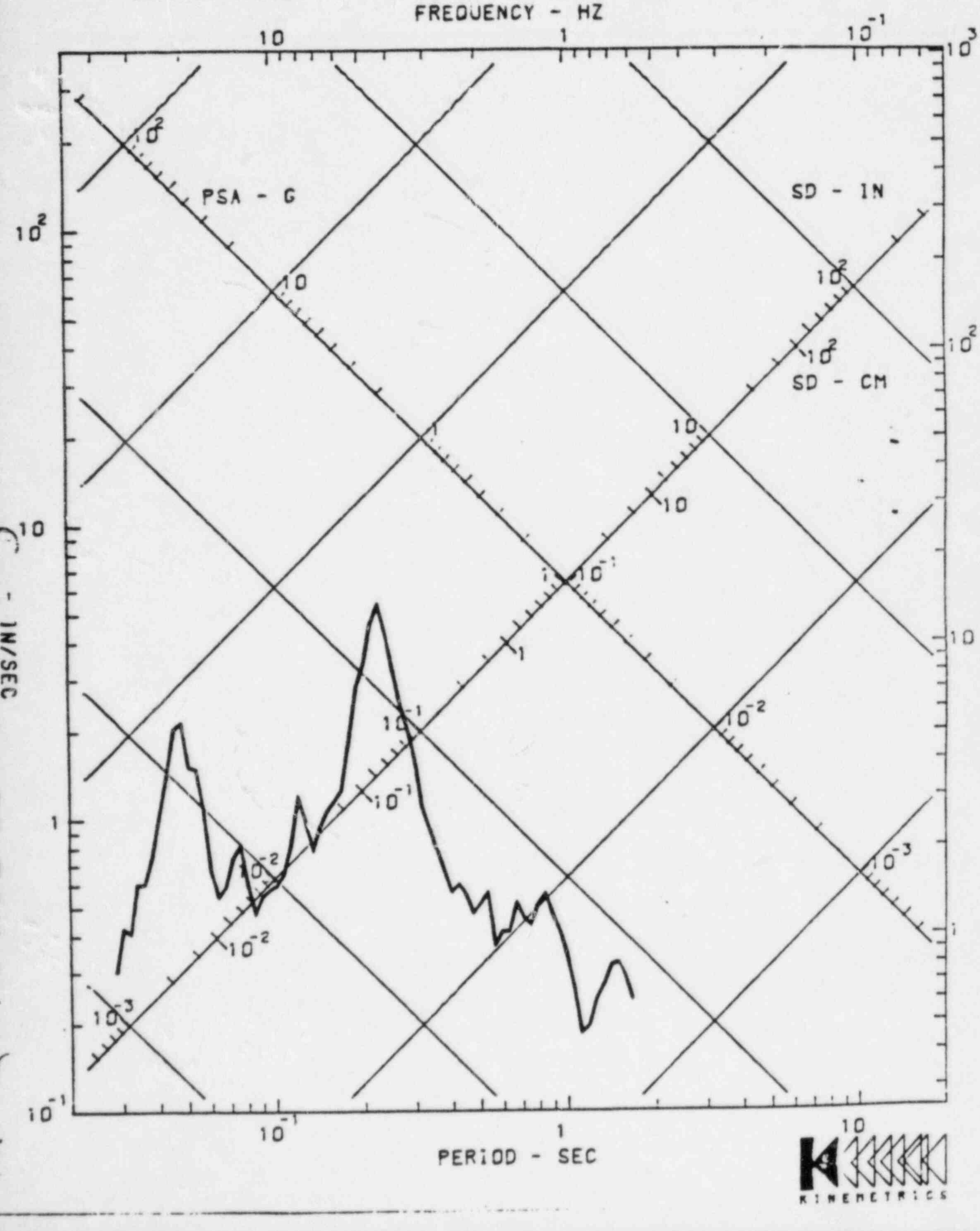

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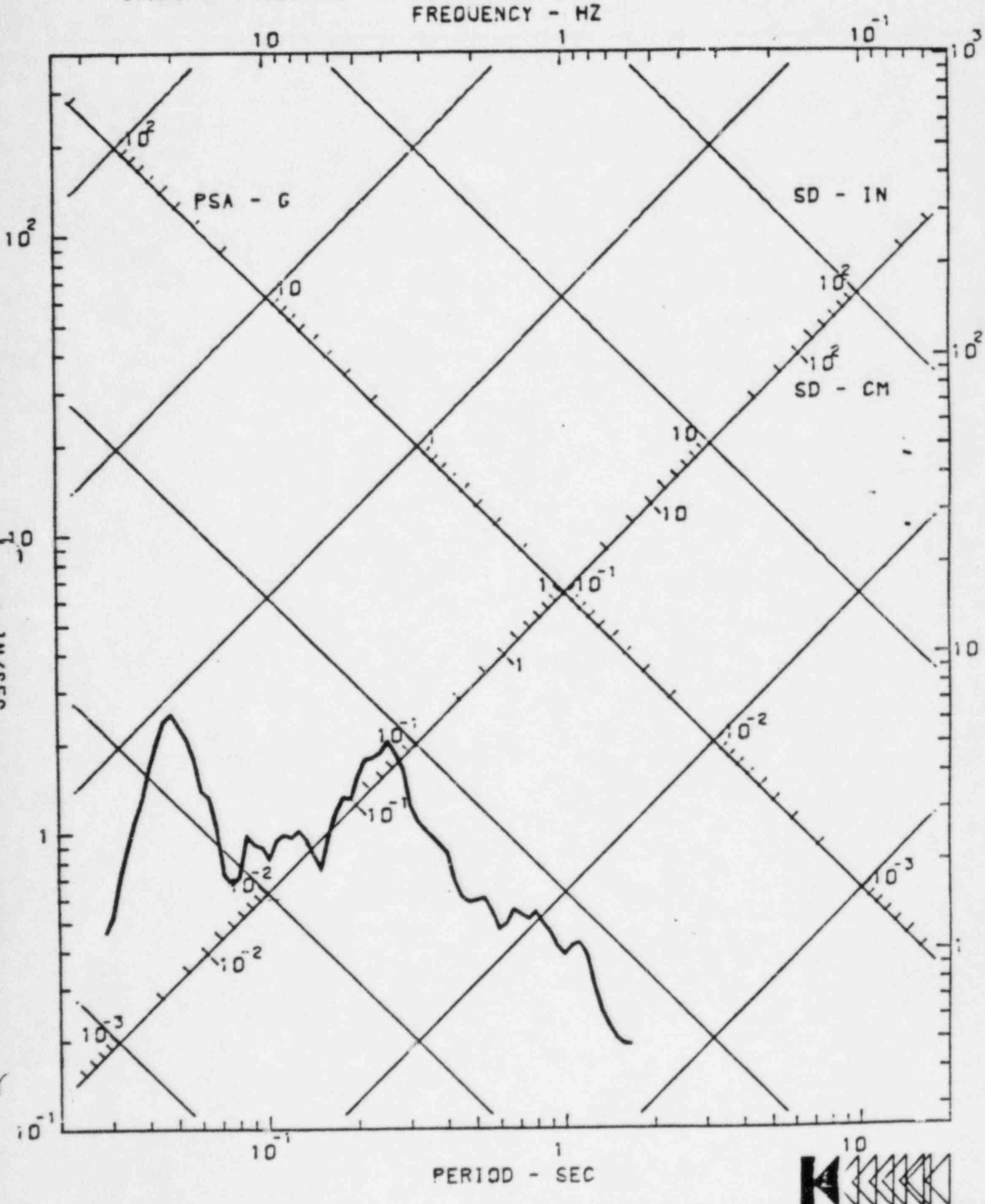

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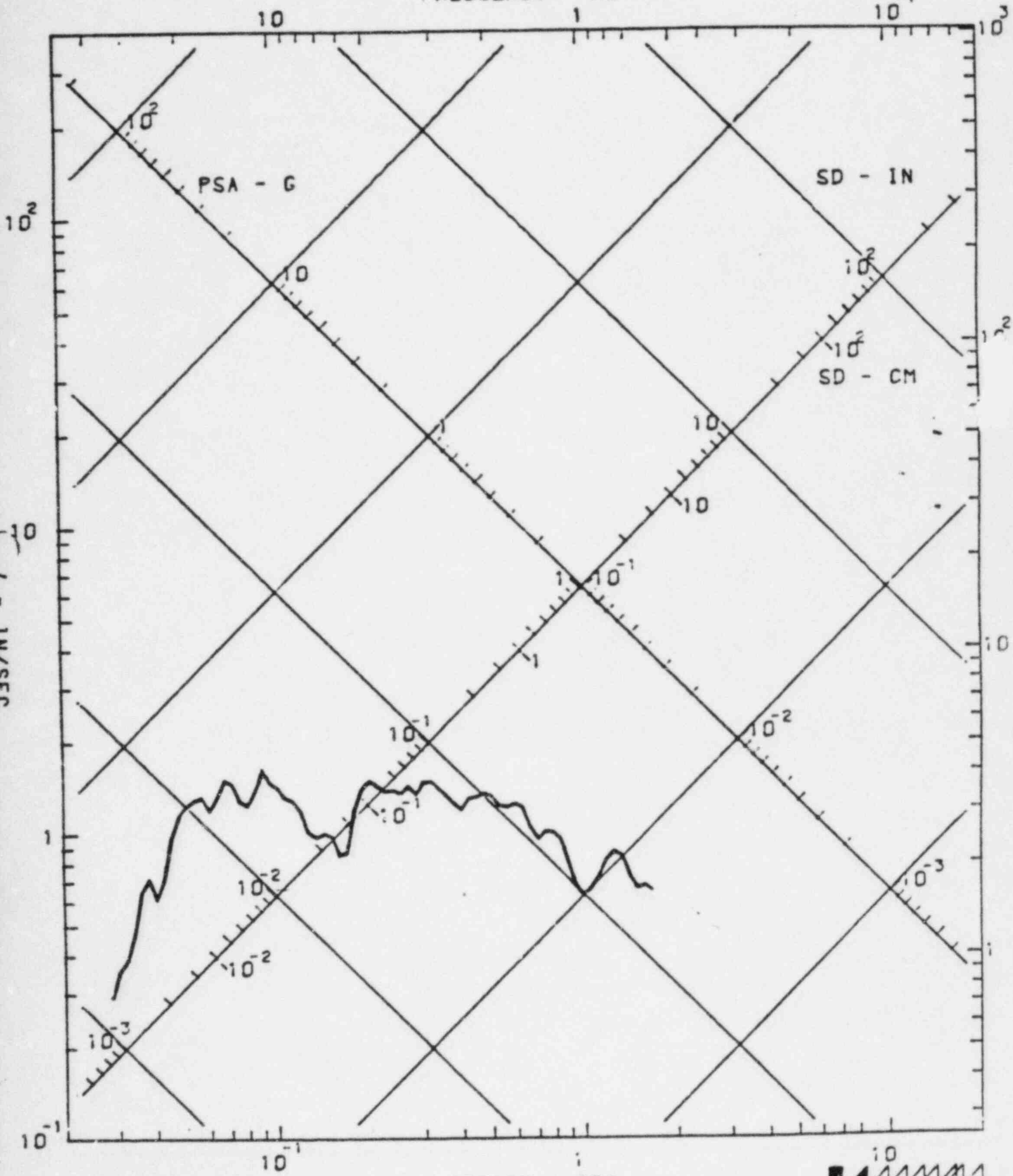

