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 DR. CHANG CHEN

County of Berks)
: ss.
State of Pennsylvania)

CHANG CHEN, being first duly sworn, deposes and says as follows:

1. I, Chang Chen, am Manager of the Civil/Structural Department and Chief Structural Engineer for Gilbert Commonwealth, Inc. ("Gilbert"). My business address is Route 10 and Pheasant Road, Green Hills, Reading, Pennsylvania, 19607. I have personal knowledge of the matters set forth in this Affidavit, which are true and correct to the best of my knowledge and belief.

2. Gilbert is an international architect-engineering firm specializing in the design of nuclear and fossil power plants in the United States and abroad. Gilbert has designed and engineered 15 nuclear plant units in the United States, Japan, Korea and Yugoslavia. Gilbert is the principal Architect/Engineer for the Perry Nuclear Power Plant.

3. In my present position, I have the overall responsibility for all civil/structural work associated with all of the power plants (both nuclear and fossil), including Perry, designed by Gilbert. I also am responsible for nuclear power plant equipment seismic qualification on all Gilbert-designed nuclear plants. There are over 100 engineers and designers reporting to me in my present position. I have been employed by Gilbert for over 16 years. I have supervised the seismic analysis and design of the Perry Plant, including development of the Perry design response spectra since Gilbert commenced the engineering for Perry in 1972. While working at Gilbert, I have also been responsible for major seismic design reviews of nuclear plants in other countries designed by other firms, including as a consultant to Kraftwerk Union (KWU) in connection with the seismic design of a 1,300 MW nuclear plant in Iran.

4. A statement of my professional qualifications is attached hereto as Exhibit "A". As indicated therein, I hold a Bachelor of Science degree in Civil Engineering (1962) from

Cheng Kung University in Taiwan; a Master of Science in Civil Engineering from Duke University (1965); and a Ph.D in Engineering Mechanics from The Pennsylvania State University (1969). I am a Registered Professional Engineer in Pennsylvania. I have published over 25 articles in the fields of nuclear plant civil/structural design and earthquake engineering.

5. On January 31, 1986, an earthquake occurred in northern Ohio (the "1986 earthquake"). Immediately afterwards, I and other Gilbert personnel under my supervision undertook a number of investigations to assess any impact of the 1986 earthquake on the sei ic design of Perry as reflected in the FSAR. Our studies were based on data recorded by seismic instrumentation in the plant buildings (see Affidavits of Kalman Lee Benuska and Paul D. Engdahl) and on equipment qualification data supplied by vendors. The purpose of this Affidavit is to describe the results of these studies and to give my conclusions as to the adequacy of the current Perry seismic design.

6. This Affidavit first gives general background information on seismic design of nuclear power plants and the development of the seismic design for Perry in particular. The Affidavit then briefly describes the seismic instrumentation installed at Perry. Next, an evaluation of the engineering significance of the 1986 earthquake is made as to Perry

structures, systems, and components, followed by a specific evaluation of equipment margins.

BACKGROUND ON NUCLEAR POWER PLANT SEISMIC DESIGN

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

8. The SSE can be described by means of a "response spectrum," which depicts the maximum acceleration, velocity or displacement response to an input excitation (here the SSE) at a specified damping value for single degree-of-freedom oscillators of varying natural frequencies. The high frequency end of a response spectrum indicates the "zero period acceleration" (ZPA) associated with the event.

9. In the design of any plant, it is difficult to predict the shape of postulated earthquake acceleration time-histories and associated ground response spectra. Appendix A of 10 CFR Part 100 therefore requires an expected SSE to be developed by statistically combining the response spectra from multiple historical earthquakes. Following this guideline, the NRC has provided in Reg. Guide 1.60 standardized response spectra that can be used in lieu of spectra developed for each site (see Fig. 1). These standardized spectra were derived by normalizing and combining spectra calculated from numerous sets of historically recorded acceleration time-histories. From these sets of spectra, smoothed response curves (acceleration, velocity and displacement) were generated at a level equal to one standard deviation greater than the mean of the responses. This method provides an 84% level of statistical confidence that responses at any particular frequency will not be exceeded by any future SSE event.

10. Thus, in lieu of developing site-specific SSE ground response spectra, the standardized response spectra of Reg. Guide 1.60 can be used. The standardized spectra need only be scaled up or down to reflect the effective maximum ground accelerations (i.e., ZPA's) expected for the SSE at that site. The SSE design ground response spectra are used to dynamically analyze a lumped-mass model of the power plant structures.

BACKGROUND ON SEISMIC DESIGN OF THE PERRY PLANT

11. The Perry design response spectra were derived by using the standard response spectrum of Reg. Guide 1.60 scaled to a ZPA of 0.15 g determined for the Perry site. This was used to generate the design response spectra at the foundation elevations for use in designing the plant buildings.

12. From these spectra, a simulated SSE time-history of ground accelerations was developed for each directional component (N-S, E-W, and Vertical). The conservatism of these simulated time-histories was checked and confirmed by assuring that the response spectra generated from the simulated time-histories envelop the Reg. Guide 1.60 design response spectra (see Fig. 2).

13. Seismic Category I structures were analyzed by applying the simulated time-histories to a lumped-mass model of the entire structure, as shown in Figure 3. From this analysis, time-history accelerations at each floor elevation were also derived. These time-histories were then used to derive response spectra for each floor of each main building. The floor response spectra were used in designing the safety class equipment, components, and systems.

14. In addition to the conservatism included in the derivation of response spectra, there were numerous other conservatisms included in the overall design of the Perry structures,

systems and components. Examples of some of the more significant conservatisms are as follows:

a. <u>Broadening the Envelope of Floor Response Spectra</u>

Frequency bands of floor response spectra were artificially broadened (typically by 15%) to account for possible frequency variations. Responses used for design were thus overestimated for systems having more than one dominant frequency falling into the broadened frequency bands of the floor response spectra.

b. <u>Equipment Qualification by Test</u>

Equipment qualified by shake table testing used time-histories simulated from the floor response spectra. The simulated time-histories were generated in such a way that their calculated response spectra envelop the broadened floor response spectra, which in turn already envelop the original floor response spectra. The conservatism of the time-histories was increased by this "envelope on top of an envelope" process. Moreover, this process resulted in simulated time-histories with maximum accelerations much higher than the ZPA's of the original floor response spectra.

c. <u>Strain Hardening Not Accounted For and Static Allowables Used for Dynamic Load</u>

In equipment design, material is assumed to behave linearly up to the yield point, then to deform continuously to collapse when the external load is maintained. All material used in equipment design exhibits characteristics of strain hardening. This means that resistance to deformation increases after the deformation exceeds the yield point. Furthermore, even if no strain hardening is assumed, the material can resist dynamic loads having peak values higher than the yield strength through the absorption of energy in the plastic region.

d. Loading Combinations

The plant was designed to withstand loading combinations with a very low probability of simultaneous occurrence. For example, some load combinations included seismic loads, hydrodynamic loads, and hypothetical loss-of-coolant-accident loads simultaneously. This results in design capability well above the loads associated with seismic alone.

e. Primary Versus Secondary Stresses

Computed seismic stresses used in design were considered to be primary, non-self-limiting stresses instead of secondary stresses with a self-limiting nature. The actual behavior of seismic stresses is somewhere between a primary and secondary nature. Consideration of seismic stresses as primary stresses resulted in conservative values used for design.

f. Damping Values

Conservative damping values were employed at Perry pursuant to NRC Regulatory Guide 1.61. The recent ASME Code Case N-411 (not employed at Perry) would have allowed increased (i.e., less conservative) damping values to be used.

SEISMIC INSTRUMENTATION AT PERRY

15. Three different types of seismic monitoring instrumentation were used to record the 1986 Ohio earthquake. Table 1 indicates the building and specific location of each of the instruments. Figure 4 shows a plan and an elevation view of each instrument location. Figures 5 through 12 show the mounting details for each instrument.

16. One type of instrument used was the Kinemetrics Model SMA-3 strong motion triaxial time-history accelerograph. This system detects and records three mutually perpendicular components of acceleration over the entire duration of the earthquake onto cassette magnetic tape. Power to the unit is supplied by internal rechargeable batteries which are kept in a charged state by 120 VAC line power. Two instruments of this type were used and were located on the Reactor Building foundation mat at an elevation of approximately 575 feet. Further information on the Kinemetrics instruments is set forth in the Affidavit of Kalman Lee Benuska.

17. The second type of instrumentation used was the Engdahl PSR 1200-H/V response spectrum recorder. This totally mechanical system also records three mutually perpendicular components of acceleration. The instrument uses twelve reeds fabricated of varying lengths and weights of spring steel, one for each frequency (ranging from approximately 2 Hz to 25 Hz). 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 made of aluminum and are plated with successive layers of nickel, tin and lead-tin. This system is totally self-contained and requires no outside power source.

18. Four instruments of this type were used -- two on the Auxiliary Building foundation mat at an elevation of approximately 568 feet, one at the Reactor Building foundation mat at an elevation of approximately 575 feet, and one at the Reactor Building Inside Drywell Platform at an elevation of approximately 630 feet.

19. The third type of instrument was the Engdahl PAR 400 peak accelerograph. This totally mechanical system records three mutually perpendicular components of peak local acceleration (i.e., the zero period acceleration). A diamond-tipped scriber at the end of an amplifier arm records a permanent mark on a record plate made of aluminum and successive layers of nickel, gold and burnt gold. Again, this system is totally

self-contained and requires no outside power source. Two instruments of this type were used and were located on the Auxiliary Building foundation mat at an elevation of approximately 568 feet and on the Reactor Recirculation Pump at an elevation of approximately 605 feet. A third instrument of this type was out of service at the time of the 1986 earthquake because it was being recalibrated. Further information on the Engdahl instruments is contained in the Affidavit of Paul D. Engdahl.

20. The instrumentation installed at Perry as described conforms to the requirements of NRC Regulatory Guide 1.12 ("Nuclear Power Plant Instrumentation for Earthquakes, Rev. 1").

EVALUATION OF THE JANUARY 31 EARTHQUAKE

21. Based on data collected by the National Earthquake Information Center of the United States Geological Survey (USGS), the January 31, 1986 earthquake had a magnitude of M_{bLg} = 4.96 with an epicenter at about 11 miles (17.7 Km.) south of the Perry plant site. This is of much less magnitude than the earthquake for which the plant was designed (the SSE) and contained substantially lower total energy than the Perry SSE. Evidence of the low energy content of the January 31 earthquake is shown by a comparison of the acceleration time-histories it induced at various elevations with the corresponding design acceleration time-histories (see Figs. 13 through 18). The time-histories used for design are 22 seconds

long and of sustained high amplitude (strong motion). By contrast, the January 31 time-histories are about 5 seconds long and contain strong motion in only less than a one-second interval (total) of the event.

22. A comparison of Figures 1 (Reg. Guide 1.60 response spectra) and 19 (sample response spectra from the January 31 earthquake) gives a further indication of the low energy content of the January 31 event. These figures show that the Reg. Guide 1.60 spectra used for design have much broader frequency contents than those of the recorded earthquake, which contain strong motion only at high frequencies. The design earthquake therefore contains much greater total energy.

23. Table 2 compares the structural response ZPA's of the recorded data with those of the SSE and OBE. The square-root-of-the-sum-of-the-squares (SRSS) comparison indicates that the recorded values of the 1986 earthquake vary from significantly below OBE values to 74% of SSE values, except at elevation 686 feet of the Reactor Building Containment Vessel. At that location, the N-S and Vertical acceleration components exceed SSE values, while the E-W acceleration component is less than the SSE value. In addition, recorded response spectra accelerations show that the design response spectra accelerations in certain instances were exceeded at the high frequency end of the spectra. At lower frequencies (at or below approximately 14 Hz) the recorded accelerations are all well under the design

values (see response spectra comparisons, Table 3, Figures 20 through 31).

24. The measurement of accelerations outside the predicted responses at the high frequency ends of certain response spectra has no engineering significance. This is explained by the interrelationships among the frequencies, accelerations, velocities, and displacements associated with a seismic event. In general, high frequency acceleration responses have correspondingly low velocity and displacement responses. The 1986 earthquake accelerations occurred at very high frequencies. Therefore, despite some recorded maximum acceleration responses which exceeded SSE values at higher frequencies, corresponding velocities and displacements (and resulting stresses) were nevertheless acceptably low.

25. Confirmation of this is shown in Table 4, which indicates the maximum relative displacements from the recorded time-histories for the Reactor Building Containment Vessel. The overall SRSS relative displacement shown in the Table is 0.34 cm for the SSE and 0.10 cm for the actual event. Since structural stress is proportional to relative displacement, and the recorded relative displacement was far less than the SSE design value, the stresses induced by the 1986 earthquake at this location were well within design capabilities despite the acceleration exceedances described above. This small relative displacement is consistent with the high frequency nature of

the disturbance. The high frequencies combined with the short duration resulted in an earthquake that contained very low total energy compared to the SSE.

26. The maximum recorded velocity at the top of the Reactor Building foundation mat during the 1986 earthquake was 0.87 inches/sec (2.21 cm/sec). This can be compared with the Bureau of Mines ("BOM") velocity threshold for no damage to <u>non-engineered</u> buildings, which is 1 inch/sec (2.54 cm/sec). This shows that the BOM considers it acceptable for blasting work or pile driving operations to induce velocity waves in nearby residential housing foundations that are greater than the maximum velocities induced by the 1986 earthquake at the Perry plant. This example provides perspective on just how low the velocities and energy content of the 1986 event were.

27. As described in the Affidavit of Robert A. Stratman, extensive plant inspections and operability checks have indicated that no structural or equipment damage resulted from the 1986 earthquake. This is as expected based upon the low energy, short duration, and low velocities and displacements of the event. The inspections and operability checks that were performed were adequate to detect any structural damage. For these reasons, it is unnecessary to perform any further investigations such as containment integrated leak rate testing, hydrostatic testing of the reactor coolant pressure boundary, nondestructive structural testing, or any other type of testing.

28. Although some hairline cracks in the structural concrete were documented during plant walkdowns, this does not constitute damage. Reinforced concrete structures are expected to show hairline cracks. Regardless of their cause, such cracks have no effect on the strength and integrity of the structures. Moreover, in my judgment, such cracking is not attributable to the 1986 earthquake because of the low magnitude of the event.

29. Section 7.5 of IEEE 344, "Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," was employed at Perry. Confirming the above discussion, this standard recognizes that short duration/high frequency/low energy input motions will not cause significant structural stresses, and thus prohibits the use of such input motions to qualify equipment. Instead, it requires qualification by long duration/broad-band frequency/high energy testing to provide conservatism.

EVALUATION OF SPECIFIC DATA

30. In light of the above discussion, recorded responses at particular locations can be evaluated. At all four instrument locations recording response spectra, SSE design spectra are well above the recorded spectra in the frequency range of 1 Hz to 14 Hz (see Figures 20 through 31). These figures compare recorded data with the appropriate design spectra at adjacent elevations. These figures also compare the data from

different types of seismic instrumentation at the same elevation.

31. At high frequencies, the design spectra are exceeded by recorded values in certain cases. However, the corresponding displacements based on recorded data are all extremely small (on the order of several one-hundredths of an inch) at 20 Hz (where peak acceleration exceedances occur). These extremely low displacements conform to the above analysis, demonstrating that the stresses at higher frequencies are insignificant despite acceleration exceedances.

32. In evaluating the spectra data recorded at the various locations, it was noted that the acceleration responses at the Reactor Building Platform outside the Biological Shield Wall varied from the general pattern of responses recorded at the other three locations. The recorded N-S and E-W acceleration components for this location are all well-enveloped by the entire range of the SSE spectra, while the recorded vertical acceleration component exceeds the SSE spectra at the high frequency end (see Fig. 28). This response may be due to the fact that this particular Engdahl PSR-1200 instrument is located near multiple supports and piping system snubbers and components. Actuation of snubbers or local loads induced by nearby components may have influenced the recorded vertical response. Such impacts would be of a local, secondary nature. Regardless, the low energy, short duration, high frequency nature of

the event indicates that these accelerations had no engineering significance. The recorded displacement spectrum value is only 0.023 inches (0.06 cm) at 25 Hz at this location.

33. In general, the high frequency acceleration content of ground motion will be filtered out by buildings and thus will not appear at higher elevations. This is due in part to the low participation factor generally associated with modes at the higher frequencies. This phenomenon is exhibited by the responses recorded at the Reactor Building mat and elevation 686 feet of the Reactor Building Containment Vessel. A very high frequency p-wave was recorded at the Reactor Building foundation mat. The time-histories shown in Figures 13 through 18 indicate that this p-wave (appearing during the first second or so of the time-histories) was filtered out by the building and did not appear at elevation 686 feet.

34. There was a response in the range of 20 Hz that was transmitted to the higher elevations. The explanation for this involves the structural characteristics of the buildings on the Reactor Building foundation mat. The Reactor Building consists of multiple structures sitting on a common foundation mat -- a concrete shield building, steel containment vessel, concrete drywell wall, and biological shield wall. The structural response of each building influences the responses of the others. The mode shapes and participation factors of the two most dominant vibration modes -- roughly 4 Hz and 18.4 Hz -- are shown

in Figures 32 through 34. These two dominant frequencies correspond to the peaks at 4 Hz and 20 Hz on the recorded spectra for the Reactor Building at the mat and elevation 686 feet. The input motion at 20 Hz (corresponding to the s-wave) was amplified by this latter mode with some rigid body motion. The 20 Hz input was thus not filtered out but did appear at the higher elevation. As discussed, the acceleration peaks at 20 Hz at this location correspond to very small relative displacements and thus are not significant in an engineering sense.

35. I have reviewed the Motion to Reopen and to Submit a New Contention submitted by intervenor Ohio Citizens for Responsible Energy ("OCRE") dated February 3, 1986 (the "OCRE Motion"). OCRE refers in its Motion to a news account "stating that accelerations from the [1986] earthquake were estimated to range from 0.19 g to 0.25 g. Perry is designed to withstand 0.15 g (safe shutdown earthquake)." OCRE Motion at 2. OCRE relies on this news account as a basis for calling the Perry seismic design basis into question. Id. The news account, however, compares two different types of measurements. The 0.19 g and 0.25 g values referred to apparently were preliminary readings of the ZPA's at two basemat locations. The value of 0.15 g, on the other hand, represents the postulated maximum vibratory ground motion (SSE) in the free-field. To compare like quantities, the recorded ZPA's should be compared against SSE ZPA's at the same locations derived by analysis, as is done

in Table 2. That Table shows that the recorded SRSS ZPA's at these two basemat locations were well under their design values (0.18 vs. 0.33; 0.23 vs. 0.31). OCRE's citation to this matter thus is not a basis for calling the Perry seismic design basis into question. In any event, exceedances above the design basis response spectra which occurred in the January 31 earthquake are of no significance to the plant's seismic design for the reasons set forth above.

REEVALUATION OF EQUIPMENT QUALIFICATION

36. As indicated in the Affidavit of Robert A. Stratman, all energized plant equipment functioned during this event as designed. To confirm the design adequacy of the active equipment, the qualification data for equipment listed in Table 5 has been compared against recorded response spectra. The evaluation shows that the original conservatism in the equipment qualification was more than adequate to accommodate the recorded event.

a. Selection of Equipment to be Evaluated

As described above, there are four sets of recorded response spectra at the following locations:

(1) Reactor Building Mat elevation 574'-10:

(2) Reactor Building Platform elevation 630'

(3) Containment Vessel elevation 686'

(4) Auxiliary Building Mat elevation 568'

There is no equipment at location 1 because of the suppression pool. At the Reactor Building 630' and 686' elevations, the single records available at each location may be biased by secondary effects of adjacent equipment on the building response. The Auxiliary Building Mat elevation 568' has two seismic instruments which provide confirmation of the measured responses. Thus, the Auxiliary Building Mat elevation 568' was selected as the most appropriate location for comparison of equipment data.

b. Method and Results of the Margins Evaluation

An envelope of the records from the two Engdahl response spectrum recorders at the Auxiliary Building Mat was used to represent the recorded response spectra. The highest frequency of the recorded data from these instruments is at 25.4 Hz. The recorded spectra were extended to higher frequencies by extrapolating to ZPA values at 40 Hz as recorded by Engdahl PAR-400 instruments No. D51-R120 and No. D51-R140, as shown in Figures 35, 36 and 37. The peaks of the 3% damping spectra were obtained by reducing the peaks of the 2% damping spectra by 12%. The 12% reduction factor was derived by examination of the ratio of 2% and 3% spectra obtained from the Kinemetrics instruments.

Active components that were evaluated are listed in Table 5. The results of the comparisons are as follows:

(1) Instrument Racks

Instrument racks were originally qualified by testing. The response spectra from testing far exceed the spectra from the 1986 earthquake. An example of this is shown in Figure 38.

(2) Pressure Transmitters and Flow Transmitters

To compare the recorded spectra with the original spectra from testing, the recorded spectra were first amplified to represent spectra at the transmitter locations inside the racks. The test response spectra were found to envelop the amplified recorded spectra with ample margin. An example of this comparison is shown in Figure 39.

(3) Pumps and Motors

Pumps and motors supplied by General Electric were originally qualified by analyses. These analyses were rerun with recorded spectra from the 1986 earthquake as input. A dynamic finite element analysis of each piece of equipment was performed using the response spectra method. The SAP finite element program was used to analyze these dynamic models. The earthquake loads derived from the dynamic modeling were combined with previously determined static loads such as piping nozzle loads, deadweight, maximum operating pressure, and pump operating loads. The resulting equipment stresses were found to be under the design allowable values.

c. Margins of Other Equipment

The above comparisons were made for equipment at the foundation level of the Auxiliary Building. Equipment and components at other locations are similarly deemed to have adequate design capability to accommodate events such as the 1986 Ohio earthquake for the following reasons:

(1) The typical comparisons of the response spectra from testing with the recorded response spectra indicate that margins are ample, as shown in Figures 38 and 39.

(2) The pumps and motors that were analyzed have natural frequencies at 18.7 Hz, which is in resonance with the peak region of the recorded response spectra after 15% broadening. This analysis therefore included the most critical response spectra comparisons in terms of the resulting stresses.

(3) Floor response spectra at higher elevations will have higher peak values compared to spectra at lower elevations when the frequency of the earthquake input coincides with the fundamental structural mode, which dominates the building response. The mode at Perry corresponding to the 20 Hz peaks in the recorded spectra is not a fundamental mode, and its mode shape is not one that would contribute to significant amplification at the higher elevations (see Figure 33). Therefore, the floor response spectra at upper elevations are not much higher than those at lower elevations for the 1986 earthquake.

(4) The BWR 6 equipment and components used at Perry are over-qualified in the high frequency region because of the conservative assumption of simultaneous occurrence of seismic and hydrodynamic loads.

(5) The majority of the equipment was qualified by the vendors for generic applications, enveloping much higher SSE values for other sites.

(6) I was involved with applicable equipment margin studies for the V.C. Summer nuclear plant in 1982 with regard to high frequency content earthquakes. Those evaluations concluded that equipment margins in the high frequency region were sufficient. The average margin between seismic response spectra and qualification response spectra was a factor of approximately 2.5.

37. To summarize, equipment margins were evaluated by comparing the recorded floor response spectra of the 1986 Ohio earthquake with the original spectra from either testing or analysis. The comparisons demonstrate that, both for equipment directly analyzed and equipment at other locations, the original design is more than adequate to accommodate events such as the 1986 Ohio earthquake.

CONCLUSION

38. The 1986 Ohio earthquake was a low energy, high frequency, short duration, low velocity, and small displacement event. As a result of these characteristics and the above discussions, the 1986 earthquake had no adverse effects on the Perry structures, systems, or components, and no changes to the Perry seismic design are required.

Chang Chen

CHANG CHEN

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

Notary Public

My Commission expires:

JANICE M. DOBROSKY, NOTARY PUBLIC
CUMRU TOWNSHIP, BERKS COUNTY
MY COMMISSION EXPIRES MAY 26, 1987
Member, Pennsylvania Association of Notaries

PROFESSIONAL QUALIFICATIONS
OF
CHANG CHEN

Sixteen years of extensive experience in the application of structural mechanics theory to the design and analysis of nuclear and fossil power plants in the U.S., Japan, Korea, Yugoslavia, Germany, and Iran. Specialization in seismic resistant design, thermal stress analysis, vibrational analysis and design for impact and impulsive loading, hydrodynamic sloshing problem, and experience in the design and analysis of ocean thermal energy conversion systems, plus project management and personnel administration.

EXPERIENCE: GILBERT/COMMONWEALTH since 1969

1982 to Present — Manager, Civil/Structural Department and Chief Structural Engineer - Responsible for technical supervision and personnel administration in the area of structural drafting, layout and models, architecture, civil engineering and structural engineering for nuclear plants, fossil plants, and continuing services.

1979-82 — Section Manager, Specialty Structures - Responsible for technical supervision and personnel administration in the areas of continuing services of all operating nuclear power plants, computer applications, applied research, engineering mechanics, and special projects.

Supervised engineering work in the area of NRC I&E Bulletins 79-02, 79-14, and 80-11, and systematic evaluation program. Seismic resistent design of reference fossil power plants. Project manager of design review of TVA Browns Ferry Units 1, 2 and 3, Long Term Torus Integrity program. Participated in the investigation of reservoir induced seismicity effects on South Carolina Gas and Electric Company's V.C. Summer Nuclear Station structural and equipment design. Technical presentation before Advisory Committee on Reactor Safeguards (ACRS) and testimony before the Atomic Safety Licensing Board (ASLB).

1978-79 — Supervising Structural Engineer - Responsible for technical supervision and personnel administration in the areas of structural mechanics and computer applications. Project Manager of the Kraftwerk Union (KWU) project for the seismic design review of the 1,300 MW nuclear power plants in Iran, and for providing technical support to the KWU Engineering Department. Provided technical supervision on the Safety Relief Valve Discharge problem of Boiling Water Reactor System.

1974-78 — Supervisor of Applied Research in Structural Mechanics - Supervision of the analytical aspects of PWR, BWR and fossil power plant designs, seismic resistant design of structures and equipment, missile protection design, pipe whip restraint design, compartment pressurization, jet impingement design, finite element stress analysis, and thermal stress analysis of reinforced concrete structures. Aircraft impact resistant design using soft shell concepts and pipe rupture restraint design for Brown Boveri Reaktor (BBR) in Germany, and hydrodynamic sloshing of water tank due to seismic disturbance. Shrinkage and creep of concrete, effect of coarse aggregates on the

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crack propagation of concrete structure. Behavior of concrete structure under multiaxial stresses. Platform and cold water pipe analysis of the ocean thermal energy conversion system under random waves and current effects.

