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Equipment Qualification Methodology Research: Tests of Pressure Switches

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EQUIPMENT QUALIFICATION METHODOLOGY RESEARCH: TESTS OF PRESSURE SWITCHES

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for the
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ABSTRACT

Pressure switches, two each of five different models from two manufacturers, were tested in baseline evaluation tests typical of IEEE-323 (1974) suggested profiles as part of the NRC-sponsored Equipment Qualification Methodology Research Test Program (A-1355). The tests incorporated generic seismic and loss-of-coolant accident (LOCA) environments to assess the functional capabilities of unaged equipment. During the baseline evaluation tests, the seismic environment did not affect the functionality of the pressure switches, but the LOCA environment caused numerous functional failures and extensive physical damage in four of five models tested. As a result, eight other switches of the same make and model as those used in the baseline evaluation tests were tested in a follow-up test. In the follow-up test (a discrete-step pressure ramp LOCA environment) erratic functional behavior or complete failure was observed in all the equipment early in the test.

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ACKNOWLEDGMENTS

The efforts of T. W. Gilmore and G. J. Seitz in conducting the tests are gratefully acknowledged. Thanks to J. A. Lewin, J. C. Bartberger, F. V. Thome, and S. M. Luker for assistance provided. Special thanks to D. Vigil and K. Palmer for issuing test plans and quick-look reports, and to Carol Schmidt for issuing the final report.

EXECUTIVE SUMMARY

Pressure switches, two each of five different models from two manufacturers, were tested in baseline evaluation tests typical of IEEE-323 (1974) suggested profiles as part of the NRC-sponsored Equipment Qualification Methodology Research Test Program (A-1355). The choice of pressure switches as an equipment item with which to investigate qualification methodology issues was based on an NRC-staff request resulting from utility submittals of in-plant safety-related equipment. The tests incorporated generic seismic and loss-of-coolant accident (LOCA) environments to assess the functional capabilities of unaged equipment. Eight other switches of the same make and model as those used in the baseline tests were tested in a follow-up test to the baseline tests. The follow-up test was prompted by the severe damage observed in the baseline tests. The follow-up test utilized a modified LOCA-simulation environment to assess the primary failure modes and failure thresholds. The performance of each switch was monitored (at predetermined intervals) by pressurizing the pressure-sensing element to open and close electrical switching elements.

During the baseline evaluation tests, the seismic environment did not affect the functionality of the pressure switches. The LOCA environment, however, caused numerous functional failures and extensive physical damage in four of the five models tested. Failures occurred very early in the test. Post-test inspection showed severe damage to all of the switches that failed. In the follow-up test, a discrete-step pressure ramp LOCA environment, erratic functional behavior or complete failure was observed early in the test (the only model that did not fail during the baseline evaluation tests, although the operating pressure was significantly higher than the 38 psi (262 kPa) factory set point, was not included in the follow-up test).

Failures observed during both the baseline evaluation and follow-up tests can be attributed to deformation and tearing of elastomeric gaskets and seals (which are an integral part of the enclosure) due to increasing pressure, allowing steam and chemical spray to enter the switch housing. The failure is manifested by shorting of the electrical system. In some cases, another failure mode observed simultaneously with the electrical failure was the rupture of pressure sensing boundaries (diaphragms).

The results of the two separate tests show that this equipment (and possibly any other similar equipment incorporating similar housing seal designs) cannot be subjected to external pressures greater than 30 psig (207 kPa) without rupturing the seal. The results also show that some equipment will exhibit anomalous behavior at pressures as low as 10 psig (69 kPa).

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1.0 INTRODUCTION

This report discusses the results of seismic and of loss-of-coolant accident (LOCA) simulation tests made on pressure switches procured from two different equipment manufacturers. The tests are part of the "Equipment Qualification Methodology Research: Tests of Pressure Switches" conducted on behalf of the Office of Nuclear Regulatory Research in response to specific direction from the Equipment Qualification Branch, Office of Nuclear Regulatory Regulation, United States Nuclear Regulatory Commission (NRC). Detailed test plans[1,2] for the tests were submitted to, reviewed, and approved by NRC staff prior to execution of the tests. The objective of the overall program is the assessment of qualification test methodologies through the testing of safety-related equipment, in this case, pressure switches.

Two separate tests were conducted. The unaged equipment baseline evaluation test program was performed to serve as a screening tool to identify unanticipated problem areas and to assess the general functional capabilities of the equipment when subjected to design-basis event environments only. Seismic and LOCA environments were incorporated sequentially on the same switches. The seismic simulation spectrum was a composite of generic required response spectra (RRS). The LOCA simulation generically followed the typical IEEE-323 accident profile.

The follow-up test to the design-basis event test involved a LOCA simulation only. It was performed to help identify primary failure modes as well as failure thresholds. The LOCA environment was simulated by using saturated steam in a step-function profile for the temperature and pressure.

Quick look reports[3,4] outlining the results of the tests were issued after each test.

2.0 EQUIPMENT SELECTION

Pressure switches were selected as generic equipment candidates for tests by the Equipment Qualification Branch, Office of Nuclear Regulatory Regulation,[5] based on the wide use of this equipment throughout the nuclear power industry. The wide use was illustrated by an analysis of utility response data compiled by the Franklin Research Center for the NRC.[6] The data identify a total of 69 nuclear power stations, 589 switch installations, and 12 pressure switch manufacturers. Of this total, Manufacturer 1 accounts for 182 switches distributed throughout 21 stations. Manufacturer 2 accounts for 173 switches in 20 stations. The data used to select specific equipment and specific models from Manufacturers 1 and 2[7] as representative of that used throughout the industry are shown as an attachment, Appendix A, to this report.

Two models from each manufacturer (Figure 1) were selected. The selected equipment, as well as all the related equipment in the NRC/Franklin data, has not, according to the manufacturers, been qualified to IEEE-323-74 requirements. One additional model (Figure 2) not included in the data but which was undergoing qualification testing to IEEE-323-74 at an independent test laboratory was added to these tests to supplement the program and to serve as a control unit.

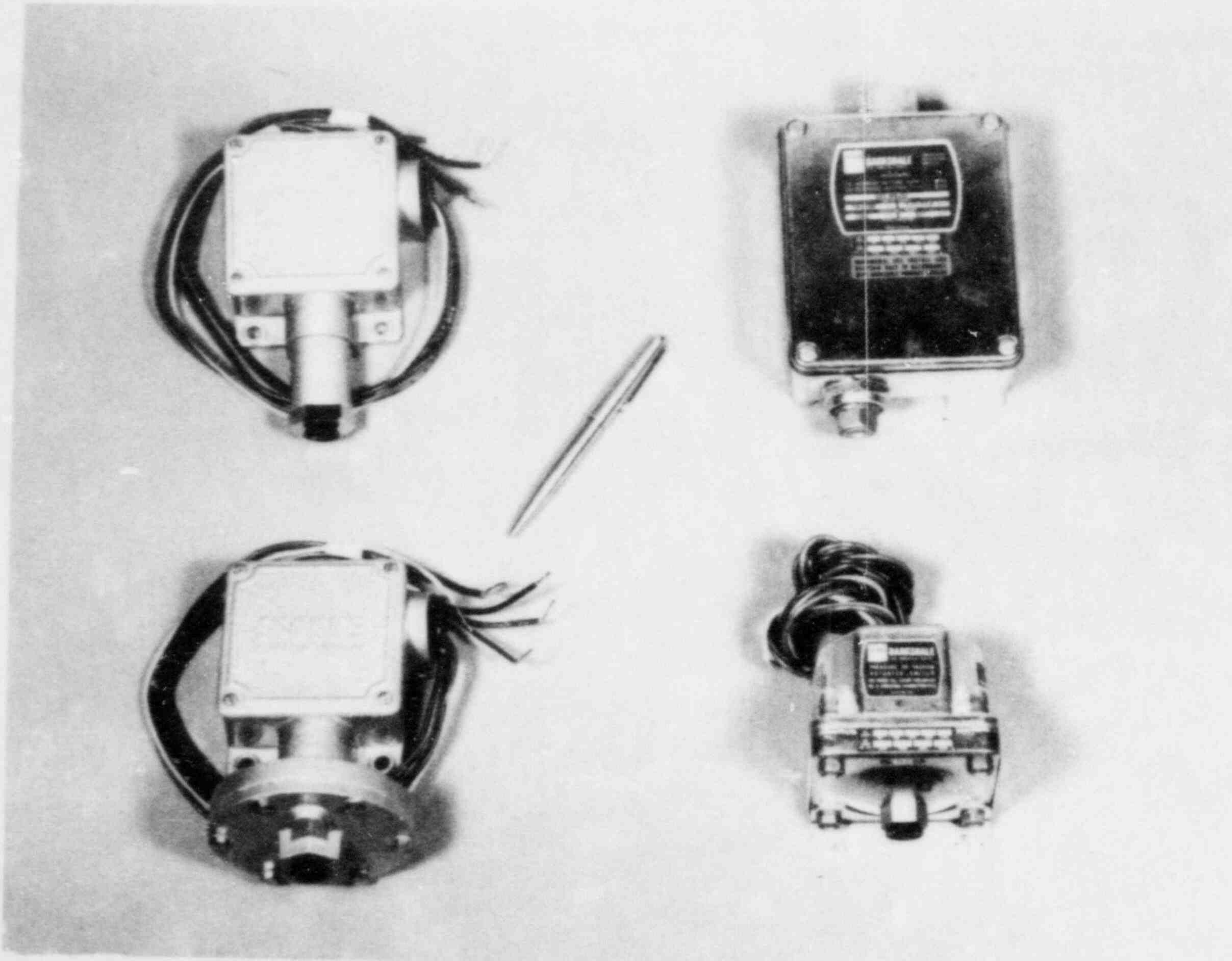

Figure 1. Equipment Photograph I - Pressure Switches 1(a,b) and 2(b,c)

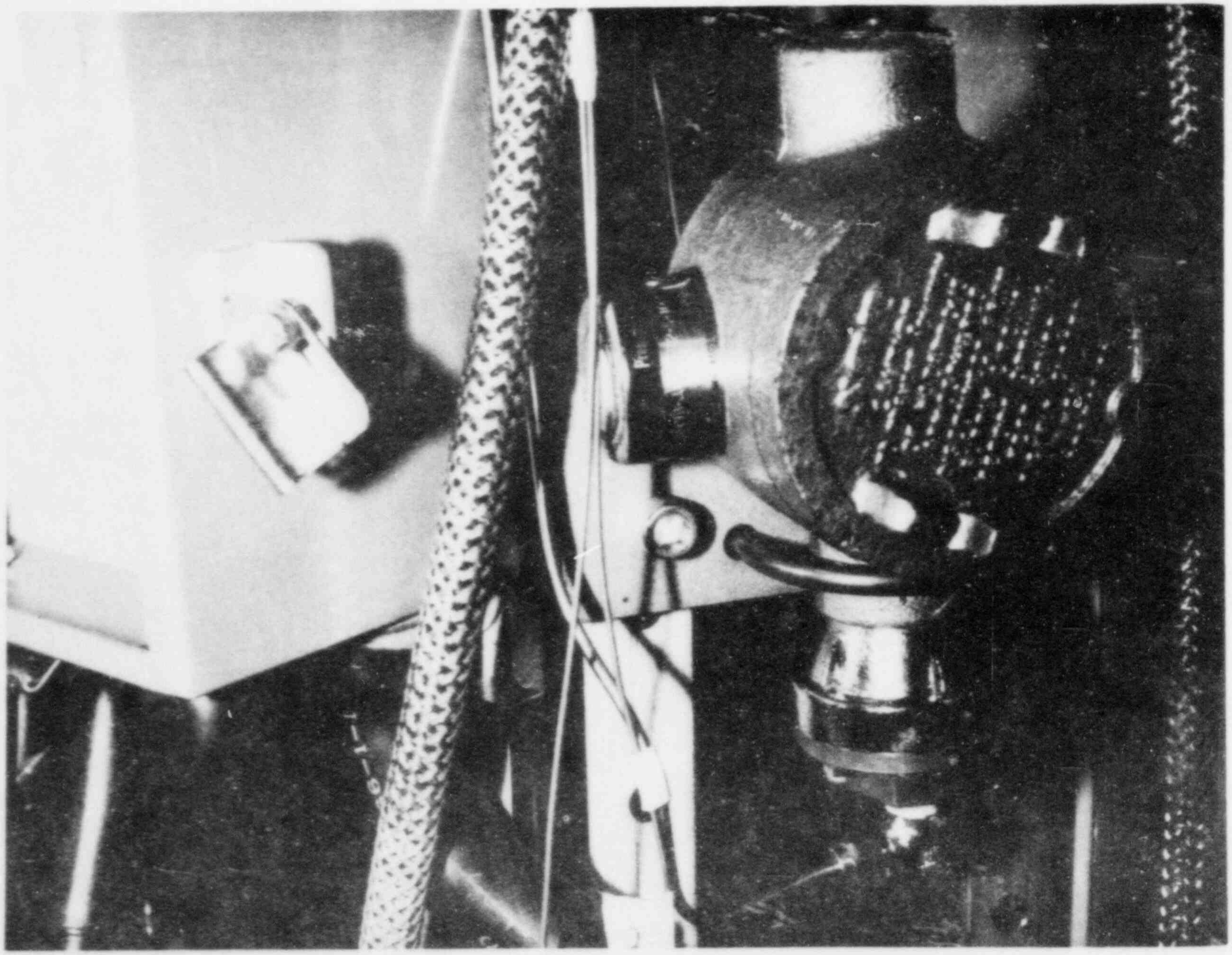

Figure 2. Equipment Photograph II - Pressure Switch 2(a)

3.0 TEST APPARATUS

3.1 Functional

The functional test apparatus is shown in Figure 3. It consists of a 0-10 Vdc Trygon power supply, Model EAL101, 0-1 amps, which supplies power to the snap action switches in the pressure switch. A nitrogen gas pressure source is used to activate the pressure sensing devices and Heise® gages are used to monitor the pressure. Resistance of the pressure switch contacts was measured with a Fluke® digital multimeter, Model 8100A.

3.2 Seismic

The seismic test machine is a bi-axial shake table with a 6- by 6-ft (1.8- by 1.8-m) mounting surface that can be simultaneously excited by independent random motion along both the vertical and horizontal axes. The maximum deadweight payload capacity is 6000 lb (2722 kg). Drive mechanisms are servo-controlled electrohydraulic with the following capabilities:

	Horizontal	Vertical
Frequency Range	0-2500 Hz	0-250 Hz
Force Capacity	10,000 lb (4536 kg)	20,000 lb (9072 kg)
Maximum Stroke	8.0 in. (20.3 cm)	7.0 in. (17.8 cm)
Maximum Velocity	90 in./s (2.29 m/s)	22 in./s (0.56 m/s)
Maximum Acceleration*	10 g	10 g

*At zero payload.

A complete detailed description of the seismic test apparatus and associated instrumentation is found in Appendix B to this report.

3.3 Loss-of-Coolant Accident (LOCA)

LOCA simulation tests were conducted in a stainless steel cylindrical chamber 21 in. (0.5 m) inside diameter with an upper section that is 24 in. (0.61 m) long and a lower section 67 in. (1.70 m) long (Figure 4). The chamber has a volume of 16 ft^3 (0.45 m^3). Nine penetrations, which serve to allow access into and out of the test chamber (steam, chemical spray, power and monitoring cables, etc.), are located in the upper section. Temperatures were monitored by thermocouples and pressure by pressure transducers. Data was collected by an Acurex Autodata Nine, Model A901 and by Hewlett-Packard Strip Chart Recorders (single-pen model 7155B and dual-pen model 7132A).

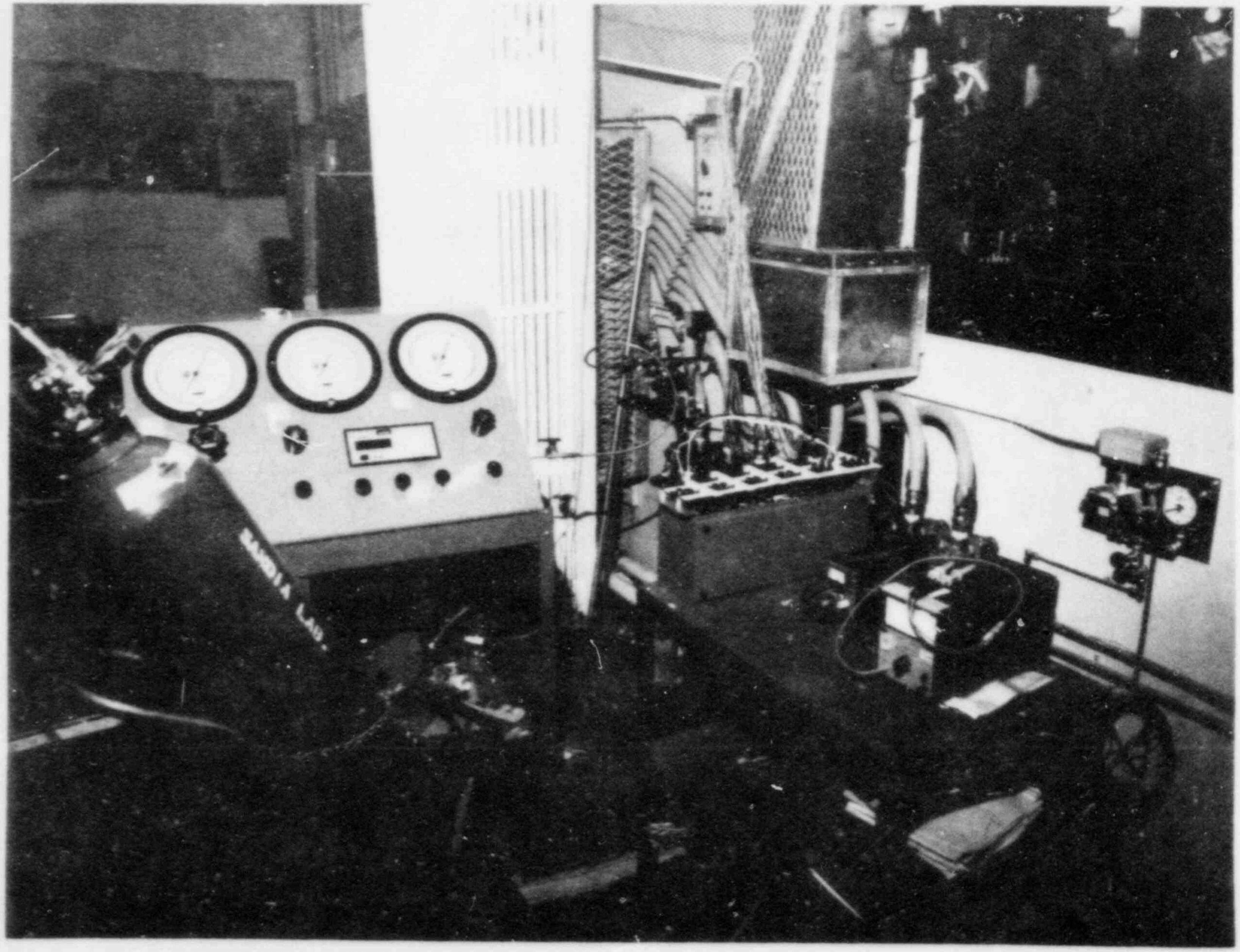

Figure 3. Test Equipment Photograph III - Functional Test Apparatus

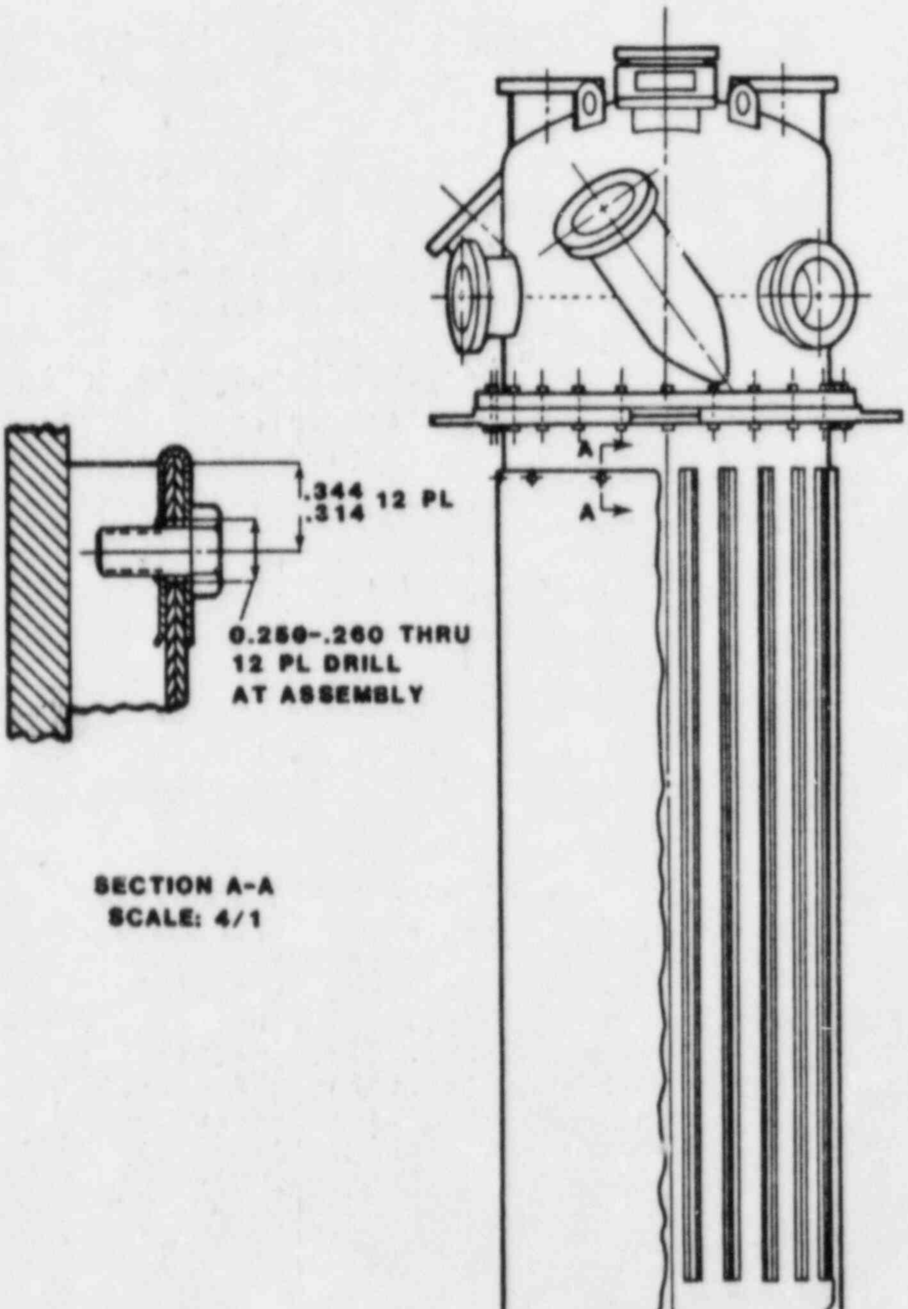

Figure 4. Assembly, Environmental Chamber

4.0 TEST SPECIMENS

4.1 Baseline Evaluation Tests

Test specimens for the "Baseline Evaluation Tests - Unaged DBE Test" consisted of two each of two models from Manufacturer 1 and two each of three models from Manufacturer 2.

Manufacturer 1 switches use a housed bourdon tube, 1(a), or a housed diaphragm actuating system, 1(b). Manufacturer 2 switches all use a diaphragm-actuated sealed piston. The switches are listed in Table 1. All the switches are basically similar in size and weight, approximately 4 by 7 by 2 in. (10 by 18 by 5 cm) and a weight of approximately 2 to 3 lb (0.9 to 1.4 kg). Switch 2(a) is the new model, mentioned earlier, currently undergoing qualification to IEEE-323-74 requirements. It had not yet been marketed.

4.2 Follow-Up Test

The test specimens used in the follow-up test were the same make and model as those used for the baseline evaluation test except for 2(a), which was not included in the follow-up test.

4.3 Switch Specifications

Switch specifications are listed in Table 1.

4.4 Operating Parameters

Pressure switches operate on an open-close electrical contact at the predetermined pressure set point within the adjustable range (Table 1). The actuating system (bourdon tube, piston, etc.) opens or closes a microswitch when the pressure, either increasing or decreasing, reaches the set point. The opening or closing of the microswitch activates a signal (light, alarm, horn). The switches operate on an input-output voltage of 10 Vdc. Gaseous nitrogen was used as the pressurizing medium.

Table 1

Switch Specifications

Manufacturer	Model	Adjustable Range psi	Adjustable Range (kPa)	Maximum "Proof" Pressure psi	Maximum "Proof" Pressure (kPa)	Factory Set Point psi	Factory Set Point (kPa)
1	a	50-1200	(345-8274)	1800	(12410)	600	(4137)
1	b	1.5-150	(10-1034)	300	(2068)	75	(517)
2	a	1-75	(6.9-517)	1000	(6895)	38	(262)
2	b	0.2-6	(1.4-41)	400	(2758)	3.1	(21.4)
2	c	12-240	(83-1655)	2500	(17237)	125	(862)

5.0 TEST SETUP

5.1 Baseline Evaluation Tests

5.1.1 Seismic

The pressure switches were mounted onto 8- by 5- by 0.5-in. (20- by 12.7- by 1.3-cm) stainless steel plates that were subsequently bolted onto mounting fixtures capable of accommodating a total of six pressure switches (Figures 5, 6). The seismic test was conducted by the Southwest Research Institute (SWRI). A complete detailed description of the seismic test setup is included in the SWRI report, included as Appendix B.

5.1.2 LOCA Simulation

The pressure switches remained attached to the same mounting fixtures used in the seismic test for assembly in the LOCA test configuration. This configuration required auxiliary wiring and pressure source tubing for remote operation. The wiring provided with the pressure switches was terminated at terminal strips inside an electrical enclosure (NEMA-4 rated), shown in Figure 7. Teflon®-insulated auxiliary wiring was used to exit the environmental test chamber from the terminal strips. All the wiring was protected with a rubber-coated, flexible conduit (Anaconda Flexible Liquid-Tight Wiring Conduit, Special Seal-Tight®, Type NWC). In addition, heat-shrink tubing, Raychem WCSF-N, was installed over all the ends of the conduit to further protect the interfaces (Figure 8). Wiring was terminated at the terminal strips inside the junction box where it interfaced with the auxiliary wiring that was used to exit the environmental test chamber (Figure 9). The terminal strips were encapsulated in the interconnecting boxes to isolate the connections from the test environment and to seal the entrance from moisture paths through the wiring into the equipment housing. A special beta-eucryptite-filled epoxy encapsulant was used to minimize stress-cracking due to variations in expansion coefficients in dissimilar materials (Figures 10, 11). The complete test configuration was mounted onto the environmental test chamber head (Figure 12) and readied for the LOCA test.

5.2 Follow-Up Test

5.2.1 LOCA

The test assembly for the follow-up test was identical to that used for the baseline evaluation test described in Section 5.1.2.

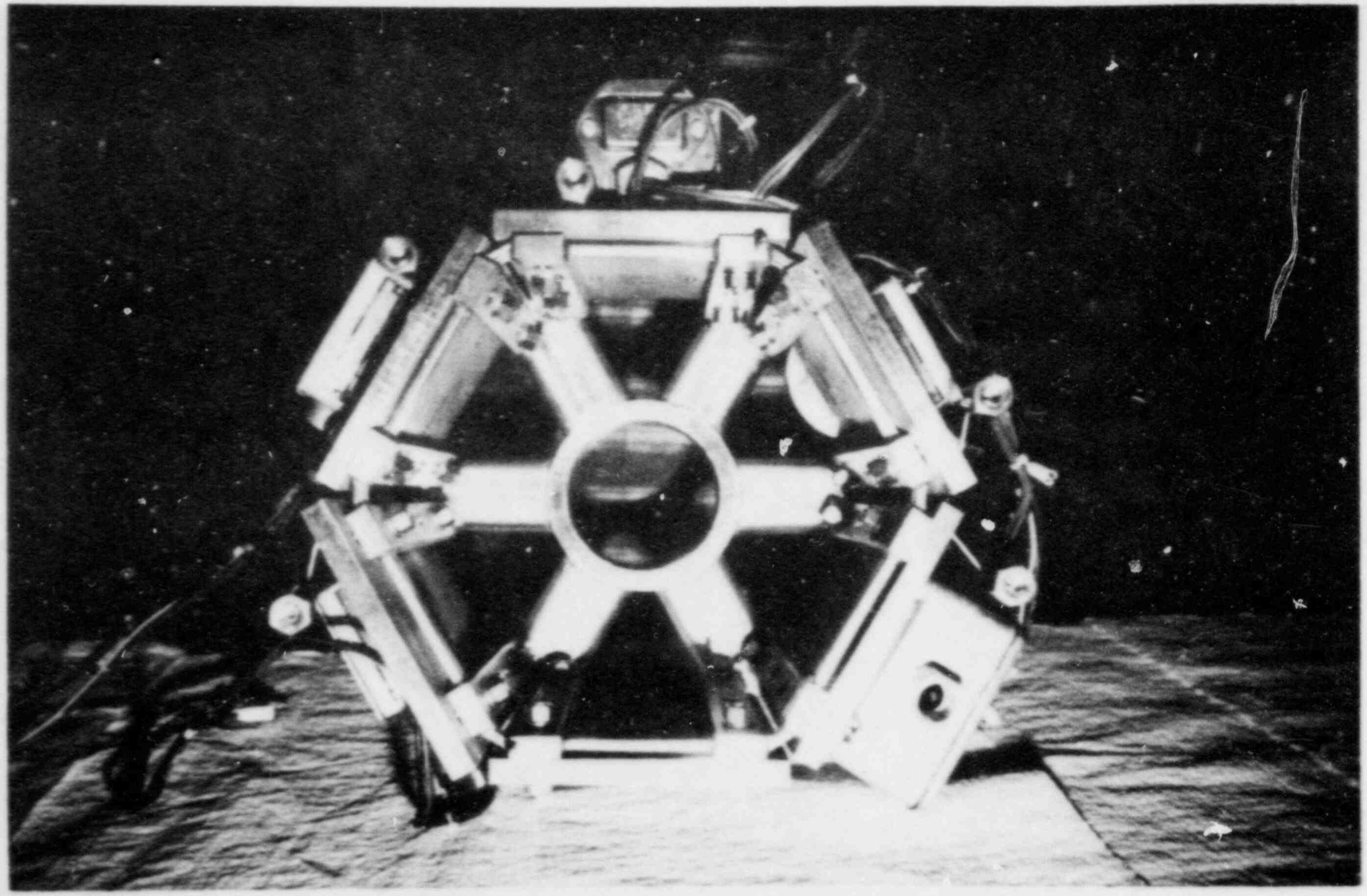

Figure 5. Preseismic Photograph I - Switch Mounting Fixture

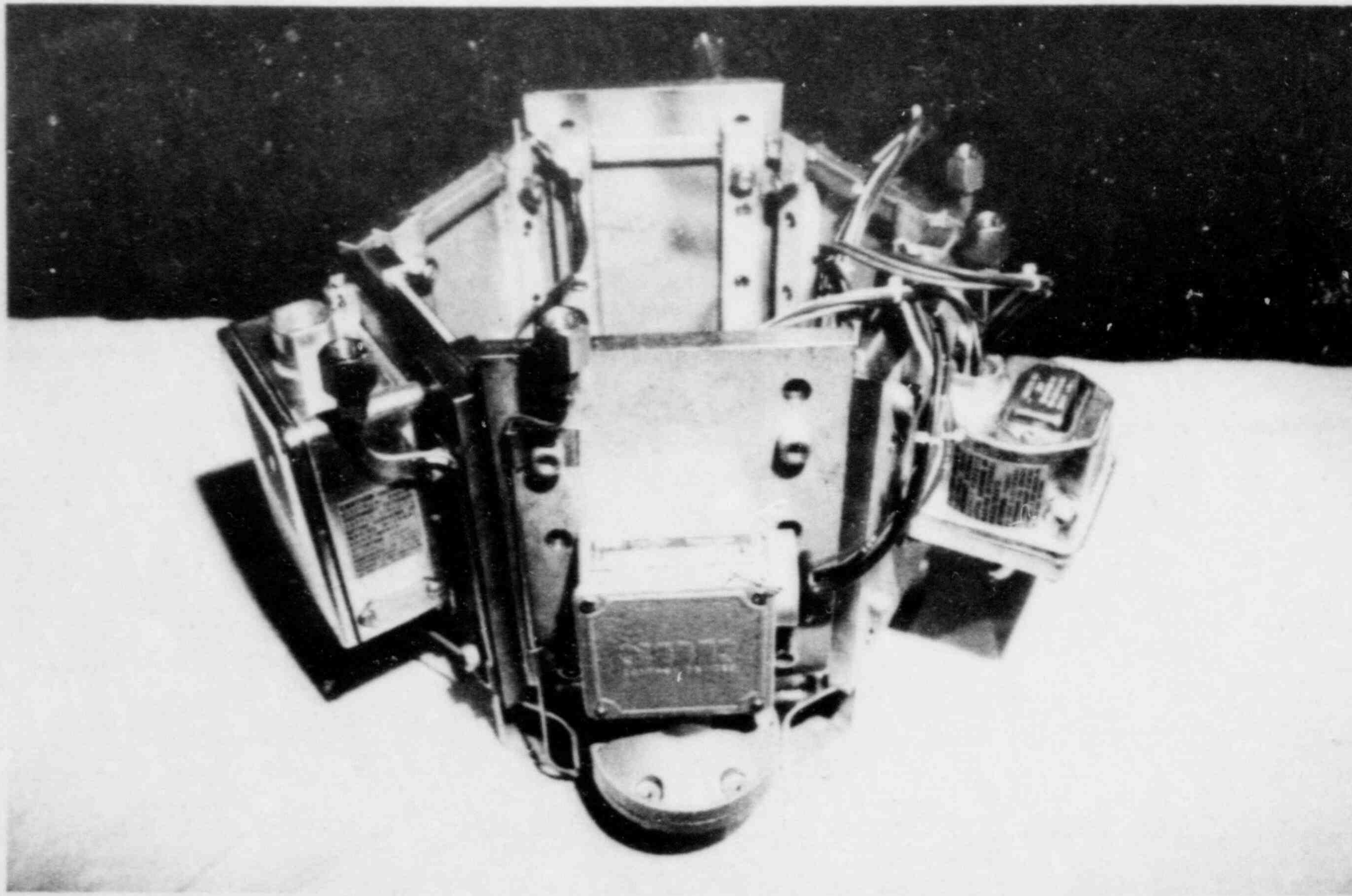

Figure 6. Preseismic Photograph II - Seismic Assembly

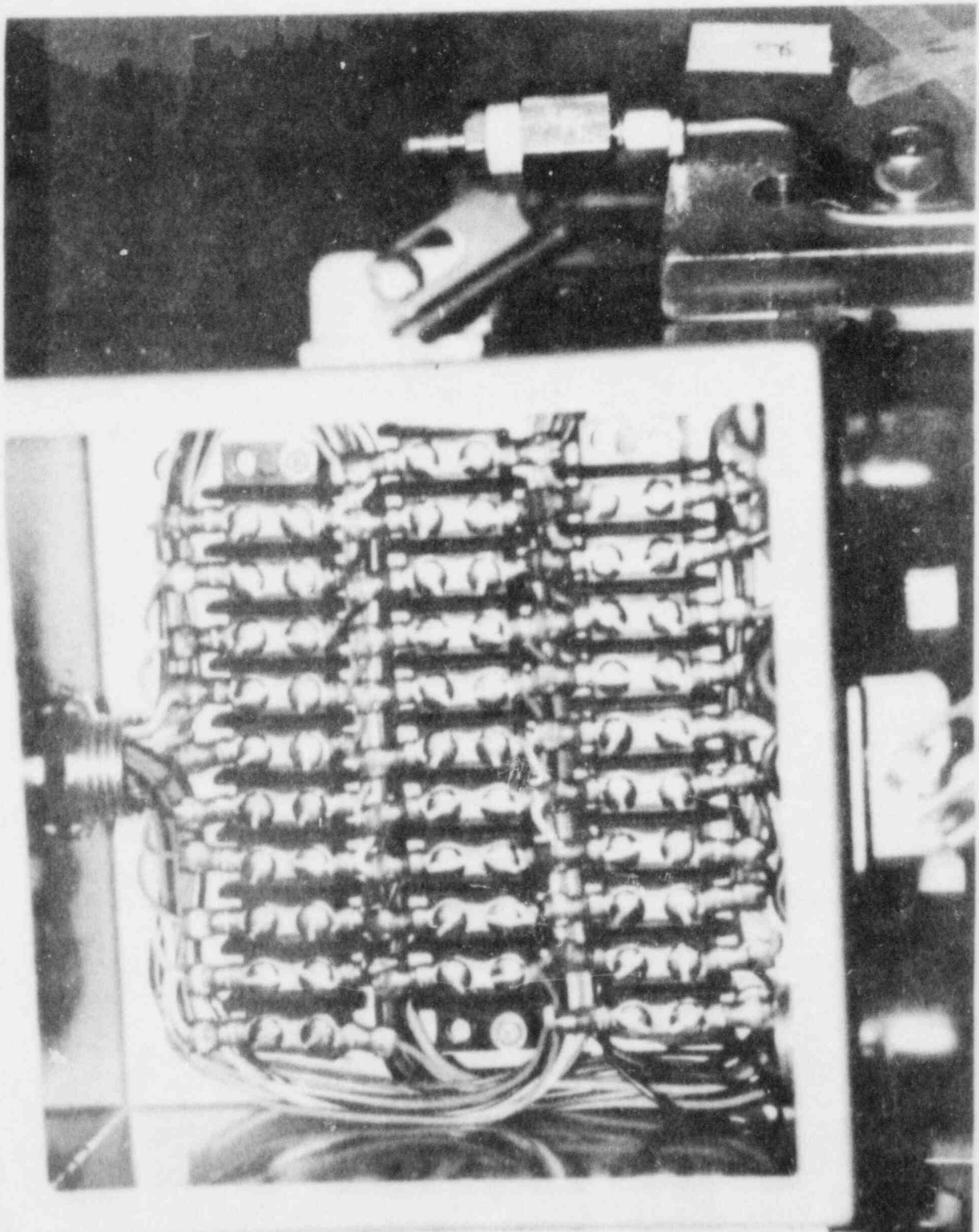

Figure 7. Assembly Photograph I - Interconnecting Box before Encapsulation

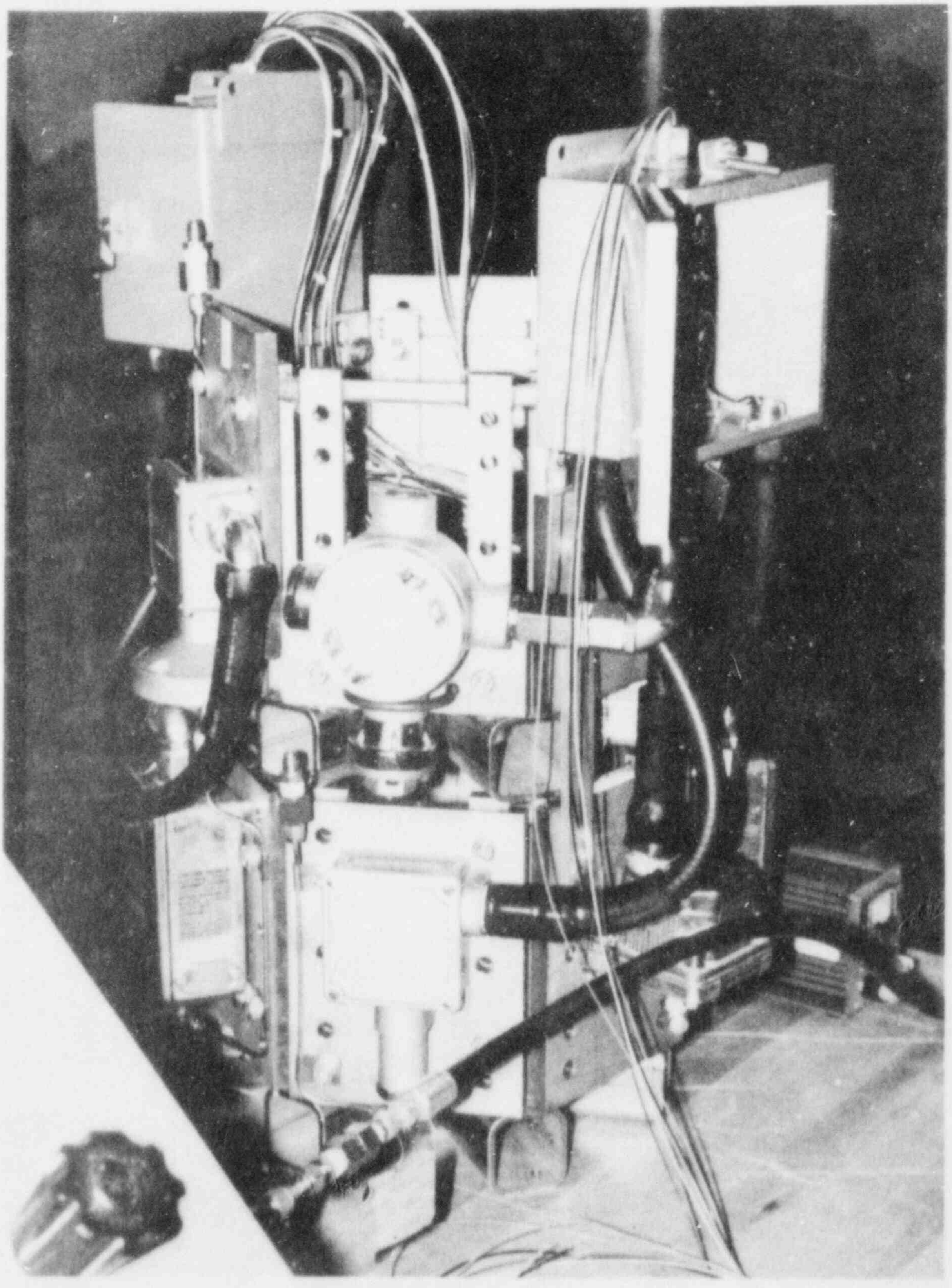

Figure 8. Assembly Photograph III - Flexible Tubing and Heat-Shrink Tubing Assemblies

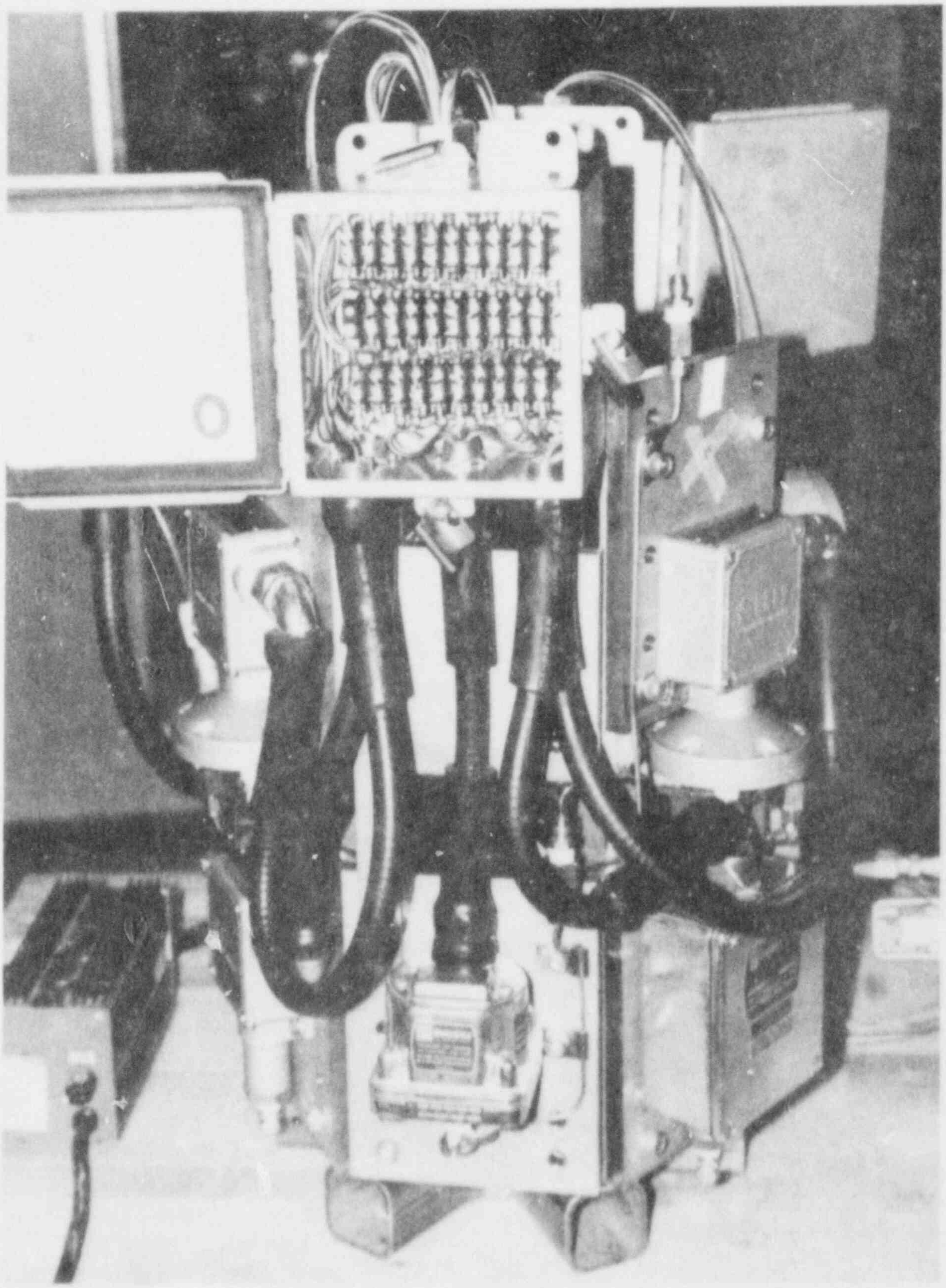

Figure 9. Assembly Photograph II - Auxiliary Wiring

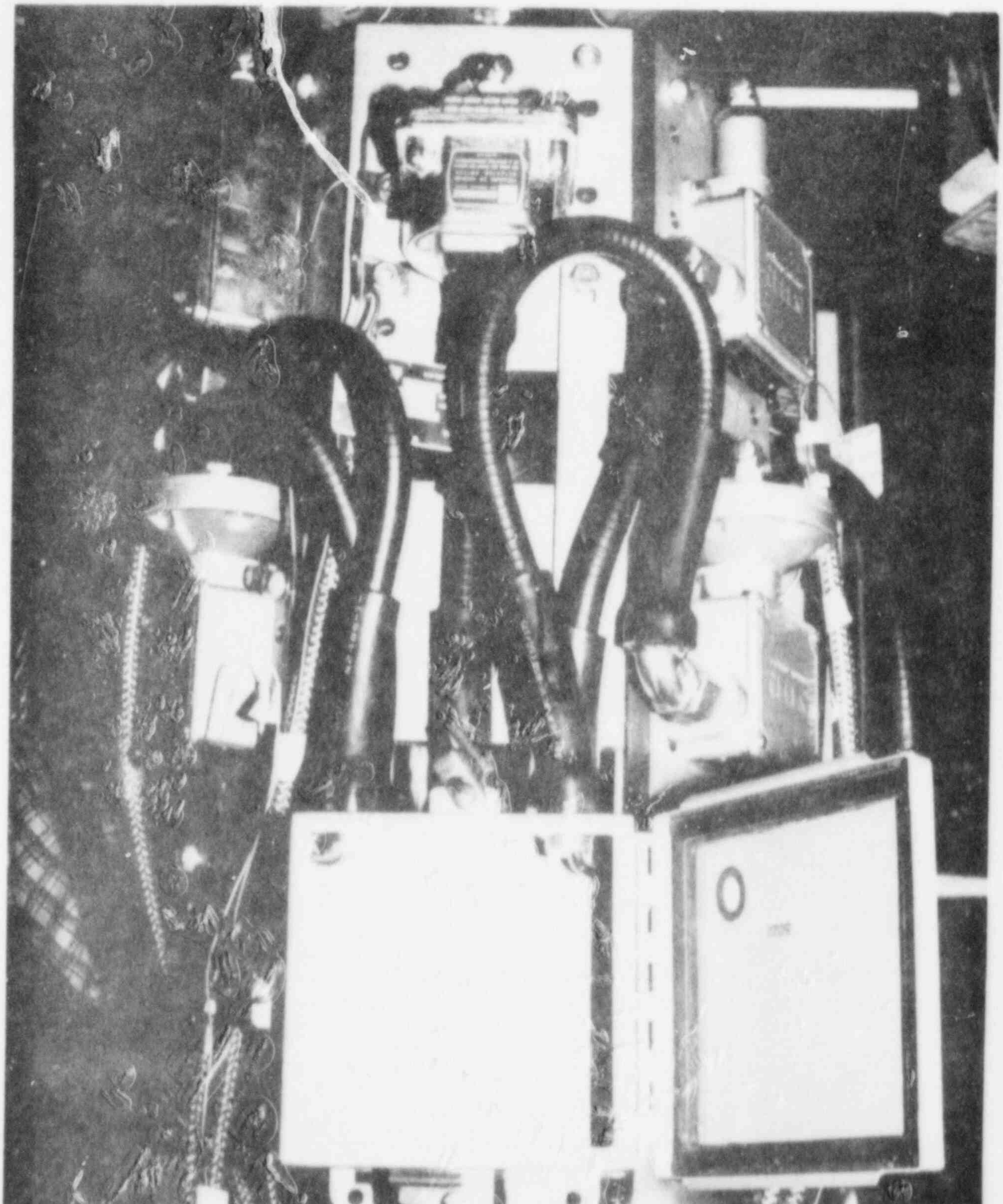

Figure 10. Assembly Photograph IV - Encapsulated Interconnecting Box

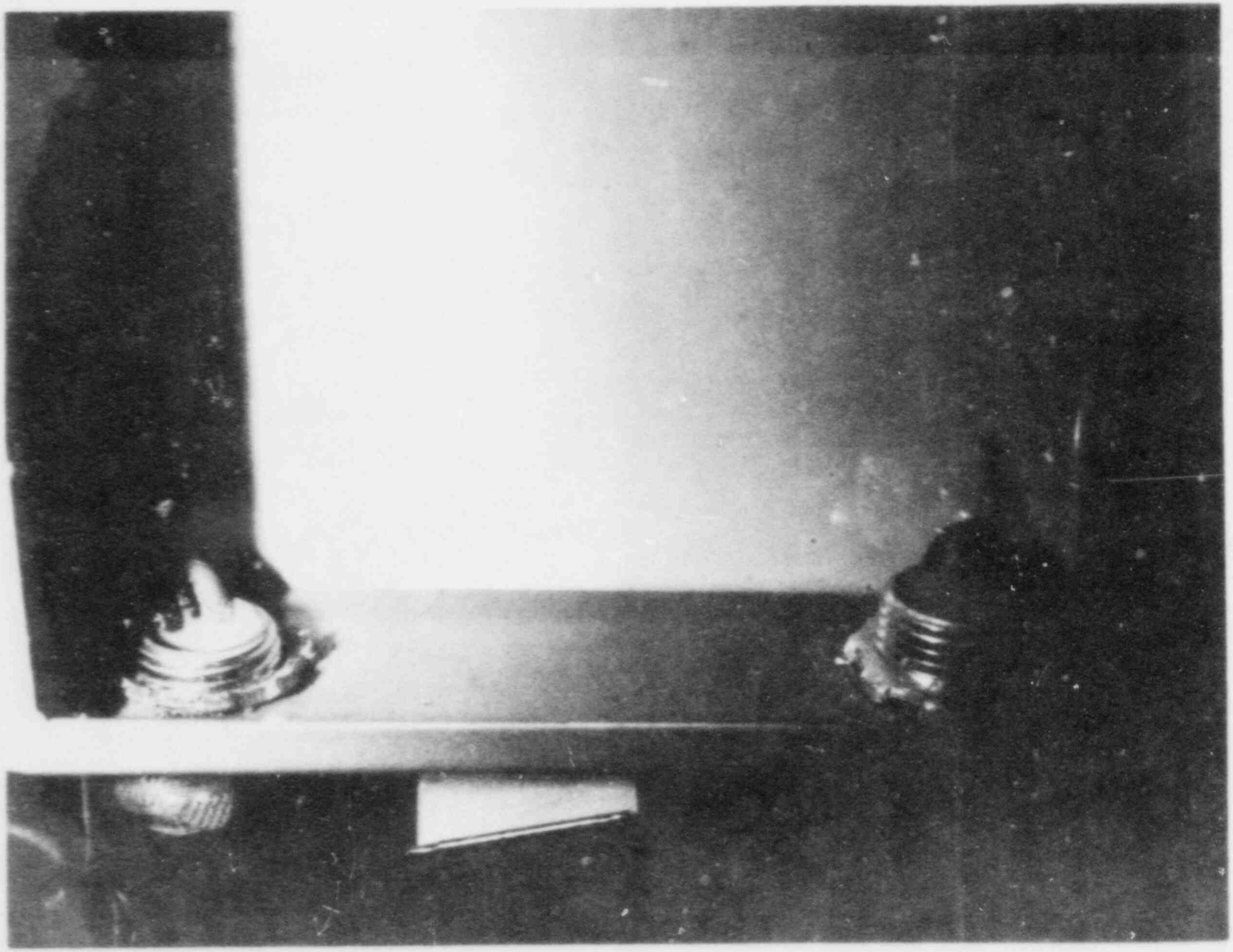

Figure 11. Assembly Photograph V - Encapsulated Wire Inlet

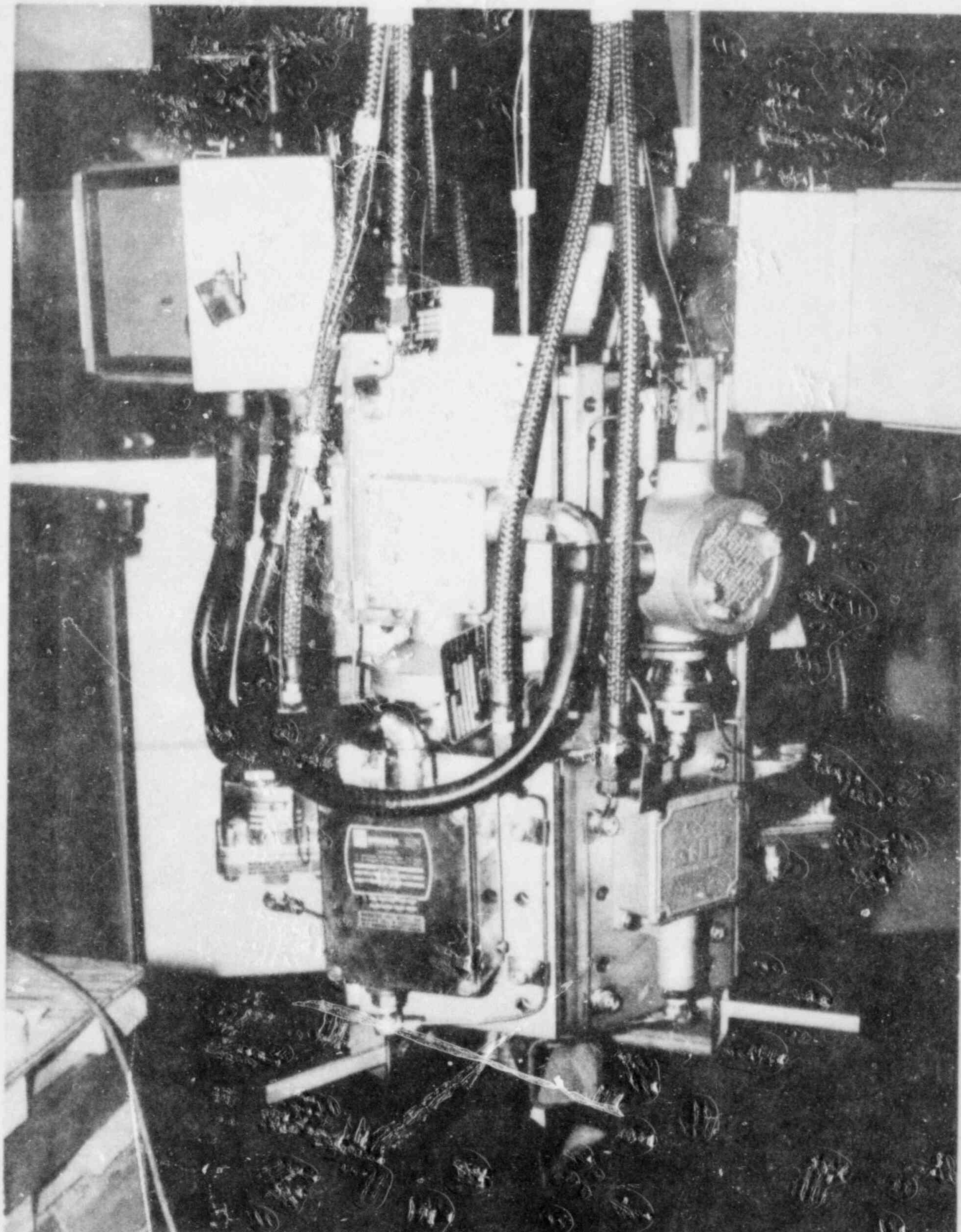

Figure 12. Assembly Photograph VI - Pressure Switch Test Assembly

6.0 EXPERIMENTAL

6.1 Seismic and LOCA Evaluation Test

Baseline evaluation tests were performed in the following sequence:

- Baseline functional
- Seismic exposure
- Functional test
- Accident exposure (LOCA and radiation)
- Functional test
- Post-test inspection

6.1.1 Baseline Functional Tests

Baseline functional tests were performed on all the switches in the as-received condition. Tests included setpoint pressure and contact resistance determinations plus a pressure leak check at 80% of the maximum limit of the applicable adjustable pressure range. The baseline data is listed in Table 2.