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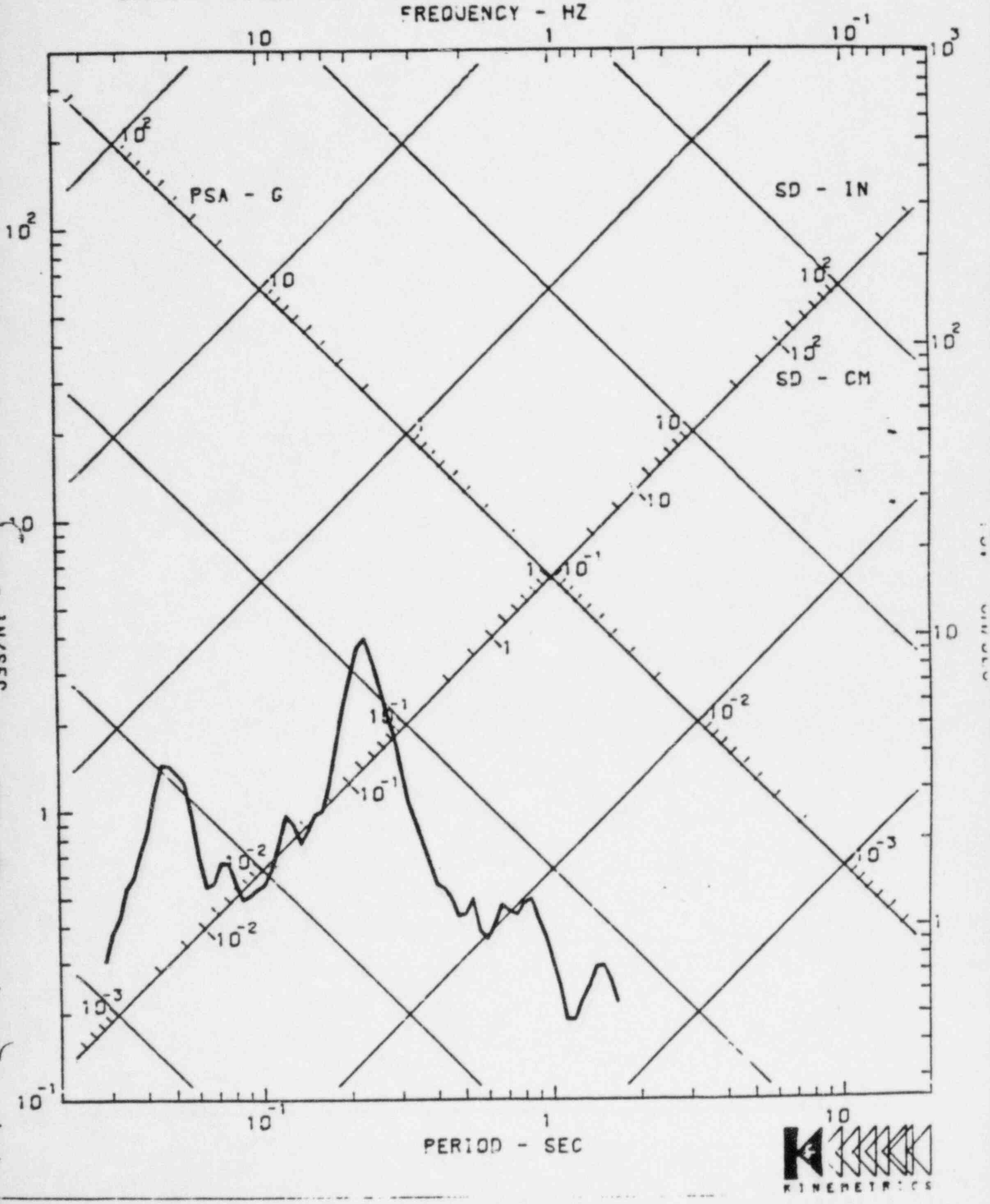
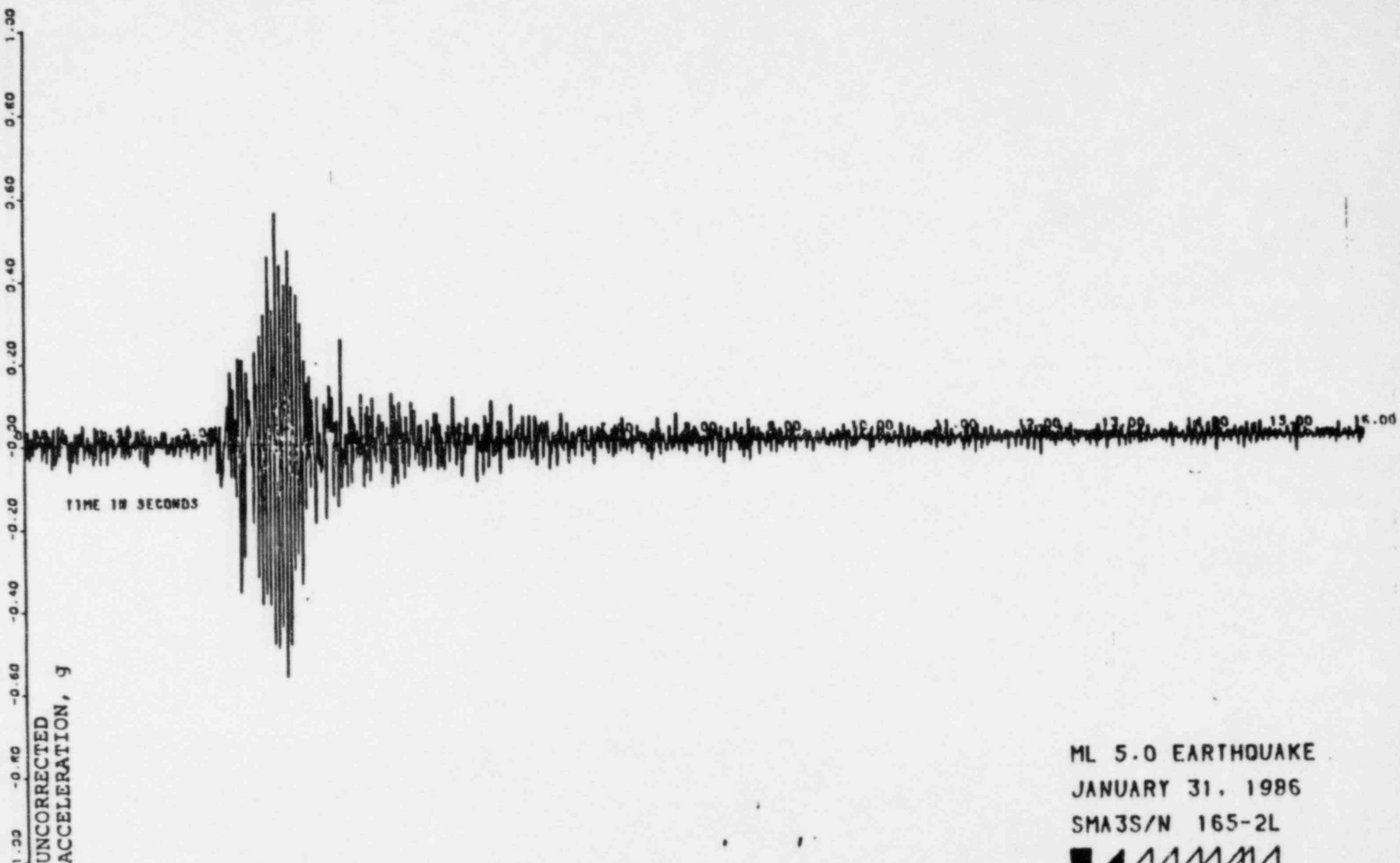


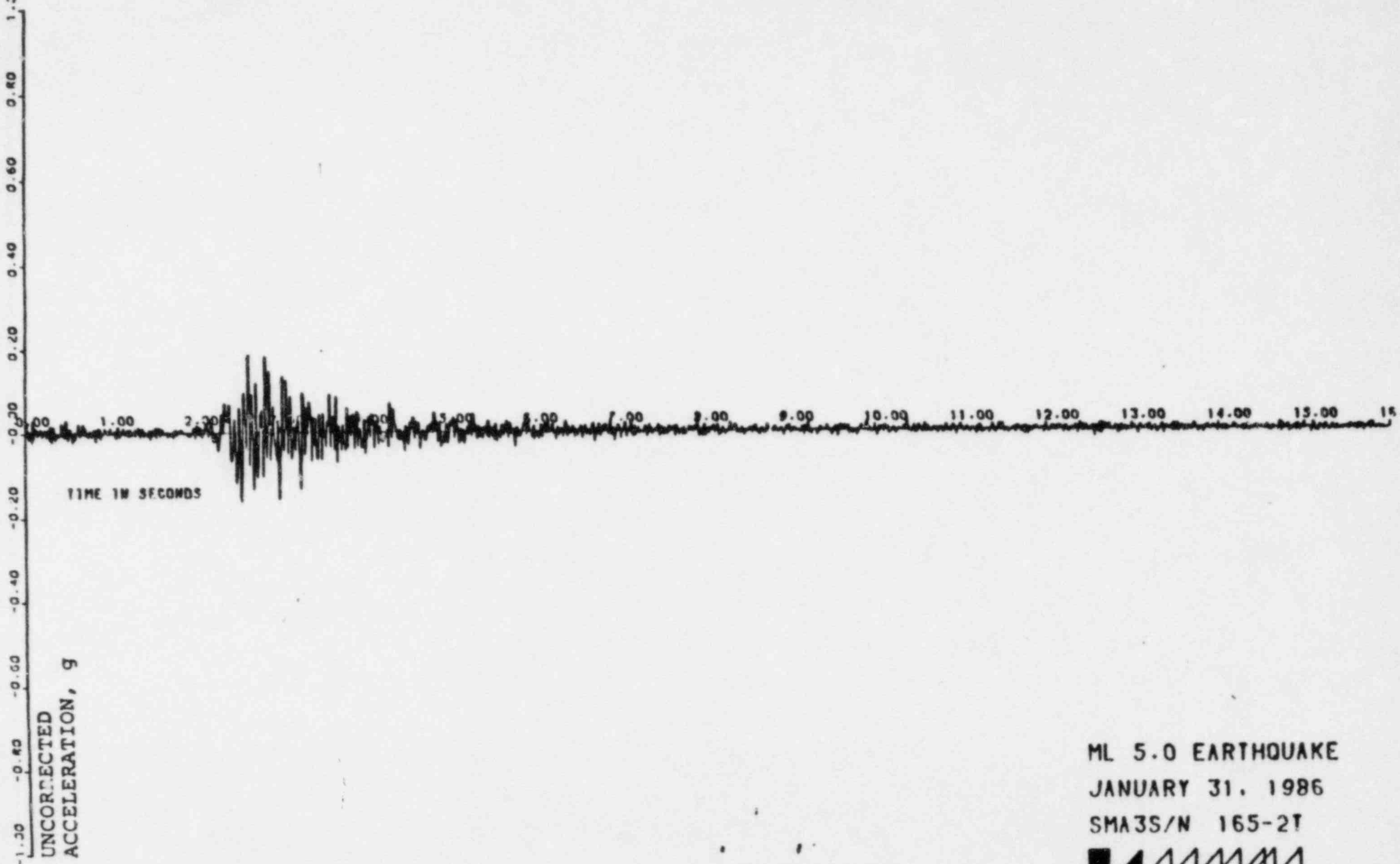
Containment Vessel Annulus, Elevation 682 Ft.

SMA-3 Serial Number 165-2
Tag Number D51-N111
Longitudinal Channel - South Orientation
Transverse Channel - West Orientation
Vertical Channel - Up Orientation



ML 5.0 EARTHQUAKE
JANUARY 31, 1986
SMA3S/N 165-2L

KINEMETRICS



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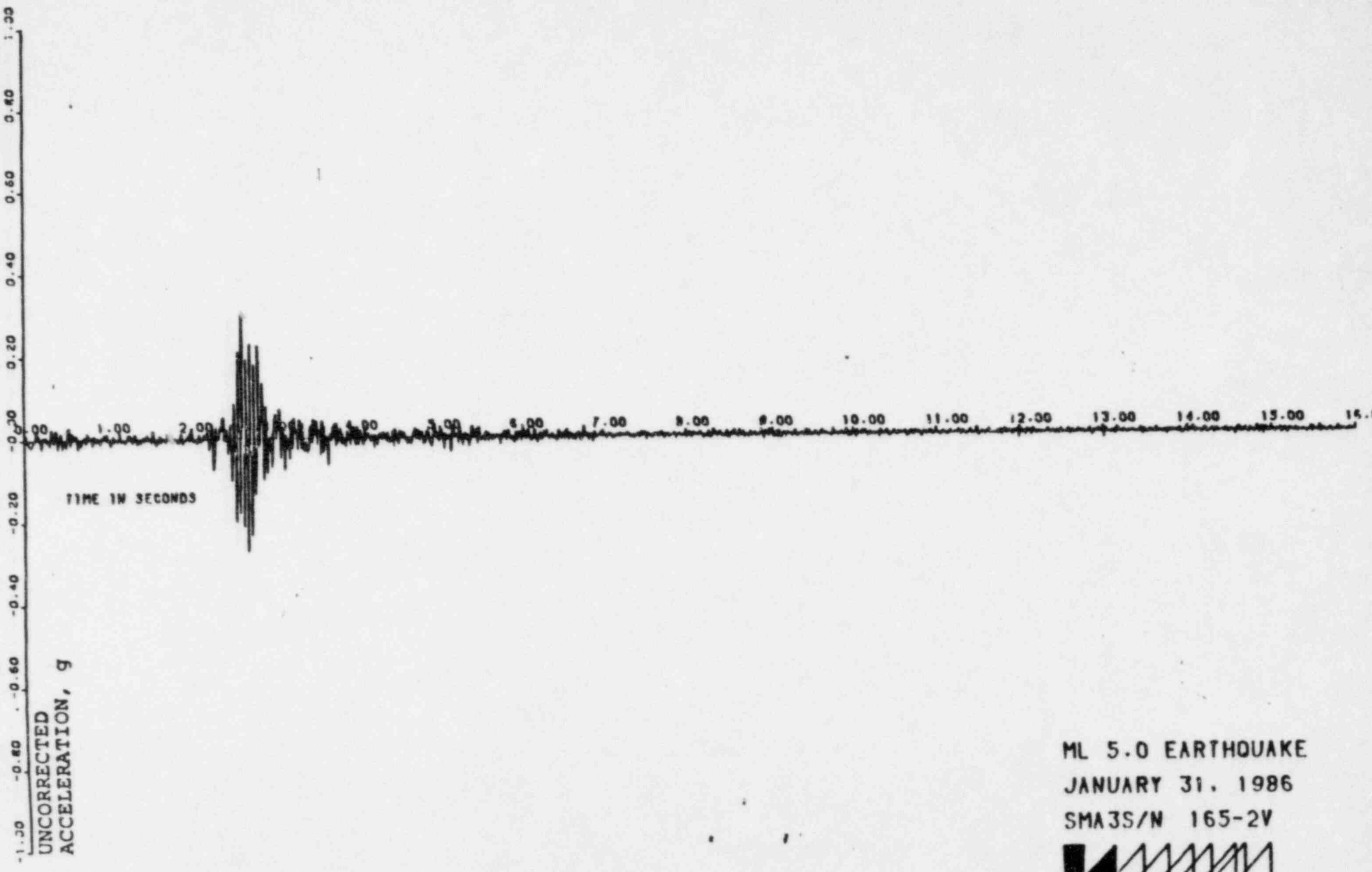
JANUARY 31, 1986
SMA3S/N 165-2T

KINEMETRICS



ML 5.0 EARTHQUAKE
JANUARY 31, 1986
SMA3S/N 165-2V

KINEMETRICS

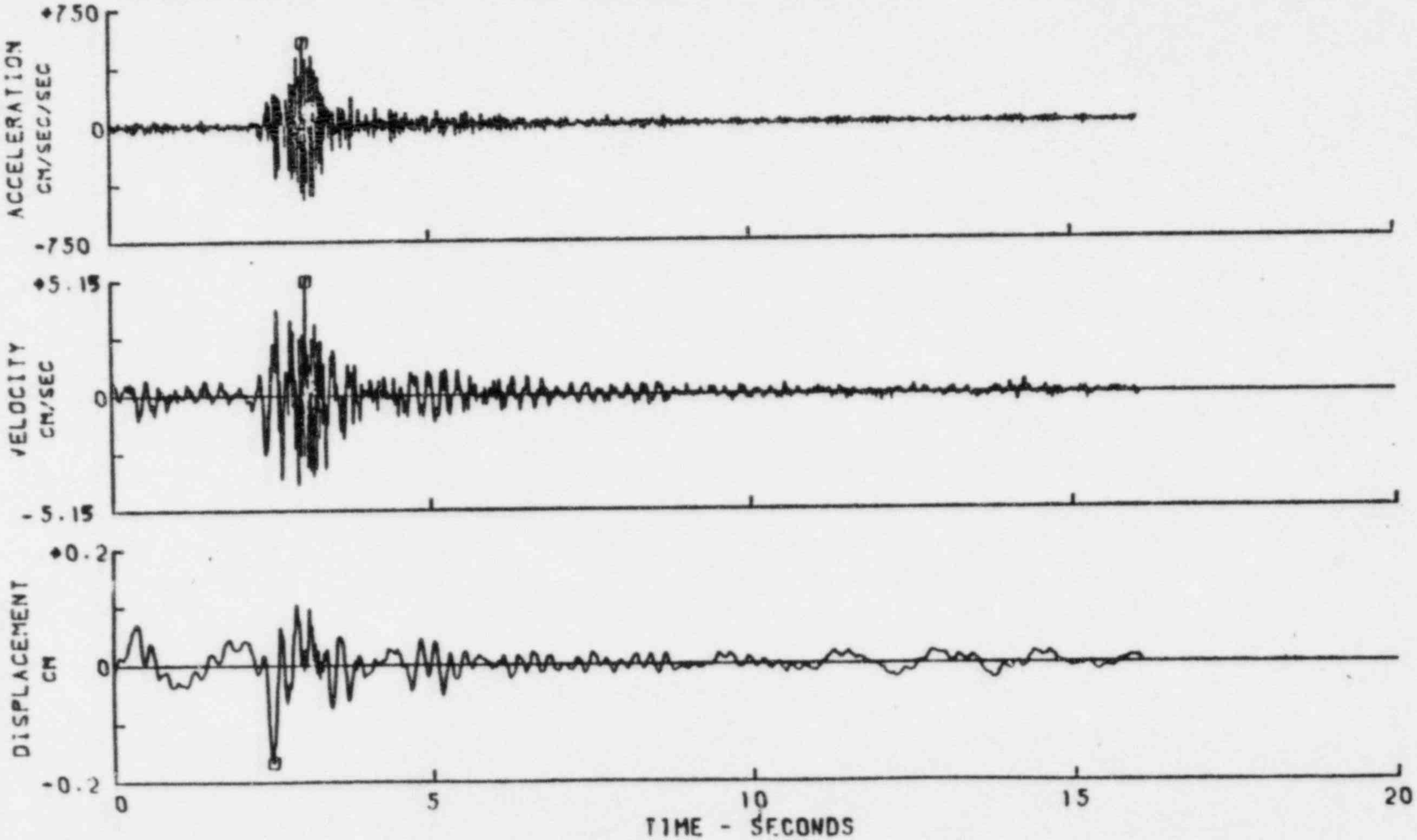
KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP SOUTH SMA3S/N 165-2L