1972-74 — Senior Research Engineer - Seismic resistant design of PWR and HTGR, preparation of equipment seismic qualification specifications, seismology study, fluid sloshing study, low-tune turbine foundation design, pipe whip restraint design, standard plant design, and PSAR, FSAR write-ups.

1973 — Consultant to Atomic Power Department of Taiwan Power Company - Seismic resistant design of nuclear power plants.

1969-72 — Research Engineer - Seismic resistant design of nuclear power plant facilities, computer programming for dynamic analysis, aircraft impact analysis of containment, and stress analysis.

1969 — Institute of Building Research, The Pennsylvania State University, University Park, Pennsylvania
Engineer - Heat transfer and thermal stress analysis of multistory steel frame structures.

1965-69 — Department of Engineering Mechanics, The Pennsylvania State University, University Park, Pennsylvania
Teaching Assistant - Class lecturing in statics, dynamics, and material testing.

1963-65 — Department of Civil Engineering, Duke University, Durham, North Carolina
Teaching Assistant - Class lecturing in material testing.

EDUCATION:
B.S.C.E., Cheng Kung University, 1962
M.S.C.E., Duke University, 1965
Ph.D., The Pennsylvania State University, 1969

REGISTRATION: Professional Engineer - Pennsylvania (1973)

SOCIETIES:
Member, IEEE Working Group 2.5 on the "Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations"
Member, ASCE Working Group of Dynamic Analysis Committee
Member, ASME Working Group-Shells
Member, AISC

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PUBLICATIONS: (Cont'd)

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"Effects of Uplift on Soil Structural Interaction and Toe Pressure Calculation," published in Vol. II of 2nd ASCE Specialty Conference on Structural Design of Nuclear Plant Facilities, New Orleans, December 1975.

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"Artificial Earthquake Generation for Nuclear Power Plant Design," Sixth World Conference on Earthquake Engineering, New Delhi, India, January 1977.

"Structural Design for Aircraft Impact Loading, 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, August 1977.

"Experimental Verification of U-Bolt Connection for Pipe Whip Restraint Design," 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, August 1977.

"The SRSS and the Static Coefficient Method for Seismic Resistant Design of Equipment and Structures," ASME Energy Technology Conference and Exhibit, Houston, September 1977.

"Seismic Resistant Design of Heavy Equipment," Proceedings of the Conference on Structural Analysis, Design and Construction in Nuclear Power Plants, Porto Allegre, Brazil, April 1978.

"Reinforced Concrete Structural Design for Thermal Effect," Proceedings of the Conference on Structural Analysis, Design and Construction in Nuclear Power Plants, Porto Allegre, Brazil, April 1978.

"Soft Shell Hard Core Concept for Aircraft Impact Resistant Design," Proceedings of the Conference on Structural Analysis, Design and Construction in Nuclear Power Plants, Porto Allegre, Brazil, April 1978.

"Research Needs and Improvement of Standards for Nuclear Power Plant Design," Nuclear Engineering and Design, Vol. 50, Number I, October 1, 1978.

"The Uncoupling Criteria for Subsystem Seismic Analysis," 5th International Conference on Structural Mechanics in Reactor Technology, Berlin, Germany, August 1979.

(Continued)

PUBLICATIONS: (Cont'd)

"Seismic Qualification of Equipment - Research Needs," 5th International Conference on Structural Mechanics in Reactor Technology, Berlin, Germany, August 1979.

"The Steel Containment Design and Analysis for High Seismic Zone Application," 1980 Symposium on Nuclear Power, sponsored by the Chinese-American Engineering & Management Institute, New York, October 1980. Also presented at 6th International Conference on Structural Mechanics in Reactor Technology, Paris, France, August 1981.

TABLE 1

PERRY NUCLEAR POWER PLANT UNIT NO. 1
SEISMIC MONITORING INSTRUMENTATION

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

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

TABLE 1

PERRY NUCLEAR POWER PLANT UNIT NO. 1
SEISMIC MONITORING INSTRUMENTATION

Instrument Number	Type	Manufacturer / Model Number	Location
D51-R160	(3)	Engdahl / PSR-1200-H / V-12A	Reactor Building Foundation Mat Elevation 574'-10" Azimuth 225°
D51-R170	(3)	Engdahl / PSR-1200-H / V	Reactor Building 630' Platform (Inside Drywell) Elevation 630'-1" Azimuth 238°
D51-R180	(3)	Engdahl / PSR-1200-H / V	Auxiliary Building Foundation Mat (HPCS Pump Room) Elevation 568'-4"
D51-R190	(3)	Engdahl / PSR-1200-H / V	Auxiliary Building Foundation Mat (RCIC Pump Room) Elevation 568'-4"

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

TABLE 2

Comparison of Design ZPA's[1] VS Recorded ZPA's

(Expressed in g values)

		Auxiliary Building Foundation Mat Elevation 568' PAR 400 (Engdahl) D51-R140	Reactor Building Foundation Mat Elevation 574'-10" SMA-3 (Kinemetrics) D51-N101	Reactor Building Recirculation Pump Elevation 605' PAR 400 (Engdahl) D51-R120	Reactor Building Platform Elevation 630' Inside Drywell PSR 1200 (Engdahl) D51-R170	Reactor Building Containment Vessel Elevation 686' SMA-3 (Kinemetrics) D51-N111
NS	Recorded	17	.18	32	09	55
	SSE	.17	.18	1 06	48	40
	OBE	.10	.10	86	40	24
EW	Recorded	06	.10	.11	.16	18
	SSE	20	.18	1 06	48	40
	OBE	.10	.10	86	40	24
VERT.	Recorded	03	.11	.05	Note 2	.30
	SSE	.20	.18	.47	.28	.24
	OBE	.10	.10	.38	.16	.15
SRSS[3]	**Recorded**	**.18**	**.23**	**.34**	**Note 2**	**.65**
	SSE[4]	**.33**	**.31**	**1.57**	**.73**	**.62**
	OBE	**.17**	**.17**	**1.27**	**.59**	**.37**

1 Zero period acceleration of structural response
2 ZPA indeterminable from available data
3 Square root of the sum of the squares
4 Licensing basis is SSE

TABLE 3

FLOOR RESPONSE SPECTRA DESIGN VERSUS RECORDED

Instrument Number	Location	Direction	OBE/SSE	Damping Percentage
D51-R180 and D51-R190	Auxiliary Building Foundation Mat	N-S	SSE	2
D51-R180 and D51-R190	Auxiliary Building Foundation Mat	E-W	SSE	2
D51-R190	Auxiliary Building Foundation Mat	VERT	SSE	2
D51-N101 and D51-R160	Reactor Building Foundation Mat	N-S	SSE	2
D51-N101 and D51-R160	Reactor Building Foundation Mat	E-W	SSE	2
D51-N101 and D51-R160	Reactor Building Foundation Mat	VERT	SSE	2

TABLE 3

Instrument Number	Location	Direction	OBE/SSE	Damping Percentage
D51-R170	Inside Drywell Reactor Building Platform—630'	N-S	SSE	2
D51-R170	Inside Drywell Reactor Building Platform—630'	E-W	SSE	2
D51-R170	Inside Drywell Reactor Building Platform—630'	VERT	SSE	2
D51-N111	Reactor Building Containment Vessel—686'	N-S	SSE	2
D51-N111	Reactor Building Containment Vessel—686'	E-W	SSE	2
D51-N111	Reactor Building Containment Vessel—686'	VERT	SSE	2

TABLE 4

Comparison of Design Displacements[1] VS Recorded Displacements[1]

(Expressed in centimeters/one inch = 2.54 cm)

		COLUMN 1	COLUMN 2	COLUMN 2 minus COLUMN 1
		Reactor Building Foundation Mat Elevation 574'-10" SMA-3 (Kinemetrics) D51-N101	Reactor Building Containment Vessel Elevation 686' SMA-3 (kinemetrics) D51-N111	Relative Displacements for the Containment Vessel
NS	Recorded	0.09	0.17	0.08
	SSE	0.044	0.28	0.24
	OBE	0.023	0.17	0.15
EW	Recorded	0.16	0.21	0.05
	SSE	0.044	0.28	0.24
	OBE	0.023	0.17	0.15
VERT.	Recorded	0.05	0.07	0.02
	SSE	0.02	0.37	0.017
	OBE	0.013	0.022	0.009
SRSS[2]	**Recorded**	—	—	**0.1**
	SSE	—	—	**0.34**
	OBE	—	—	**0.21**

1 Displacements based on same time step to determine relative displacements

2 Square root of the sum of the squares

TABLE 5

EQUIPMENT LIST AT AUXILIARY BUILDING ELEVATION 568'

1H22P0001	LPCS	Instrument Rack	
1H22P0017	RCIC	Instrument Rack	
1H22P0018	RHR	Instrument Rack	A
1H22P0021	RHR	Instrument Rack	B
1H22P0055	RHR	Instrument Rack	C
1C61N0001		Differential Press Transmitter	
1E12N0007A,B		Differential Press Transmitter	
1E12N0015A,B,C		Differential Press Transmitter	
1E12N0026A,B		Pressure Transmitter	
1E12N0028		Pressure Transmitter	
1E12N0050A,B		Pressure Transmitter	
1E12N0051A,B		Pressure Transmitter	
1E12N0052A,B,C		Differential Press Transmitter	
1E12N0055A,B,C		Pressure Transmitter	
1E12N0056A,B,C		Pressure Transmitter	
1E12N0058 C		Pressure Transmitter	
1E21N0003		Pressure Transmitter	
1E21N0050		Pressure Transmitter	
1E21N0051		Flow Transmitter	
1E21N0052		Pressure Transmitter	
1E21N0053		Pressure Transmitter	
1E21N0054		Pressure Transmitter	
1E31N0075A		Pressure Transmitter	
1E31N0077A		Pressure Transmitter	
1E31N0083A,B		Pressure Transmitter	
1E51N0003		Differential Press Transmitter	
1E51N0050		Pressure Transmitter	
1E51N0051		Differential Press Transmitter	
1E51N0053		Pressure Transmitter	
1E51N0055A,B,E,F		Pressure Transmitter	
1E51N0056A, E		Pressure Transmitter	
1E12C002A	RHR	Pump & Motor	
1E12C002B	RHR	Pump & Motor	
1E12C002C	RHR	Pump & Motor	
1E21C001	LPCS	Pump & Motor	
1E22C001	HPCS	Pump & Motor	

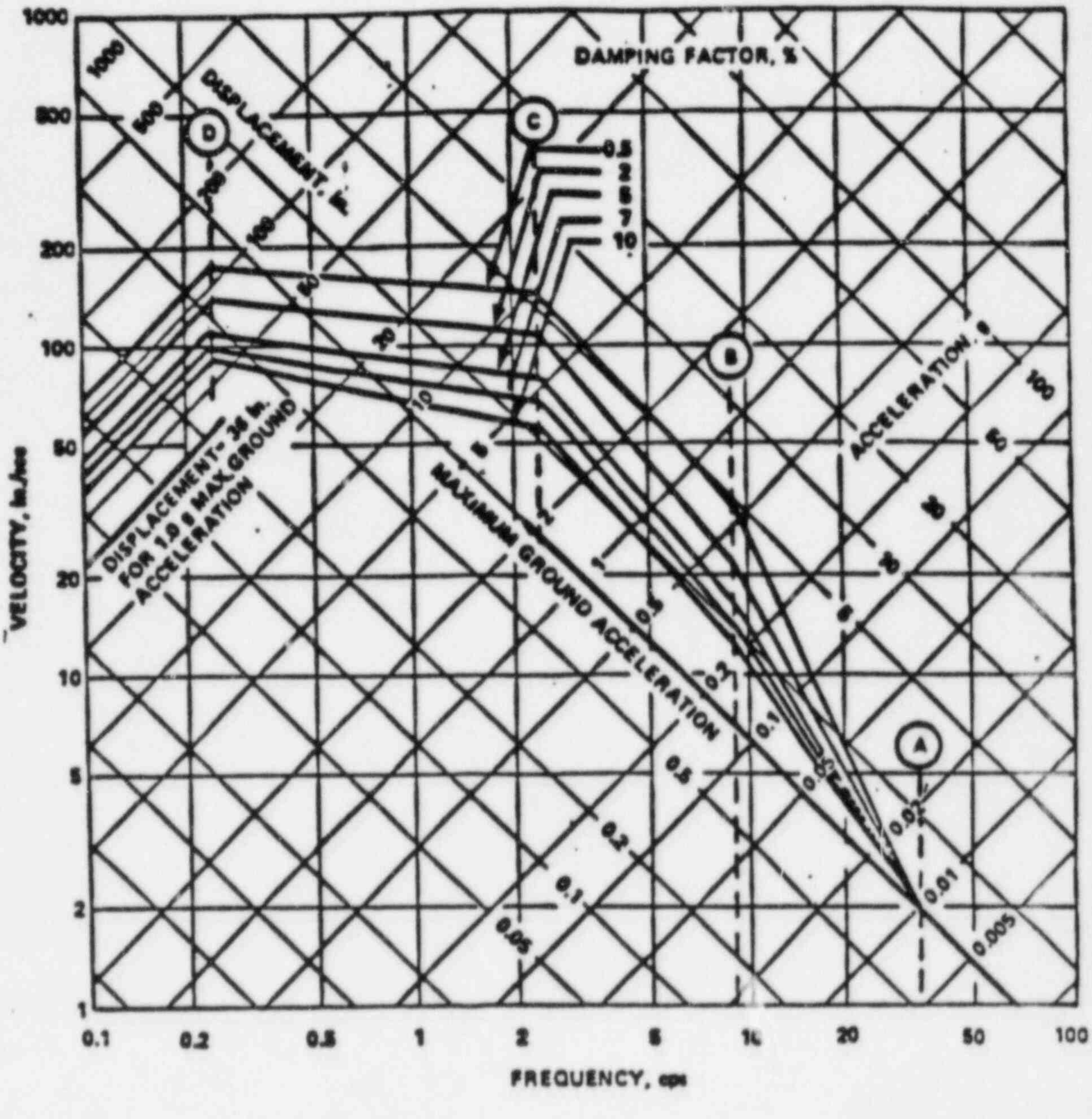
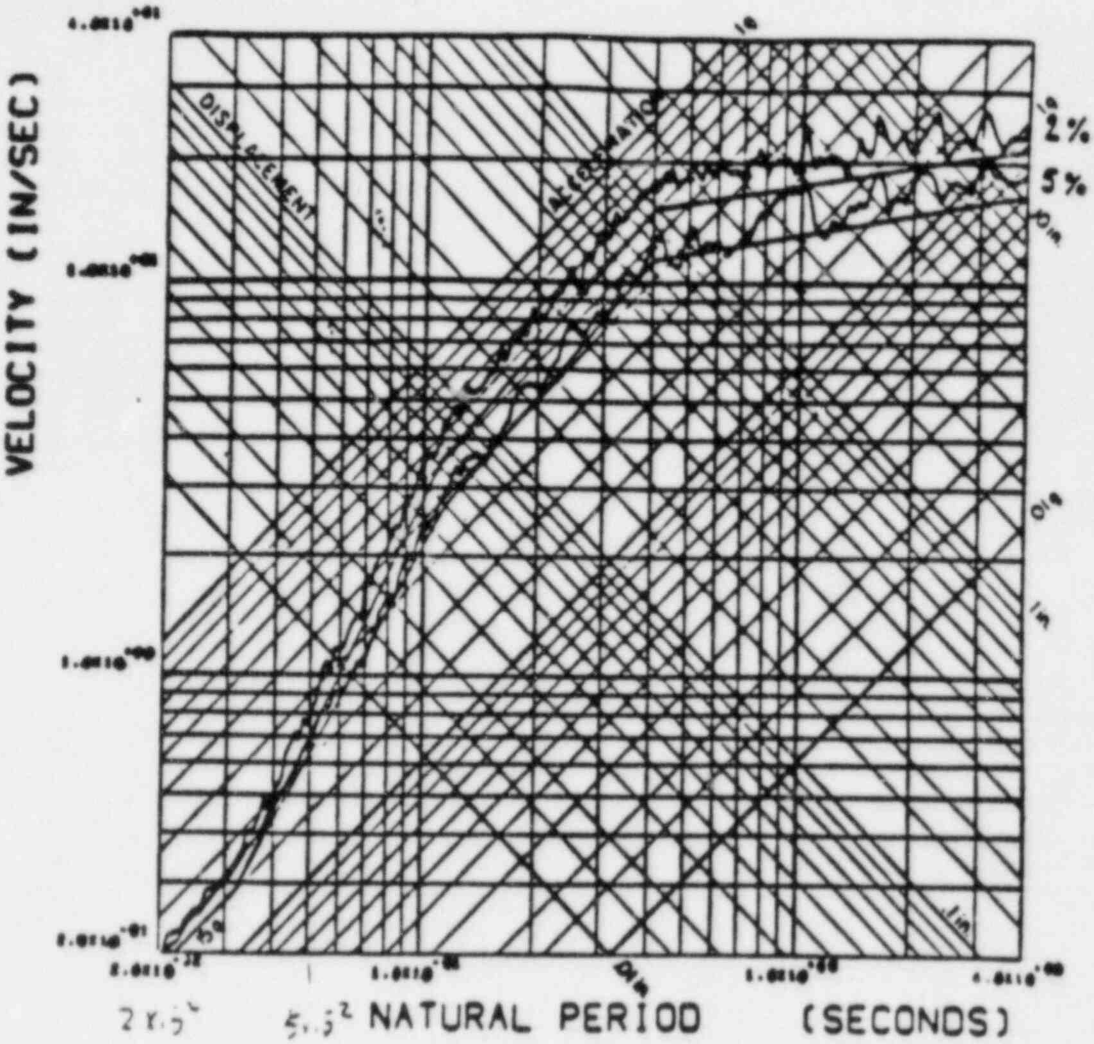


FIGURE 1. HORIZONTAL DESIGN RESPONSE SPECTRA – SCALED TO 1g HORIZONTAL GROUND ACCELERATION

FIGURE 1

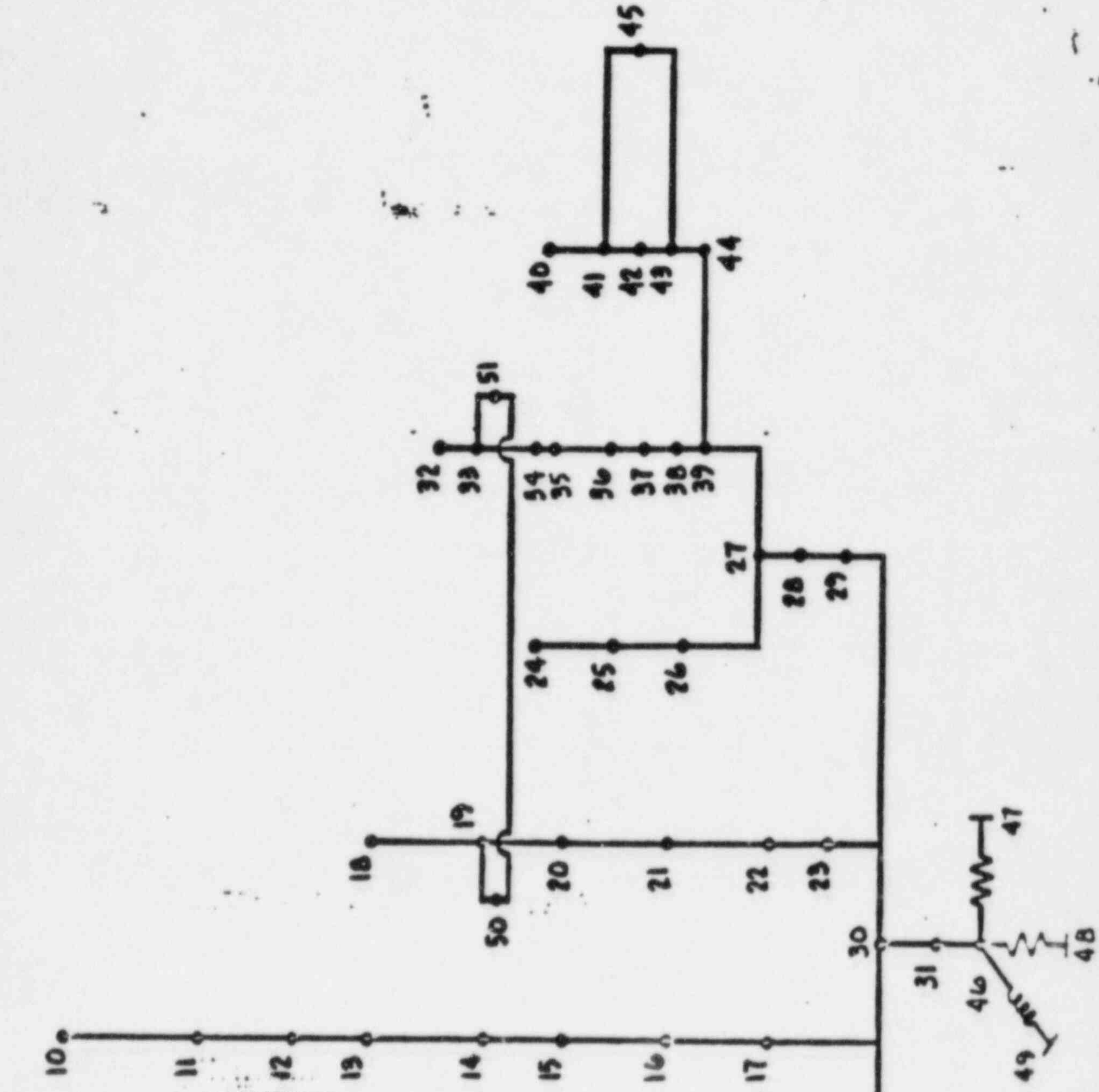


PERRY NUCLEAR POWER PLANT
THE CLEVELAND ELECTRIC
ILLUMINATING COMPANY

Response Spectra -
Horizontal Motion H1
(2% and 5% Damping)

Figure 3.7-5

FIGURE 2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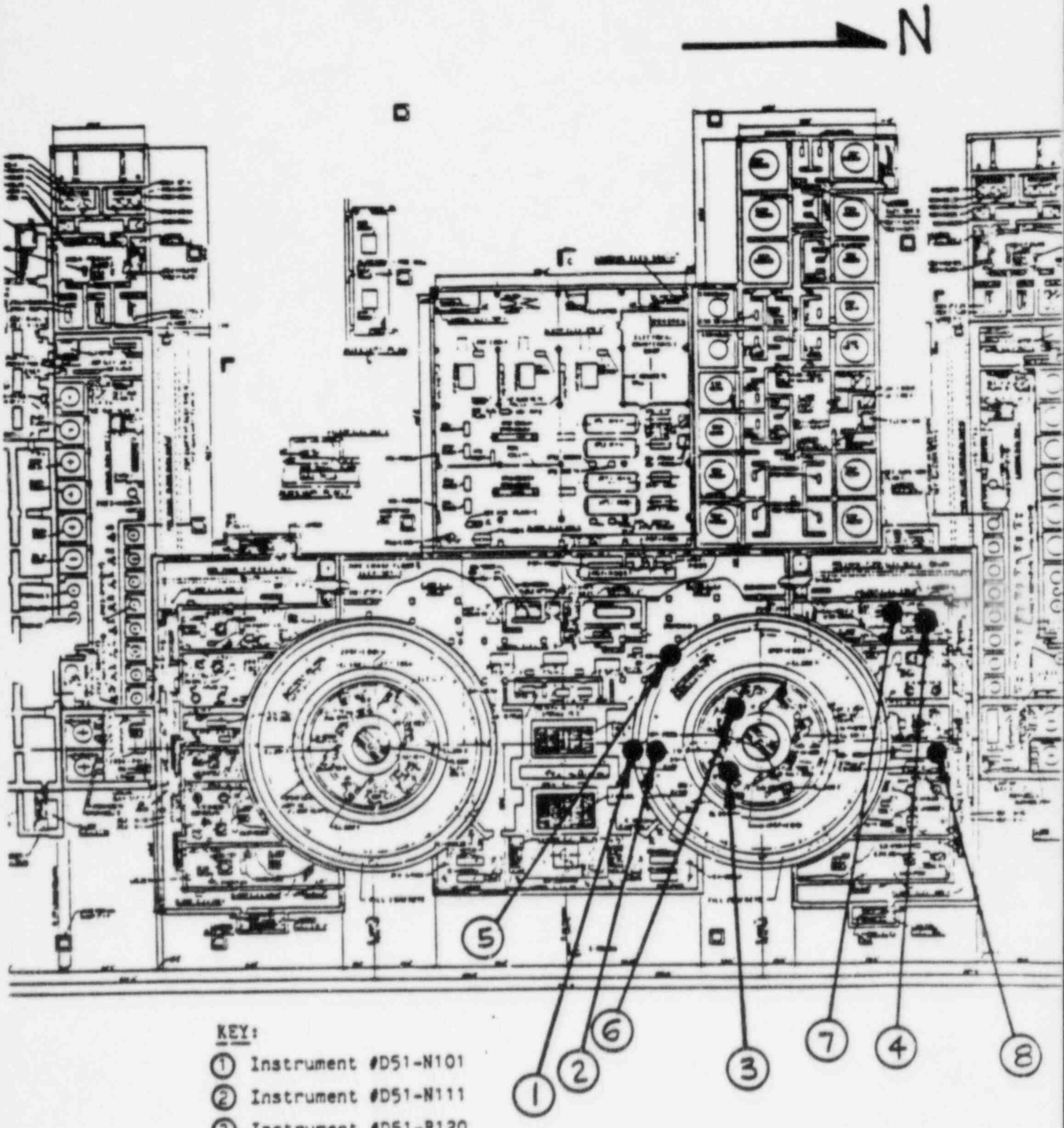
50
51

FIGURE 3



KEY:

