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 PAUL D. ENGDAHL

City of Washington)
: ss:
District of Columbia)

Paul D. Engdahl, being duly sworn, deposes and says as follows:

1. I, Paul D. Engdahl, am President of Engdahl Enterprises ("Engdahl"). Engdahl designs, develops, and manufactures seismic instruments used principally at nuclear power plants in the U.S. and abroad. At present, Engdahl seismic instruments are installed in over 70 domestic and foreign nuclear power plants. My business address is 2850 Monterey Avenue, Costa Mesa, California 92626.

2. A statement of my professional qualifications is attached to this Affidavit as Exhibit "A." I began working with response spectra recorders in 1953 while employed at the

U.S. Naval Ordnance Test Station in Pasadena, California. Since that time, I have performed a variety of work involving response spectra recorders and peak accelerographs. I have invented and hold patents for a number of different types of response spectra recorders and peak accelerographs. These include the Engdahl Peak Shock Recorder, Models PSR1200-H/V and PSR1200-H/V-12A, and the Engdahl Peak Acceleration Recorder, Model PAR400, that were installed and operational at the Perry Nuclear Power Plant on January 31, 1986, as discussed below.

3. The Engdahl recorders installed at Perry conform to the requirements of American National Standards Institute/American Nuclear Society Standard 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"). I am certified as meeting the Level III requirements of ANSI N45.2.6-1978 to read, reduce and evaluate the data recorded by these instruments.

4. During the January 31, 1986 earthquake that occurred in the vicinity of the Perry Plant, the Engdahl seismic instruments installed in the plant recorded the response spectra and the peak accelerations associated with the earthquake. I and a member of my staff have since reduced the data that was recorded. The data, and the results of my evaluation of the data, are discussed in "Report On The Peak Shock Recorders And Peak Acceleration Recorders Installed At The Perry Nuclear

Power Plant During The Seismic Event on January 31, 1986" dated February 7, 1986 (Exhibit "B" hereto). I have personal knowledge of the matters set forth in this Affidavit and the attached exhibits, including Exhibit B, and believe the information in the Affidavit and accompanying exhibits to be true and correct.

Paul D. Engdahl

Paul D. Engdahl

Subscribed and sworn to before me
this 13th day of February, 1986.

Tonya H. Earnhart

Notary Public

My Commission Expires:

My Commission Expires May 14, 1990

Exhibit "A"

PROFESSIONAL QUALIFICATIONS

OF

PAUL D. ENGDAHL

Employment

1971 - Present	President, Engdahl Enterprises General management of company. The company designs, develops, manufactures, installs, and calibrates seismic instrumentation. Most of these instruments are purchased for use in nuclear power plants.
1964 - 1971	Chief Mechanical Engineer, Astroscience Corporation Management of mechanical engineering. Design and development of high frequency (one megahertz) multi-channel tape recorders used for high speed data gathering.
1960 - 1964	Retired
1958 - 1960	Operations Manager, Leach Corporation General management of company division involved in the design, development, and manufacture of response spectrum recorders and high environmental, multi-channel tape recorders.
1956 - 1958	President, Engdahl Enterprises Designed, developed, and manufactured response spectrum recorders and multi-channel high environmental tape recorders. Products sold to Leach Corporation.
1955 - 1956	Mechanical Engineer, North American Instruments

Management of mechanical engineering. Design and development of high g peak acceleration recorders and multi-channel tape recorders.

1952 - 1954 — Mechanical Engineer, U.S. Naval Ordnance Test Station

Design and development work on steering mechanisms for torpedos, exploders for warheads, and reed gages (response spectrum recorders) for measuring the impacts of high speed water entry of torpedos.

1951 - 1952 — Mechanical Engineer, Consolidated Vultee Aircraft Company

Design and development of steering mechanisms for anti-aircraft missiles.

1949 - 1951 — Mechanical Engineer - Self employed

Education

University of Minnesota (Bachelors in Mechanical Engineering, 1949)

Affiliation

American Nuclear Society working group on ANSI/ANS-2.2 "Earthquake Instrumentation Criteria for Nuclear Power Plants," and ANSI/ANS-2.10 "Guidelines for Retrieval, Review, Processing and Evaluation of Records Obtained from Seismic Instrumentation."

Patented Inventions

Six patents on instruments for recording response spectra and peak accelerations.

Technical Publications

Various publications on response spectrum recorders, exploders, and steering mechanisms.

EXHIBIT "B"

ENGDAHL ENTERPRISES 2850 Monterey Avenue, Costa Mesa, California 92626, (714) 540-0398

REPORT ON THE PEAK SHOCK RECORDERS AND PEAK ACCELERATION RECORDERS INSTALLED AT THE PERRY NUCLEAR POWER PLANT DURING THE SEISMIC EVENT ON JANUARY 31, 1986

Copy Number 04

Engdahl Enterprises
Costa Mesa, CA 92626

February 7, 1986

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A. Bulletins (3)

1. INTRODUCTION

On January 31, 1986, the effects of a seismic event were recorded by the Engdahl PSR1200, Peak Shock Recorders and PAR400, Peak Acceleration Recorders at the Perry Nuclear Power Plant located at Perry, Ohio. The record plates were removed from the recorders within hours and new plates were installed by Perry Plant and Engdahl personnel. A preliminary data reduction was completed the same day. A second independent data reduction was made on February 2, 1986. Photographs of all of the scribed records were made on February 2-3, 1986.

This report reviews the status of the instruments at the time of the event, contains the recorded data, and evaluates the data. The report also reviews the present status of the recorders and work to be done in the near future.

2. INSTRUMENT DESCRIPTIONS

2.1 PEAK SHOCK RECORDER (Response Spectrum Recorder and Response Spectrum Switch)

The Model PSR1200-H/V, Peak Shock Recorder, is designed to meet the characteristics of the Response Spectrum Recorder and the Response Spectrum Switch as described in the American Nuclear Society Standard ANSI/ANS-2.2-1978, "Earthquake Instrumentation Criteria for Nuclear Power Plants", and NRC Regulatory Guide 1.12 (Rev. 1), "Instrumentation for Earthquakes". It is a completely passive device covering the range of 2-25 HZ in 1/3 octave increments. Damping of each accelerometer is nominally 2%. It is completely self contained. Three recorders are arranged triaxially.

Twelve reeds of different lengths and weights, one for each frequency, are fabricated from spring steel. A diamond-tipped stylus is attached to the free end of each reed to inscribe a permanent record of its deflection on one of twelve record plates. The record plates are aluminum, plated with successive layers of nickel, tin, and lead-tin.

The Model PSR1200-H/V-12A comprises the standard PSR1200-H/V plus the capability of providing instantaneous warning signals when preset accelerations at selected frequencies have been exceeded. This is achieved by adding dual contacts which are closed by the reed when it is deflected through a predetermined distance.

2.2 PEAK ACCELERATION RECORDER (Peak Accelerograph)

The Model PAR400, Peak Acceleration Recorder, is designed to meet the characteristics of the Peak Accelograph described in ANSI/ANS-2.2-1978 and NRC Regulatory Guide 1.12. It senses and records peak accelerations triaxially. It is a self-contained passive device requiring no external power or control connections and has a minimum band width of 0 to 26 Hertz with a sensitivity as low as .01 g. The recorder is nominally 60% damped. A diamond tipped scriber at the end of an amplifier arm traces a very fine visible permanent record on an aluminum record plate with successive layers of nickel, gold, and burnt gold.