ACCELEROGRAM IS BAND-PASS FILTERED BETWEEN 0.400- 0.625 AND 35.00- 40.00 HERTZ

▣ PEAK VALUES: ACCEL= +535.17 CM/SEC/SEC VEL= +5.13 CM/SEC DISPL=-0.17 CM



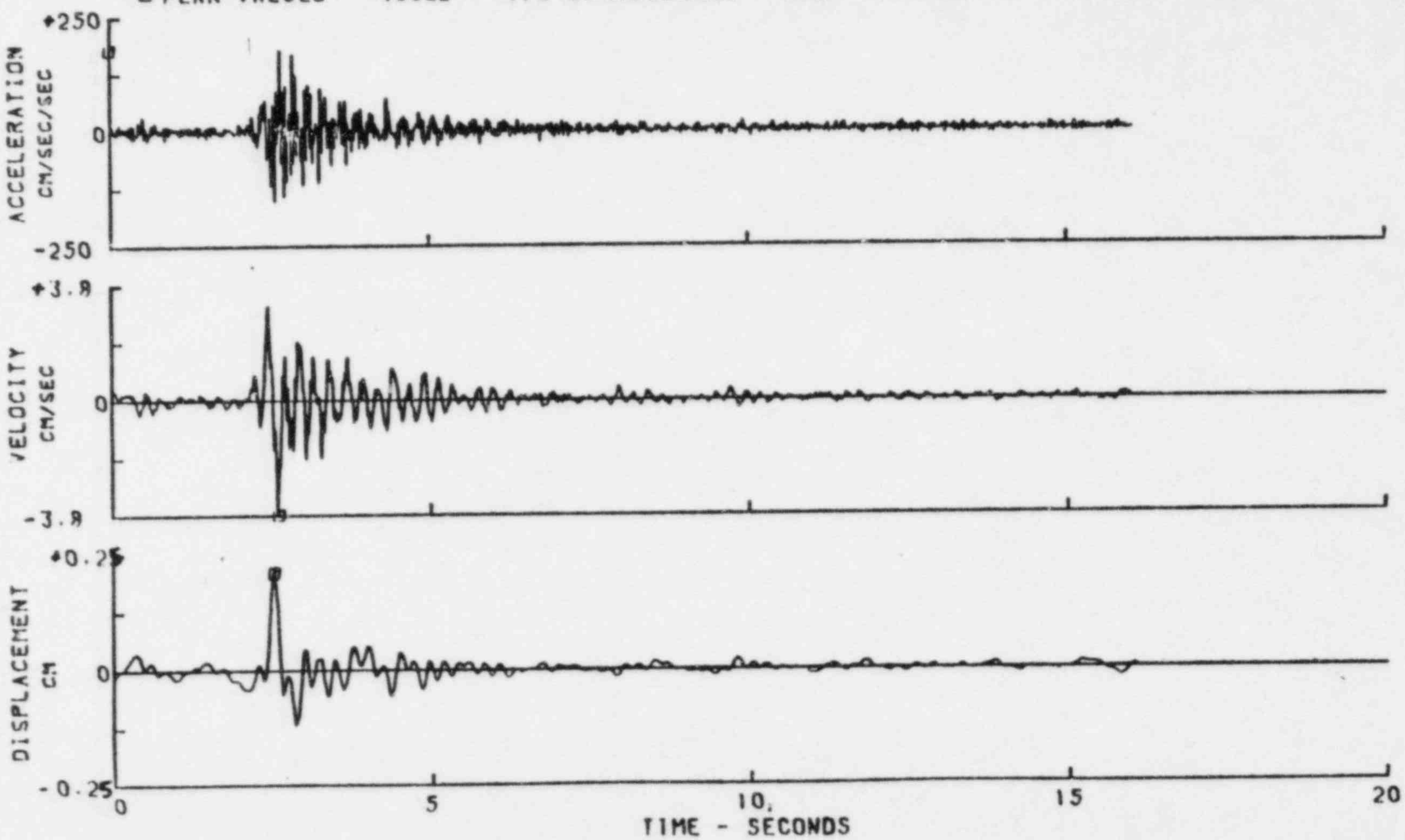
KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP WEST SMA3S/N 165-2T

ACCELEROGRAM IS BAND-PASS FILTERED BETWEEN 0.400- 0.625 AND 35.00- 40.00 HERTZ

⊡ PEAK VALUES: ACCEL= +178.35 CM/SEC/SEC VEL= -3.77 CM/SEC DISPL= +.21 CM



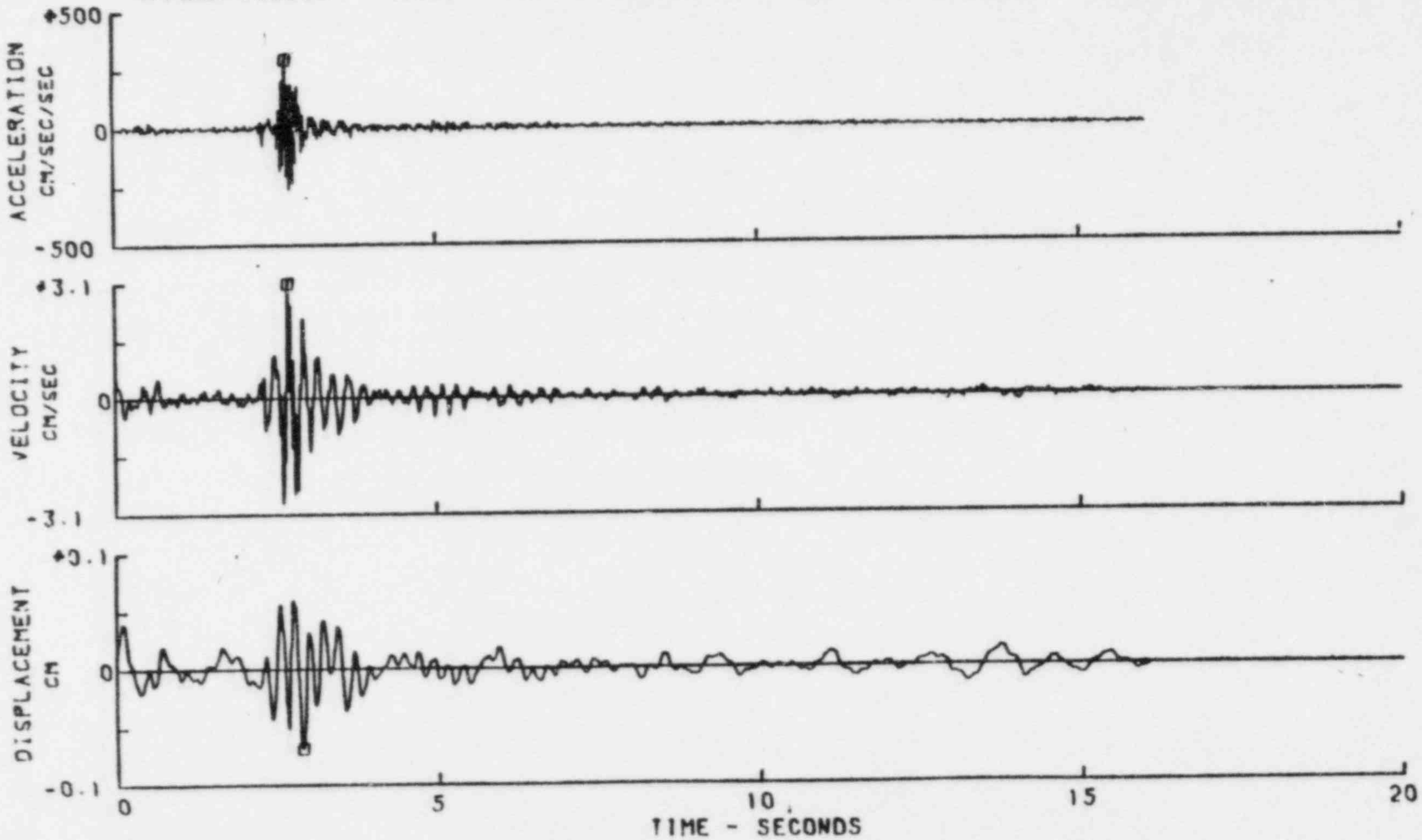
KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP UP SMA3S/N 165-2V