6.1.2 Seismic and Functional Tests

The switches were subsequently mounted onto test fixtures, five per fixture (as previously shown in Figure 5), and transported to SWRI for seismic simulation exposure. The seismic tests are described in detail in Appendix B. Following the seismic tests, functional tests were performed on all the equipment. The post-seismic data are compared with the baseline data in Table 3.

A visual inspection for external damage following seismic simulation exposure also was made.

6.1.3 Accident Exposure and Functional Tests

The equipment was returned to Sandia National Laboratories where it was assembled into the LOCA test configuration (Section 5.1.2), attached to the environmental test chamber head (Figure 12), and readied for the LOCA test. Two switches of each model were tested.

Figures 13 and 14 show the environmental test chamber in place prior to the LOCA simulation test. Figure 15 describes the desired accident simulation profile. The peak environment conditions obtained were:

Pressure = 117 psig (807 kPa) in 26 s
Temperature = 351°F (177°C)
Radiation = 0.65 Mrad/h (dose rate)
Chemical Spray = Boric acid/sodium thiosulfate/sodium hydroxide (adjusted to pH = 10)

Table 2

Pre-Test Functional Test Data

Mfg. (Model) Unit Number	Mfg. Set Point psig	(kPa)	Baseline Value psig	(kPa)	Adjustable Range psig	(kPa)	80% of Maximum of Adjustable psig	(kPa)	Baseline Contact Resistance (milliohms)
1(b)1	75	(517)	73	(503)	1.5-150	(10-1034)	120	(827)	19
2(a)2	38	(262)	38	(262)	1-75	(7-517)	60	(414)	42
2(c)3	125	(862)	124	(855)	10-240	(69-1655)	192	(1324)	28
2(a)4	38	(262)	38.4	(265)	1-75	(7-517)	60	(414)	43
1(a)5	600	(4137)	608	(4192)	50-1200	(345-827)	960	(6619)	32
1(b)6	75	(517)	78	(538)	1.5-150	(10-1034)	120	(827)	19
2(b)7	3.1	(21.4)	3.3	(22.8)	0.2-6	(1.4-41)	4.8	(33)	29
1(a)8	600	(4.37)	600	(4137)	50-1200	(345-827)	960	(6619)	32
2(b)9	3	(21)	3.2	(22)	0.2-6	(1.4-41)	4.8	(33)	29
2(c)10	125	(862)	120	(827)	10-240	(69-1655)	192	(1324)	28.5

Table 3

Comparison of Post-seismic and Baseline Test Data

Mfg. (Model) Switch Number	Switch Operating Pressure, psig (kPa)		Contact Resistance (milliohms)	
	Baseline	Post-seismic	Baseline	Post-seismic
1(a)5	608 (4192)	607 (4185)	32	32
1(a)8	600 (4137)	601 (4144)	32	32
1(b)1	73 (503)	78 (538)	19	19
1(b)6	78 (538)	74 (510)	19	19
2(a)2	38 (262)	38.5 (265.4)	42	43
2(a)4	38.4 (265)	38.3 (264.1)	43	42
2(b)7	3.3 (22.8)	3.3 (22.8)	29	29
2(b)9	3.2 (22)	3.4 (23.4)	29	29
2(c)3	124 (855)	120 (827)	28	29
2(c)10	120 (827)	119 (820)	28	28

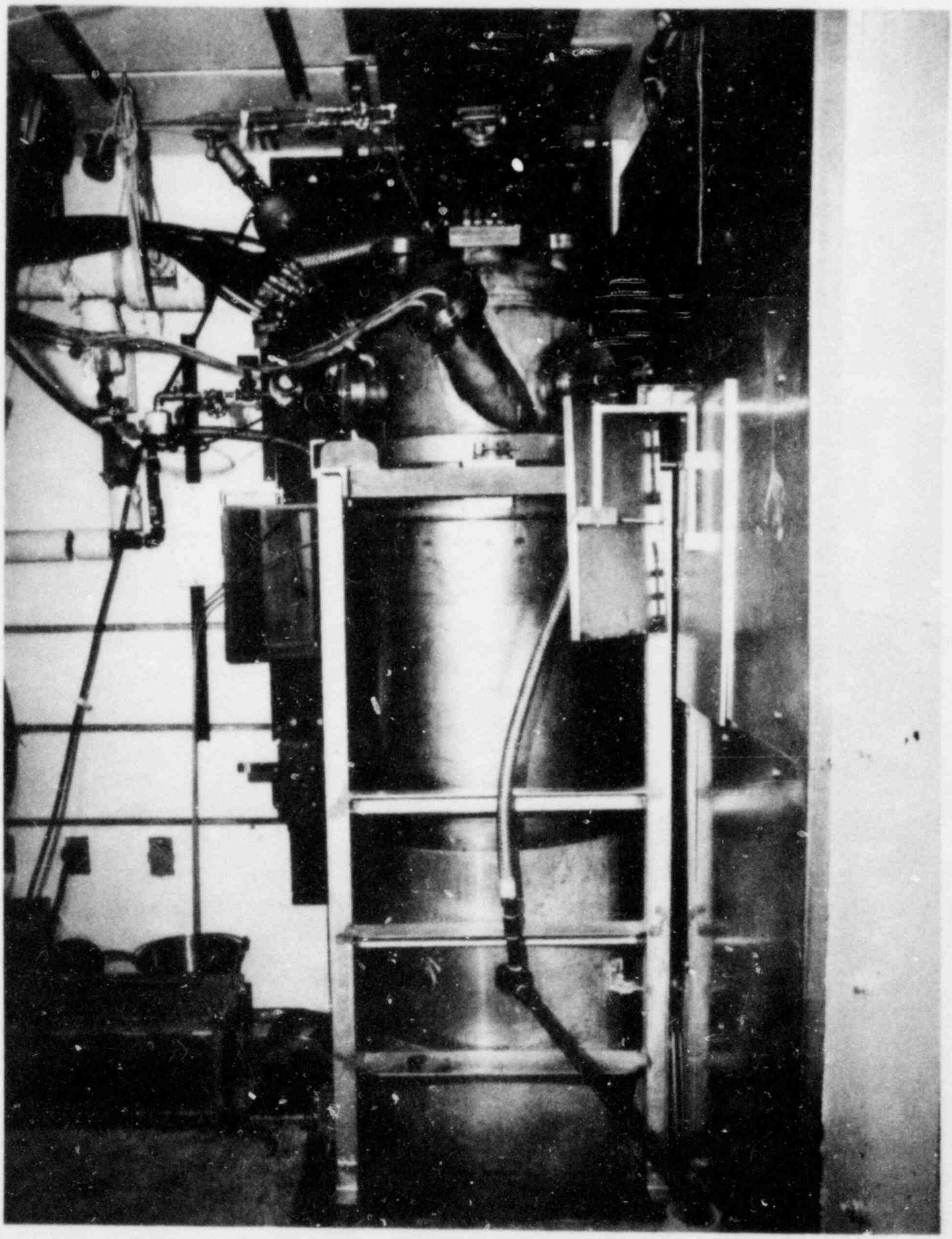

Figure 13. Test Photograph I - Environmental Test Chamber

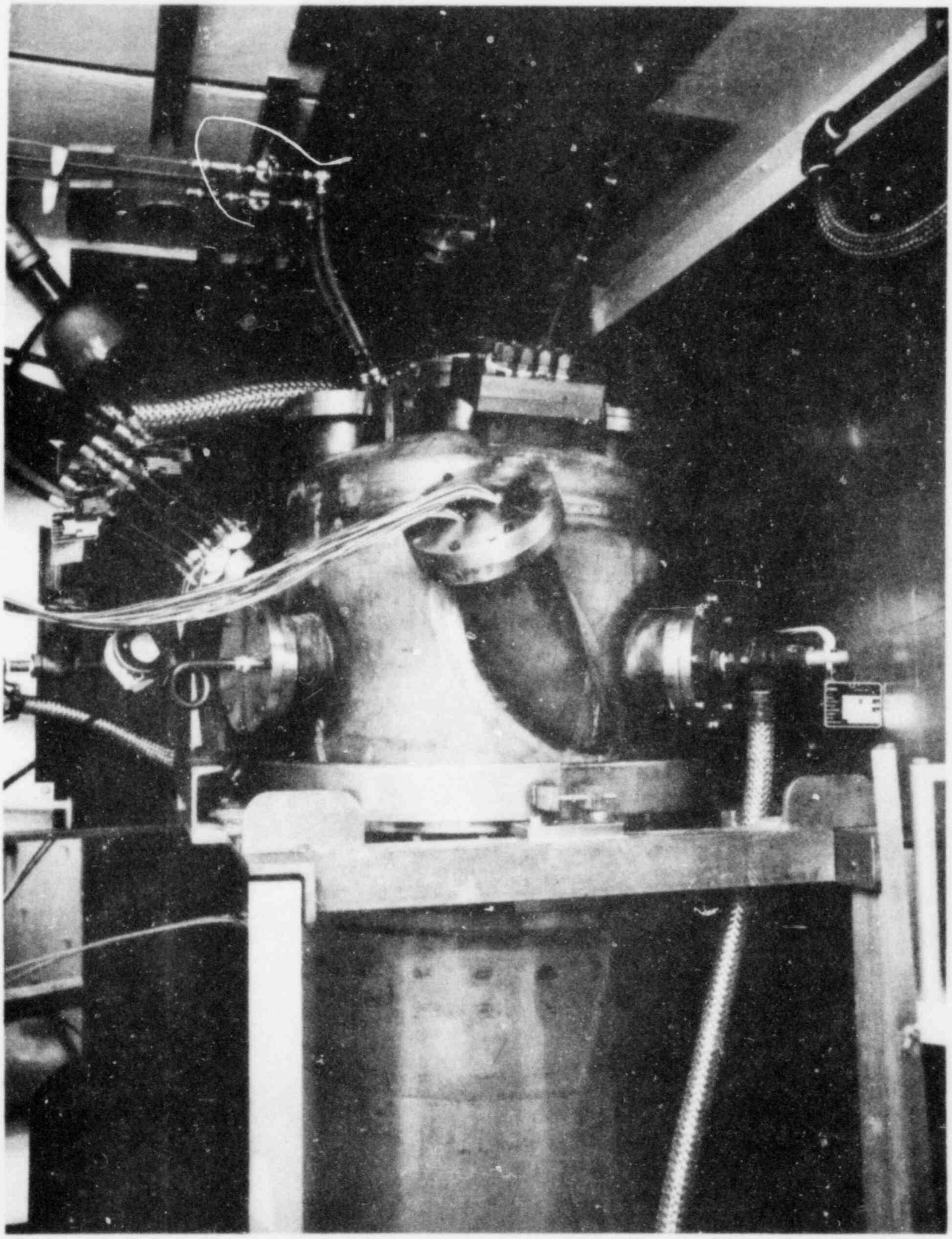

Figure 14. Test Photograph II - Penetrations - Electrical and Pressure

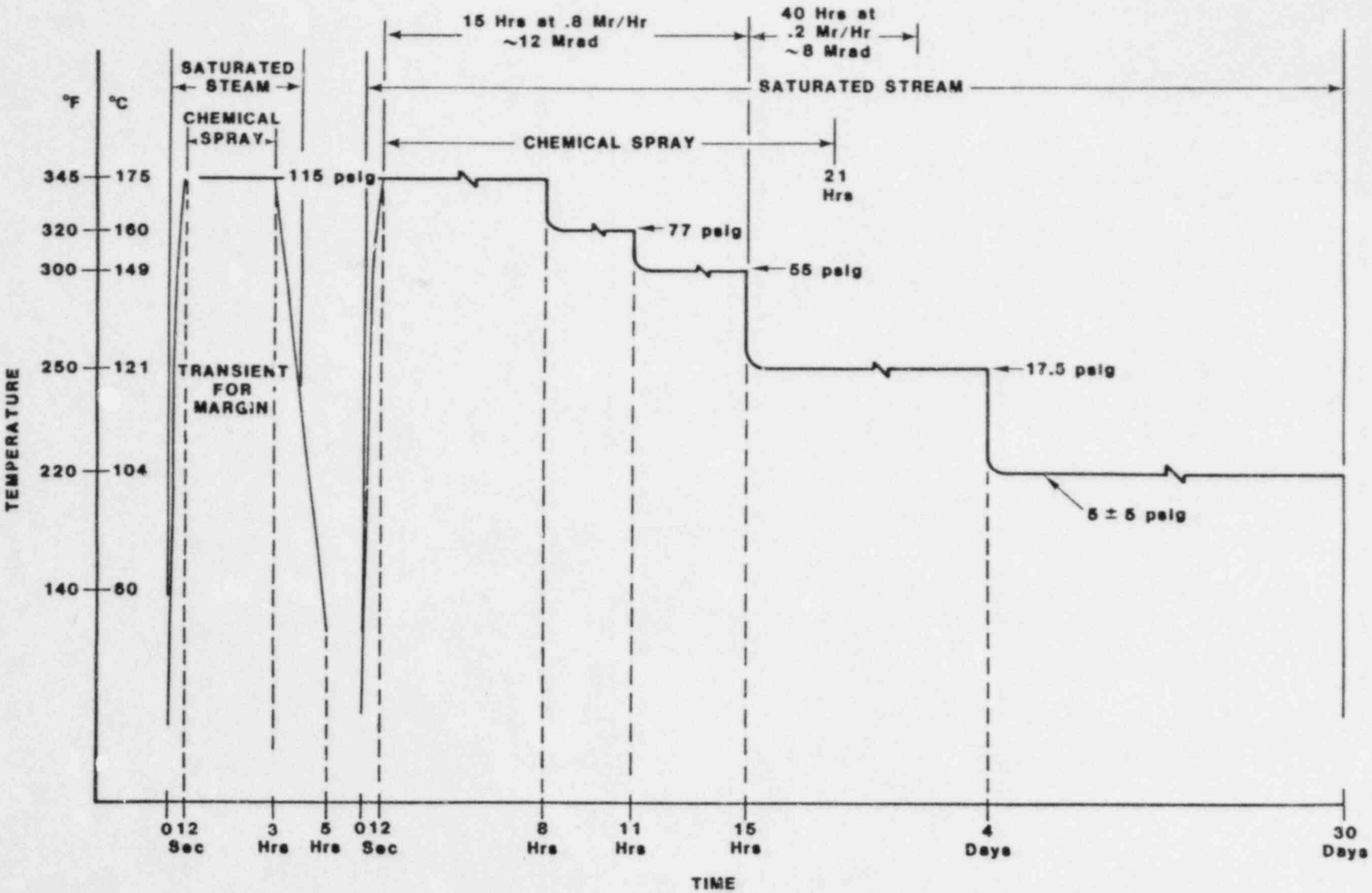

Figure 15. Specified Accident Simulation Profile/Baseline Evaluation

6.2 Follow-Up Test

The follow-up test was conducted to evaluate failure modes and failure thresholds in the pressure switches. The test was prompted by the severity of the failures observed very early into the Baseline Evaluation LOCA Test. One model (Manufacturer 2(a)) was not part of the follow-up test.

6.2.1 Accident Exposure

Eight unaged pressure switches of similar make and model as those used in the baseline evaluation test (Section 6.1) were used in the follow-up test. The test assembly was identical to the one used for the baseline tests. The follow-up test (designed to determine failure modes and thresholds), however, used a modified DBE which incorporated a saturated-steam environment of pressure and temperature with chemical spray added. The profile, describing the step-function of increasing temperature/pressure, is shown in Figure 16. The initial environmental conditions were:

Pressure = 10 psig (69 kPa) in ~15 s
Temperature = 234°F (112°C)
Radiation = 0.65 Mrad/h (dose rate)
Chemical Spray = Boric acid/sodium hydroxide (adjusted to pH = 10)

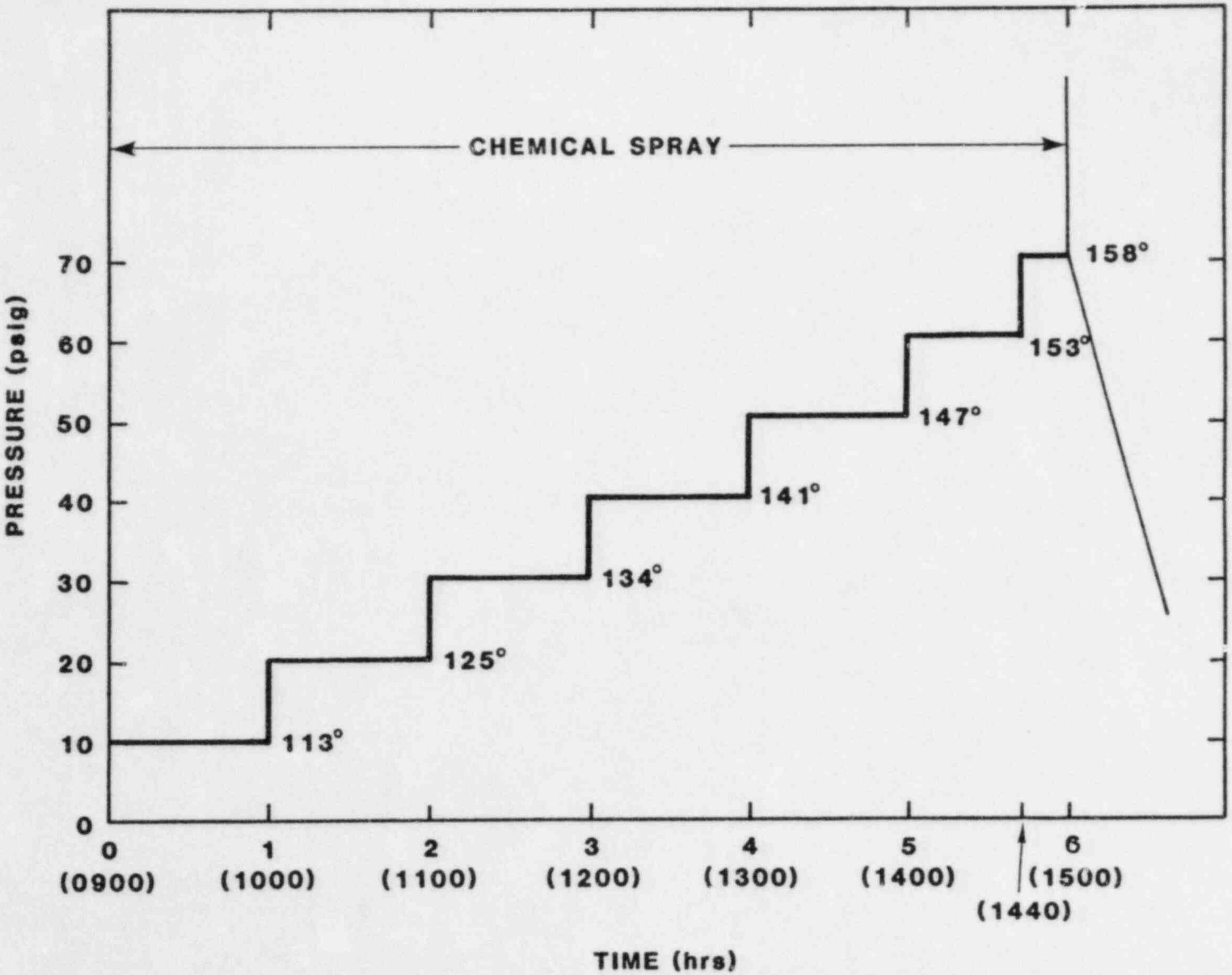

Figure 16. Specified Accident Simulation Profile/Follow-Up Test

7.0 RESULTS

7.1 Baseline Evaluation Tests

7.1.1 Functional Tests

Functional tests (checks) were made on unaged pressure switches in the as-received condition, after seismic, and prior to LOCA simulation exposures. Contact resistance determinations and pressure leak checks at 80% of the maximum limit of the adjustable pressure range were also made. In addition, functional tests were made during the LOCA simulation. The results are shown in Table 4 and are also described in a chronology of the LOCA test, which is part of this report. The results show the observed failures and anomalous behavior early into the test. Only units 2(a)2 and 2(a)4 remained functional for the duration of the test, approximately 4 days. At the end of the test, unit 2(a)2 was operating at 51.0 psig (352 kPa) and 2(a)4 was operating at 53.0 psig (365 kPa). A post-LOCA functional test of units 2(a)2 and 2(a)4 shows essentially no change when compared with the baseline functional values. The data are compared in Table 5.

7.1.2 Seismic

The results of the seismic simulation are discussed in detail in Appendix B.

7.1.3 LOCA Simulation

The accident profile for the LOCA varied only insignificantly from the desired accident simulation profile shown Figure 15. The peak temperature and pressure were only 2°C and 2 psig higher than desired although it took 26 s to reach those conditions. The test, projected for 30 days duration, was terminated in just over 4 days. Numerous functional failures and extensive physical damage in all the equipment (except the model not yet marketed, units 2(a)2 and 2(a)4) prompted the early termination. Within minutes into the test, two switches, 2(c)3 and 2(c)10, lost seal integrity of the housing and experienced ruptured diaphragms, resulting in high-pressure steam venting to the atmosphere through the pressure monitoring lines. Approximately 3.5 h later, two other pieces of equipment (2(b)7 and 2(b)9) lost seal integrity of the housing with similar results. The remaining equipment exhibited erratic and abnormal electrical behavior.

Switches 2(a)2 and 2(a)4 remained functional throughout the test although operating at a higher pressure than the manufacturers set point. A chronology indicating significant events in the LOCA test is presented in Table 6 with the corresponding events shown in Figure 15.

Table 4

Functional Tests - Pre-LOCA and LOCA Tests

Switch Number	Mfg. Set Point psig (kPa)	Baseline psig/mohms (kPa/mohms)	80% Max. Adj. Range psig (kPa)	Post-seismic psig/mohms (kPa/mohms)	Pre-LOCA psig/mohms (kPa/mohms)	LOCA Plus 5 min psig (kPa)	LOCA Plus 11 min psig (kPa)	LOCA Plus 289 min psig (kPa)	LOCA Plus 342 min psig (kPa)	LOCA Plus 459 min psig (kPa)
1(a)5	600 (4137)	608/32 (4192/32)	960 (6619)	607/32 (4185/32)	608/32 (4192/32)	745-short (5137)	short	570-short (3930)	short	short
1(a)8	600 (4137)	600/32 (4137/32)	960 (6619)	601/32 (4144/32)	601/32 (4144/32)	750 (5171)	738 (5088)	520 (3585)	short	---
1(b)1	75 (517)	73/19 (503/19)	120 (827)	78/19 (538/19)	78/19 (538/19)	short	short	58 (400)	short	short
1(b)6	75 (517)	78/19 (538/19)	120 (827)	74/19 (510/19)	73/19 (503/19)	155 (1069)	163-short (1124)	58 (400)	short	short
2(a)2	38 (262)	38/42 (262/42)	60 (414)	38.5/43 (265.4/43)	38.5/42 (265.4/42)	53 (365)	53.6 (369.6)	53.6 (369.6)	57 (393)	59 (407)
2(a)4	38 (262)	38.4/43 (264.8/43)	60 (414)	38.3/42 (264.1/43)	38.3/43 (264.1/43)	50 (345)	53 (365)	53 (365)	57.5 (396.4)	59.5 (410.2)
2(b)7	3.1 (21.4)	3.3/29 (22.8/29)	4.8 (33.1)	3.3/29 (22.8/29)	3.3/29 (22.8/29)	short	-----	-----	---	---
2(b)9	3.0 (20.7)	3.2/29 (22.1/29)	4.8 (33.1)	3.4/29 (23.4/29)	3.3/29 (22.8/29)	short	-----	-----	---	---
2(c)3	125 (862)	124/28 (855/28)	192 (1324)	120/29 (827/29)	124/29 (855/29)	failed	-----	-----	---	---
2(c)10	125 (862)	120/28.5 (827/28.5)	192 (4014)	119/28.5 (820/28.5)	120/28.5 (827/28.5)	failed	-----	-----	---	---

Table 5

Comparison of Post-LOCA and Baseline Test Data

Mfg. (Model) Switch Number	Switch Operating Pressure, psig (kPa)		Contact Resistance (milliohms)	
	Baseline	Post-LOCA	Baseline	Post-LOCA
2(a)2	38 (262)	38.5 (265.4)	42	41
2(a)4	38.4 (264.8)	38.6 (266.1)	43	42

Table 6

Chronology - LOCA Test/Baseline Evaluation

	Elapsed Time (min)	
1)	0	Transient pressure ramp initiation.
2)	2	Pressure Switch Number 2(c)3 housing was penetrated, resulting in diaphragm rupture and steam blowing out through the pressure line. Electrically the circuit exhibited shorts across the microswitches. The pressure line was plugged to prevent steam blowing.
3)	4	Pressure Switch Number 2(c)10 housing was penetrated. Results similar to Switch Number 2(c)3. (Switch 2(c)10 and 2(c)3 are identical models.)
4)	5	Functional Tests Pressure Switch Numbers 1(b)1, 2(b)9, and 2(b)7 exhibited electrical shorts across the microswitches. 2(a)2 Operational @ 53 psig (365 kPa) 2(a)4 Operational @ 50 psig (345 kPa) 1(a)5 Microswitch A - operational @ 745 psig (5137 kPa) Microswitch B - short 1(b)6 Operational @ 155 psig (1069 kPa) 1(a)8 Operational @ 750 psig (5171 kPa)
5)	11	Functional Tests Pressure Switch Number 1(a)5 now exhibits electrical shorts across both microswitches. 2(a)2 Operational @ 53.6 psig (369.6 kPa) 2(a)4 Operational @ 53.0 psig (365.4 kPa) 1(b)6 Microswitch A - operational @ 167 psig (1151 kPa) Microswitch B - short 1(a)8 Operational @ 738 psig (5088 kPa)
6)	96 (1 h 36 m)	Pressure Switch Number 2(b)9 housing was penetrated. Results identical to Pressure Switch 2(c)3.
7)	201 (3 h 21 m)	Pressure Switch Number 2(b)7 housing was penetrated. Results identical to Pressure Switch 2(b)9. (Switch 2(b)7 and 2(b)9 are identical models.)

Table 6

Chronology - LOCA Test/Baseline Evaluation (cont.)

	Elapsed Time (min)	
8)	289 (4 h 49 m)	Functional Tests 1(b)1 Operational @ 58 psig (400 kPa) 2(a)2 Operational @ 53.6 psig (369.6 kPa) 2(a)4 Operational @ 53.0 psig (365.4 kPa) 1(a)5 Microswitch A - operational @ 570 psig (3930 kPa) Microswitch B - short 1(b)6 Operational @ 58 psig (400 kPa) 1(a)8 Operational @ 520 psig (3585 kPa)
9)	342 (5 h 42 m)	Functional Tests Pressure Switch Numbers 1(b)1, 1(a)5, 1(b)6, and 1(a)8 exhibited electrical shorts across both microswitches.
10)	459 (7 h 39 m)	Functional Tests 2(a)2 Operational @ 59.0 psig (406.8 kPa) 2(a)4 Operational @ 59.5 psig (410.2 kPa)
	NOTE:	At this point in the test, Pressure Switches 2(c)3, 2(c)10, 2(b)9, and 2(b)7 have been plugged and switches 1(b)1, 1(a)5, 1(b)6, and 1(a)8 are shorted across the microswitches. Only Pressure Switches 2(a)2 and 2(a)4 remain operational.
11)	614 (10 h 14 m)	Functional Tests 2(a)2 Operational @ 59.8 psig (412.3 kPa) 2(a)4 Operational @ 60.4 psig (416.4 kPa)
12)	785 (13 h 5 m)	Functional Tests 2(a)2 Operational @ 59.0 psig (406.8 kPa) 2(a)4 Operational @ 59.4 psig (409.5 kPa)
13)	1230 (20 h 30 m)	Functional Tests 2(a)2 Operational @ 55.5 psig (382.7 kPa) 2(a)4 Operational @ 55.0 psig (379.2 kPa)
14)	5920 (98 h 40 m)	Functional Tests 2(a)2 Operational @ 51.0 psig (351.6 kPa) 2(a)4 Operational @ 53.0 psig (365.4 kPa)

TEST TERMINATED

7.1.4 Post-Test Inspection

Post-test visual inspection revealed extensive damage to all the equipment except 2(a)2 and 2(a)4 (Figure 17). The remaining Manufacturer-2 equipment exhibited significant erosion of the metal housing and cover (Figure 18). Elastomeric seals were "blown" into the housings and were torn. The wire insulation was severely degraded and mechanical damage in the form of dislodged microswitch plates was observed (Figures 19 through 21). All were partially full of water.

Manufacturer-1 equipment did not suffer the same amount of erosion of the metal housing and cover as Manufacturer-2 equipment. However, it did experience "blown" seals and a significant amount of standing water in the switch housings. This equipment also suffered severe degradation of the wire insulation (Figures 22, 23).

There was no evidence of moisture penetration into the switch housings through the flexible conduit (although it showed unusual ballooning [Figure 18]) or the heat-shrink tubing. There also was no evidence that moisture penetrated, or had any adverse effect on, the encapsulating material although moisture did penetrate the NEMA-4 enclosures (Figure 24).

7.2 Follow-Up Test

The follow-up test, prompted by severe failures observed early in the LOCA simulation tests, was conducted to assess the failure thresholds and the primary mode of failure.

7.2.1 Screw Torque Values

"Blown" cover seals observed in the LOCA simulation test (Section 7.1.3) suggested an evaluation of the torque values for the cover mounting screws and the diaphragm bolts to determine the magnitude and uniformity of the pressure exerted on the elastomer seals. Manufacturers do not impose torque requirements, nor do they recommend torque values. After determining the torque values to be low, the torque was adjusted to recommended ASME values* prior to the test. The torque values were also measured after the LOCA tests. The results, outlined in Table 7, show a large variation in torque values due to loss of back pressure and indicate severe permanent-set properties in the elastomer seals.

7.2.2 Functional

Functional tests (checks) were made on the unaged equipment in the as-received condition, prior to the LOCA simulation,

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*Torque Manual - 7th Ed. P. A. Sturtevant Co.

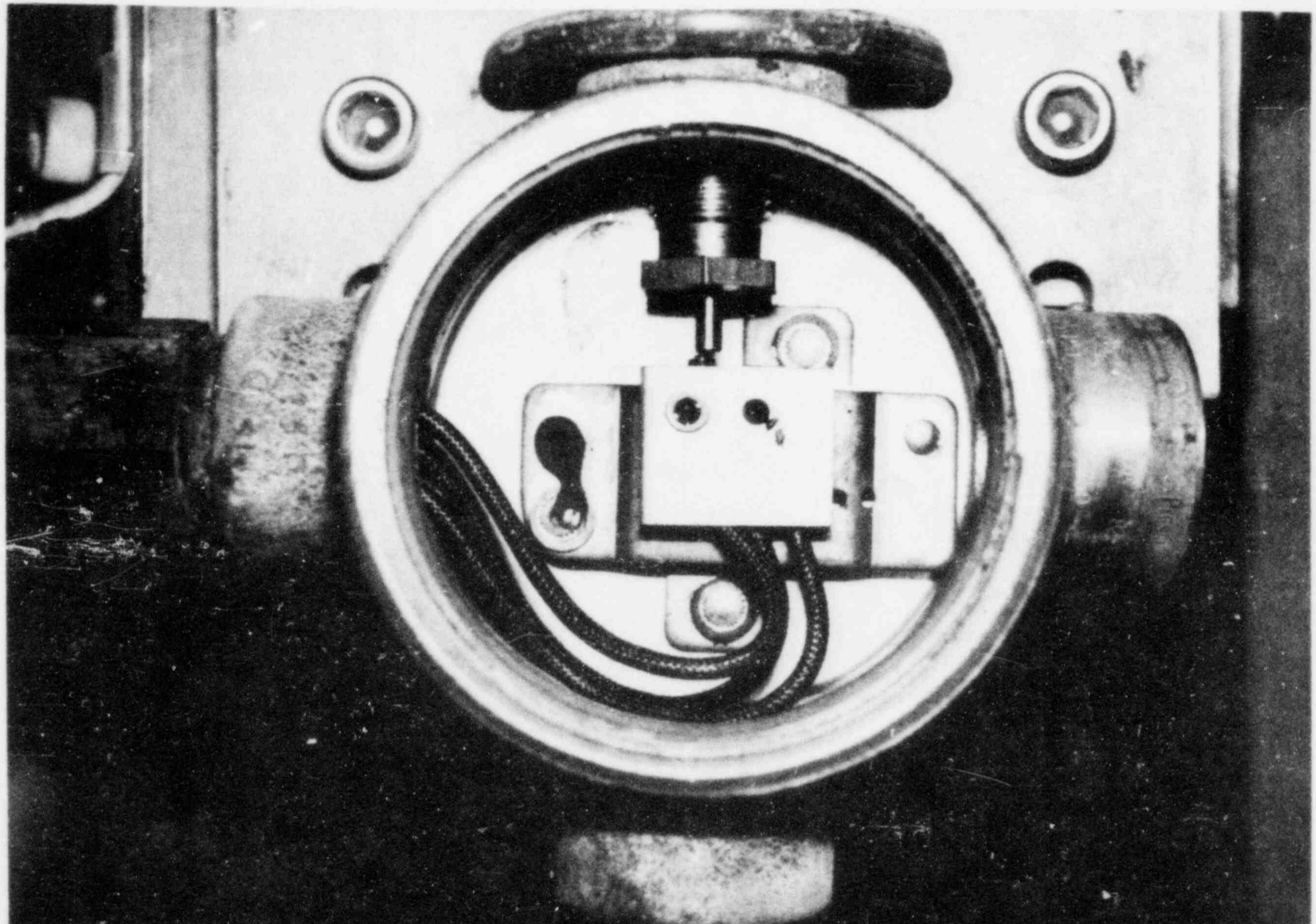

Figure 17. Post-LOCA Photograph I - Pressure Switch 2(a) after Accident Environment Exposure

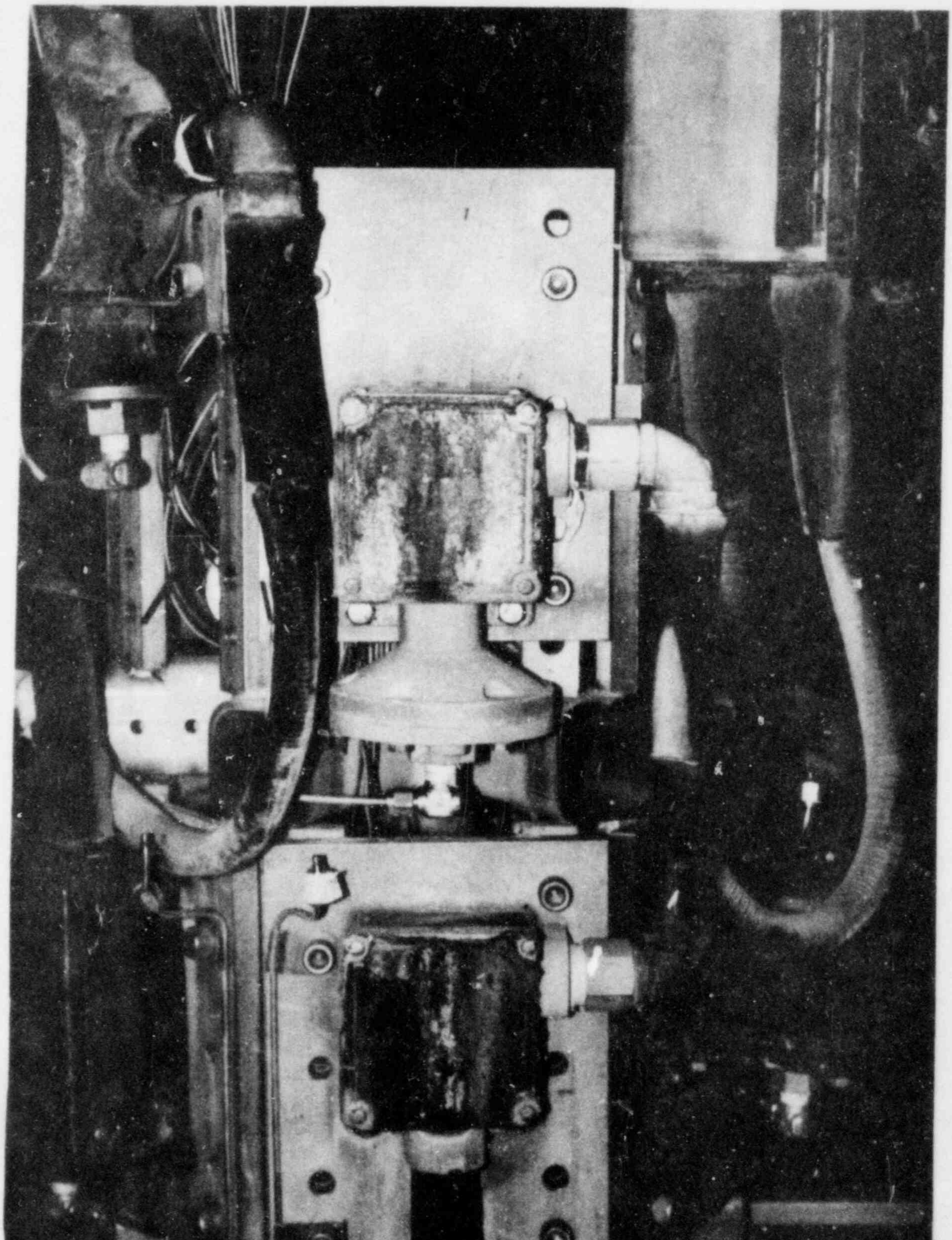

Figure 18. Post-LOCA Photograph II - Pressure Switches 2(b,c) after Accident Environment Exposure

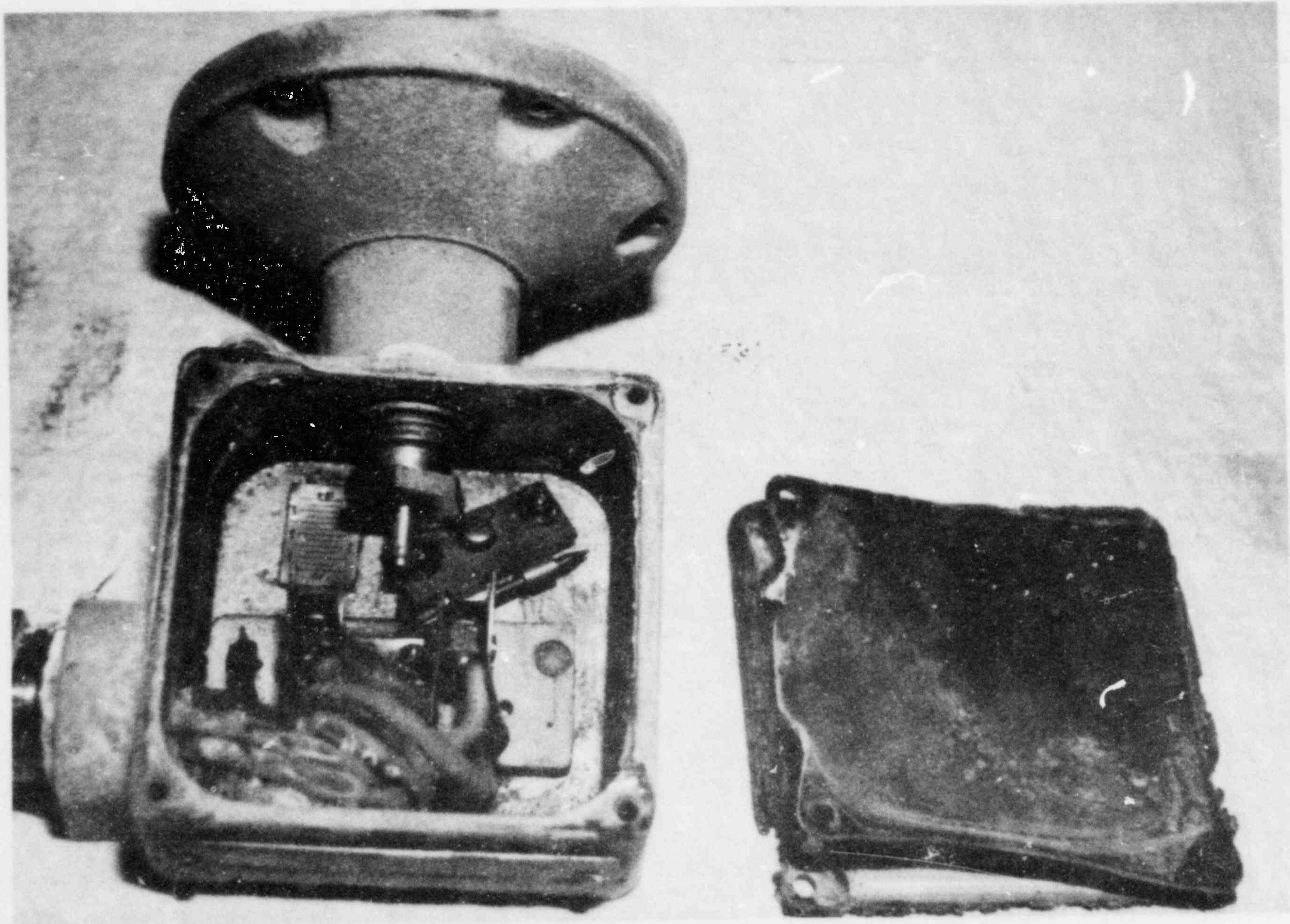

Figure 19. Post-LOCA Photograph III - Internal Damage - Pressure Switch 2(b)

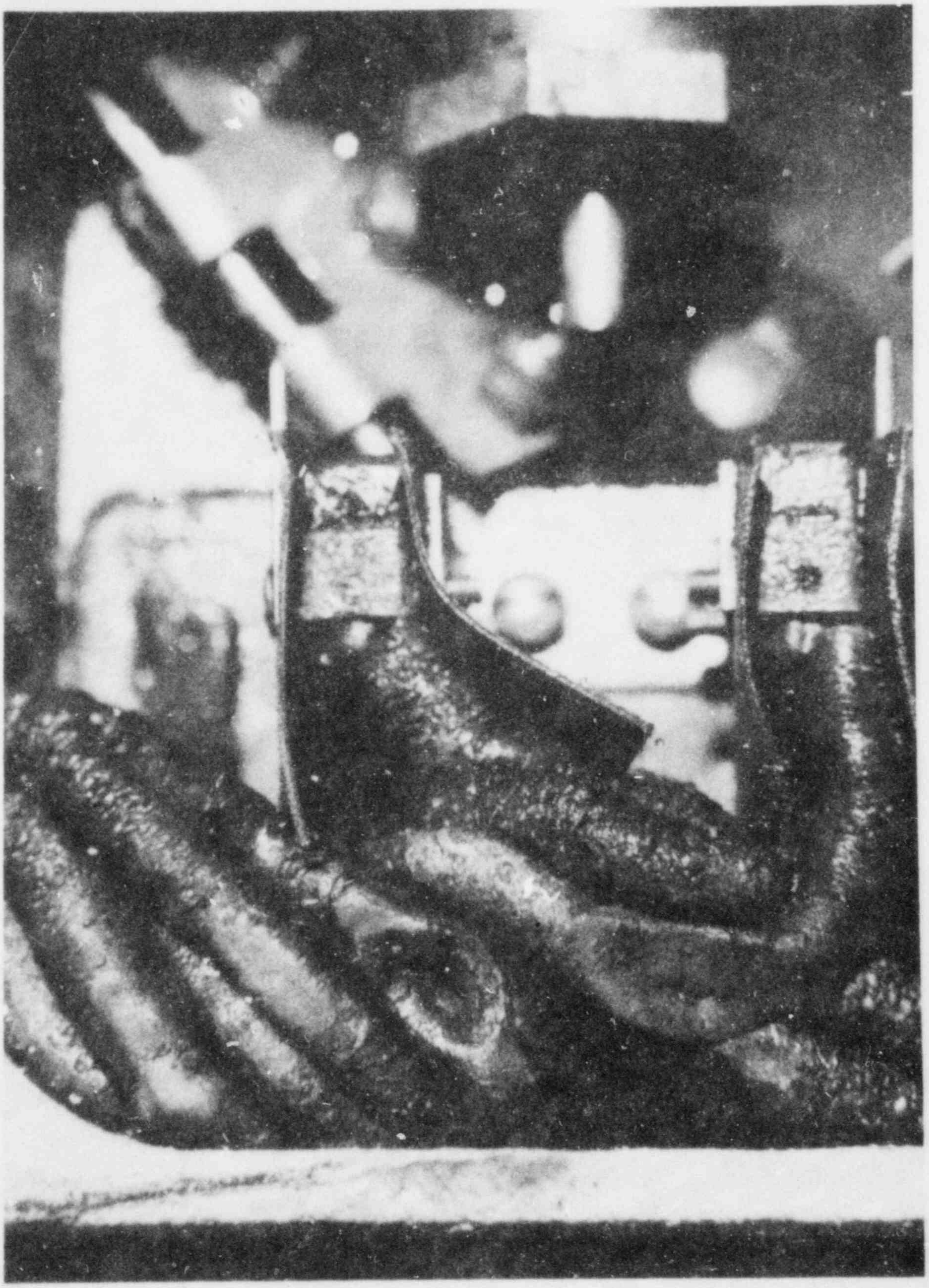

Figure 20. Post-LOCA Photograph IV - Wire Insulation Degradation

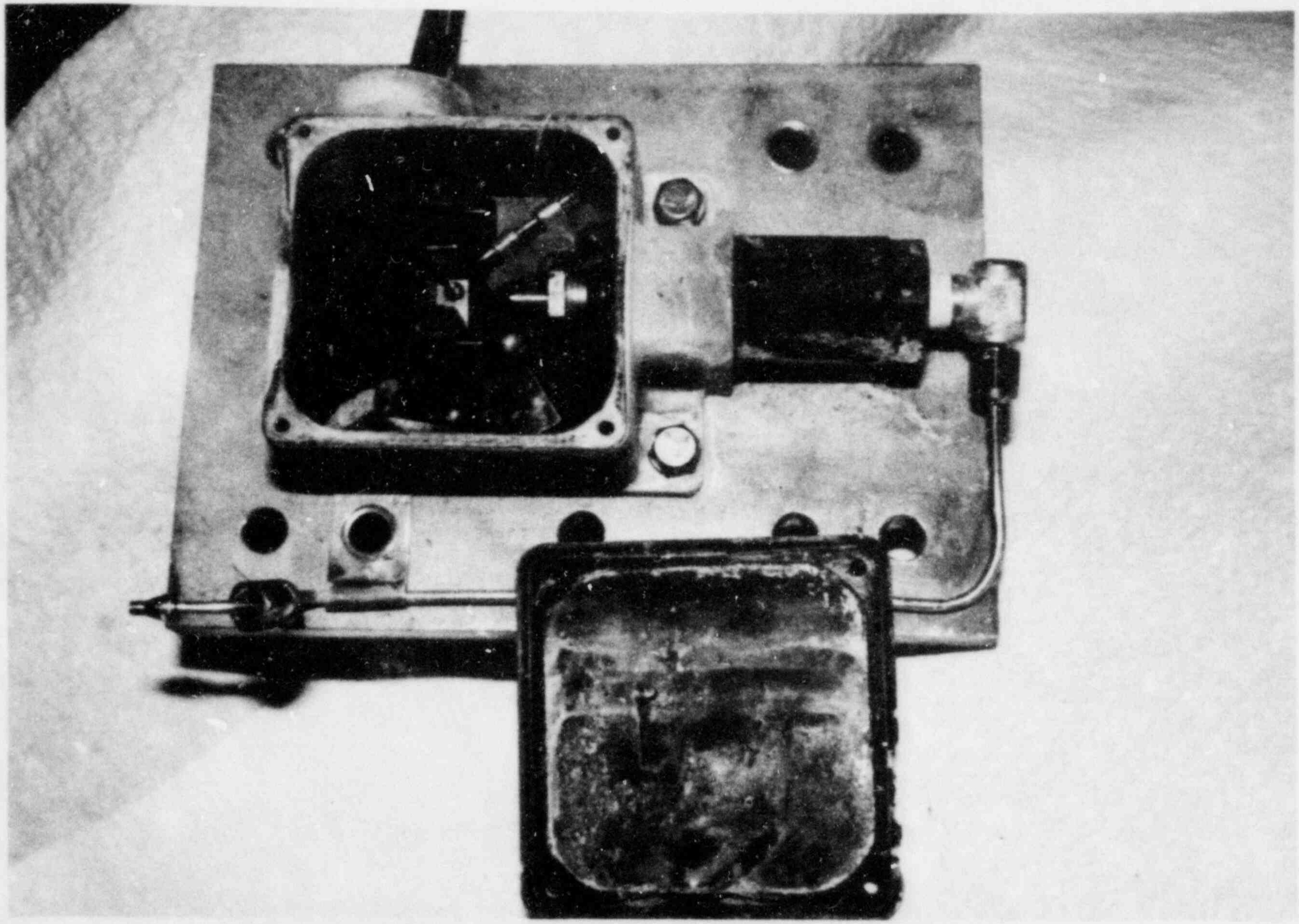

Figure 21. Post-LOCA Photograph V - Internal Damage - Pressure Switch 2(c)

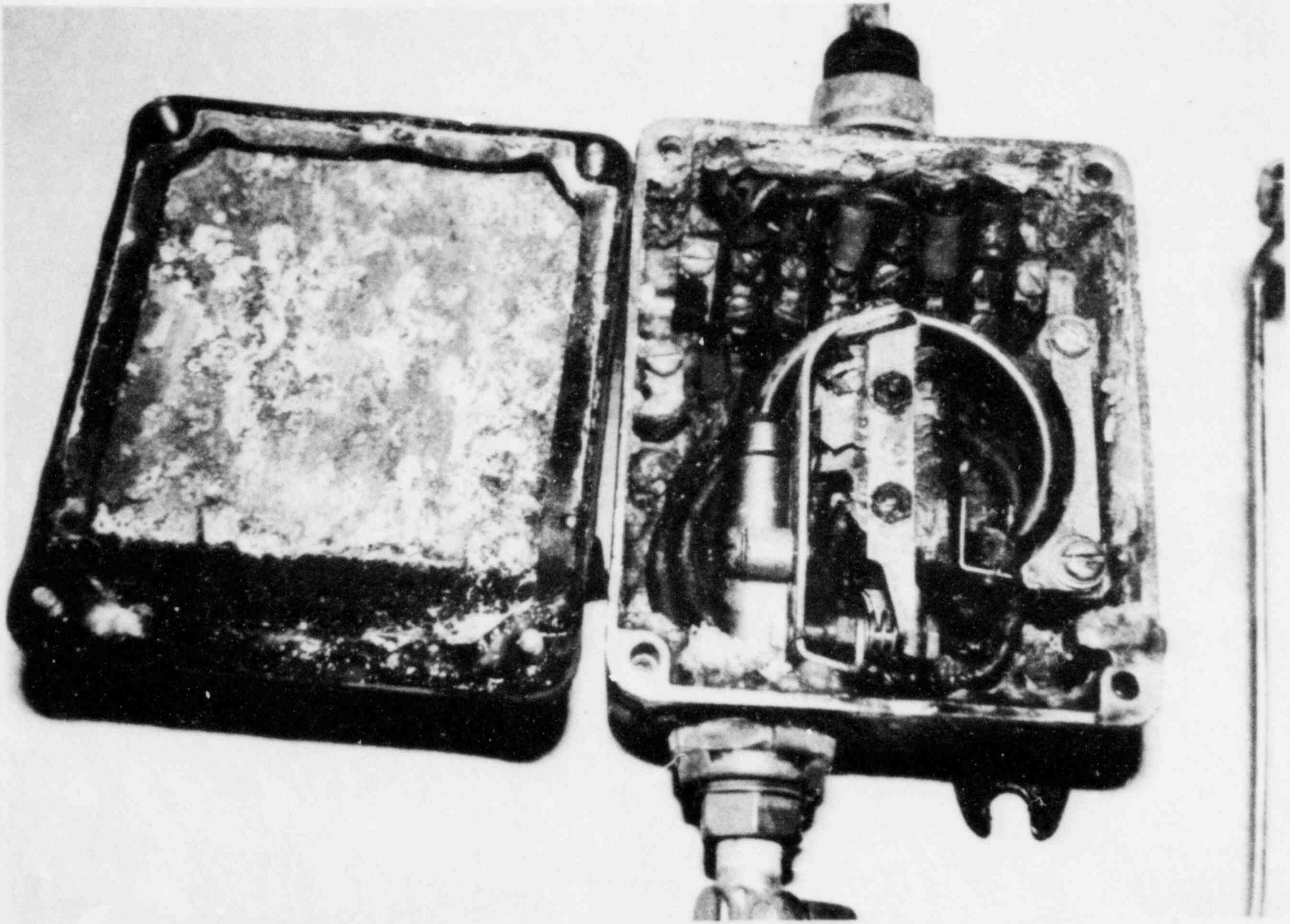

Figure 22. Post-LOCA Photograph VI - Internal Damage - Pressure Switch 1(a)

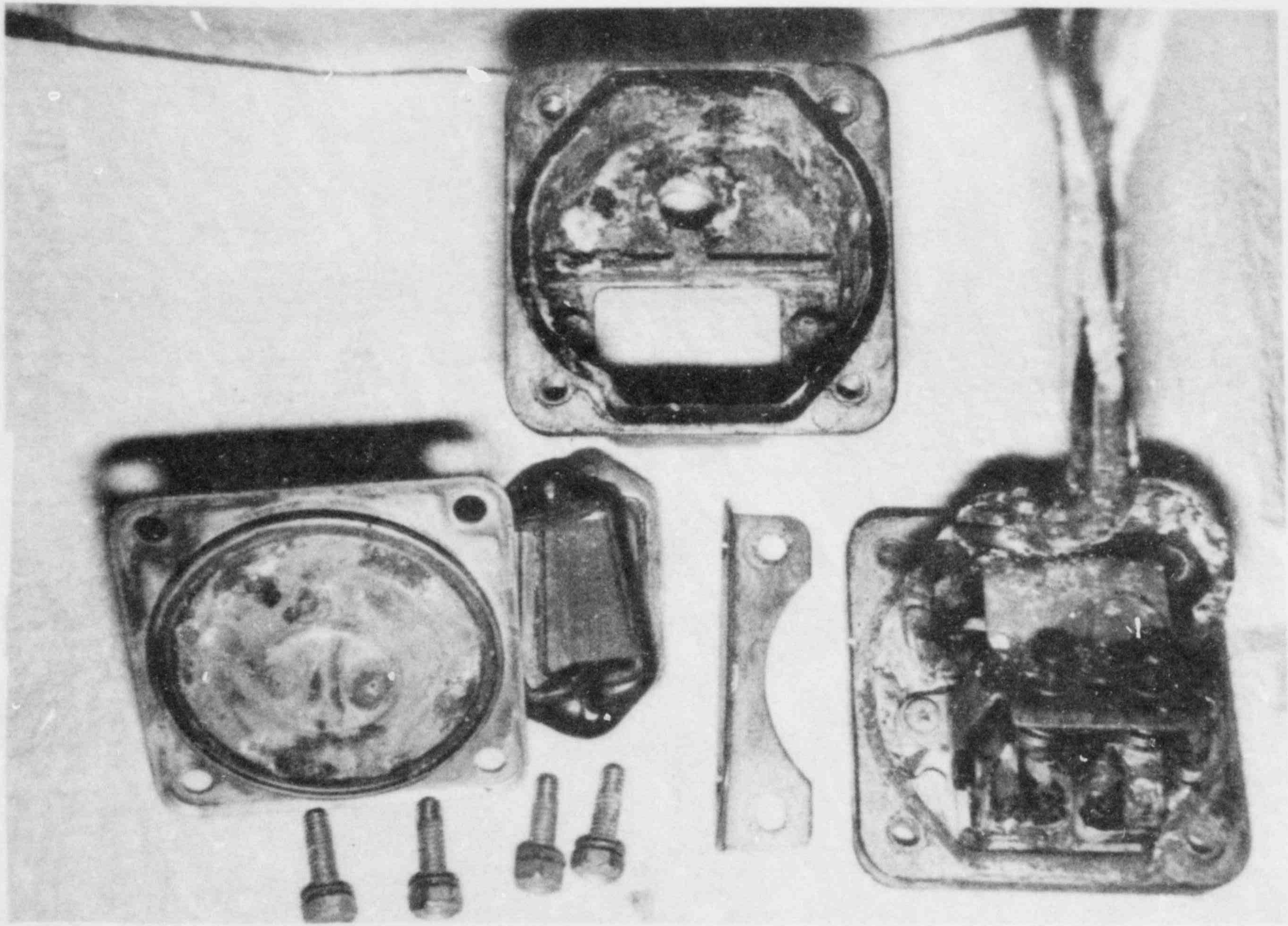

Figure 23. Post-LOCA Photograph VII - Internal Damage - Pressure Switch 1(b)

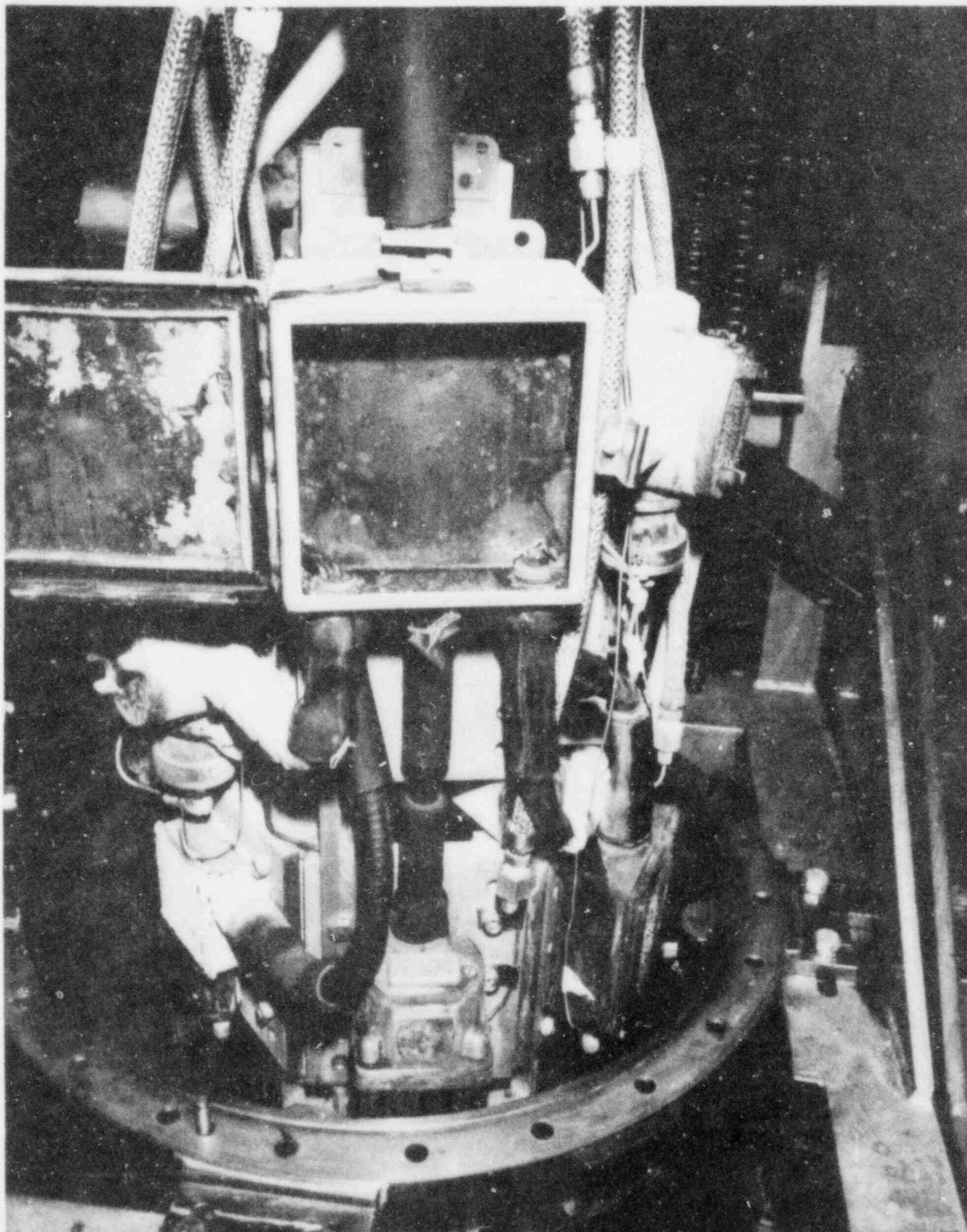

Figure 24. Post-LOCA Photograph VIII - Encapsulation after Accident Environment Exposure

Table 7

Torque Value - Adjustment/Follow-Up Test

		Torque Value, in•lb (cm•kg)		
Unit No.	Screw No.	Pre-LOCA	Adjusted	Post-LOCA
2(b)1	1	2.5 (2.9)	7.0 (8.1)	0
	2	2.5 (2.9)	7.0 (8.1)	0
	3	3.0 (3.5)	7.0 (8.1)	0
	4	<2.5 (2.9)	7.0 (8.1)	0
diaphragm*	-	6.0 (6.9)	8.0 (9.2)	3.0
2(b)2	1	7.0 (8.1)	7.0 (8.1)	0
	2	7.0 (8.1)	7.0 (8.1)	0
	3	7.0 (8.1)	7.0 (8.1)	0
	4	7.0 (8.1)	7.0 (8.1)	0
diaphragm*	-	8.0 (9.2)	8.0 (9.2)	2.5
2(c)3	1	<2.5 (2.9)	7.0 (8.1)	0
	2	<2.5 (2.9)	7.0 (8.1)	0
	3	3.0 (3.5)	7.0 (8.1)	0
	4	2.5 (2.9)	7.0 (8.1)	0
2(c)4	1	7.0 (8.1)	7.0 (8.1)	0
	2	7.0 (8.1)	7.0 (8.1)	0
	3	7.0 (8.1)	7.0 (8.1)	0
	4	7.0 (8.1)	7.0 (8.1)	0
1(a)7	1	7.0 (8.1)	8.0 (9.2)	5.0
	2	5.0 (5.8)	8.0 (9.2)	4.5
	3	7.0 (8.1)	8.0 (9.2)	5.0
	4	4.0 (4.6)	8.0 (9.2)	4.0
1(a)8	1	7.0 (8.1)	8.0 (9.2)	0
	2	6.0 (6.9)	8.0 (9.2)	0
	3	6.0 (6.9)	8.0 (9.2)	0
	4	6.0 (6.9)	8.0 (9.2)	0
1(b)5	1	7.0 (8.1)	7.0 (8.1)	3.0
	2	5.0 (5.8)	7.0 (8.1)	4.0
1(b)6	1	7.0 (8.1)	7.0 (8.1)	3.0
	2	5.0 (5.8)	7.0 (8.1)	3.0

*Diaphragm bolts varied insignificantly. Values shown are lowest value obtained from the six bolts.