3. DESIGNATIONS, LOCATIONS, AND CALIBRATION STATUS OF INSTRUMENTS

3.1 D51-R160 - REACTOR BUILDING FOUNDATION

Triaxial Response Spectrum Recorder (PSR1200-H/V-12A)
Location - 574' Reactor Building foundation mat, azimuth 210° (see drawing D-811-801 and D-814-663-909)
Active scratch recorder, which alarms on control room panel 1H13-P969, annunciator panel D51-R215
Most recent calibration on 1-14-85. *

3.2 D51-R170 - REACTOR BUILDING I.D.W. 630' PLATFORM

Triaxial Response Spectrum Recorder (PSR1200-H/V)
Location - inside Drywell platform - 630', azimuth, 240° (see drawing D-811-605 and D-814-665-910)
Most recent calibration completed on 1-30-86. *

3.3 D51-R180 - HPCS PUMP BASE MAT

Triaxial Response Spectrum Recorder (PSR1200-H/V)
Location - HPCS Pump Room - Auxiliary Building foundation mat 574' (see drawing D-811-701 and D-814-663-911)
Equipment being calibrated on 1-31-86 during earthquake. (North-Southn and East-West recorders operable).
Previous calibration on 1-14-85. *

* Calibration interval is established at 18 months by ANSI/ANS - 2.2-1978, "Earthquake Instrumentation Criteria for Nuclear Power Plants."

3.4 D51-R190 - RCIC PUMP BASE MAT
Triaxial Response Spectrum Recorder (PSR1200-H/V)
Location - RCIC Pump Room - Auxiliary Building foundation mat 574' (see drawing D-811-702 and D-814-663-912)
Equipment being calibrated on 1-31-86 during earthquake (all recorders operable).
Previous calibration on 1-14-85.*

3.5 D51-R120 - REACTOR RECIRCULATION PUMP
Peak Acceleration Recorder (PAR400)
Location - inside Drywell - 574' elevation. (see drawing D-811-602 and D-814-663-906). Located on recirculation pump B33-C001A.
Most recent calibration 12-4-85.*

3.6 D51-R140 - HPCS PUMP BASE MAT
Peak Acceleration Recorder (PAR400)
Location - Auxiliary Building - 574'
HPCS Pump Room - Auxiliary Building foundation mat 574' (see drawing D-814-633-908 and D-811-701)
Most recent calibration on 1-30-86. *

4. DATA REDUCTION

The following tabulations on Pages 8 through 13, show the initial data reduction made on January 31, 1986 by Perry Plant personnel and a field representative of Engdahl Enterprises. An independent data reduction made by Engdahl Enterprises on February 2, 1986 is listed alongside the initial reduction.

A total of 129 data point readings were tabulated. A comparison of the two independent data reductions indicates a very close correspondence. Most indicate no significant differences. For those cases where differences exist, the greatest differences (with one exception) are on the order of 0.03g. The largest acceleration difference between the two data reductions was 9% (MPL Number D51-R170, reed number 12, vertical). Even in this case, the difference is within tolerances allowed by industry standards.

5. DATA EVALUATION

The record plates from three of the four triaxial PSR1200 recorders had many scratches and some had multiple zero lines which made them difficult to read. This condition was due to construction work in progress since the recorders had been calibrated and installed in January 1985. Although initial review of these plates indicated that data reduction might be questionable, further review (including comparison with data from the Kinemetrics Time-History recorders**) has established the validity of the data reduction.

**Kinemetrics/Systems, "Strong-Motion Data Report for the M_L 5.0 Earthquake of 1147 EST, January 31, 1986" (February 4, 1986)

5.1 D51-R120, Reactor Recirculation Pump and
D51-R140, HPCS Pump Base Mat

The records from these PAR400 recorders were good. D51-R120 had the best records. D51-R140 had poorer zero lines but the results were nonetheless in close agreement with Reactor Building foundation mat data from Kinemetrics Time-History recorder data.

5.2 D51-R160, Reactor Building Foundation

A reading was made for each reed in the horizontal directions. The North/South accelerations were in very close agreement with the response spectrum generated from the Time-History recorder (D51-N101). The East/West did not agree as well but was similar. Only six of twelve vertical data points were readable. All of these values were quite low indicating a low vertical component of acceleration.

5.3 D51-R170, Reactor Building I.D.W. 630' Platform

The most readable of the PSR1200 records were on the Reactor Building I.D.W. 630' Platform. The North/South was especially good with very good zero lines. The East/West and the vertical recorders each had two of twelve records that were difficult to read.

5.4 D51-R180, HPCS Pump Base Mat and
D51-R190, RCIC Pump Base Mat

These two installations are both on the Auxiliary Building foundation mat but separated by approximately 80 feet. The resulting North/South response spectra are almost identical. The East/West response spectra were similar. The vertical D51-R180 recorder was not in service due to recalibration activities, so no comparison can be made. The vertical D51-190 recorder is questionable since the zero lines were offset by large amounts in most cases.

5.5 Dual records were noted on some of the record plates. The clearest of these are on D51-R160, East/West. A separate tabulation is made of the six best records (see page 14). A dual record is normally made when the record plate moves a very slight amount (.001 to .002 inches) after one record is made and then a second record is made. It is possible that all six plates moved at low levels and that the second record is just a continuation of the same event. It is also possible that the low level event was recorded and then the plates moved before the second event.

6. CURRENT STATUS

6.1 At present, the instruments are in operation with new record plates except the vertical recorder, D51-R180, which has been removed for recalibration.

6.2 Plans have been made to start the recalibration of all of the instruments on February 10, 1986. This recalibration is in preparation of fuel loading, and not as a result of the seismic event.

7. CONCLUSIONS

Although the records were not always easy to read because of activity at the plant during the construction phase, the records were clear enough in most cases to give very good overall results. Recalibration of the instruments was not required by the seismic event. Recalibration will be performed starting February 10, 1985 in preparation for fuel loading.

Paul D. Engdahl

cjw

MPL NUMBER: D51-R120
LOCATION: REACTOR RECIRCULATION PUMP

SENSOR LOCATION	ACCELERATION (g)	
	1-31-86	2-2-86
NORTH/SOUTH (L)	.32	.318
EAST/WEST (T)	.10	.106 *
VERTICAL	.07	.048 *

* Zero lines not clear, best estimate

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

SENSOR LOCATION	ACCELERATION (g)	
	1-31-86	2-2-86
NORTH/SOUTH (L)	.15	.167
EAST/WEST (T)	.06	.058
VERTICAL	.04	.029

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

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical	
		1-31-86	2-2-86	1-31-86	2-2-86	1-31-86	2-2-86
1	2.00	.027	.027	.029	.030	.007	**
2	2.52	.038	.038	.046	.046	.013	.011
3	3.17	.062	.060	.039	.040	**	**
4	4.00	.032	.035	.022	.026	**	**
5	5.04	.067	.069	.056	.054	**	.018
6	6.35	.065	.075	.054	.054	**	.016
7	8.00	.143	.133	.056	.051	.010	**
8	10.1	.136	.091	.176	.160	.061*	.053*
9	12.7	.196	.227	.236	.230	.032	.038
10	16.0	.286	.305	.284	.284	.101	.111
11	20.2	1.04	1.02	.605	.586	.224	**
12	25.4	.7657	.766	.540	.513	.329	**

* "C" surface
** Unreadable

MPL NUMBER: D51-R170
LOCATION: REACTOR BUILDING I.D.W. 630' PLATFORM - DW 630', 240°

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical	
		1-31-86	2-2-86	1-31-86	2-2-86	1-31-86	2-2-86
1	2.00	.047	.048	.049	.051	.007	.007
2	2.52	.082	.082	.086	.084	*	.013
3	3.17	.184	.184	.144	.140	.015	.014
4	4.00	.226	.223	.128	.127	.023	.023
5	5.04	.132	.134	.158	.158	.035	.033
6	6.35	.131	.134	.058	.055	.033	.030
7	8.00	.104	.104	.109	.090	*	.019 (2)
8	10.1	.093	.093	*	.052 (1)	.093	.085 (2)
9	12.7	.188	.182	.166	.080 (2)	.198	.199
10	16.0	.194	.204/ .167	.348	.312	.490	.500
11	20.2	.152	.152	.191	.175	.973	.973
12	25.4	.114	.091	.155	.158	1.7	1.54