ACCELEROGRAM IS BAND-PASS FILTERED BETWEEN 0.400- 0.625 AND 35.00- 40.00 HERTZ

▫ PEAK VALUES: ACCEL= +297.21 CM/SEC/SEC VEL= +3.09 CM/SEC DISPL=-0.07 CM

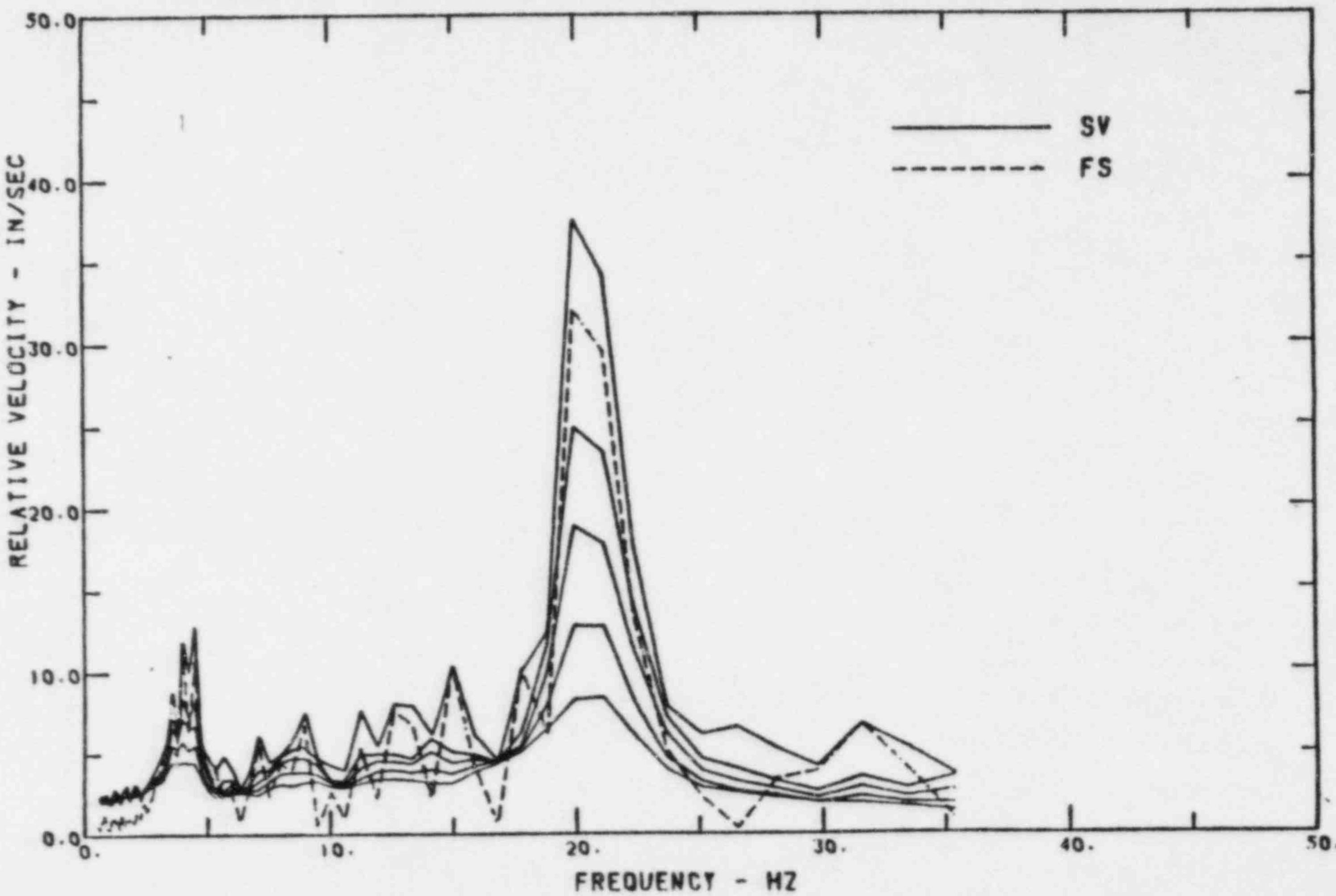


RELATIVE VELOCITY RESPONSE SPECTRUM

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP SOUTH SMA3S/N 165-2L

DAMPING VALUES ARE 0. 1. 2. 4. 7 PERCENT OF CRITICAL



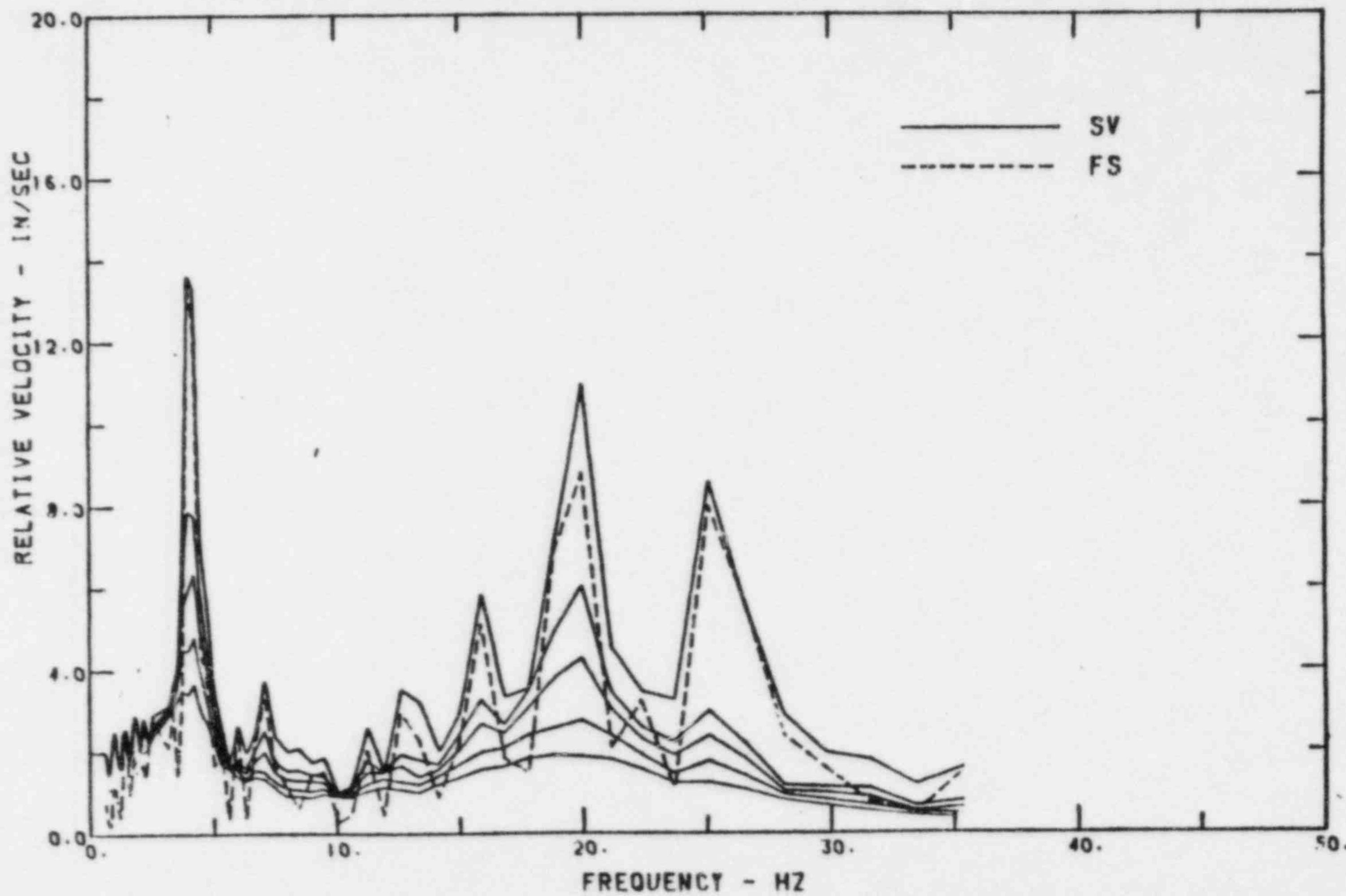
KINEMETRICS

RELATIVE VELOCITY RESPONSE SPECTRUM

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP WEST SMA3S/N 165-2T

DAMPING VALUES ARE 0. 1. 2. 4. 7 PERCENT OF CRITICAL



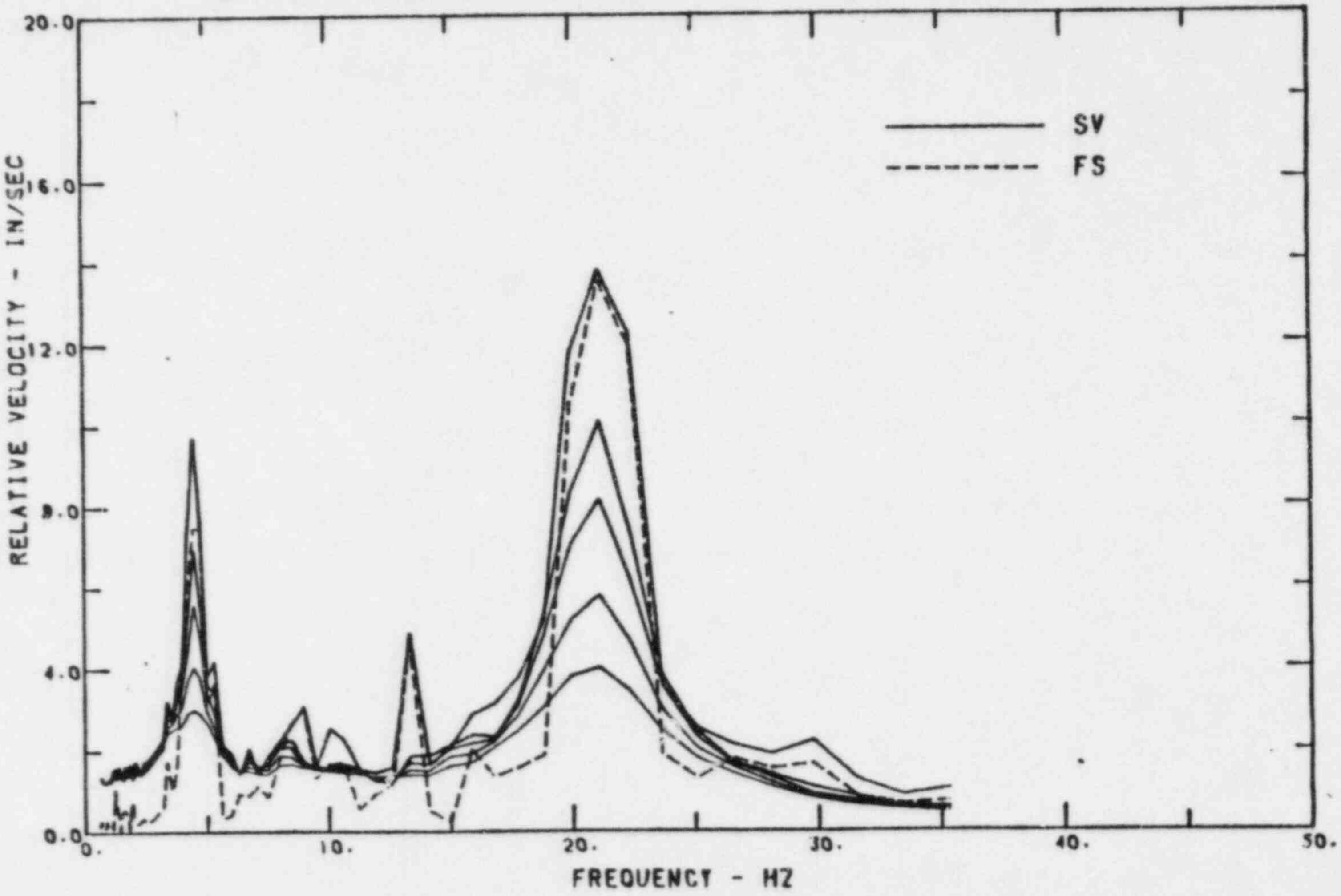
KINEMETRICS

RELATIVE VELOCITY RESPONSE SPECTRUM

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP UP SMA3S/N 165-2V

DAMPING VALUES ARE 0, 1, 2, 4, 7 PERCENT OF CRITICAL



KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

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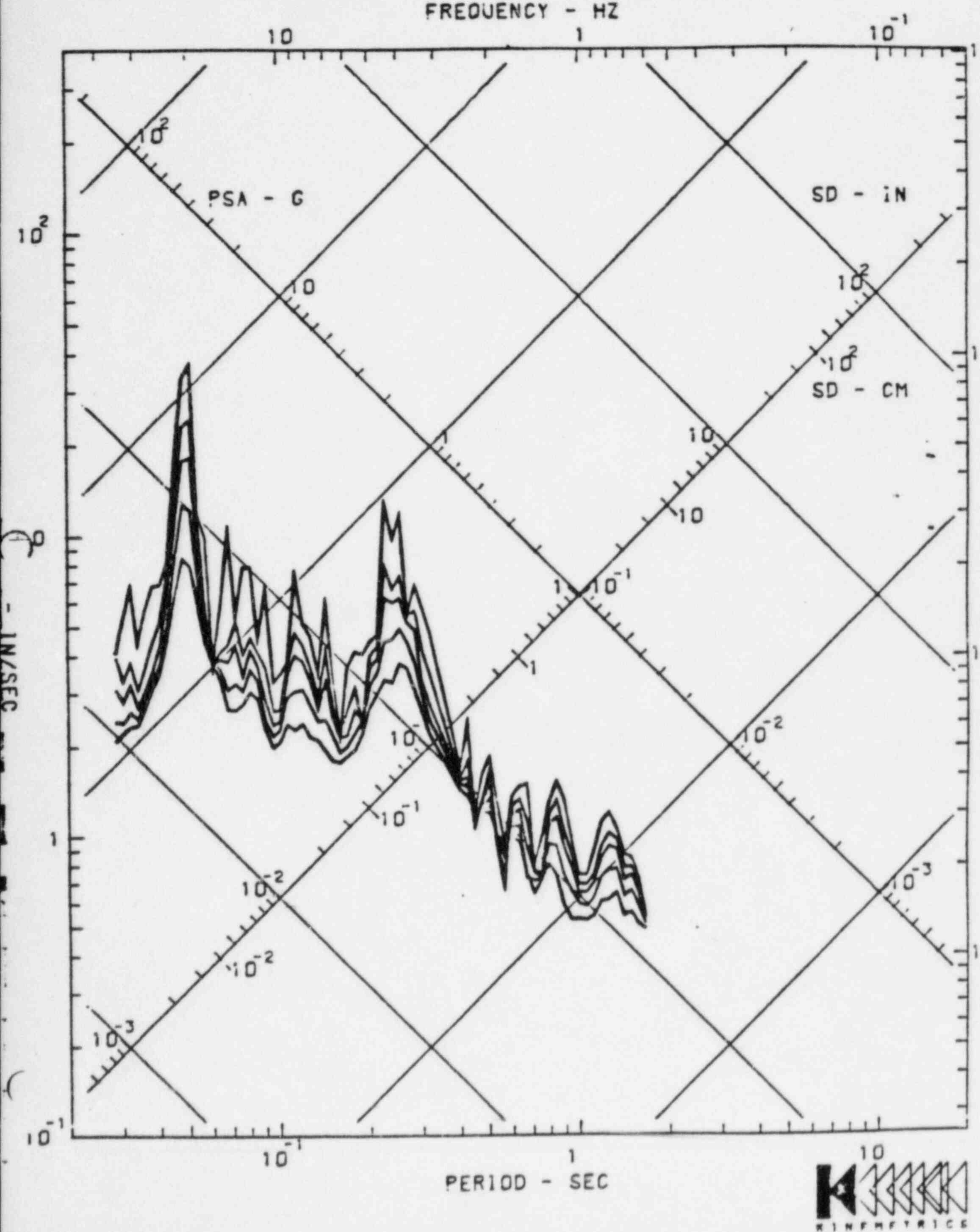
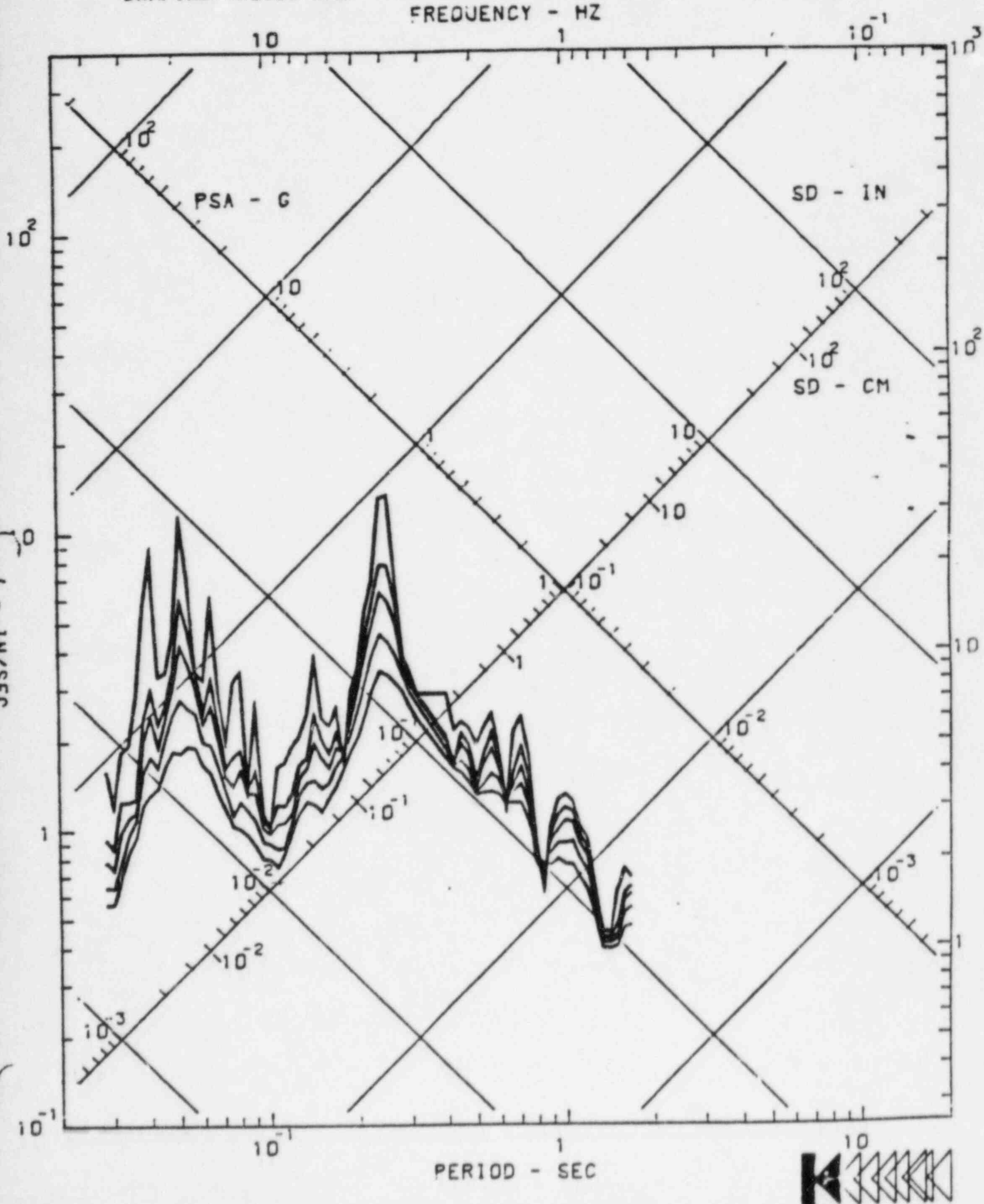
DAMPING VALUES ARE 0. 1. 2. 4. 7 PERCENT OF CRITICAL



ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP WEST SMA3S/N 165-2T

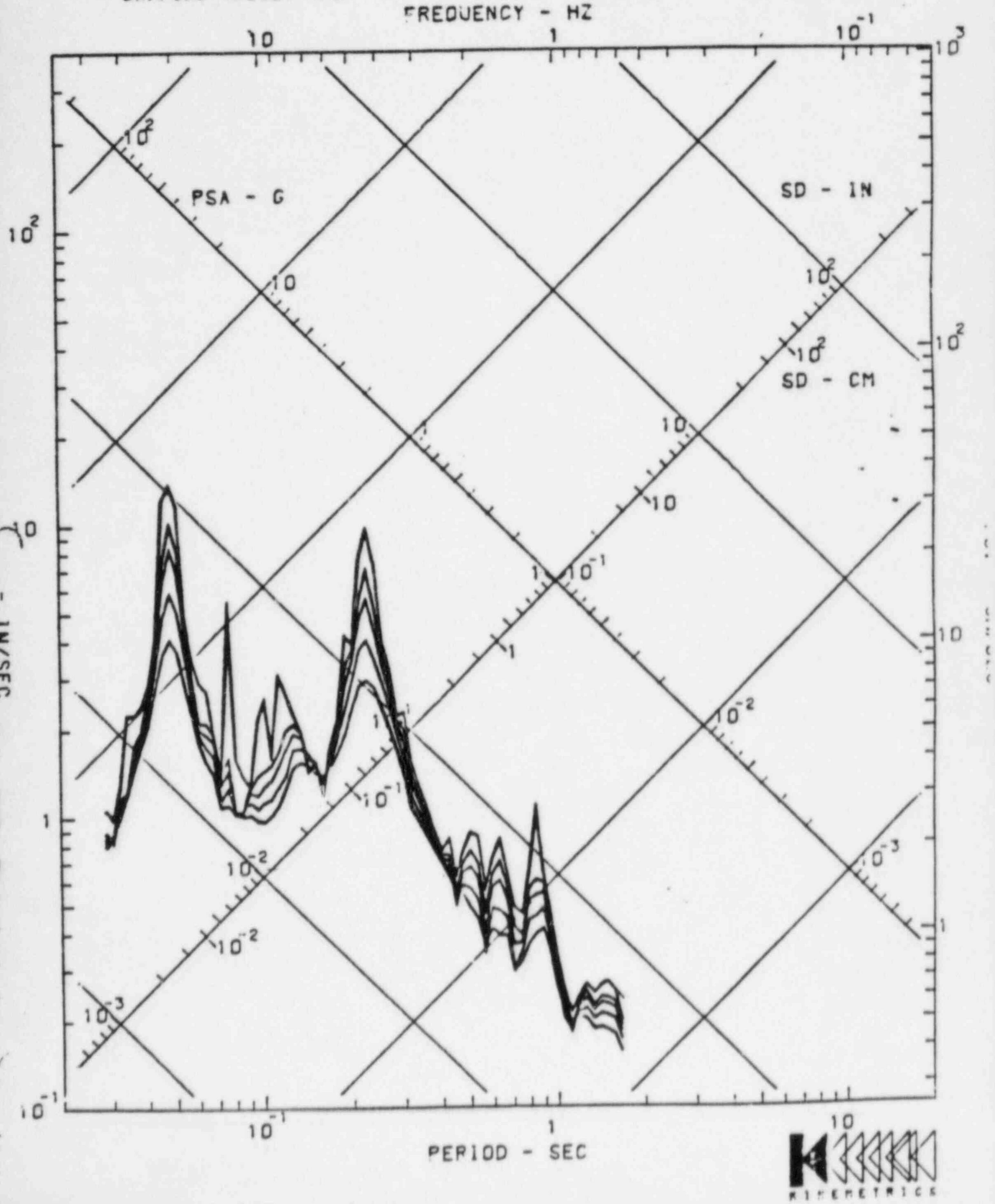
DAMPING VALUES ARE 0. 1. 2. 4. 7 PERCENT OF CRITICAL



ML 5.0 EARTHQUAKE JANUARY 31, 1986

11AB002 PERRY NUCLEAR POWER PLANT COMP UP SMA3S/N 165-2V

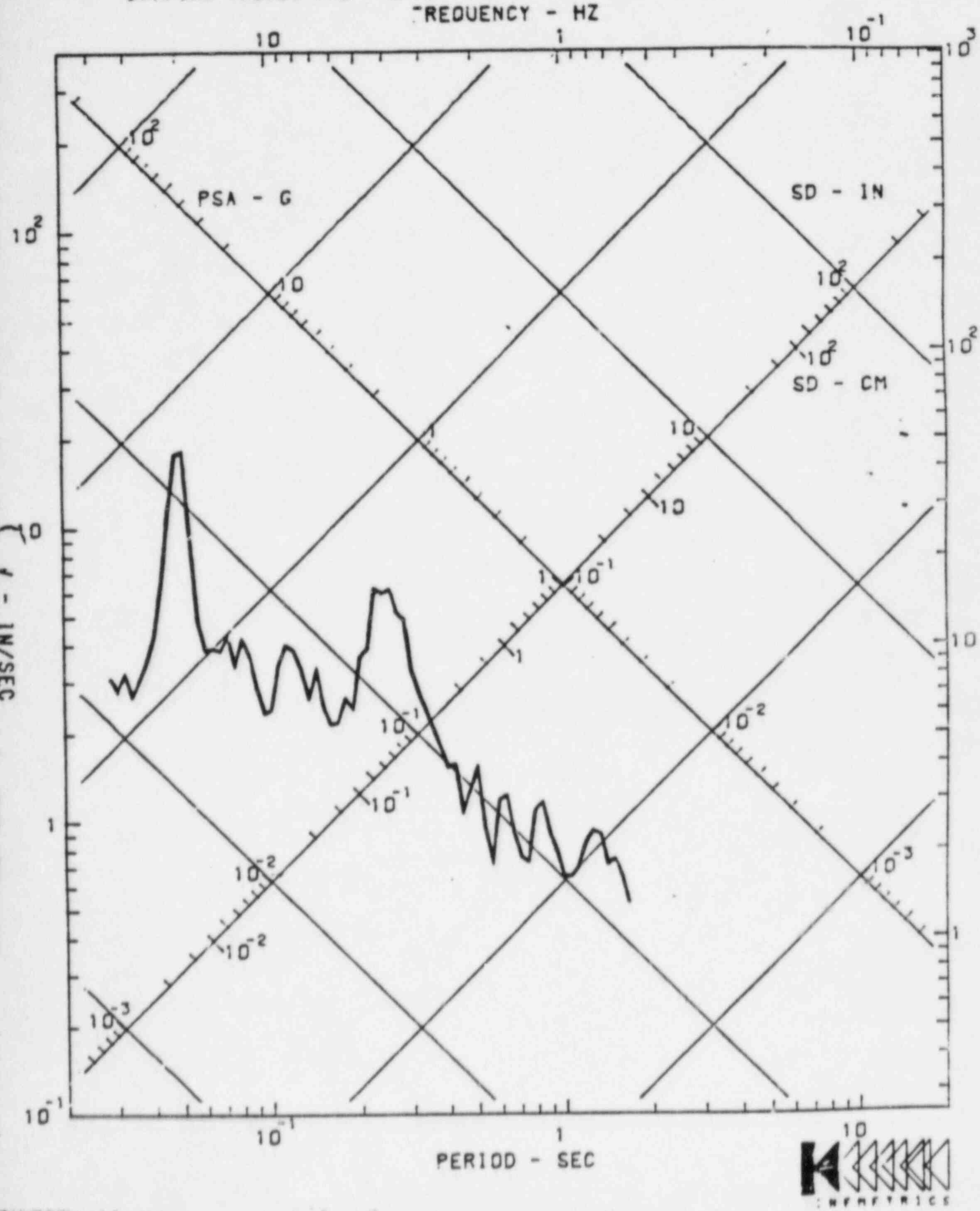
DAMPING VALUES ARE 0. 1. 2. 4. 7 PERCENT OF CRITICAL



ML 5.0 EARTHQUAKE JANUARY 31, 1986

11AB002 PERRY NUCLEAR POWER PLANT COMP SOUTH SMA3S/N 165-2L

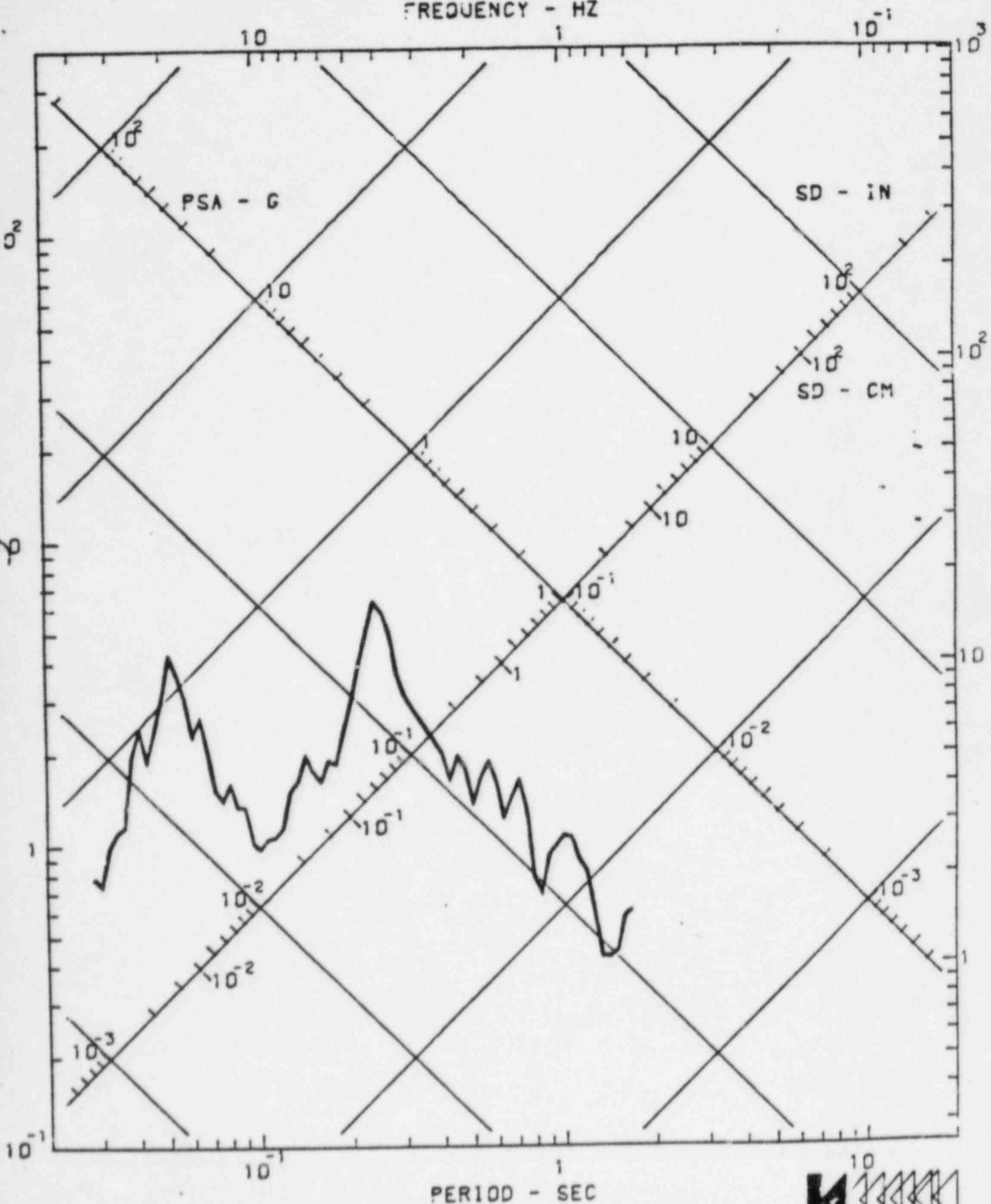
DAMPING VALUES ARE 2 PERCENT OF CRITICAL



ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP WEST SMA3S/N 165-21

DAMPING VALUES ARE 2 PERCENT OF CRITICAL

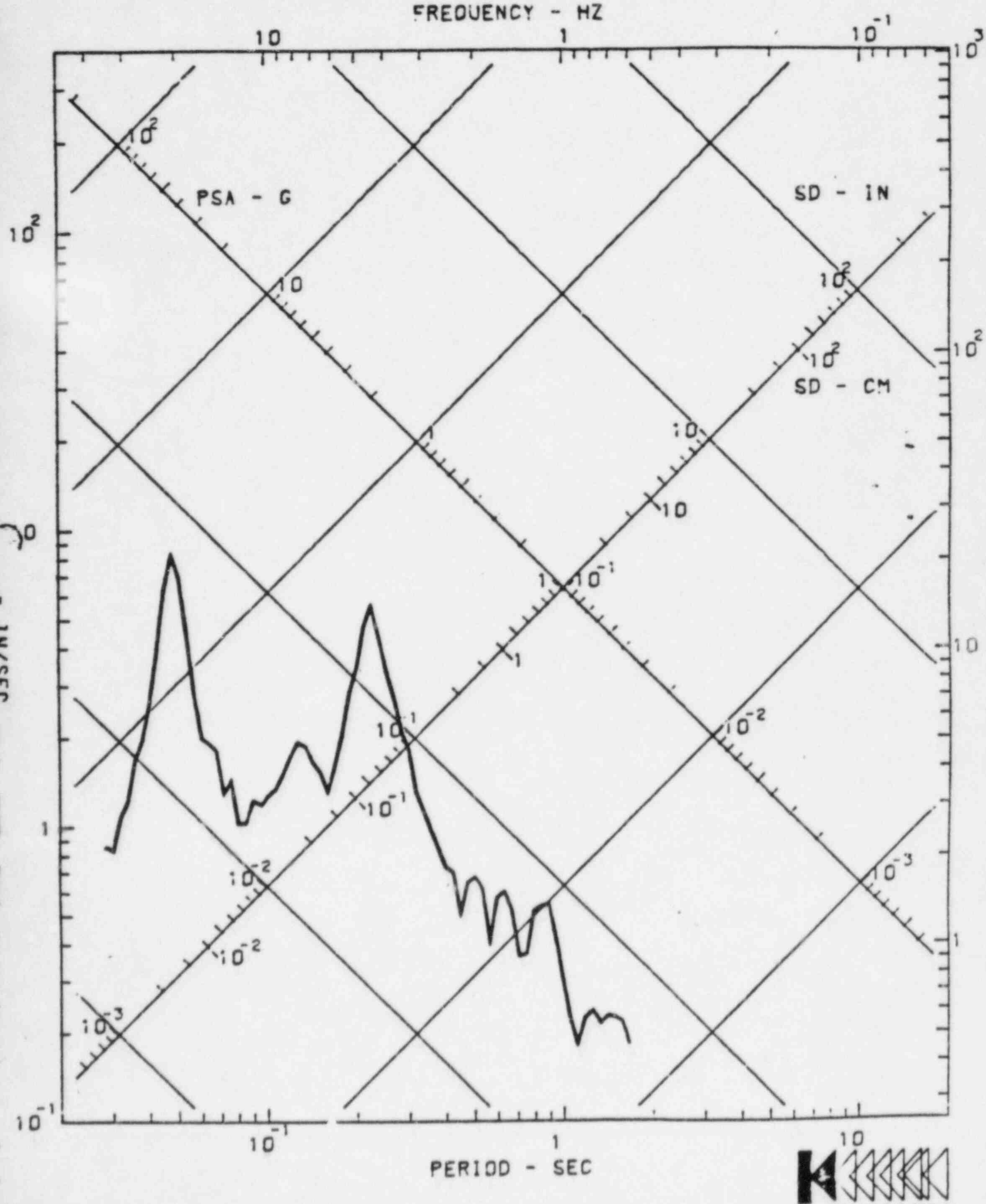


KINEMETRICS

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A8002 PERRY NUCLEAR POWER PLANT COMP UP SMA3S/N 165-2V