Table 8

Functional Test/Follow-Up Test (Pressure to Activate Pressure Switch)

Mfg. (Model) Unit Number	As Received	Pre-LOCA	Environment Chamber Pressure psig, (kPa)						Post-LOCA
			10	20	30	40	50	60	
2(b)1	3.2 (22.1)	3.3 (22.8)	15* (103)	23.6* (163)	33.4* (230)	43.3* (299)	53.4* (368)	63.0* (434)	4.0 (27.6)
2(b)2	3.3 (22.8)	3.2 (22.1)	15* (103)	23.5* (162)	33.3* (230)	43.7* (301)	53.7* (370)	64.0* (441)	4.0 (27.6)
2(c)3	124 (855)	124 (855)	183* (1262)	227* (1565)	(S)	----	----	----	short
2(c)4	154 (1062)	155 (1069)	160* (1103)	169* (1165)	179* (1234)	(S)	----	----	short
1(b)5	55.8 (385)	63.1 (435)	short	----	----	----	----	----	----
1(b)6	68.8 (474)	65.5 (452)	65.5 (452)	76 (524)	85.6* (590)	86.7* (598)	91.2 (629)	96.0 (662)	short
1(a)7	610 (4206)	580 (3999)	595 (4102)	607 (4185)	620* (4275)	628* (4330)	612* (4220)	617* (4254)	520 (3585)
1(a)8	485 (3344)	484 (3337)	492 (3392)	518 (3571)	556* (3833)	585* (4033)	626* (4316)	647* (4461)	552 (3806)

* = Water in pressure line
(S) = steamline capped

at each pressure level and after the LOCA. The results are presented in Table 8. They show anomalous electrical behavior even at the lowest pressure level studied.

7.2.3 LOCA Simulation

The LOCA simulation was conducted using a modified DBE which incorporated a saturated steam accident environment of pressure, temperature, and chemical spray to evaluate the performance of unaged equipment during the step-function, increasing temperature/pressure profile shown in Figure 16. The equipment was exposed to an initial rise in pressure of 10 psig (69 kPa) in approximately 15 s followed by chemical spray approximately 3 min later. The pressure was raised in increments of 10 psig (69-kPa) and held at each pressure level (except the 60-psig (414-kPa) and 70-psig (483-kPa) level) for a period of 60 min (Figure 16). The test was terminated after 6 h.

At 10 psig (69 kPa), from 15 minutes to 48 minutes into the test, all of Manufacturer-2 equipment exhibited water flowing from the equipment pressure lines. At this point, either the cover seals or the diaphragm seal had been penetrated. One switch, 1(b)5, completely shorted electrically, indicating seal penetration. All the remaining switches exhibited erratic pressure readings.

At 20 psig (138 kPa), water continued to escape through the pressure lines of the Manufacturer-2 equipment.

At 30 psig and 40 psig, water turned to steam and the pressure lines were capped. All the remaining equipment exhibited anomalous electrical behavior. At this point, all of the equipment either did not function or functioned in an abnormal manner. Switches 2(b)1 and 2(b)2 experienced typical behavior for a pressure switch that has been penetrated by external pressure at the diaphragm. The pressure required to activate the switches increased by ~10 psig every time the environmental chamber pressure was increased by 10 psig (69 kPa). The test was continued to 70 psig (483 kPa) (Figure 16) without significant change in behavior (Table 8).

Post-test visual inspection showed damage inside switch 2(c)3 (contact plate dislodged) and switch 1(b)5 (full of water). All the equipment exhibited deformation in the elastomeric seals. Switches 2(c)3 and 2(c)4 exhibited torn diaphragms.

8.0 CONCLUSIONS

The results clearly show the primary mode of failure to be the rupture of the elastomeric gaskets and seals. In some instances, an almost simultaneous failure of the diaphragms (also elastomeric) was observed. The failure threshold is shown to be less than 10 psig (69 kPa) to 30 psig (207 kPa) pressure. In both tests (baseline evaluation and follow-up) failures resulted from deformed or torn gaskets or seals that allowed steam and chemical spray into the switch housing. The failures were manifested by shorting of the electrical system. Ruptured diaphragms resulted from environmental test chamber pressure seeking relief through the weak, unsupported inlet side of the pressure switch diaphragm and out the pressure-sensing line.

Considering the failure mode, the relatively short time to failure, and the failure threshold, it appears the failures are related to seal design rather than to seal material. The equipment was unaged and the duration of the tests too limited to expect any appreciable material degradation.

In assessing the design, the switch covers are too thin to support the gaskets adequately, the bearing surfaces for the gaskets also are too thin, and the distance between cover mounting screws is too great. This equipment or any equipment incorporating a similar seal design will not withstand (based on the results) external pressures in excess of 30 psig (207 kPa) without penetration of the sealed housing. Some of the equipment will not withstand pressures as low as 10 psig (69 kPa).

REFERENCES

1. E. A. Salazar, D. M. Jeppesen, "Test Plan for Equipment Qualification Methodology Research Test Using Pressure Switches," Rev. 4., September 10, 1982.

2. E. A. Salazar, "Test Plan for Follow-Up Test on Baseline Evaluation Test Using Pressure Switches," December 21, 1982.

3. E. A. Salazar, "Quick Look Report - Pressure Switch Test," December 14, 1982.

4. E. A. Salazar, "Quick Look Report - Follow-up Test on Baseline Evaluation Test Using Pressure Switches," January 27, 1983.

5. Memo of Z. R. Rosztoczy to G. W. Reinmuth and D. F. Sullivan, "Equipment Selection for the NRC Test Program," November 19, 1981.

6. USNRC/Franklin Research Center, "Equipment Qualification Data Bank."

7. E. A. Salazar and D. M. Jeppesen, Memo to distribution, "Equipment Selection for the NRC Equipment Qualification Research Test Program," Sandia National Laboratories, Albuquerque, NM, January 11, 1982.

APPENDICES

A) USNRC/Franklin Research Center - "79-01B Responses on Pressure Switches

B) Seismic Test of Ten Pressure Switches, SWRI-7279-001, dated 10/29/82

APPENDIX A

USNRC/Franklin Research Center

"79-01B Responses on Pressure Switches

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Big Rock Point	S-O-R	4NN-E411-YX5TT	NA	Atmospheric	2 E04	Electrical Penetration
	S-O-R	12L-AA5-FSS	NA	14.7	2 E04	Electrical Penetration
	S-O-R	9TA-S4-11SSX12	235F>	41.7	2 E05<	Containment Elevation
Oyster Creek	Barksdale	B2T	230F	16	1.4 E04<	EL. 72' RKO-1
	Barksdale	B2T	215F	16	6.1 E04<	EL. 72' RKO-2
	Barksdale	B2T	230F	16	1.4 E04<	EL. 72' RKO-1
	Barksdale	B2T	215F	16	6.1 E04<	EL. 72' RKO-2
	Barksdale	B2T - A12SS	215F	16	6.1 E04<	EL. 72' RKO-2
	Barksdale	B2T - A12SS	230F	16	1.4 E04<	EL. 72' RKO-1
	Barksdale	B2T - A12SS	230F	16	1.4 E04<	EL. 72' RKO-
	Barksdale	B2T - A12SS	215F	16	6.1 E04<	EL. 72' RKO-2
	Barksdale	B2T - A12SS	230F	16	1.4 E04<	EL. 72' RKO-1
	Barksdale	B2T - A12SS	215F	16	6.1 E04<	EL. 72' RKO-2
	Barksdale	B2T - M12SS	215F	16	6.1 E04<	EL. 72' RKO-2
	Barksdale	B2T - M12SS	230F	16	1.4 E04<	EL. 72' RKO-1
	S-O-R	12 NKA	77F=	15	1.5 E06>	Reactor Vessel X R6-
	S-O-R	12 NKA	77F=	15	1.5 E06>	Reactor Vessel X R6-
	S-O-R	12 NKA	77F=	15	2.8 E06>	Rex North Drywell W
	S-O-R	12 NKA	77F=	15	2.8 E06>	Rex North Drywell WA
Dresden 2	Barksdale	B2T-12SS-GE	103	14.7	<1.0 E0	Rack 2202-28 Columns
	Barksdale	B2T-M12SS-GE P	103	14.7	<1.0 E0	Note 1 Elevation 517'6"
	Barksdale	B2T-M12SS-GE P	103>	14.7	<1.0 E0	Note (1) Elevation 545'
	Barksdale	D2X-H18-DL PUR	103	14.7	<1.0 E0	Notes (1), (2) Elevation
	S-O-R	12N-K4-PURCHA[illegible]	103F	14.7	<1.0 E0	Note (1) Elevation 545'
	S-O-R	5N-AA8	150F	14.7	6.1 E05	Note (2) Elevation 479'
	S-O-R	CAT 5N-AA3	150F	14.7	2.5 E06	Rack 2202-19 A&B SE
	Barksdale	B2T-12SS-GE	103	14.7	<1.0 E0	Rack 2202-28 Columns
	Barksdale	B2T-M12SS-GE P	103	14.7	<1.0 E0	Note 1 Elevation 517'6"
	Barksdale	B2T-M12SS-GE P	103>	14.7	<1.0 E0	Note (1) Elevation 545'
	Barksdale	D2X-H18-DL PUR	103	14.7	<1.0 E0	Notes (1), (2) Elevation
Dresden 3	Barksdale	B2T-12SS-GE	103F	14.7	<1.0 E0	Rack 2203-28 Columns
	Barksdale	B2T-M12SS-GE	103F>	14.7	<1.0 E0	Rack 2203-5 Columns
	Barksdale	B2T-M12SS-GE	103F>	14.7	<1.0 E0	Rack 2203-7 Columns
	Barksdale	D2X-H18-UL	103F	14.7	<1.0 E0	Rack 2203-5 Columns
	S-O-R	12N-K4	103F	14.7	<1.0 E0	Rack 2203-5 Columns
	S-O-R	12N-AA5	103F	14.7	<1.0 E0	Rack 2203-5 Columns
	S-O-R	5N-AA3	150F	14.7	6.1 E05	SE Corner Room Elevation
	S-O-R	CAT 5N-AA3	150F	14.7	2.5 E06	Rack 2203-19 A SE Corner

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Browns Ferry 1, 2, 3	Barksdale	D2H - M1[illegible]SS	ND	ND	3.1 E04<	3
	Barksdale	B2T - A12SS	ND	ND	2.3 E06<	9
	Barksdale	B2T - A12SS	ND	ND	2.3 E06<	9
	Barksdale	B2T - A12SS	ND	ND	3 E07<	2
	Barksdale	B2T - M12SS	ND	ND	5.2 E05<	9
	Barksdale	B2T - M12SS	ND	ND	3 E07<	2
	Barksdale	Barksdale	ND	ND	3 E07<	3
	Barksdale	D2H - M150SS	ND	ND	5 E04<	1
Browns Ferry 1, 2, 3	S-O-R	12N/AA4	ND	212F	2.3 E06<	9
	S-O-R	12N/AA4	ND	212F	2.3 E06<	9
	S-O-R	5A - AA3	ND	212F	3 E07<	2
	S-O-R	5A - AA3 Series	ND	212F	3 E07<	2.5
	S-O-R	5N - AA3 Series	ND	212F	3 E07<	2
	S-O-R	5N - AA3 Series	ND	212F	3 E07<	5
	S-O-R	6N-AA-21-V	ND	212F	5 E04<	1
	S-O-R	6N-AA-21 Series	ND	212F	3 E07<	3
	S-O-R	B2T-M12SS	ND	212F	23 E07<	9
Monticello	Barksdale	B2T-A12SS	NA>	NA	1.4 E04>	Instrument Rack C-55
	Barksdale	B2T-A12SS	NA>	NA	ND>	Tube Building SE Corner
	Barksdale	B2T-A12SS	NA>	NA	1.4 E04>	Instrument Rack C-122
	Barksdale	B2T-A12SS	NA>	NA	1.4 E04>	Instrument Rack C-122
	Barksdale	B2T-A12SS	NA>	NA	1.4 E04>	Instrument Rack C-121
	Barksdale	B2T-M12SS	NA>	NA	ND>	Instrument Rack C-55, C-56
	Barksdale	B2T-M12SS	NA>	NA	1.4 E04>	Instrument Rack C-122
	Barksdale	B2T-M12SS	NA>	NA	7.5 E04=	Instrument Rack C-129
	Barksdale	B2T-M12SS	NA>	NA	7.5 E04=	Instrument Rack C-215
	Barksdale	B2T-M12SS	NA>	NA	1.4 E04=	Instrument Rack C-121
	Barksdale	D2H-M150	NA	NA	ND	RCIC Room Instrument Rack
	S-O-R	12N-AA2	NA>	NA	1.4 E04>	Instrument Rack C-55, C-56
	S-O-R	12N-AA4	NA	ND	7.5 E04=	Instrument Rack C-55, C-56
	S-O-R	12N-AA4	NA>	NA	7.5 E04=	Instrument Rack C-55, C-56
	S-O-R	12N-K4	NA>	NA	1.4 E04>	Instrument Rack C-55, C-56
	S-O-R	5N-AA-3X	NA>	NA	7.5 E04=	RHR Room Instrument Rack C
	S-O-R	6N-AA-3	NA>	NA	1.4 E04>	Instrument Rack C-122
	S-O-R	D2H-M150	NA	NA	ND	RCIC Room Instrument Rack
	S-O-R	12N-AA2	NA>	NA	1.4 E04>	Instrument Rack C-55, C-56
	S-O-R	12N-AA4	NA	ND	7.5 E04=	Instrument Rack C-55, C-56
	S-O-R	12N-AA4	NA>	NA	7.5 E04=	Instrument Rack C-55, C-56
	S-O-R	12N-K4	NA>	NA	1.4 E04>	Instrument Rack C-55, C-56
	S-O-R	5N-AA-3X	NA>	NA	7.5 E04=	RHR Room Instrument Rack C
	S-O-R	6N-AA-3	NA>	NA	1.4 E04>	Instrument Rack C-122

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Quad Cities 1 & 2	Barksdale	B2T-A12SS	104F	14.7	<1.0E	Rack 2202-5 Near Column
	Barksdale	B2T-A12SS	104F	14.7	<1.0E	Rack 2202-7 Near Column
	Barksdale	B2T-A12SS	104F	14.7	<1.0E	Rack 2202-5 Near Column
	Barksdale	B2T-A12SS	114F	14.7	<1.0E	Rack 2202-58 SW Corner
	Barksdale	B2T-A12SS	104F	14.7	<1.0E	Rack 2202-28 Columns
	Barksdale	B2T-M12SS	104F	14.7	<1.0E	Rack 2202-5 Near Column
	Barksdale	D2H-M150SS	120F	14.7	<1.0E	Rack 2202-29 HPCI
	S-O-R	12N-AA5-PP	104F	14.7	<1.0E	Rack 2202-5 Columns
	S-O-R	12N-AA5-PP	104F	14.7	7.1 E04	Rack 2202-5 Columns
	S-O-R	12N-AA5-PP	104F	14.7	3.2 E05	Rack 2202-6 Columns
	S-O-R	12NN-KK215-VX	104F	14.7	4.0 E05	SE Corner Room EL
	S-O-R	6NN-AA21-VRR	120F	14.7	<1.0E	Rack 2202-29 HPCI
Vermont Yankee	Barksdale	B2T-A12SS	NA>	NA	1 E06	Area: Reactor Building
	Barksdale	B2T-M12SS	NA>	NA	5 E04	Area: Reactor Building
	Barksdale	B2T-M12SS	NA>	Atmosphere	5 E04	Area: Reactor Building
	Barksdale	B2T-M12SS	NA>	Atmosphere	5 E04	Area: HPCI Room EL
	Barksdale	D2H-A150SS	NA>	NA	5 E09	Area: RCIC Room EL
	Barksdale	D2H-M12SS	NA>	Atmosphere	5 E04	Area: Reactor Building
Peach Bottom 2	Barksdale	B2T-M12SS	NA>	NA	1.8 E02	Room 403
	Barksdale	B2T-M12SS	NA>	NA	3.51 E0	Room 212
	Barksdale	PIH-M340SS-V	NA>	NA	6.0 E04	Room 8
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 403
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 403
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 403
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 403
	S-O-R	5N-AA3	NA>	NA	1.8 E02	Room 101
	S-O-R	5N-AA3	NA>	NA	ND	Room 104
	S-O-R	5N-AA3	NA>	NA	ND	Room 108
	S-O-R	5N-AA3	NA>	NA	ND	Room 108
	S-O-R	5N-AA3	NA>	NA	6.0 E04	Room 8
	S-O-R	6N-K21-X9-VSTT	NA>	NA	6.0 E04	Room 8
Peach Bottom 3	Barksdale	PIH-M340SS-V	NA>	NA	6.06 E04	Room 46
	Barksdale	B2T-M12SS	NA>	NA	1.8 E02	Room 444
	Barksdale	B2T-M12SS	NA>	NA	3.51 E0	Room 444
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 444
	S-O-R	12N-AA4	NA>	NA	3.5 E05	Room 257
	S-O-R	12N-AA4	NA>	NA	1.82 E0	Room 444
	S-O-R	12N-AA4	NA>	NA	3.51 E0	Room 257
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 444
	S-O-R	12N-AA4	NA>	NA	ND	Room 156
	S-O-R	5N-AA3	NA>	NA	ND	Room 159
	S-O-R	5N-AA3	NA>	NA	1.8 E02	Room 444
	S-O-R	5N-AA3	NA>	NA	ND	Room 257
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 444
	S-O-R	12N-AA4	NA>	NA	3.5 E05	Room 257

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Peach Bottom 3	S-O-R	12N-AA4	NA>	NA	1.82 E0	Room 444
	S-O-R	12N-AA4	NA>	NA	3.51 E0	Room 257
	S-O-R	12N-AA4	NA>	NA	1.8 E02	Room 444
	S-O-R	12N-AA4	NA>	NA	ND	Room 156
	S-O-R	5N-AA3	NA>	NA	ND	Room 159
	S-O-R	5N-AA3	NA>	NA	1.8 E02	Room 444
	S-O-R	5N-AA3	NA>	NA	ND	Room 257
	S-O-R	5N-AA3	NA>	NA	ND	Room 161
	S-O-R	5N-AA3	NA>	NA	ND	Room 160
	S-O-R	5N-AA3	NA>	NA	6.0 E04	Room 46
	S-O-R	5N-AA3	NA>	NA	6.01 E04	Room 46
	S-O-R	6N-AA21-X10-VST	NA>	NA		
Three Mile Island-1	S-O-R	12N-K45-CM3RRY	Ambient	Atmospheric	4 E04>	Auxiliary Building
	S-O-R	12N-K45-CMRR	Ambient	Atmospheric	1.7 E06>	Auxiliary Building
	S-O-R	12N-K45-CMRR	Ambient	Atmospheric	1.7 E06>	Auxiliary Building
	S-O-R	12N-K45-CMRR	Ambient	Atmospheric	1.7 E06>	Auxiliary Building
	S-O-R	9N-05-BR	NA		4 E05<	Containment
	S-O-R	9N-05-BR	NA		4 E05<	Containment
	S-O-R	9N-05-BR	NA		4 E05<	Containment
	S-O-R	9N-05-BR	NA		4 E05<	Containment
	S-O-R	9N-05-BR	NA		4 E05<	Containment
	S-O-R	9N-05-BR	NA		4 E05<	Containment
	S-O-R	9N-05-BR	NA		4 E05<	Containment
	S-O-R	9N-05-BR	NA		4 E05<	Containment
Pilgrim	Barksdale	B2T-A12SS	168F>	Ambient	Not Req	1.7
	Barksdale	B2T-A12SS	192F>	16 psia	Not Exp	1.11
	Barksdale	B2T-A12SS	192F>	16 psia	Not Exp	1.12
	Barksdale	B2T-A12SS	192F>	16 psia	Not Exp	1.11
	Barksdale	B2T-A12SS	192F>	16 psia	Not Exp	1.12
	Barksdale	B2T-A12SS	Not Req>	Not Req	Not Req	2.11
	Barksdale	B2T-A12SS	Not Req>	Not Req	Not Req	2.11
	Barksdale	B2T-A12SS	Not Req>	Not Req	Not Req	2.11
	Barksdale	B2T-A12SS	Not Req>	Not Req	Not Req	2.12
	Barksdale	B2T-M12SS	Not Req>	Not Req	Not Exp	1.11
	Barksdale	B2T-M12SS	ND>	ND	ND	1.12
	Barksdale	B2T-M12SS	192F>	16 psia	Not Exp	1.11
	Barksdale	B2T-M12SS	192F>	16 psia	Not Exp	1.11
	Barksdale	B2T-M12SS	192F>	16 psia	Not Exp	1.12
	Barksdale	BT-A12SS	262F>	Ambient	62 E05	1.8
	Barksdale	D1T-H18SS	Not Req	Not Req	Not Req	2.11A
	Barksdale	D1T-H18SS	Not Req	Not Req	Not Req	2.11A
	Barksdale	D1T-H18SS	Not Req	Not Req	Not Req	2.12A
	Barksdale	D1T-H18SS	Not Req	Not Req	Not Req	2.12A
	Barksdale	D2H-A150-SS	Not Req	Not Req	3.5 E04	1.4
	Barksdale	P1H-M855SV	Not Req	Not Req	3.5 E04	1.2 Outside Containment
	S-O-R	12N-AA4-PP	Not Req	Not Req	Not Exp	1.14
	S-O-R	12N-AA4-PP	Not Req	Not Req	Not Exp	1.12

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Pilgrim	S-O-R	12N-AA4-PP	140F>	16 psia	Not Exp	1.14
	S-O-R	12N-AA4-PP	192F>	16 psia	Not Exp	1.12
	S-O-R	12N-AA4-PP	192F>	16 psia	Not Exp	1.14
	S-O-R	12N-AA4-PP	140F>	16 psia	Not Exp	1.12
	S-O-R	12N-AA4-PP	140F>	16 psia	Not Exp	1.14
	S-O-R	12N-AA4-PP	Not Req	Not Req	Not Exp	1.14
	S-O-R	12N-AA4-PP	Not Req	Not Req	Not Exp	1.12
	S-O-R	12N-AA4-PP	140F>	16 psia	Not Exp	1.14
	S-O-R	12N-AA4-PP	192F>	16 psia	Not Exp	1.12
	S-O-R	12N-AA4-PP	192F>	16 psia	Not Exp	1.14
	S-O-R	12N-AA4-PP	140F>	16 psia	Not Exp	1.12
	S-O-R	12N-AA4-PP	140F>	16 psia	Not Exp	1.14
	S-O-R	12N-AA4-PP	192F>	16 psia	Not Exp	1.12
	S-O-R	12N-AA5	Not Req	Not Req	Not Exp	1.14
	S-O-R	12N-AA5	Not Req	Not Req	Not Exp	1.12
	S-O-R	5N-AA3	250F<	Ambient	5.0 E04>	1.1, 1.2
	S-O-R	5N-AA3	250F<	Ambient	5.0 E04>	1.1, 1.2
	S-O-R	5N-AA3-6X3PP	250F<	Ambient	5.0 E04>	1.1, 1.2
Zion 1	Barksdale	9672-3	375F	43.7	ND	T4 ELEV:ND
Cooper	Barksdale	B2T-A12SS	NA>	NA	7.95 E0=	R-931 NW
	Barksdale	B2T-M12SS	NA>	NA	7.95 E0=	R-931 NW
	Barksdale	B2T-M12SS	NA>	NA	7.95 E0=	R-931 NM
	Barksdale	B2T-M12SS	NA>	NA	7.95 E0=	R-931 NW
	Barksdale	B2T-M12SS	NA>	NA	7.95 E0=	R-881 NE Quad
	Barksdale	B2T-M12SS	NA>	NA	7.95 E0=	R-859 SW Quad
	Barksdale	B2T-M12SS	NA>	NA	7.95 E0=	R-859 NE Quad
	Barksdale	B2T-M12SS	NA>	NA	7.95 E0=	R-859 SE Quad
	Barksdale	D2H-A150SS	NA>	NA	7.95 E0=	R-881 NE Quad
	Barksdale	D2H-A150SS	NA>	NA	7.95 E0=	R-881 NE
	Barksdale	D2H-M80SS	NA>	NA	7.95 E0=	R-881 NE Quad
	Barksdale	D2T-M150SS	NA>	NA	7.95 E0=	R-931 NE Quad
	S-O-R	12N-AA4	NA>	NA	7.95 E0=	R-931 NW
	S-O-R	12N-AA4-N	NA>	NA	7.95 E0=	R-931 NW
	S-O-R	12N-BB-5-N	NA>	NA	7.95 E0=	R-931 NW
	S-O-R	12N-BB-4-N	NA>	NA	7.95 E0=	R-931 NW
	S-O-R	4NN-H5	NA>	NA	1.75 E05<	D-931-WW(A) SE(B)
	S-O-R	4NN-H5	NA>	NA	1.75 E05<	R-903-SE(B) NE
	S-O-R	5N-AA3	NA>	NA	7.95 E0=	R-881-NE Quad
	S-O-R	5N-AA3	NA>	NA	7.95 E0=	R-859-SW Quad
	S-O-R	5N-AA3	NA>	NA	7.95 E0=	R-859-SW Quad
	S-O-R	5N-AA3-2X	NA>	NA	7.95 E0=	R-859-NE Quad
	S-O-R	5N-AA3-2X	NA>	NA	7.95 E0=	R-859 Quad
	S-O-R	5N-AA3-2X	NA>	NA	7.95 E0=	R-859 SE Quad
	S-O-R	5N-AA3-SX	NA>	NA	7.95 E0=	R-859 NE Quad
	S-O-R	6N-AA21V	NA>	NA	7.95 E0=	R-859 SW Quad
	S-O-R	6NN-Y3-S1TTXG	NA>	NA	7.95 E0=	R-859 NW Quad
	S-O-R	9N-AA45-X9TT	NA>	NA	7.95 E0=	R-931 NW

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Brunswick 1 & 2	Barksdale	P1H-M340SS	C	D	1 E07=	?
	Barksdale	P1H-M340SS	C	D	1 E07=	Outside Containment
	Barksdale	P1H-M340SS	C	D	1 E07=	Outside Containment
	Barksdale	P1H-M340SS-V	MM	NN	1 E07=	Outside Containment
	Barksdale	P1H-M340SS-V	E	F	1 E05=	?
	Barksdale	TC-9622-1	C	D	1 E07=	Outside Containment
	Barksdale	TC-9622-1	C	D	1 E07=	Outside Containment
	Barksdale	D2T-M18SS	C	D	1 E07=	Outside Containment
	Barksdale	D2T-M18SS	KK	LL	1 E07=	Outside Containment
	Barksdale	P1H-M340SS	C	D	1 E07=	?
	Barksdale	P1H-M340SS	C	D	E07=	Outside Containment
	Barksdale	P1H-M340SS	C	D	1 E07=	Outside Containment
	Barksdale	P1H-M340SS-V	MM	NN	1 E07=	Outside Containment
	Barksdale	P1H-M87SS-V	E	F	1 E05=	?
	Barksdale	TC-9622-1	C	D	1 E07=	Outside Containment
	Barksdale	TC-9622-1	C	D	1 E07=	Outside Containment
	S-O-R	12N-AA4-X10TT	E>	F	1 E05>	Outside Containment
	S-O-R	12N-AA4-X10TT	E>	F	1 E05>	Outside Containment
	S-O-R	12N-AA4-X10TT	E>	F	1 E05>	?
	S-O-R	12N-AA4-X10TT	E>	F	1 E05>	?
	S-O-R	5N-AA3-X9TT	MM>	NN	1 E07=	Outside Containment
	S-O-R	5N-AA3-X9TT	MM>	NN	1 E07=	Outside Containment
	S-O-R	5N-AA3-X9TT	MM>	NN	1 E07=	Outside Prim Containment
	S-O-R	6N-AA21-X9SVTT	C>	D	1 E07=	Outside Containment
	Barksdale	B2T-M12SS	NA>	NA	1 E05=	?
	Barksdale	B2T-M12SS	NA>	NA	1 E07=	Outside Containment
	Barksdale	B2T-M12SS	NA>	NA	1 E05>	Outside Containment
	Barksdale	B2T-M12SS	NA>	NA	1 E07>	Outside Containment
	Barksdale	B2T-M12SS	NA>	NA	1 E05=	Outside Containment
	Barksdale	D2H-M150SS	NA>	NA	1 E05=	Outside Containment
	Barksdale	D2H-M150SS	NA>	NA	1 E07=	Outside Containment
	Barksdale	D2T-M150SS	NA>	NA	1 E07=	Outside Containment
	Barksdale	D2T-M18SS	NA>	NA	1 E07=	Outside Containment
	Barksdale	D2T-M18SS	NA>	NA	1 E07=	Outside Containment
	Barksdale	P1H-M340SS	NA>	NA	1 E07=	Outside Containment
	Barksdale	P1H-M340SS	NA>	NA	1 E05=	Outside Containment
Brunswick 1 & 2	S-O-R	12N-AA4-X10TT	NA	NA	1 E05>	Outside Containment
	S-O-R	12N-AA4-X10TT	NA	NA	1 E05>	Outside Containment
	S-O-R	12N-AA4-X10TT	NA	NA	1 E05>	Outside Containment
	S-O-R	12N-AA4-X10TT	NA	NA	1 E05>	Outside Containment
	S-O-R	12N-AA4-X10TT	NA	NA	1 E05>	Outside Containment
	S-O-R	12N-AA4-X10TT	NA	NA	1 E05>	Outside Containment
	Barksdale	T2H-M2515-12	NA	NA	1 E05=	Outside Containment

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Crystal River 3	S-O-R	12N-K5-CM2	N2>	19.15	1.0 E04	INT Building EL 95'
	S-O-R	12N-K5-CM2	Ambient	14.17	1.0 E04	INT Building EL 95'
	S-O-R	9R2YY5NCXJ	N4>	19.15	1.0 E04	Intermediate Building E
Zion 2	Barksdale	9672-3	375F	43.7	ND	T4 ELEV
Arkansas Nuclear One	Barksdale	B2TMT2SS	100F	14.7	4.9 E02	Out of Containment
	Barksdale	B2TMT2SS	100F	14.7	4.9 E02	Out of Containment
	S-O-R	9NN ES-C1X8	100F	14.7	4.9 E02	Out of Containment
	S-O-R	9NN ES-C1X8	100F	14.7	4.9 E02	Out of Containment
	S-O-R	0MN ES-C1X8	100F	14.7	4.9 E02	Out of Containment
	S-O-R	0MN ES-C1X8	100F	14.7	4.9 E02	Out of Containment
Hatch 1	Barksdale	B2T-M12SS	210F>	15.4	1.2 E06	Reactor Building Elevation 158'
	Barksdale	B2T-M12SS	214F<	16.7	5.1 E04	Reactor Building Elevation 130'
	Barksdale	B2T-M12SS	148F>	14.7	1.86 E0	SE Corner Room
	Barksdale	B2T-M12SS	148F>	14.7	1.86 E0	SE Corner Room
	Barksdale	B2T-M12SS	148F>	14.7	1.86 E0	NE & SE Corner Rooms
	Barksdale	B2T-M12SS	214F>	16.7	5.1 E04	Reactor Building Elevation 130'
	Barksdale	B2T-M12SS	148F>	26.6	1.4 E06	HPCI Room
	Barksdale	B2T-M12SS	214F>	16.7	5.1 E04	Reactor Building Elevation 130'
	Barksdale	D2H-M80SS	310F<	16.7	1.4 E06	SW Corner Room
	S-O-R	12N-AA4-(X9)TT	210F<	15.4	1.2 E06	Reactor Building Elevation 158'
	S-O-R	12N-AA5-(X9)TT	210F>	15.4	1.2 E06	Reactor Building Elevation 158'
	S-O-R	12N-AA5-(X9)TT	210F>	15.4	1.2 E06	Reactor Building Elevation 158'
	S-O-R	5N-AA3-(X10)-SE	148F>	26.6	1.4 E06	HPCI Room
	S-O-R	5N-AA3-(X10)-S17	148F>			
	S-O-R	5N-AA3-(X10)S1T	148F>	14.7	1.86 E0	NE Corner Room
	S-O-R	5N-AA3-(X10)S1T	148F>	14.7	1.86 E0	NE & SE Corner Rooms
	S-O-R	6N-AA2-(X10)S1	148F>	26.6	1.4 E06	HPCI Room
	S-O-R	6N-AA21-(X100)V	148F>	26.6	1.4 E06	HPCI Room
	S-O-R	6NN-K3-Y1	300F	NA	1.8 E14	Containment?
	S-O-R	6NN-K3-Y1	300F	NA	1.8 E14	Containment
	S-O-R	7924-100	148F>	14.7	1.8 E14	NE & SE Corner Rooms?
Brunswick 1 & 2	Barksdale	B2T-M12SS	E	F	1 E05=	?
	Barksdale	B2T-M12SS	E	F	1 E05>	Outside Containment
	Barksdale	B2T-M12SS	E	F	1 E05>	Outside Containment
	Barksdale	B2T-M12SS	E	F	1 E05>	Outside Containment
	Barksdale	B2T-M12SS	C	D	1 E07>	?
	Barksdale	B2T-M12SS	E	F	1 E05>	Outside Containment
	Barksdale	B2T-M12SS	E	F	1 E05>	Outside Containment
	Barksdale	B2T-M12SS	C	D	1 E07=	Outside Containment
	Barksdale	D2H-M150SS	C	D	1 E07=	Outside Containment
	Barksdale	D2H-M150SS	C	D	1 E07=	Outside Containment
	Barksdale	D2T-M18SS	C	D	1 E07=	Outside Containment
	Barksdale	D2T-M18SS	KK	LL	1 E07=	Outside Containment

PLANT NAME	MANUFACTURER	MODEL NO.	S TEMP	S PRESSURE	S RAD	LOCATION
Duane Arnold	Barksdale	B2T-M12SS	ND	ND	ND	SE Corner Room
	Barksdale	D2T-A80	ND	ND	ND	HPCI Room Rack/C-12
	Barksdale	D2T-M18SS	ND	ND	ND	SE Corner Room Rack 10
	S-O-R	12N-AA5	ND	ND	ND	SE Corner Room Rack
	S-O-R	5N-AA3	ND	ND	ND	HPCI Room Rack 10-1
	S-O-R	5N-AA3	ND	ND	ND	HPCI Room Rack 12
	S-O-R	5N-AA3	ND	ND	ND	Reactor Building North
	S-O-R	5N-AA3	ND	ND	ND	HPCI Room Rack 10-12
	S-O-R	6N-AA2	ND	ND	ND	Torus Room South EL
	S-O-R	6N-AA21VX9STT	ND	ND	ND	
Fitzpatrick	Barksdale				4.05 E0	Outside
	S-O-R	5N-AA3			9.38 E0<	EL 242'-8" Rack 25-5
	S-O-R	5N-AA3			9.38 E0<	EL 242'-8" Rack 25-5
	S-O-R	6N-AA21-V			9.38 E0<	EL 242'-8" Rack 25-5
	S-O-R	6N-AA3-(X9)-STT			9.38 E0<	EL 242'-8" Rack 25-5
	S-O-R	6N-AA3-(X9)-579			9.38 E0<	Reactor Building Rack 25
Hatch 2	S-O-R	22R3-K614-C1T	160	14.76	5.1 E04	Reactor Building EL 130'
	S-O-R	22R3-K614-C1T	160	14.76	5.1 E04	Reactor Building EL 130'
	Barksdale	B2T-M12SS	210>	15.06	1.2 E06	Reactor Building EL 158'
	Barksdale	B2T-M12SS	160>	14.76	5.1 E04	Reactor Building EL 130'
	Barksdale	B2T-M12SS	145>	14.7	1.52 E0	Nelse Corner Rooms
	Barksdale	B2T-M12SS	145>	14.7	1.52 E0	Nelse Corner Rooms
	Barksdale	B2T-M12SS	145>	14.7	1.52 E0	Nelse Corner Rooms
	Barksdale	B2T-M12SS	145>	14.7	1.52 E0	Nelse Corner Rooms
	Barksdale	B2T-M12SS	160>	14.76	5.1 E04	Reactor Building EL 13
	Barksdale	B2T-M12SS	100>	27.4	2.4 E06	HPCI Room, Note 3
	Barksdale	B2T-M12SS	100>	27.4	2.4 E06	HPCI Room, Note 3
	Barksdale	B2T-M12SS	160>	14.76	5.1 E04	Reactor Building EL 130'
	Barksdale	D2H-M150SS	100>	27.4	2.0 E06	Low
	Barksdale	D2H-M18SS	210>	15.06	1.2 E06	Reactor Building EL 158'
	Barksdale	D2H-M18SS	210>	15.06	1.2 E06	Reactor Building EL 158'
	Barksdale	D2H-M18SS	210>	15.06	1.2 E06	Reactor Building EL 158'
	Barksdale	D2H-M80SS	310<	16.23	2.4 E06	RCIC (NW) Corner Room
	S-O-R	6N-AA21-(X9)-VS	100>	27.4	2.4 E06	Low
	S-O-R	6NN-R3-Y1	310	NA	1.8 E14	Containment
	S-O-R	6NN-R3-Y1	310	NA	1.8 E14	Containment
	S-O-R	7924-100	145>	14.7	1.52 E0	Nelse Corner Room

APPENDIX B

Seismic Test of Ten Pressure Switches,

SWRI-7279-001, Dated 10/29/82

TEST REPORT

SEISMIC TEST OF
TEN PRESSURE SWITCHES

for

SANDIA NATIONAL LABORATORIES
Albuquerque, NM 87185

by

SOUTHWEST RESEARCH INSTITUTE
6220 Culebra Road
San Antonio, Texas 78284

SwRI-7279-001

October 29, 1982

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TEST REPORT

1.0 PURPOSE

The purpose of this test report is to describe the tests performed on ten unaged pressure switches for Sandia National Laboratories of Albuquerque, New Mexico. The tests were performed in accordance with Sandia's Test Plan, "Equipment Qualification Methodology Research Test Using Pressure Switches", Reference 2.1; Section 11.1.1, Unaged DBE Test. The switches underwent preliminary seismic tests to provide baseline data for comparison against pressure switches which will be aged and then tested to the same seismic response spectrum.

2.0 REFERENCES

2.1 Sandia National Laboratories Test Plan for "Equipment Qualification Methodology Research Test Using Pressure Switches", Document FIN A1355, Rev. 4, dated 10 September 1982.

2.2 SwRI Division 06 Nuclear Projects Operating Procedure XI-EE-101-2, Seismic Test of Electrical and Mechanical Components, November, 1981.

2.3 SwRI Division 06 Nuclear Projects Operating Procedure XII-EE-101-3, Calibration of Mechanical Sciences Dynamics Test Equipment, November, 1981.

3.0 TEST ITEM IDENTIFICATION

The following ten pressure switches were seismically tested:

Manufacturer	Model	Number Tested	Serial Numbers
Barksdale	D2H-A150SS	2	None
Barksdale	B2T-M12SS	2	None
SOR, Inc.	4N6-E45-NX-C1A-GGX5	2	82-5-1647, 82-5-1649
SOR, Inc.	5N-AA3X-S1-X2	2	82-5-1632, 82-5-1643
SOR, Inc.	12N-AA4X-X3	2	82-5-1635, 82-5-1637

4.0 TEST FACILITY

4.1 Location

Southwest Research Institute
Department of Engineering Mechanics
6220 Culebra Road
San Antonio, Texas 78284

4.2 General Purpose

This facility has the capability of realistic simulation of an earthquake dynamic environment as well as all accepted standard approximations of such an environment. It has been designed principally for qualification testing of typical components to be used in nuclear and conventional power generation stations. It is also particularly suited to the study of structural scale model responses to seismic excitation. It can further be used as a general purpose shaker facility within its range of operation, and therefore can simulate nuclear plant operating transients.

4.3 Mechanical Table Description

A mounting surface of up to 6 by 6 foot can be excited with simultaneous vertical and horizontal motion that is arbitrary and independent along each axis. Extenders are utilized for mounting somewhat larger specimens, when necessary. Maximum table payload capacity is 6,000 pounds deadweight. Drive mechanisms are servo-controlled electro-hydraulic, and having the following capabilities:

	Horizontal	Vertical
Frequency Range	0-250 Hz	0-250 Hz
Force Capacity	10,000 lb	20,000 lb
Maximum Stroke	8.0 in.	7.0 in.
Maximum Velocity	90 in./sec	22 in./sec
Maximum Acceleration*	10 g	10 g

*At zero payload.

4.4 Associated Instrumentation

Excitation signals are provided typically by function generators or actual seismic signals recorded on analog instrumentation tape. Table displacement is accurately controlled at low to medium frequencies by automatic feedback to respond to an arbitrary voltage signal. Deterioration in control is experienced at higher frequencies such that open-loop operation is necessary in this range. Table responses are monitored by accelerometers whose outputs can be analyzed according to several standard parameters. Acceleration or velocity response spectrum can be computed and plotted within seconds by a Spectral Dynamics SD321 Shock Spectrum Analyzer, or by a DEC PDP 1170 computer system. Power spectral density can be computed by a Nicolet Scientific UA500A Real Time Analyzer or a Nicolet 444A FFT Analyzer. Probability density and other associated statistical parameters are computed with a Saicor 43A Real Time Analyzer or with a Zonic multichannel FFT processor. All time histories can be recorded on analog or digital tape, on oscillographs, or monitored on oscilloscopes. Large volumes of data are usually recorded first on analog tape and then digitized fo processing through a digital system which includes a DEC PDP 1170 computer as its central processor.

4.5 The Digitizing Process

The digitization process is carried out via equipment located in the Laboratory Data Processing Center. The equipment used to perform the analog to digital operations consists of 14 channels of high speed bandpass filters and operational amplifiers, and 14 channels of high speed A/D converters housed in a CAMAC crate. An external trigger source consisting of a square wave set at 5 volts zero to peak at the desired digital sampling rate is used to pulse the ADC units to begin the data transfer. Each ADC unit has a 40 kHz sample rate, however, the maximum overall channels, via transfer to the PDP 11/70 is on the order of 50 kHz. Thus, the system is quite sufficient for most earthquake simulation data analyses. At the present time, the software used with the system limits the A/D process to eight channels.

5.0 TEST EQUIPMENT IDENTIFICATION

The equipment used for simulation of the dynamic environment, acquisition and processing of dynamic data is given in Table 5.1.

Sandia personnel performed the functionality checks and also provided all equipment necessary for these checks.

6.0 CALIBRATION

Instrumentation calibration was performed in accordance with the Engineering Sciences Division Nuclear Projects Operating Procedure XII-EE-101-3, "Calibration of Mechanical Sciences Dynamics Test Equipment."

All accelerometers were calibrated using reference standard Kistler 808K/561T which is traceable to the National Bureau of Standards.

A terminal peak sawtooth signal is used for calibrating the digital response spectrum subroutine used in the Division 06 DECPDP 1170 computer system and A to D system and comparing the results with the analytically known results.

The Hewlett-Packard 3964A tape recorder was used solely as a signal source and was not calibrated on an absolute basis.

7.0 TEST METHOD

7.1 Purpose of Tests

The purpose of these tests was to expose the test items identified in Section 3.0 to the seismic environment described by Figures II and III, in accordance with Section 11.1.1 of Sandia's Test Plan, Reference 2.1.

TABLE 5.1 EQUIPMENT LIST

MECHANICAL SCIENCES DYNAMICS EQUIPMENT LIST 17-MAR-82 REV. 1

NO	ITEM	MAKE	MODEL	SERIAL	REMARKS
4	SWEEP OSCILLATOR	SPECTRAL DYNAM	SD104A-5	1119	FC 3 DECADE SW
10	POWER AMPLIFIER	TEAM	1528	102	FC PILOT VALVE
11	ACCELEROMETER	ENDEVCO	2221D	JC 15	BU 1-5000 HZ
18	ACCELEROMETER	ENDEVCO	2220	MD-75	BU 1-5000 HZ
25	ACCELEROMETER	ENTRAN	EGC-500DS-20	27C7D-M3-3	BU 20G
26	ACCELEROMETER	ENTRAN	EGC-500DS-20	30H8I-R8-8	BU 20G
28	ACCELEROMETER	ENTRAN	EGC-500DS-20	30H8IR1212	BU 20G
41	AMPLIFIER	KISTLER	504	864	BU CHARGE
43	AMPLIFIER	KISTLER	504D	1545	BU CHARGE
57	OP. AMP. MANIFOL	ANALOG DEVICES	194	136	BU ANALOG OPNS.
65	ACCELEROMETER	BELL & HOWELL	4-202-0001	19742	6M HORIZ. TABLE
66	ACCELEROMETER	BELL & HOWELL	4-202-0001	22529	6M VERT. TABLE
67	CONTROLLER	TEAM	1522		6M HORIZ. TABLE
69	CONTROLLER	SWRI		2	6M VERT. TABLE
77	OSCILLOSCOPE	TEKTRONIX	5111	B118209	6M STORAGE
78	SCOPE PLUG-IN	TEKTRONIX	5A14N	B053025	6M 4-CHANNEL
79	SCOPE PLUG-IN	TEKTRONIX	5A14N	B053045	6M 4-CHANNEL
80	SCOPE PLUG-IN	TEKTRONIX	5B12N	B065791	6M DUAL TIME BASE
83	TAPE RECORDER	AMPEX	FR 1800 L	7040122	6M 14-CHANNEL
87	DIGITAL SERVO DI	TEAM	1564	102	6M W/ TEAM 1522
93	ACCELEROMETER	ENTRAN	EGC-500DS-20	2TITR20-20	BU 20 G
94	ACCELEROMETER	ENTRAN	EGC-500DS-20	2TIT-E14-1	BU 20 G
95	ACCELEROMETER	ENTRAN	EGC-500DS-20	2TITR15-15	BU 20 G
96	ACCELEROMETER	ENTRAN	EGC-500DS-20	21VOT1R7-1	BU 20 G
97	ACCELEROMETER	ENTRAN	EGC-500DS-20	20L8T1R9-2	BU 20 G
115	TAPE RECORDER	HEWLETT-PACK	3964A	1925A01016	BU 4-CHAN
128	CAMAC	STANDARD ENGR.	PS3742	2318	1Y HI-BAY SYSTEM
129	COMPUTER	DEC	11/23	WF17625	FC HI-BAY SYSTEM

In addition the following equipment was also used.

HARD COPY	TEKTRONIX	4611	B012330	FC THERMAL
TERMINAL	TEKTRONIX	4051	B093725	FC GRAPHICS
AMPLIFIER CARD POWER SUPPLY		SwRI	None	FC $\pm$ 15 VDC

7.2 Preliminary Tests

The preliminary drive signals were created by our computer using the RRS break points and table transfer functions. The table transfer functions, which were previously measured from several different mass and center of gravity configurations, are stored in the computer. The transfer functions, horizontal and vertical, are selected from the mass and center of gravity configuration which most closely matches the test item mass and center of gravity. Drive signals for each run were formed by a digital computer process which is described by the diagram in Figure 7.1. This synthesis process is accomplished within the computer by operating on 34 bands of narrow band random data, each of 1/6 octave bandwidth. The amplitude of each band is modified according to the RRS and table transfer function in that band. The final result is summed together and a proportional analog time history is formed for each axis independently.

7.3 Test Item Mounting

The test items were supplied already mounted on two test fixtures provided by Sandia. The test fixtures were made of six stainless steel plates bolted to a stainless steel frame in a hexagonal arrangement. A line diagram of the test fixtures can be found in Figure I of the test plan, Reference 2.1. Photographs of the test fixtures with the test items mounted on the SwRI biaxial shake table are shown in Figures 9.1 and 9.2. Two methods were used to mount the test fixtures to the biaxial shake table. The first method which was used for the X-Z axis OBE tests utilized four 9/16-12 hex head bolts and four 1-3/4" x 1-1/2" angeled washers. The washers were placed over the bottom edge of four of the stainless steel box beams and the bolts were then tightened as shown in Figure 9.5. The second method was employed to allow the test items to be rotated 90^{0} and was used for the remainder of the tests. In this case a 3/4-10 threaded rod was screwed into the table top and a one inch aluminum round plate was slipped over the rod. The plate was secured against the test fixture with a nut as shown in Figure 9.6. Either of the methods described above provided the test fixtures with secure and rigid mounting to the shake table top. The locations of the test items on the test fixtures during seismic tests are shown in Figures 7.2 and 7.3 for the X-Z and Y-Z axis test respectively.

7.4 Seismic Test Procedure

Full level seismic tests of 30 seconds duration were conducted for each of the two orientations. A series of five OBE tests were conducted in the X-Z axis. The test items were then turned 90^{0} and a series of five OBE tests were conducted in the Y-Z axis. A functional check of the test items was then conducted by Sandia personnel. Subsequent to the functional check a series of three SSE level tests were run in the Y-Z axis. The reason for the extra tests during the SSE level runs was that the TRS failed to envelope the RRS. During the third SSE level test in the Y-Z axis the horizontal TRS enveloped the RRS, however there was one point at 5.5Hz which was below the RRS of the Vertical Response Spectrum. This was acceptable to Sandia personnel and further SSE tests were not repeated in the Y-Z axis. The test items were then rotated 90^{0} for the SSE level test in the X-Z axis. Prior to

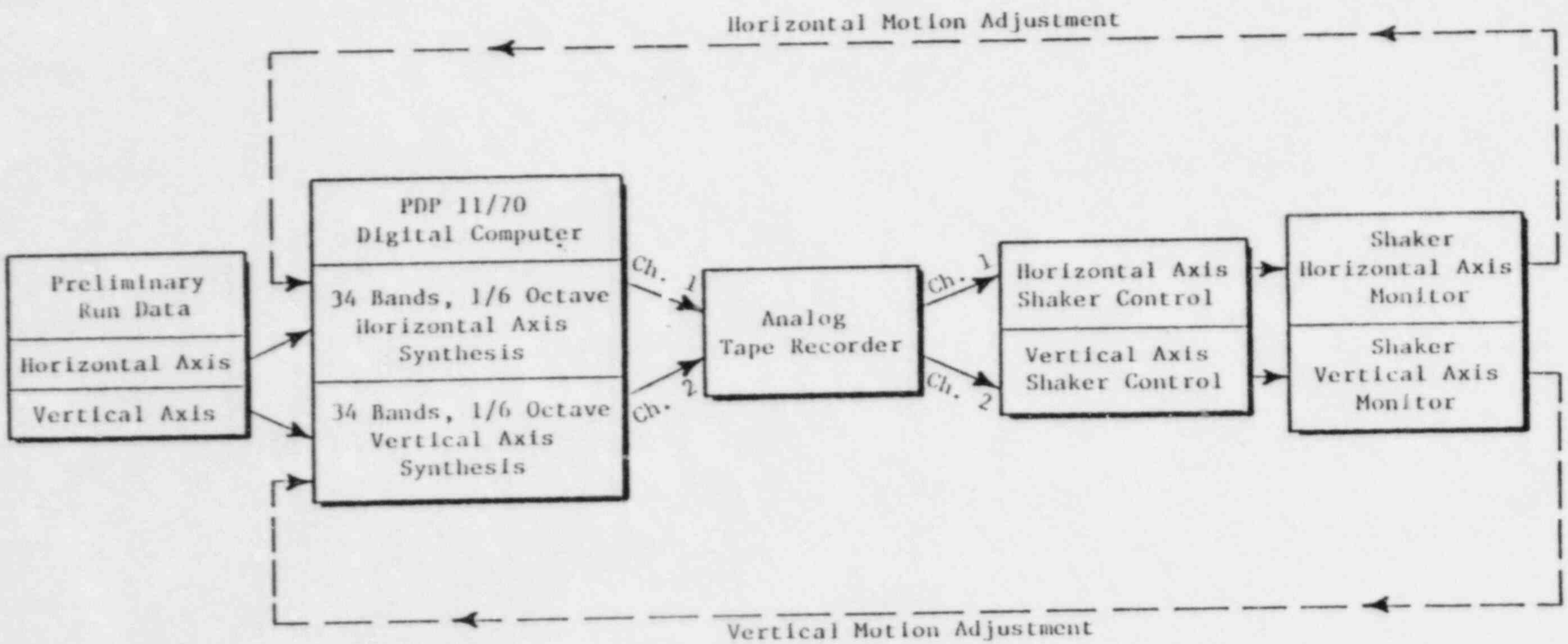


Figure 7.1 OBE and DBE Shaker Table Drive

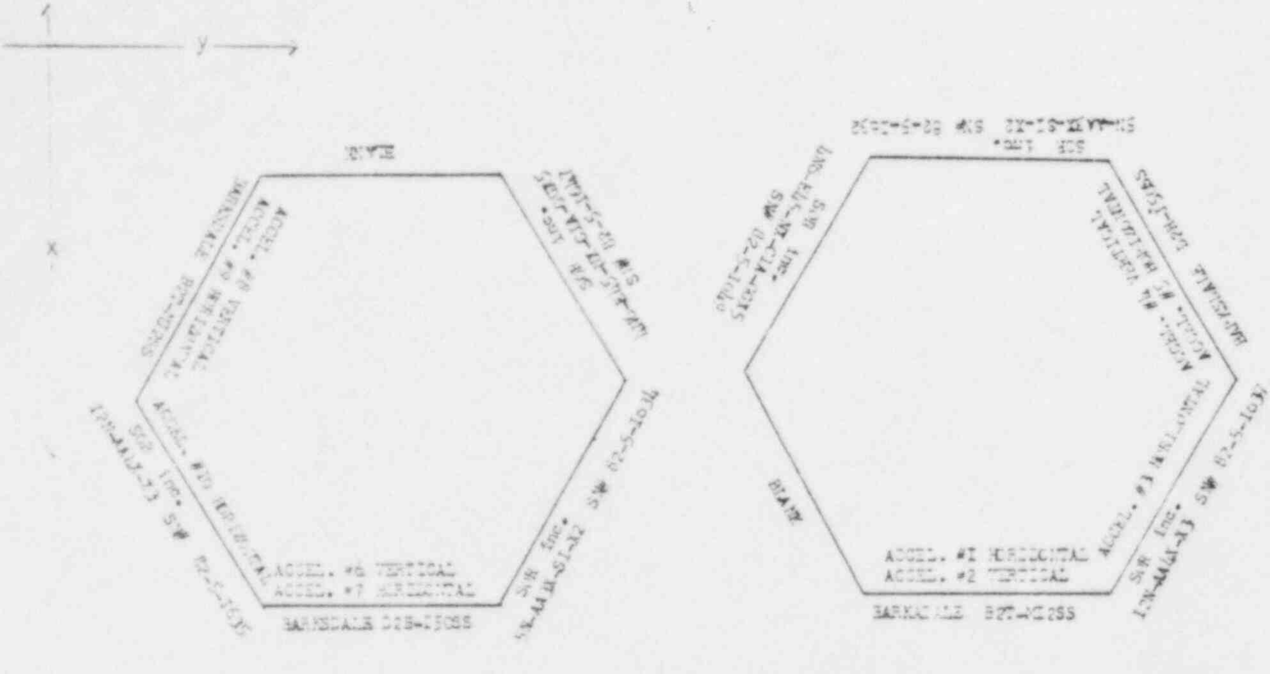


Figure 7.2 Locations of Pressure Switches During X-Z Seismic Tests. Also shown are the Response Accelerometer Locations used to monitor the items during tests.