* Unreadable
(1) Unusual appearance
(2) Very difficult to read - best estimate

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

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical*	
		1-31-86	2-2-86	1-31-86	2-2-86	1-31-86	2-2-86
1	2.00	.0198	.020	.022	.021	-	-
2	2.52	.0358	.036	.033	.031	-	-
3	3.17	.0677	.068	.045	.048	-	-
4	4.00	.0474	.047	.022	.020	-	-
5	5.04	.0637	.064	.033	.029	-	-
6	6.35	.0735	.068	.054	.050	-	-
7	8.00	.0473	.052	.046	.046	-	-
8	10.1	.0744	.074	.566	**	-	-
9	12.7	.125	.149	.182	.176	-	-
10	16.0	.4582	.449	.253	.214	-	-
11	20.2	.9130	.896/ .432	.413	.429	-	-
12	25.4	.6100	.610/ .293	.191	**	-	-

* Not in service
** Unreadable

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

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical	
		1-31-86	2-2-86	1-31-86	2-2-86	1-31-86	2-2-86
1	2.00	.021	.018	.026	.022	**	**
2	2.52	.039 (1)	.030	.031	.021	**	.013
3	3.17	*	*	.024	.017	**	**
4	4.00	.0367	.031	.028	.023	.029	**
5	5.04	.0305	.045	.037	.038	**	**
6	6.35	.0896	.065	.057	.048	**	**
7	8.00	.0750	.040	.068	.034	.019	.014
8	10.1	*	*	.097	.044	**	**
9	12.7	.130	.124	.142	.136	.053	.024
10	16.0	.409	.400	.162	.162	.082	.055
11	20.2	.810	.794	.237	**	**	.099
12	25.4	.556	.557	**	.156	.256	.256

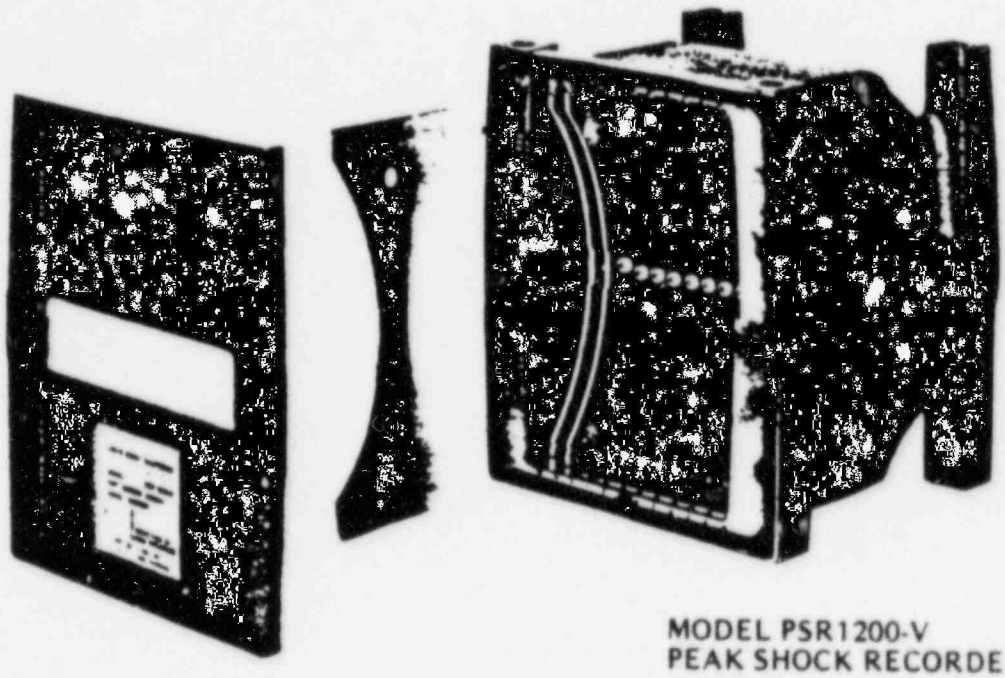
(1) Mathematical error corrected. Originally reported acceleration 0.198.
* Unable to read due to corrosion
** Unreadable

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

REED NUMBER	NOMINAL FREQUENCY (HERTZ)	ACCELERATION (g)					
		North/South		East/West		Vertical	
		1-31-86	2-2-86	1-31-86	2-2-86	1-31-86	2-2-86
1	2.00	-	-	-	.006	-	-
2	2.52	-	-	-	.009	-	-
3	3.17	-	-	-	.010	-	-
4	4.00	-	-	-	.026	-	-
5	5.04	-	-	-	.054	-	-
6	6.35	-	-	-	.035	-	
7	8.00	-	-	-	-	-	-
8	10.1	-	-	-	-	-	-
9	12.7	-	-	-	-	-	
10	16.0	-	-	-	-	-	
11	20.2	-	-	-	-		-
12	25.4	-	-	-	-	-	-

APPENDICES

MODEL
PSR1200-H/V-4A
and
PSR1200-H/V-12A



MODEL PSR1200-V
PEAK SHOCK RECORDER™

SENSES AND PERMANENTLY RECORDS THE SPECTRAL ACCELERATION AT SPECIFIED FREQUENCIES

PROVIDES SIGNALS FOR IMMEDIATE REMOTE INDICATION THAT SPECIFIED PRESET SPECTRAL ACCELERATIONS HAVE BEEN EXCEEDED

- EARTHQUAKES
- STORMS
- EXPLOSIONS

RELIABLE and ECONOMICAL

ENGDAHL ENTERPRISES

2850 Monterey Avenue · Costa Mesa, California 92626 · (714) 540-0398

Introduction

Traditionally, measurement of acceleration has implied measurement with the aid of a device whose resonant frequency was far removed from the frequency range of interest. A typical accelerometer for aerospace applications might have a mass of 10 grams and a resonant frequency of 10 kHz or higher. Such devices were designed primarily for attachment to a structural member to measure its response to shock or vibration. Their low mass was necessary to avoid modifying the characteristics of the device under test, while the resonant frequency had to be at least five times that of the highest frequency of interest. At the other end of the spectrum, earthquakes and other low frequency phenomena are conventionally detected and recorded using instruments whose resonant frequencies are much lower than the frequency range of interest.

A structure such as a large office building, a missile silo or an electrical generating station has many members and subassemblies with a wide range of resonant frequencies, and many of these are lightly damped, i.e., a shock will cause them to "ring" for a relatively long time. To measure the effects of an earthquake or other shock on such a structure in the traditional way, would require a very large number of transducers and a complex data acquisition system followed by computer analysis to digest the raw data and decide whether or not structural damage had been sustained.

To simplify the design of shock resistant structures, dynamicists frequently define shocks and earthquakes in terms of response shock spectra. Basically, a response shock spectrum is a plot of acceleration vs. frequency in which each point represents the peak acceleration experienced by an accelerometer tuned to that specific frequency. The range of frequencies covered by the peak shock accelerometers corresponds to those found in most structures, systems, and components. Since all structural elements possess some low inherent damping, the Peak Shock Recorder™ has been designed with 2% of critical damping. The output obtained is thus directly applicable to structural design and analysis.

A response spectrum may be derived from the conventional acceleration vs. time record of a suitable recording accelerometer, but this involves either digitizing the records followed by computer manipulation of the data or the use of a large amount of auxiliary equipment. The first method is time consuming, while the second is expensive. The Model PSR1200-H/V is an inexpensive instrument requiring no source of power, and virtually no maintenance. It provides a permanent record of data from which the response spectrum may be plotted by a very simple reduction process.

Description

The Model PSR1200-H/V, Peak Shock Recorder™, is a completely passive device covering the range of 2-25 Hz in 1/3 octave increments. Damping of each accelerometer is nominally 2%. It is completely self contained.