① Instrument #D51-N101

② Instrument #D51-N111

③ Instrument #D51-R120

④ Instrument #D51-R140

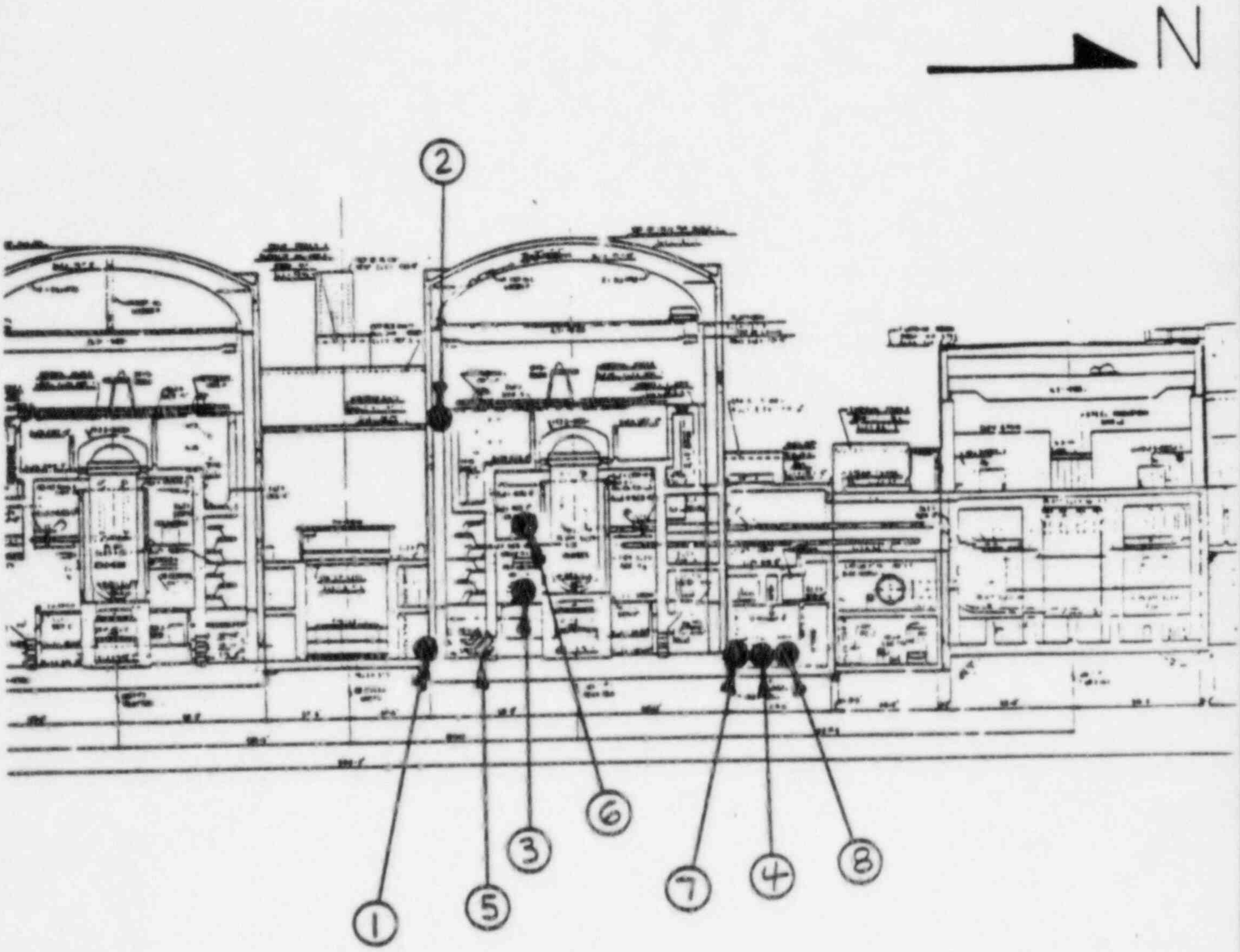
⑤ Instrument #D51-R160

⑥ Instrument #D51-R170

⑦ Instrument #D51-R180

⑧ Instrument #D51-R190

FIGURE 4



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

FIGURE 4

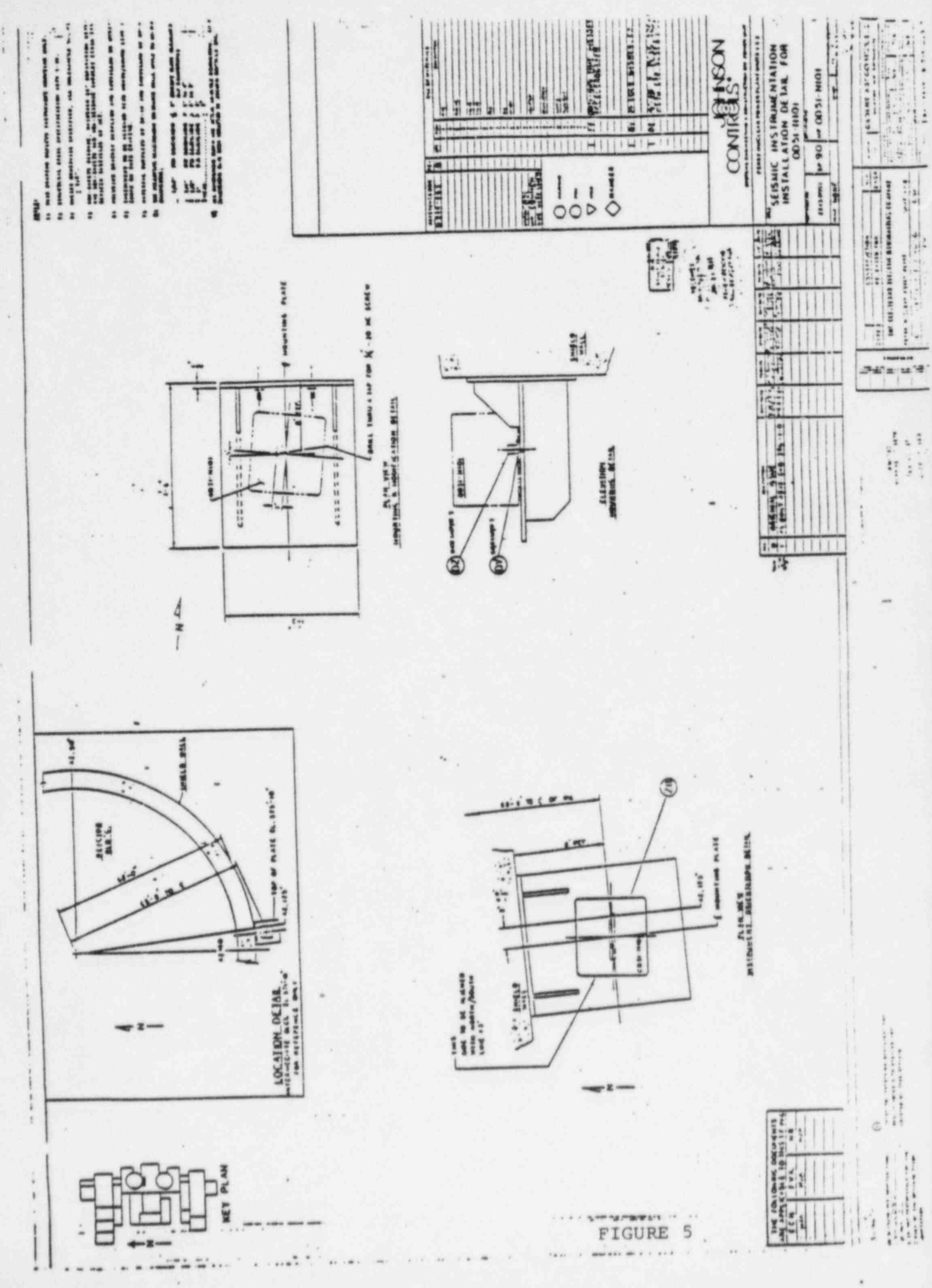

KEY PLAN
LOCATION DETAIL
JOHNSON CONTROLS
SEISMIC INSTRUMENTATION
INSTALLATION DETAIL FOR

FIGURE 5

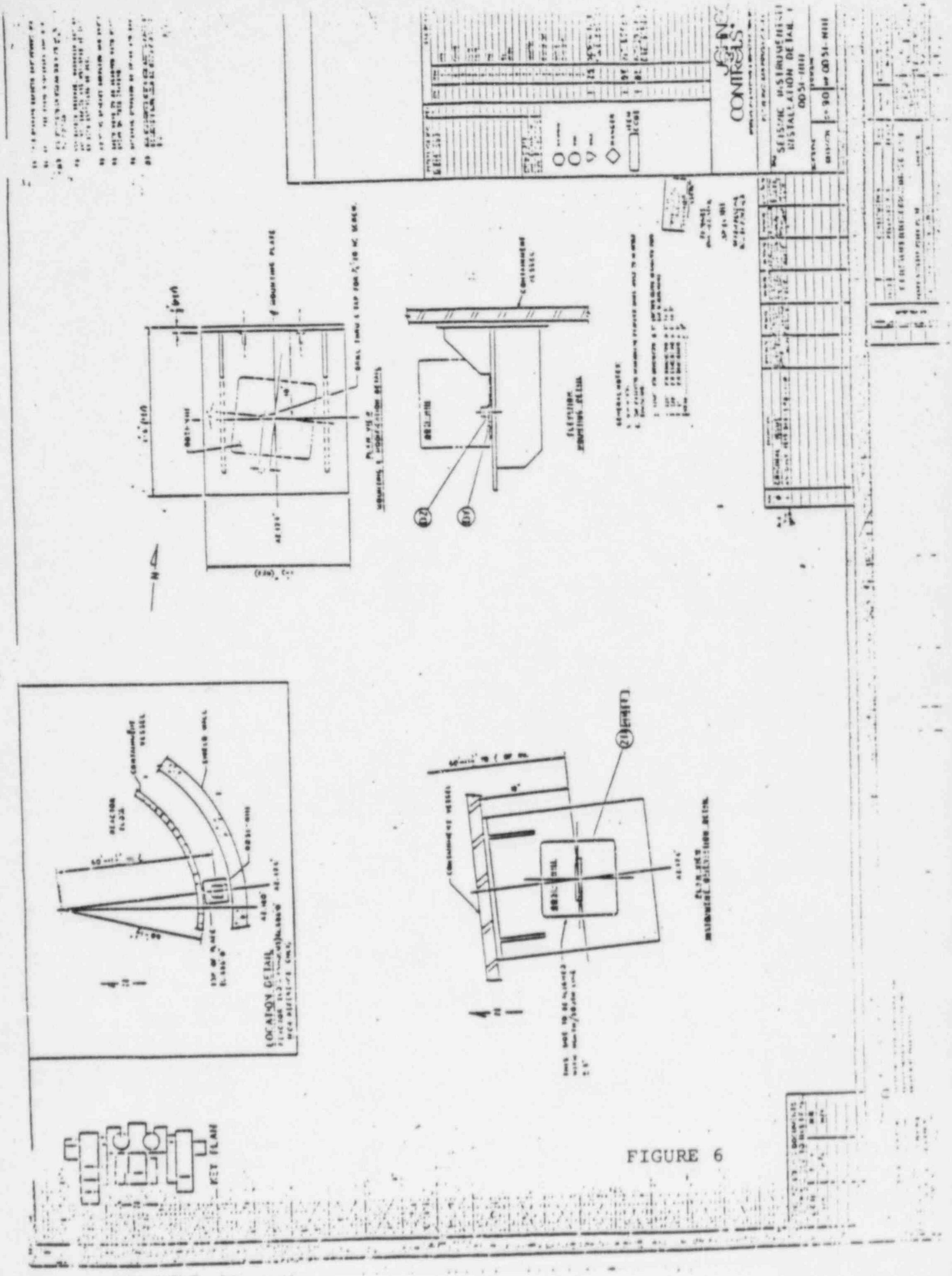

SEISMIC INSTRUMENTATION
INSTALLATION DETAIL
JOHNSON CONTROLS
KEY PLAN
LOCATION DETAIL
PLAN VIEW
ELEVATION

FIGURE 6

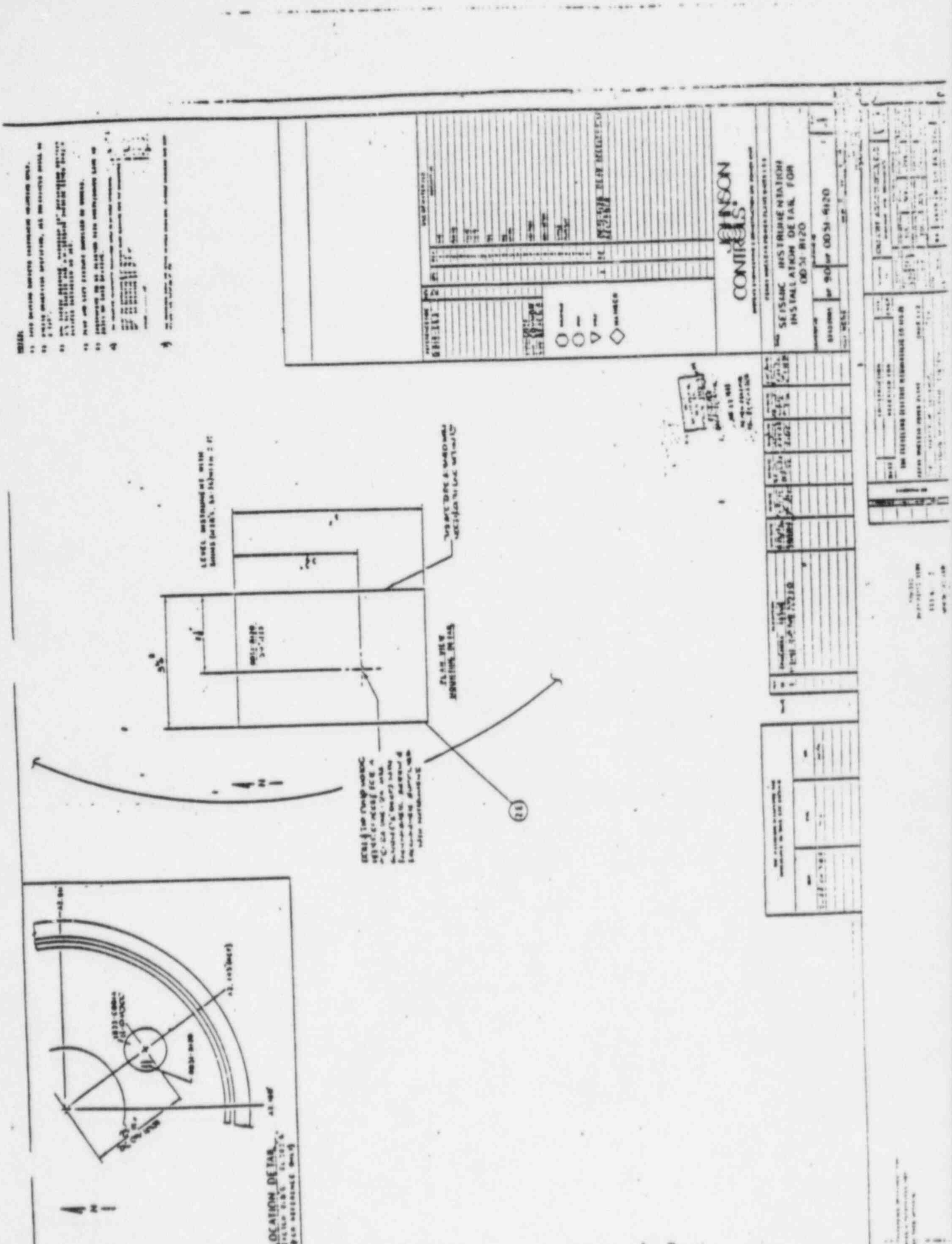

SEISMIC INSTRUMENTATION INSTALLATION DETAIL FOR ODSI-R120
JOHNSON CONTROLS
LOCATION DETAIL

FIGURE 7

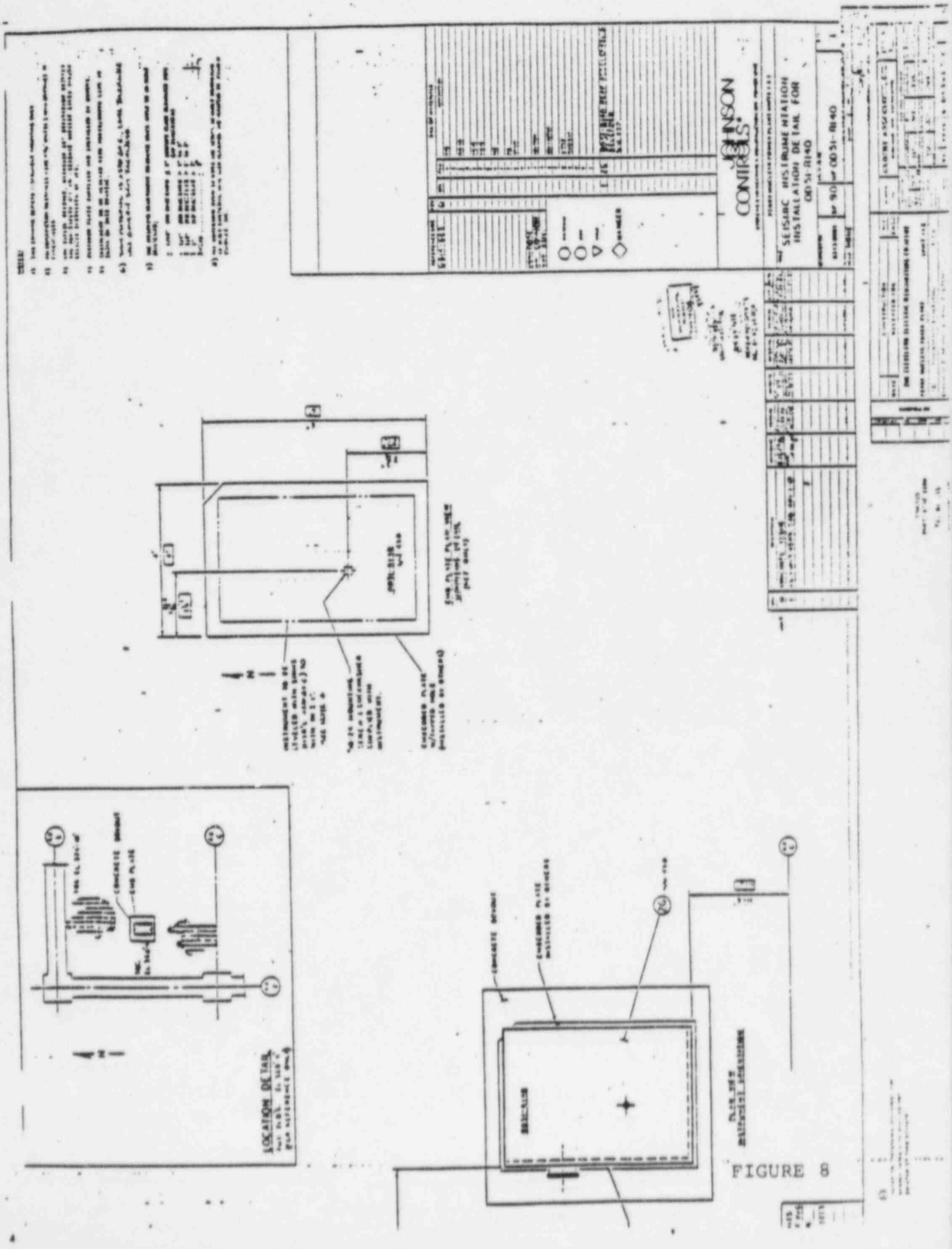

JOHNSON CONTROLS
SEISMIC INSTRUMENTATION INSTALLATION DETAIL FOR 0051-R140
0051-R140