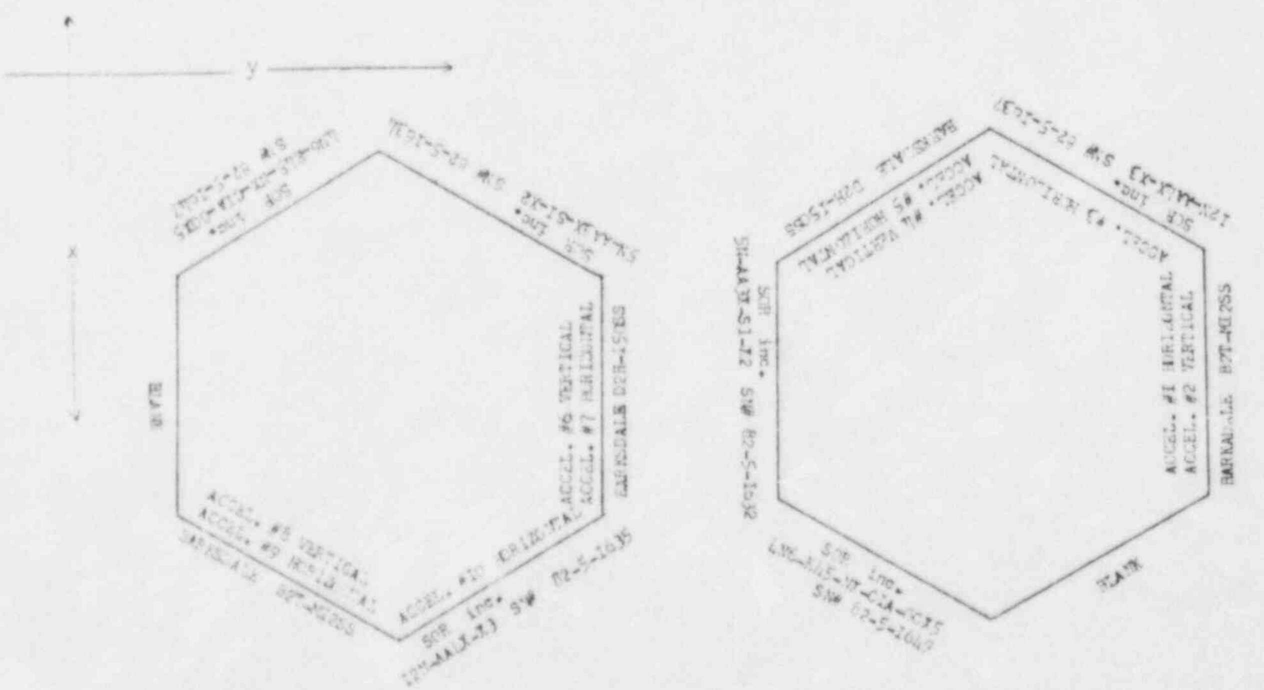


Figure 7.3 Locations of Pressure Switches During Y-Z Seismic Tests. Also shown are the Response Accelerometer Locations used to monitor the items during tests.

the SSE test in the X-Z axis the volume on the shake tables hydraulic power supply was increased. It had been determined that an increase of the hydraulic pow^^ supply's volume was needed to drive the table to envelope the RRS. One SSE level test was run in the X-Z axis with the TRS enveloping the RRS. Verification of table motion enveloping the TRS over the RRS was performed with the DEC PDP 11/23 computer for all the OBE and SSE level runs. Response data plots at 2.0% damping are shown in Section 10.0.

7.5 Structural Response Measurements

During the random motion tests the outputs of ten response accelerometers placed on several of the pressure switches were recorded on magnetic tape. The specific locations of the response accelerometers are shown in Figures 9.3 and 9.4. The following is a listing of the specific accelerometer locations.

Accelerometer No. 1 - Horizontal on Barksdale B2T-M12SS mounted on test fixture 1.

Accelerometer No. 2 - Vertical on Barksdale B2T-M12SS mounted on test fixture 1.

Accelerometer No. 3 - Horizontal on SOR Inc. 12N-AA4X-X3, SN#82-5-1637 mounted on test fixture 1.

Accelerometer No. 4 - Vertical on Barksdale D2H-A150SS mounted on test fixture 1.

Accelerometer No. 5 - Horizontal on Barksdale D2H-A150SS mounted on test fixture 1.

Accelerometer No. 6 - Vertical on Barksdale D2H-150SS mounted on test fixture 2.

Accelerometer No. 7 - Horizontal on Barksdale D2H-150SS mounted on test fixture 2.

Accelerometer No. 8 - Vertical on Barksdale B2T-M12SS mounted on test fixture 2.

Accelerometer No. 9 - Horizontal on Barksdale B2T-M12SS mounted on test fixture 2.

Accelerometer No. 10 - Horizontal on SOR Inc. 12N-AA4X-X3, SN#82-5-1635 mounted on test fixture 2.

TRS plots at 2.0% damping for the above accelerometer locations for the OBE and SSE level tests in the X-Z and Y-Z orientations are shown in Figures 10.29 to 10.162. During the first test in the X-Z axis the charge amplifiers for accelerometers 9 and 10 were not turned on, so there is no data for these channels during OBE X-Z 1. While digitizing the data it was discovered that there was no data on the tape for the No. 10 response accelerometer during any of the SSE level runs. This loss of data was probably due to a recording error during the SSE level runs. It should also be noted that during the seismic tests some of the response accelerometers were not directly in-line with the axis of excitation. For the X-Z and Y-Z axis seismic tests, accelerometers 3, 5, 9 and 10 were at an angle in comparison to the input excitation. This causes the accelerometers to have less of an output signal than the excitation actually felt by the test items. The RRS for all runs has been included on the plots so that a comparison can be made between the RRS and the actual response of the test items monitored.

7.6 Summary of Seismic Tests Performed

Table 7.1 contains a summary of the seismic tests performed on ten pressure switches.

Table 7.1 SUMMARY OF SEISMIC TESTS

Axis of Excitation	Test Level and Number	Horizontal TRS	Vertical TRS
X-Z	OBE#1	Fig. 10.1	Fig. 10.2
X-Z	OBE#2	Fig. 10.3	Fig. 10.4
X-Z	OBE#3	Fig. 10.5	Fig. 10.6
X-Z	OBE#4	Fig. 10.7	Fig. 10.8
X-Z	OBE#5	Fig. 10.9	Fig. 10.10
Y-Z	OBE#1	Fig. 10.11	Fig. 10.12
Y-Z	OBE#2	Fig. 10.13	Fig. 10.14
Y-Z	OBE#3	Fig. 10.15	Fig. 10.16
Y-Z	OBE#4	Fig. 10.17	Fig. 10.18
Y-Z	OBE#5	Fig. 10.19	Fig. 10.20
Y-Z	SSE#1	Fig. 10.21	Fig. 10.22
Y-Z	SSE#1A	Fig. 10.23	Fig. 10.24
Y-Z	SSE#1B	Fig. 10.25	Fig. 10.26
X-Z	SSE#1	Fig. 10.27	Fig. 10.28

7.7 Analog Tape Log

TABLE 7.2 ANALOG TAPE LOG

Tape speed 3-3/4 ips

Tape channel designation and accelerometer location

Channel 1, AH, Horizontal Table Accelerometer

Channel 2, AV, Vertical Table Accelerometer

Channel 3, AHR, Horizontal Response Accelerometer on Barksdale B2T-M12SS

Channel 4, AVR, Vettical Response Accelerometer on Barksdale B2T-M12SS

Channel 5, AHR, Horizontal Response Accelerometer on SOR Inc.12N-AA4X-X3, SN#82-5-1637

Channel 6, AVR, Vertical Response Accelerometer on Barksdale D2H-A150SS

Channel 7, AHR, Horizontal Response Accelerometer on Barksdale D2H-A150SS

Channel 8, AVR, Vertical Response Accelerometer on Barksdale D2H-A150SS

Channel 9, AHR, Horizontal Response Accelerometer on Barksdale D2H-A150SS

Channel 10, AVR, Vertical Response Accelerometer on Barksdale B2T-M12SS

Channel 11, AHR, Horizontal Response Accelerometer on Barksdale B2T-M12SS

Channel 12, AHR, Horizontal Response Accelerometer on SORinc. 12N-AA4X-X3 SN#82-5-1635

Tape Footage	Data
72	Sine wave cal., 1g peak @ 10Hz
98	OBEXZ1
123	OBEXZ2
151	OBEXZ3
177	OBEXZ4
203	OBEXZ5
228	OBEYZ1
254	OBEYZ2
278	OBEYZ3
306	OBEYZ4
333	OBEYZ5
358	SSEYZ1
385	SSEYZ1A
413	SSEYZ1B
439	SSEXZ1

8.0 RESULTS AND CONCLUSIONS

8.1 Results

Visual inspection of the test items revealed no apparent physical damage. Functional checks of the test items electrical functions indicated no loss of functionality before or after seismic tests.

All functional checks were performed by Sandia personnel.

8.2 Conclusions

All mechanical and electrical systems were functional before and after the tests. It is our conclusion that the test specimens identified in Section 3.0 did pass the seismic tests when tested in accordance with the Test Plan, Reference 2.1, Section 11.1.1.

SECTION 9.0

PHOTOGRAPHS

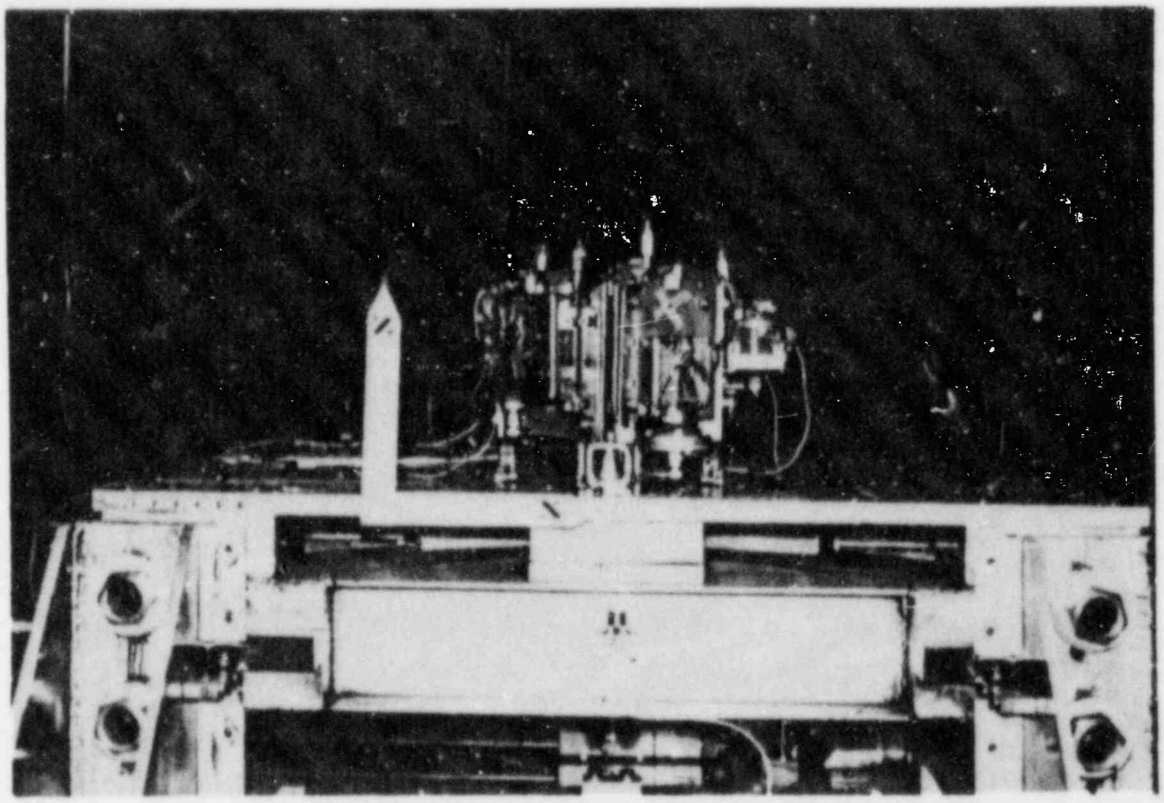


Figure 9.1 View of Test Items mounted on SwRI biaxial shake table for X-Z Random Tests.

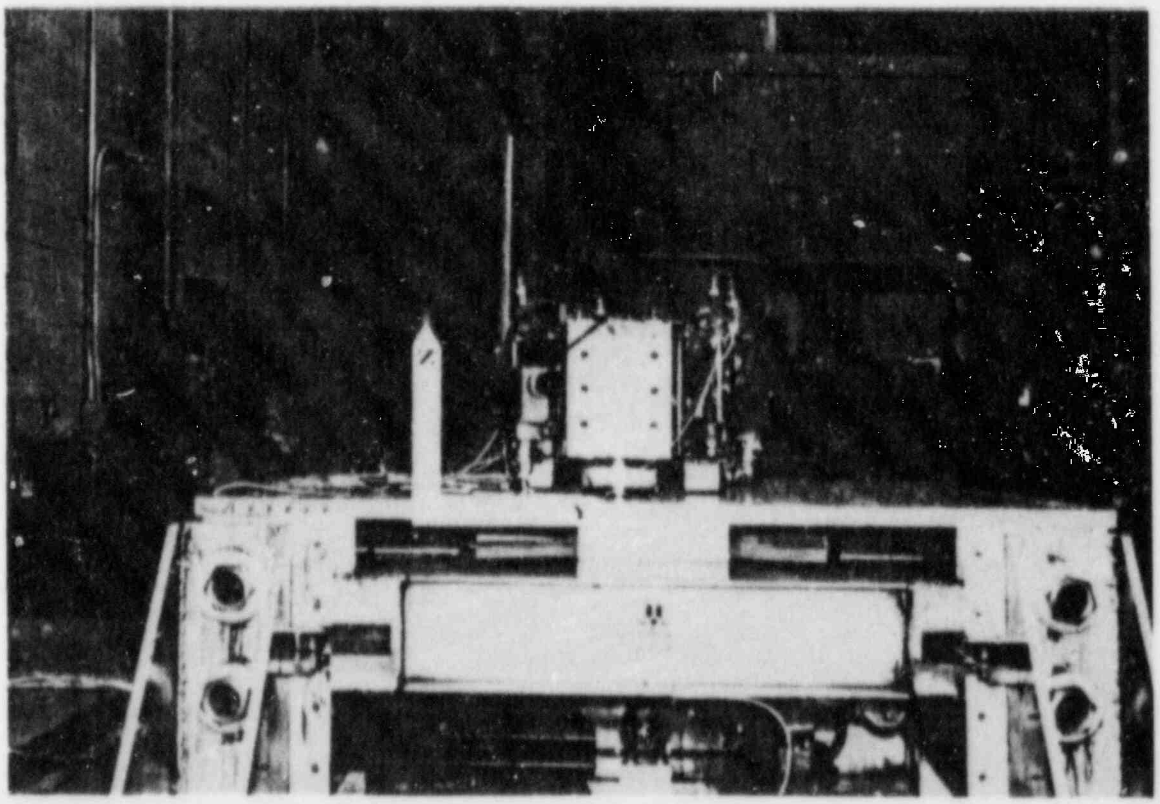


Figure 9.2 View of Test Items mounted on SwRI biaxial shake table for Y-Z Random Tests.

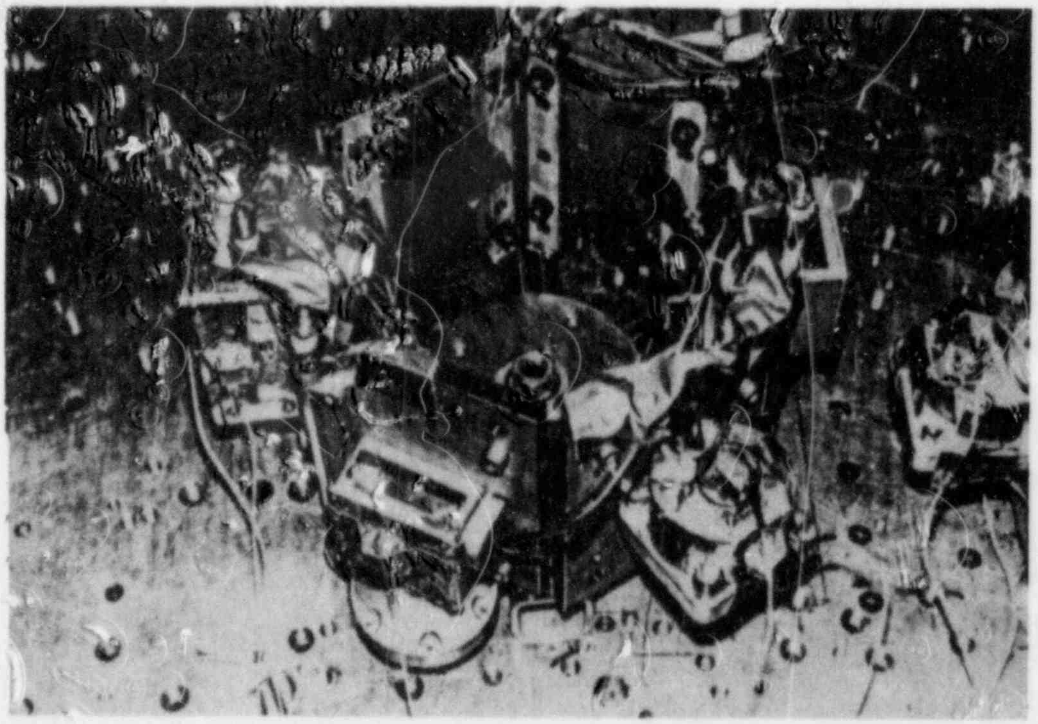


Figure 9.3 View of Accelerometer locations on pressure switches which were mounted on Test Fixture No. 1. The response Accelerometers used to monitor the items during seismic tests are shown circled.

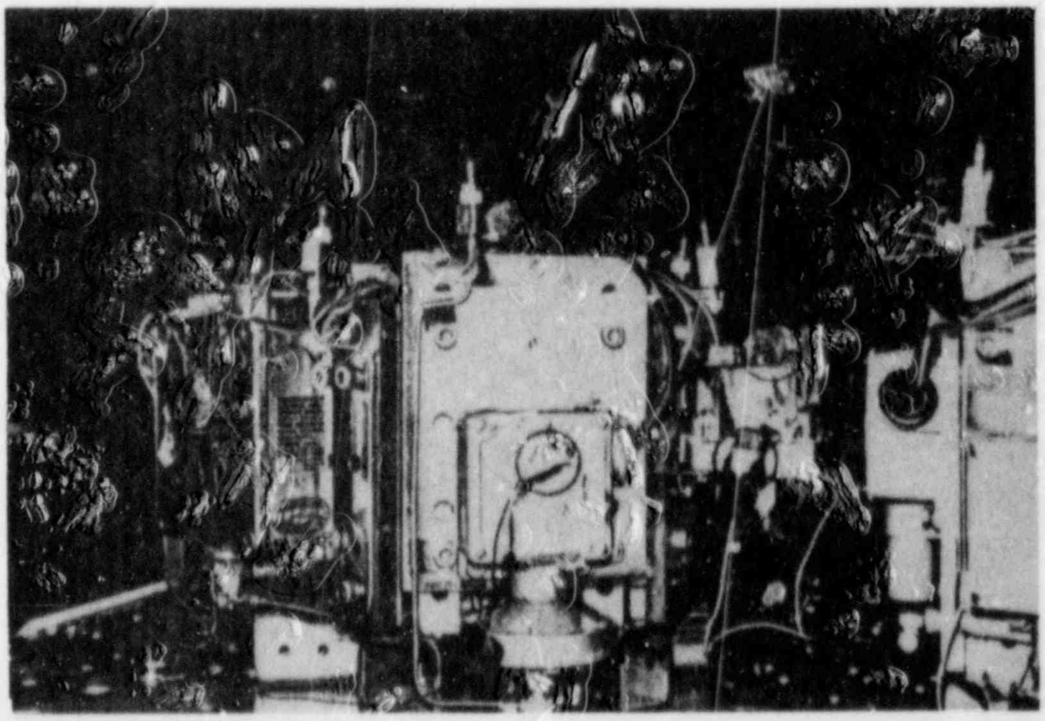


Figure 9.4 View of Accelerometer locations on pressure switches which were mounted on Test Fixture No. 2. The response Accelerometers used to monitor the items during seismic tests are shown circled.

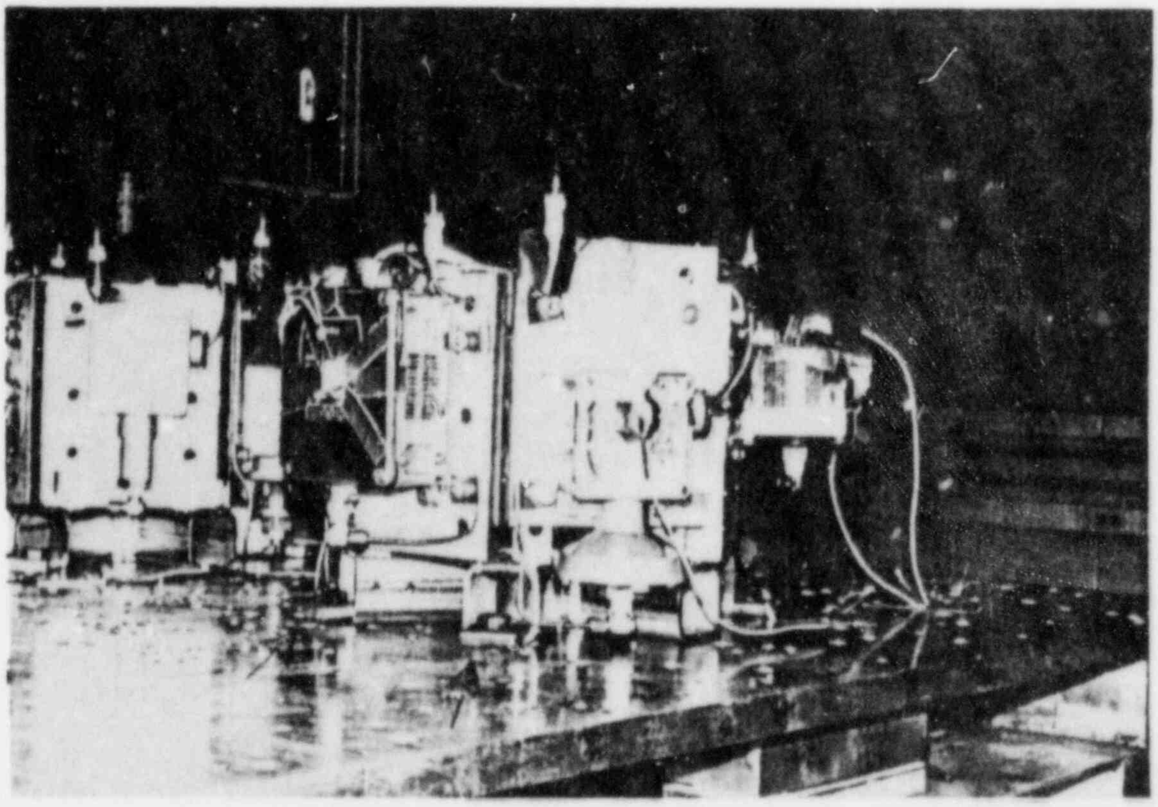


Figure 9.5 View showing method used to mount test items to the biaxial shake table for X-Z Random Tests.

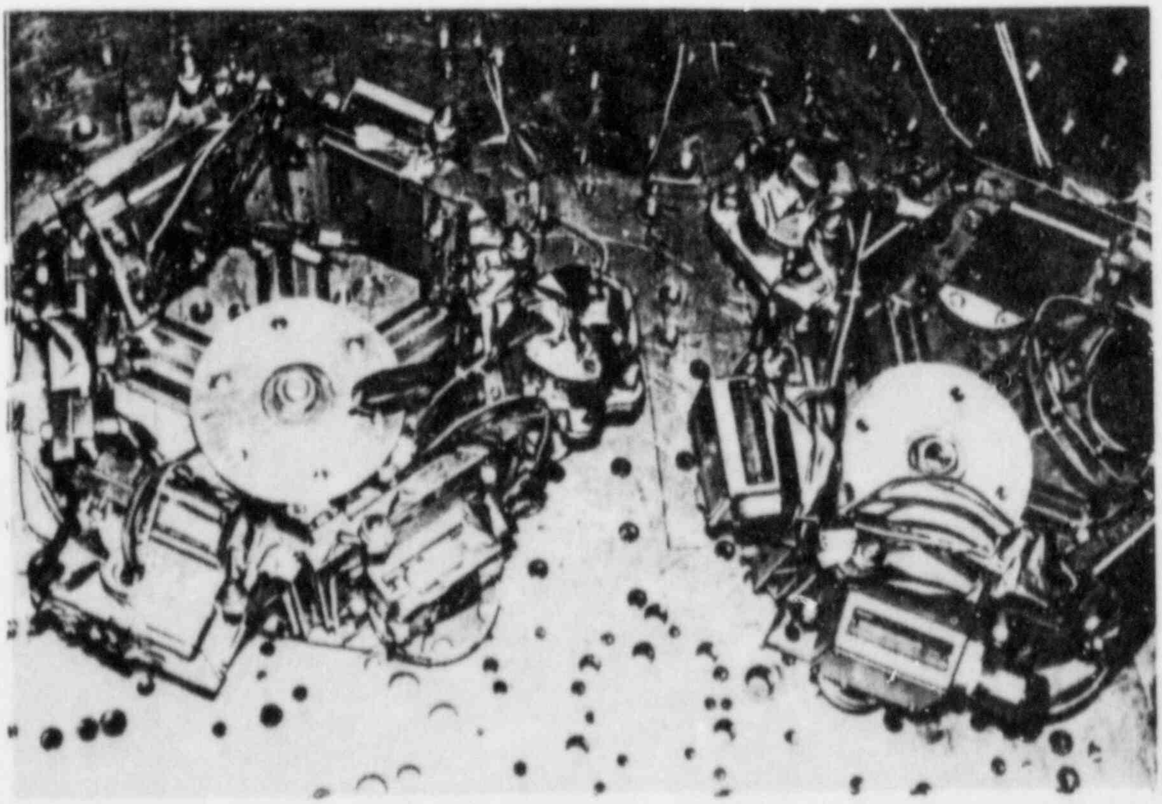


Figure 9.6 View showing method used to mount test items to the biaxial shake table for Y-Z Random Tests.