Twelve reeds of different lengths and weights, one for each frequency, are fabricated from spring steel. A diamond-tipped stylus is attached to the free end of each reed to inscribe a permanent record of its deflection on one of twelve record plates. A calibration sheet for each recorder lists the resonant frequency and g-sensitivity of each reed.

–V designates a recorder designed for vertical shock recording (compensated for earth's gravitational force). –H designates a recorder designed for horizontal shock recording.

The Model PSR1200-H/V-4A/12A comprises the standard PSR1200-H/V plus the capability of providing instantaneous warning signals when preset accelerations at selected frequencies have been exceeded. This is achieved by adding dual contacts which are closed by the reed when it is deflected through a predetermined distance. Model –4A monitors four selected reeds, while –12A monitors all of the reeds.

Uses

The PSR1200, Peak Shock Recorder™, is useful whenever acceleration measurements are desired at low frequencies. These accelerations may be due to earthquakes, storms, or explosions. The plot of the recorder's twelve individual measurements is the response spectrum of the acceleration to which the recorder was subjected.

The response spectrum switch (–A) version of the PSR1200 is useful whenever remote indications are desired that acceleration limits have been exceeded. The remote indication that four or twelve dual acceleration limits have or have not been exceeded provides immediate information on which to act.

The Peak Shock Recorder™ can be used in connection with:

1. Nuclear power plants
2. Steel mills
3. Refineries
4. Bridges and dams
5. High-rise structures
6. Oil explorations
7. Mines
8. Ships
9. Earth studies
10. Towers

Features

Dzus, quarter-turn fasteners, are used to secure the cover, making it easily removable. The cover is clamped tight enough against the gasket bonded to the watertight housing to provide protection of the u it to 50 PSI (3.6 kg/Cm^2) of water pressure.

The record plates are serialized so only one set of twelve have the same number. In addition, the plates have two types of slots to allow keying. The narrow key slot allows the plate to slide into only one slot in the housing to its full depth. That is, the plates all have to be in their correct locations in the housing to attach the cover.

The record plates can be inserted four different ways into the housing, allowing four records to be made before using a second set of plates. To prevent mixing the records, all plates must be inserted for the record to appear at A, B, C, or D or, again, the cover cannot be attached. A viewing window is provided, and the appropriate letter A through D will show so the cover need not be removed to know how the plates are inserted. During shipping, a red dot is seen. This means that the plates have been removed and the reed support structure is in place.

Additional keying is provided between the covers and housings in the form of dowel pins. These pins prevent the cover from being put on upside down. They also prevent a cover from a horizontal recorder (–H) being put on a vertical recorder (–V) or a –V on a –H.

Since a lower atmospheric pressure could be created inside the recorder than outside during shipment by air, a jackscrew is provided in the cover to lift a corner of the cover and break the partial vacuum. It will also be of assistance when the unit has been closed for a long period of time as the neoprene gasket may adhere slightly to the cover.

The recorder is reliable because of its simplicity. It does not contain any of the more complex and less reliable components, i.e., batteries, connectors, motors, and bearings. Its rugged structure is fabricated from aluminum alloy. Only a few parts are used. The recorder is self-contained, and requires no start-up time.

The recorder is economical in that no external connections or power are required. The record plates are reusable by replating after four records have been obtained. Maintenance is very low since the unit can be unattended for long periods of time. Data reduction is very simple, requiring only one measurement and one multiplication for each record plate to plot its point on the response spectrum.

The response spectrum switch (—A) version of the recorder has all of the features of the PSR1200.

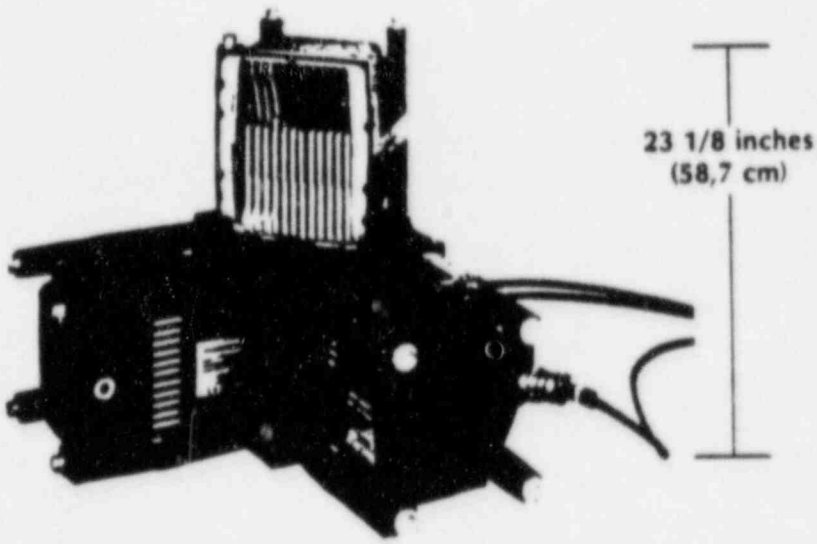
To retain the basic reliability of the PSR1200, no batteries, motors, or bearings have been added. Electrical power is provided from the Peak Shock Annunciator™.

Every effort has been made to achieve the utmost reliability in the switching circuitry so as to match the reliability of the basic Peak Shock Recorder™. Closure of a switch contact sets an electronic latching switch which energizes the appropriate circuit in the annunciator and holds it energized until reset by the key-switch.

High impedance circuitry permits normal operation even if switch contact resistance exceeds several hundred thousand ohms. Ceramic encapsulated integrated circuits offer maximum resistance to the effects of temperature and humidity.

Finally, the heavy cast aluminum housing of the recorder offers protection against radiated interference or spurious mechanical operation caused by striking the recorder.

The recorder can be used singly, biaxially, or triaxially.



TRIAXIAL INSTALLATION OF THREE MODEL PSR 1200-H/V-12A PEAK SHOCK RECORDERS™ ON TRIAXIAL MOUNT

Switch Settings (—A version only)

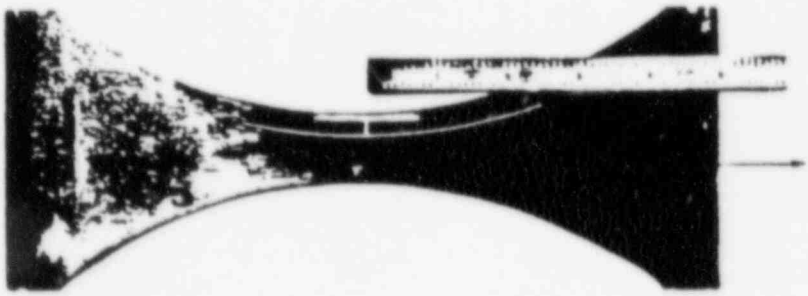
The switch settings are permanently set to positions required by the customer's application. The —4A allows four dual settings, that is, the customer selects four frequencies to be monitored between 2 and 25 Hertz. Two acceleration levels can be selected for switch contacts for each reed frequency, e.g., .47 g and .70 g at 3.2 Hertz. The —12A has twelve dual settings between 2 and 25 Hertz. See the tabulation of "Frequency and Switch Setting Limits" for selection available.

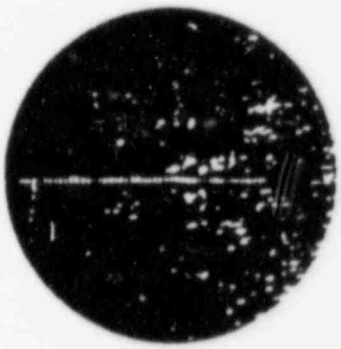
Data Reduction

Data reduction is done by measuring the maximum distance of the scratched record from the zero line. Normally just the maximum is recorded regardless of the direction. List this distance under "Displacement" on the calibration sheet.

Multiply the "Displacement" times the "Acceleration sensitivity" and record in the "Equivalent static acceleration" column. Plot the response spectrum graph.