LOCATION DETAIL

FIGURE 8

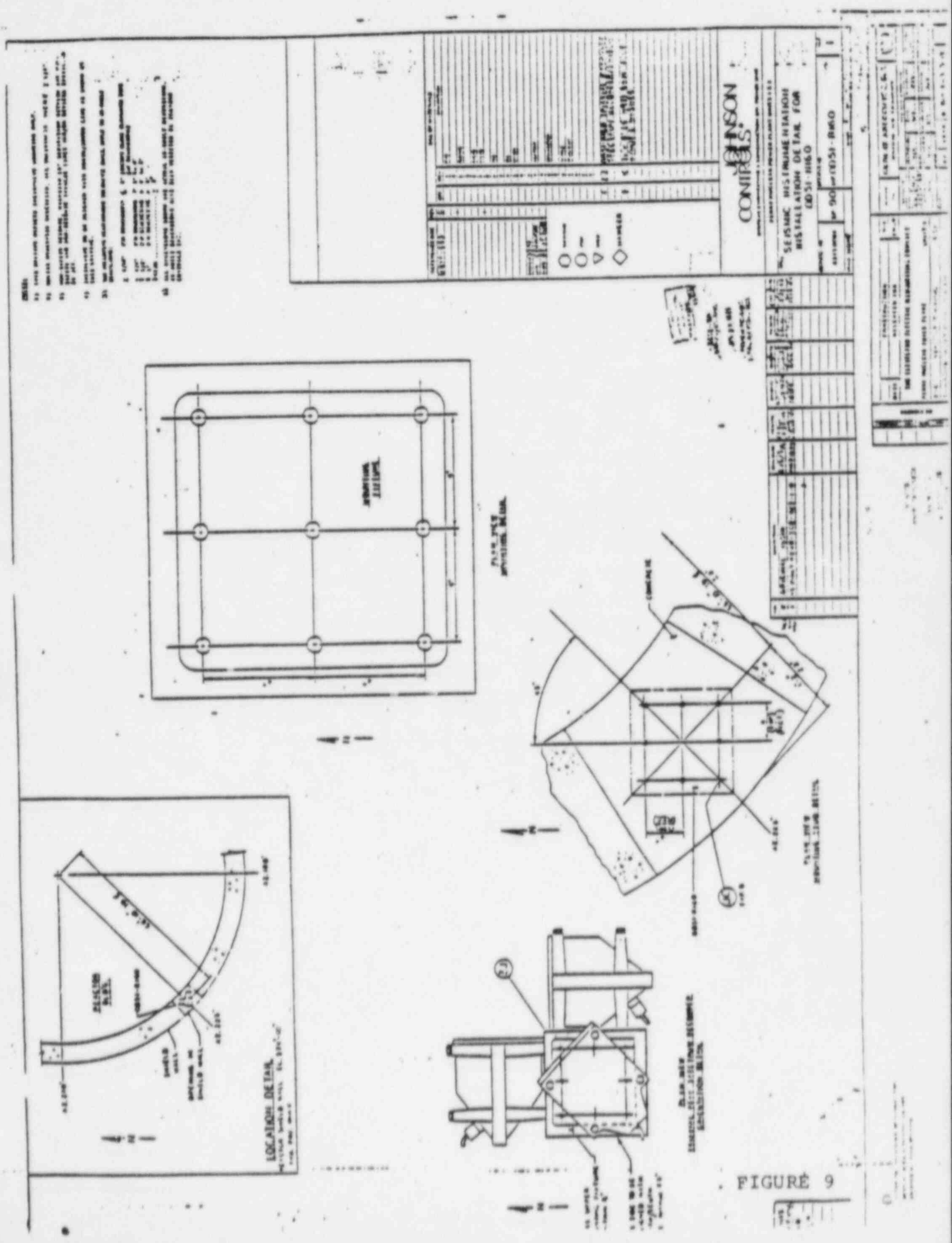

JOHNSON CONTROLS
SEISMIC INSTRUMENTATION
INSTALLATION DETAIL FOR
0D51-R160
LOCATION DETAIL

FIGURE 9

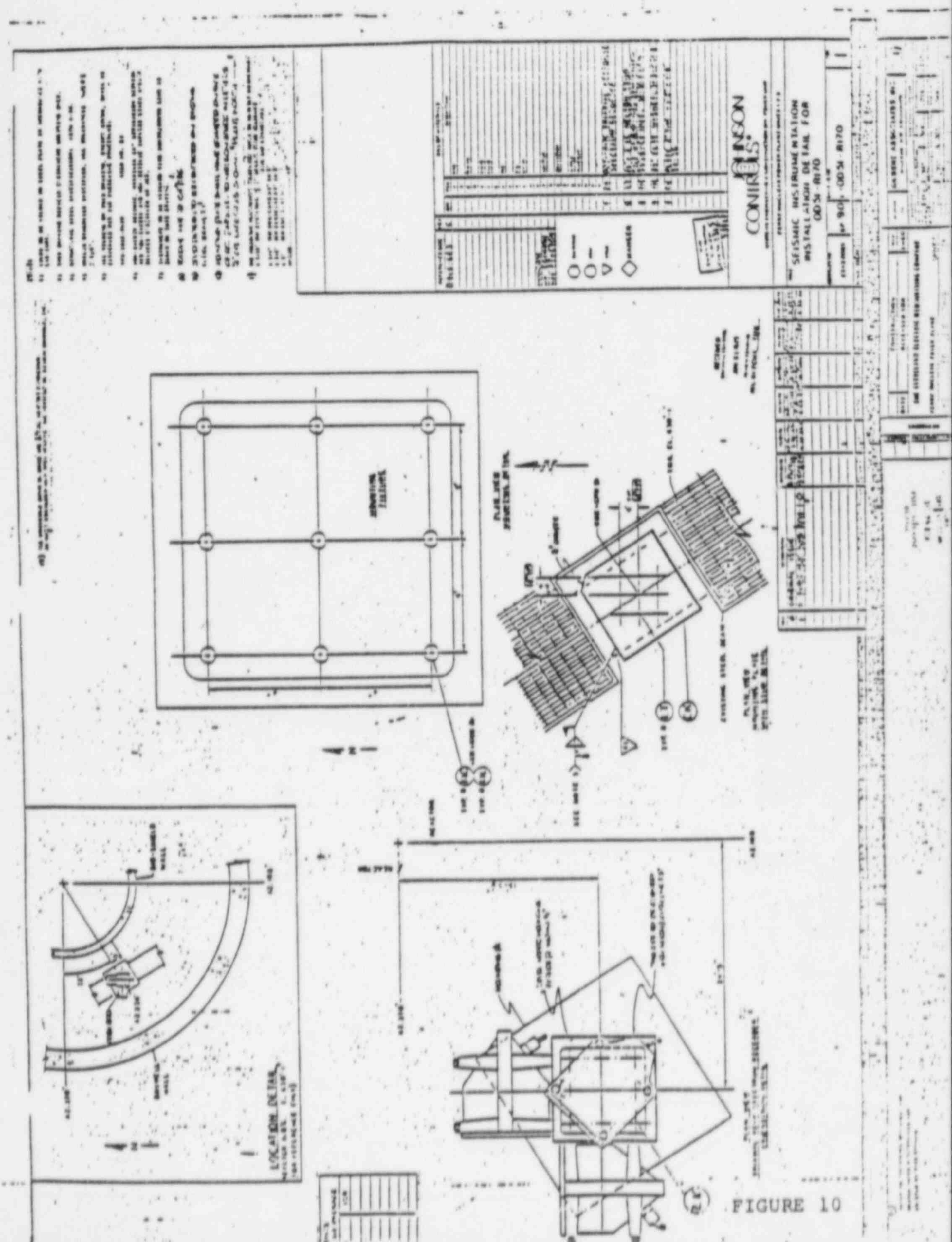

SEISMIC INSTRUMENTATION
INSTALLATION DETAIL FOR
LOCATION DETAIL

FIGURE 10

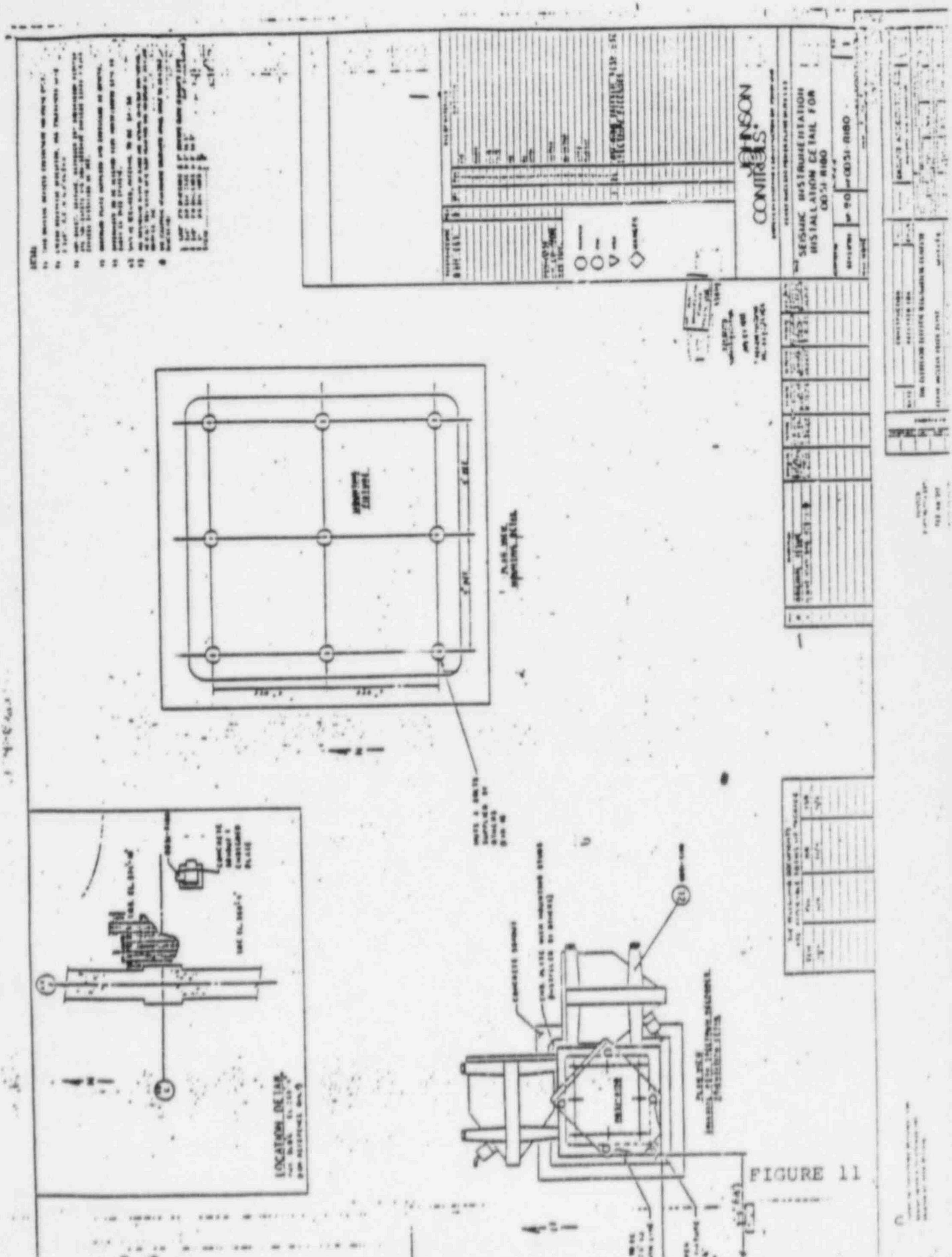

JOHNSON CONTROLS
SEISMIC INSTRUMENTATION
INSTALLATION DETAIL FOR
LOCATION DETAIL

FIGURE 11

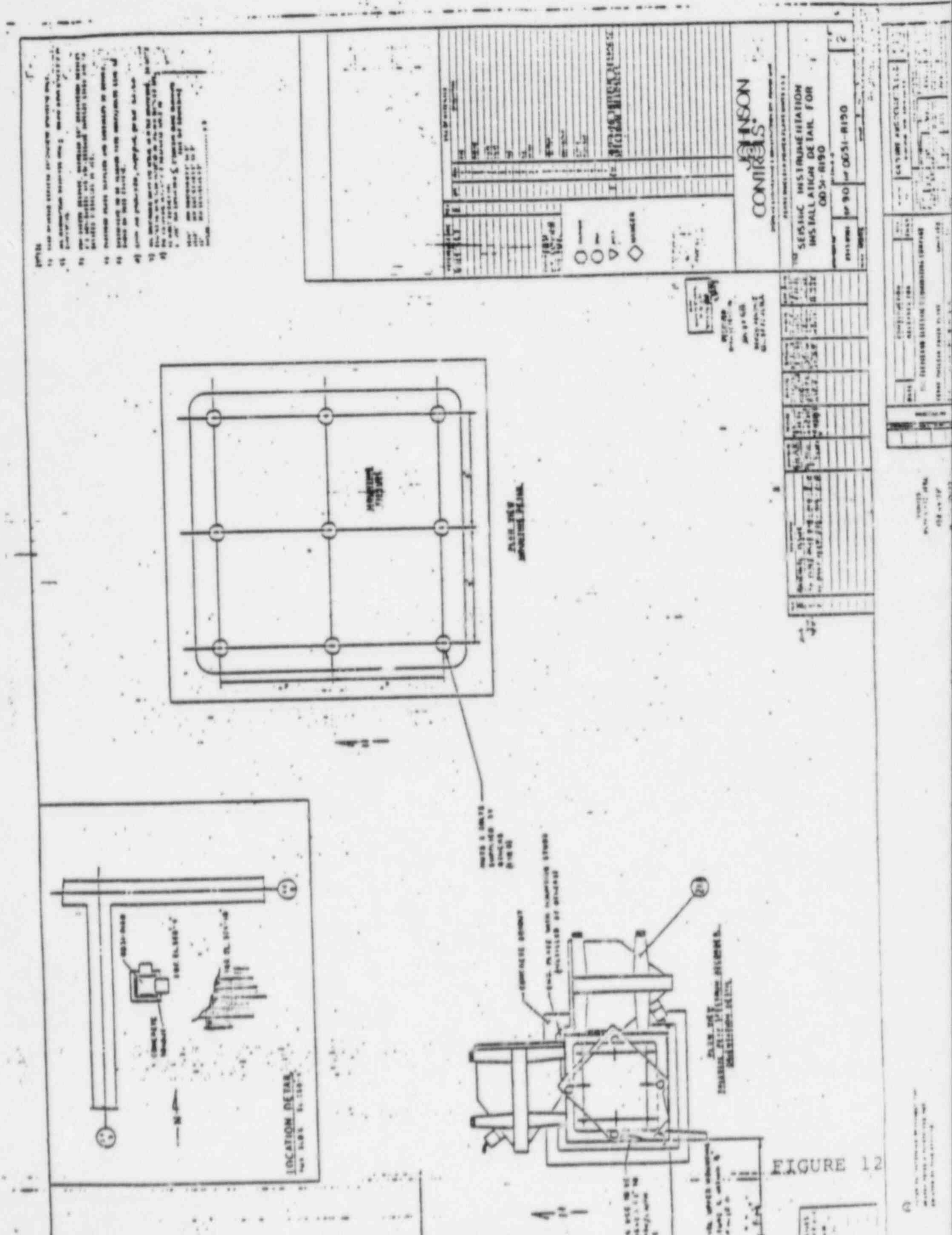
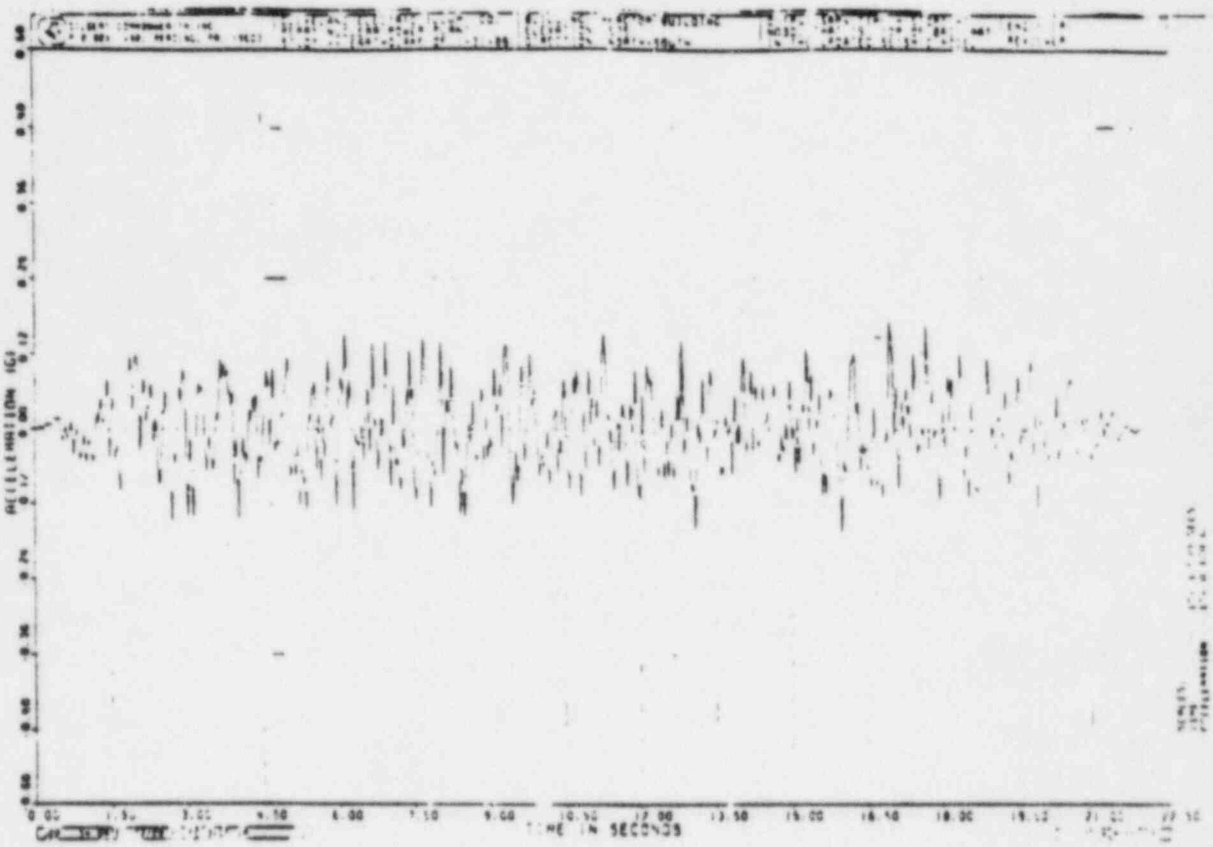

JOHNSON CONTROLS
SEISMIC INSTRUMENTATION
INSTALLATION DETAIL FOR
LOCATION DETAIL

FIGURE 12



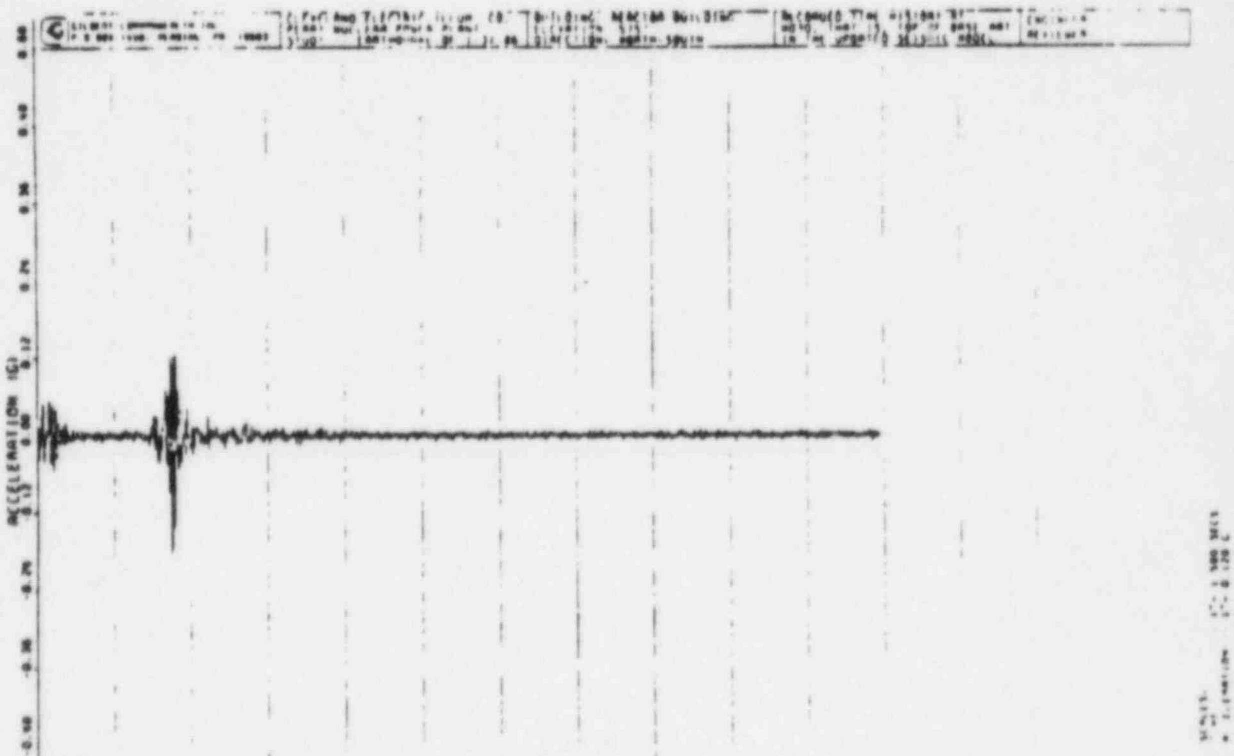
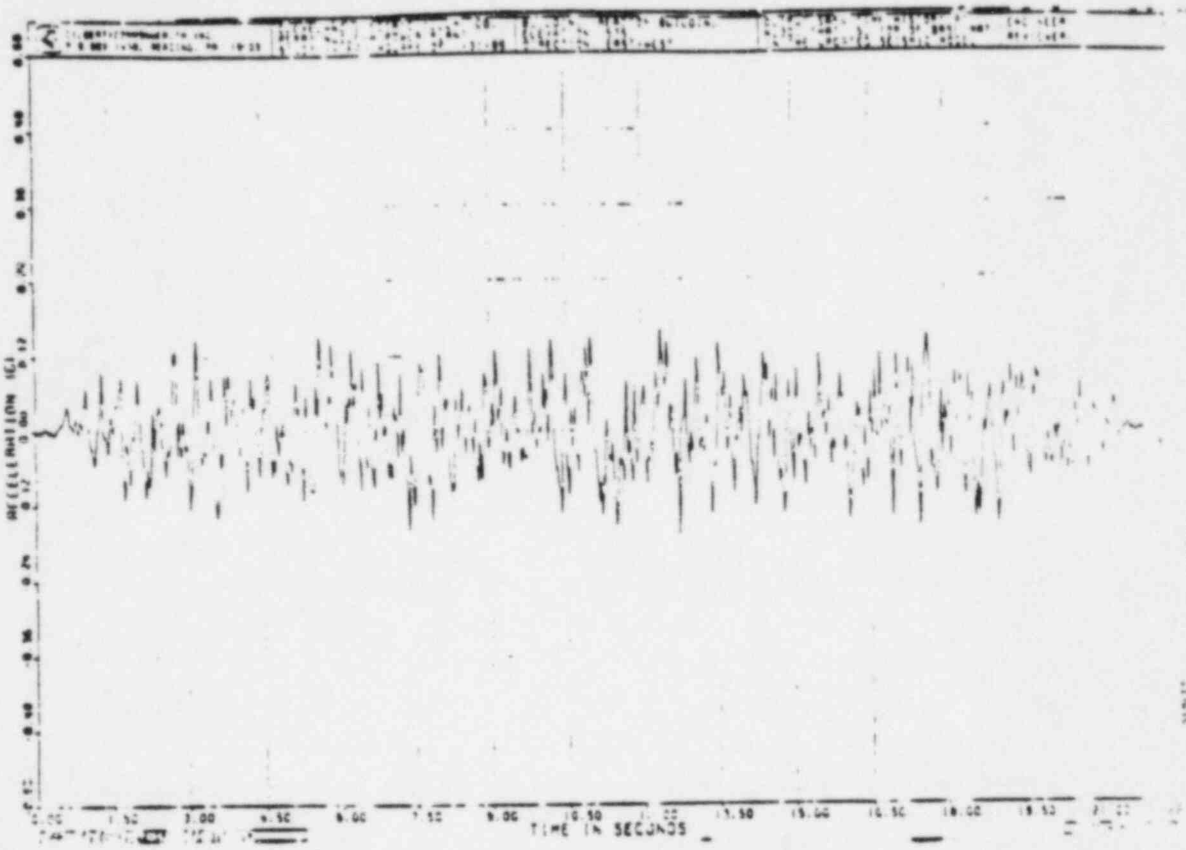


FIGURE 13



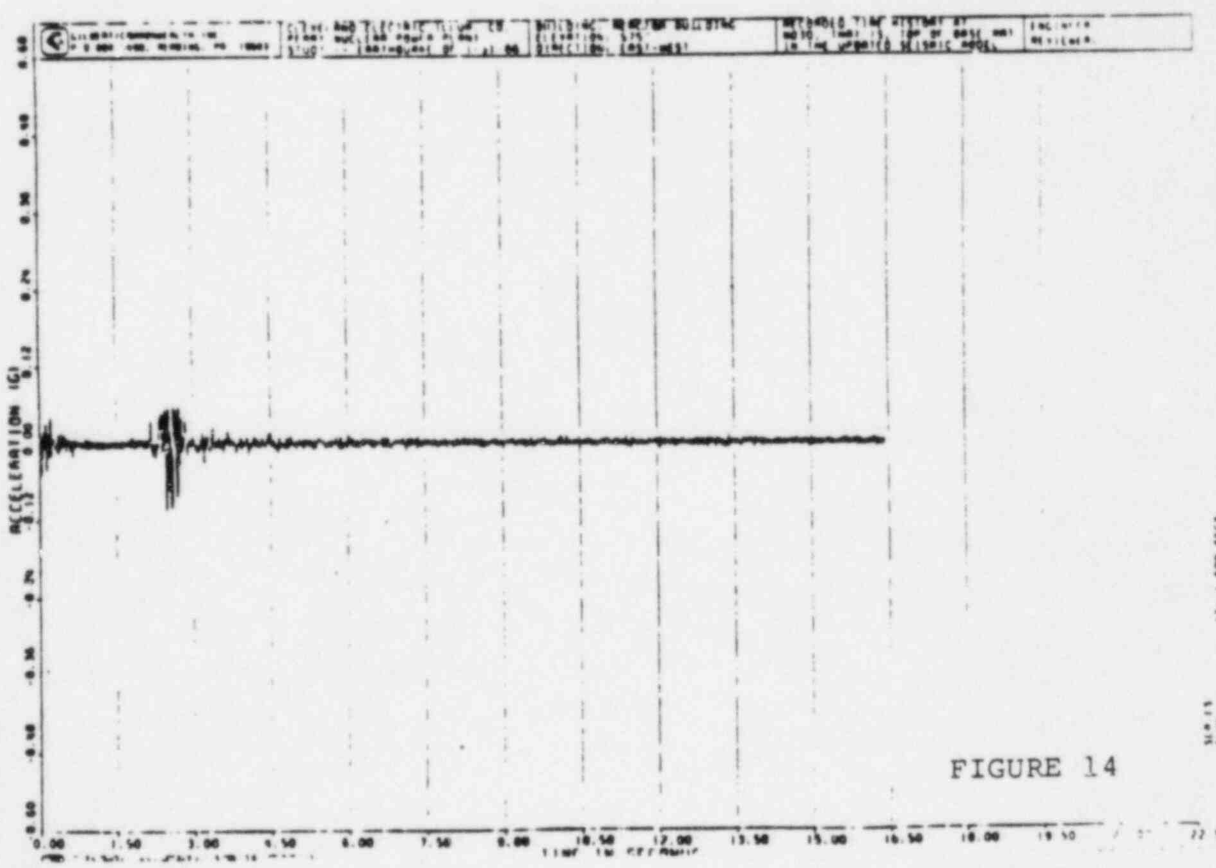
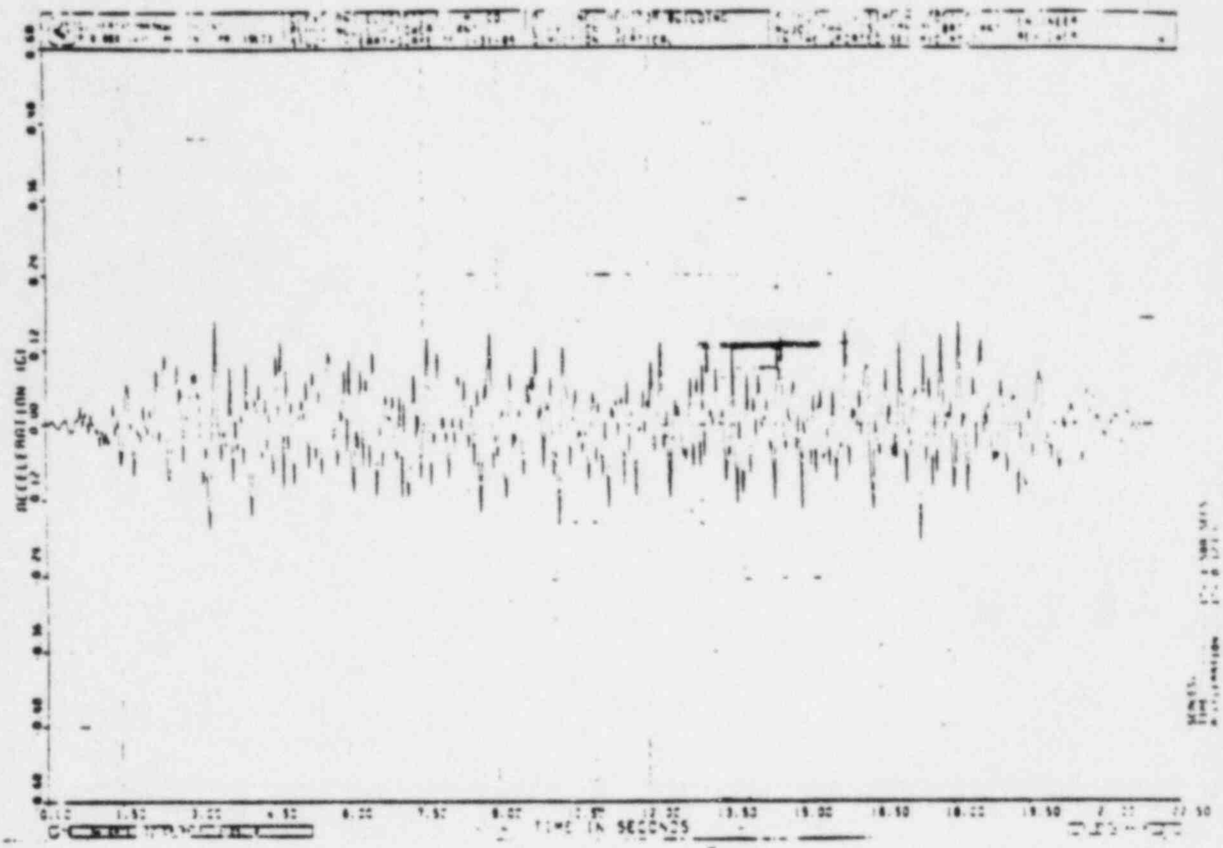


FIGURE 14



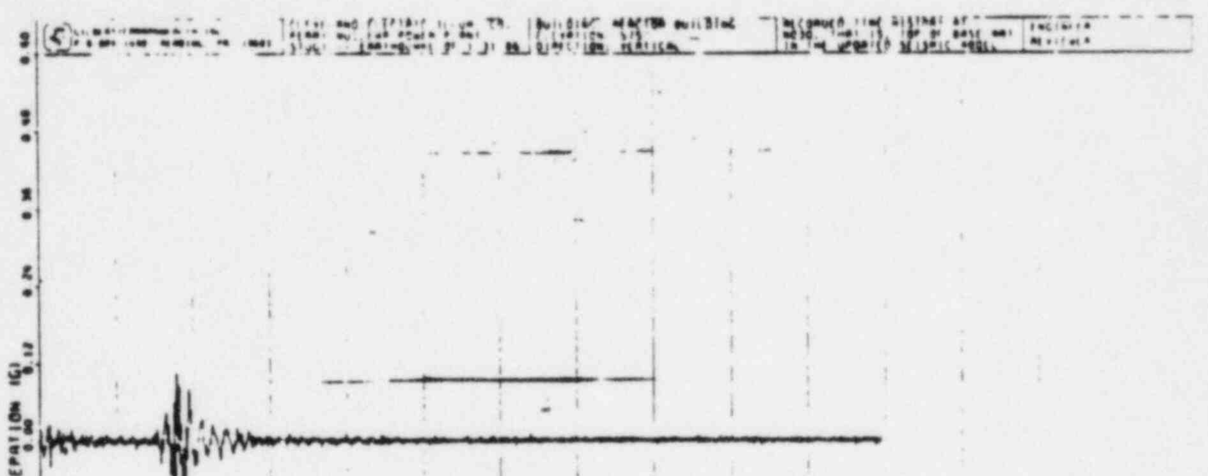
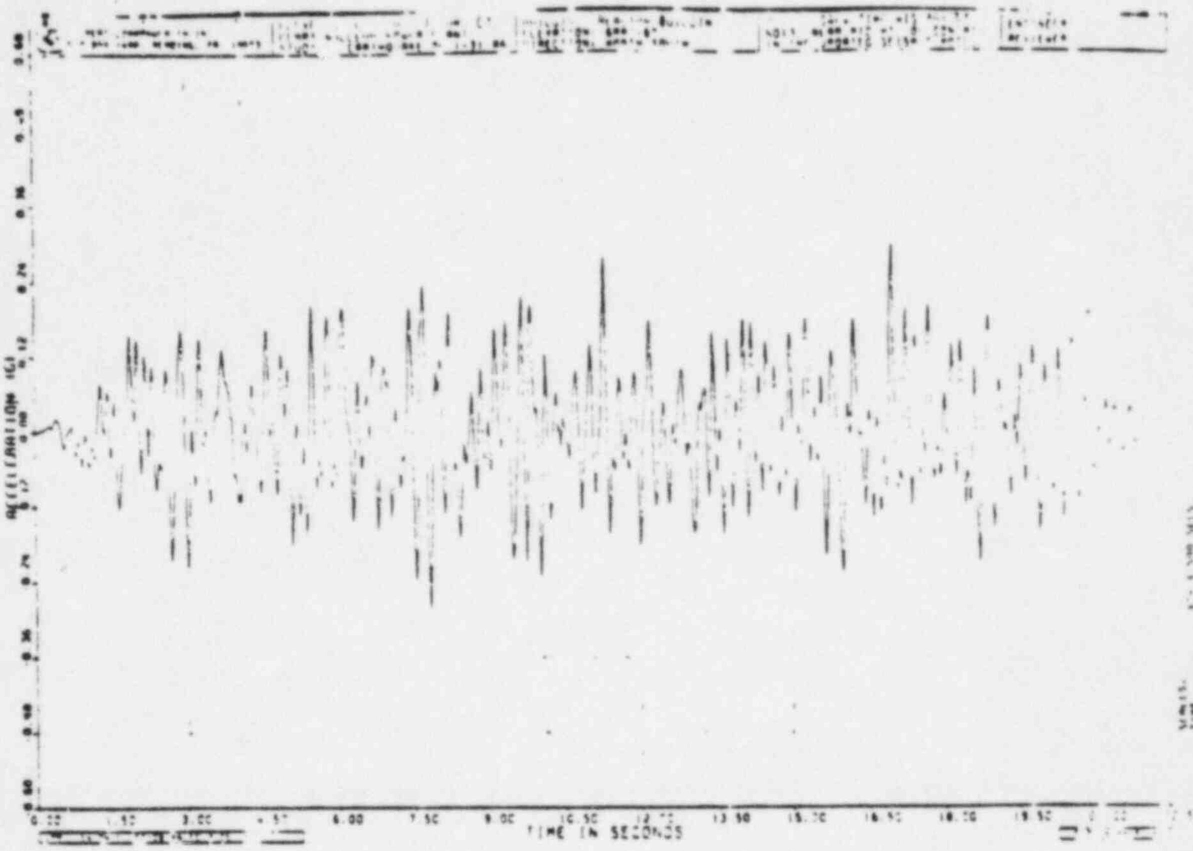