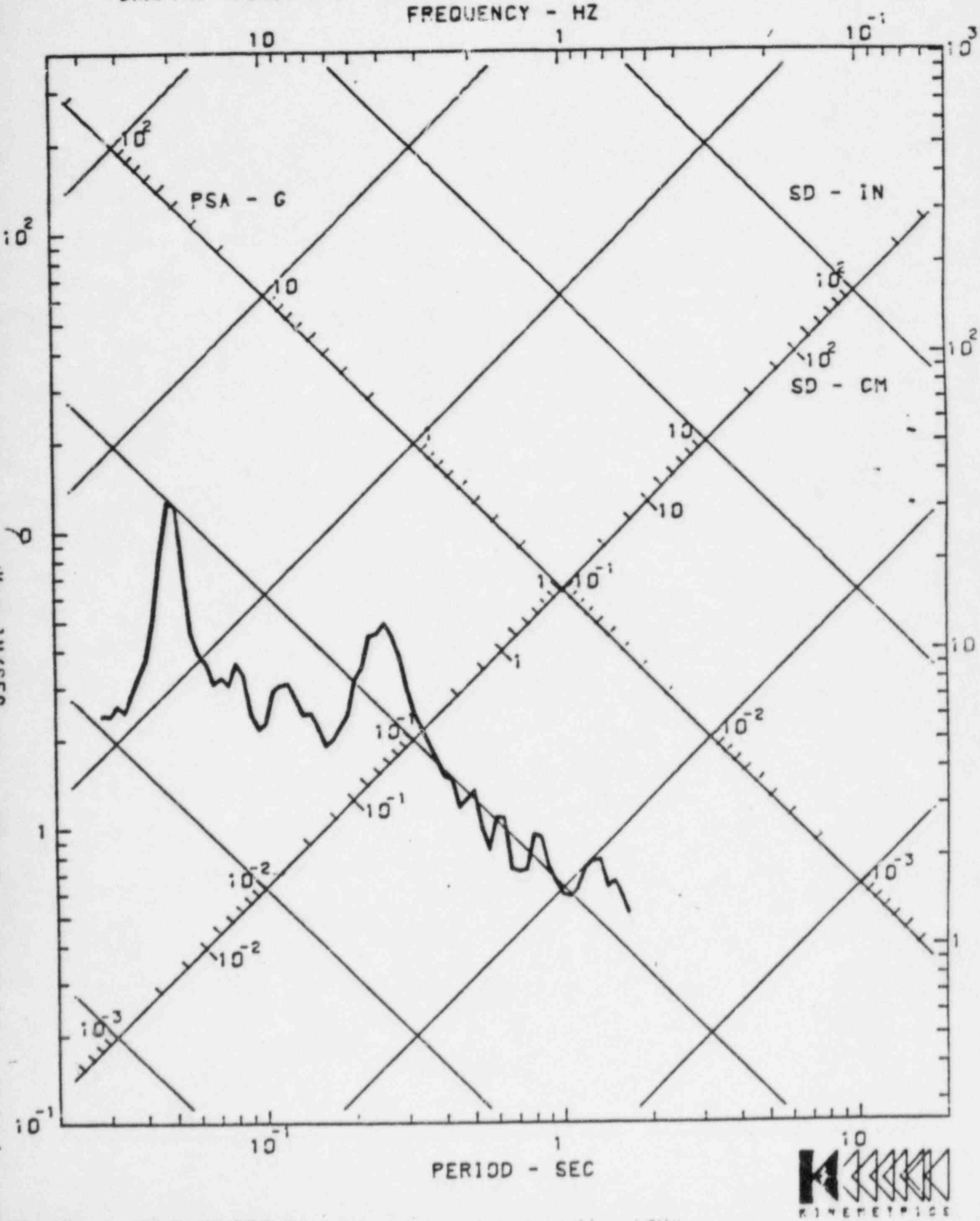
DAMPING VALUES ARE 2 PERCENT OF CRITICAL



ML 5.0 EARTHQUAKE JANUARY 31, 1986

IIAB002 PERRY NUCLEAR POWER PLANT COMP SOUTH SMA3S/N 165-2L

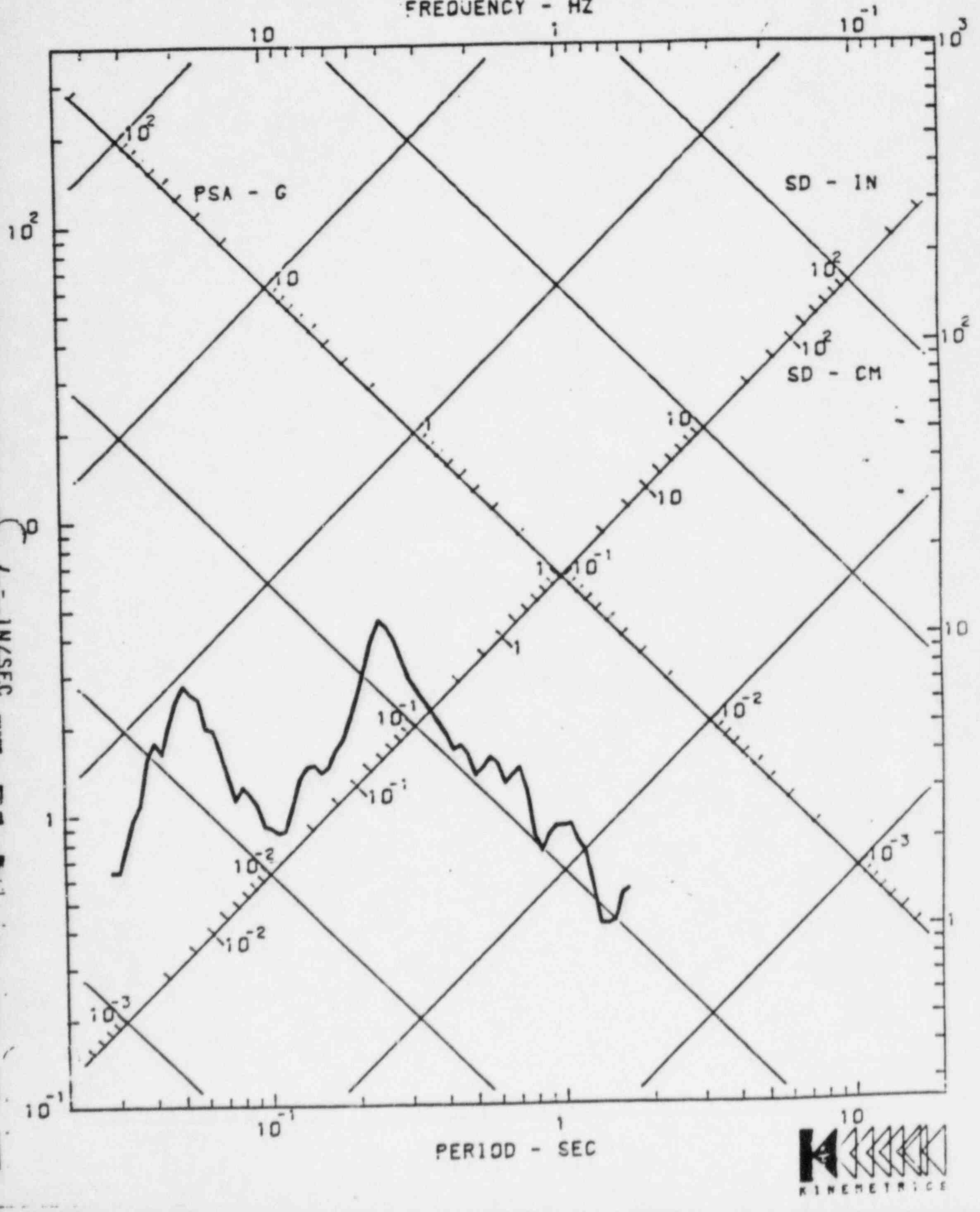
DAMPING VALUES ARE 4 PERCENT OF CRITICAL



ML 5.0 EARTHQUAKE JANUARY 31, 1986

IIA8002 PERRY NUCLEAR POWER PLANT COMP WEST SMA3S/N 165-27

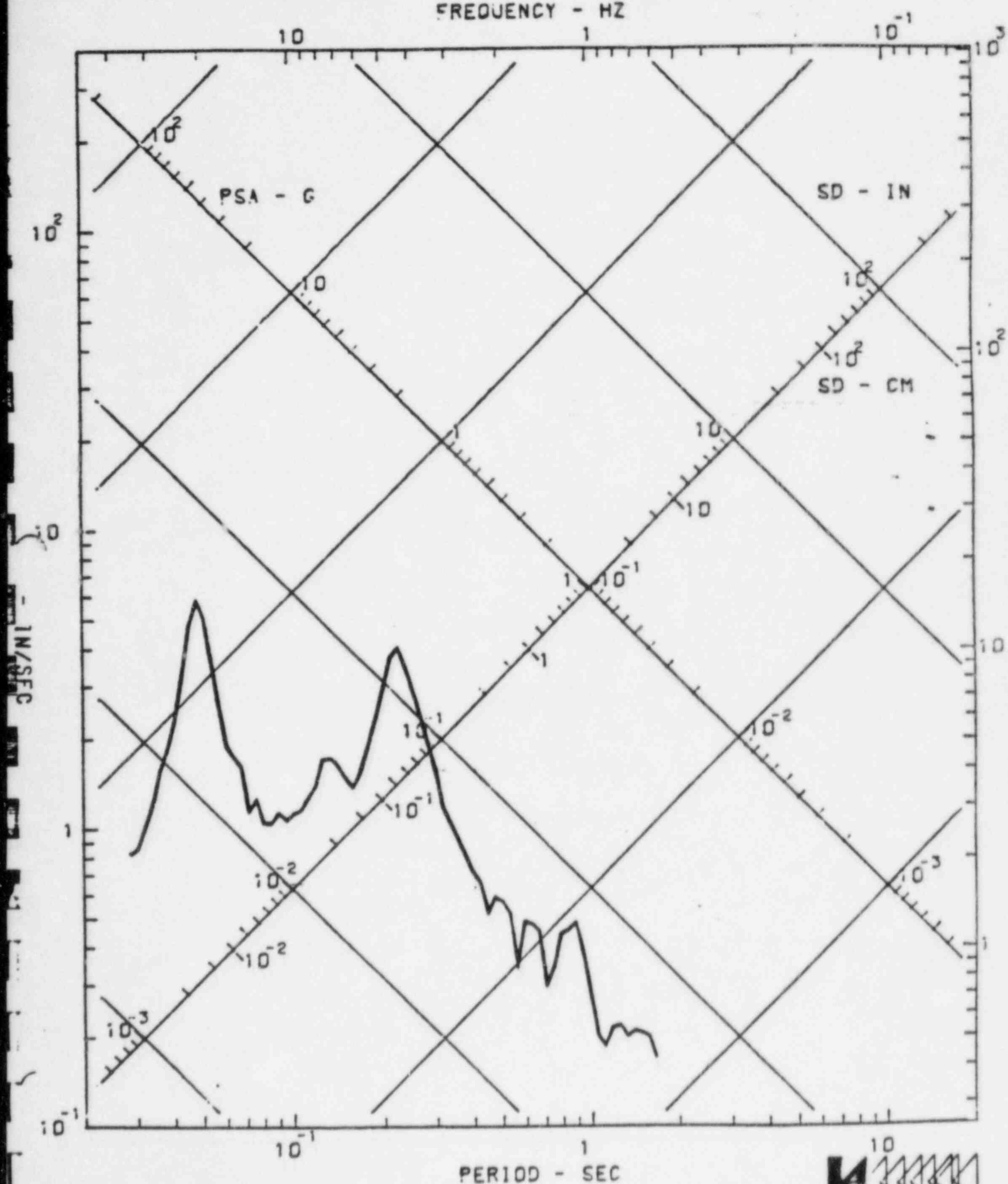
DAMPING VALUES ARE 4 PERCENT OF CRITICAL



ML 5.0 EARTHQUAKE JANUARY 31, 1986

11AB002 PERRY NUCLEAR POWER PLANT COMP UP SMA3S/N 165-2V

DAMPING VALUES ARE 4 PERCENT OF CRITICAL



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

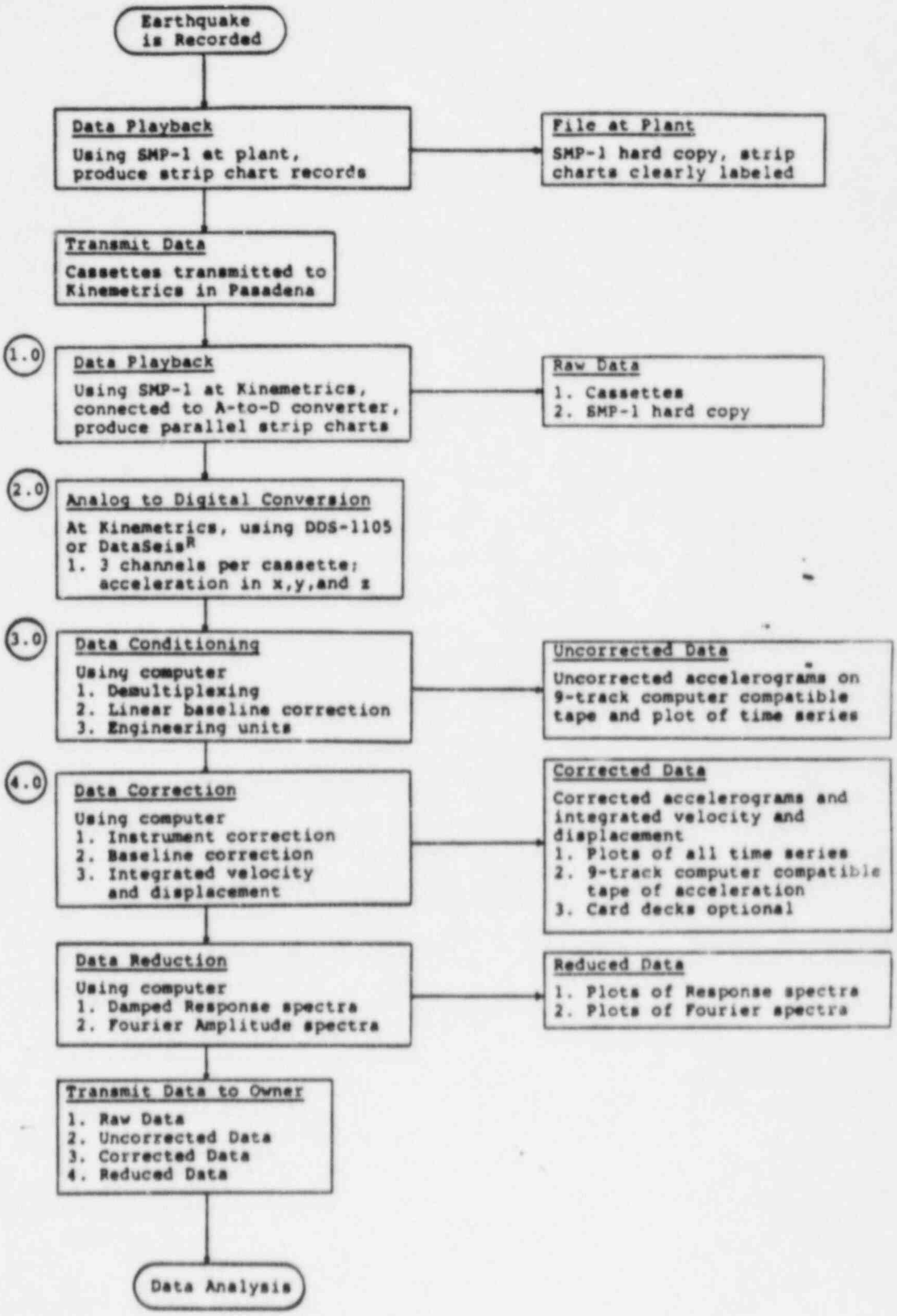


FIGURE 1 Flow Diagram for Kinemetrics E.D.R.S. (Earthquake Data Reduction Sequence)

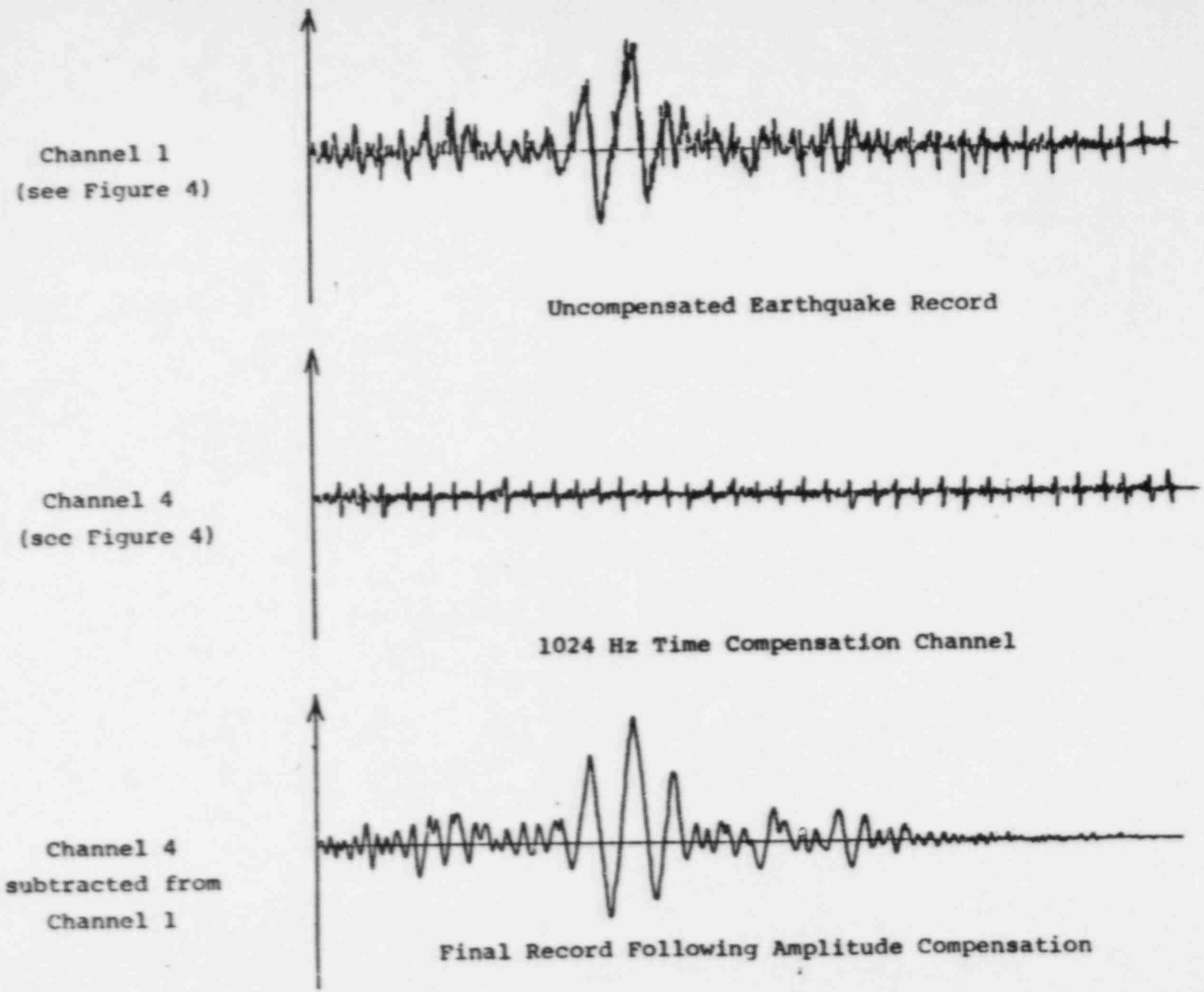


FIGURE 2 Amplitude Compensation

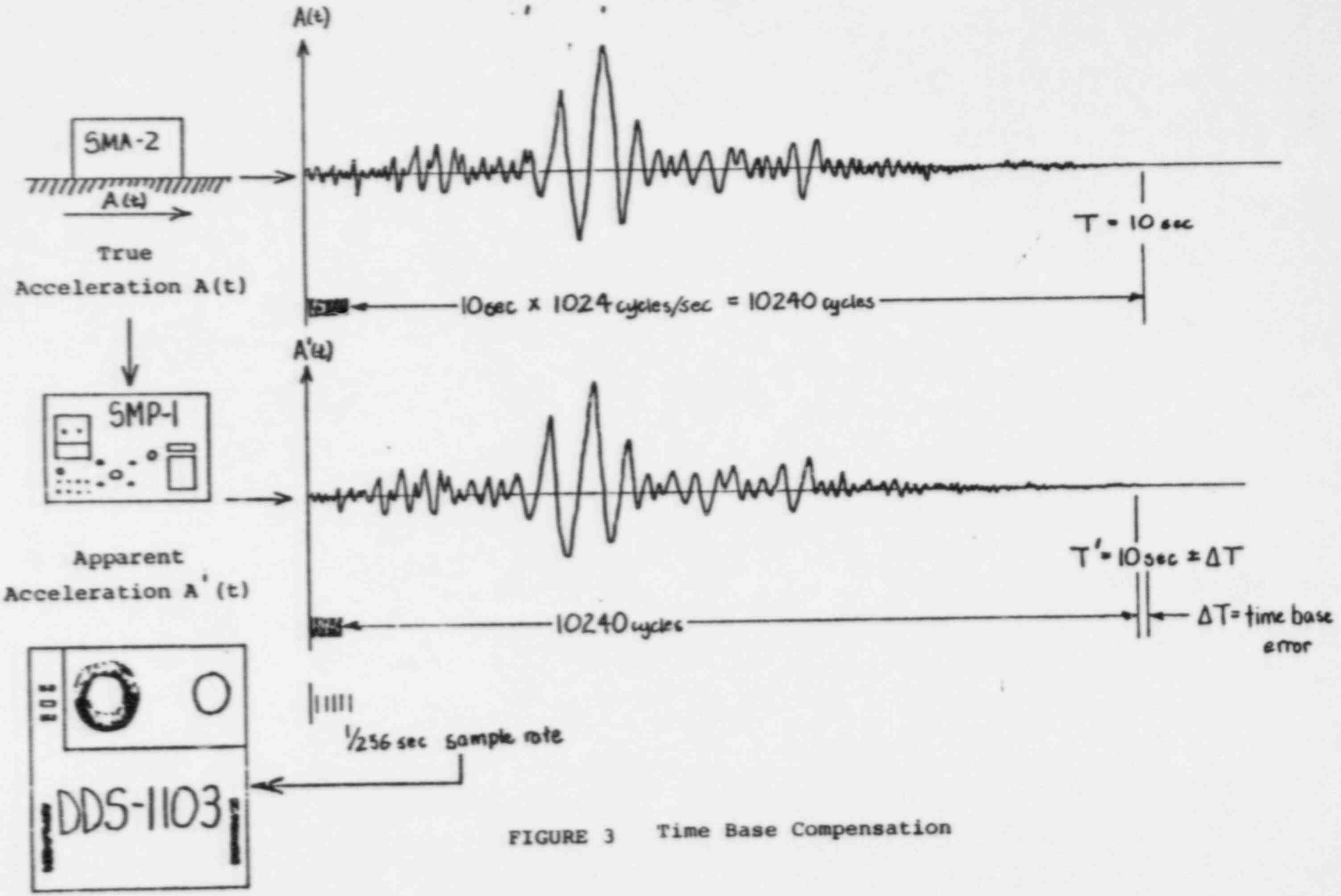
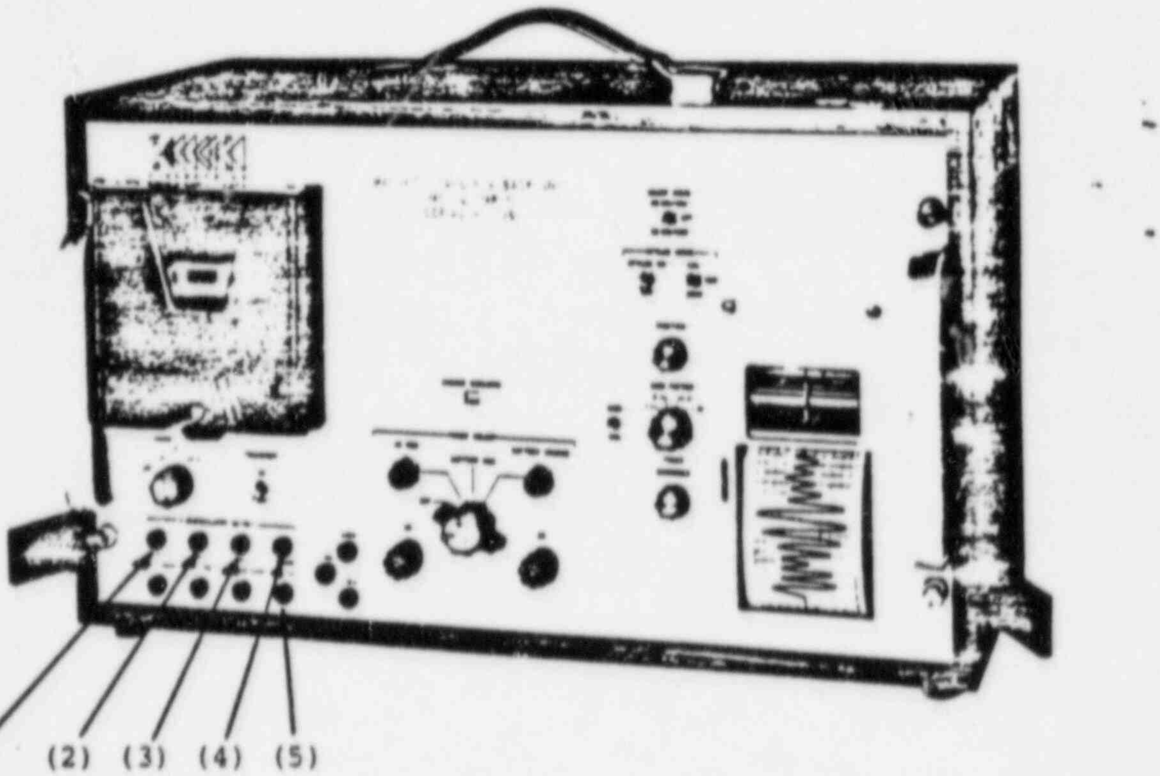


FIGURE 3 Time Base Compensation

SMP-1

Magnetic Tape Playback System

FIGURE 4



The SMP-1 is a versatile magnetic tape playback system designed for use with the Kinemetrics SMA-2 and SMA-3 Magnetic Tape Acceleration Systems. The combination of the SMA-2 or SMA-3 Acceleration Systems with the SMP-1 Magnetic Tape Playback System meets the applicable requirements of US NRC Regulatory Guide 1.12, and provides immediate visual playback capability of recorded acceleration data.

The SMP-1 is portable and may be operated either from 110 Vac or internal rechargeable batteries. Optionally the unit may be mounted in a standard 19-inch cabinet. An internal battery charger is included with the unit.

which appear on the 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.

If this Data Compensator is used, the electrical signals are amplitude compensated by electronic subtraction of Channel 4 from Channels 1, 2, and 3. 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.