Large displacement measurements can be made with a six-inch (152 mm) scale with graduations in hundreths (.01) of an inch (.25 mm). Small displacements can be made using a microscope with a reticle having graduations in thousandths (.001) of an inch (.025 mm).



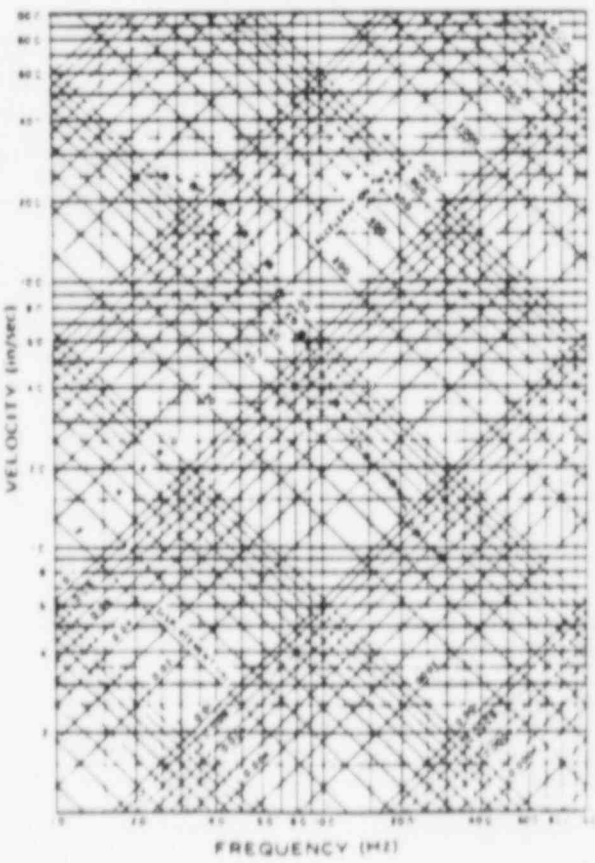


CALIBRATION SHEET AND TEST DATA

Reed Number	Frequency (Hertz)	Acceleration Sensitivity (g/inch)	Displacement (inches)	Equivalent Static Acceleration (g)
1	2.02	.359	2.51	.90
2	2.54	.55	2.00	1.1
3	3.20	.85	1.41	1.2
4	4.02	1.32	.98	1.3
5	4.92	2.34	.56	1.3
6	6.02	3.62	.33	1.2
7	8.08	5.5	.15	.83
8	10.2	7.6	.079	.6
9	12.7	6.6	.076	.5
10	16.2	10.5	046	.5
11	20.6	17.5	.022	.4
12	26.1	26.8	.015	.4

CALIBRATION DATA REDUCTION

RESPONSE SPECTRUM



PEAK SHOCK RECORDER™

MODELS PSR1200-H/V-4A and PSR1200-H/V-12A

QUALIFIED TO: GUIDE FOR SEISMIC QUALIFICATION OF CLASS 1 ELECTRICAL EQUIPMENT FOR NUCLEAR POWER GENERATING STATIONS — IEEE GUIDE 344

Designed to meet the characteristics of the Response Spectrum Recorder and the Response Spectrum Switch described in the American Nuclear Society's Standard, ANSI/ANS-2.2-1978, Earthquake Instrumentation Criteria for Nuclear Power Plants and the U.S. Nuclear Regulatory Commission's Regulatory Guide 1.12, Nuclear Power Plant Instrumentation for Earthquakes, Revision 1. NOTE: Frequency range from 2.00 to 25.4, instead of 1.00 to 30.0.

PHYSICAL

Length	12-27/32 inches (32,6 cm)
Width	11-1/2 inches (29,2 cm)
Thickness	10 inches (25,4 cm)
Weight	34 pounds (15,4 kg)
	36 pounds (−A) (16,3 kg)

ENVIRONMENTAL

Temperature	−40°C to +85+C
Altitude	To 50,000 feet (15,240 meters)
Humidity	To 100% RH
RFI	No adverse radiated or conducted RFI
Water-Tight	To 50 PSI (3,6 kg/cm²)
	To 10 PSI (−A) (,7 kg/cm²)
Nuclear Radiation	No effect on performance of permanent recorder. Switch electronics are not radiation hardened, unless requested at extra cost.

SENSORS

Number of Sensing Elements	12
Damping	2% (Q of 25)
Arrangement of Sensing Elements	Coplanar
Number of Switch Contacts	
−4A	4 Dual Contacts
−12A	12 Dual Contacts

ACCURACY

Frequency	±1%
Acceleration	±3% at 1g
Dynamic Range	See Table
Switch Settings	±3% at 1g

MOUNTING

4 through holes for 1/2 inch bolts

FREQUENCY, RANGE, and SWITCH SETTING LIMITS OF SENSING ELEMENTS

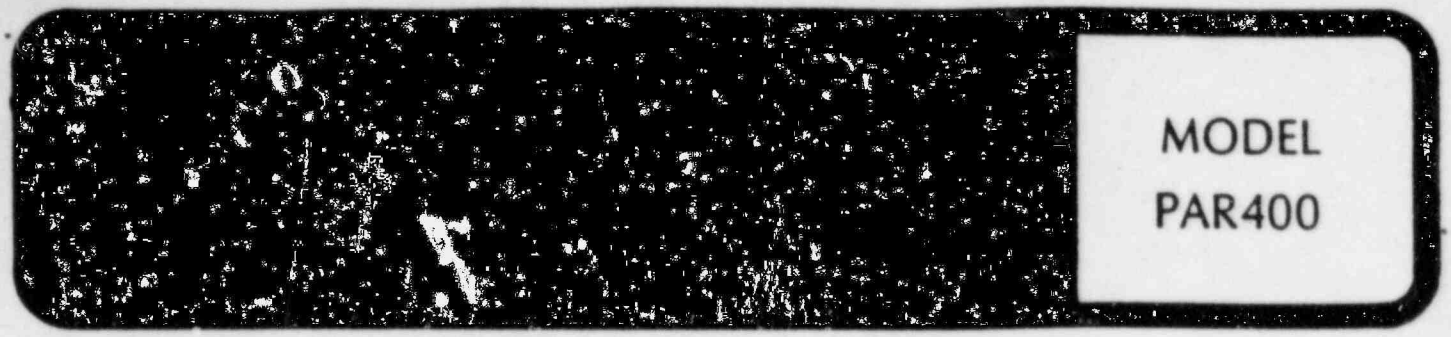
Reed Number	Nominal* Resonant Frequency (Hertz)	Full Scale Acceleration (g)	Dynamic Range		Switch Setting Limits** (g)	
			(db)	Ratio	Minimum*** (Accuracy ±100%)	Maximum (Physical Stops)
1	2.00	1.6	54.5	530:1	.003	1.6
2	2.52	2.5	55.8	620:1	.004	2.5
3	3.17	4	58.1	800:1	.005	4
4	4.00	6	58.7	860:1	.007	6
5	5.04	10	60.9	1110:1	.009	10
6	6.35	16	61.8	1230:1	.013	16
7	8.00	24	63.0	1410:1	.017	24
8	10.1	34	64.6	1700:1	.020	34
9	12.7	8	54.5	530:1	.015	8
10	16.0	12	55.6	600:1	.020	12
11	20.2	4	46.0	200:1	.020	4
12	25.4	6	49.5	300:1	.020	6

* — 4A Allows choice of 4 frequencies to be monitored from 2 to 25 Hertz
— 12A Allows all 12 frequencies to be monitored from 2 to 25 Hertz