FIGURE 15


ACCELERATION (G)
TIME IN SECONDS

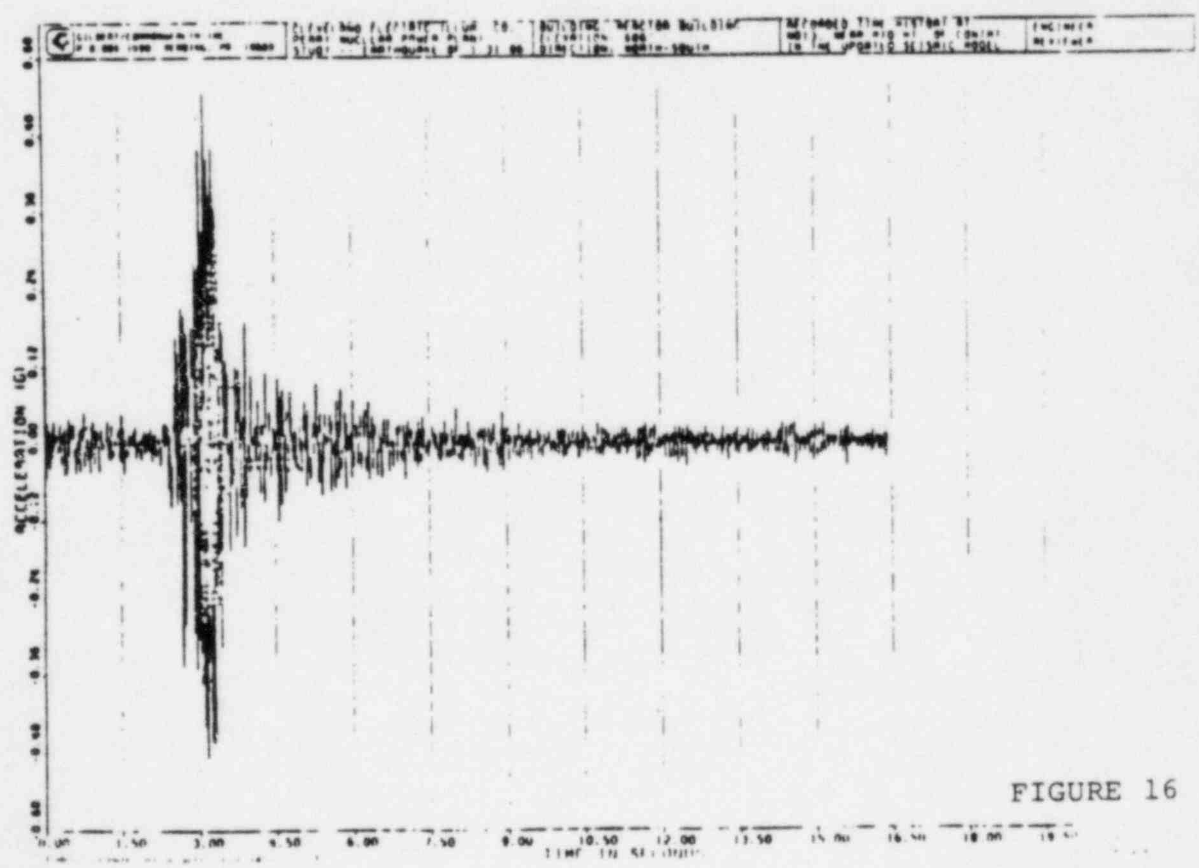
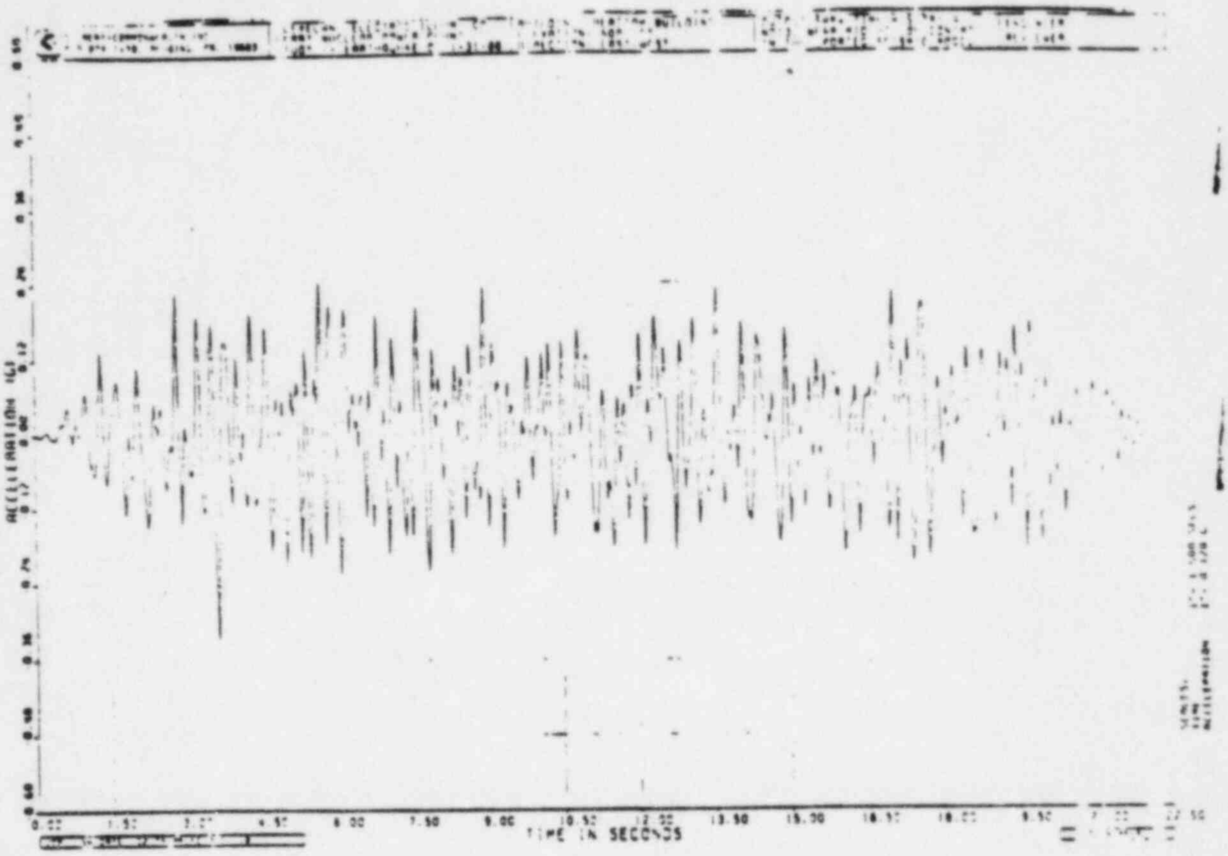

ACCELERATION (G)
TIME IN SECONDS

FIGURE 16



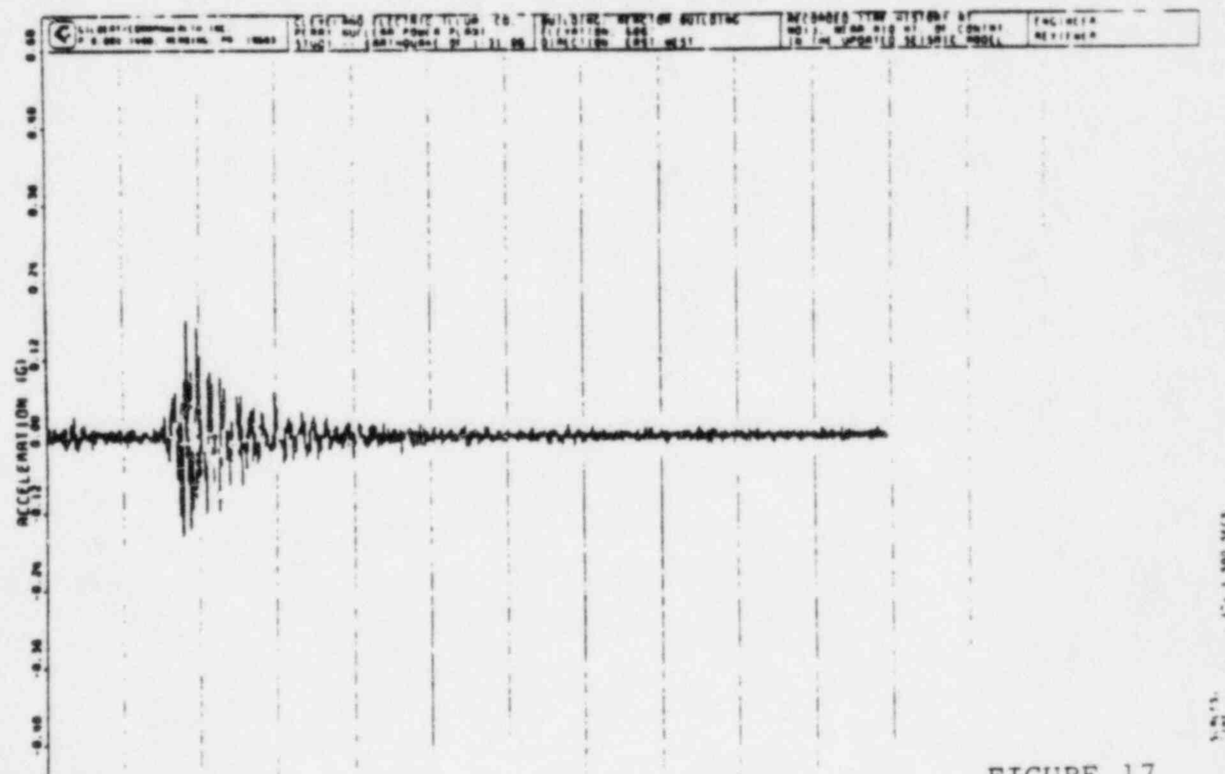
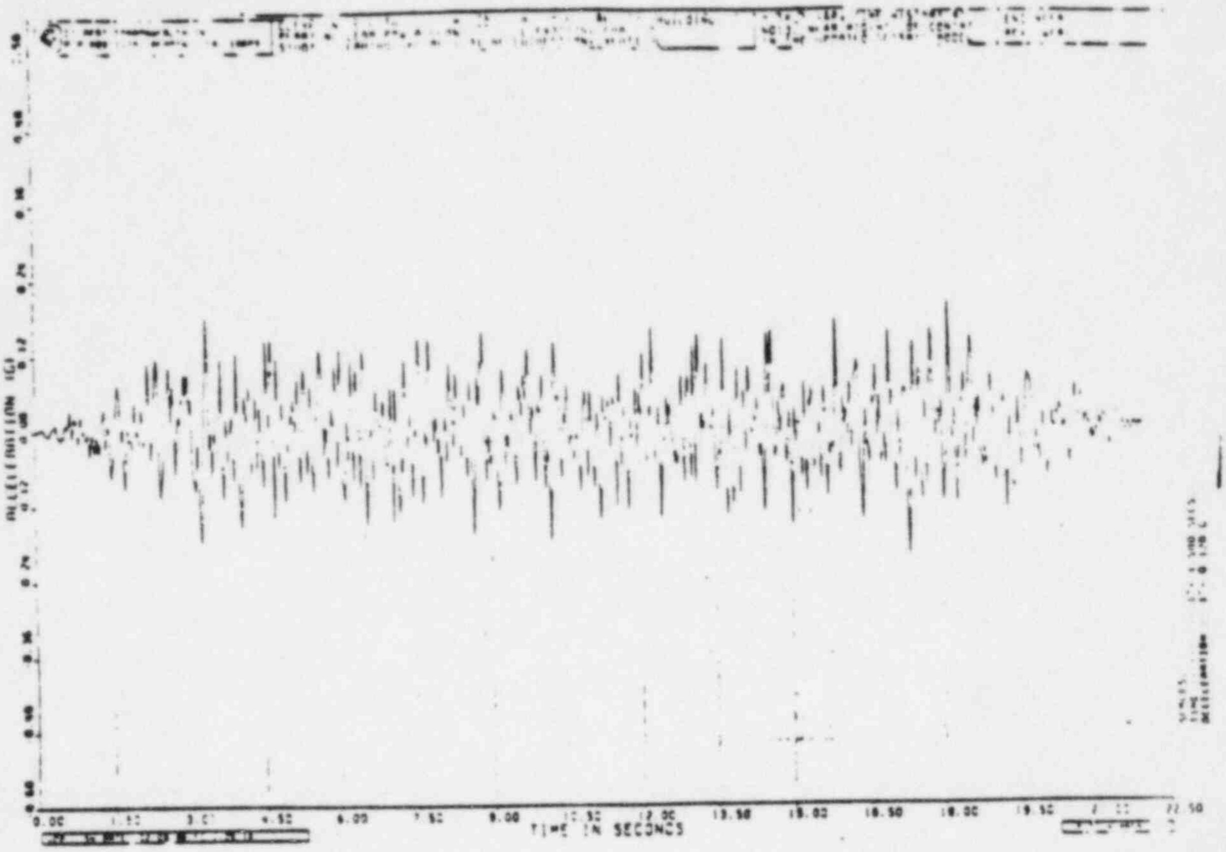


FIGURE 17



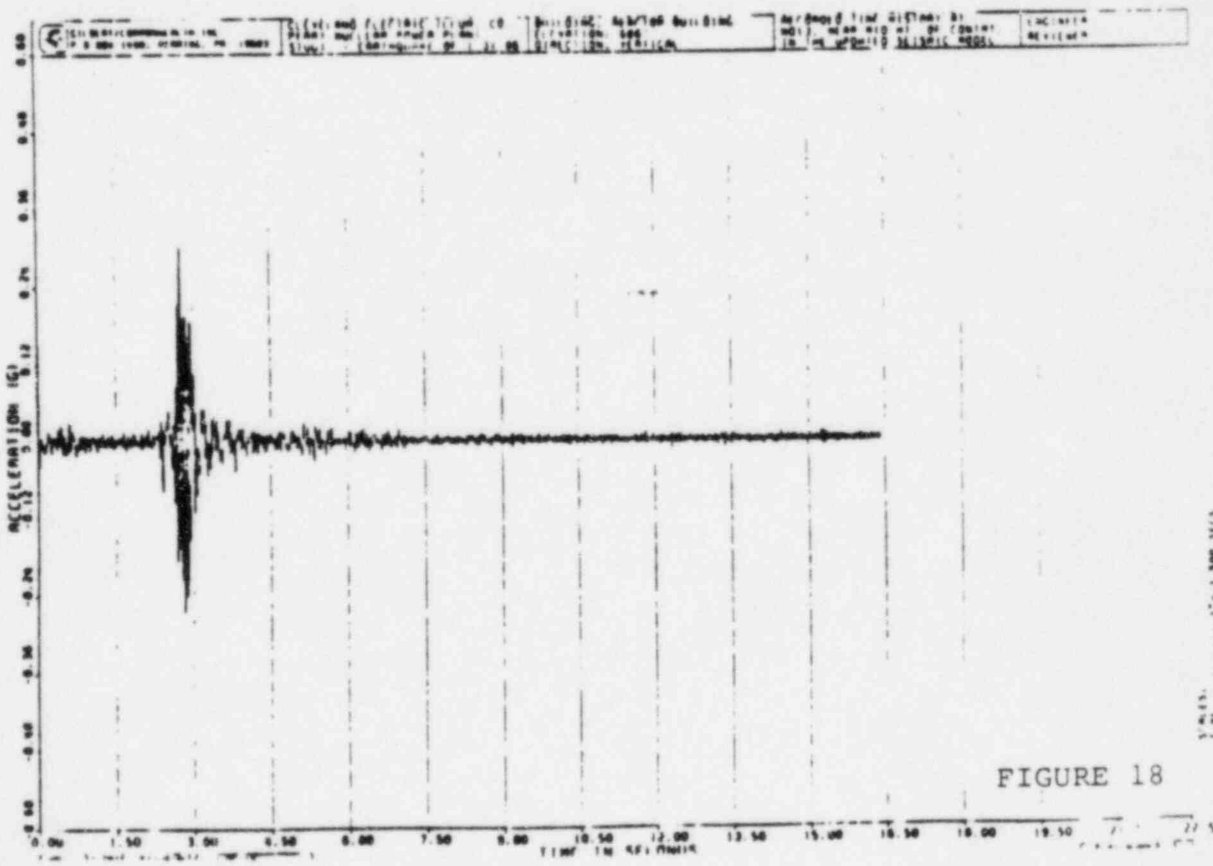


FIGURE 18

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A800I PERRY NUCLEAR POWER PLANT COMP WEST SMA3S/N 165-

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

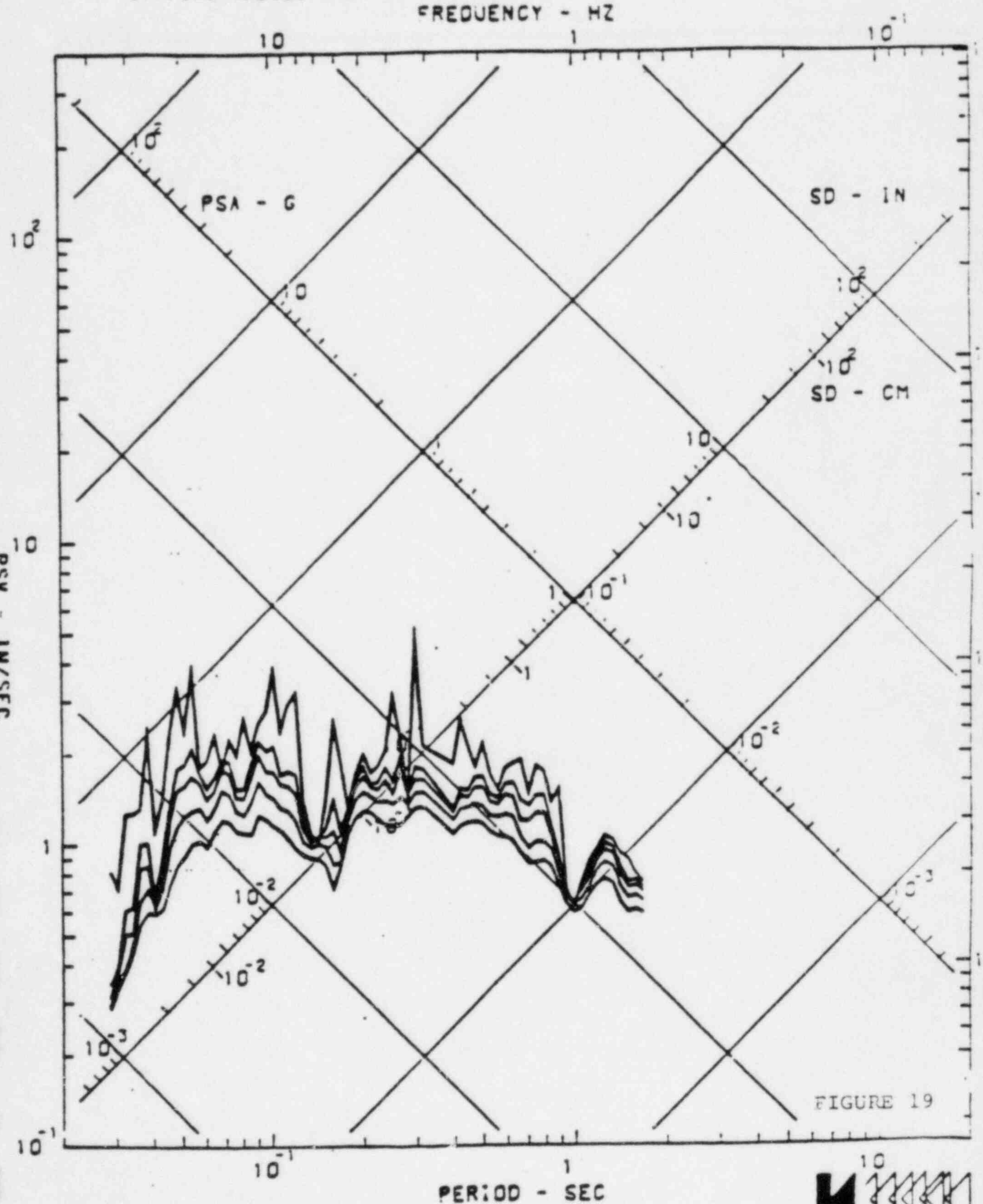


FIGURE 19

PNPP UNIT NO.1
AUXILIARY BUILDING
RESPONSE SPECTRA (SSE)
N/S DIRECTION
ELEVATION 568'-4"

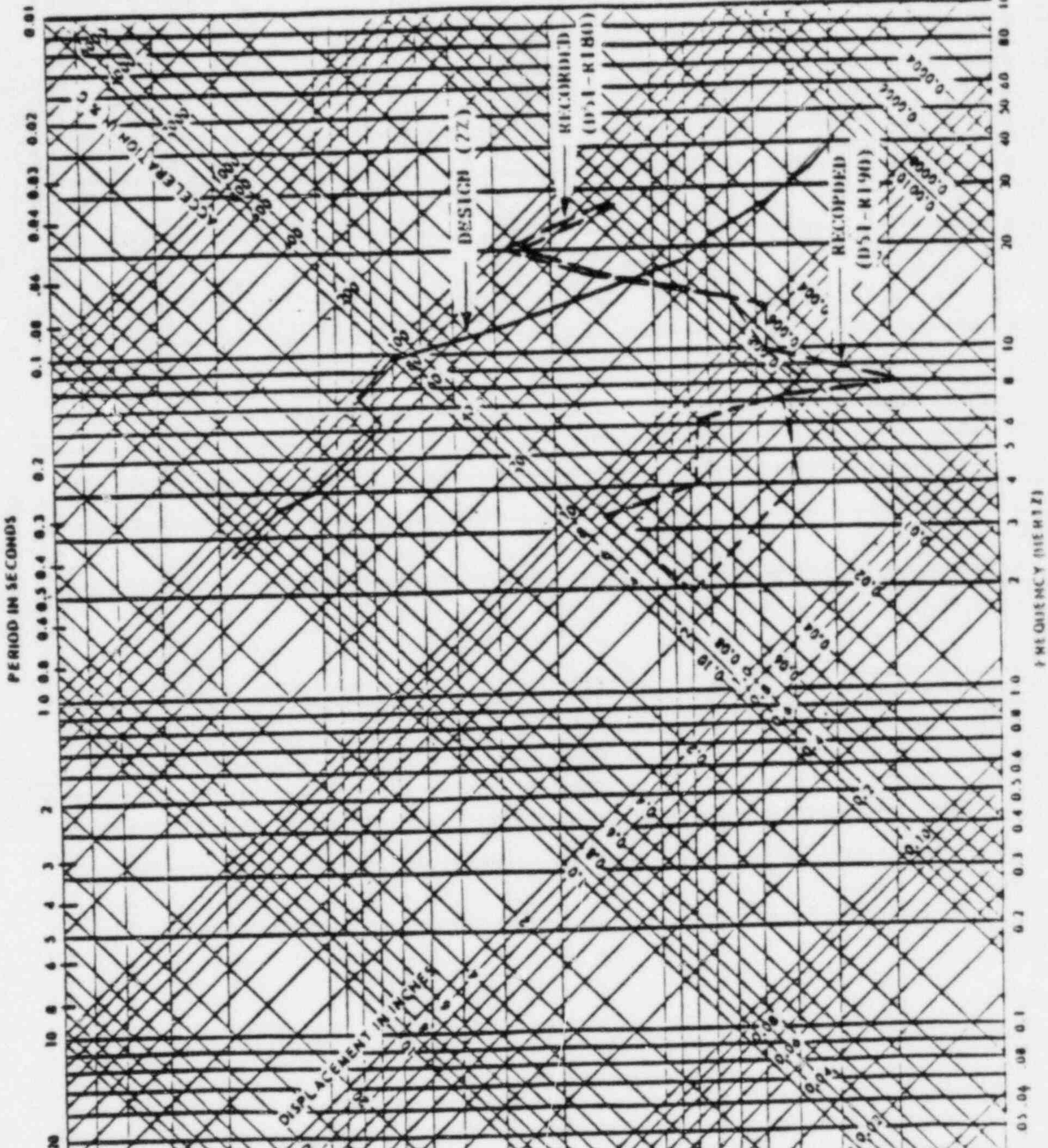


FIGURE 20

PNPP UNIT NO. 1
AUXILIARY BUILDING
RESPONSE SPECTRA (SSE)
E/W DIRECTION
ELEVATION 568'-4"