SECTION 10.0

RESPONSE SPECTRUM DATA

Figure 10.1 RUN OBEX71 AH

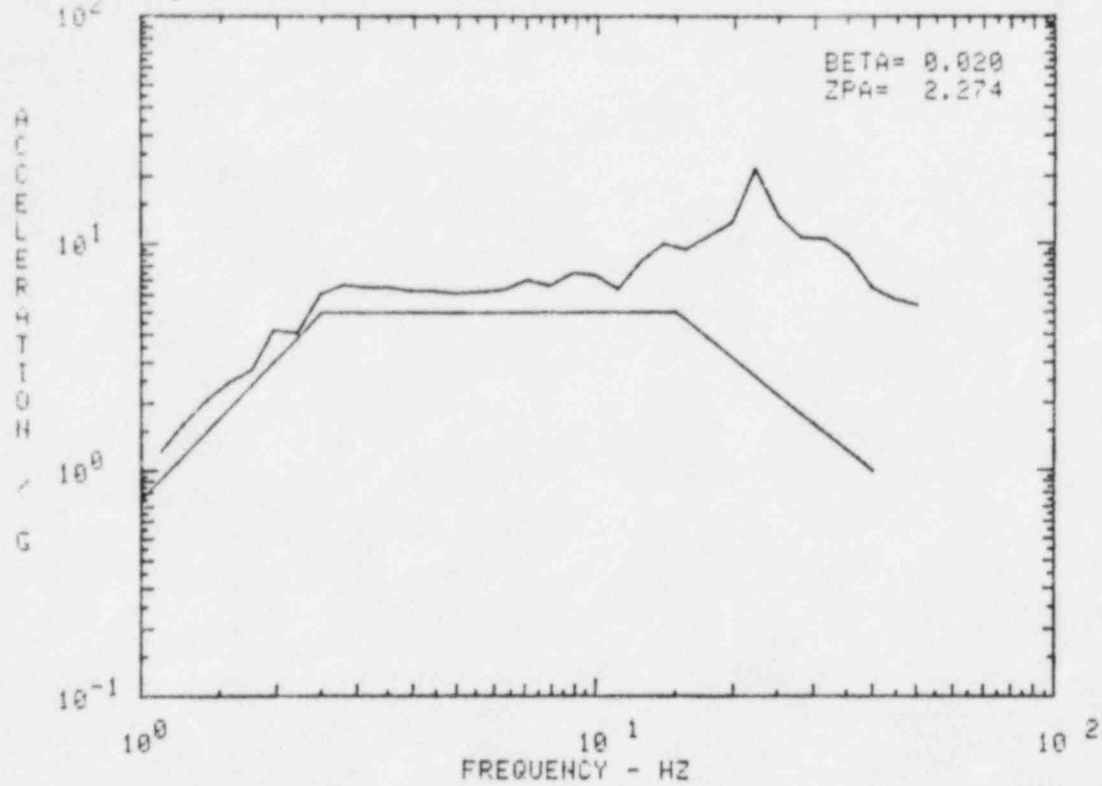


Figure 10.2 RUN OBEXZ1 AV

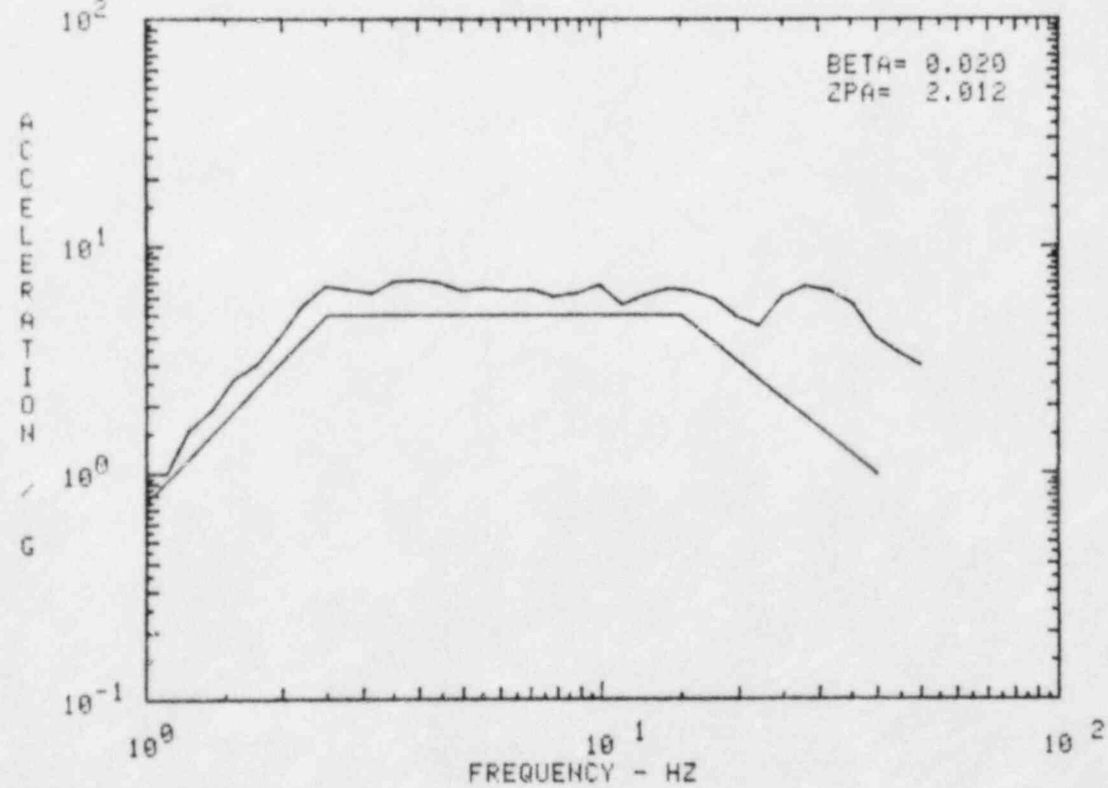


Figure 10.3 RUN OBEXZ2 AH

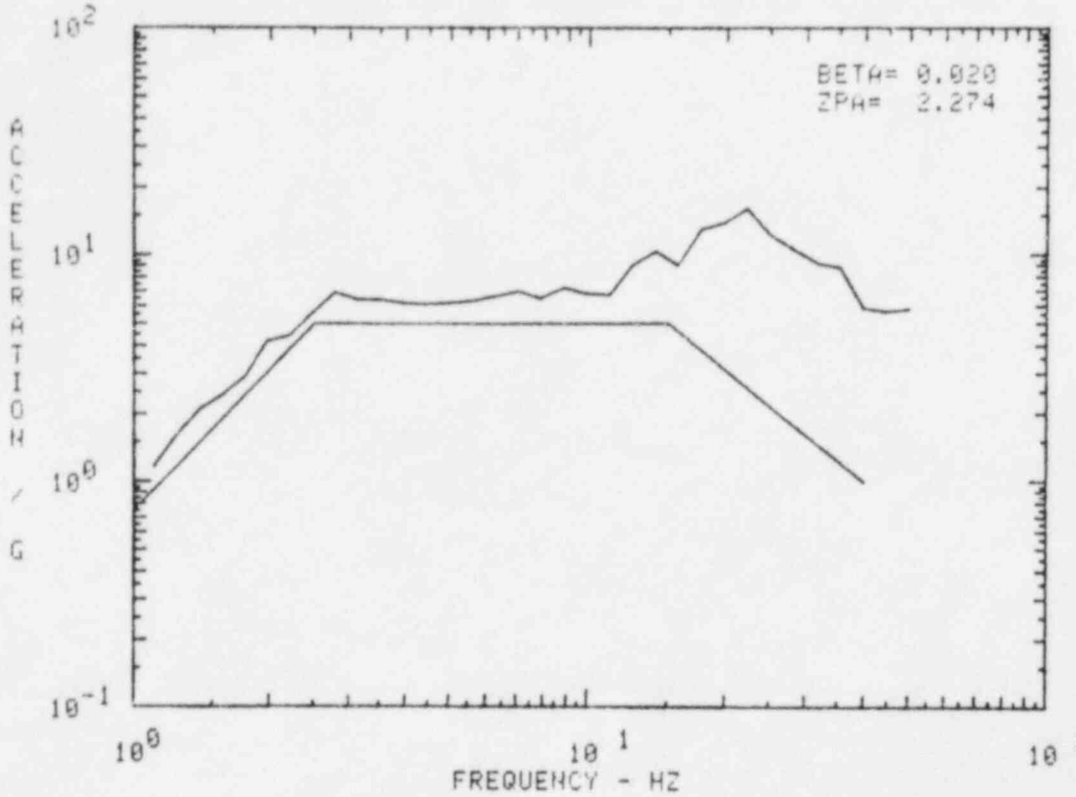


Figure 10.4 RUN OBEXZ2 AV

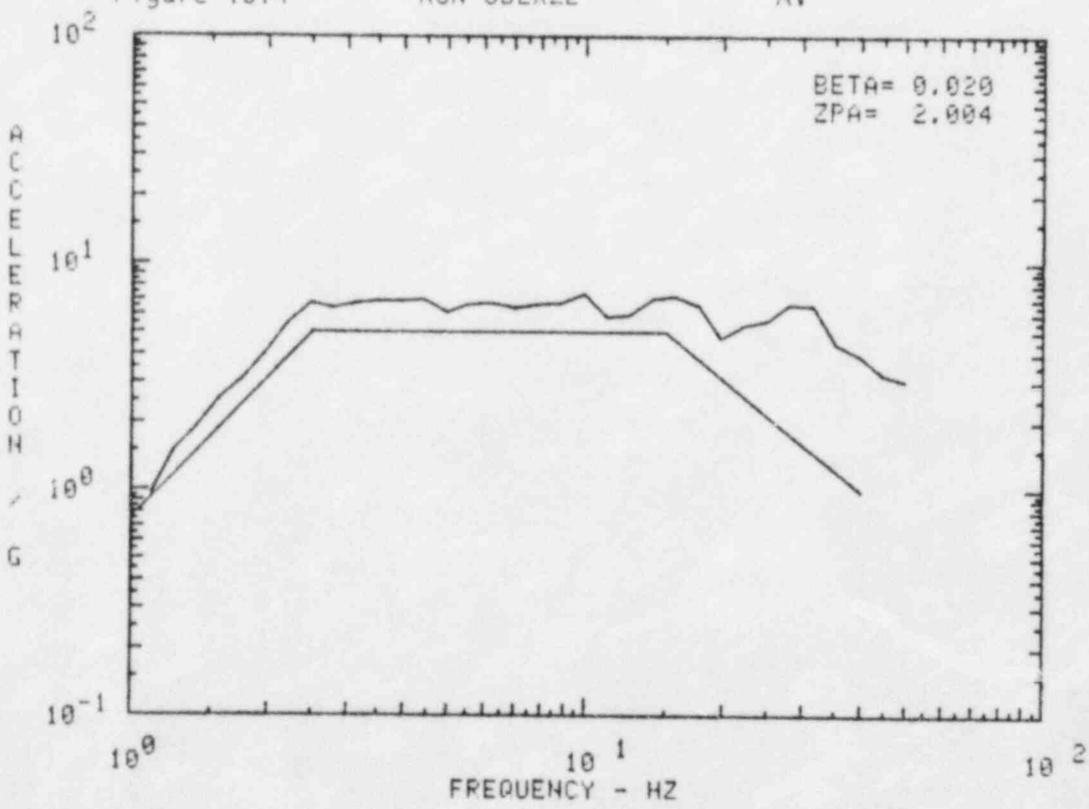


Figure 10.5 OBEXZ3 AH

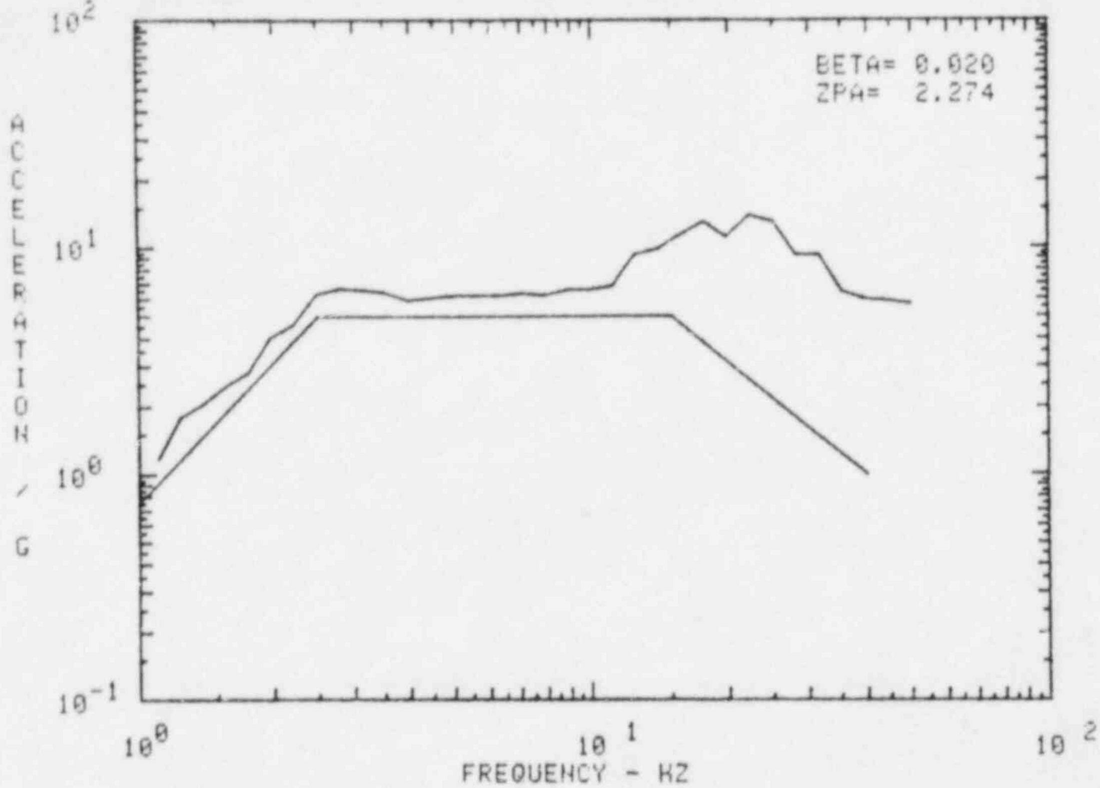


Figure 10.6 OBEXZ3 AV

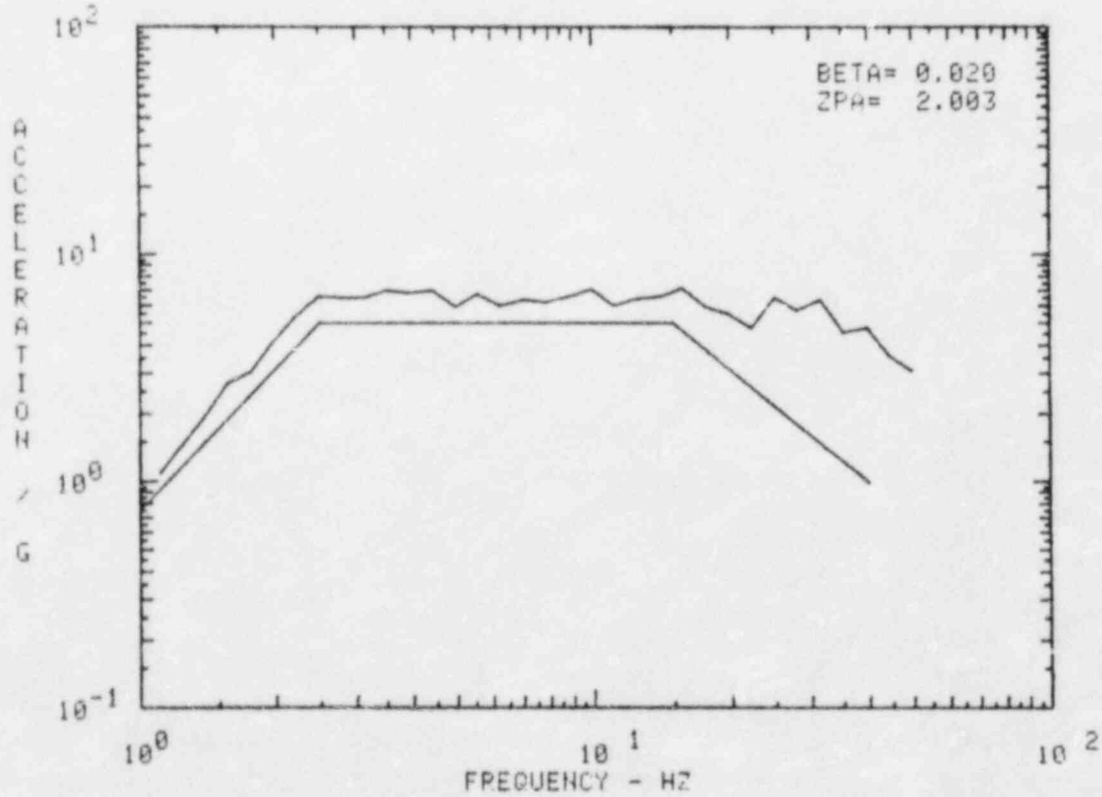


Figure 10.7 RUN OBEXZ4 AH

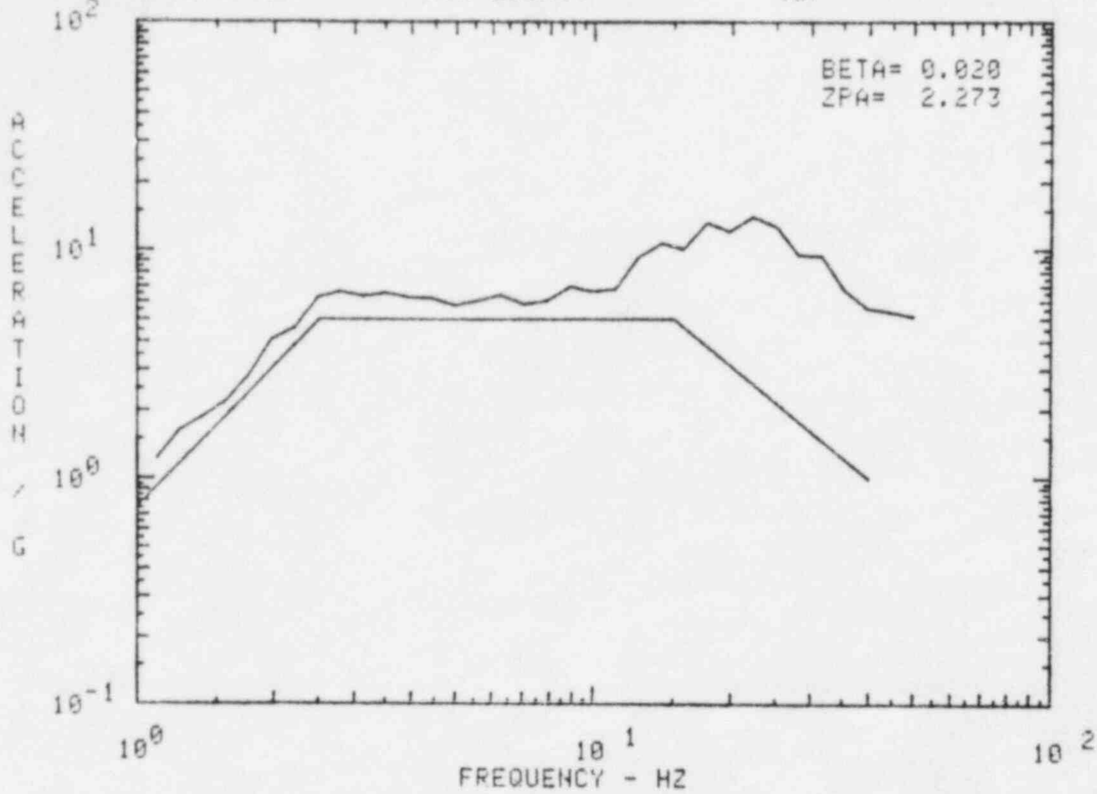


Figure 10.8 RUN OBEXZ4 AV

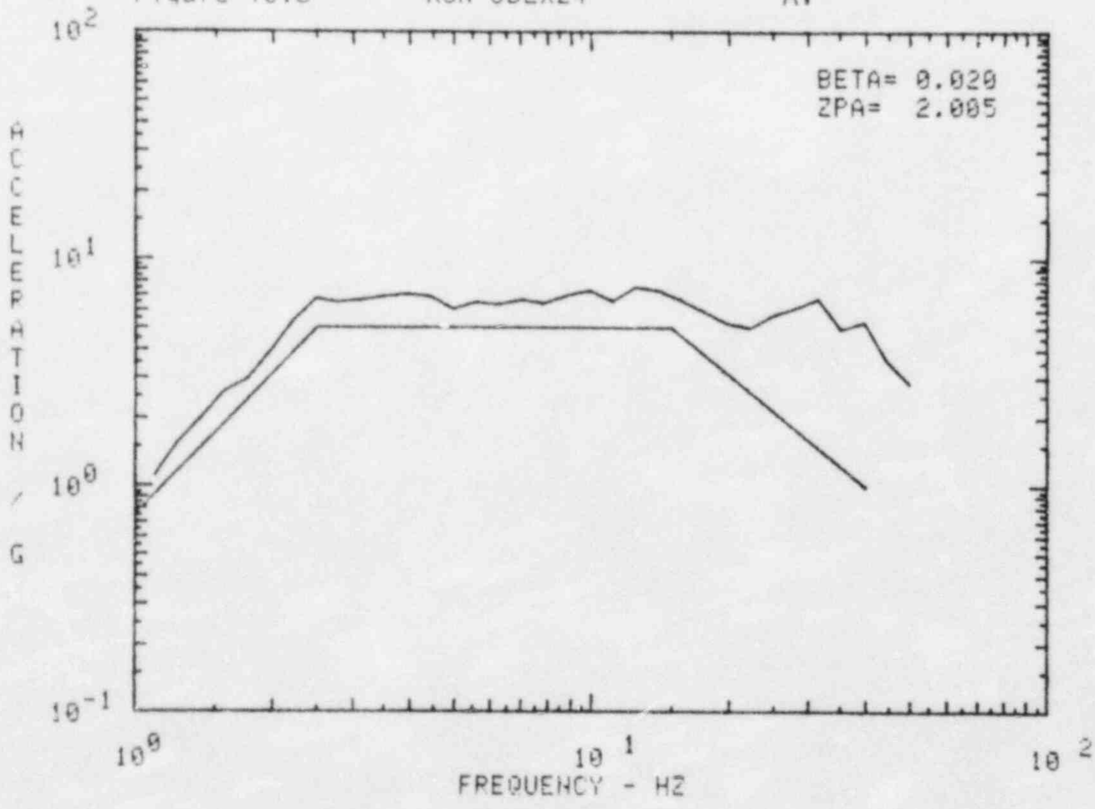


Figure 10.9 RUN OBEXZ5 AH

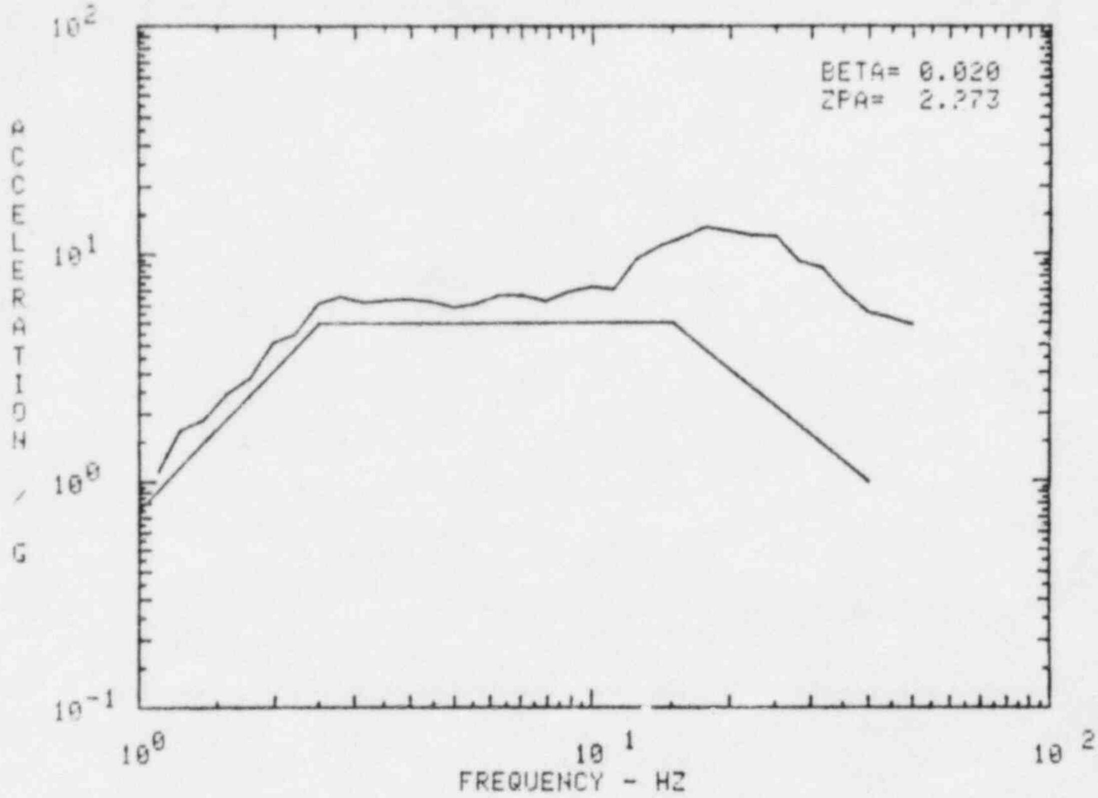


Figure 10.10 RUN OBEXZ5 AV

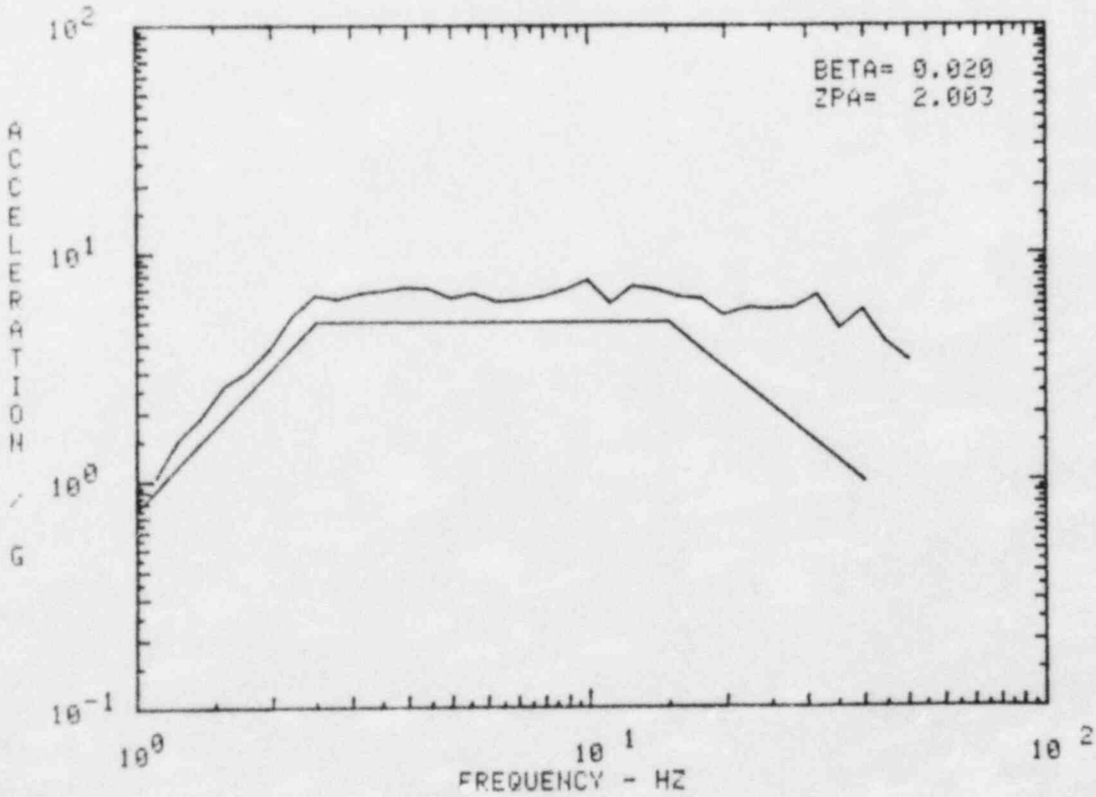


Figure 10.11 RUN OBEYZ1 AH

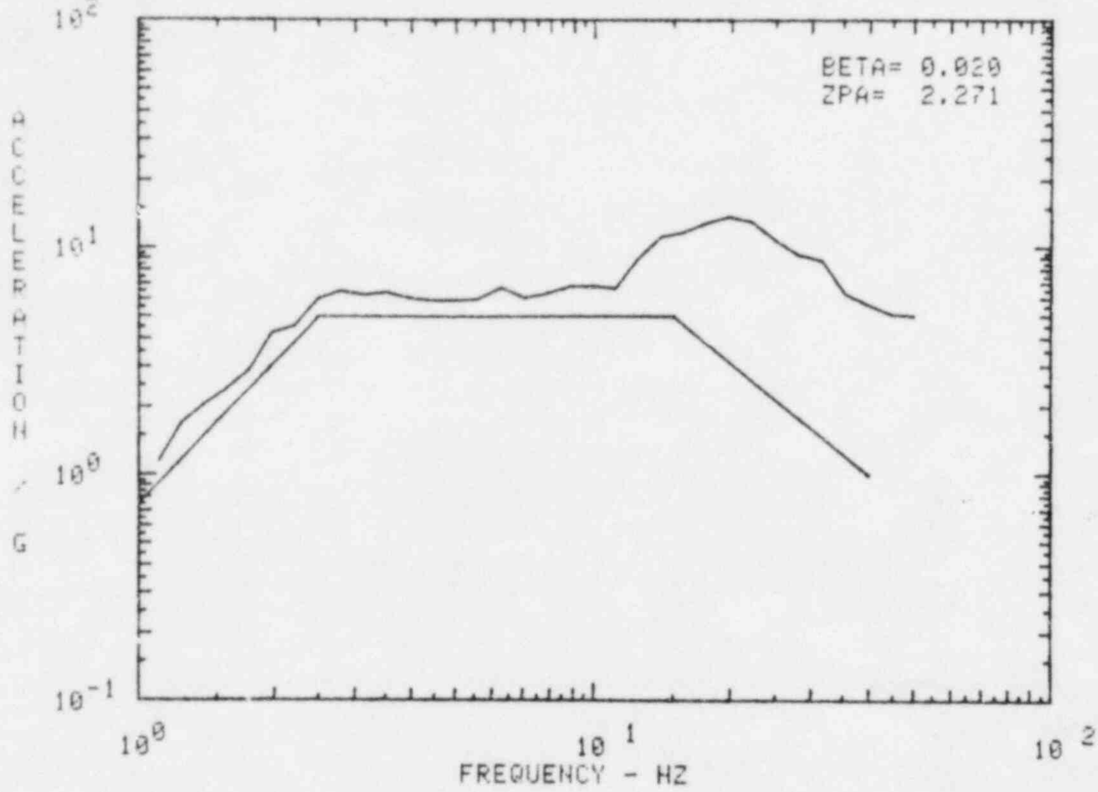


Figure 10.12 RUN OBEYZ1 AV

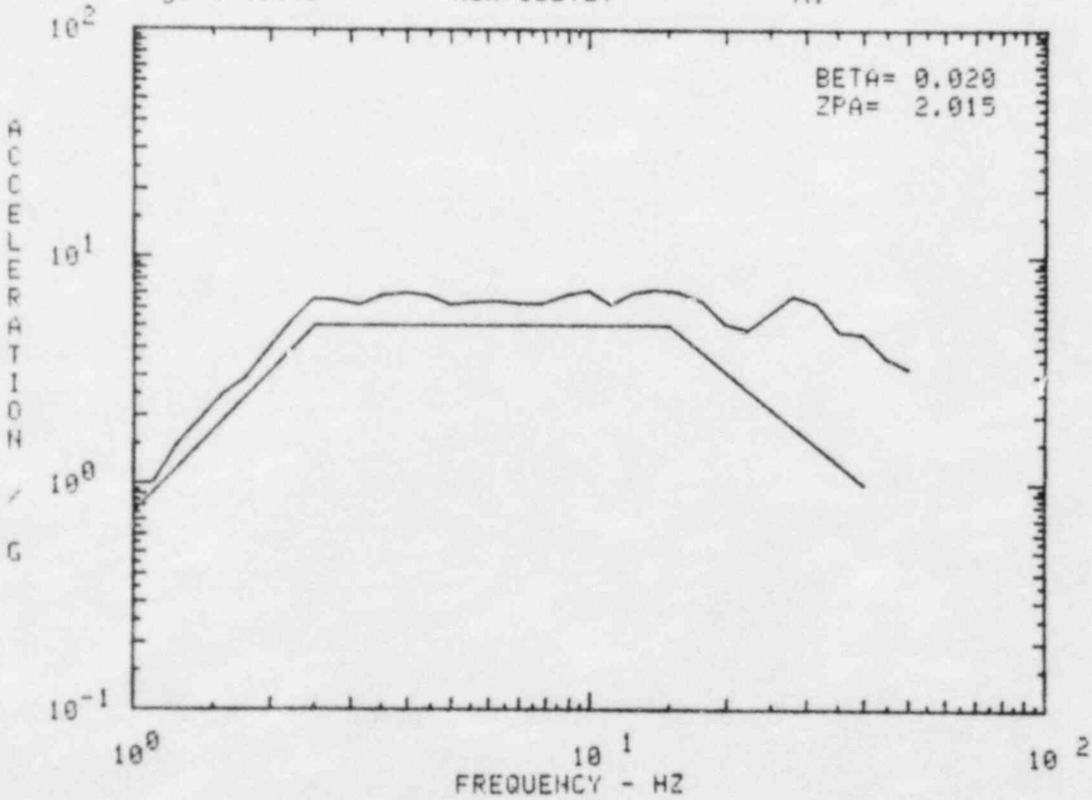


Figure 10.13 RUN OBEYZ2 AH

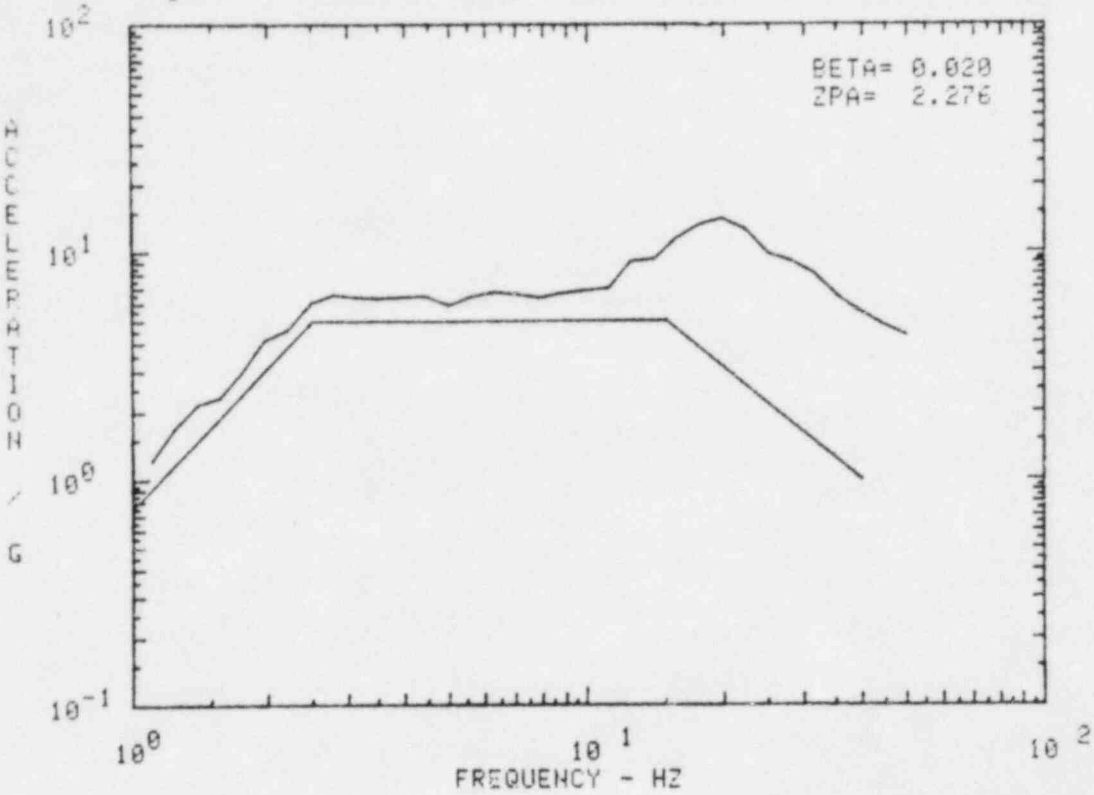


Figure 10.14 RUN OBEYZ2 AV

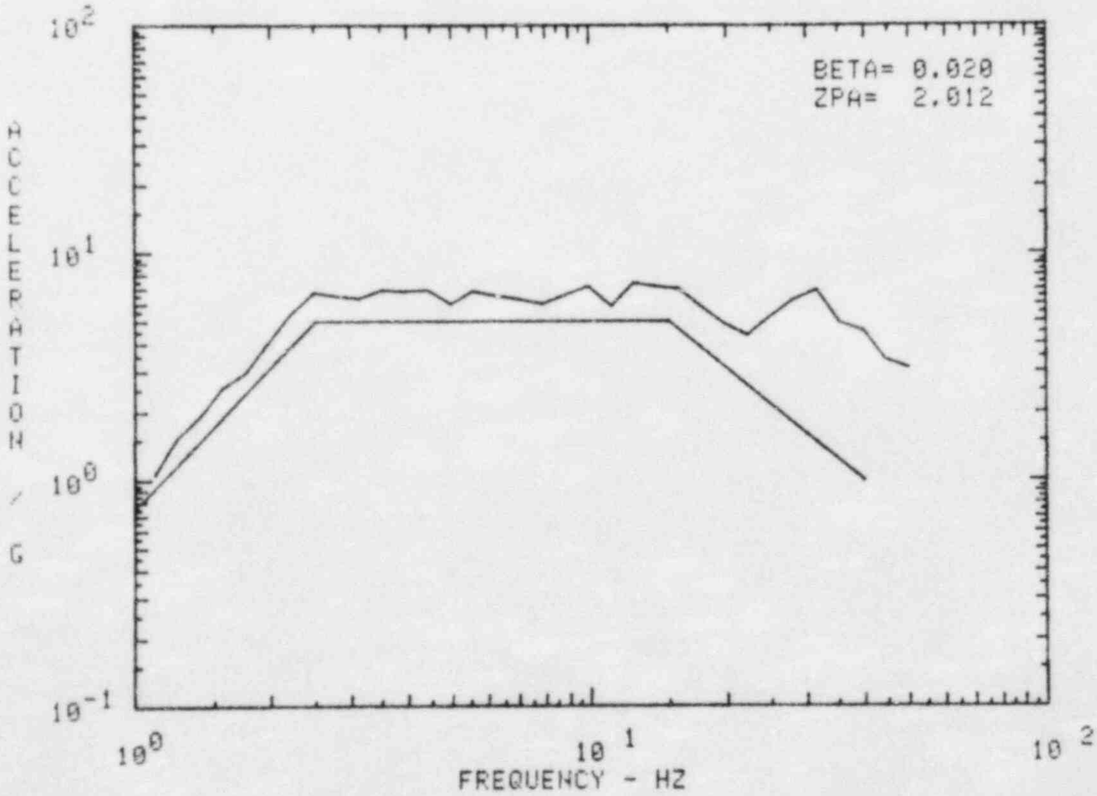


Figure 10.15 RUN OBEYZ3 AH

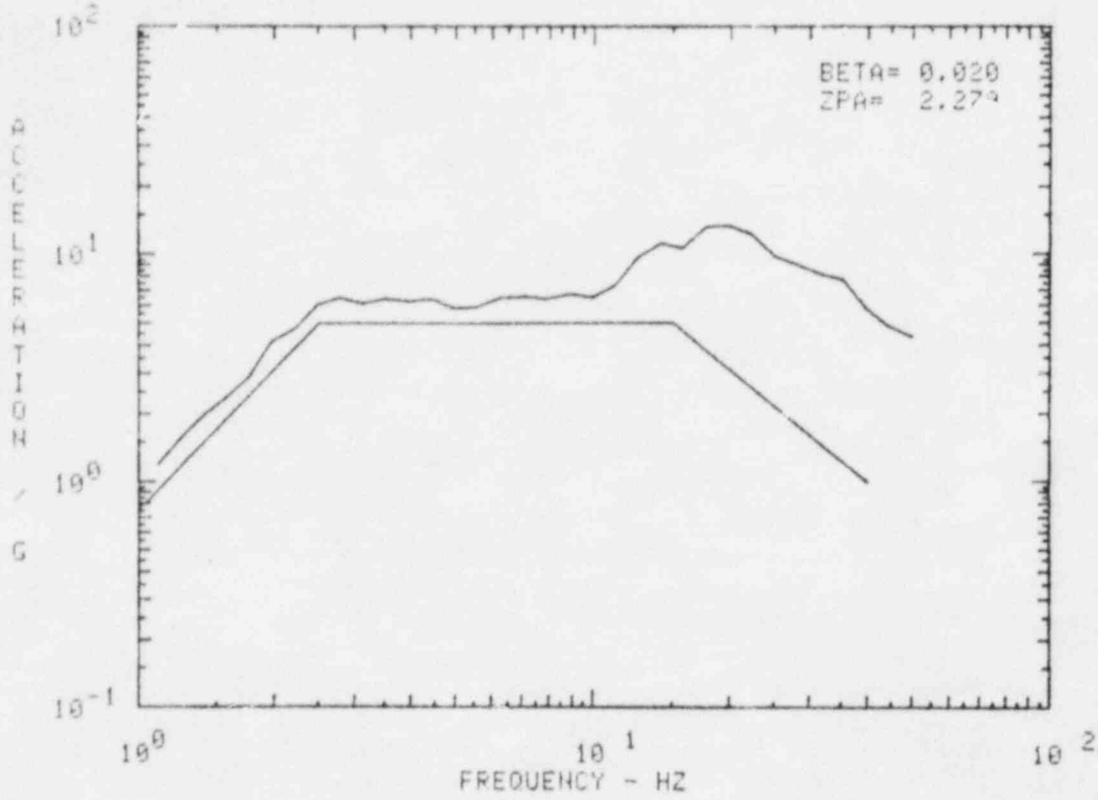


Figure 10.16 RUN OBEYZ3 AV

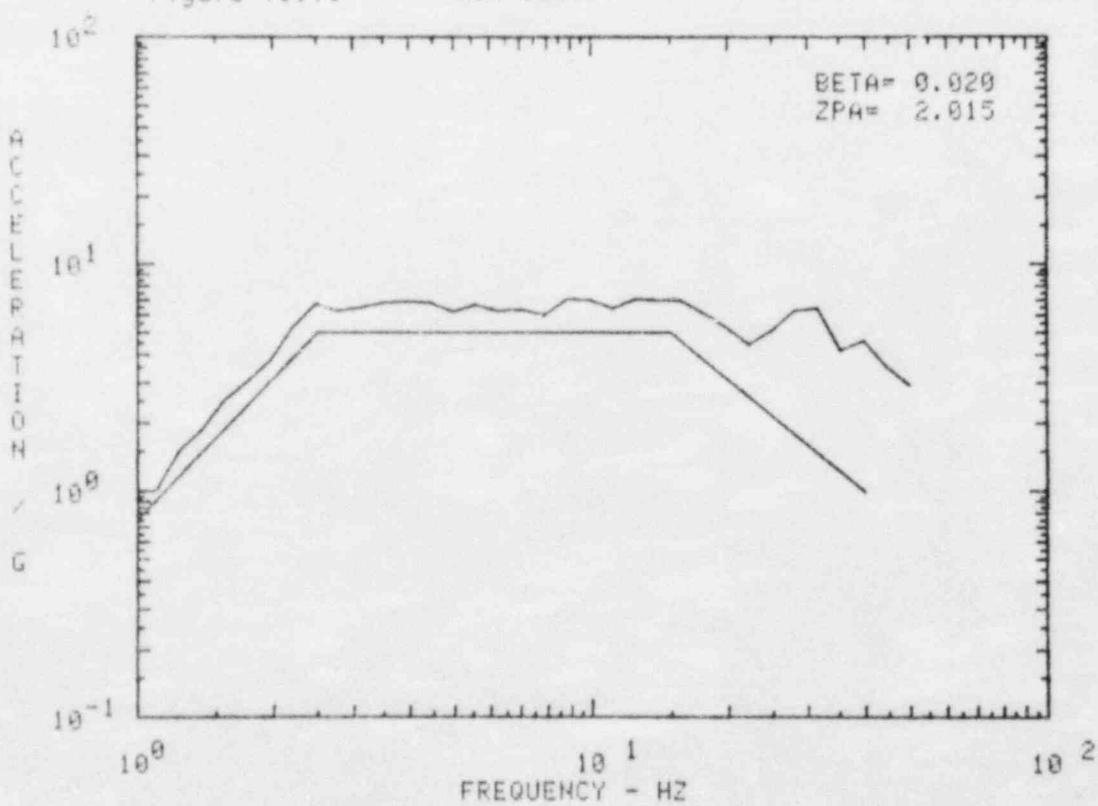


Figure 10.17 RUN OBEYZ4 AH

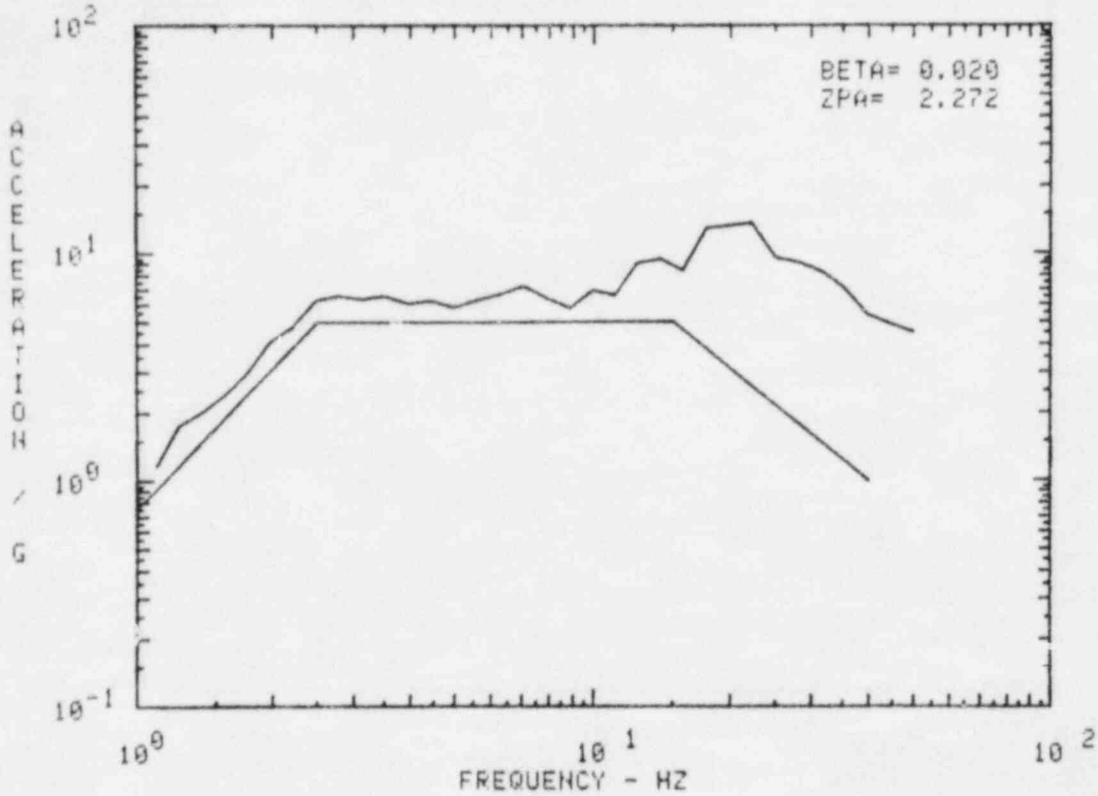


Figure 10.18 RUN OBEYZ4 AV

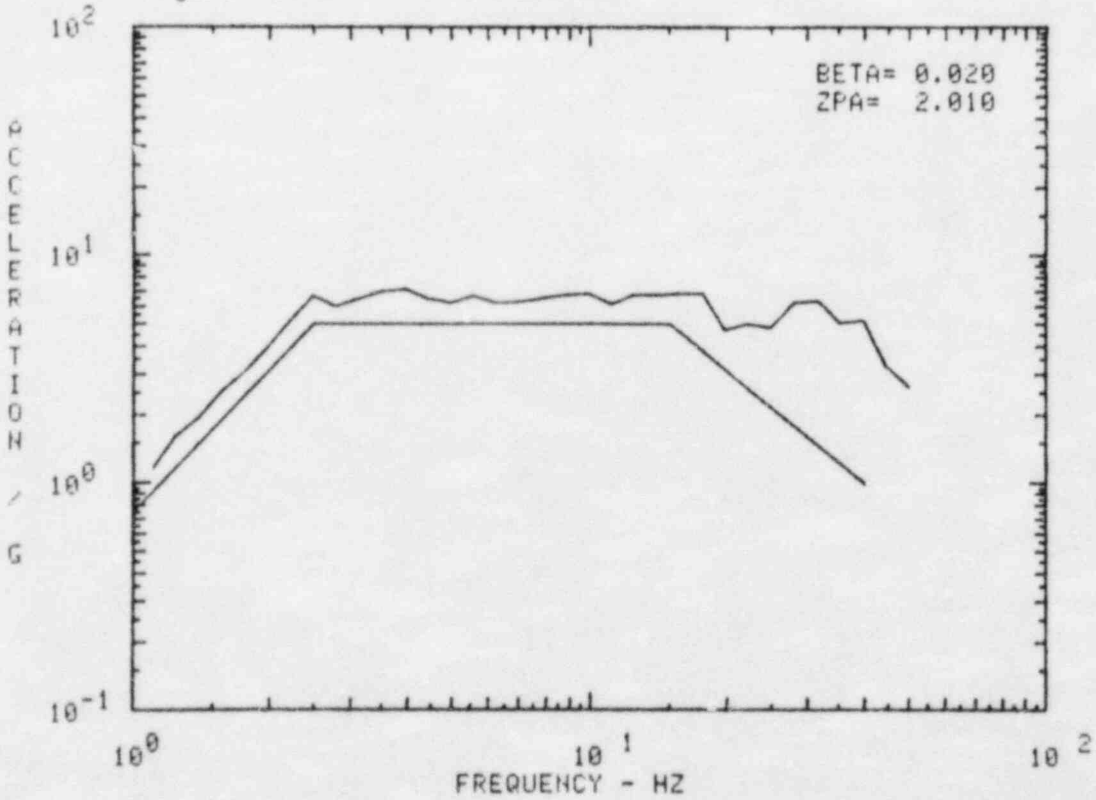


Figure 10.19 RUN OBEYZ5 AH

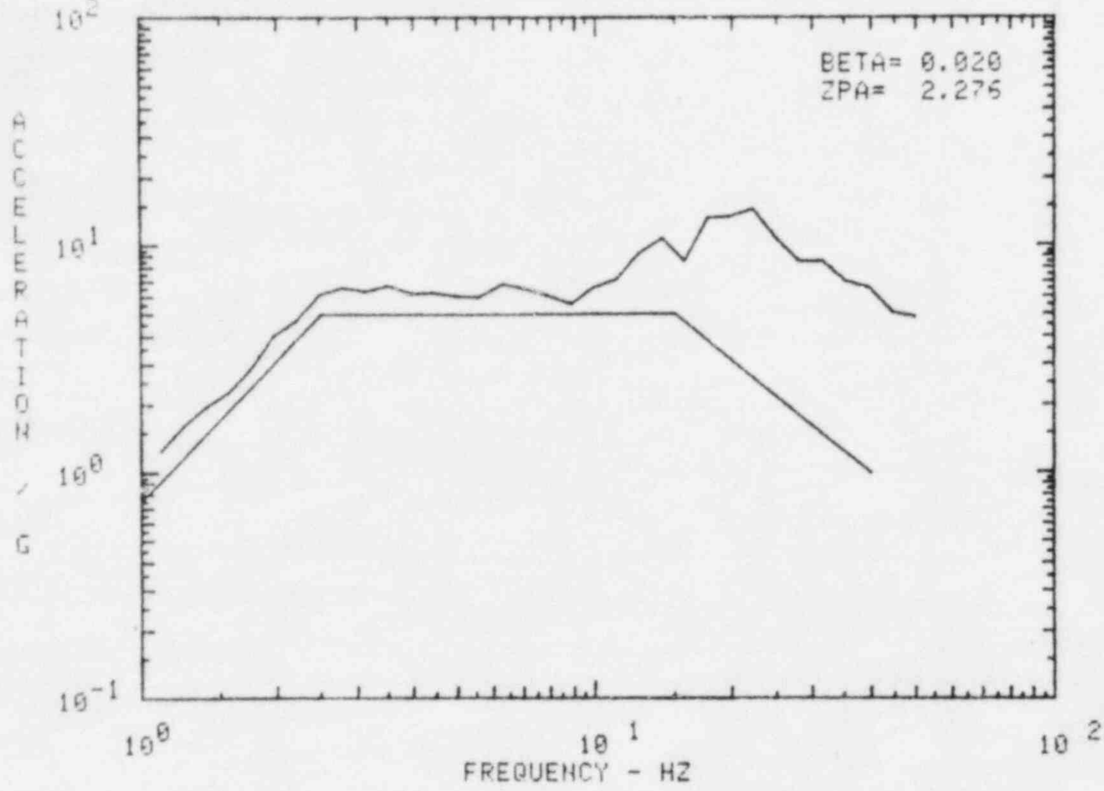


Figure 10.20 RUN OBEYZ5 AV

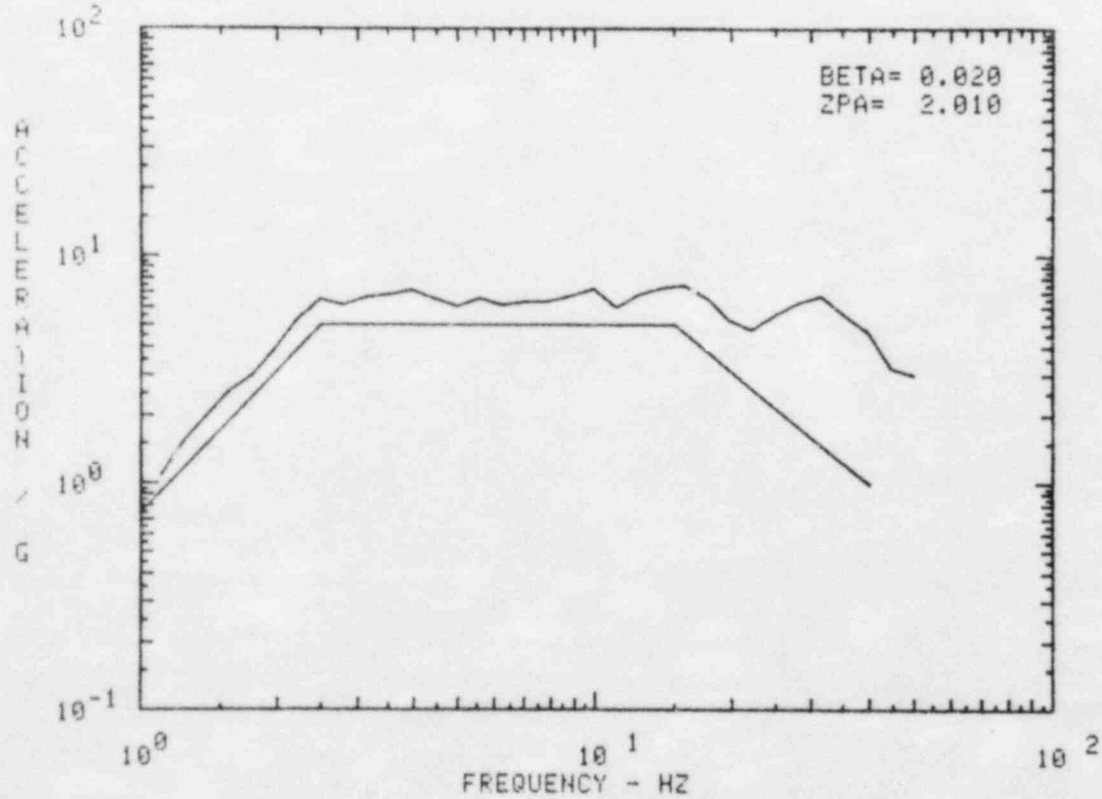


Figure 10.21 RUN SSEYZ1 AH

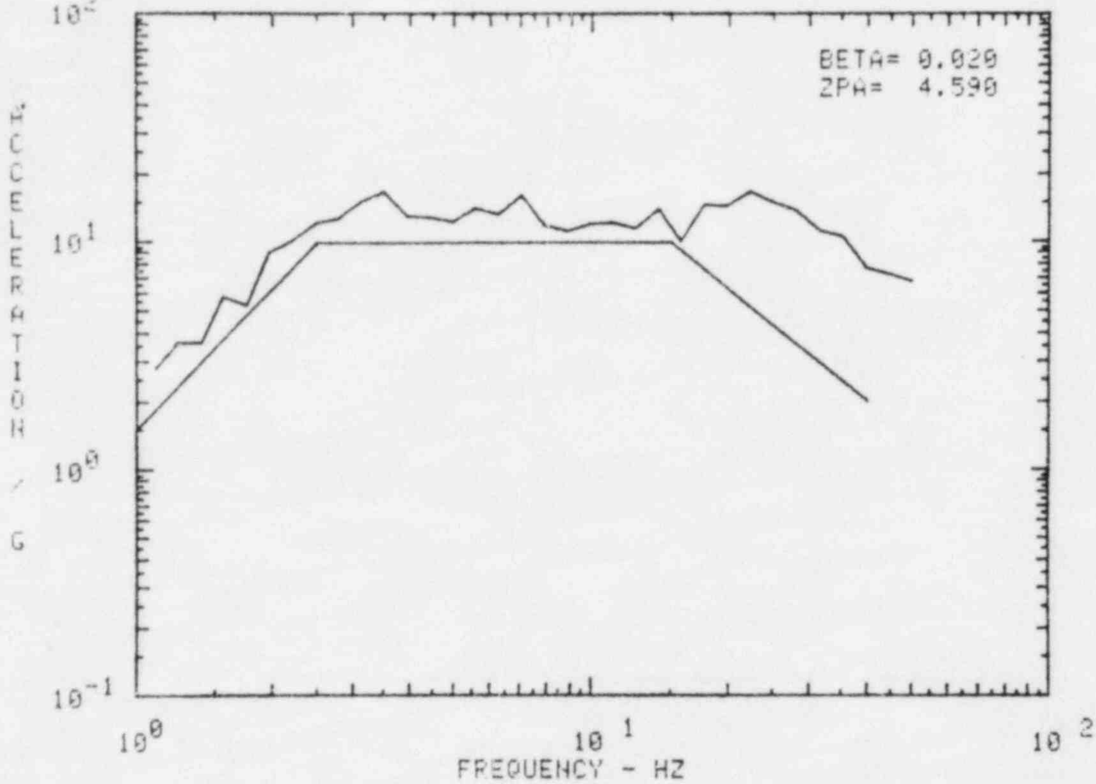


Figure 10.22 RUN SSEYZ1 AV

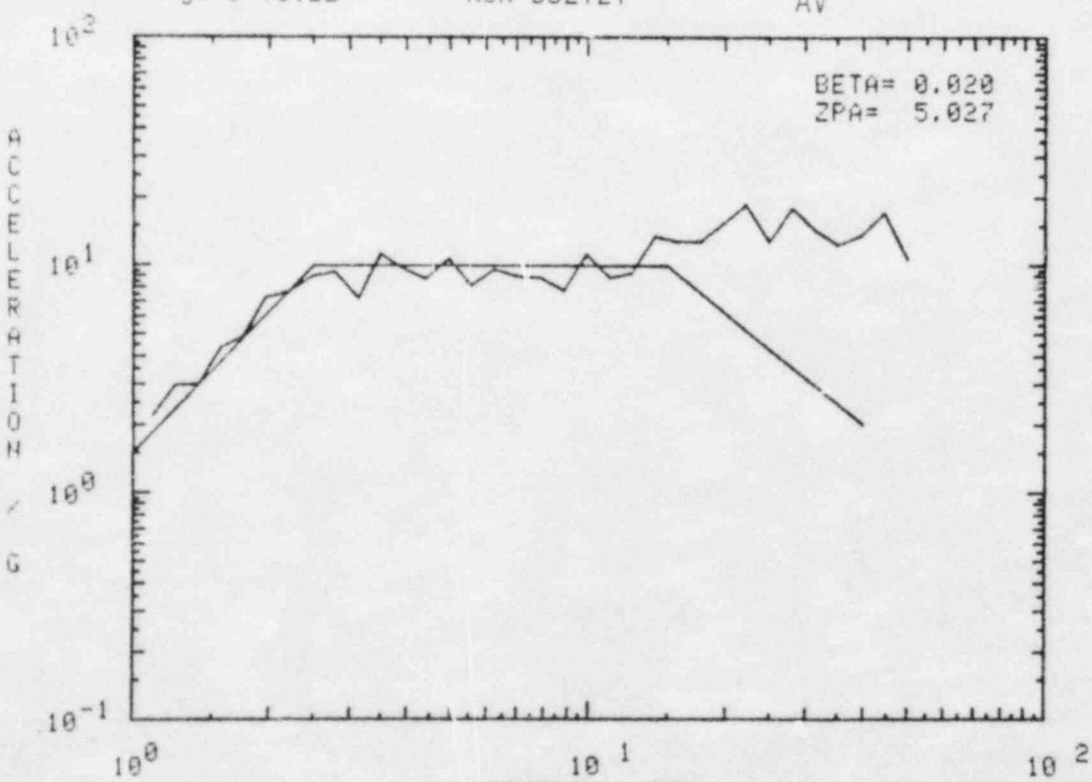


Figure 10.23 RUN SSEYZ1A AH

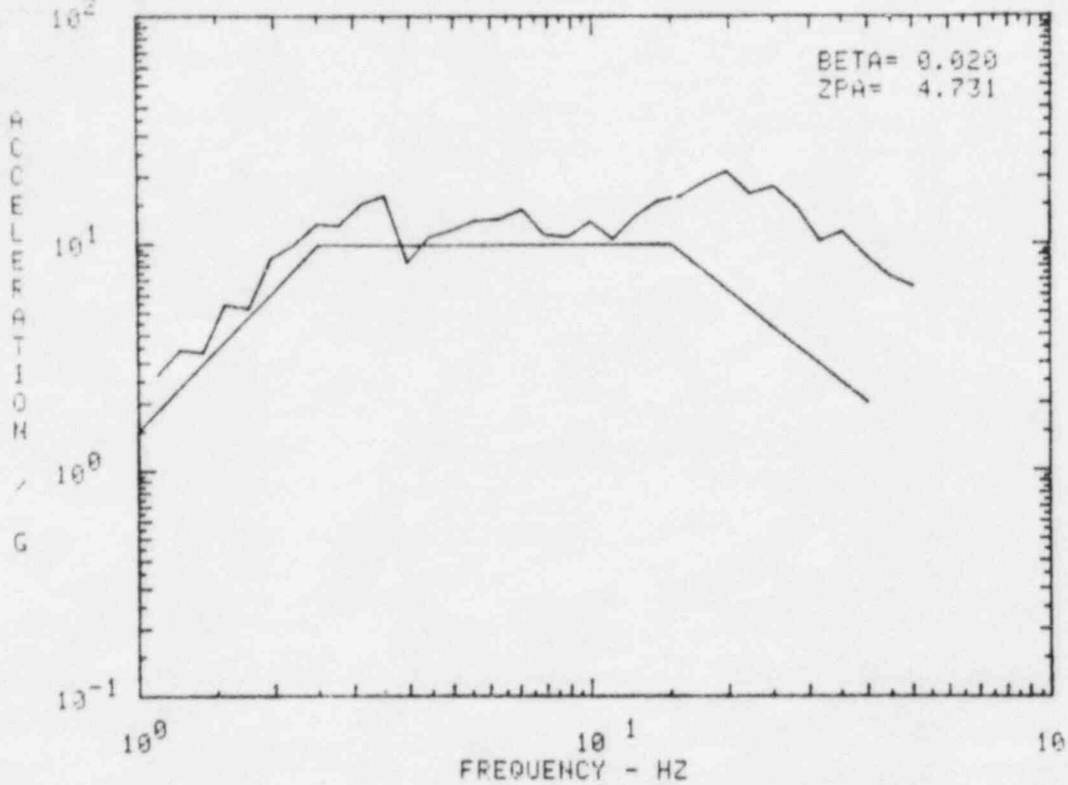


Figure 10.24 RUN SSEYZ1A AV

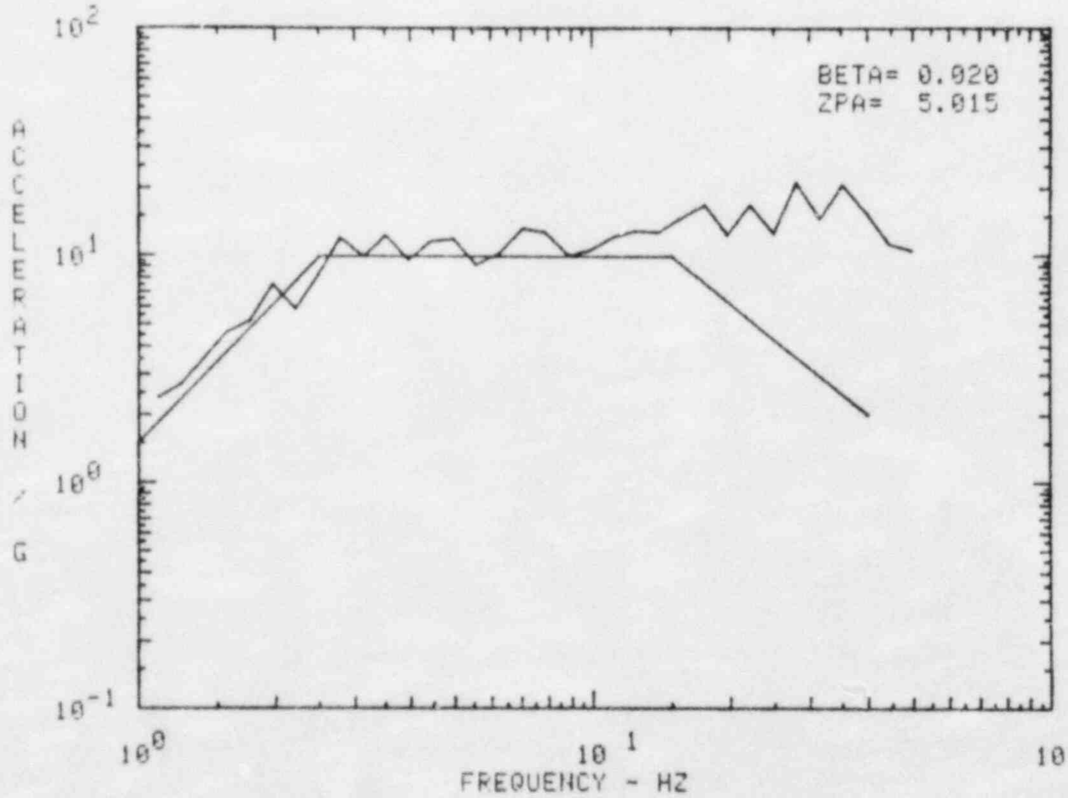


Figure 10.25 RUN SSEYZ1B AH

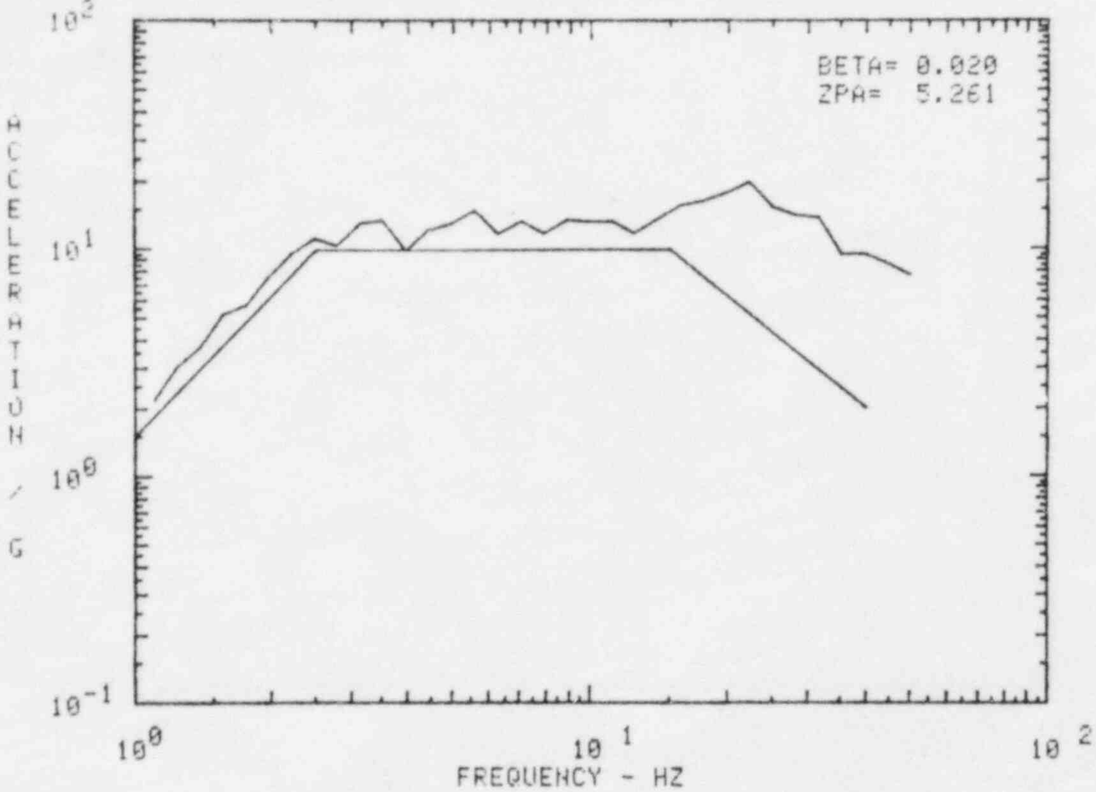


Figure 10.26 RUN SSEYZ1B AV

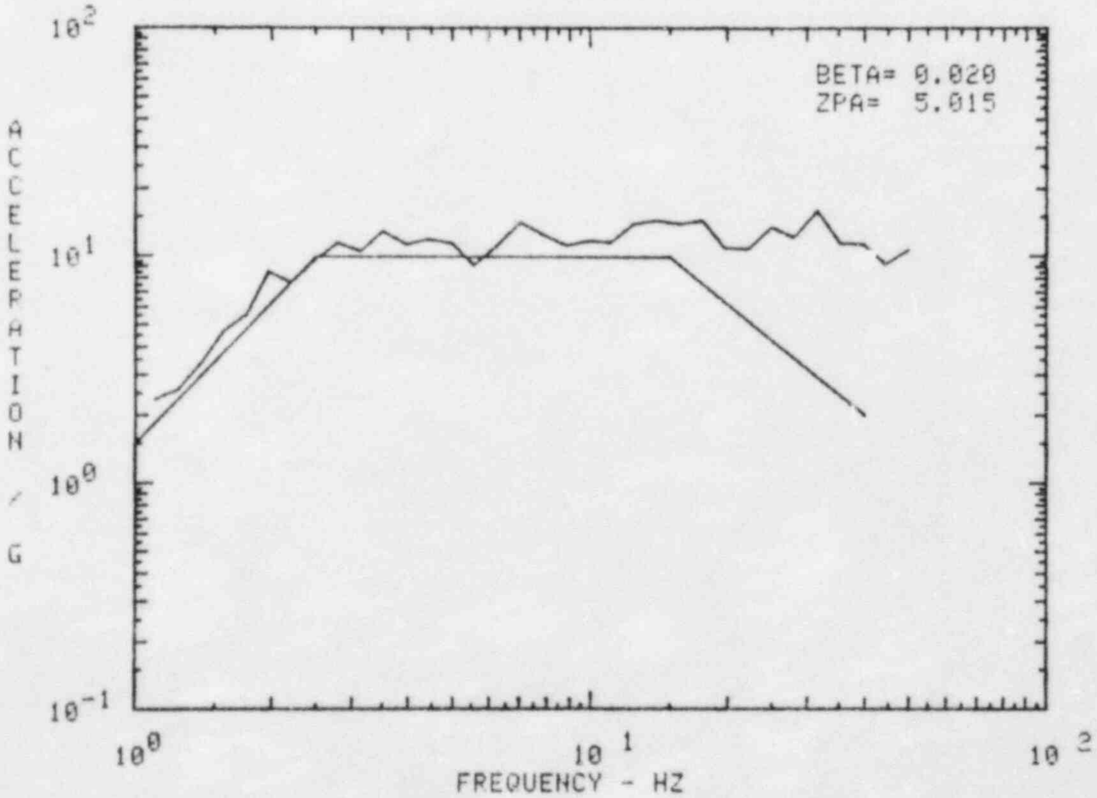


Figure 10.27 RUN SSEXZ1 AH

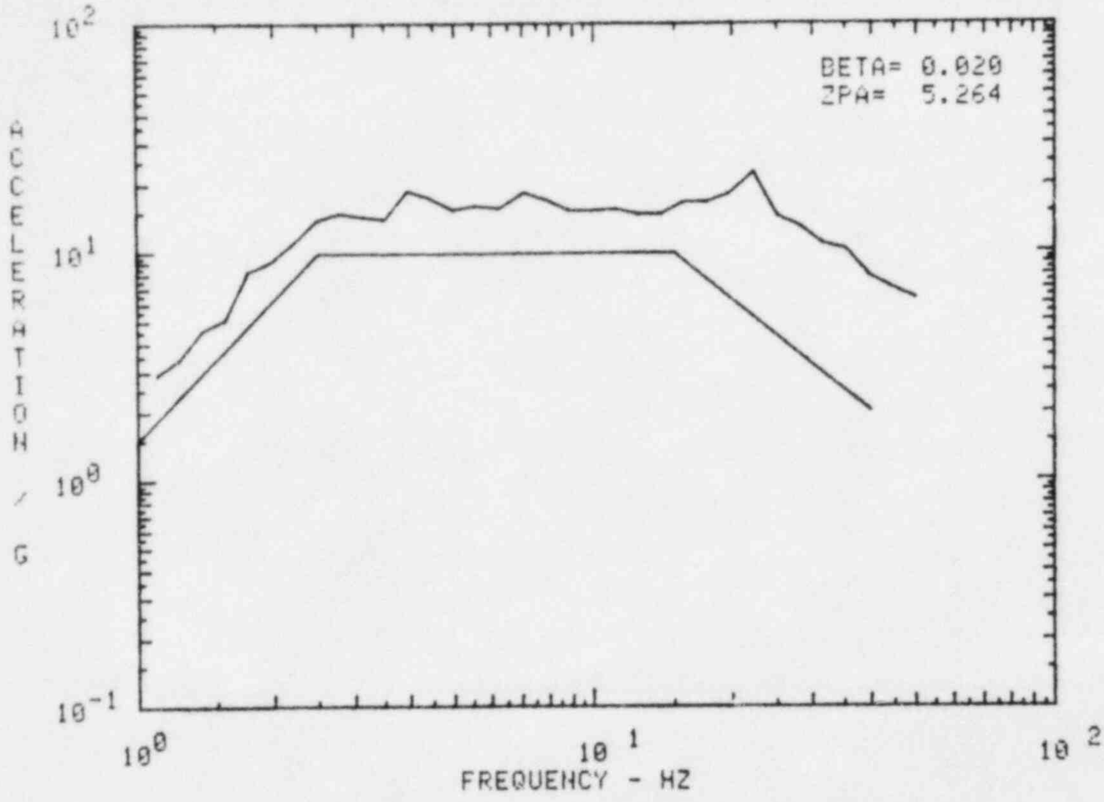


Figure 10.28 RUN SSEXZ1 AV

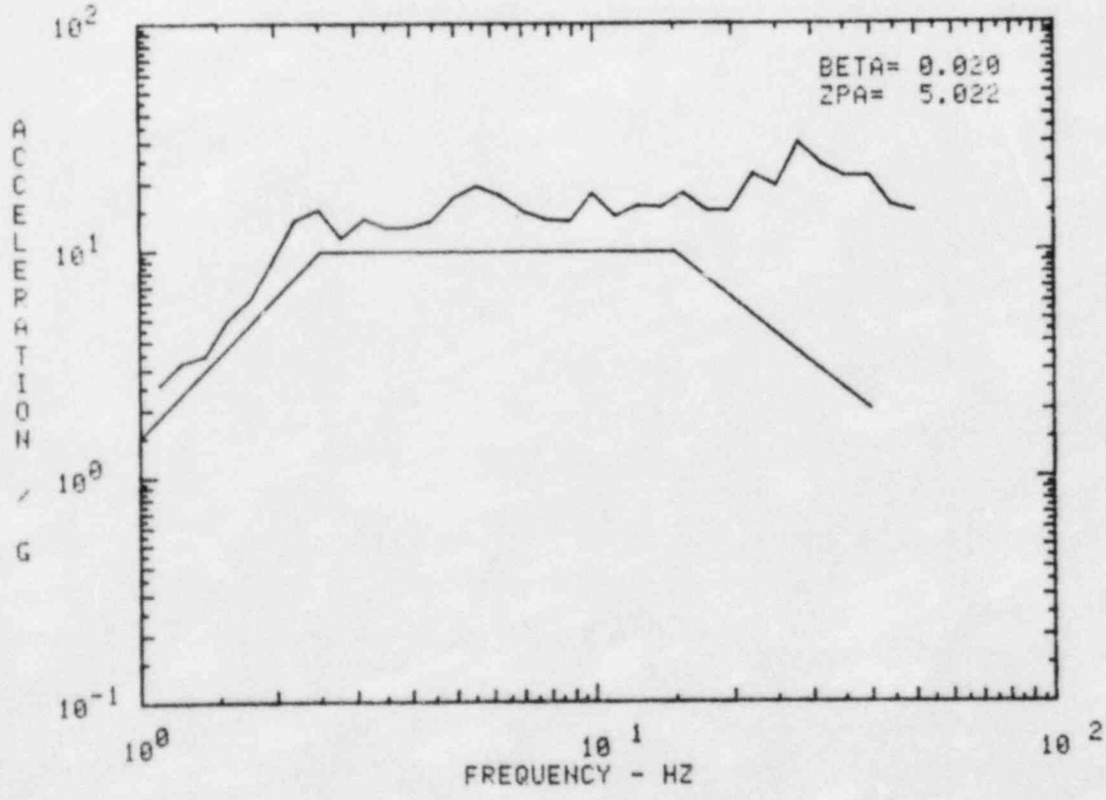