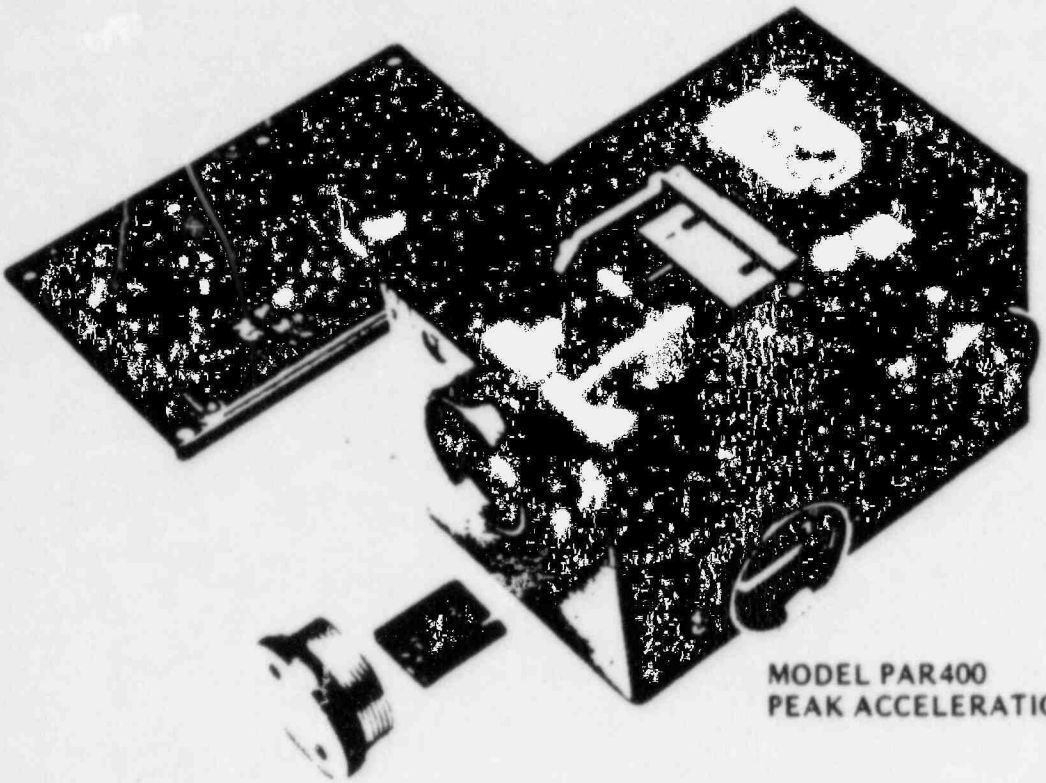
** — Two switch settings for each frequency to be monitored.

*** — Do not use PSR1200-H/V-A for settings under 0.10g
For lower settings use PSR1600-H/V-A

REPRESENTED BY



MODEL PAR400



3-3/16 inches
(8.1 cm)

MODEL PAR400
PEAK ACCELERATION RECORDER™

SENSES AND PERMANENTLY RECORDS PEAK ACCELERATIONS

- EARTHQUAKES
- STORMS
- EXPLOSIONS

RELIABLE and ECONOMICAL

ENGDAHL ENTERPRISES

2850 Monterey Avenue · Costa Mesa, California 92626 · (714) 540-0398

Introduction

Seismic events are random events, and may occur in remote and inaccessible locations or in built-up areas. Scientists and engineers frequently need to know the acceleration levels associated with these events, and for this reason, have developed instruments requiring no source of power, which can provide permanent records of peak acceleration.

Instruments of this type have been used for many years, but with the advent of the nuclear power plant, higher sensitivity and increased bandwidth are required to measure the accelerations induced in piping and other equipment. Since the older types of peak accelerometers had been pushed to their design limits, an entirely new instrument was required.

This requirement has been met with the Model PAR400, Peak Acceleration Recorder™. It is an inexpensive triaxial unit which requires no power supply, and is virtually maintenance free. Peak accelerations as low as .01 g can be recorded, and the minimum bandwidth extends from 0 to 26 Hertz. Permanent records are scribed by diamond stylii on replaceable metal plates. The peak acceleration is computed by multiplying the maximum excursion of the trace by the acceleration sensitivity of the recorder.

Description

The Model PAR400, Peak Acceleration Recorder™, senses and records peak accelerations triaxially. It is a self-contained passive device requiring no external power or control connections and has a minimum band width of 0 to 26 Hertz with a sensitivity as low as .01 g.

Each sensor of the PAR400 incorporates a new method of mechanical amplification which makes it more than five times as sensitive as previous devices. With the aid of optical magnification, its permanent record can be read to .001 of an inch (.025 mm) or less. With a full scale deflection of .200 inches (5 mm), the −1 version (2 g full scale) has a dynamic range of 200:1 (46 db).

Air damping is used since it is very efficient for its size and weight. Minor adjustments of damping can be made in the field, if required.

Sensors are available in three natural frequencies: 32, 51 and 64 Hertz. The assemblies are mechanically identical and completely interchangeable, so any combination may be included in a triaxial recorder.

The record is scratched permanently on a metal plate which is both serialized and keyed to the recorder to assure that the records are not confused among the three axes. Since the record is scratched, it can be measured without further processing. The record plates are inserted through side holes in the casting without taking off the cover. This minimizes the possibility of damaging the recorder or inadvertently recording on the record plate during insertion or removal by touching the mechanism.

Applications

The PAR400 is useful whenever low frequency peak acceleration measurements are needed. These accelerations may be due to earthquake, storms, or explosions. The three records give the acceleration levels along three mutually perpendicular axes.

The Peak Acceleration Recorder™ can be used in connection with:

1. Nuclear power plants
2. Steel mills
3. Refineries
4. Bridges and dams
5. High-rise structures
6. Mines
7. Ships
8. Off-shore oil rigs
9. Transportation shock

Features

The PAR400 is a very sensitive, wide band, low frequency acceleration recording instrument. The high sensitivity is obtained by using a heavy mass to detect the acceleration, and then mechanically amplifying its motion. A diamond tip scriber at the end of the amplifier arm traces a very fine visible permanent record of the arm's excursions. The scribe line widths are on the order of .0004 inches (.01 mm).

Three plates, stamped L, T, and V, respectively, are used to record the excursions in the three axes. Slotted keyways on the plates match up with pins in the housing so that only the correctly stamped plate can be inserted full depth into the corresponding sensor. Each set of three plates also carries a unique serial number. This permanent identification system eliminates the possibility of confusing the records.

The rugged cast aluminum housing has three pads to contact the mating surface when mounted. A single screw is used for attachment. Shims can be slid under the appropriate pad to level the unit. The screw is then tightened. A clearance hole is provided in the cover for the screw head so the cover need not be removed during mounting of the recorder.

To install the record plates, three plugs are removed from the side walls of the casting and the plates are slipped into the appropriate holders. The plugs are of such a size as to preclude damage to the mechanism during insertion or removal of the record plates. Since the cover does not have to be removed to replace record plates, the mechanism is not exposed to inadvertent damage.

When a record plate is inserted, a spring-loaded pin forces the plate to one side of the track to eliminate any side play which would introduce an error in the recorded acceleration. The insertion produces a zero line on the plate. On removal, a zero line is also scratched. These zero lines should coincide if there is no mechanical shifting between insertion and removal. If there is a shift, the user is made aware that a problem exists.

To obtain wide band response, the instrument is damped to 60% of critical. A preadjusted air damper is used for damping to keep the size and weight of the total package as small as possible.

The recorder is reliable because of its simplicity. It does not contain any of the more complex and less reliable components, i.e., batteries, connectors, motors, and bearings. The recorder is self-contained, and requires no start-up time.

The recorder is economical in that no external connections or power are required. The record plates are reusable by replating. Maintenance is very low since the unit can be unattended for long periods of time.

Materials have been selected for long life even when exposed to nuclear radiation. The cast housing, along with the cover and three plugs, is chemically filmed (alodine) and painted with epoxy paint. The gaskets are made of EPDM to increase resistance to radiation. All hardware is stainless steel. An indicating silica gel desiccant is also provided to decrease the humidity inside the recorder.

Data reduction is very simple requiring only one measurement and one multiplication for each of the three record plates to obtain its maximum acceleration.