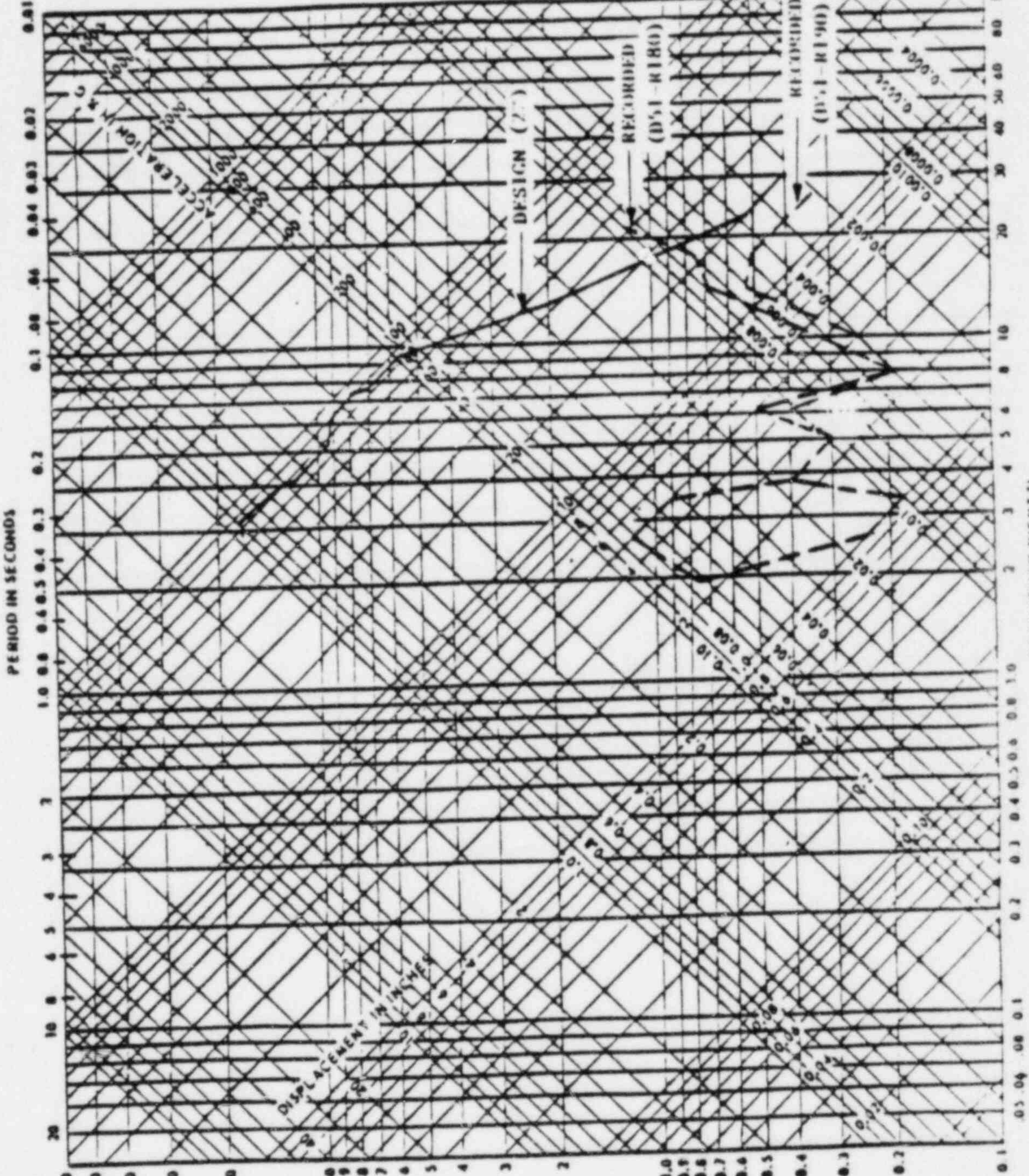


FIGURE 21

PNPP UNIT NO. 1
AUXILIARY BUILDING
RESPONSE SPECTRA (SSE)
VERTICAL
ELEVATION 568'-4"

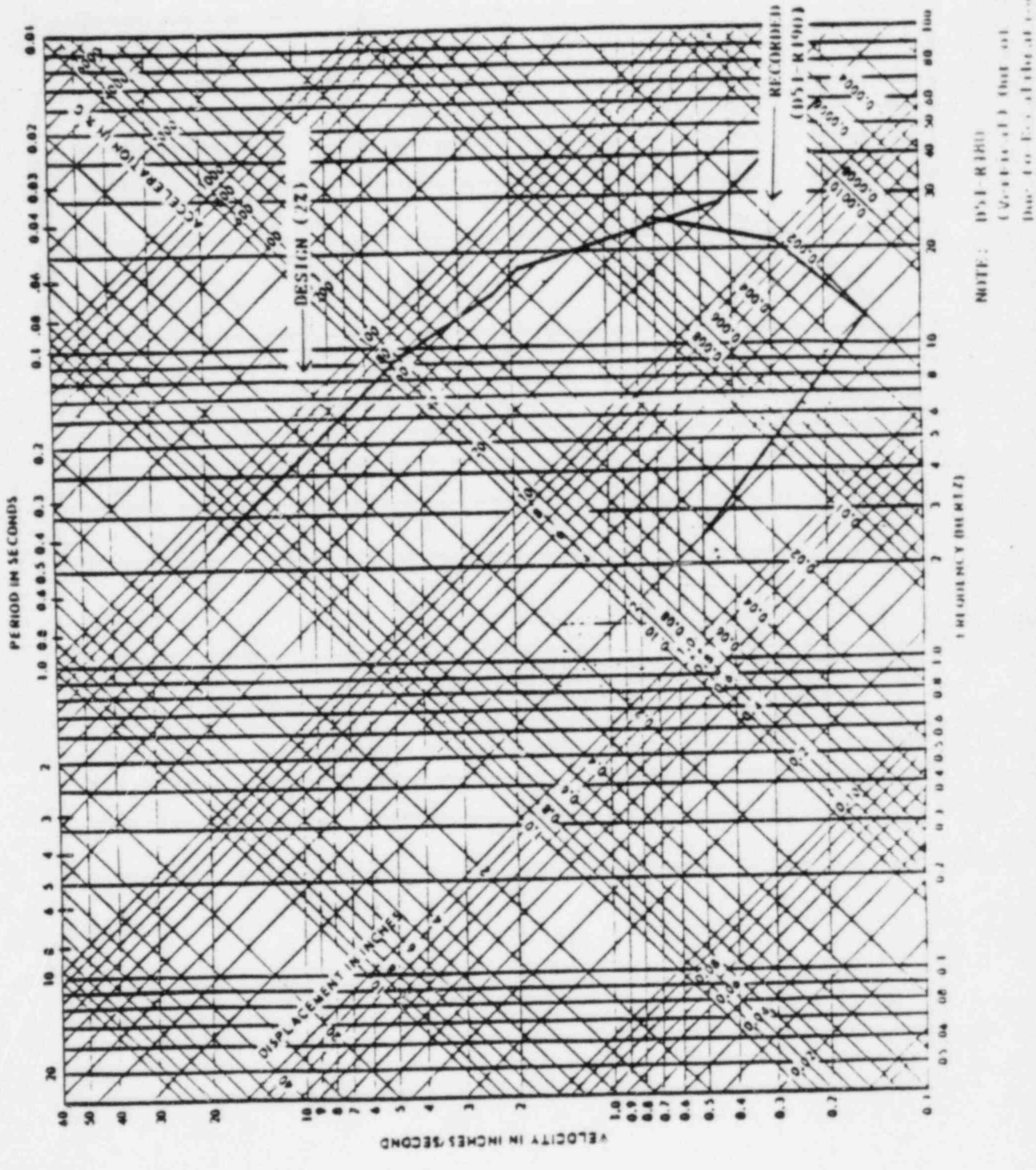


FIGURE 22

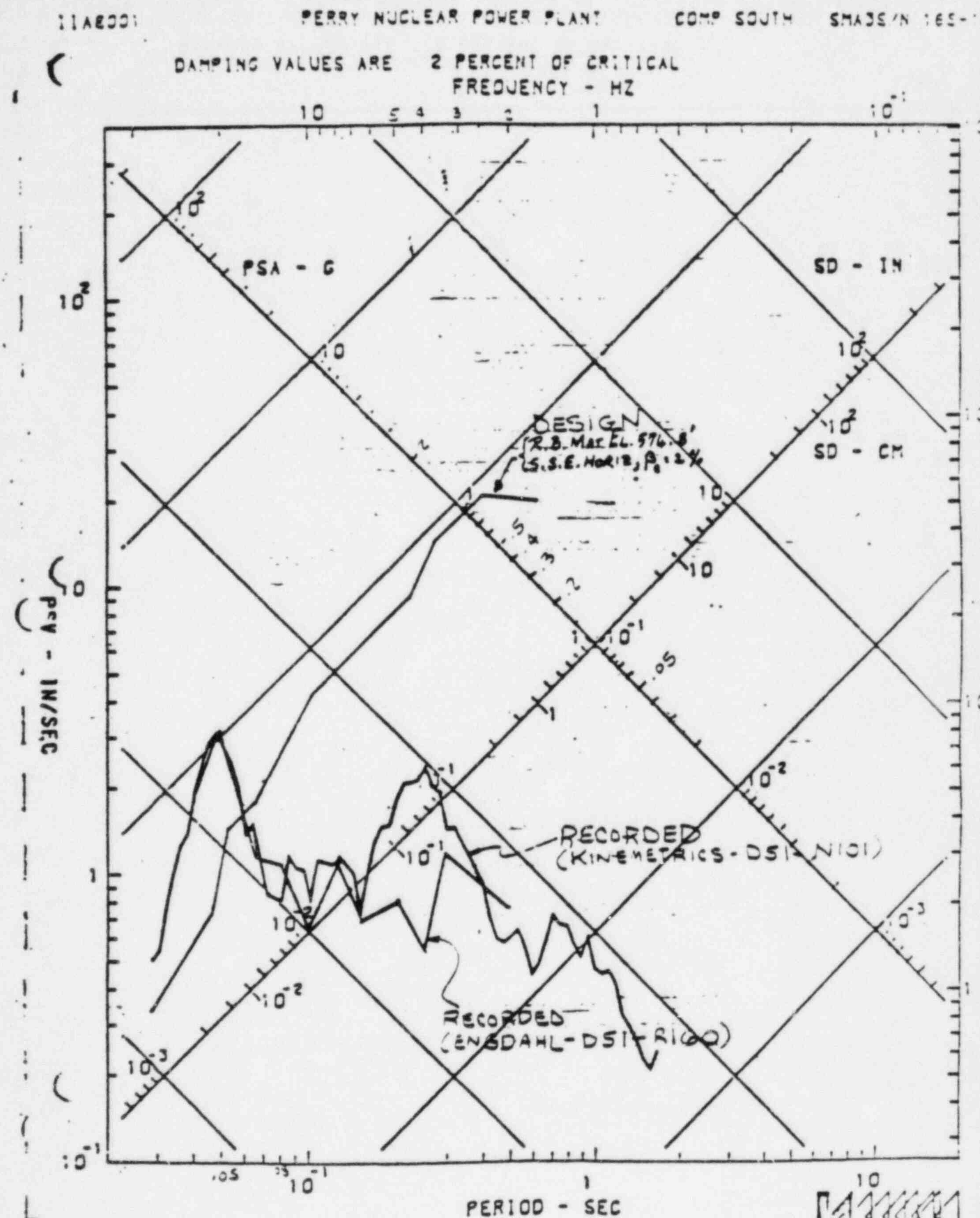
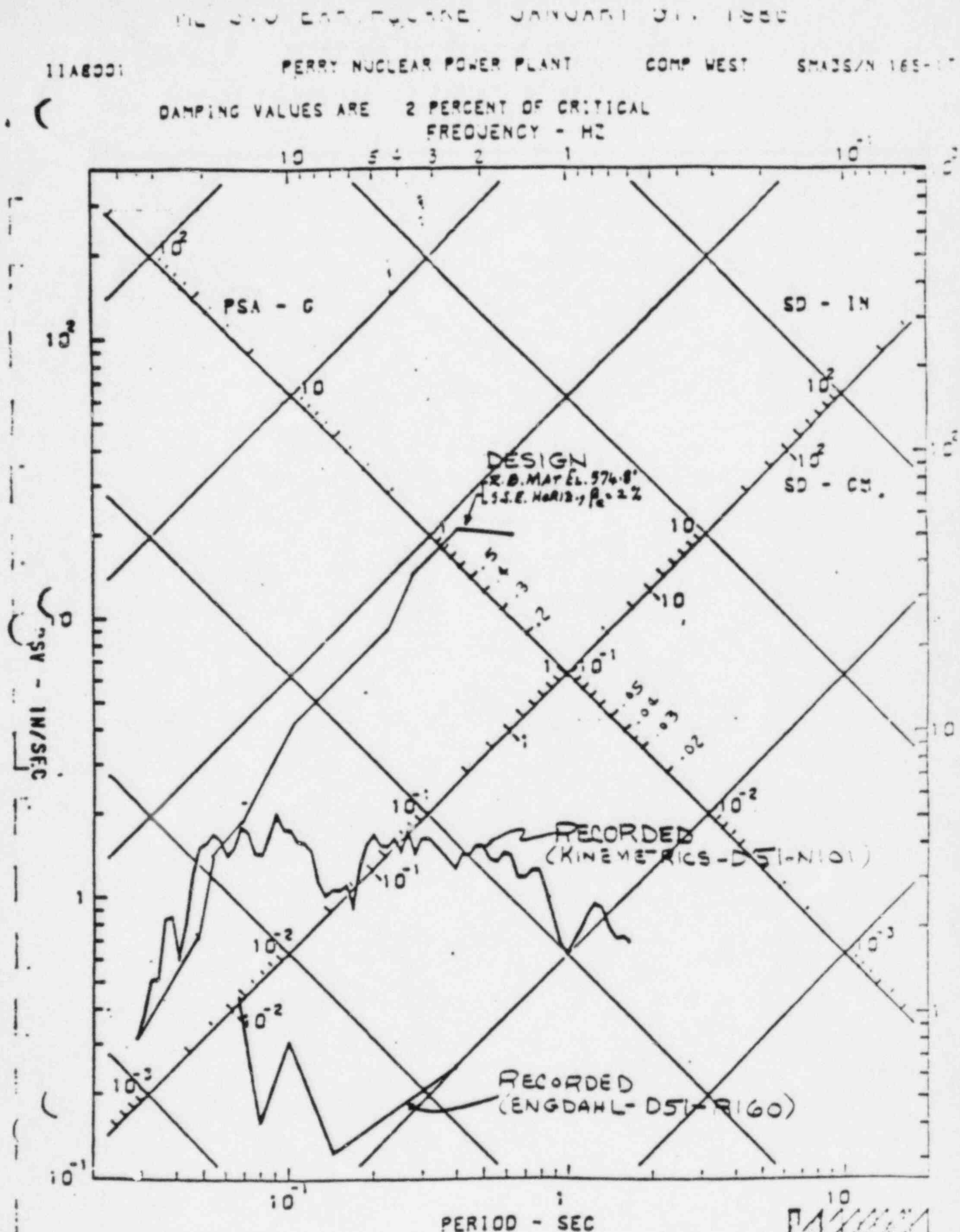
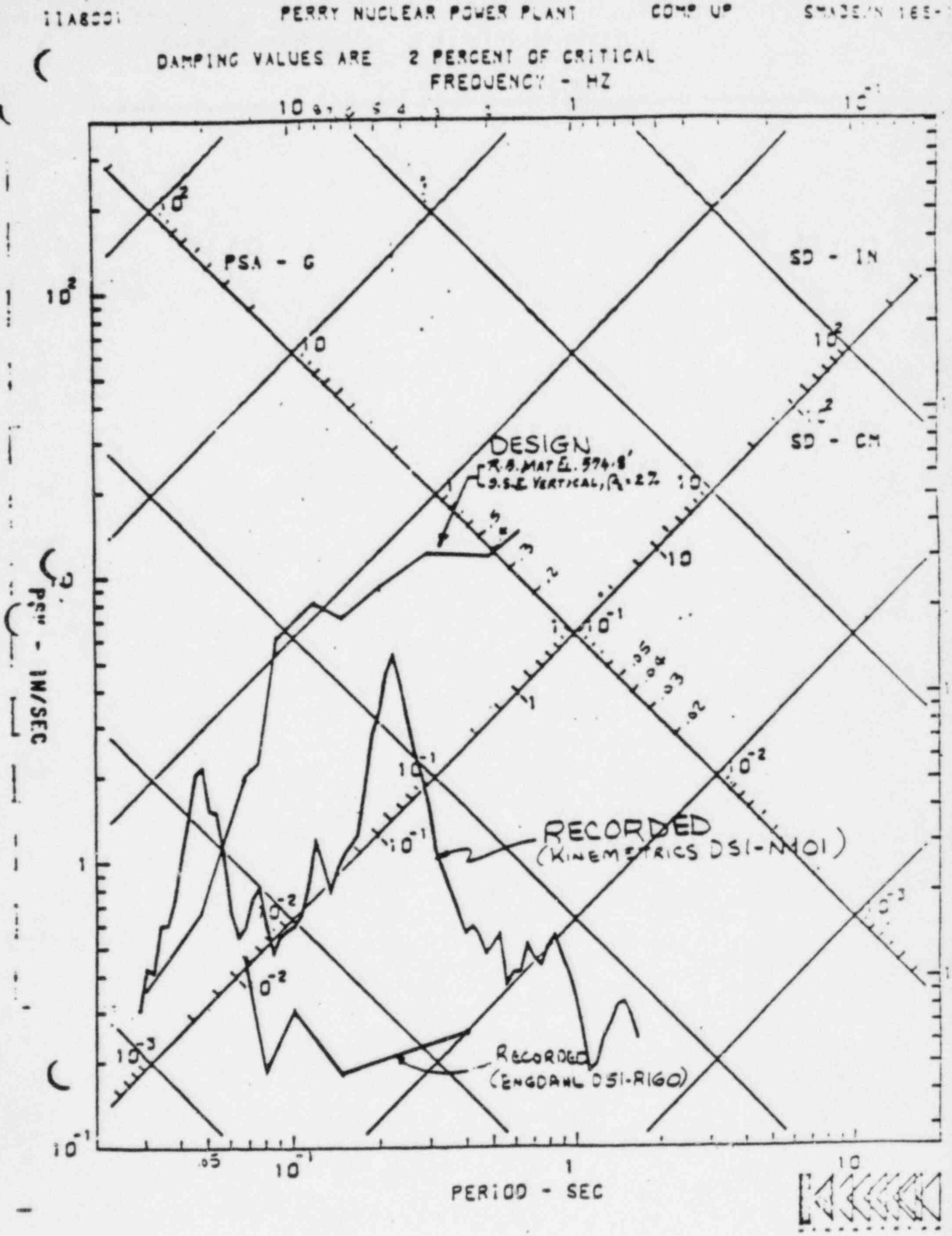

IIA8001
PERRY NUCLEAR POWER PLANT
COMP SOUTH
DAMPING VALUES ARE 2 PERCENT OF CRITICAL
FREQUENCY - HZ
PSA - G
SD - IN
SD - CM
PSV - IN/SEC
PERIOD - SEC
DESIGN
RECORDED
(KINEMETRICS-DSI-NIOI)
RECORDED
(ENGDAHL-DSI-RIGO)

FIGURE 23



11A8001
PERRY NUCLEAR POWER PLANT
COMP WEST
DAMPING VALUES ARE 2 PERCENT OF CRITICAL
FREQUENCY - HZ
PSA - G
SD - IN
SD - CM.
DESIGN
RECORDED
(KINEMETRICS-D51-N101)
RECORDED
(ENGDAHL-D51-R160)
PSV - IN/SEC
PERIOD - SEC

FIGURE 24



PERRY NUCLEAR POWER PLANT
COMP UP
DAMPING VALUES ARE 2 PERCENT OF CRITICAL
FREQUENCY - HZ
PSA - G
SD - IN
SD - CM
DESIGN
R.B. MAT EL. 574.8'
S.S.E. VERTICAL, β = 2%
RECORDED
(KINEMETRICS DSI-M101)
RECORDED
(ENGDAHL DSI-R160)
PSV - IN/SEC
PERIOD - SEC

FIGURE 25

RNPP UNIT NO. [illegible]
REACTOR BUILDING
RESPONSE SPECTRA [illegible]
NORTH-SOUTH
EL [illegible] PLATFORM