Figure 10.29 RUN OBXZ1 Accelerometer Location 1H

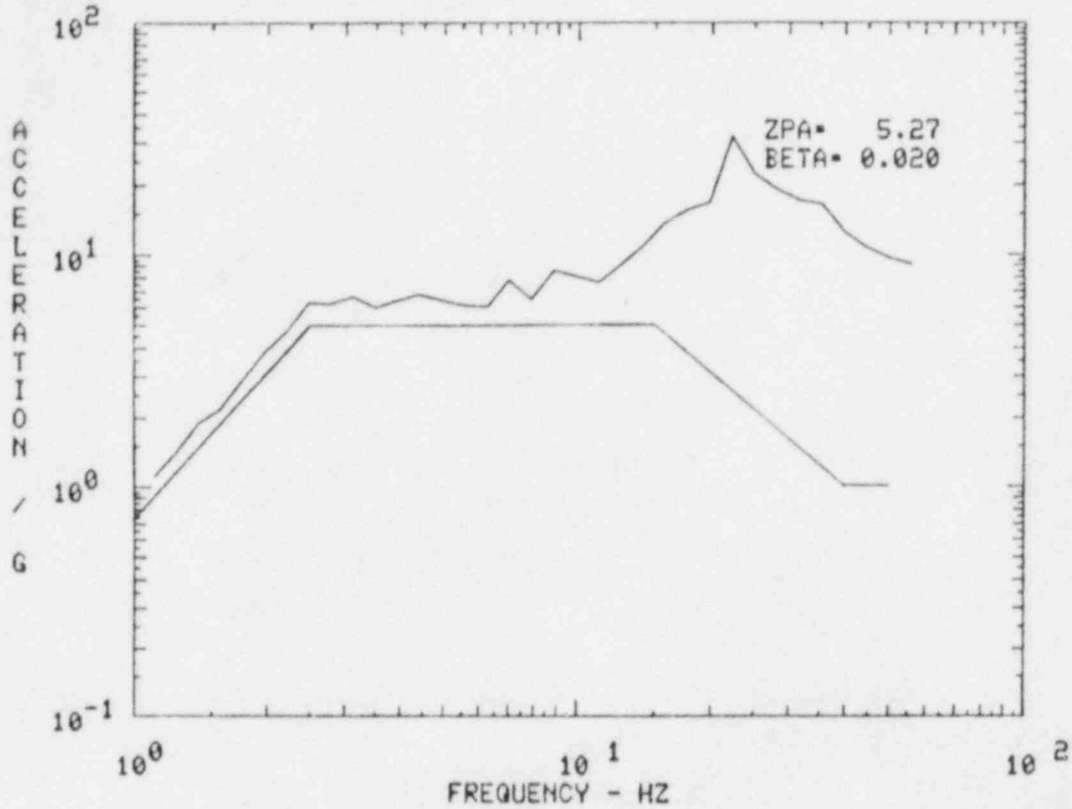


Figure 10.30 RUN OBXZ1 Accelerometer Location 2V

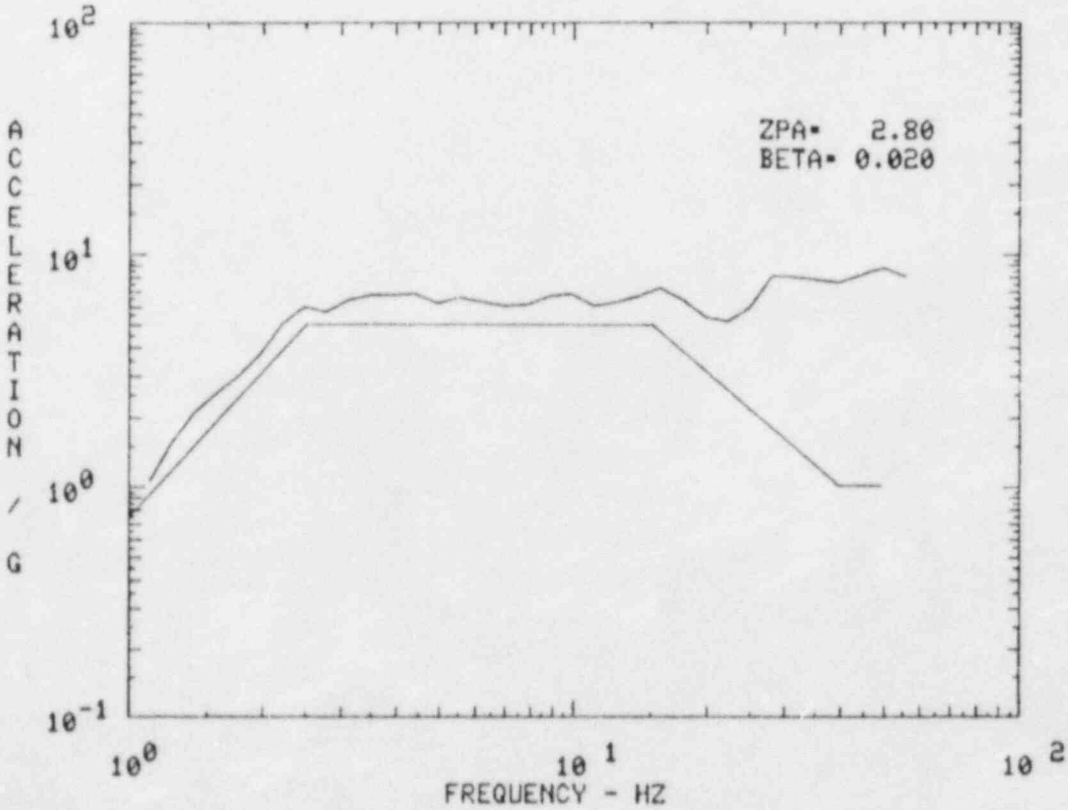


Figure 10.31   RUN OBXZ1   Accelerometer Location 3H

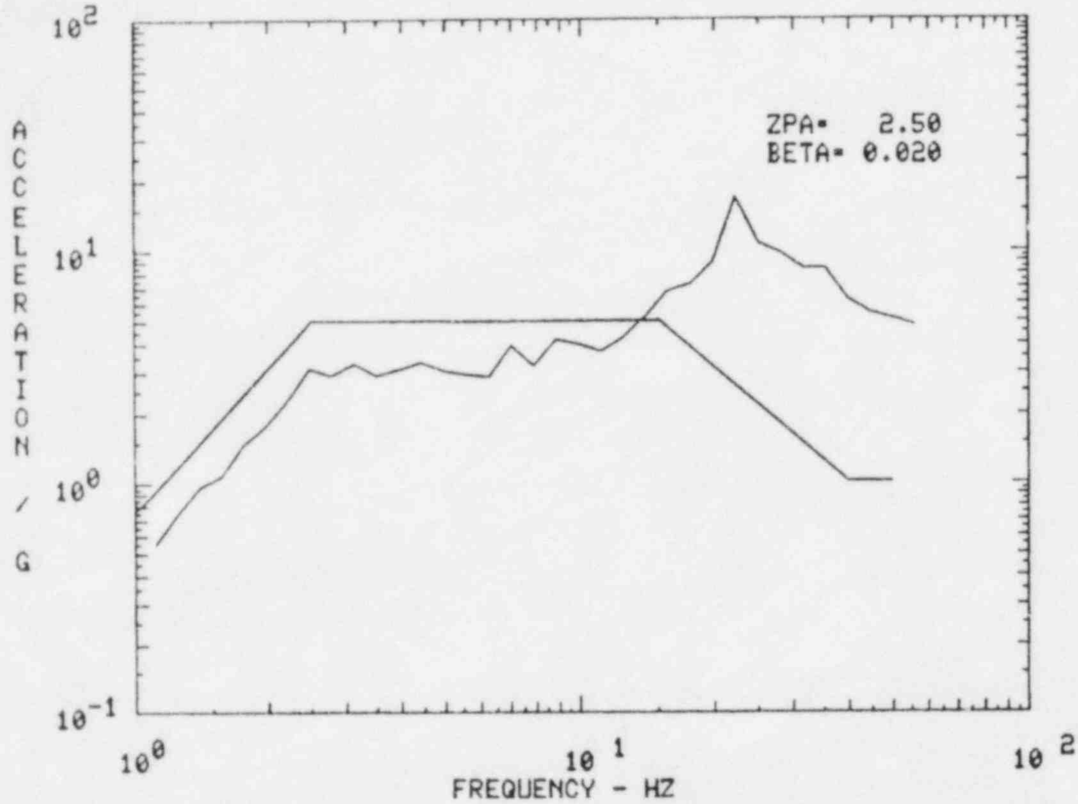


Figure 10.32   RUN OBXZ1   Accelerometer Location 4V

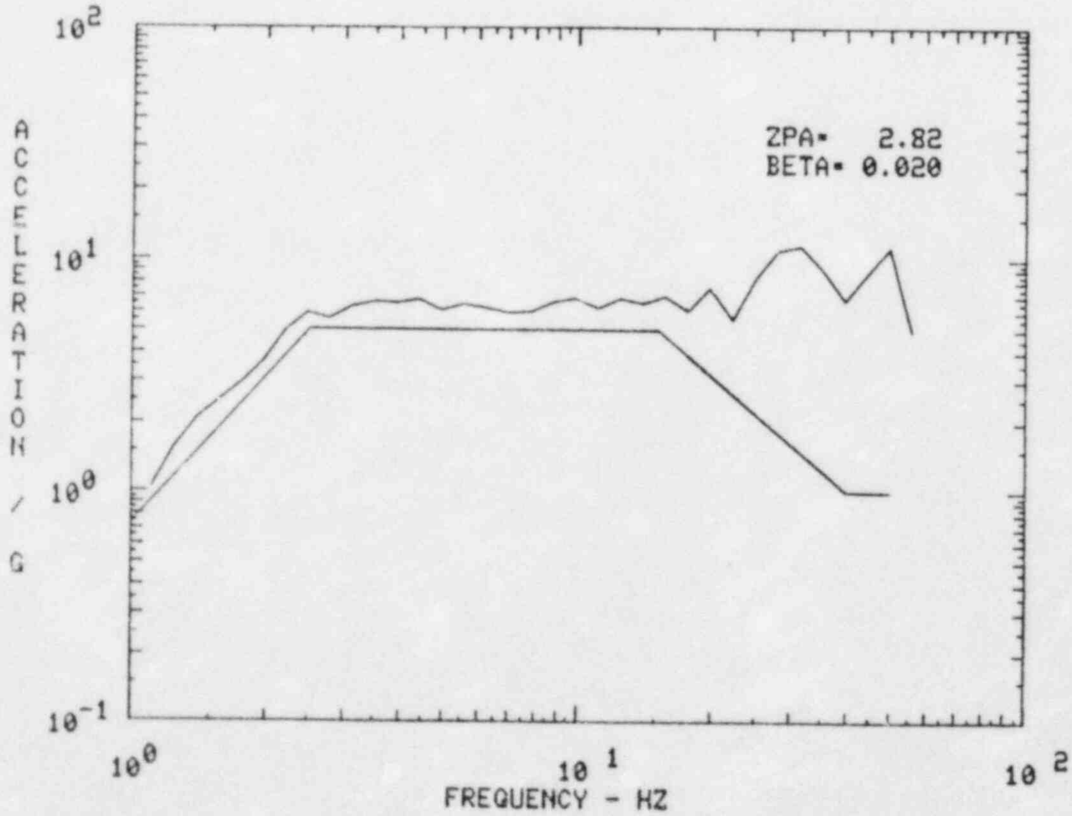


Figure 10.33 RUN OBXZ1 Accelerometer Location 5H

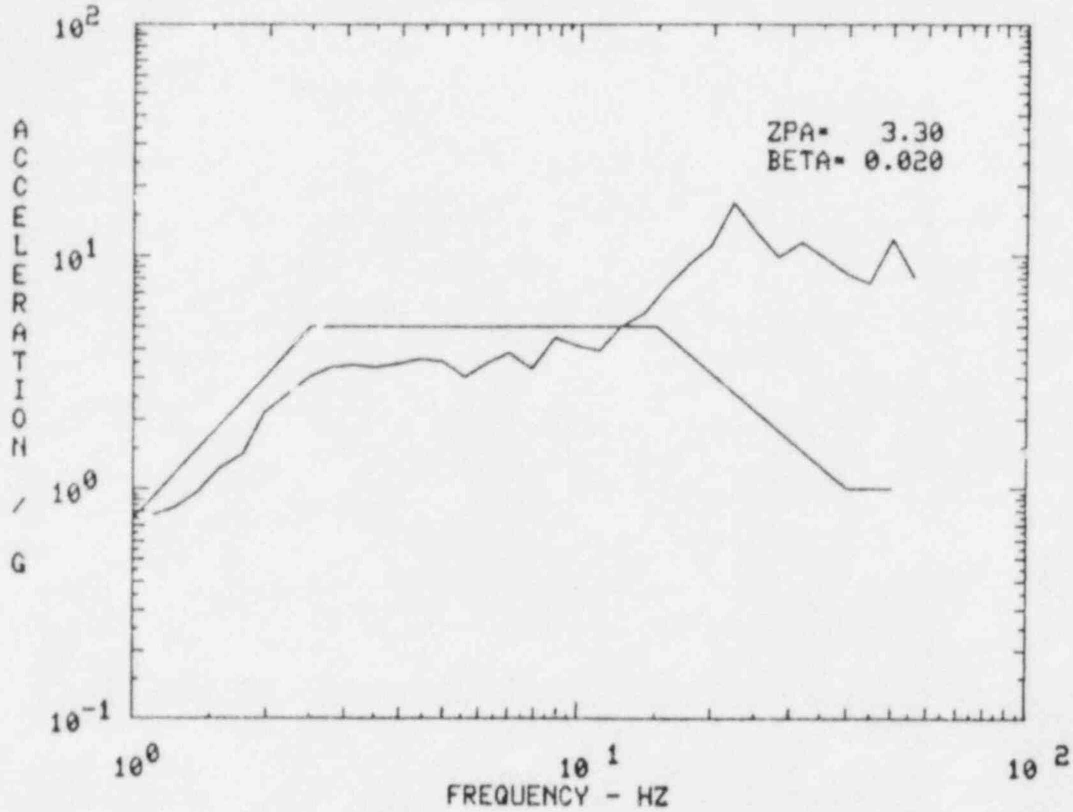


Figure 10.34 RUN OBXZ1 Accelerometer Location 6V

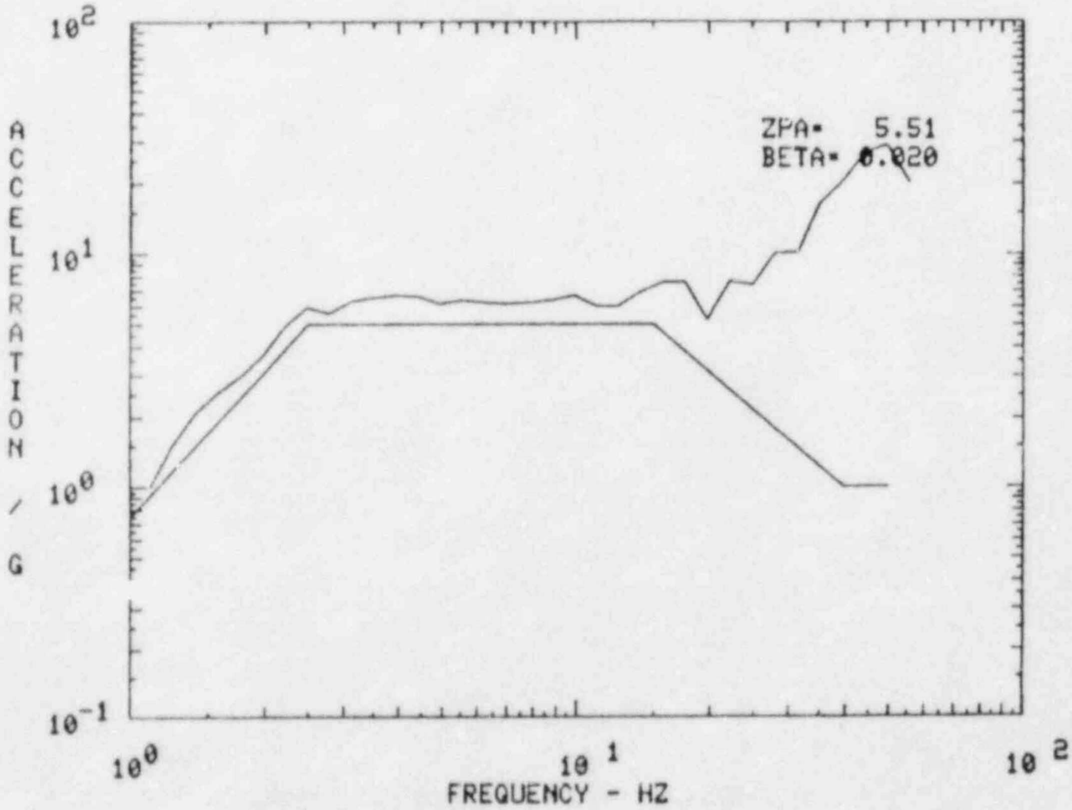


Figure 10.35 RUN OBXZ1 Accelerometer Location 7H

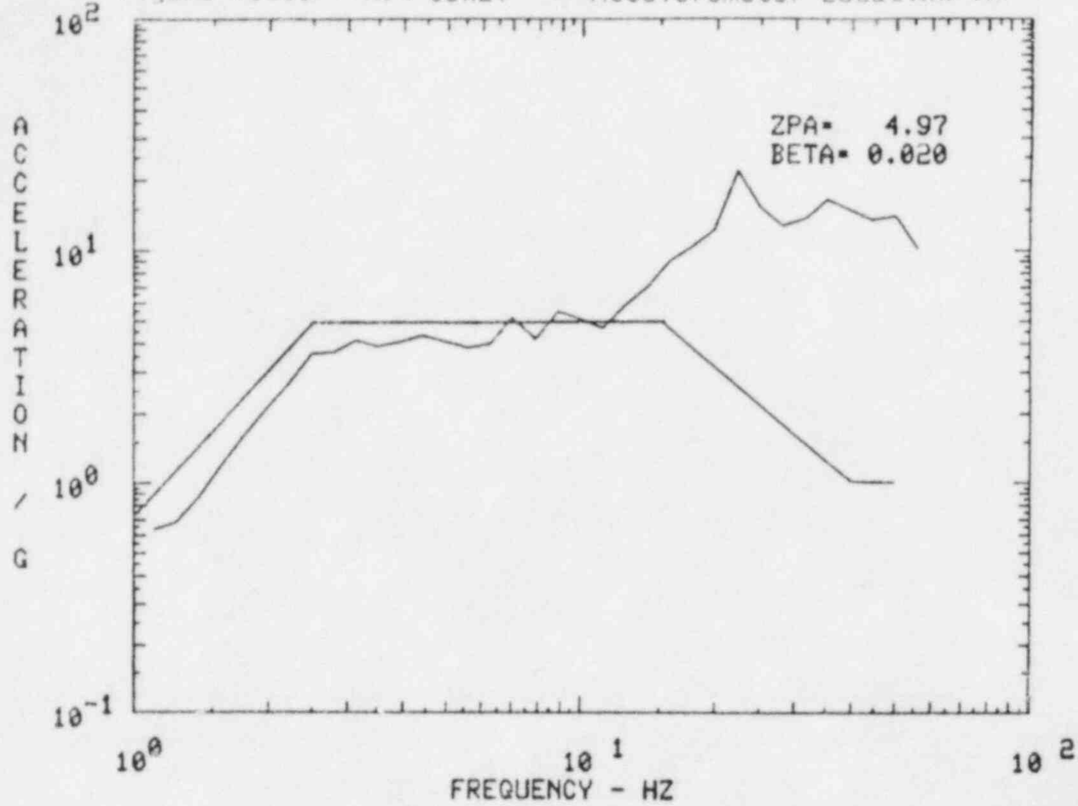


Figure 10.36 RUN OBXZ1 Accelerometer Location 8V

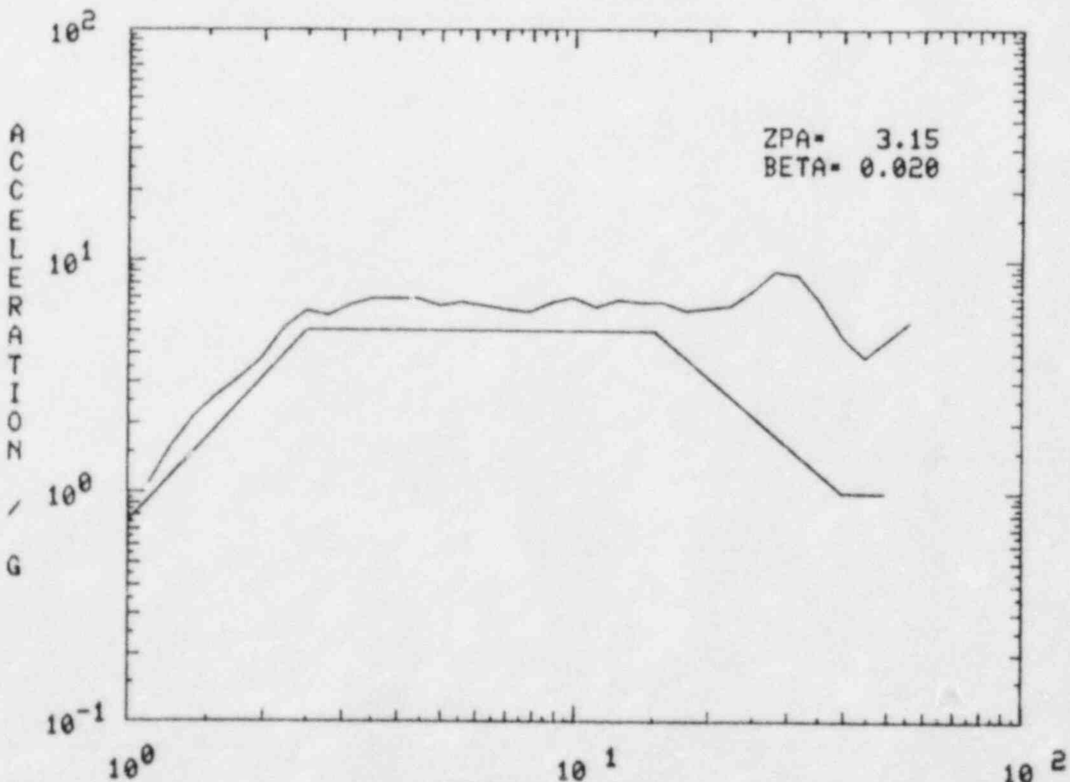


Figure 10.37 RUN OBXZ2 Accelerometer Location 1H

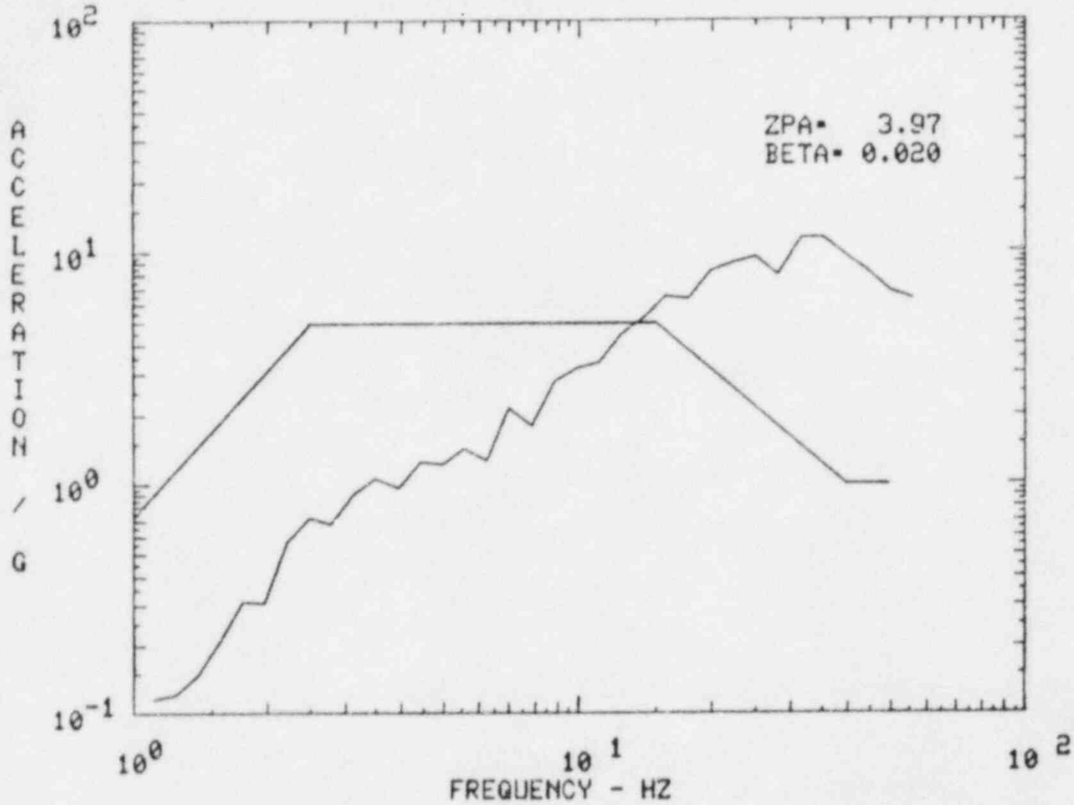


Figure 10.38 RUN OBXZ2 Accelerometer Location 2V

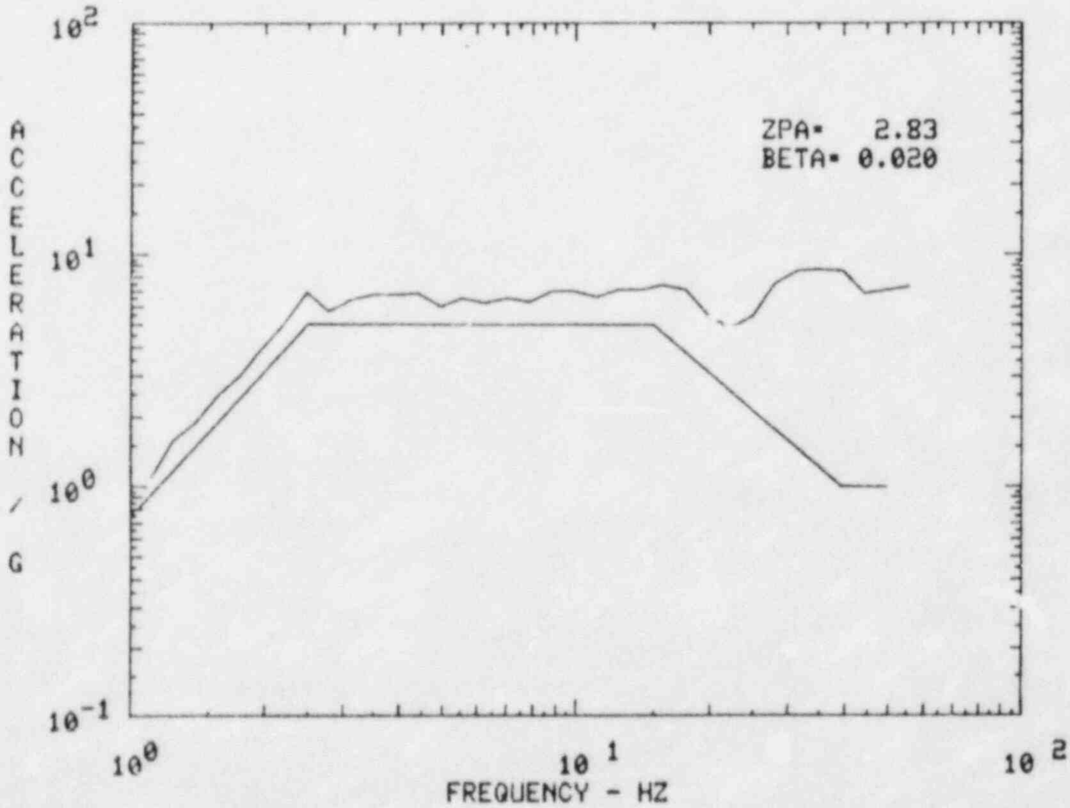


Figure 10.39 RUN OBXZ2 Accelerometer Location 3H

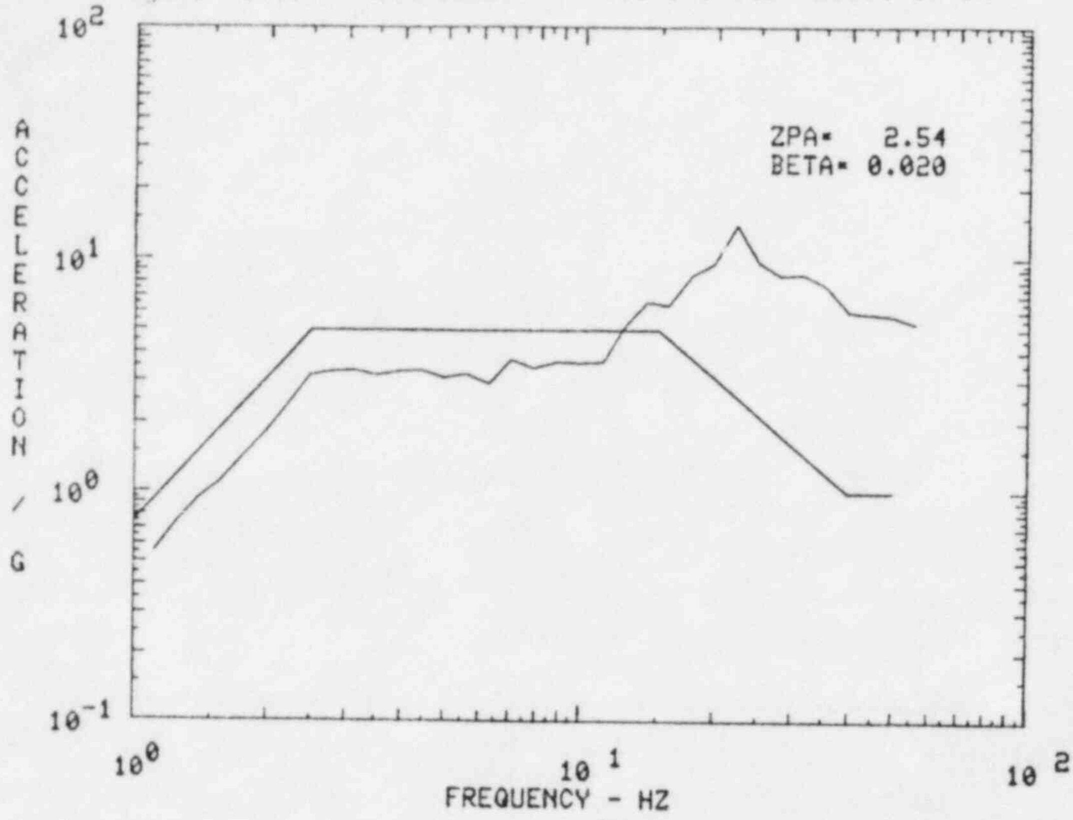


Figure 10.40 RUN OBXZ2 Accelerometer Location 4V

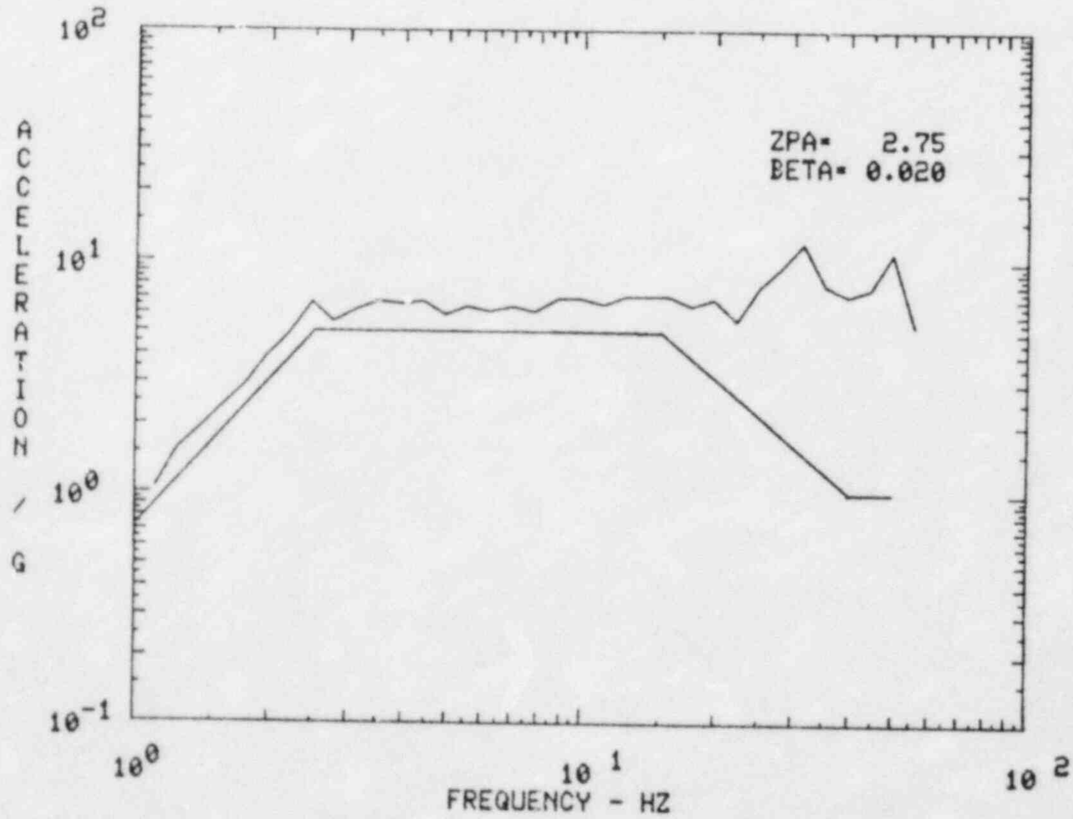


Figure 10.41 RUN OBXZ2 Accelerometer Location 5H

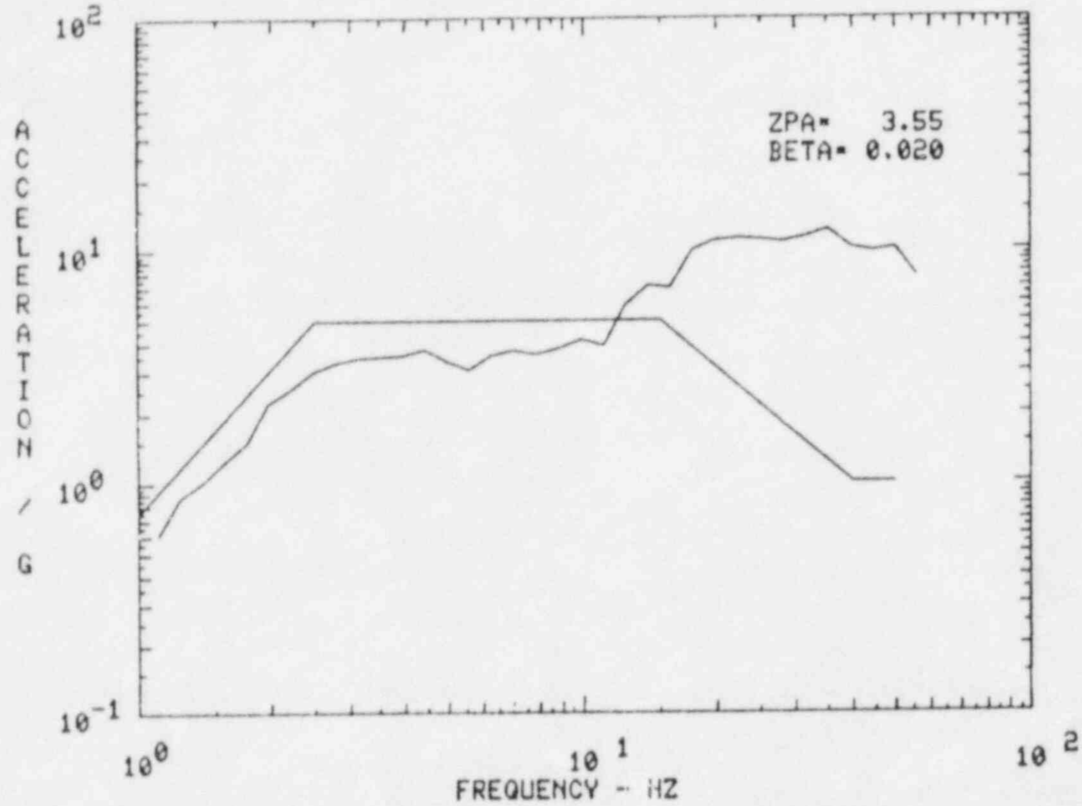


Figure 10.42 RUN OBXZ2 Accelerometer Location 6V

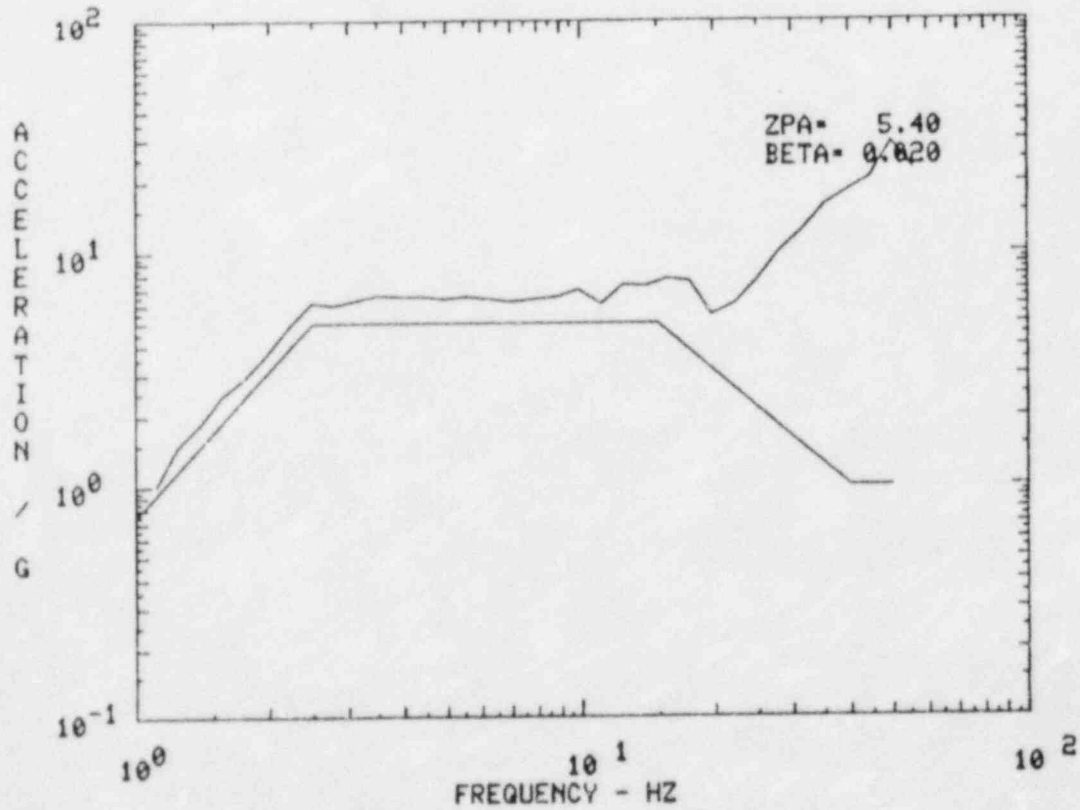


Figure 10.43 RUN OBXZ2 Accelerometer Location 7H

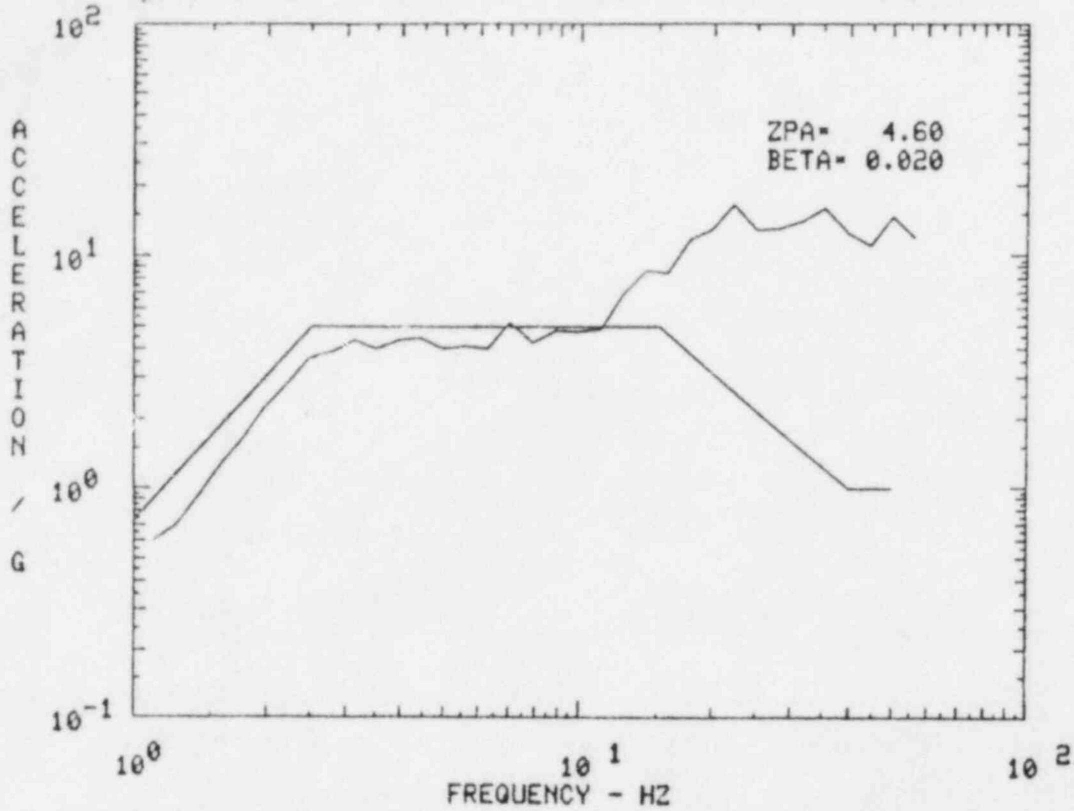


Figure 10.44 RUN OBXZ2 Accelerometer Location 8V

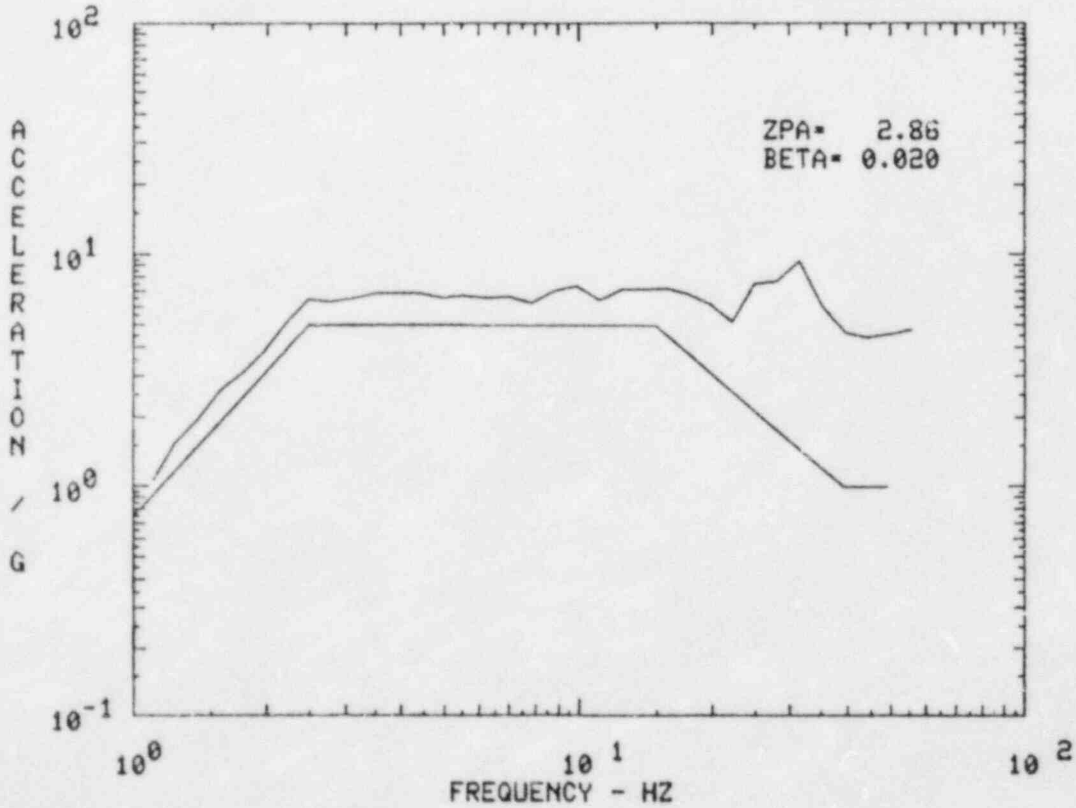


Figure 10.45 RUN OBXZ2 Accelerometer Location 9H

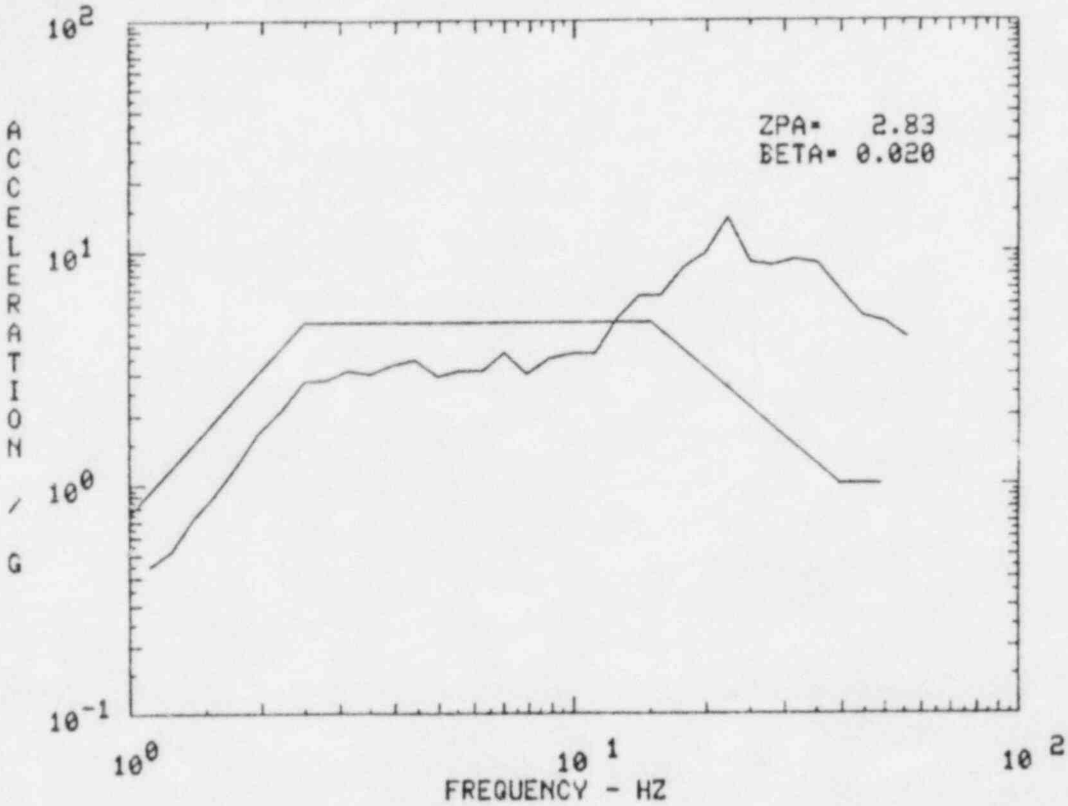


Figure 10.46 RUN OBXZ2 Accelerometer Location 10H

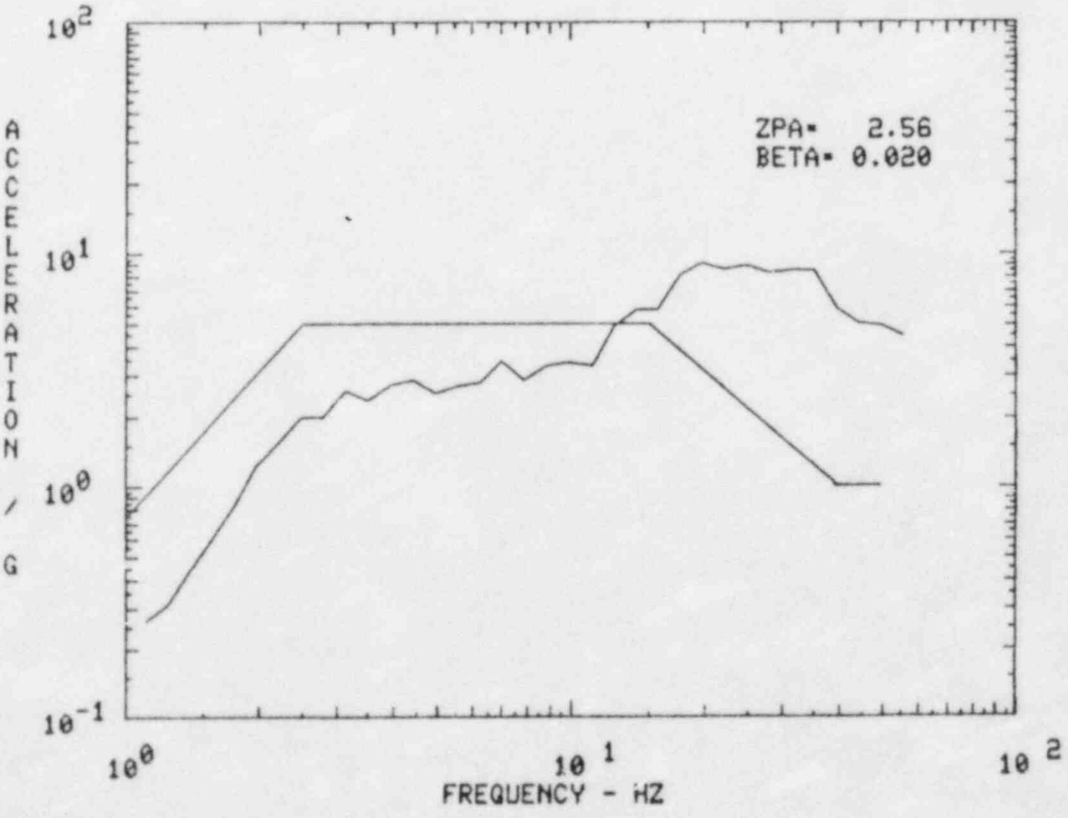


Figure 10.47   RUN OBXZ3   Accelerometer Locatic.. 1H

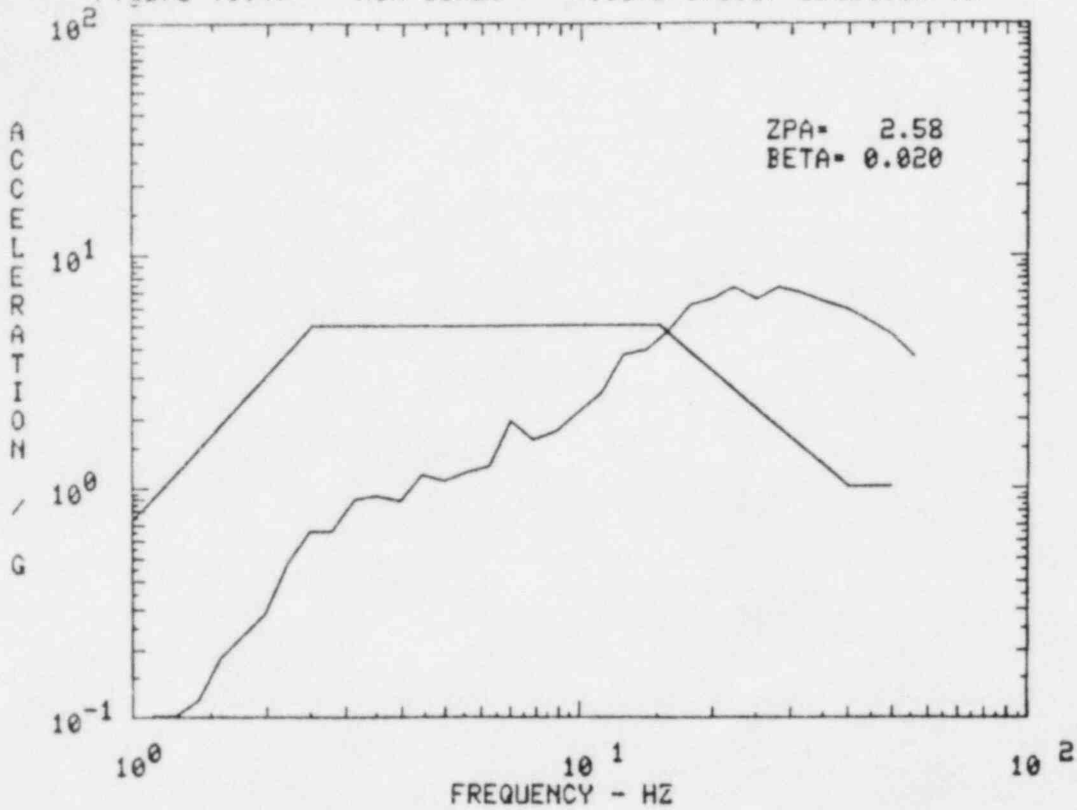


Figure 10.48   RUN OBXZ3   Accelerometer Location 2V

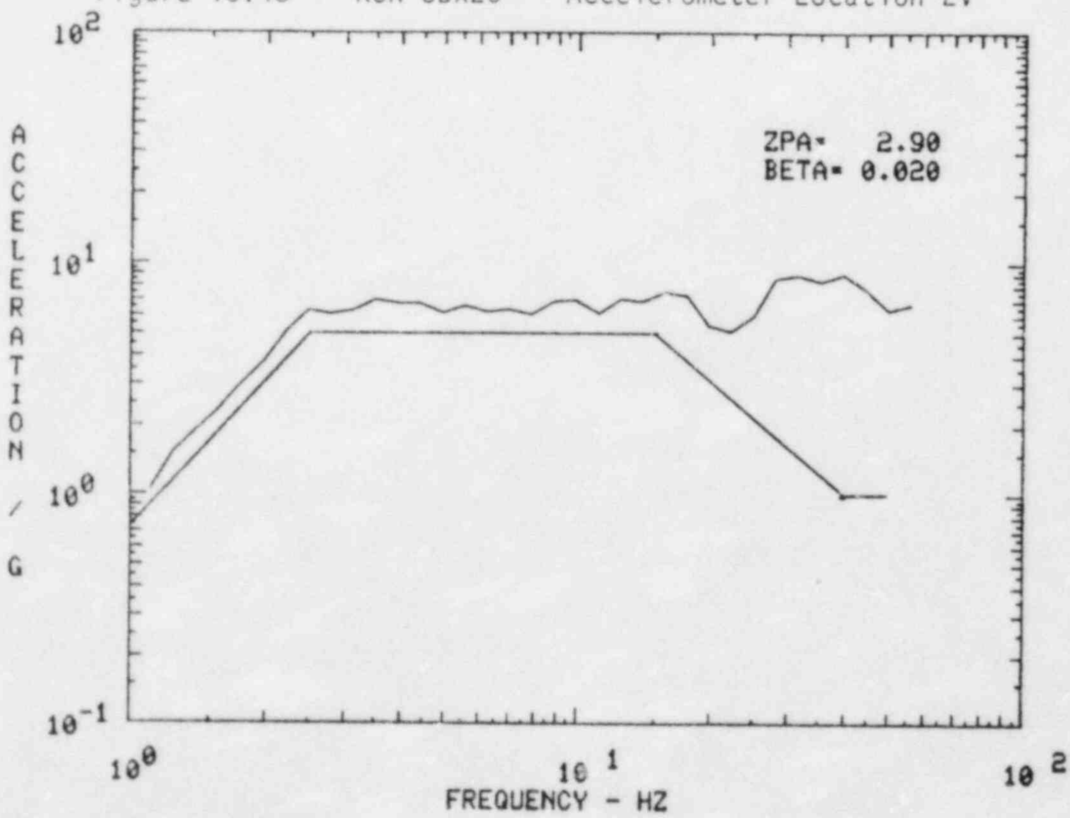


Figure 10.49 RUN OBXZ3 Accelerometer Location 3H

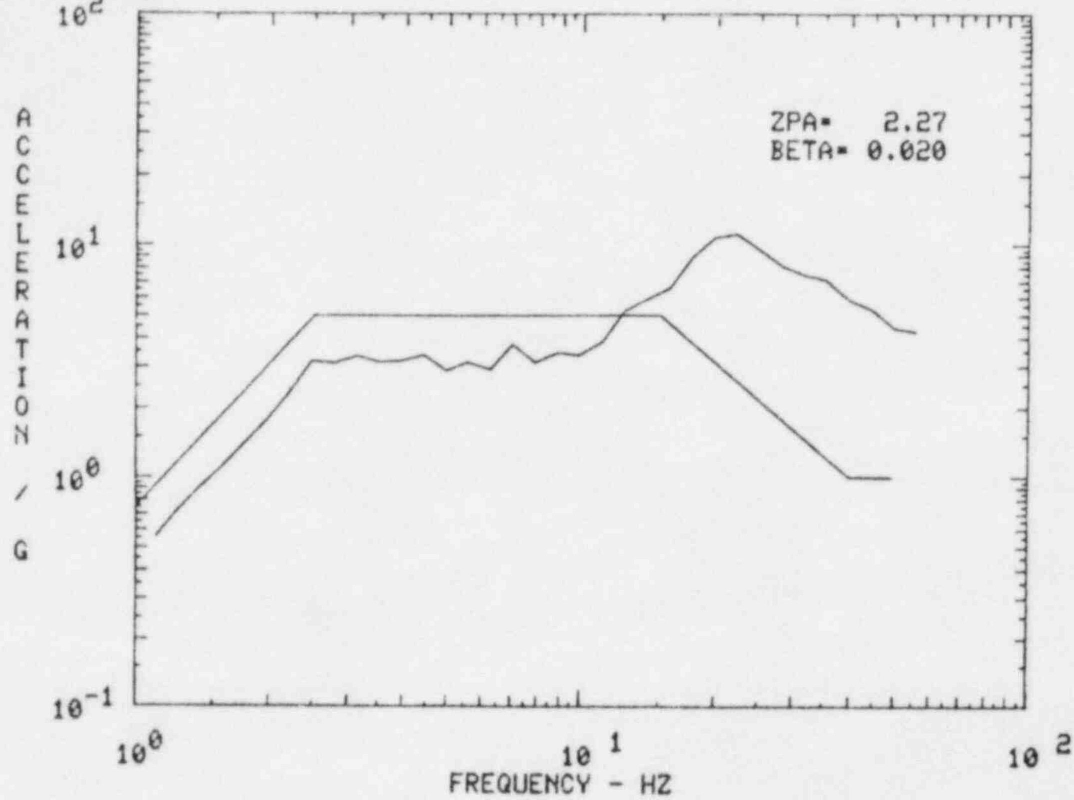


Figure 10.50 RUN OBXZ3 Accelerometer Location 4V

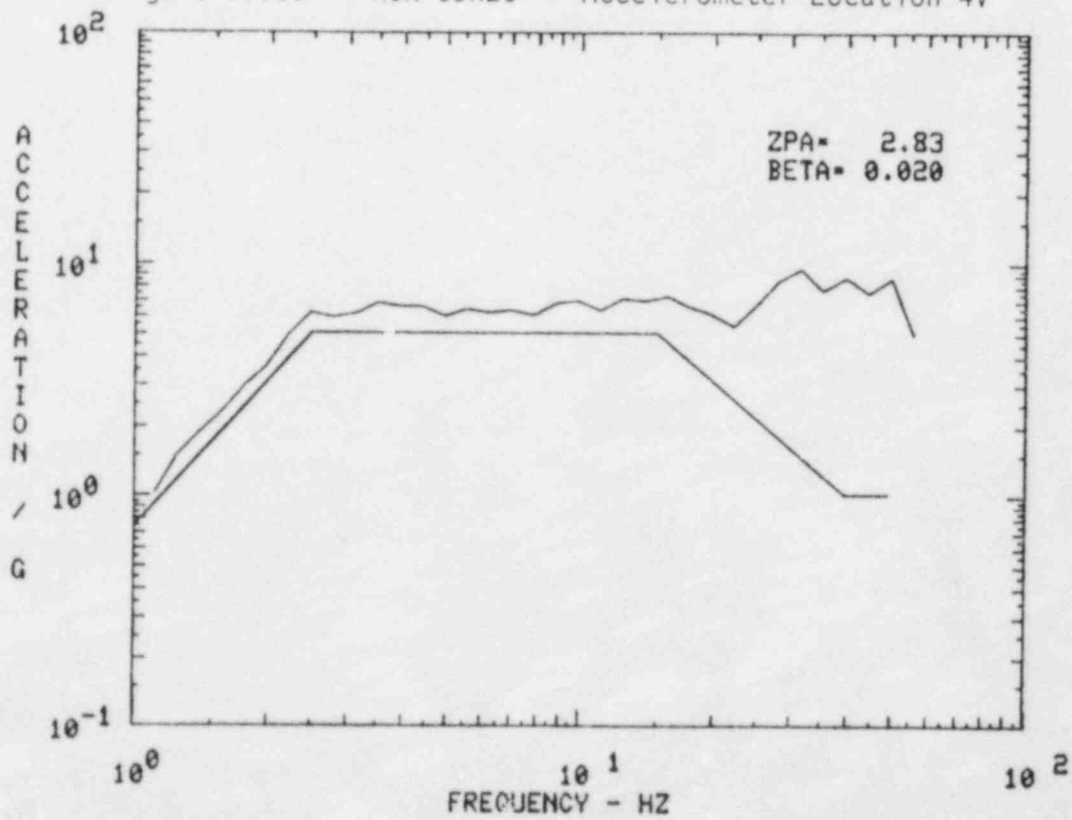