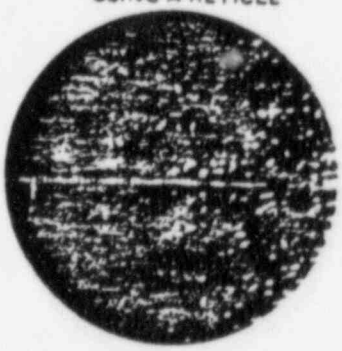
Data Reduction

Data reduction is accomplished by measuring the maximum displacement of the scratched record from the zero line. Normally just the maximum is recorded regardless of the direction. List this distance under "Displacement" on the calibration sheet.

Multiply the "Displacement" times the "Acceleration Sensitivity" and record in the "Acceleration" column.

Small displacement measurements can be made using a microscope with a reticle having graduations in thousandths (.001) of an inch. A magnifier with a reticle graduated in tenths (.1) of a mm can be used for medium displacements. Consult Engdahl Enterprises for microscopes.

MAGNIFIED RECORD USING A RETICLE



SAMPLE OF A CALIBRATION AND TEST DATA SHEET

Sensor	Natural Frequency (Hertz)	Acceleration Sensitivity (g/inch) [g/mm]	Displacement (inches) [mm]	Acceleration (g)
L	32.3	14.0 (.551)	.023 (.58)	.32
T	30.9	13.5 (.532)	.010 (.26)	.14
V	33.3	14.2 (.559)	.005 (.13)	.07
		CALIBRATION	DATA REDUCTION	

PEAK ACCELERATION RECORDER™

MODEL PAR400

QUALIFIED TO IEEE RECOMMENDED PRACTICES FOR SEISMIC QUALIFICATION OF CLASS 1E EQUIPMENT FOR NUCLEAR POWER GENERATING STATIONS, STD. 344-1975

Designed to meet the characteristics of the Peak Accelerograph described in the American National Standard ANSI/ANS-2.2-1978, Earthquake Instrumentation Criteria for Nuclear Power Plants and the U.S. Nuclear Regulatory Commission's Regulatory Guide 1.12, Nuclear Power Plant Instrumentation for Earthquakes, Revision 1.

SENSORS

Number of Sensing Elements	3	
Arrangement of Elements	Triaxial	
Full Scale Acceleration	−1	2 g
	−2	5 g
	−3	10 g
Dynamic Range	−1	200:1 (46 db)
	−2	385:1 (52 db)
	−3	500:1 (54 db)
Natural Frequency (± 5%)	−1	32 Hz
	−2	51 Hz
	−3	64 Hz
Damping	55 to 70% of Critical[1]	
Bandwidth	−1	0 to 26 Hz
	−2	0 to 41 Hz
	−3	0 to 52 Hz
Overall Accuracy	Within ± 5% at full scale, changing linearly to ± 1.5% of full scale at 0.01 g	
Detail Acceleration Accuracy	−1	.01 to .50 g ± .01 g
		.50 to 1¼ g ± 2%
		1¼ to 2 g ± 3%
	−2	.013 to .65 g ± .013 g
		.65 to 2 g ± 2%
		2 to 5 g ± 3%
	−3	.02 to 1 g ± .02 g
		1 to 3 g ± 2%
		3 to 10 g ± 3%

Spurious Resonances: None within frequency range of interest

Cross Axis Sensitivity: Less than .03 g/g

PHYSICAL DIMENSIONS

Length	5-1/4 inches (13.34 cm)
Width	3-5/8 inches (9.21 cm)
Height	3-11/32 inches (8.49 cm)
Weight	2-3/4 pounds (1.3 kg)

[1]Damping adjusted at nominal atmospheric pressure expected at time of operation.

MOUNTING

One (1) #10-24 Screw.

Level Recorder to ± 1° (1/16 inch in 3½ inches) (1.6 mm in 90 mm) by adding shims under the appropriate mounting pad. "V" will measure the vertical accelerations. Align long side of recorder within 3° (¼ inch in 5-1/8 inches) (6.4 mm in 130 mm) of designated North/South line. "L" (longitudinal) will measure N/S accelerations. "T" (transverse) will measure E/W.

ENVIRONMENTAL

Temperature	−40°C to + 85°C
Humidity	To 100% RH
RFI	Does not radiate or conduct RFI. Not affected by external RFI.
Water	Water-Tight to 70 PSI (5 kg/cm^2)

Nuclear Radiation

The following materials are used in the construction of the PAR400.

1. Metals: Aluminum, Brass, Stainless Steel, Beryllium Copper, Gold, Nickel
2. Non-Metallic Materials

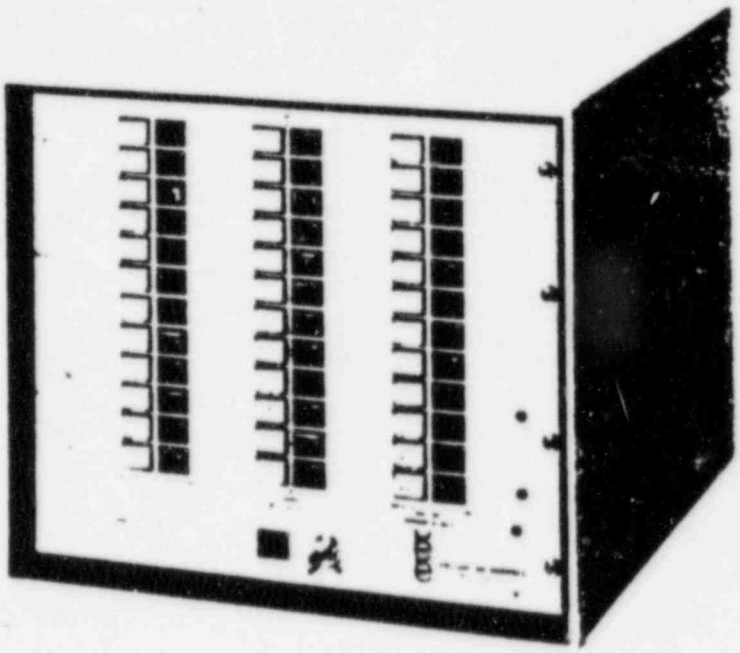
Description	Material	Stress Level	Approx. Stability[2] (RAD)
Paint	Epoxy	Low	1 x 10^8
Adhesive	Epoxy	Low	1 x 10^8
Adhesive	Anaerobic	Low	2 x 10^8
Adhesive	Cyanocrylate	Low	2 x 10^8
Gaskets	EPDM	Low	1 x 10^8
Piston	Graphite	Low	2 x 10^8
Cylinder	Pyrex	Low	2 x 10^8
Scriber	Diamond	Low	2 x 10^8

POWER REQUIREMENTS – None

[2]Source: Dow Corning Corporation, Loctite Corporation, Corning Glass Work, E.I. Du Pont De Nemours & Company, Parker Seal Company, Raychem Corporation, General Electric

REPRESENTED BY:

MODEL PSA875 and PSA1575



17¼ inches
(43.8 cm)

MODEL PSA1575
PEAK SHOCK ANNUNCIATOR™

INDICATES THAT SPECIFIED PRESET SPECTRAL ACCELERATIONS HAVE BEEN EXCEEDED

PROVIDES CONTACT CLOSURES FOR REMOTE INDICATORS OR ALARMS

- EARTHQUAKES
- STORMS
- EXPLOSIONS

RELIABLE and ECONOMICAL

ENGDAHL ENTERPRISES

2850 Monterey Avenue • Costa Mesa, California 92626 • (714) 540-0398

Description

The Models PSA875 and PSA1575, Peak Shock Annunciators™, give visual warning that predetermined acceleration limits, making up a response spectrum, have been exceeded at certain frequencies. They are designed to operate in conjunction with tuned Peak Shock Recorders™, PSR1200-H/V-4A/12A. Both models have three banks of indicator lamps, one bank for each of three mutually perpendicular axes. Amber lights indicate accelerations approaching design limits (normally 70%) while red lights indicate that design limits have been exceeded. Model PSA875 monitors four frequencies per axis while Model 1575 monitors twelve. Both models may be equipped with relays to operate remote indicators or alarms. (See "Options and Accessories".)