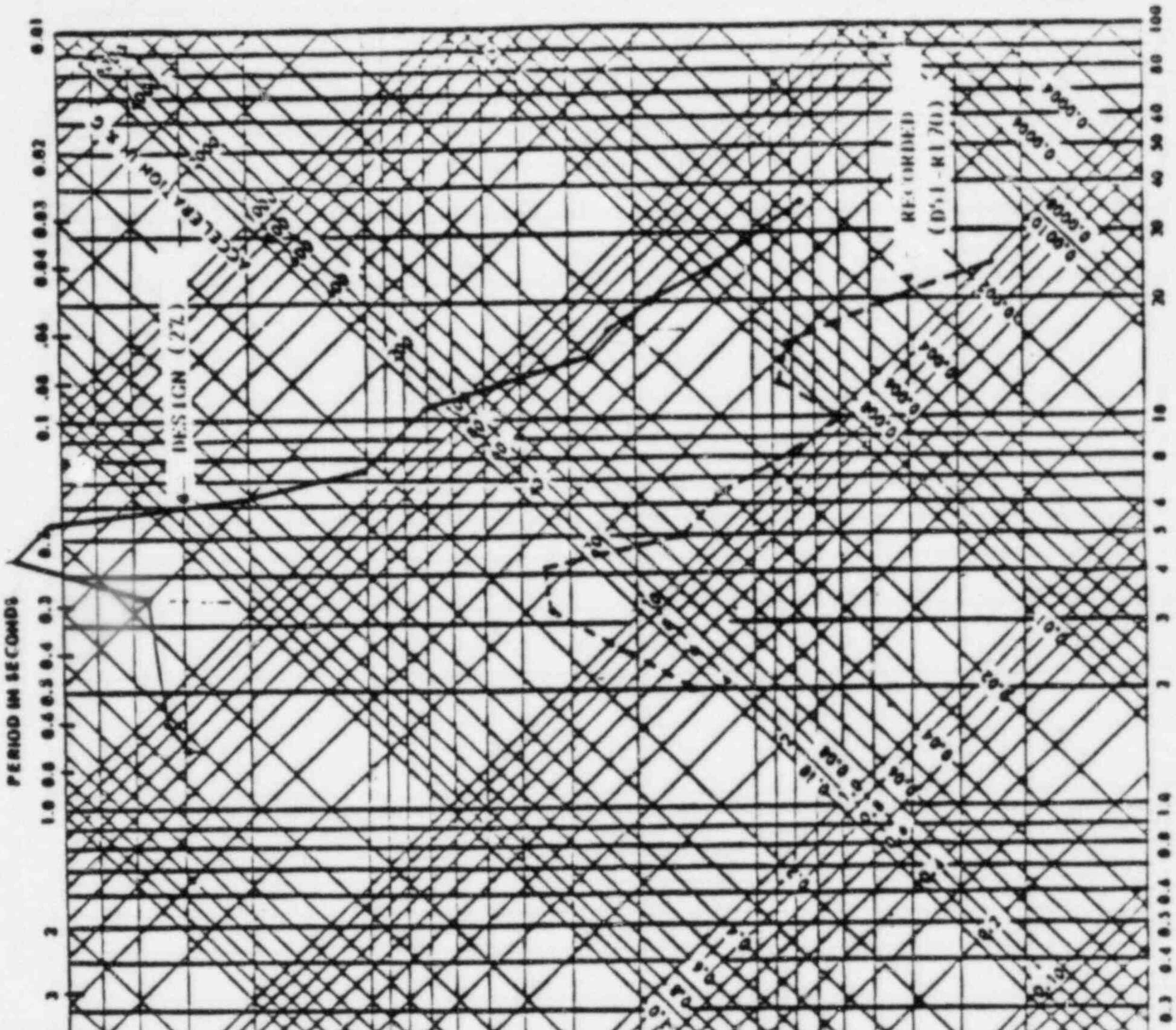


FIGURE 26

PNPP UNIT NO. 1
REACTOR BUILDING
RESPONSE SPECTRA
EAST-WEST
EL 631' PLATFORM

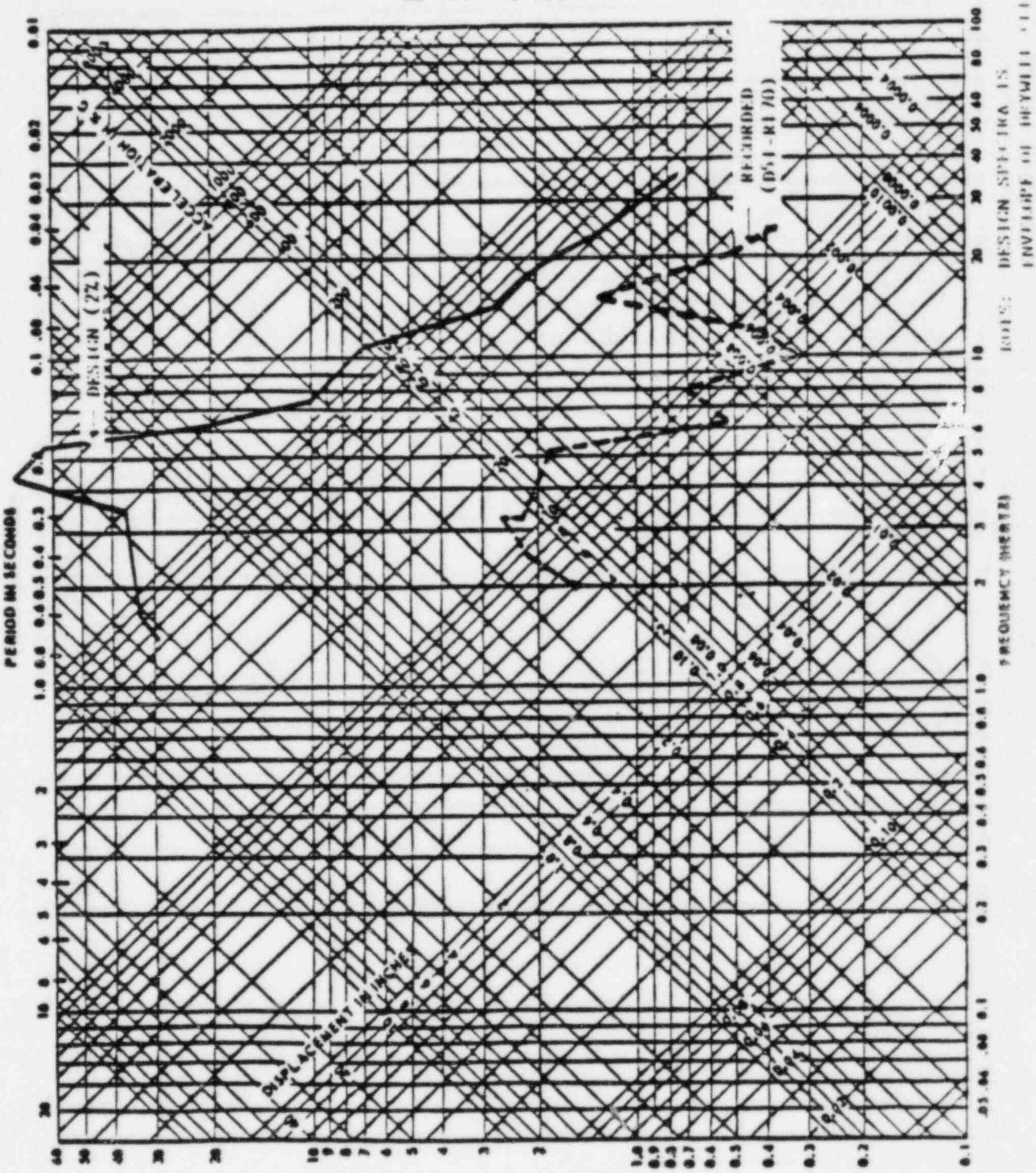


FIGURE 27

BFNP UNIT NO. 1
REACTOR BUILDING
RESPONSE SPECTRA SSE
VERTICAL
EL 631' PLATFORM

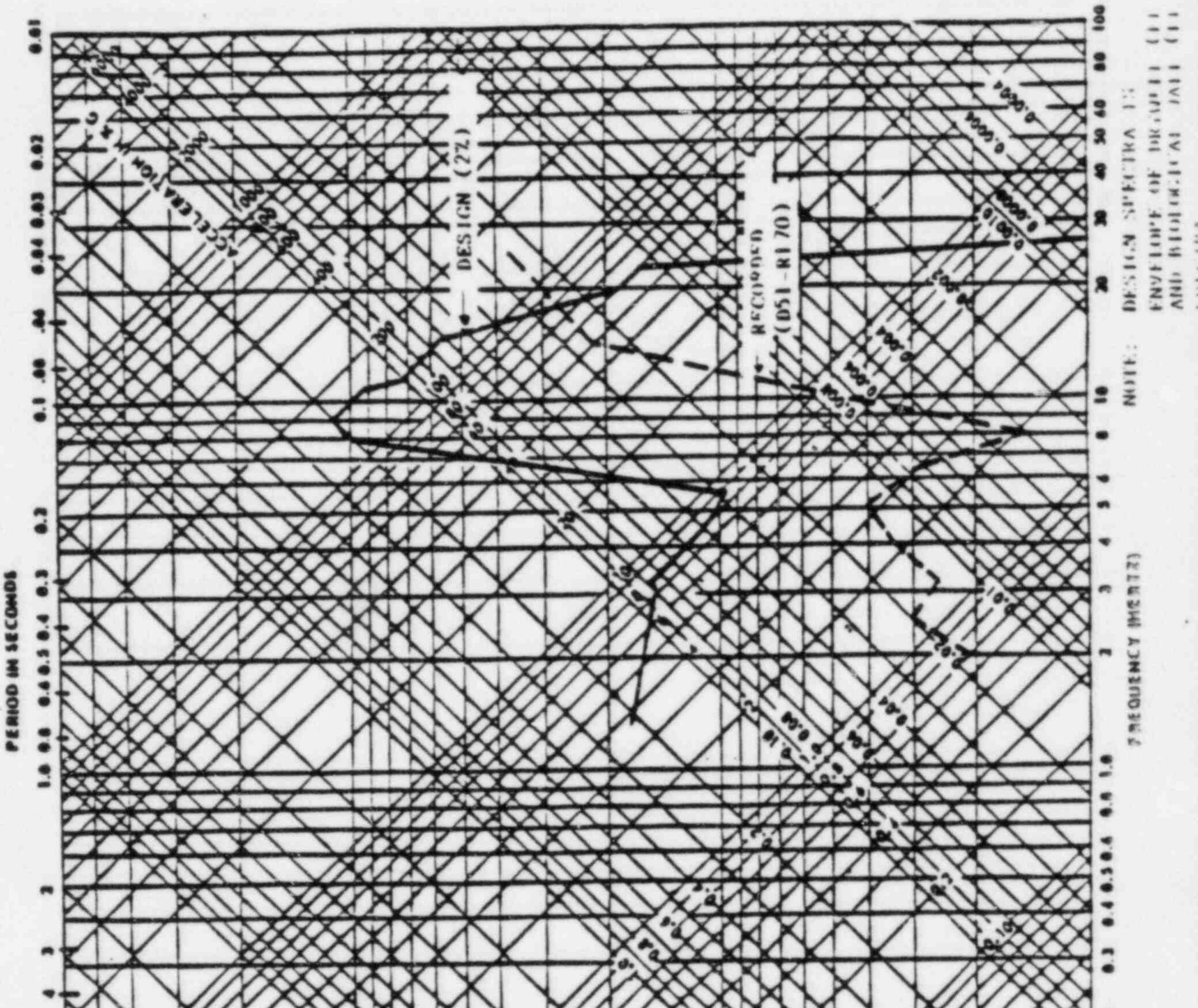


FIGURE 28

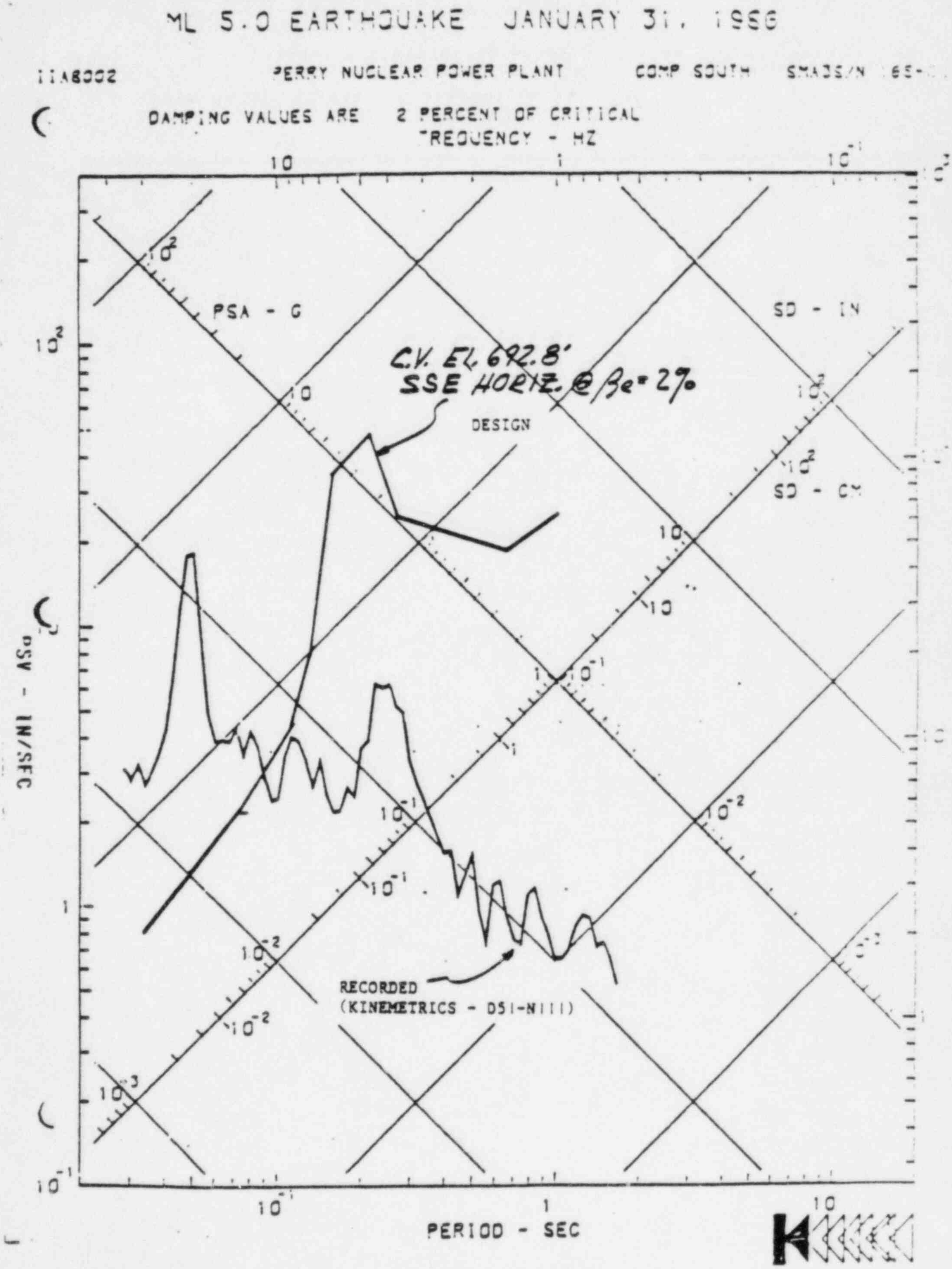

ML 5.0 EARTHQUAKE JANUARY 31, 1986
11A8002 PERRY NUCLEAR POWER PLANT COMP SOUTH
DAMPING VALUES ARE 2 PERCENT OF CRITICAL
FREQUENCY - HZ
PSA - G
SD - IN
SD - CM
C.V. El. 692.8'
SSE HORIZ. @ βe = 2%
DESIGN
RECORDED
(KINEMETRICS - DSI-N111)
PSV - IN/SEC
PERIOD - SEC

FIGURE 29

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A6002 PERRY NUCLEAR POWER PLANT COMP WEST SMA3S/N 165-2

DAMPING VALUES ARE 2 PERCENT OF CRITICAL

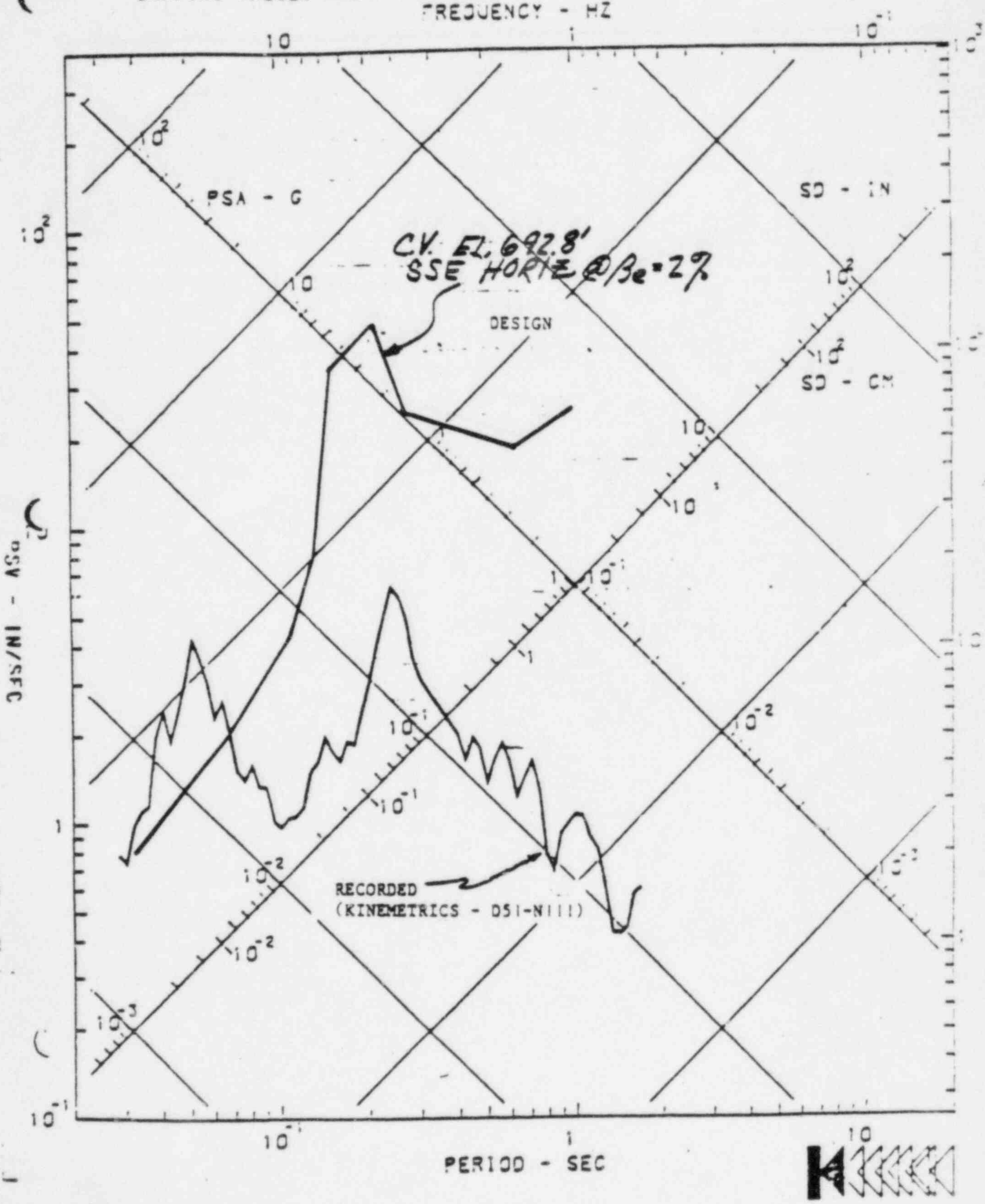


FIGURE 30

ML 5.0 EARTHQUAKE JANUARY 31, 1986

11A6002 PERRY NUCLEAR POWER PLANT COMP UP SMA3S/N 165-

DAMPING VALUES ARE 2 PERCENT OF CRITICAL

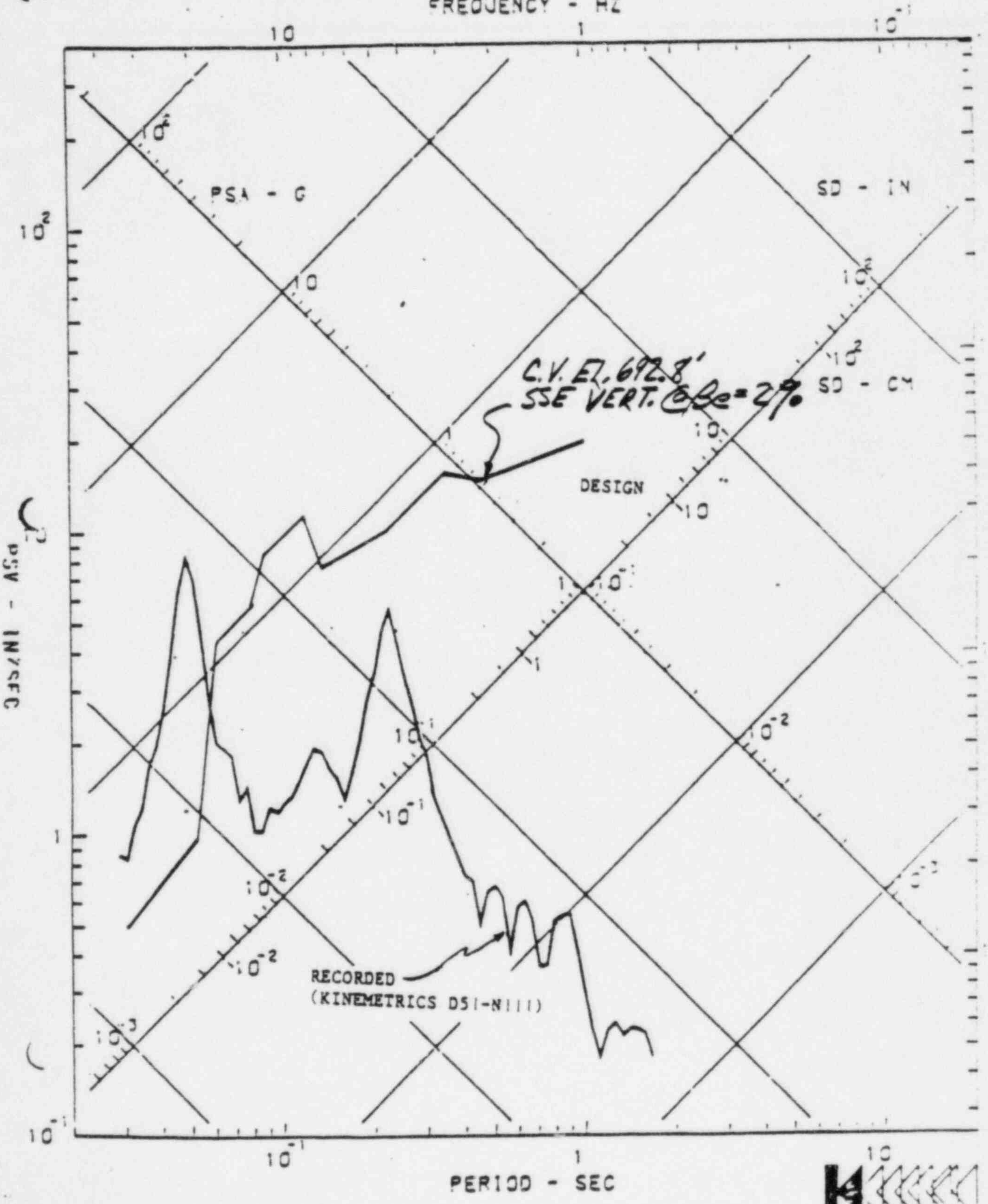
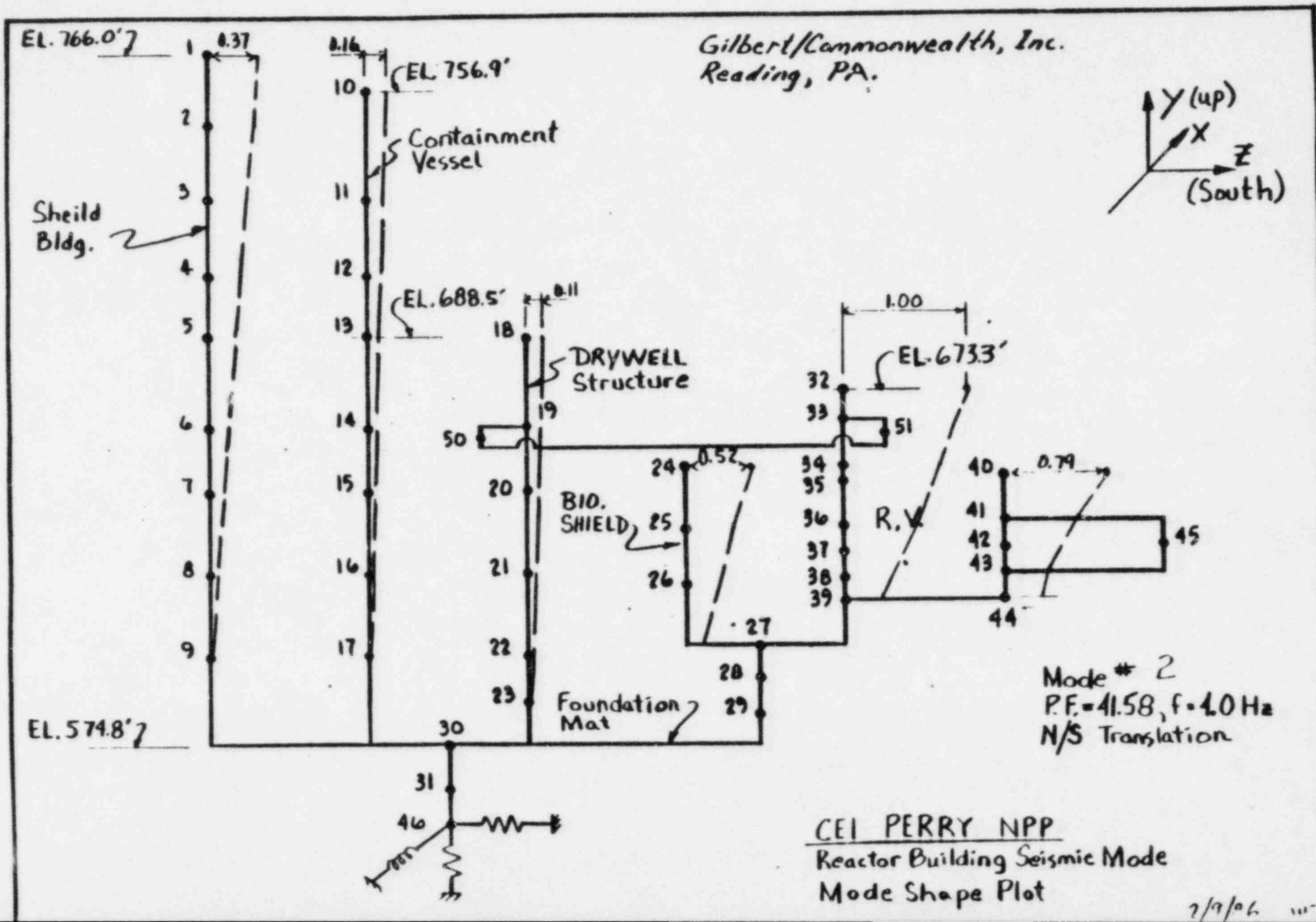
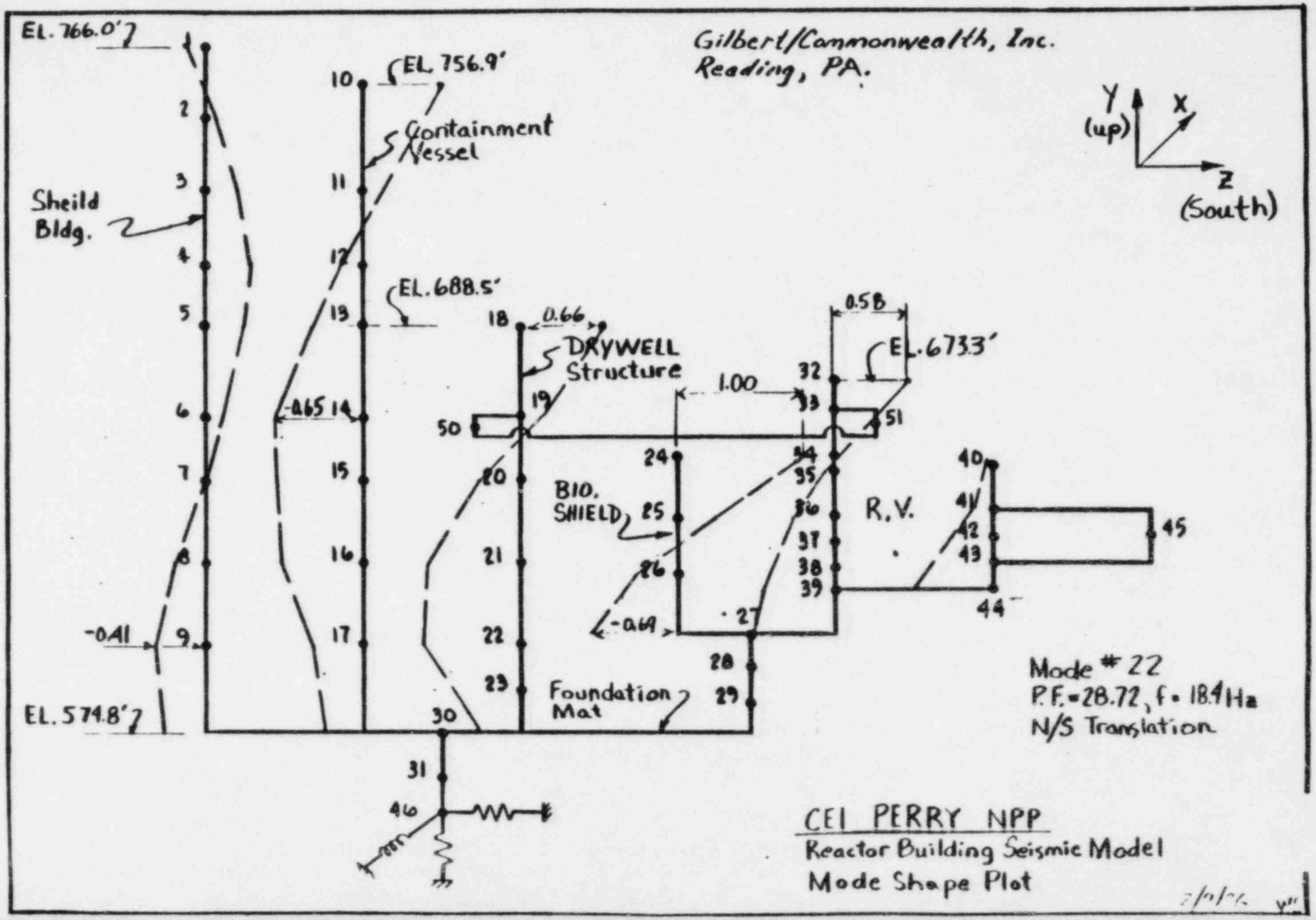


FIGURE 31



Gilbert/Commonwealth, Inc.
Reading, PA.
EL. 766.0'
0.37
0.16
EL. 756.9'
Containment Vessel
Sheild Bldg.
EL. 688.5'
0.11
DRYWELL Structure
1.00
EL. 673.3'
0.52
0.79
BIO. SHIELD
R.V.
Foundation Mat
EL. 574.8'
Y (up)
X
Z (South)
Mode # 2
P.F. = 41.58, f = 1.0 Hz
N/S Translation
CEI PERRY NPP
Reactor Building Seismic Mode
Mode Shape Plot

FIGURE 32



Gilbert/Commonwealth, Inc.
Reading, PA.
EL. 766.0'
EL. 756.9'
Containment Vessel
Sheild Bldg.
EL. 688.5'
0.66
DRYWELL Structure
0.58
EL. 673.3'
1.00
-0.65
BIO. SHIELD
R.V.
-0.69
-0.41
EL. 574.8'
Foundation Mat
Y (up)
X
Z (South)
Mode # 22
P.F. = 28.72, f = 18.4 Hz
N/S Translation
CEI PERRY NPP
Reactor Building Seismic Model
Mode Shape Plot