Figure 10.51 RUN OBXZ3 Accelerometer Location 5H

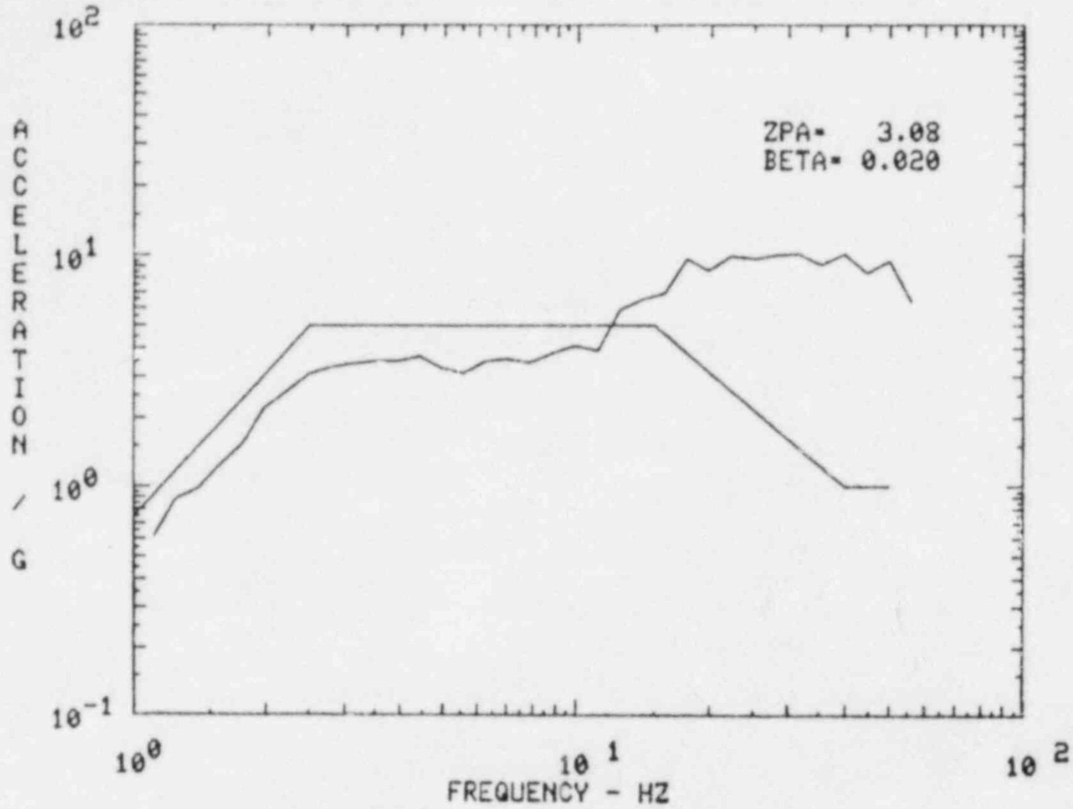


Figure 10.52 RUN OBXZ3 Accelerometer Location 6V

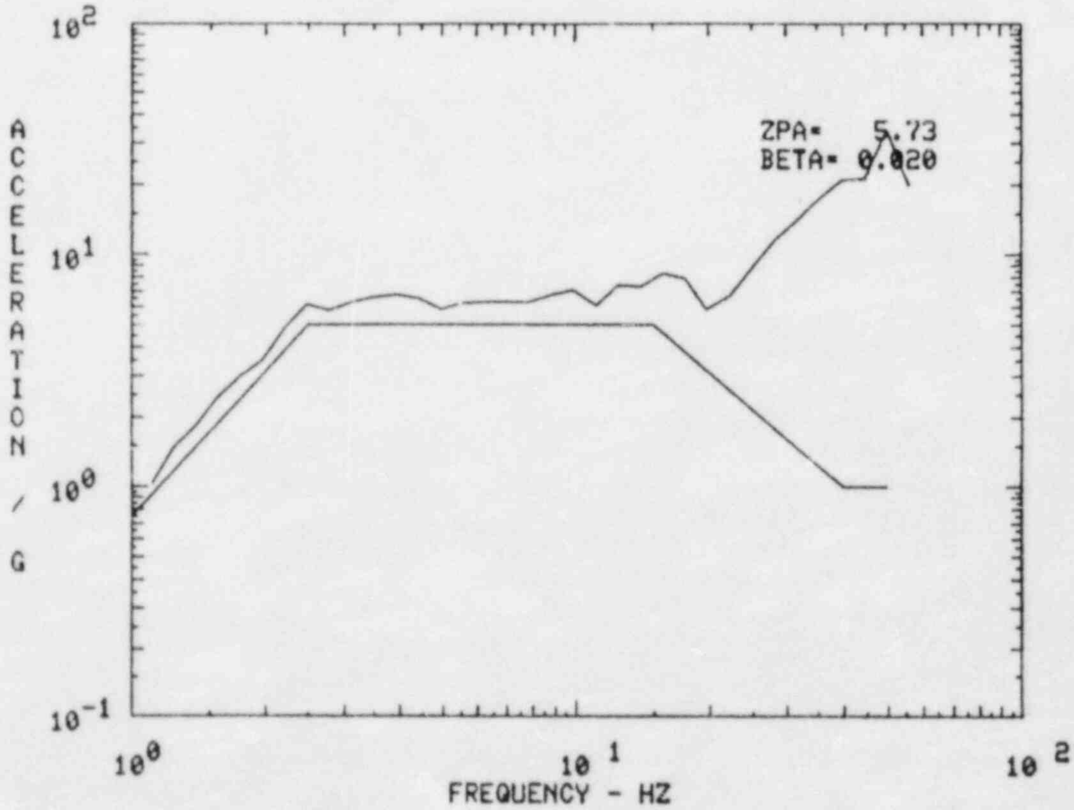


Figure 10.53 RUN OBXZ3 Accelerometer Location 7H

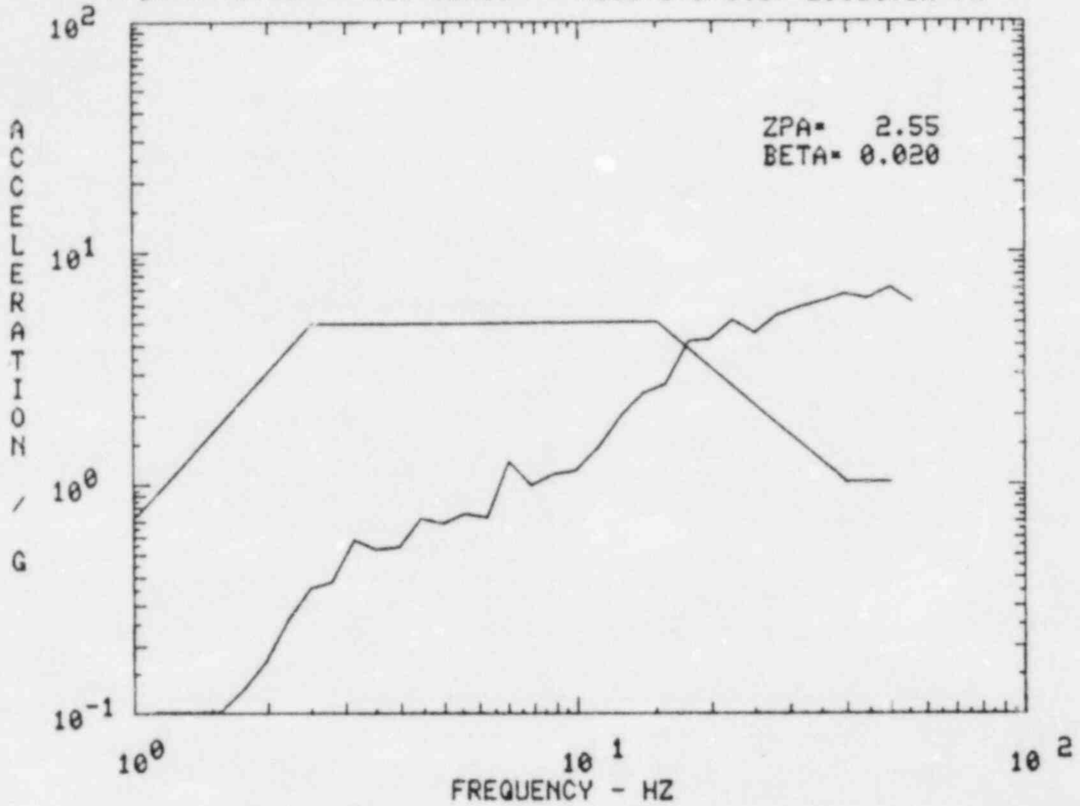


Figure 10.54 RUN OBXZ3 Accelerometer Location 8V

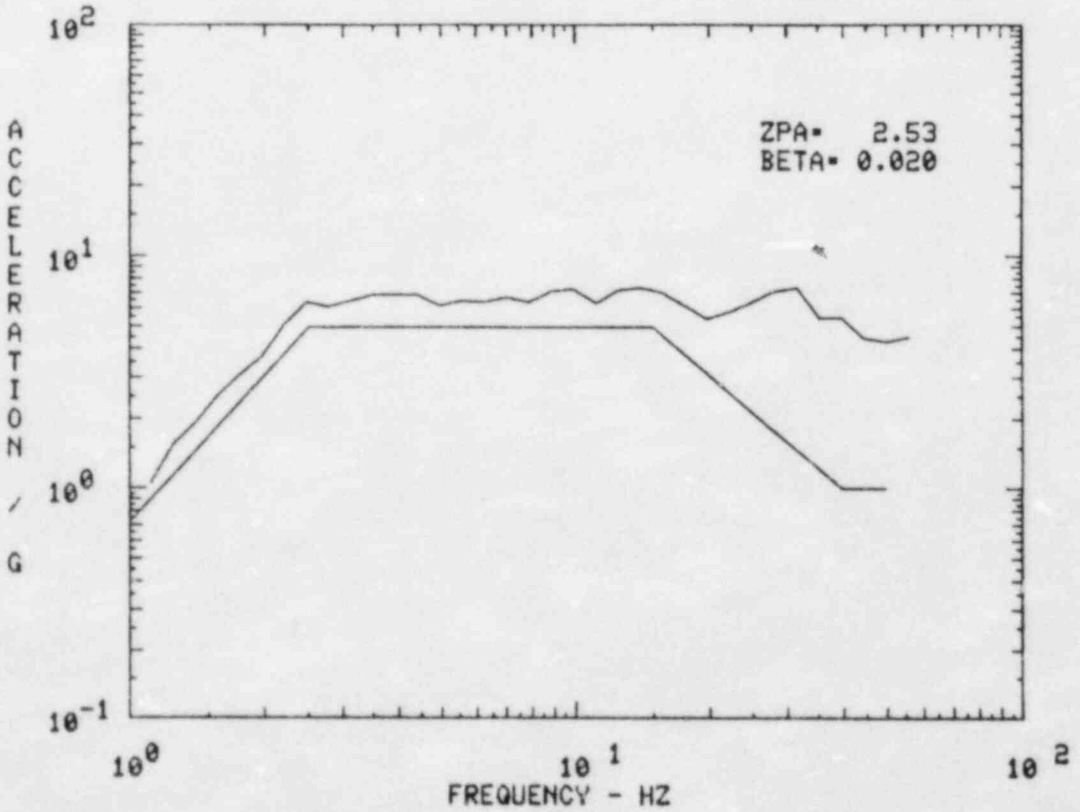


Figure 10.55 RUN OBXZ3 Accelerometer Location 9H

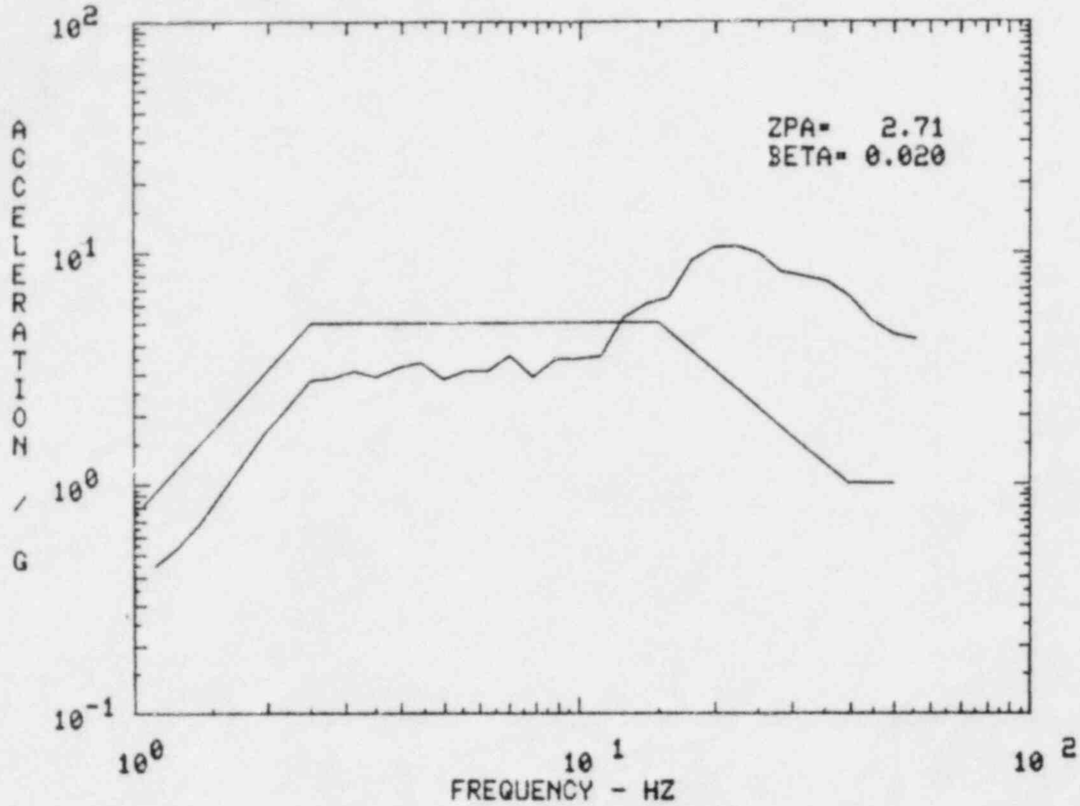


Figure 10.56 RUN OBXZ3 Accelerometer Location 10H

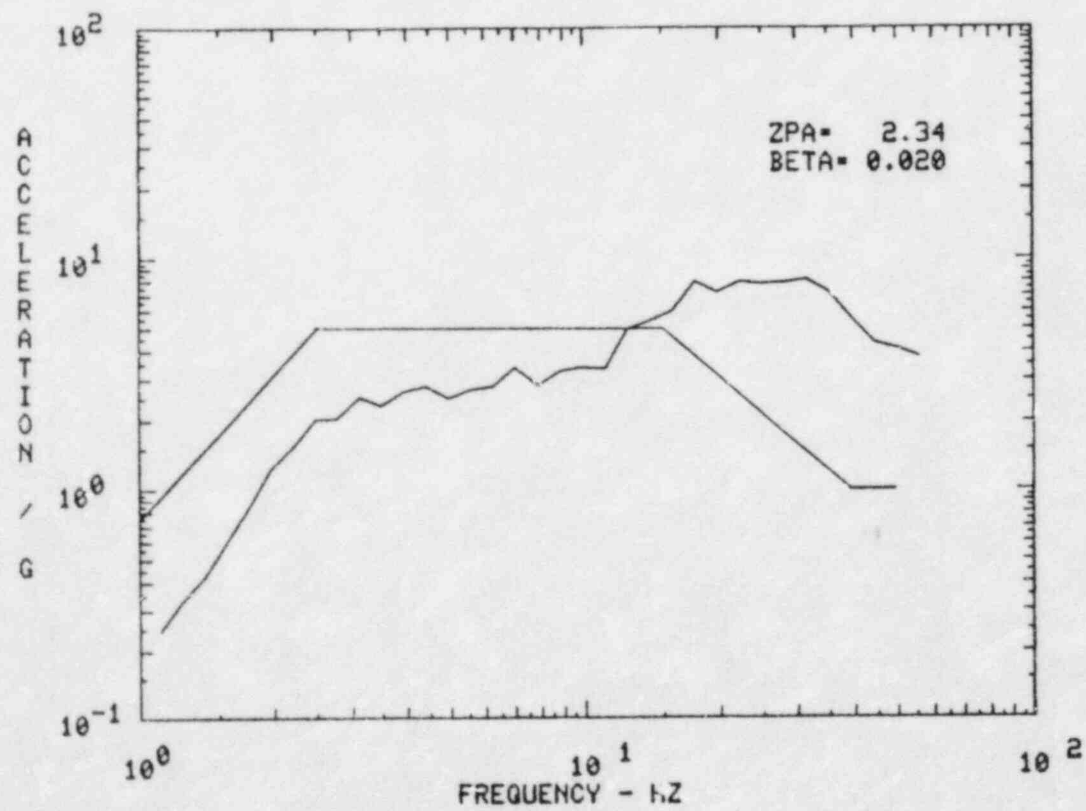


Figure 10.57   RUN OBXZ4   Accelerometer Location 1H

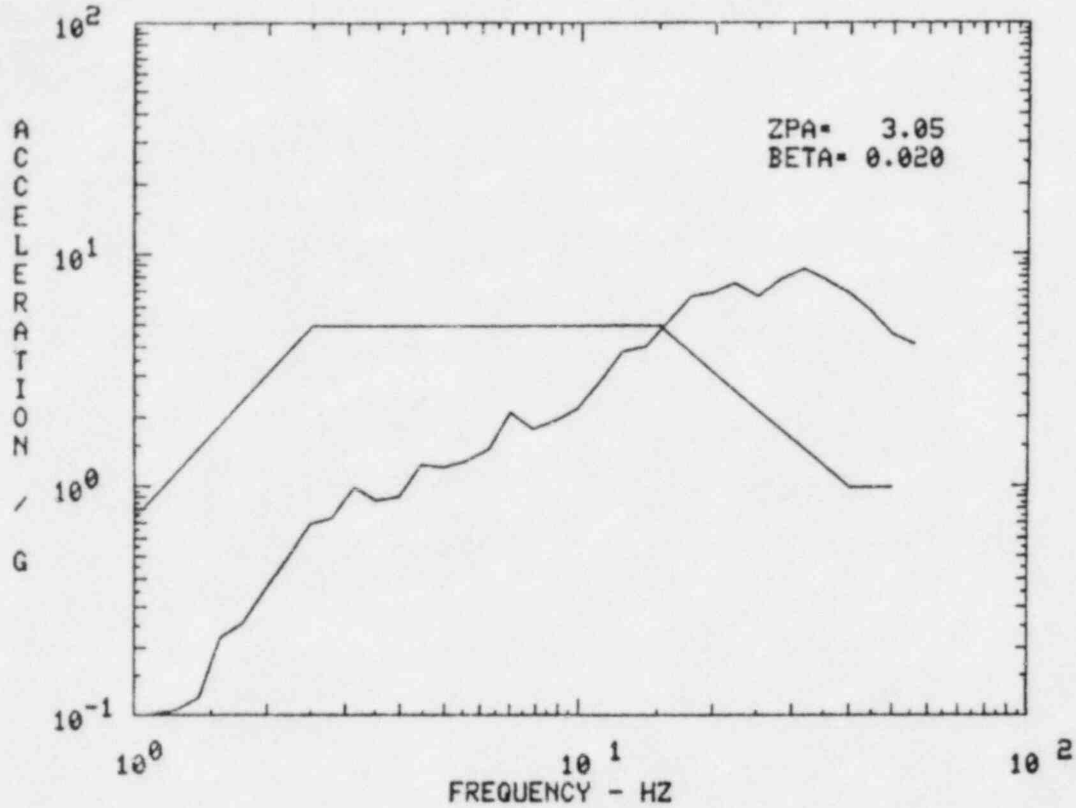


Figure 10.58   RUN OBXZ4   Accelerometer Location 2V

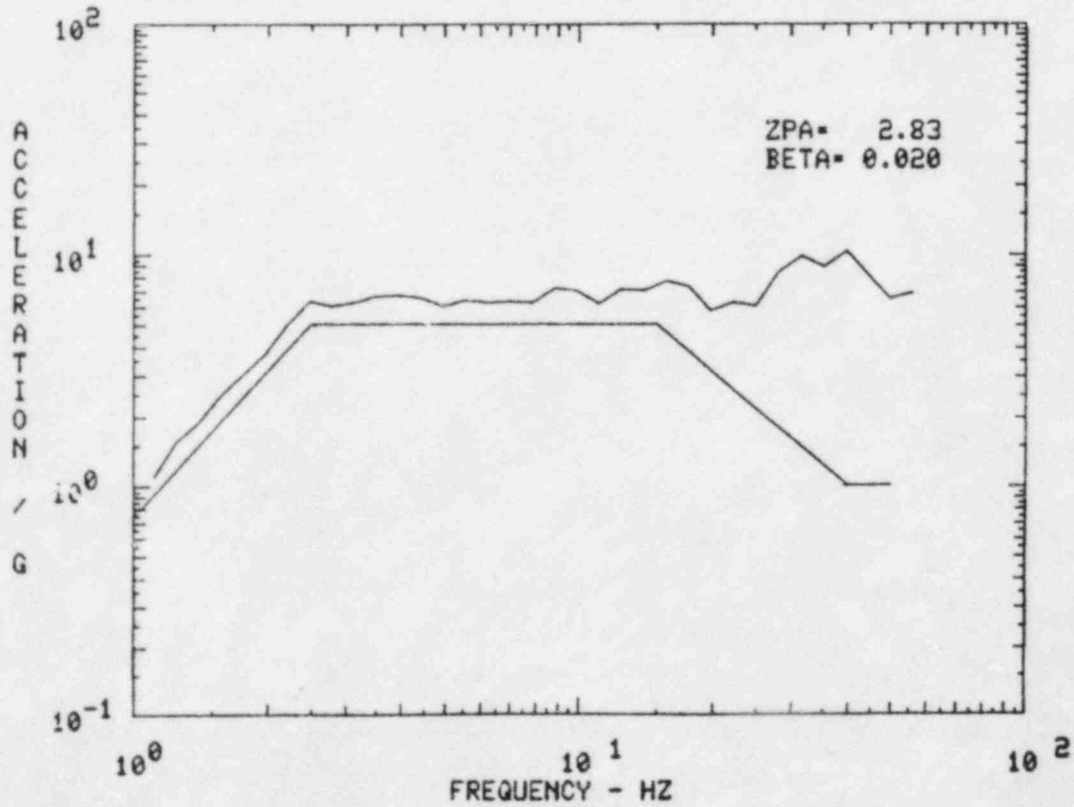


Figure 10.59 RUN OBXZ4 Accelerometer Location 3H

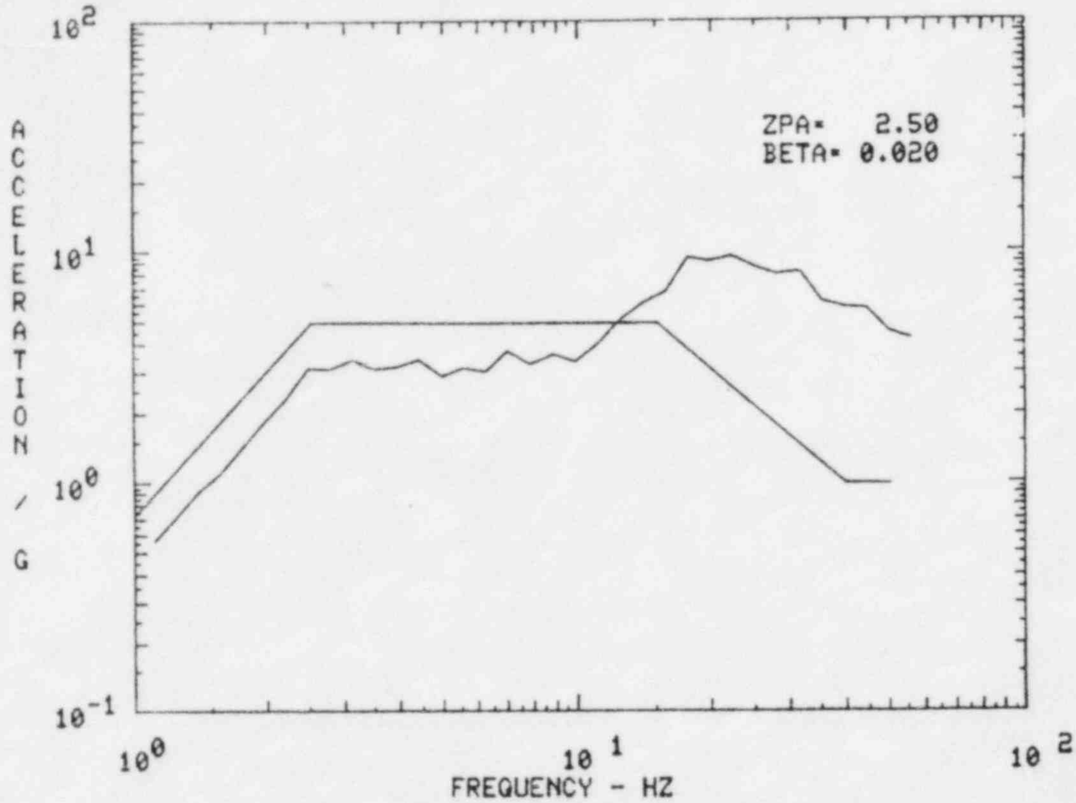


Figure 10.60 RUN OBXZ4 Accelerometer Location 4V

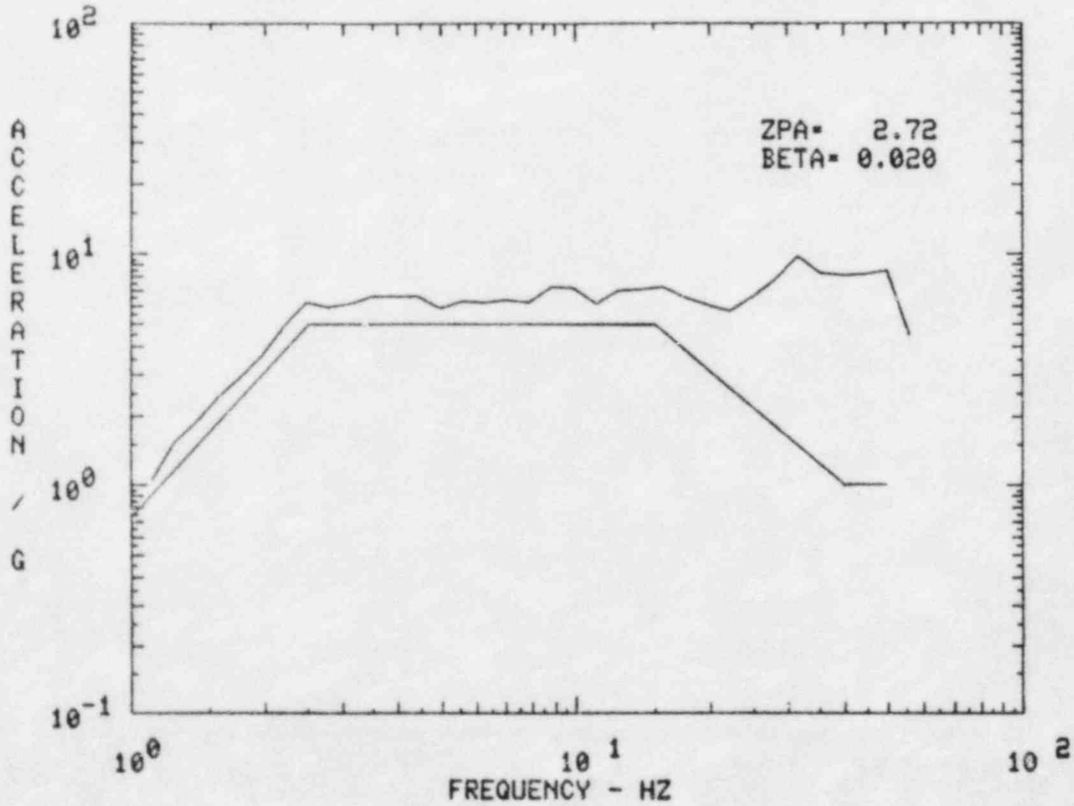


Figure 10.61 RUN OBXZ4 Accelerometer Location 5H

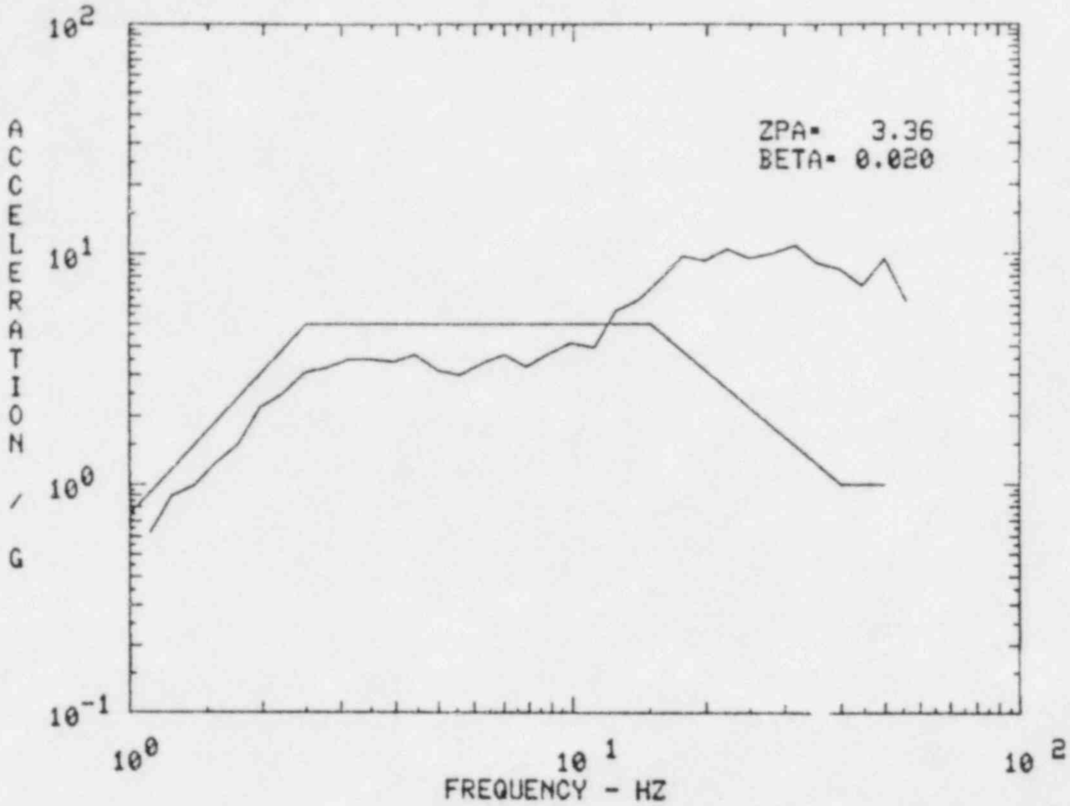


Figure 10.62 RUN OBXZ4 Accelerometer Location 6V

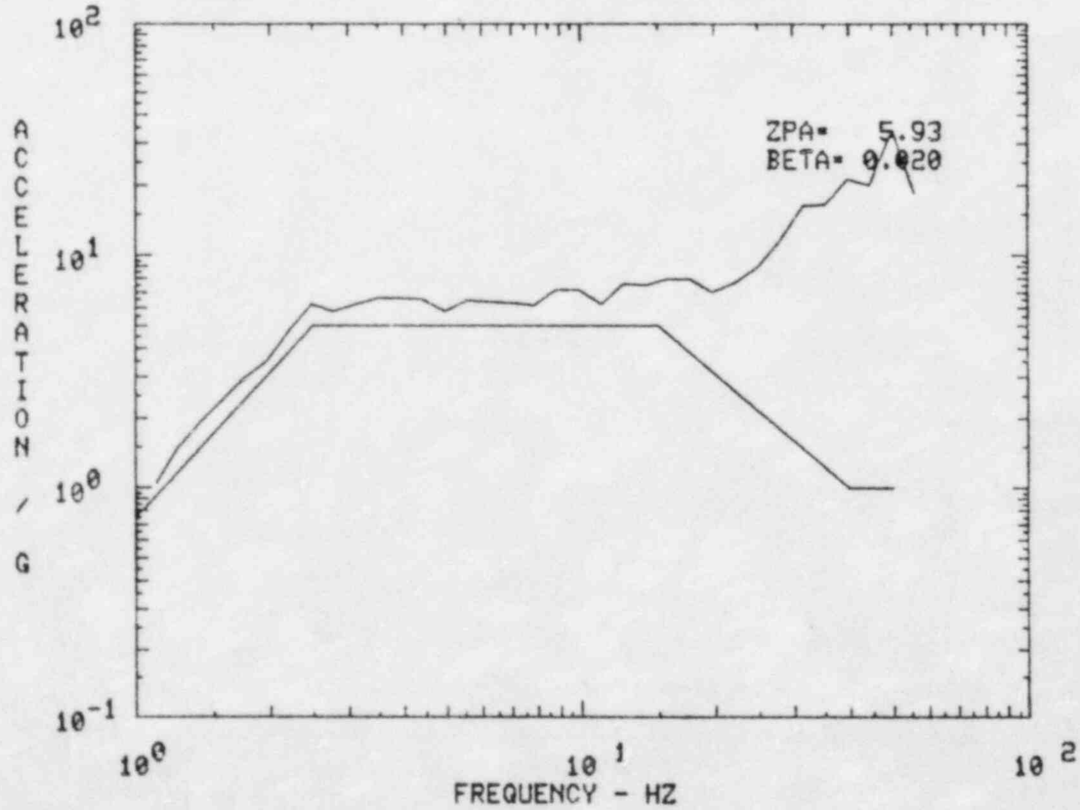


Figure 10.63 RUN OBXZ4 Accelerometer Location 7H

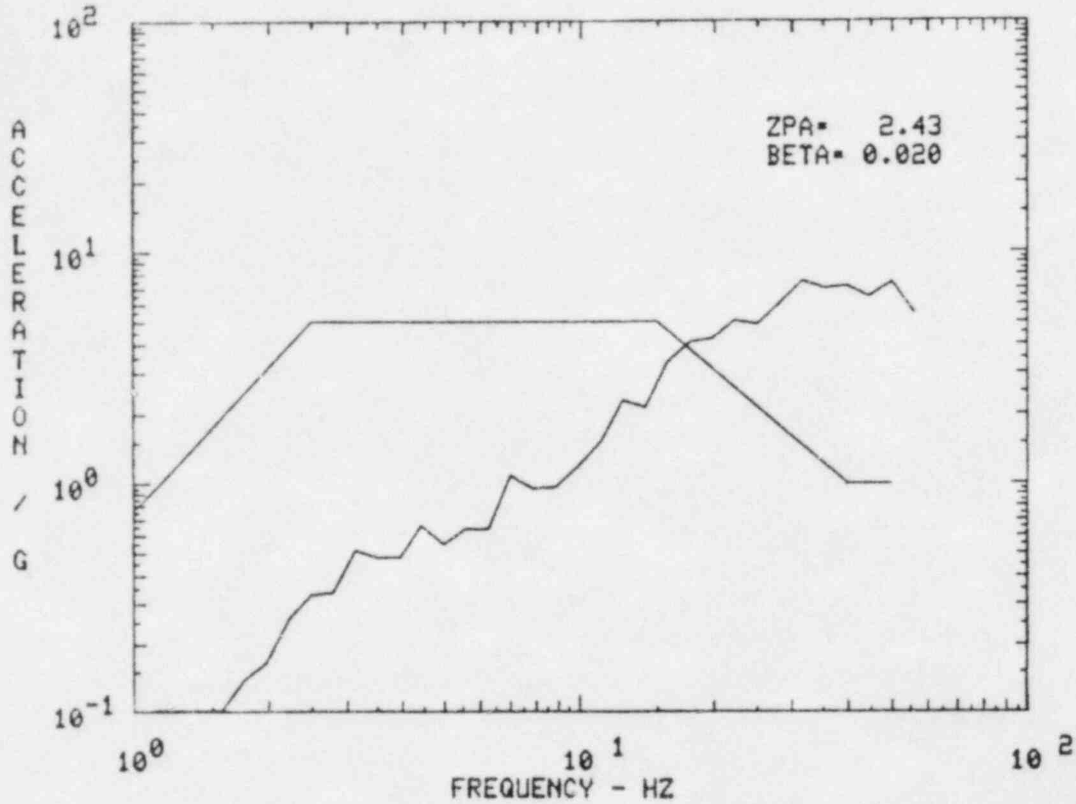


Figure 10.64 RUN OBXZ4 Accelerometer Location 8V

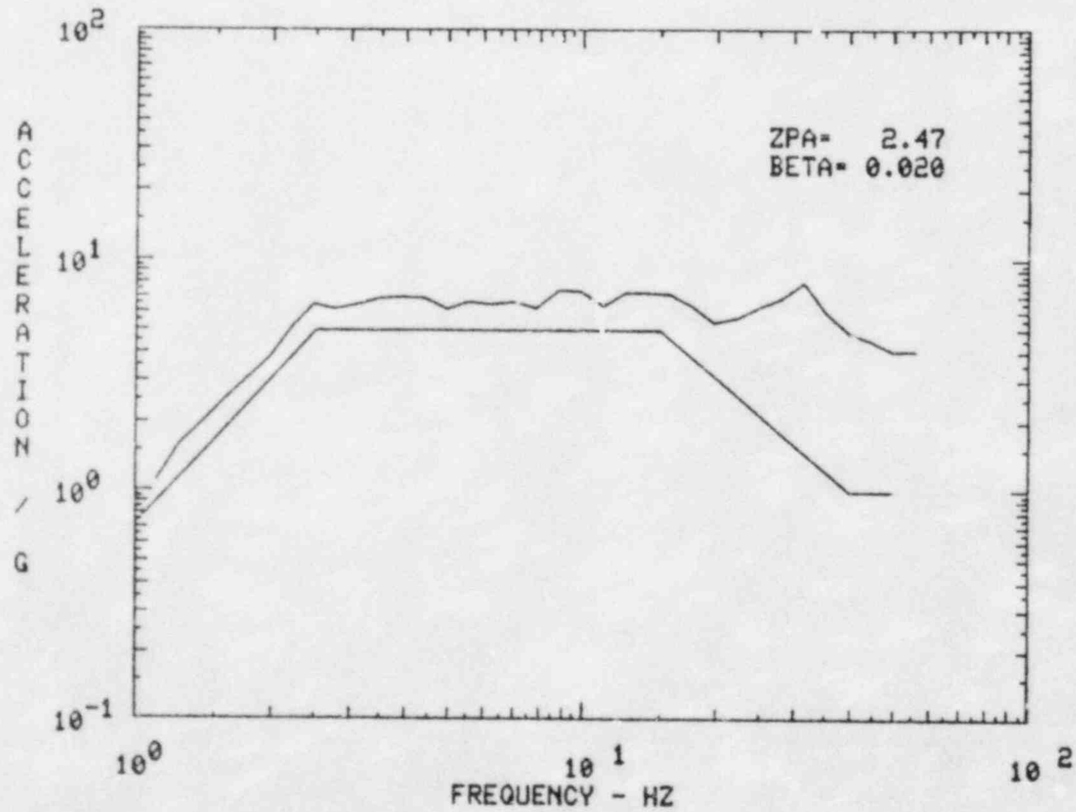


Figure 10.65 RUN OBXZ4 Accelerometer Location 9H

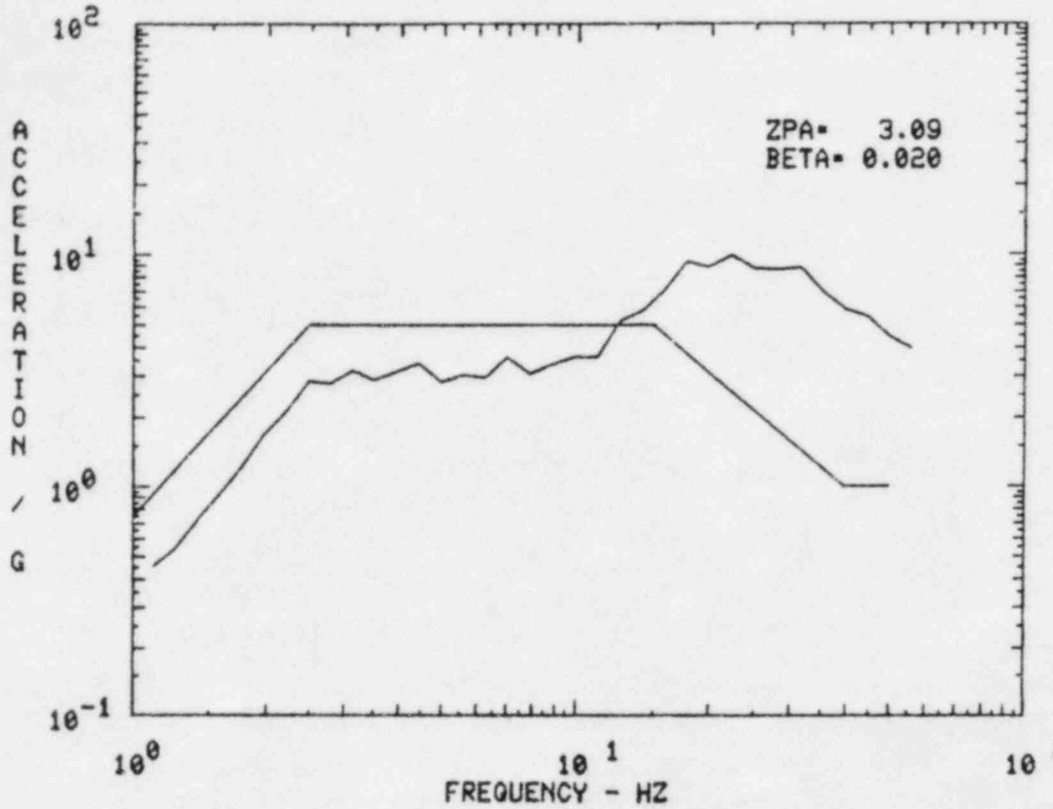


Figure 10.66 RUN OBXZ4 Accelerometer Location 10H

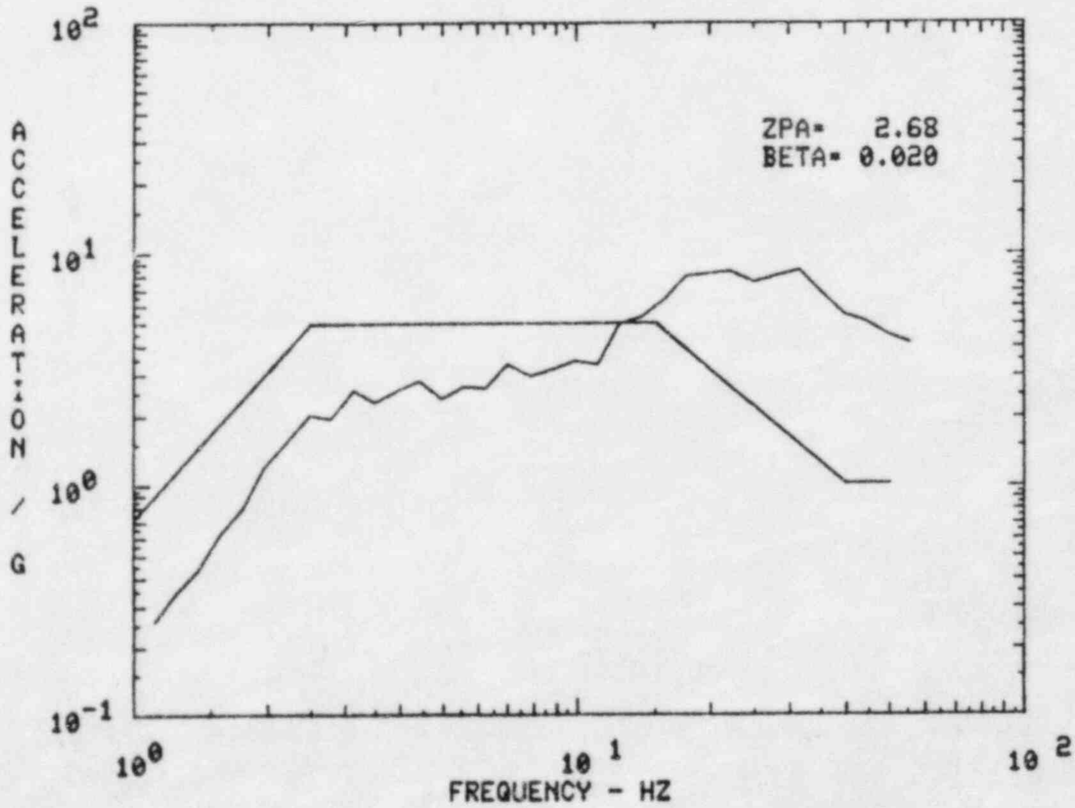


Figure 10.67 RUN OBXZ5 Accelerometer Location 1H

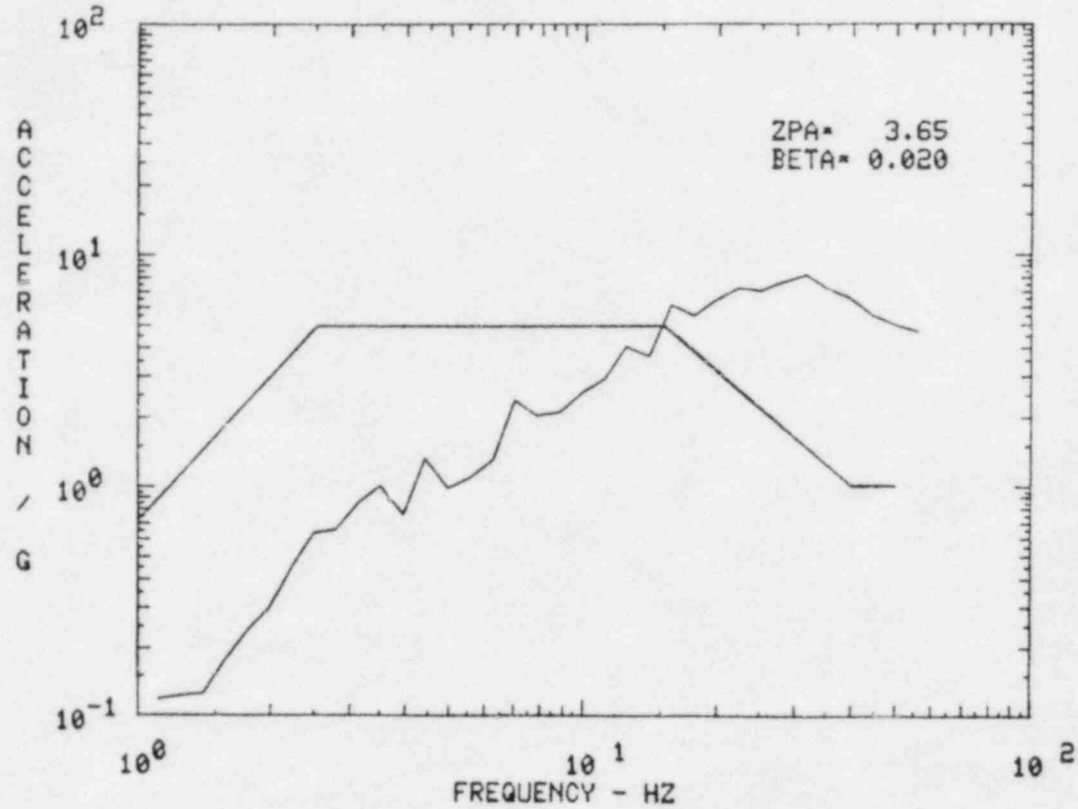


Figure 10.68 RUN OBXZ5 Accelerometer Location 2V

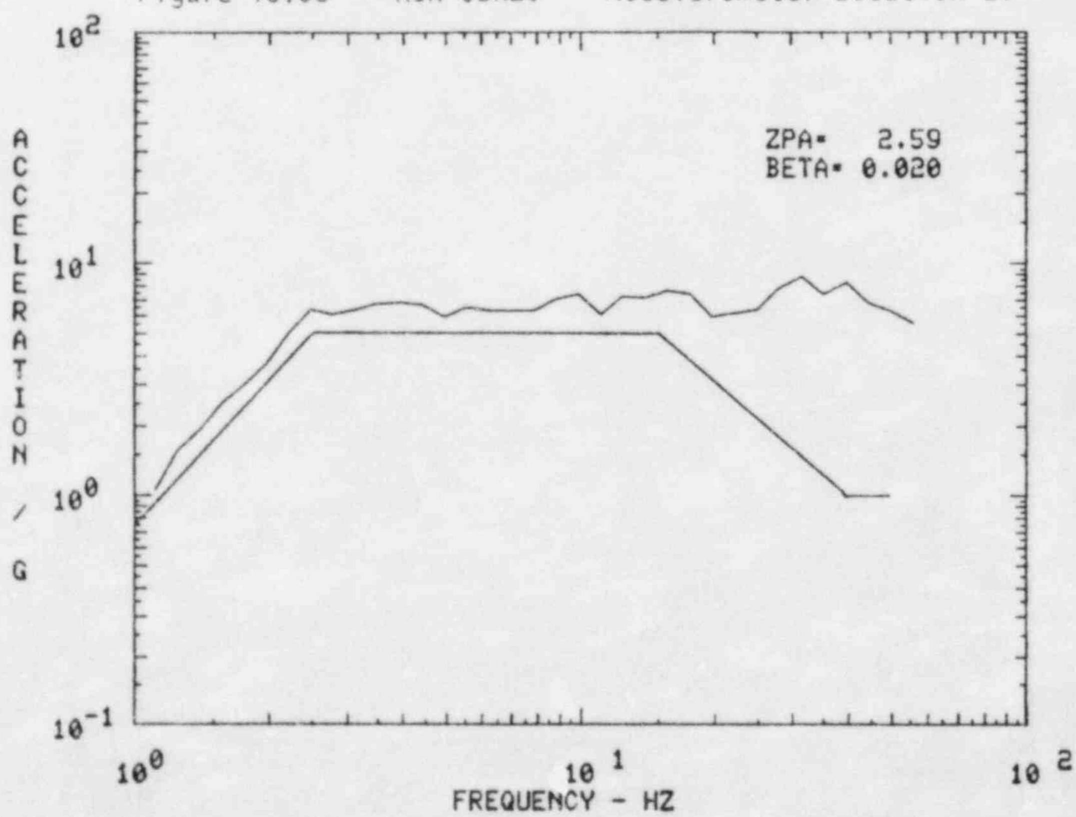


Figure 10.71 RUN OBXZ5 Accelerometer Location 5H

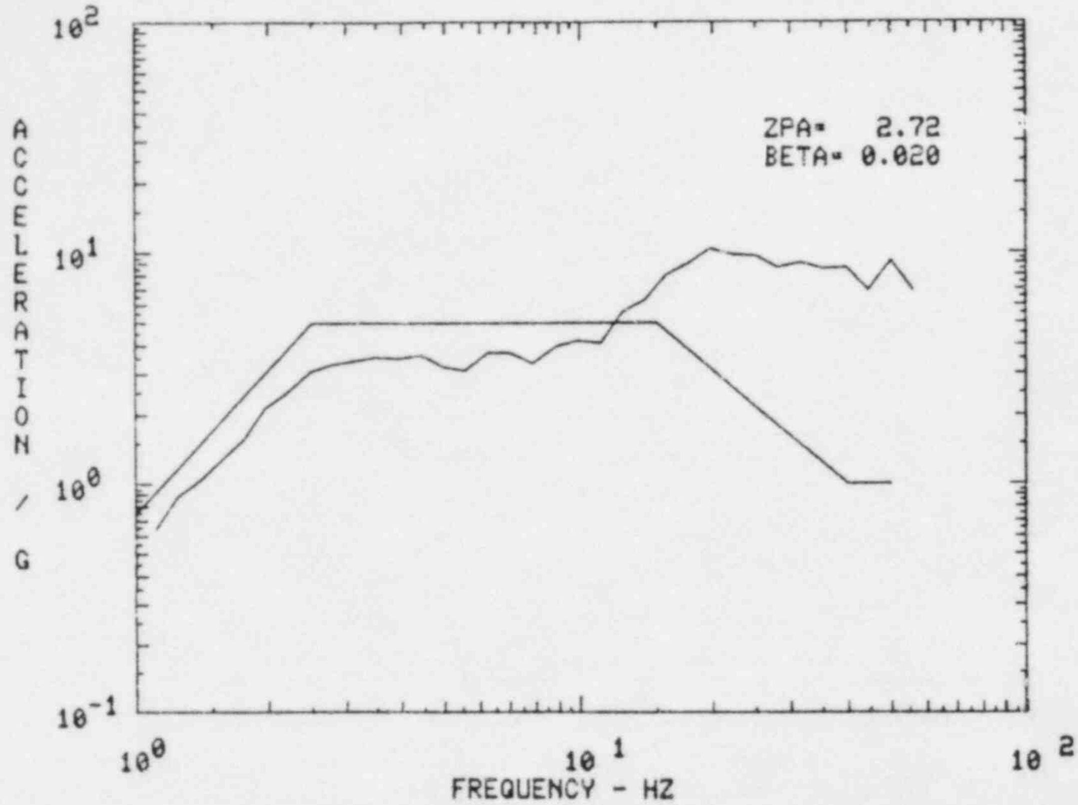


Figure 10.72 RUN OBXZ5 Accelerometer Location 6V

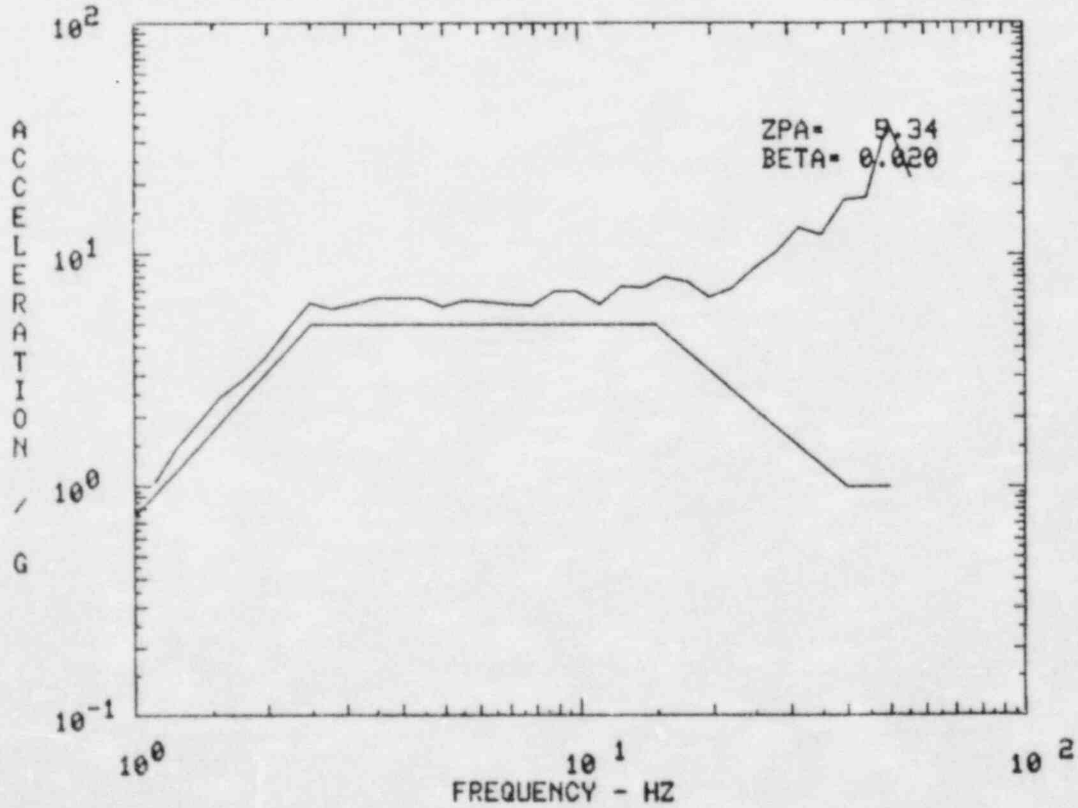


Figure 10.69 RUN OBXZ5 Accelerometer Location 3H

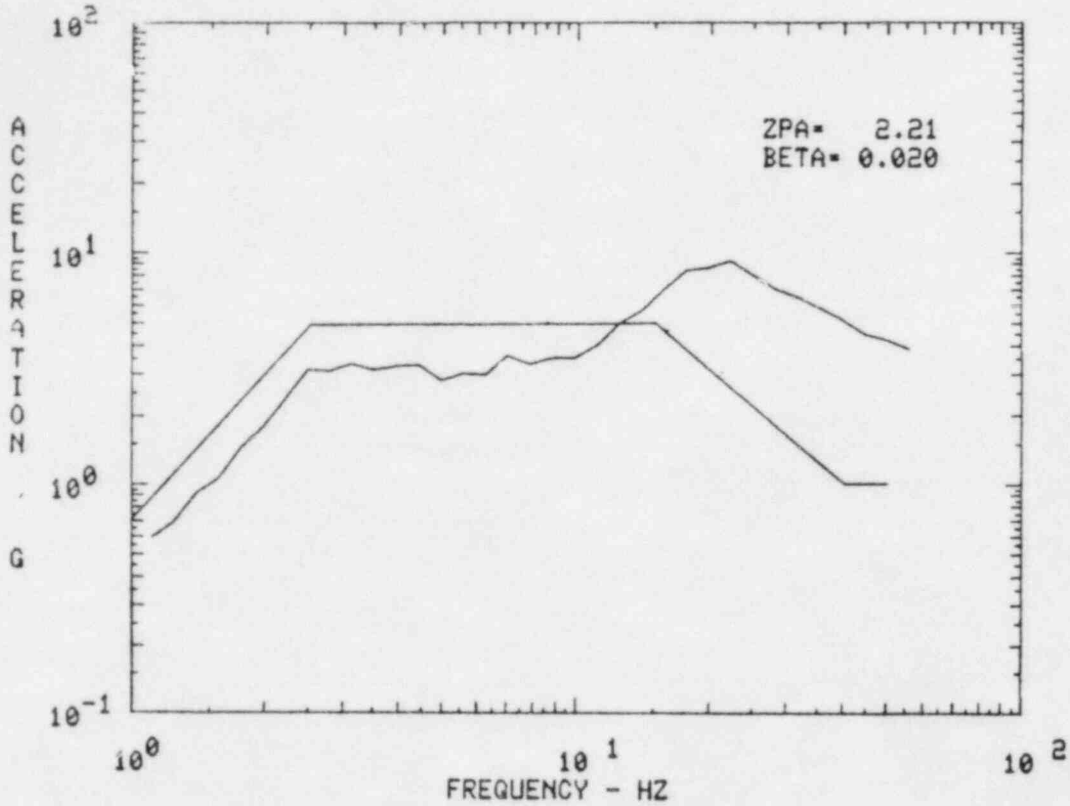


Figure 10.70 RUN OBXZ5 Accelerometer Location 4V