1.3.2 Without a Data Compensator, have software perform amplitude compensation.

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[R].

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. 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[R].

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 by using the FM time reference output (Channel 5 of Figure 4) as the timing signal for the analog-to-digital converter. The amplitude has been compensated 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 data and integrated ground velocity and displacement curves in as accurate a form and over as wide a frequency range as is compatible with the original data. The modified data is believed to be the most accurate form of input data feasible to produce from the original record for structural response calculations and for response spectrum determinations.

Instrument correction is introduced to compensate for the accelerometers' frequency response. The Caltech publication EERL 71-05 discusses the approach used. The 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.

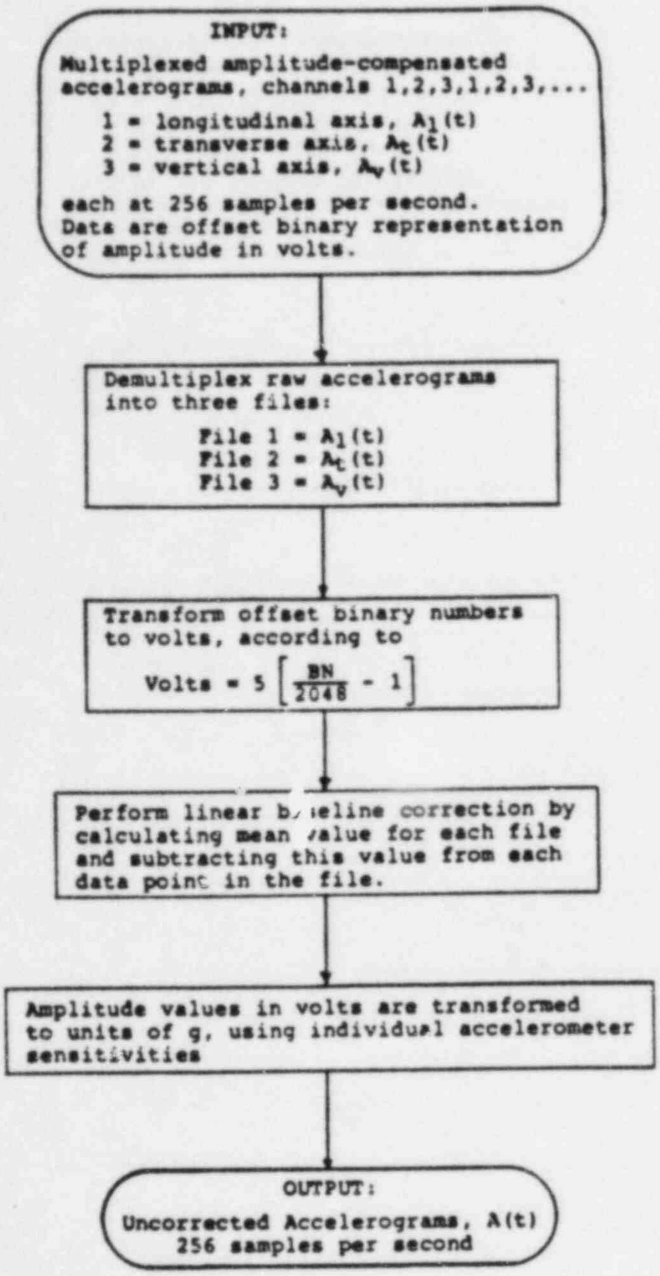


FIGURE 5

Data Conditioning, E.D.R.S.

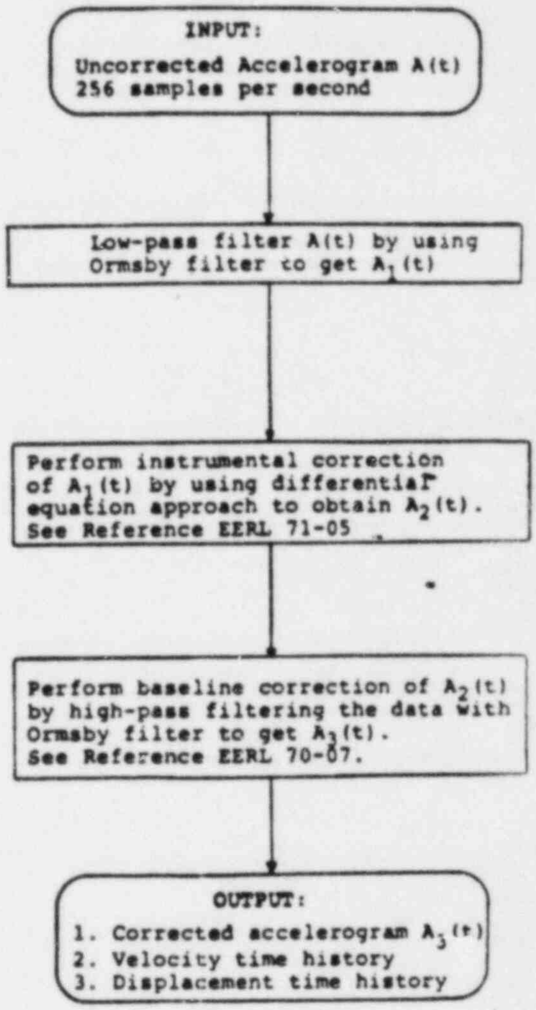
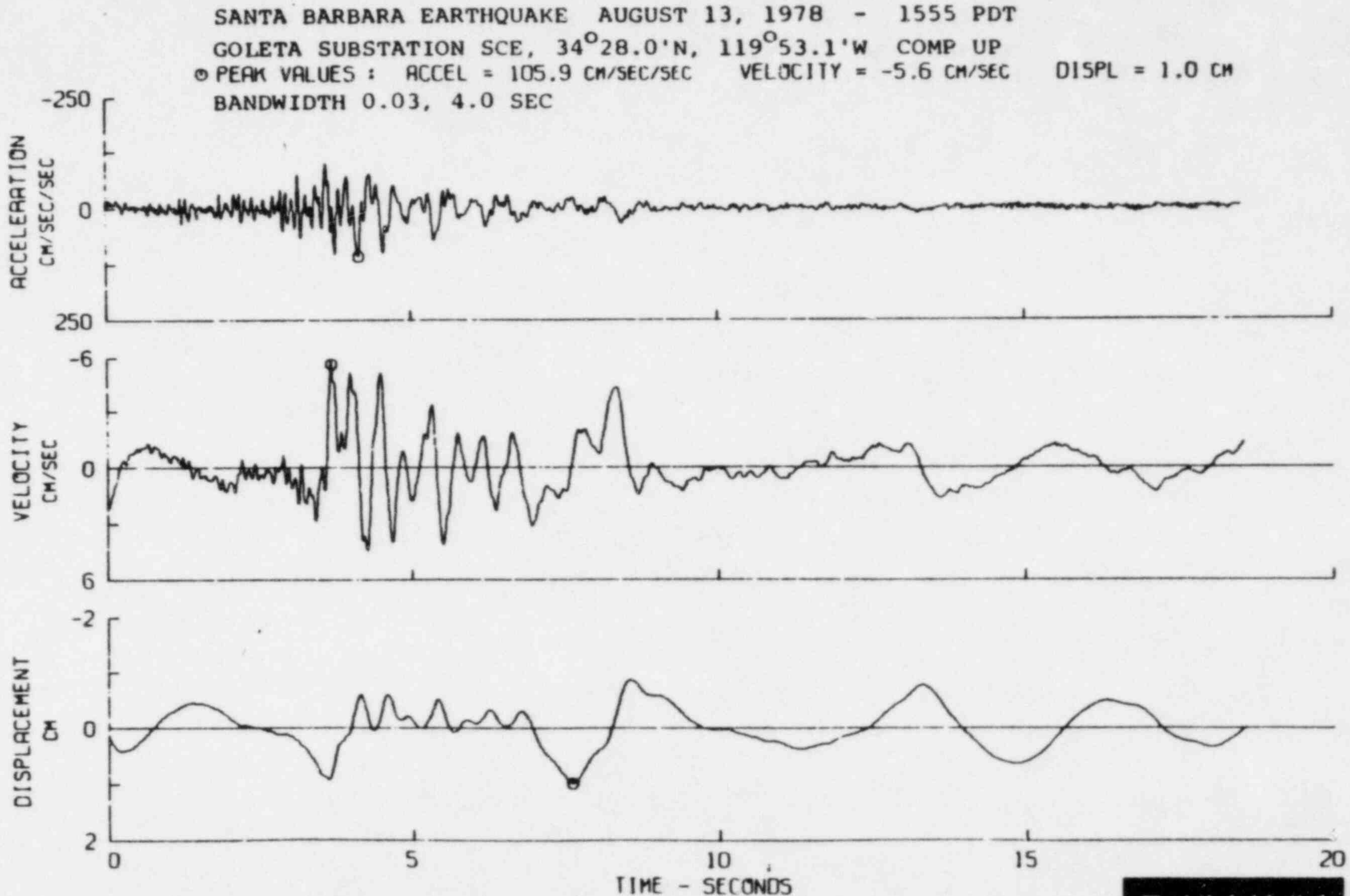


FIGURE 6

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

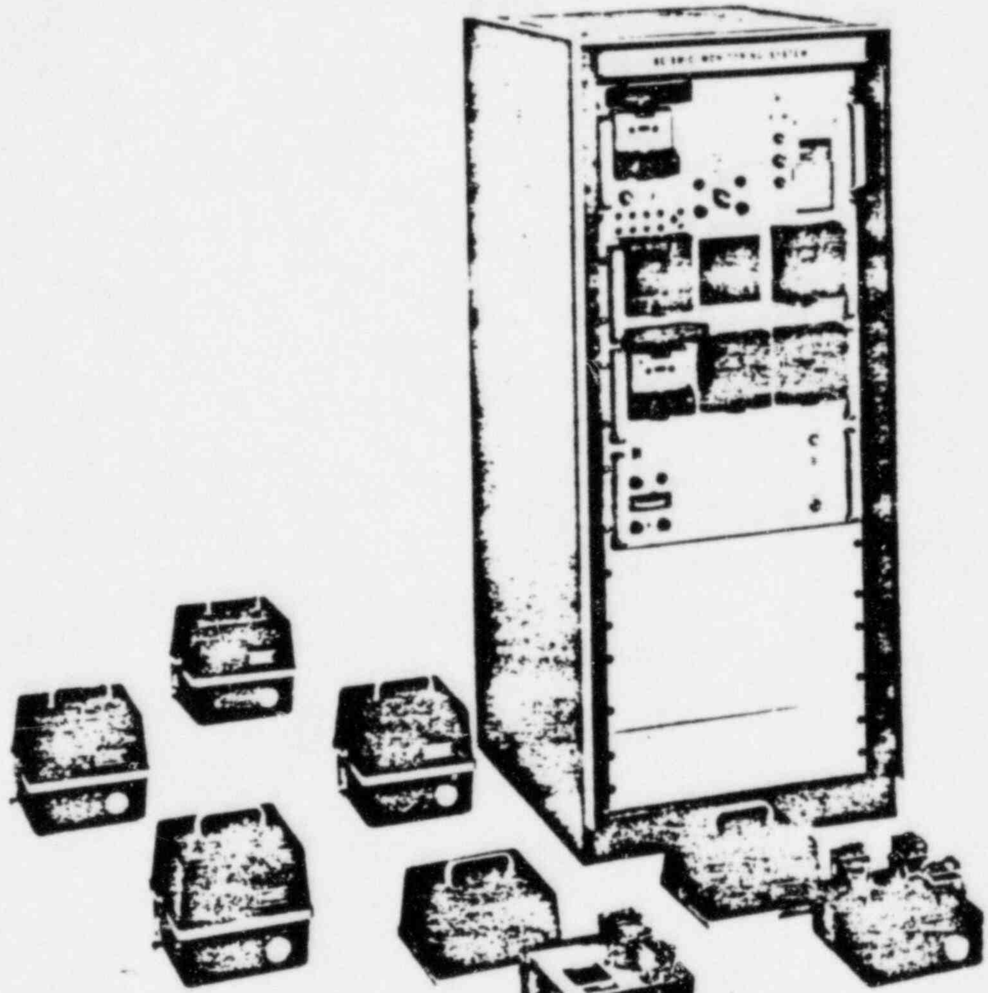
Trifunac, M. D., F. E. Udwadia and A. G. Brady (1971). High Frequency Errors and Instrument Corrections of Strong-Motion Accelerograms, Earthquake Engineering Research Laboratory, EERL 71-05, pgs. 33-47, California Institute of Technology, Pasadena

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 SYSTEMS

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.

KINEMETRICS / SYSTEMS, 222 VISTA AVENUE; PASADENA, CA 91107 (818) 795-2220; TELEX 67-5402 KMETRICS PSD

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

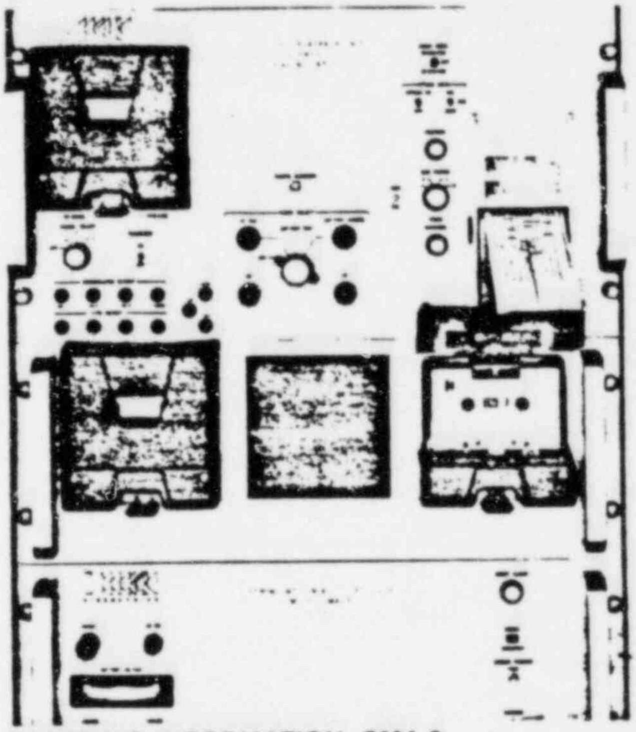
Type: Frequency modulation
Tape: Four track magnetic tape cassette
Tape Speed: 1-7/8'' per second
Recording Time: 30 minutes
Bandwidth: 0 to 50 Hz
Dynamic Range: 40 dB from 15° to 35° C (with SMP-1)
Modulation Frequency: 1000 Hz ± 50% modulation
Timing Frequency: 1024 Hz ± 0.2%
System Accuracy (with 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



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

ATTACHMENT 5