FIGURE 33

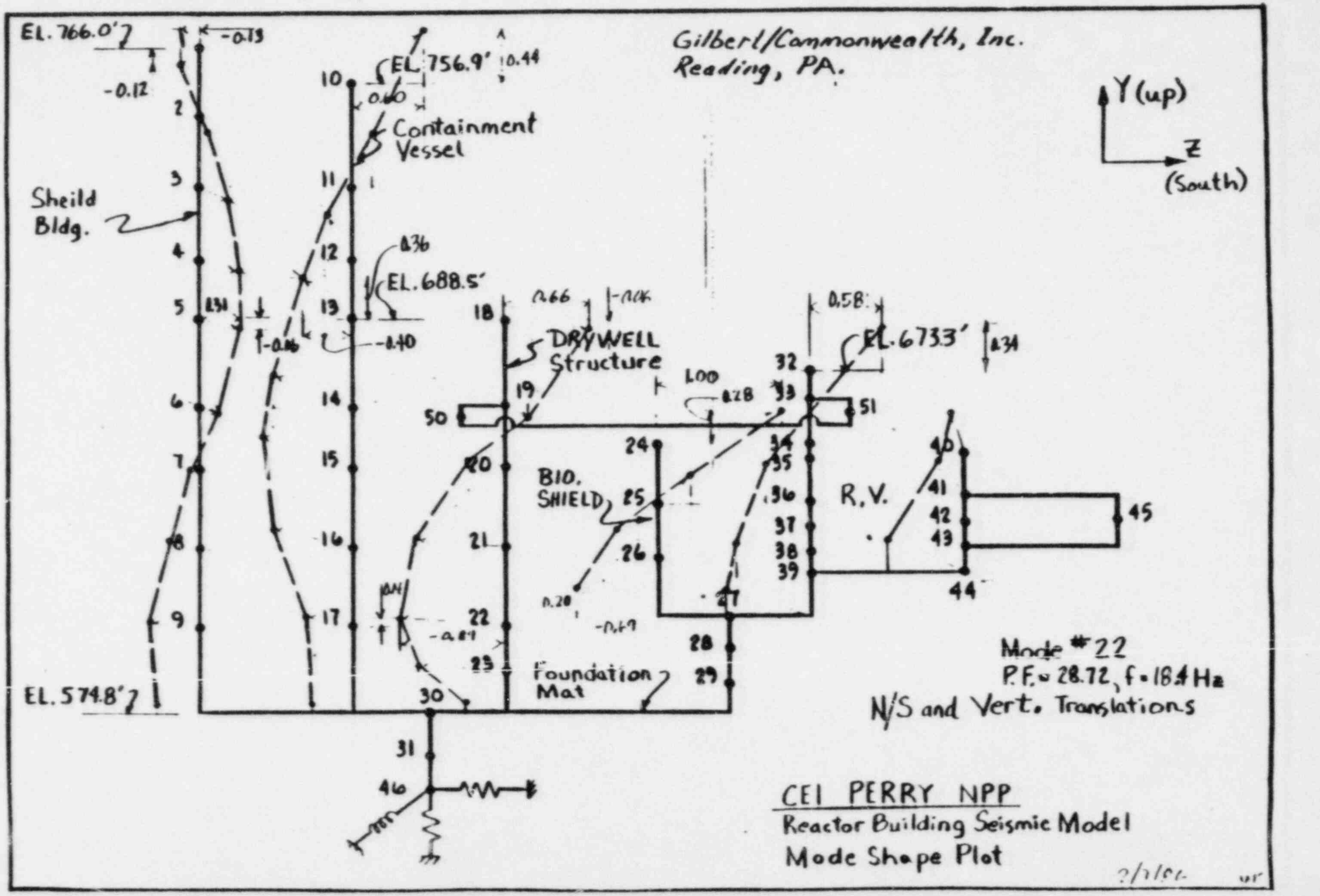

Gilbert/Commonwealth, Inc.
Reading, PA.
Y (up)
Z
(South)
EL. 766.0'
EL. 756.9'
Containment Vessel
Sheild Bldg.
EL. 688.5'
DRYWELL Structure
EL. 673.3'
BIO. SHIELD
R.V.
Foundation Mat
EL. 574.8'
Mode # 22
P.F. = 28.72, f = 18.4 Hz
N/S and Vert. Translations
CEI PERRY NPP
Reactor Building Seismic Model
Mode Shape Plot

FIGURE 34

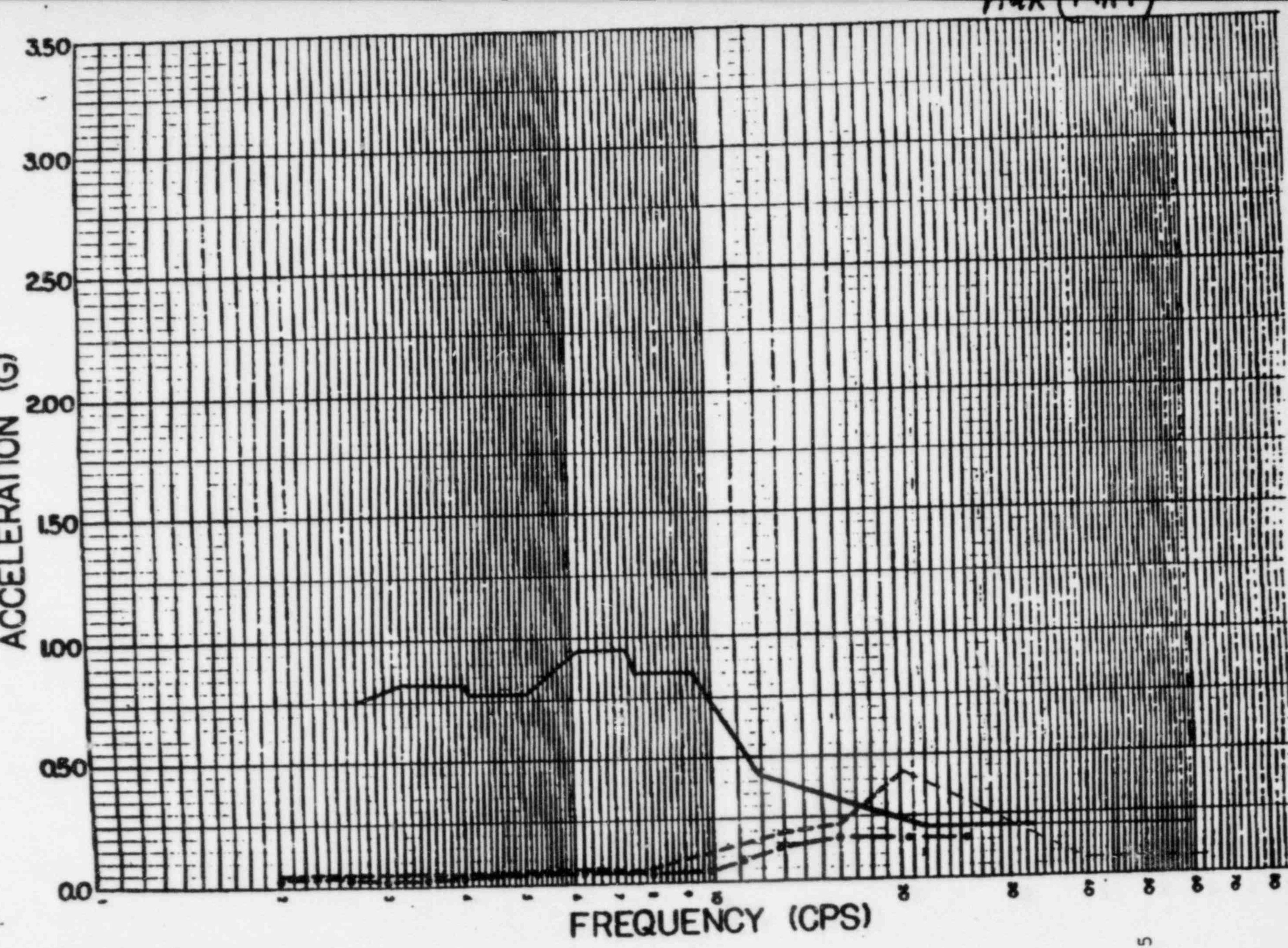


FIGURE 35

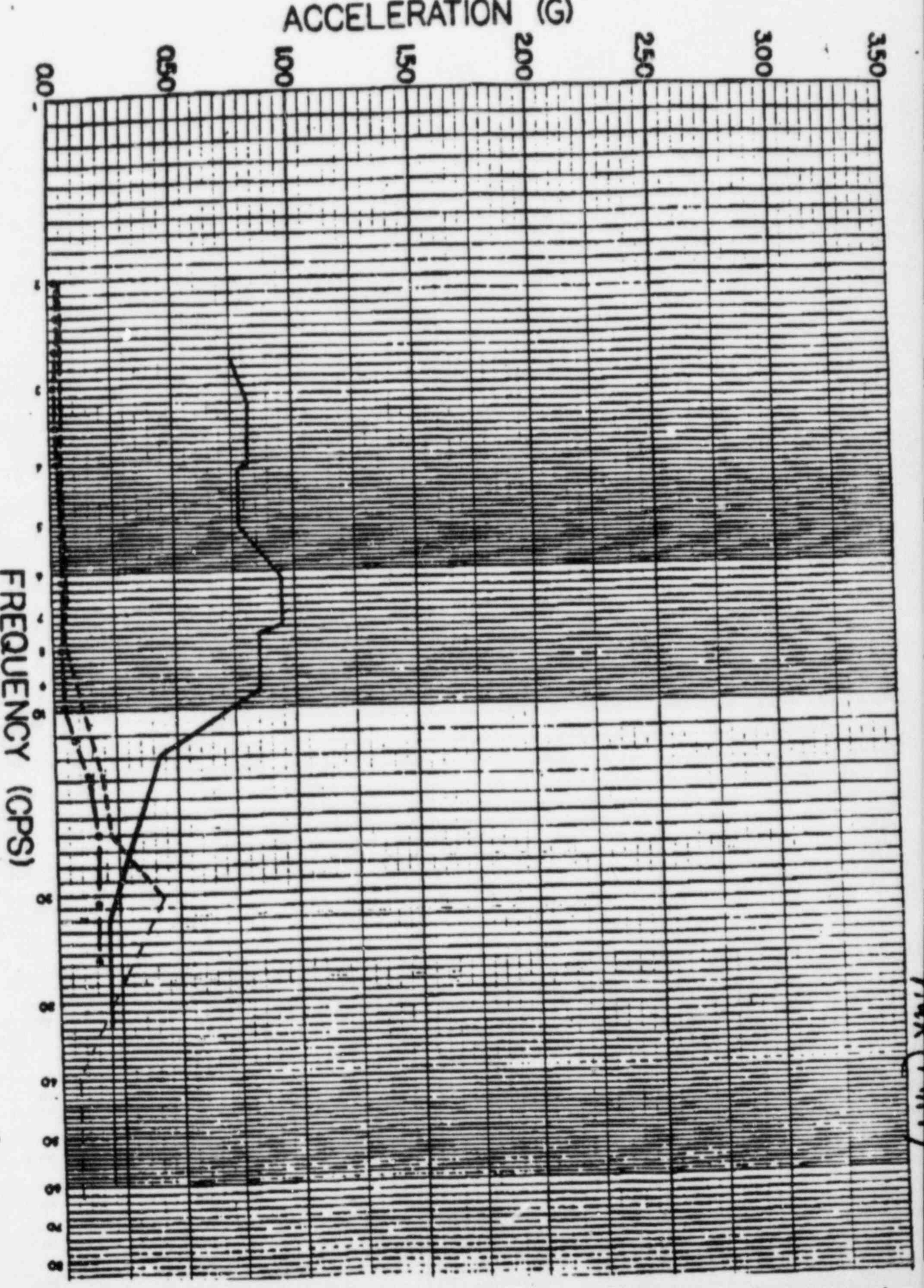


FIGURE 35

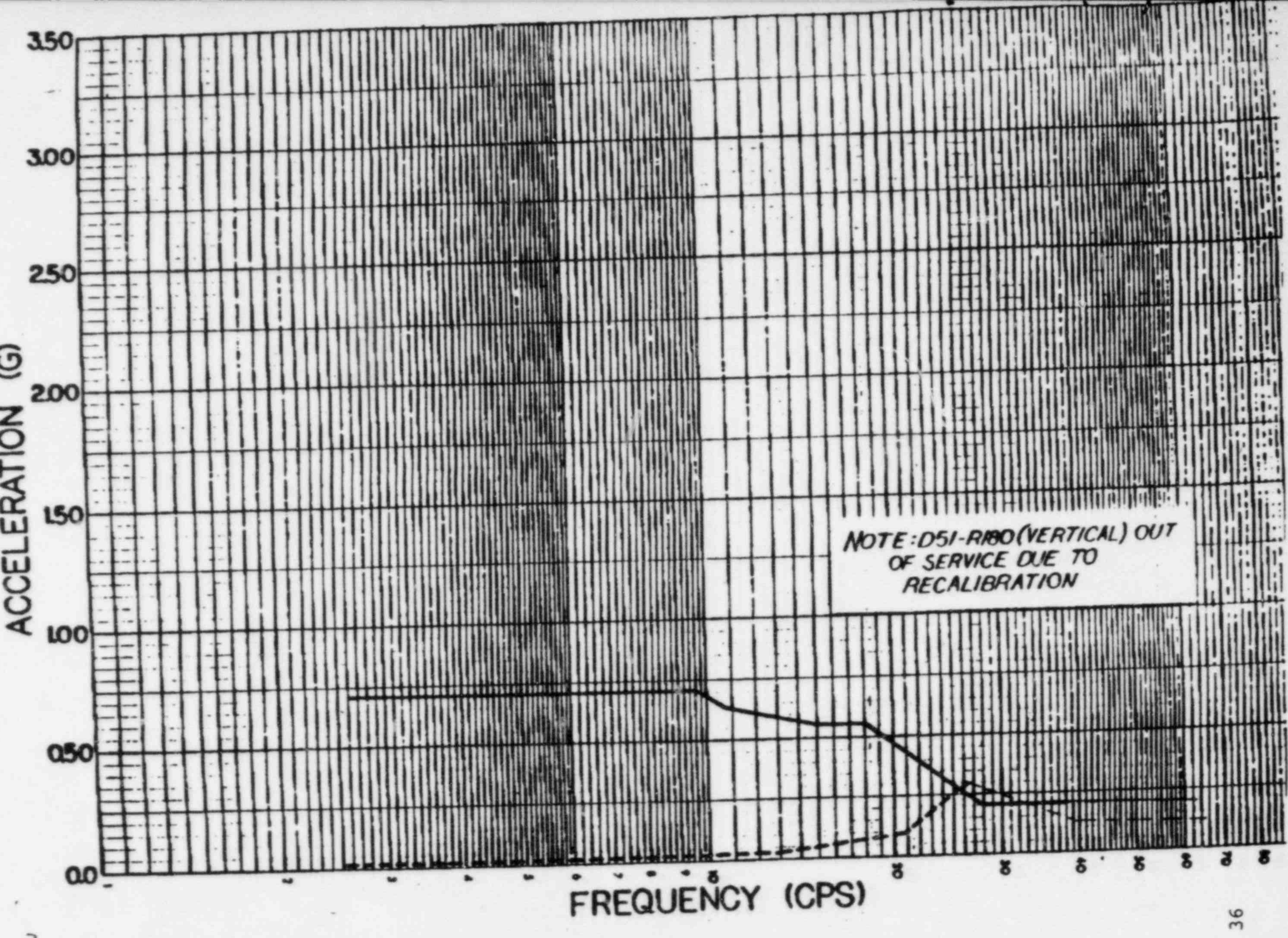

ACCELERATION (G)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.0
FREQUENCY (CPS)
NOTE: D51-R180 (VERTICAL) OUT
OF SERVICE DUE TO
RECALIBRATION

FIGURE 36

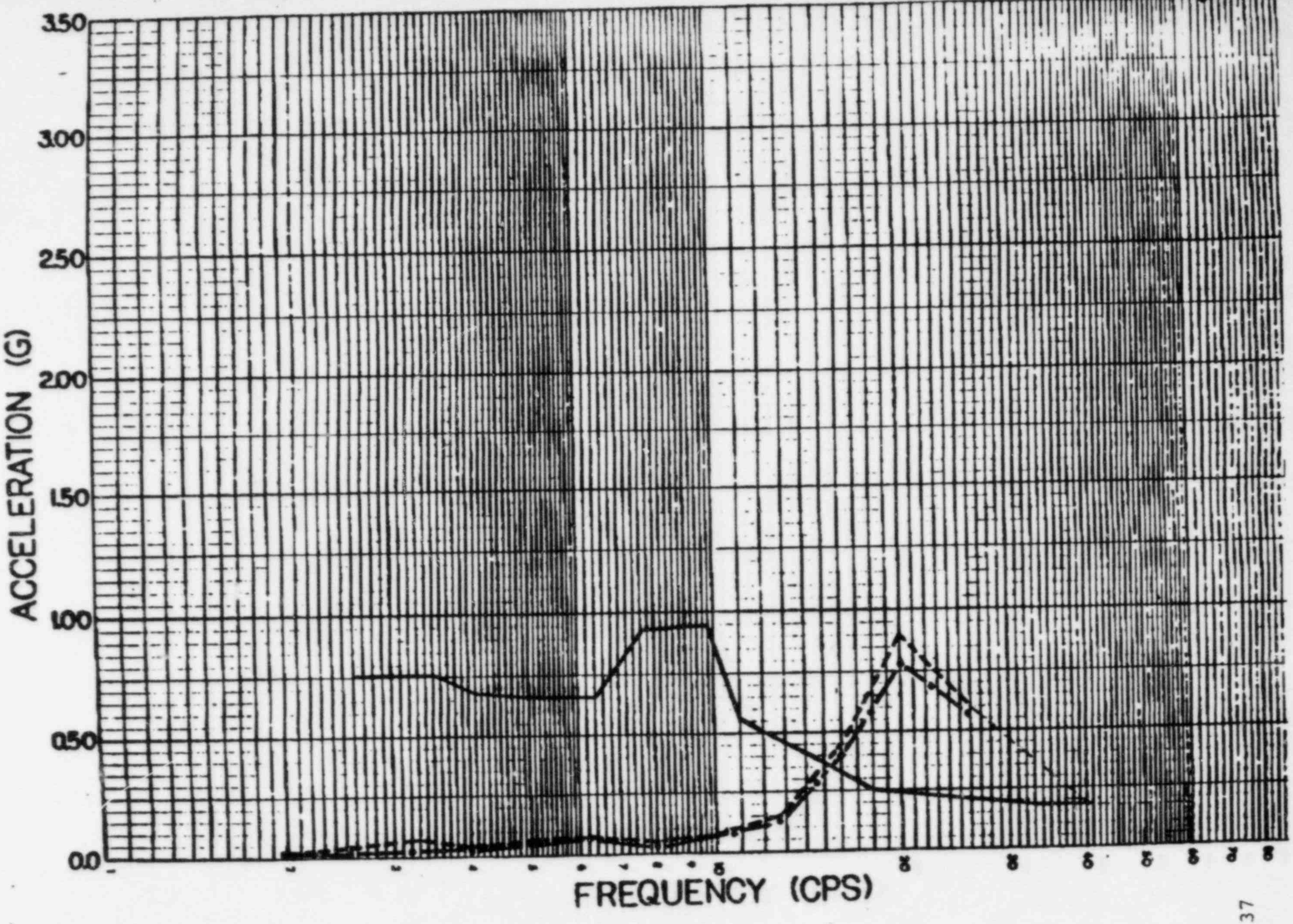
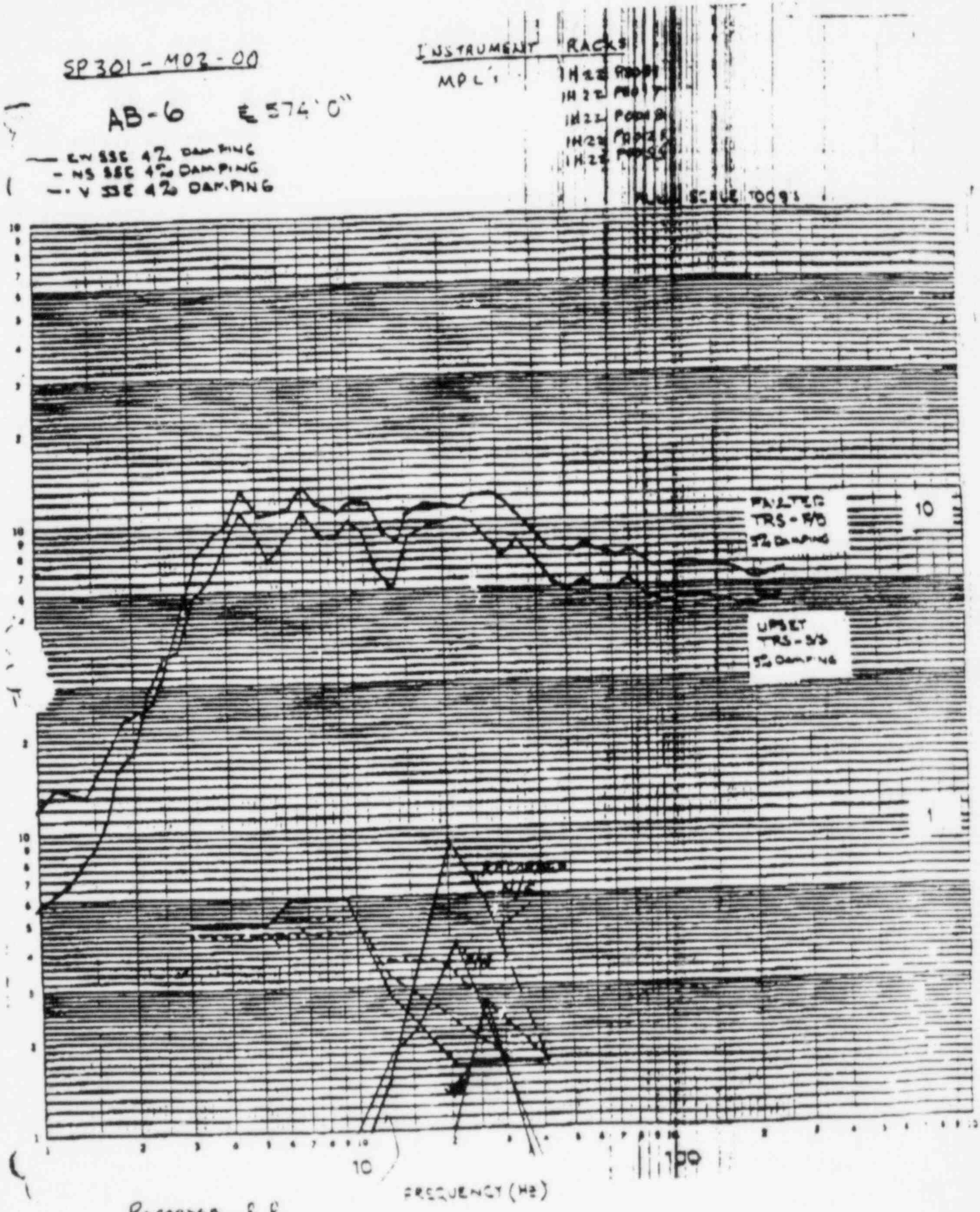
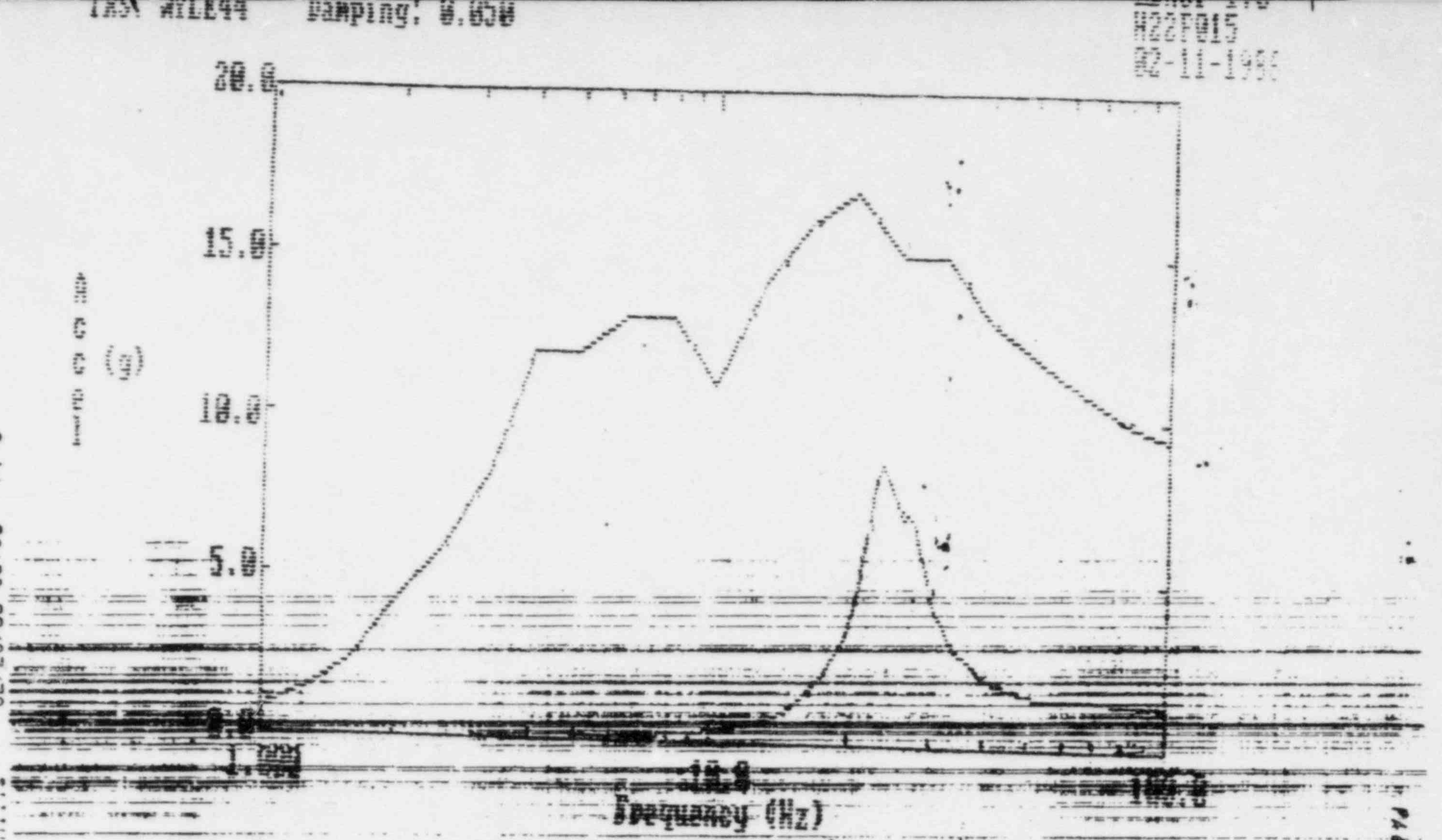


FIGURE 37



RECORDED R.R
FOR AUX. BLG 63A

FIGURE 38



ARS FOR RACK H22 P0021 (FOR TRANSMITTERS)

HORZ. (Z-DIR.) 5% DAMPING

PAGE 40:64-23

FIGURE 39

ATTACHMENT 6