Applications

The annunciators may be used whenever it is desired to indicate instantaneously the reaction of a structure to a complex shock such as an earthquake or an explosion. The information provided permits an immediate decision as to whether or not the operation can continue or must be shut down.

The Peak Shock Annunciator™ can be used in connection with:

1. Nuclear power plants
2. Steel mills
3. Refineries
4. Bridges and dams
5. High-rise structures
6. Mines
7. Ships
8. Off-shore oil rigs
9. Transportation shock

Features

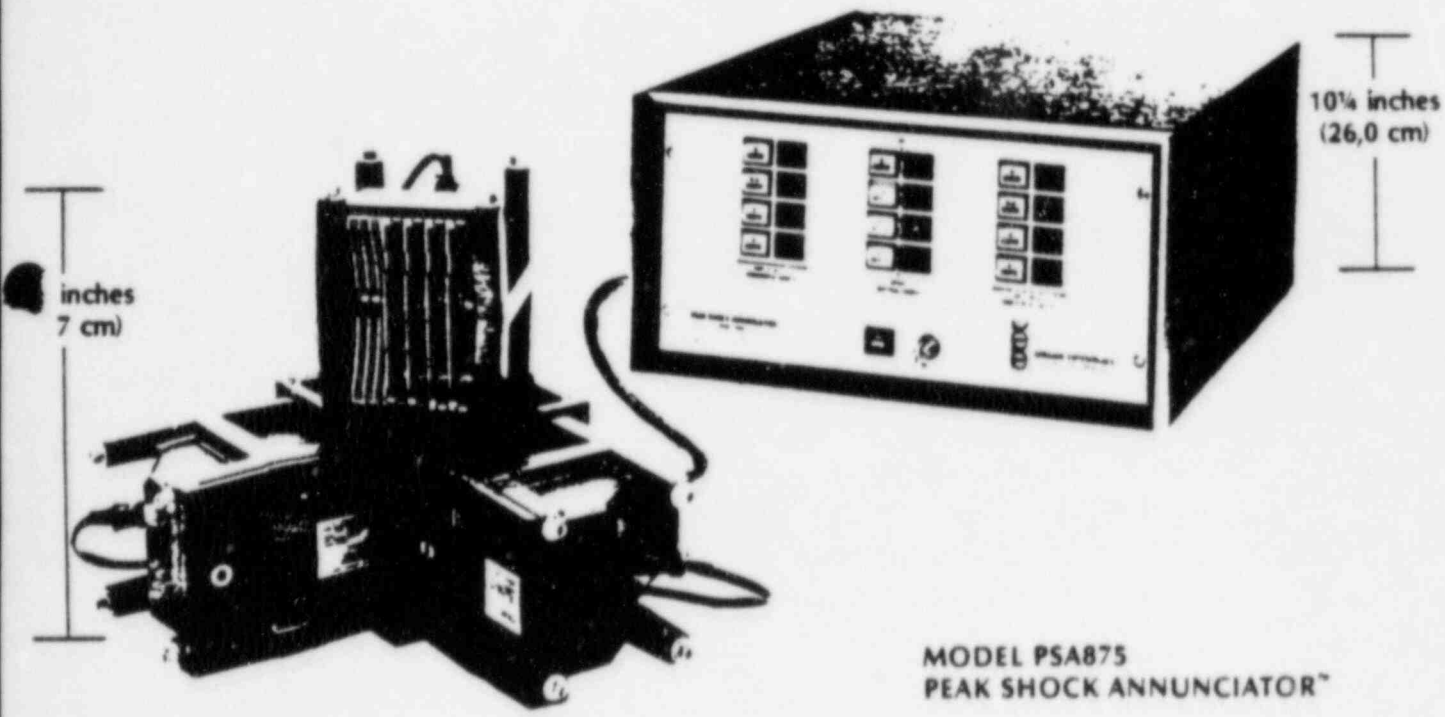
The "AC Power" indicator lamp is fed from the DC power on the printed circuit boards and shows that the incoming power line and the regulated DC supply are both operating normally.

A key-operated test/reset switch is provided. It controls two functions. In the "test" position, all of the indicator lamps should be illuminated and all relays (if provided) should be energized. This permits an immediate check that the annunciator is functioning correctly. When the key is returned to the "reset" position and removed from the switch, all indicators will be de-energized, the latches will be reset, and the annunciator is ready to receive signals from the Response Spectrum Recorder™. Once a signal has been received, the

appropriate lamp and relay, if any, will remain energized until the annunciator is reset with the key.

Where relays are provided for remote indicators or alarms, separate electronic driving circuitry is provided. Dual redundancy is thereby achieved for additional reliability.

Uninterruptible power supplies incorporating batteries for emergency operation can also be provided. If power failure is anticipated, battery operation is strongly recommended since power failure will reset any annunciated signal at the time of failure. Two additional indicators are mounted on the panel. One monitors the AC power at the transformer of the battery charger. The second monitors the charging circuit.



MODEL PSA875
PEAK SHOCK ANNUNCIATOR™

TRIAXIAL INSTALLATION OF THREE
MODEL PSR-1200-H/V-4A,
PEAK SHOCK RECORDERS™
ON TRIAXIAL MOUNT

PEAK SHOCK ANNUNCIATOR™
Models PSA875 and PSA1575

QUALIFED TO: GUIDE FOR SEISMIC QUALIFICATION OF CLASS I ELECTRICAL EQUIPMENT FOR NUCLEAR POWER GENERATING STATIONS – IEEE GUIDE 344

Designed to meet the characteristics of the Control Room Indicator for Response Spectrum Switch described in the American Nuclear Society's Standard ANSI/ANS-2.2-1978, Earthquake Instrumentation Criteria for Nuclear Power Plants and the U.S. Nuclear Regulatory Commission's Regulatory Guide 1.12, Nuclear Power Plant Instrumentation for Earthquakes, Revision 1.

PHYSICAL

	PSA875	PSA1575
Length	19 inches (48,3 cm)	19 inches (48,3 cm)
Width	20⅝ inches (52,4 cm)	20⅝ inches (52,4 cm)
Thickness	10¼ inches (26,0 cm)	17¼ inches (43,8 cm)
Weight	33 pounds (15 kg)	45 pounds (20,5 kg)

INDICATORS

Number of Axes Monitored	3	3
Number of Frequencies Monitored	12	36
Number of Indicators	24	72

ENVIRONMENTAL

Temperature	0 to +70°C
Humidity	To 100% RH
RFI	No adverse radiated or conducted RFI

POWER REQUIREMENTS

Voltage	115 VAC
Current	2½ amperes maximum

MOUNTING

Bench or Standard 19" (48,3 cm) Relay Rack
8¾" (22,2 cm) high or
15¾" (40,0 cm) high
27 lbs. (12,3 kg)

Options and Accessories (available at extra cost)

1. Relay closures for remote indication and alarm. One relay with Form C contacts can be provided for each output indicator. A connector on the back of the chassis facilitates system implementation. The connector is wired for normally open or normally closed operation.

To date, most customers have selected a two-relay system. One relay indicates that the lower level (amber) has been exceeded. The second relay indicates the upper level (red) has been exceeded at least once.

Relays are rated at: 1/10 Hp, 3 amps @ 120 VAC or 3 amps @ 28 VDC resistive.

2. Uninterruptible power supplies incorporating batteries for emergency operation can be furnished within the confines of the annunciator. If power failure is anticipated, battery operation is strongly recommended since power failure will reset any annunciated signals at the time of the failure.

REPRESENTED BY:

ATTACHMENT 4