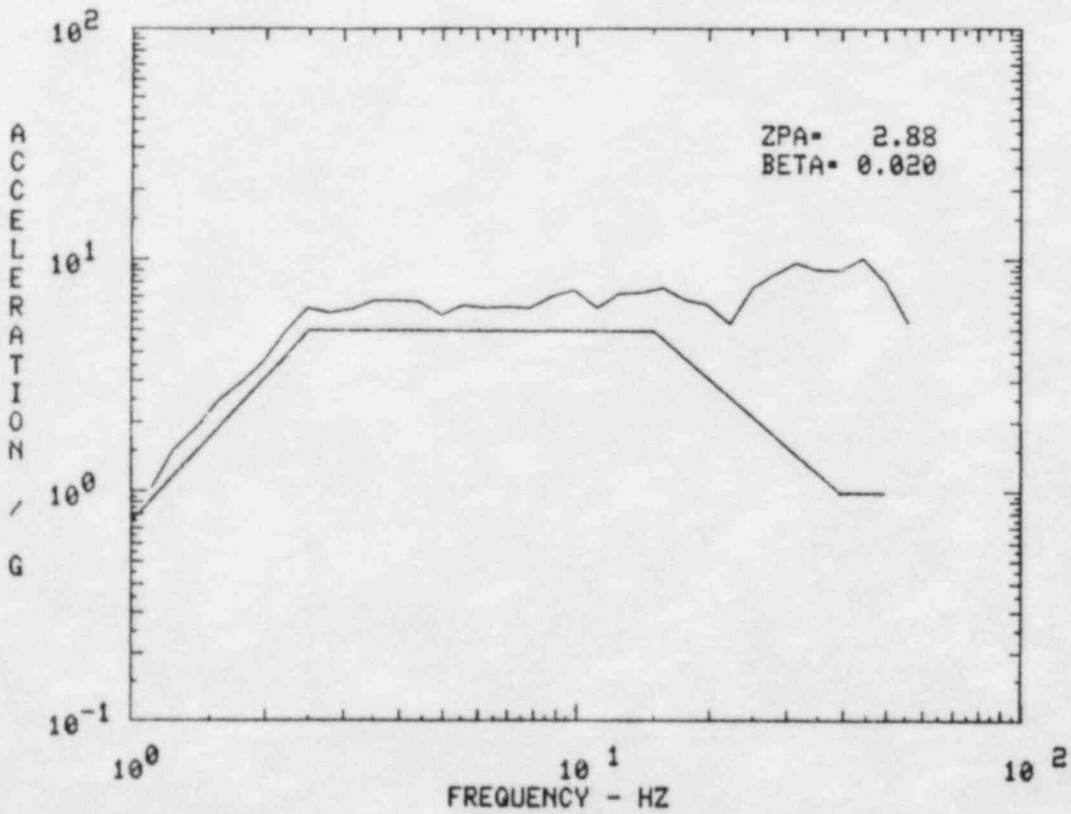


Figure 10.73 RUN OBXZ5 Accelerometer Location 7H

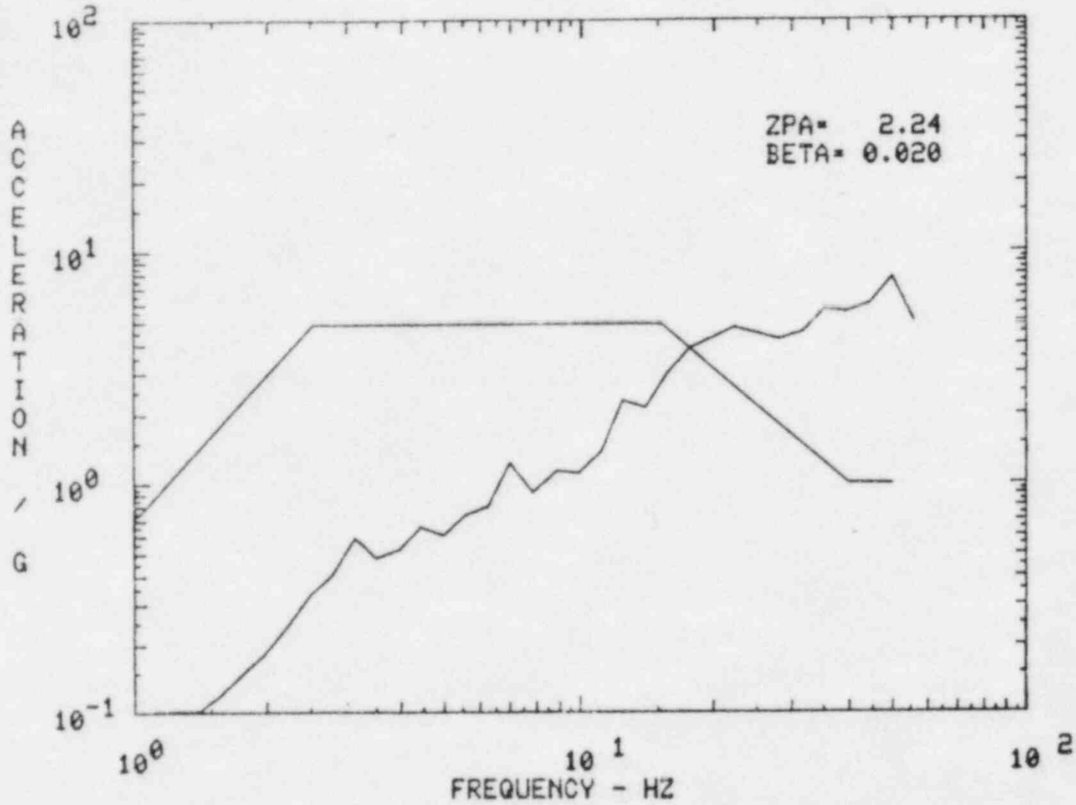


Figure 10.74 RUN OBXZ5 Accelerometer Location 8V

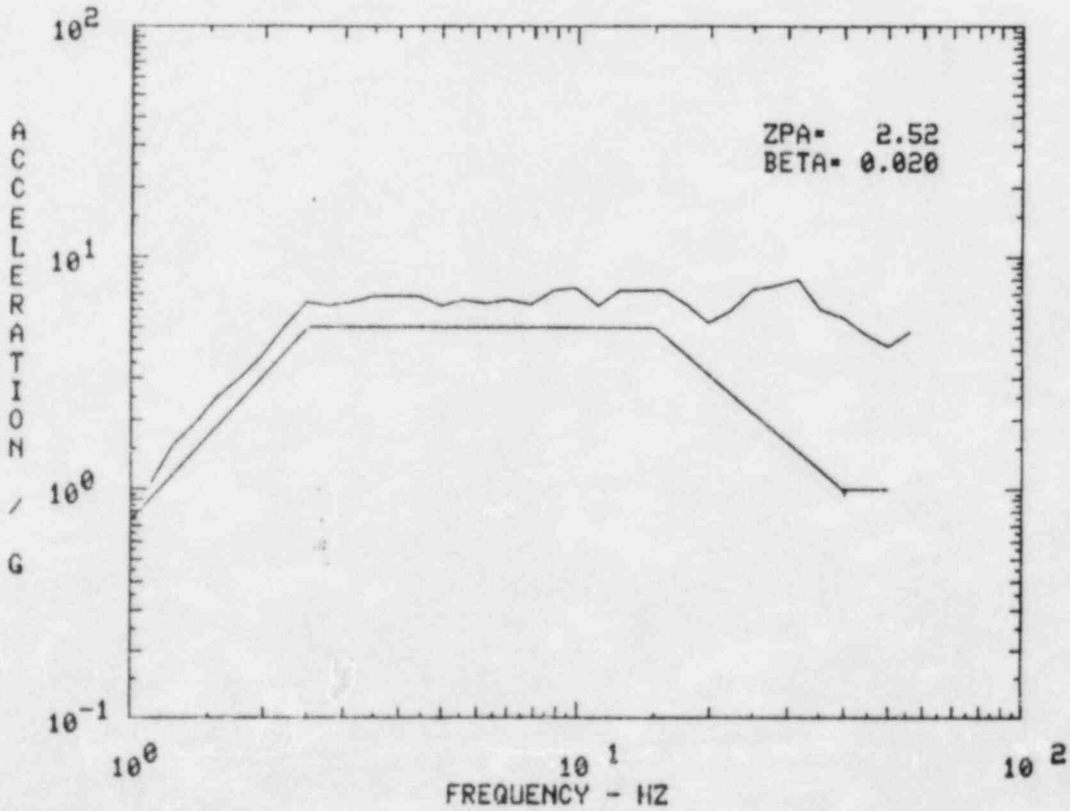


Figure 10.75 RUN OBXZ5 Accelerometer Location 9H

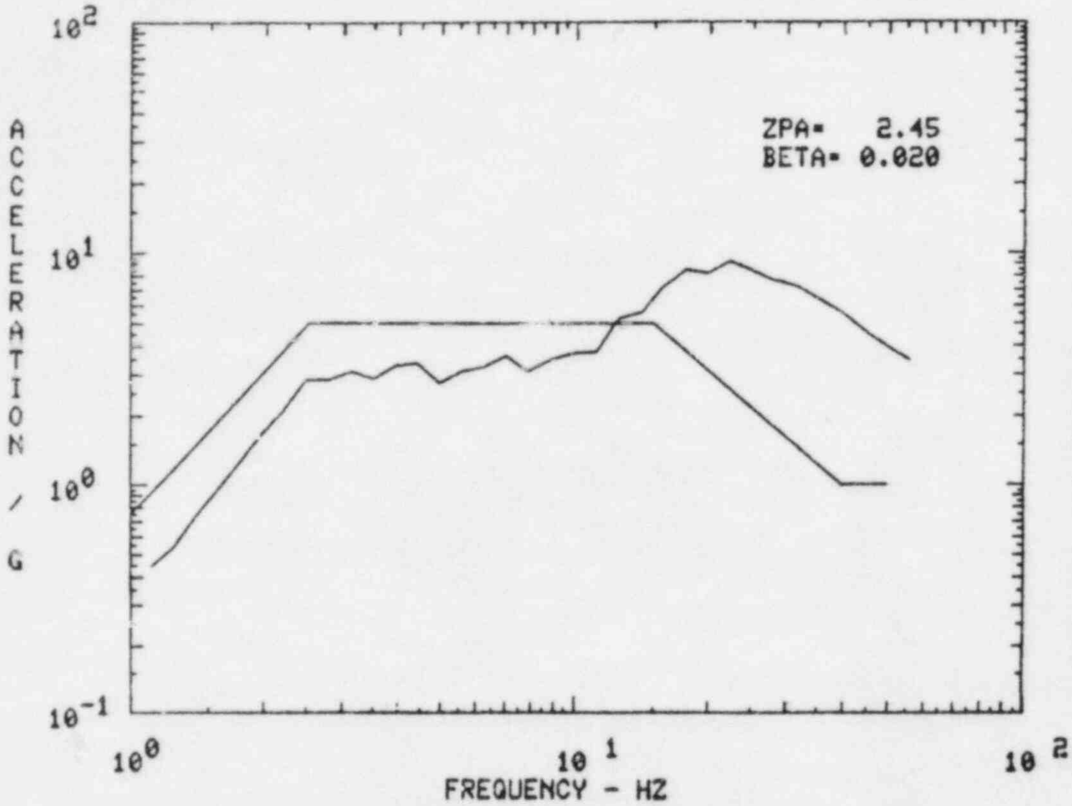


Figure 10.76 RUN OBXZ5 Accelerometer Location 10H

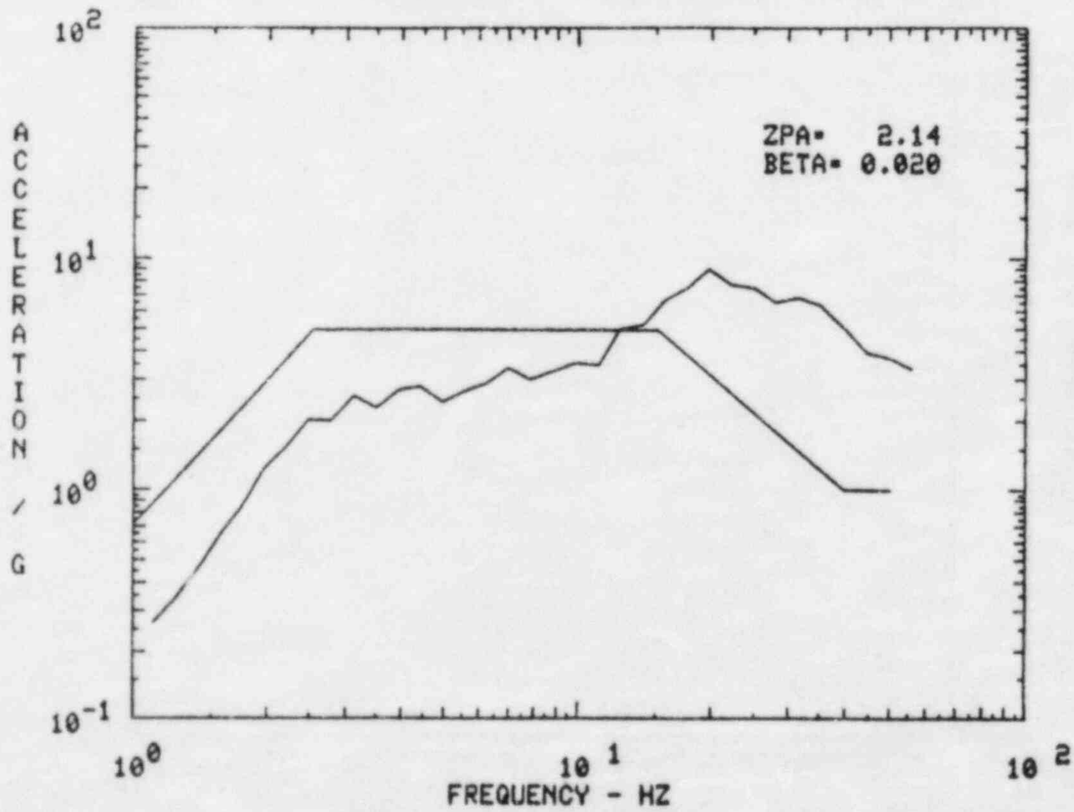


Figure 10.77 RUN OBYZ1 Accelerometer Location 1H

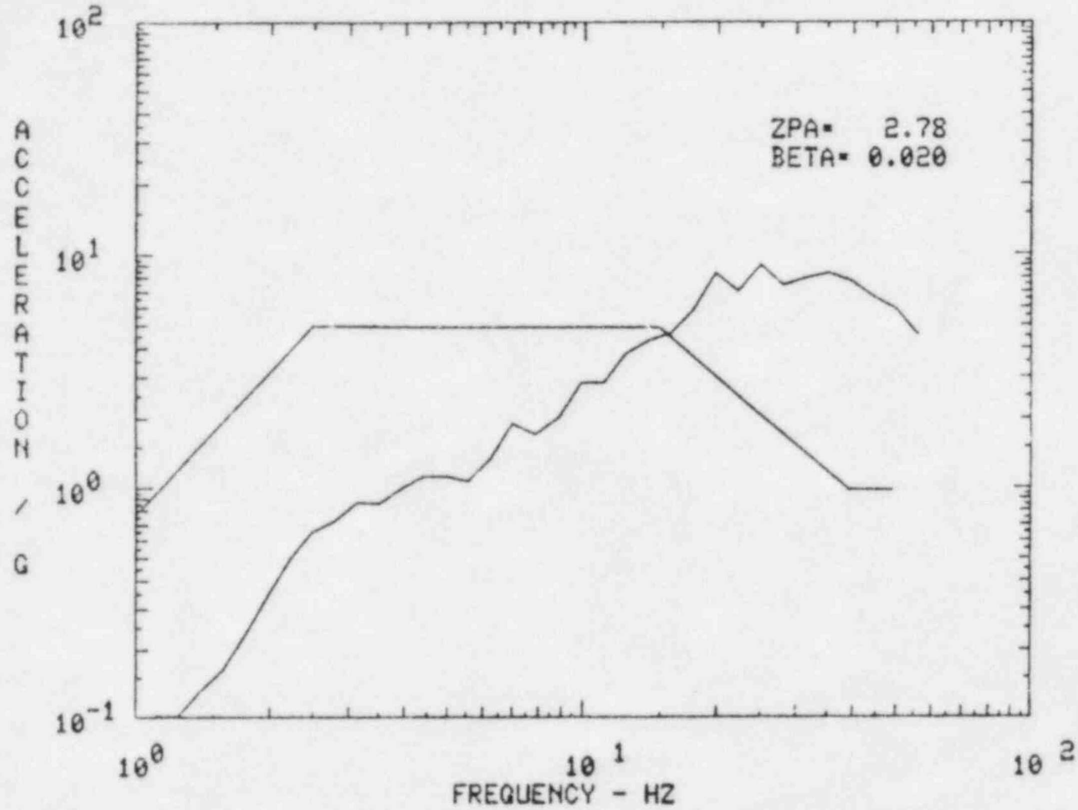


Figure 10.78 RUN OBYZ1 Accelerometer Location 2V

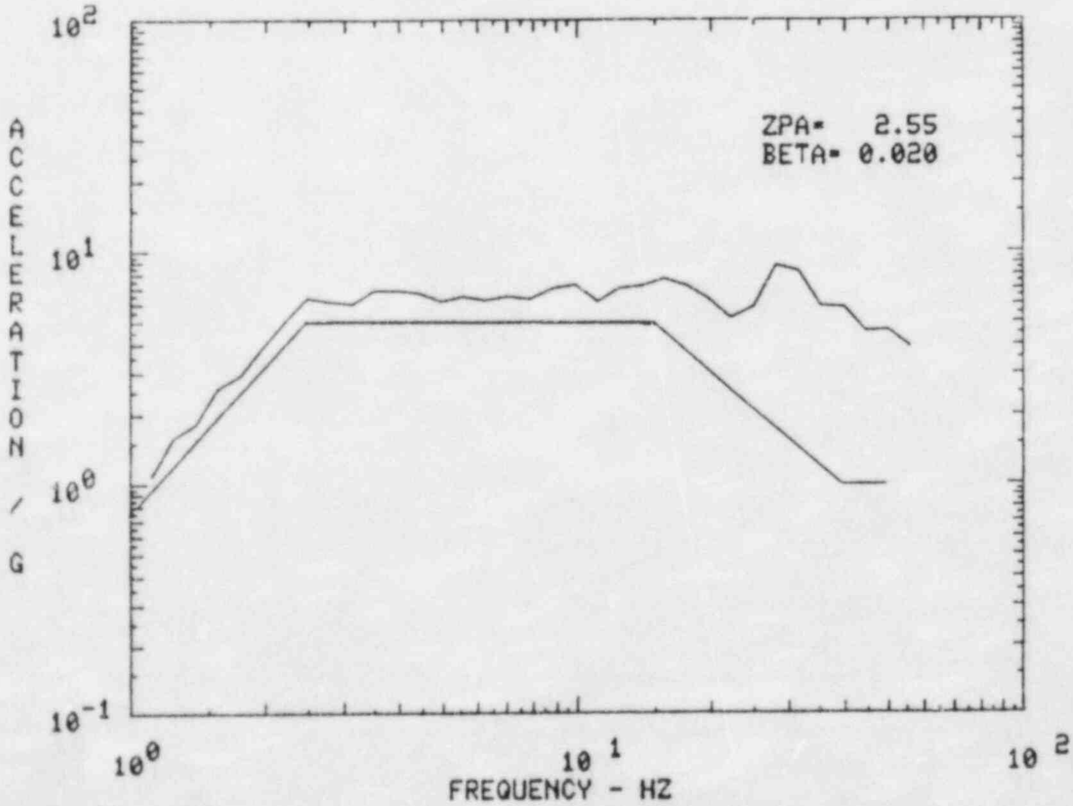


Figure 10.79 RUN OBYZ1 Accelerometer Location 3H

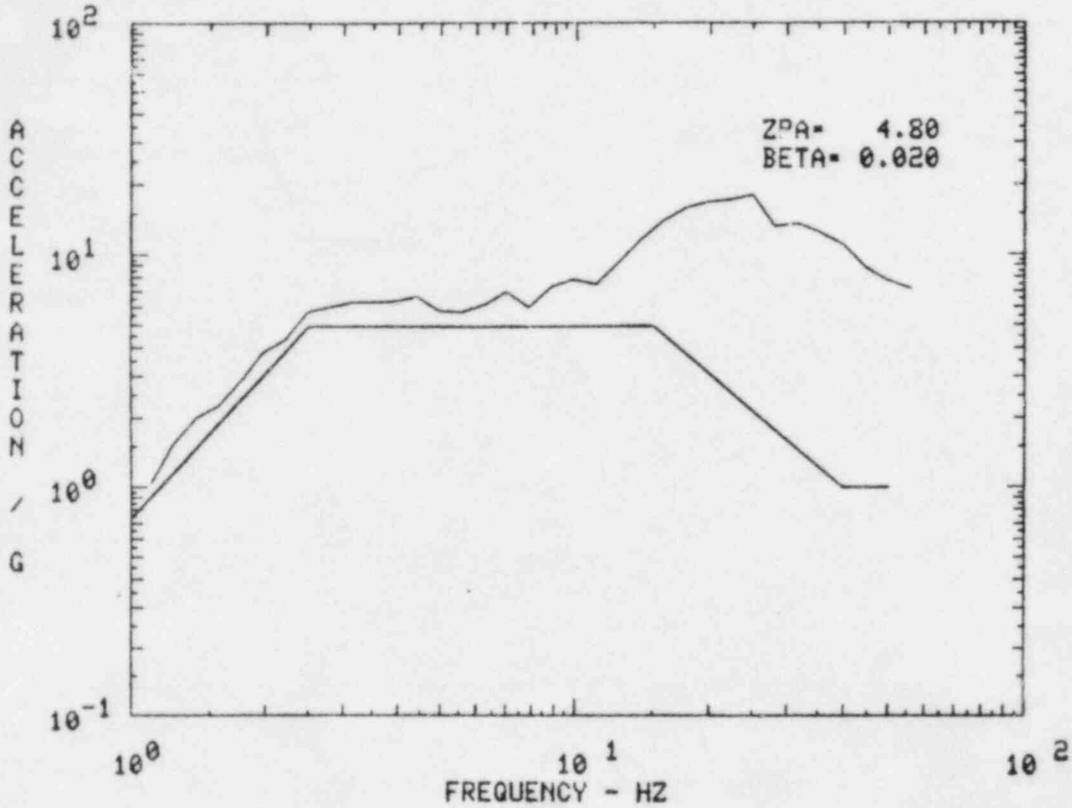


Figure 10.80 RUN OBYZ1 Accelerometer Location 4V

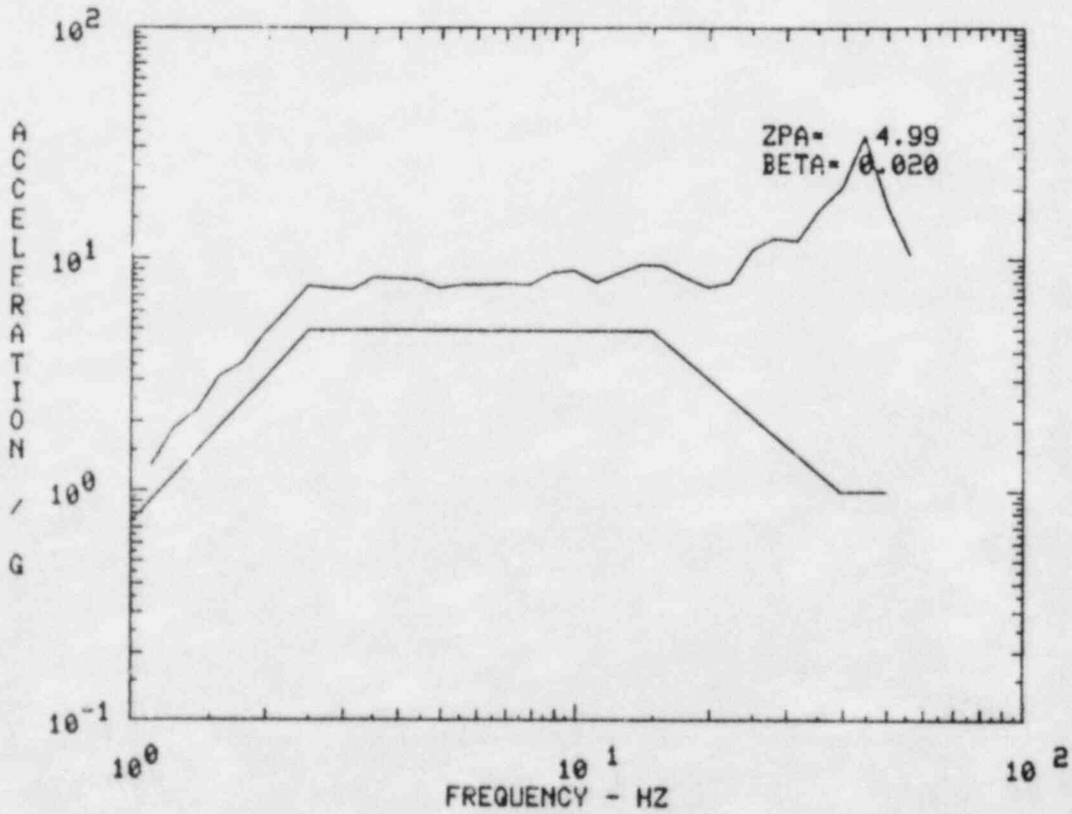


Figure 10.81 RUN OBYZ1 Accelerometer Location 5H

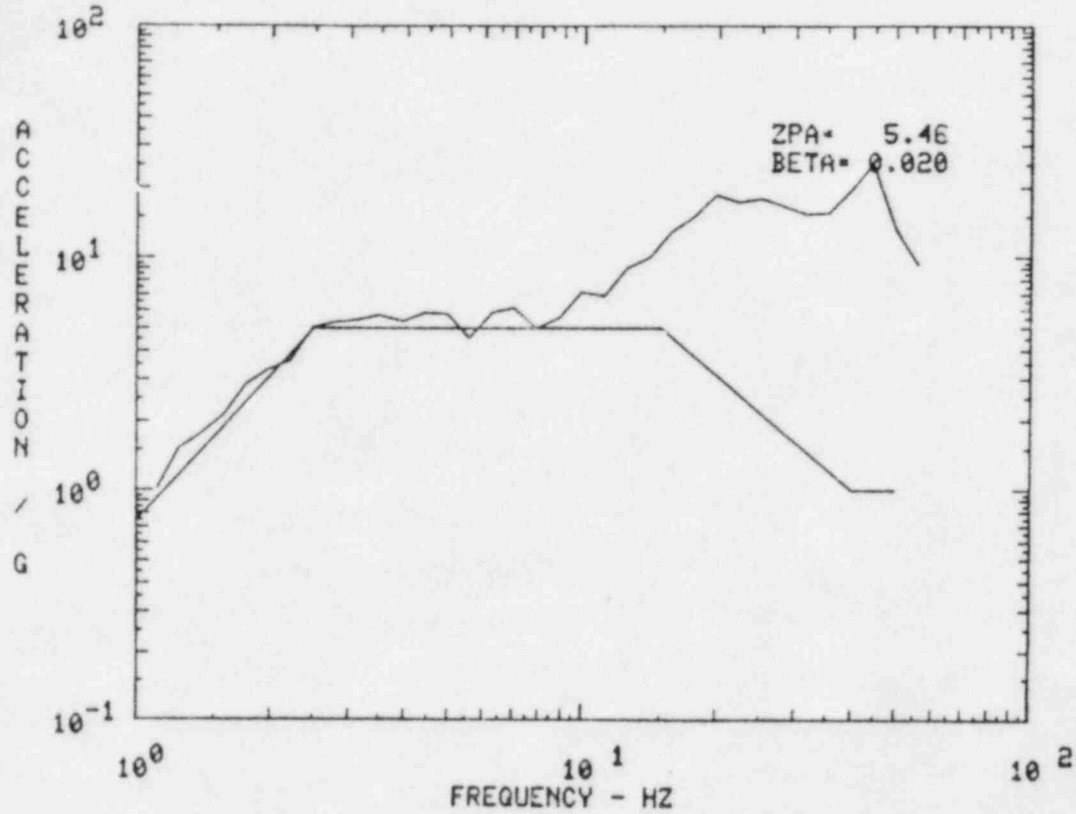


Figure 10.82 RUN OBYZ1 Accelerometer Location 6V

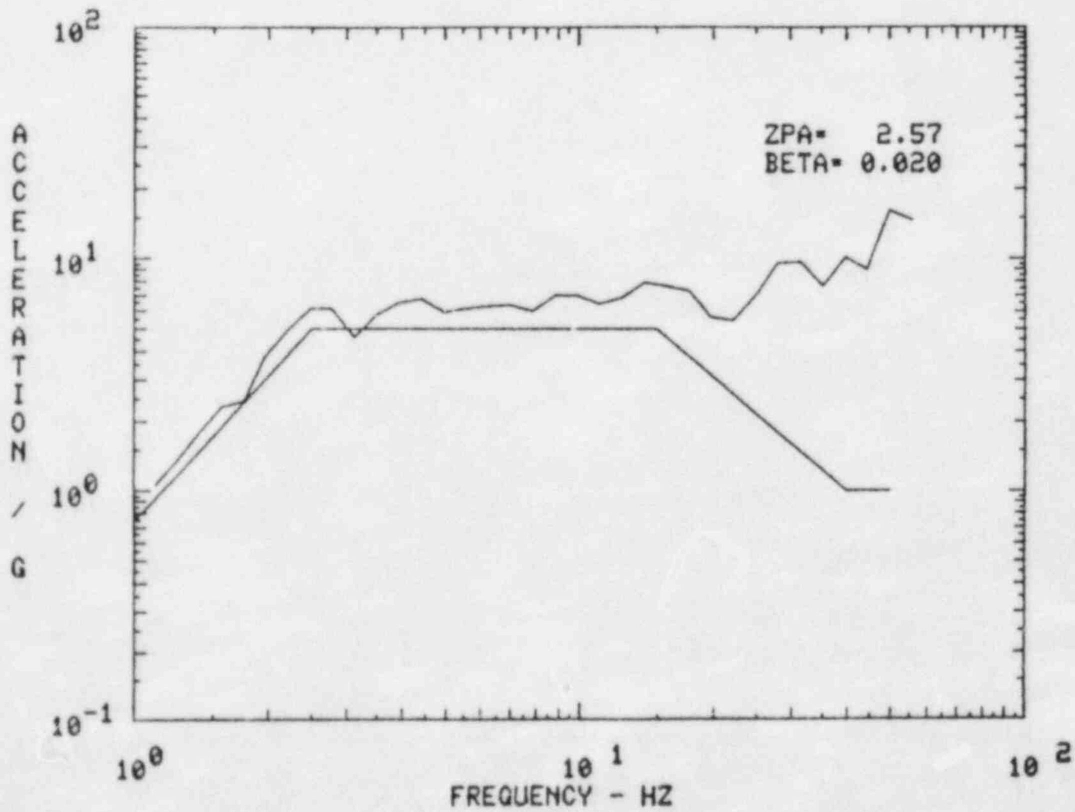


Figure 10.83 RUN OBYZ1 Accelerometer Location 7H

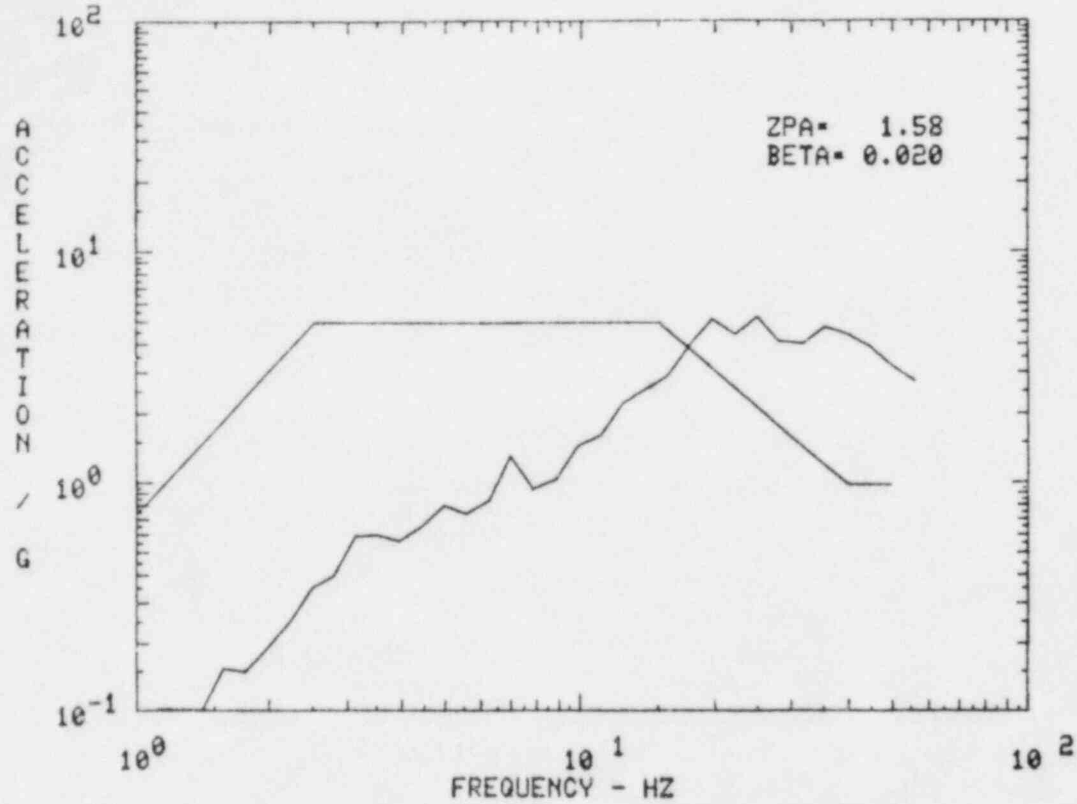


Figure 10.84 RUN OBYZ1 Accelerometer Location 8V

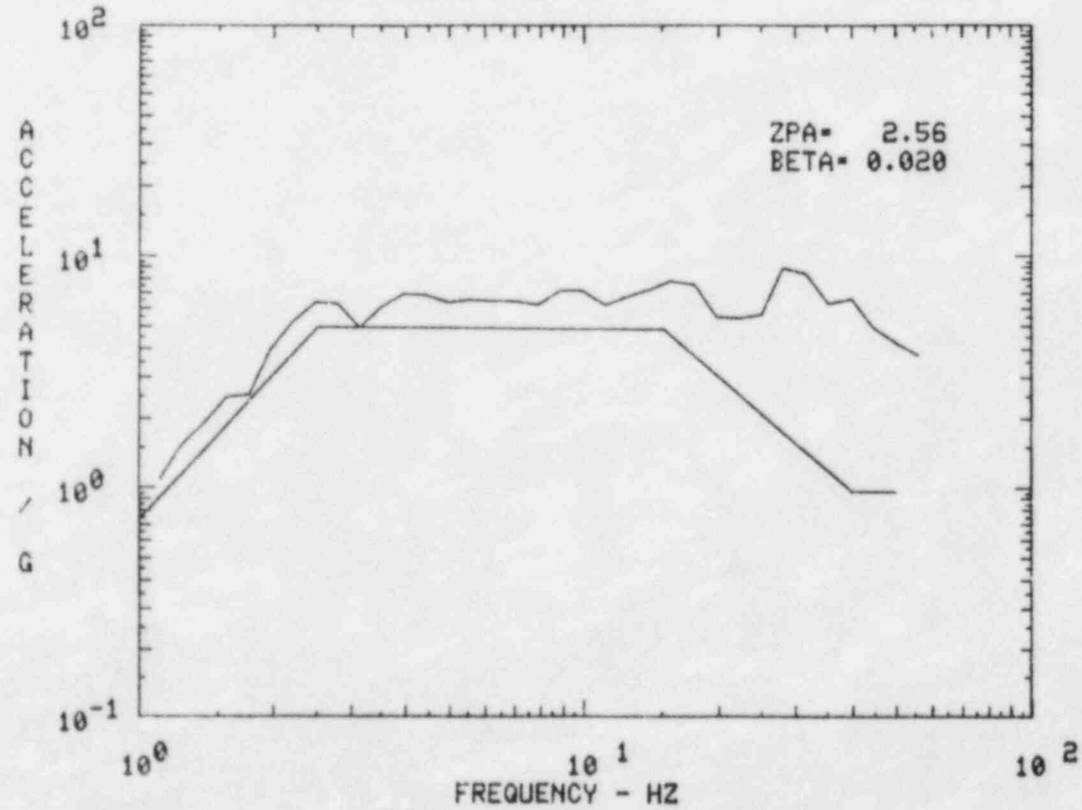


Figure 10.85 RUN OBYZ1 Accelerometer Location 9H

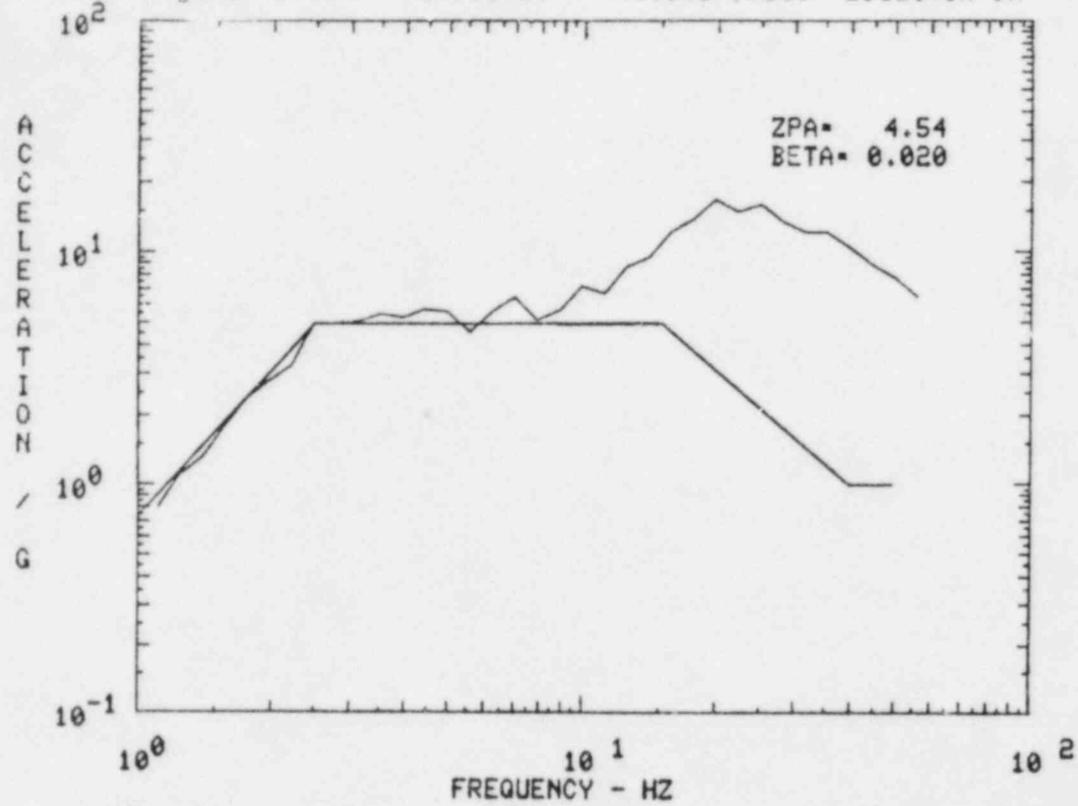


Figure 10.86 RUN OBYZ1 Accelerometer Location 10H

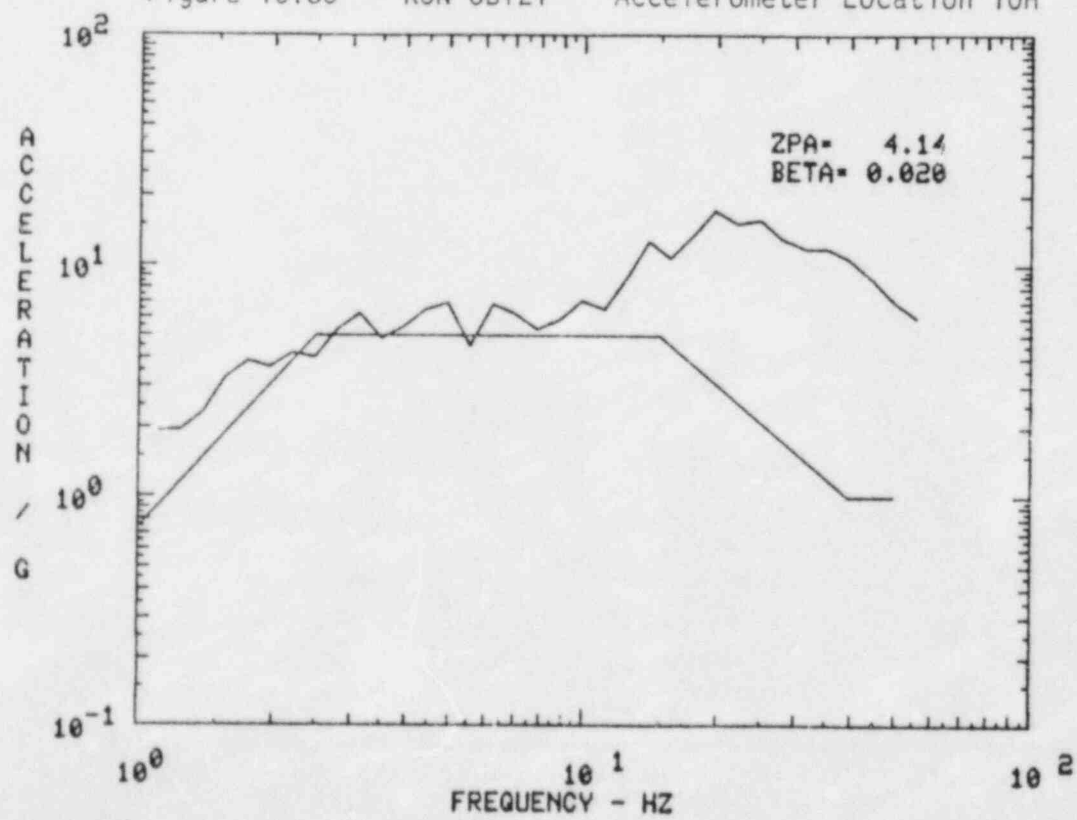


Figure 10.87 RUN OBYZ2 Accelerometer Location 1H

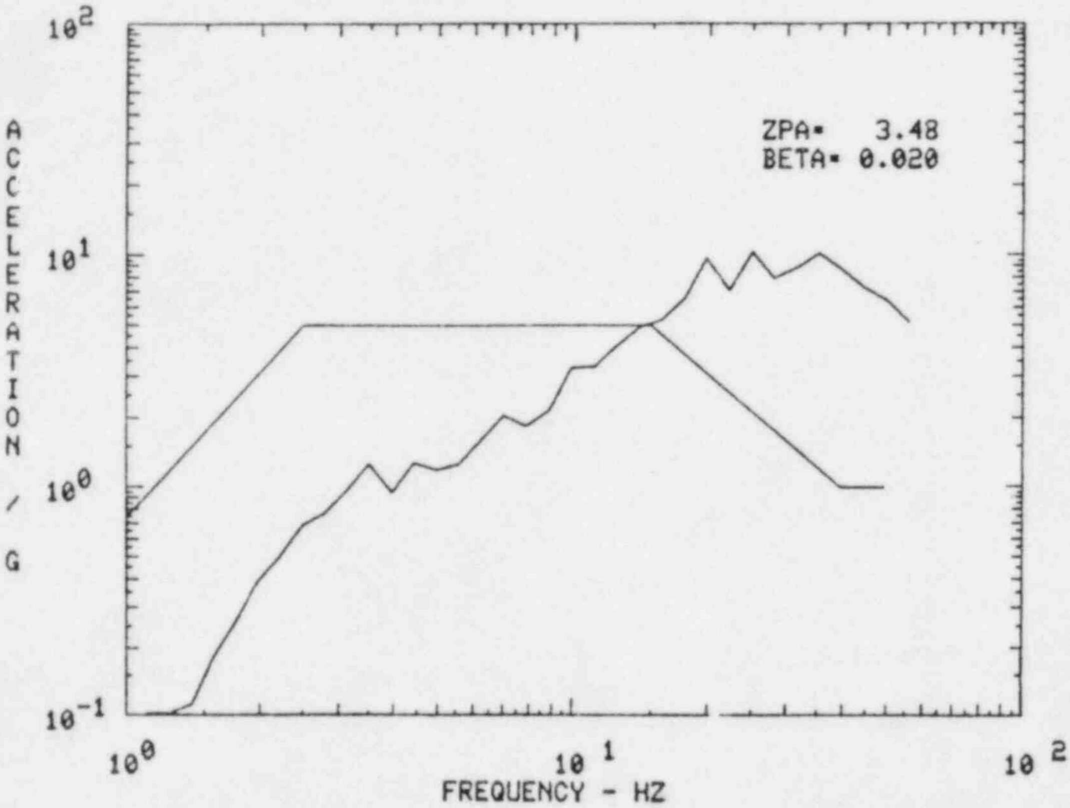


Figure 10.88 RUN OBYZ2 Accelerometer Location 2V

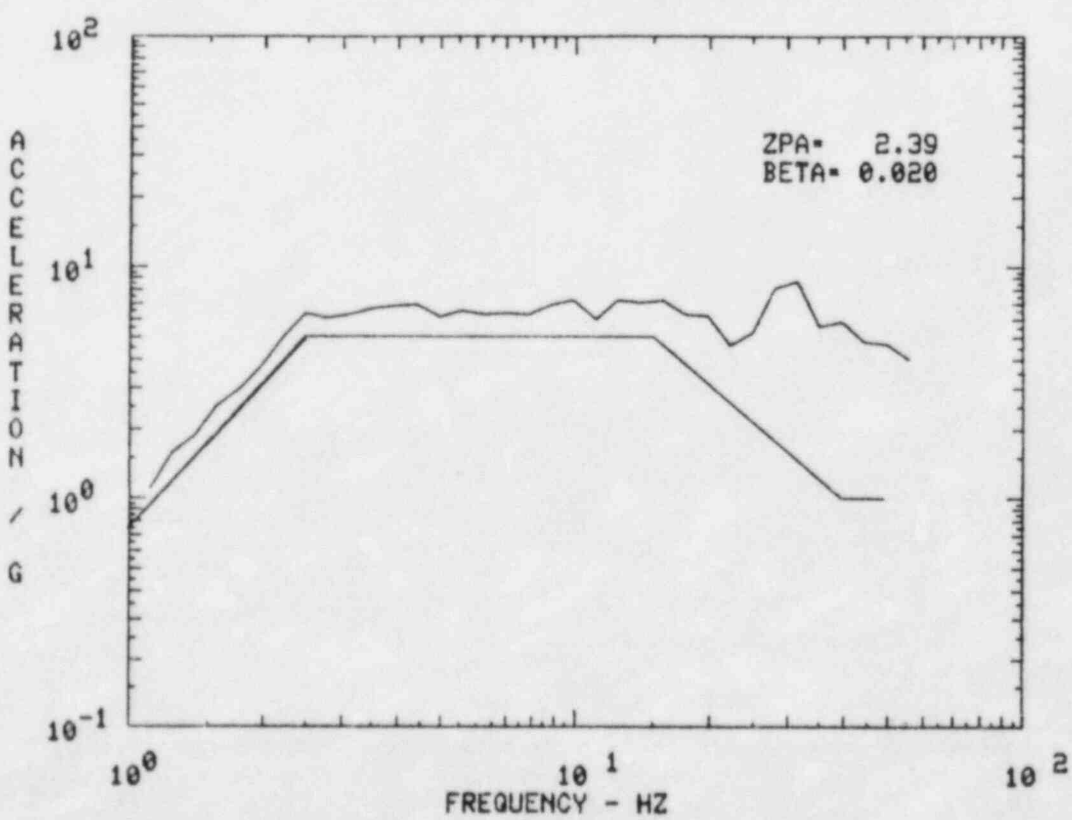


Figure 10.89 RUN OBYZ2 Accelerometer Location 3H

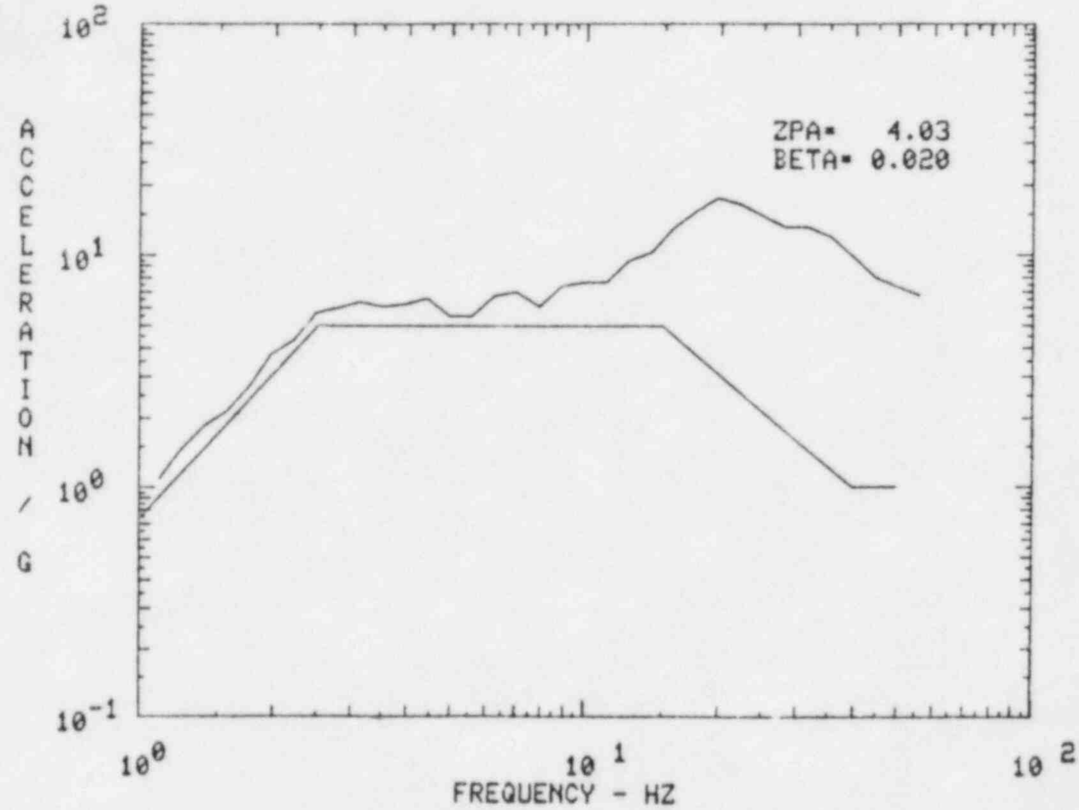


Figure 10.90 RUN OBYZ2 Accelerometer Location 4V

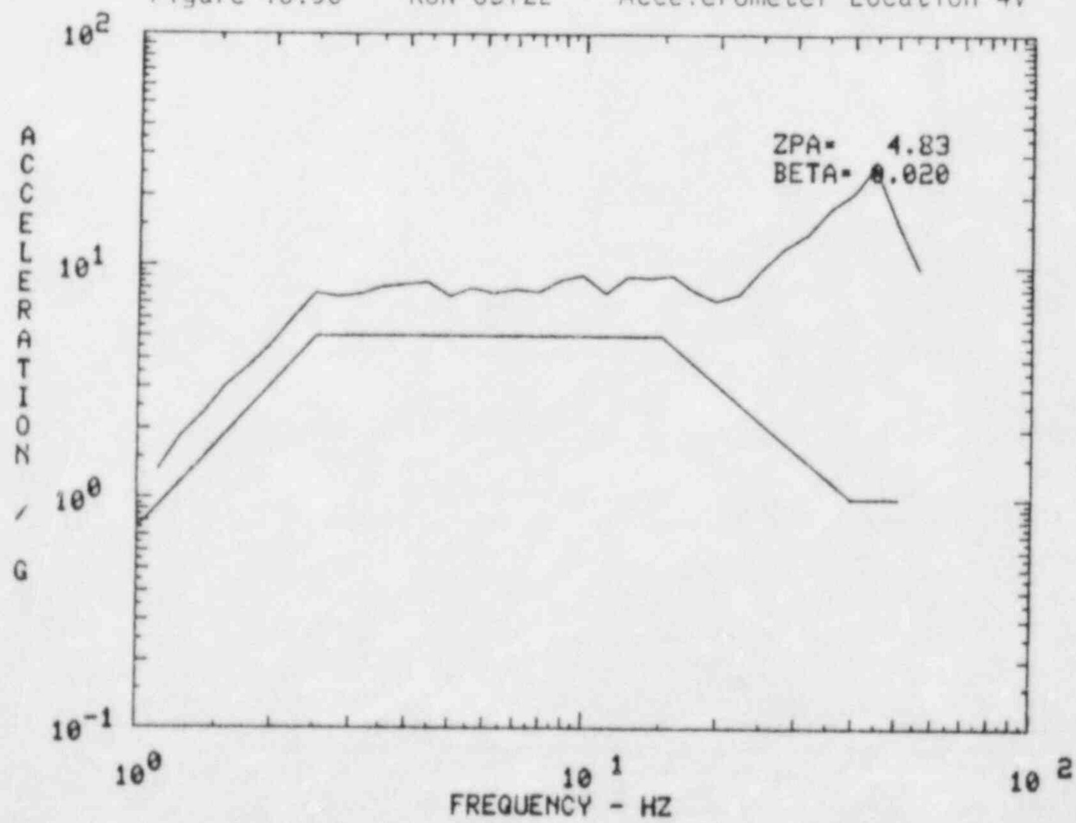


Figure 10.91 RUN OBYZ2 Accelerometer Location 5H

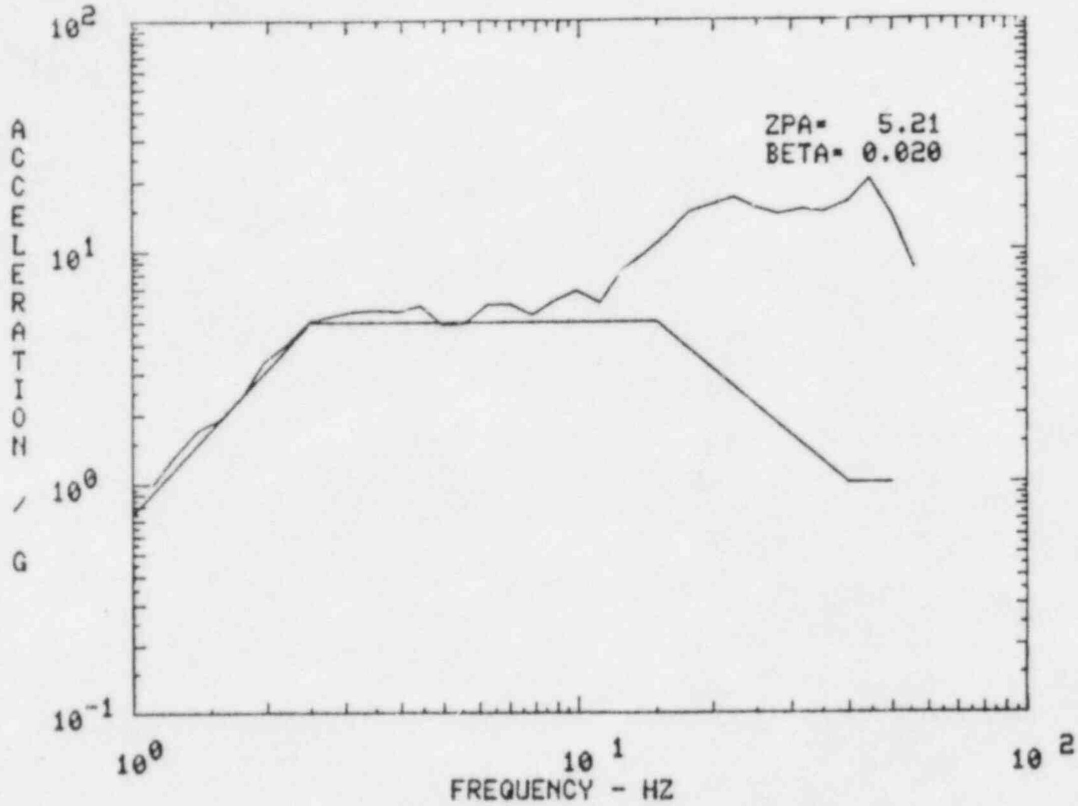


Figure 10.92 RUN OBYZ2 Accelerometer Location 6V

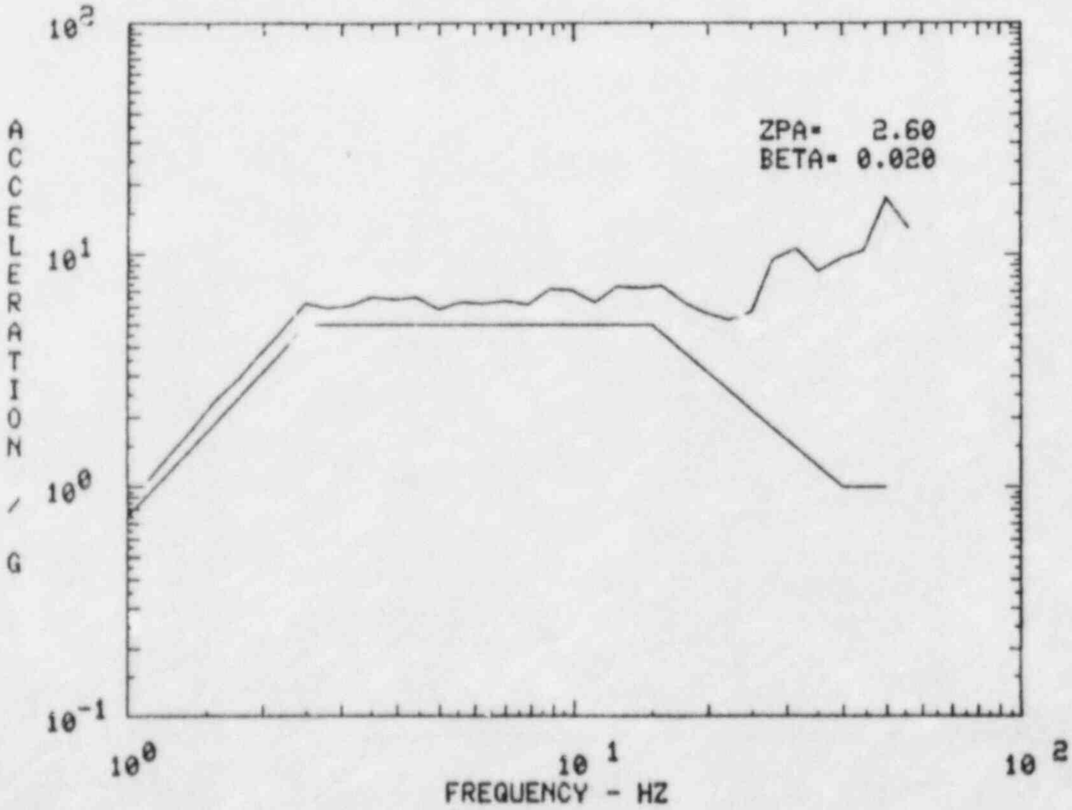


Figure 10.93 RUN OBYZ2 Accelerometer Location 7H

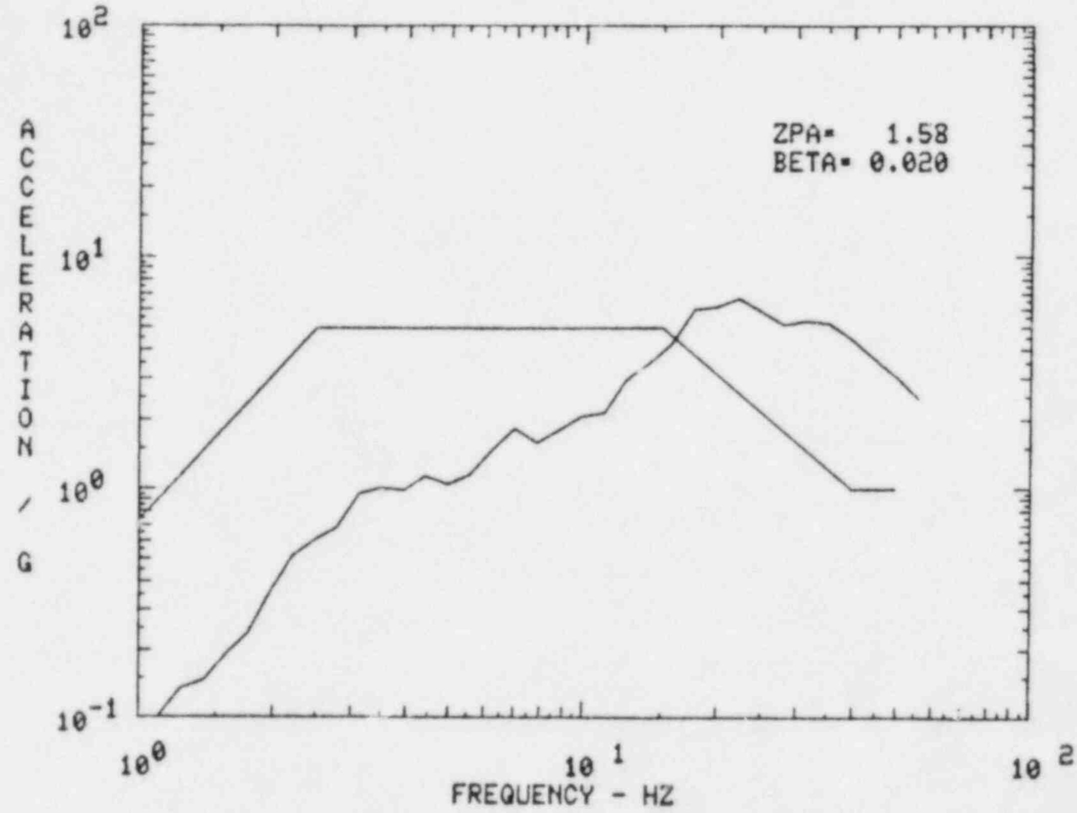


Figure 10.94 RUN OBYZ2 Accelerometer Location 8V

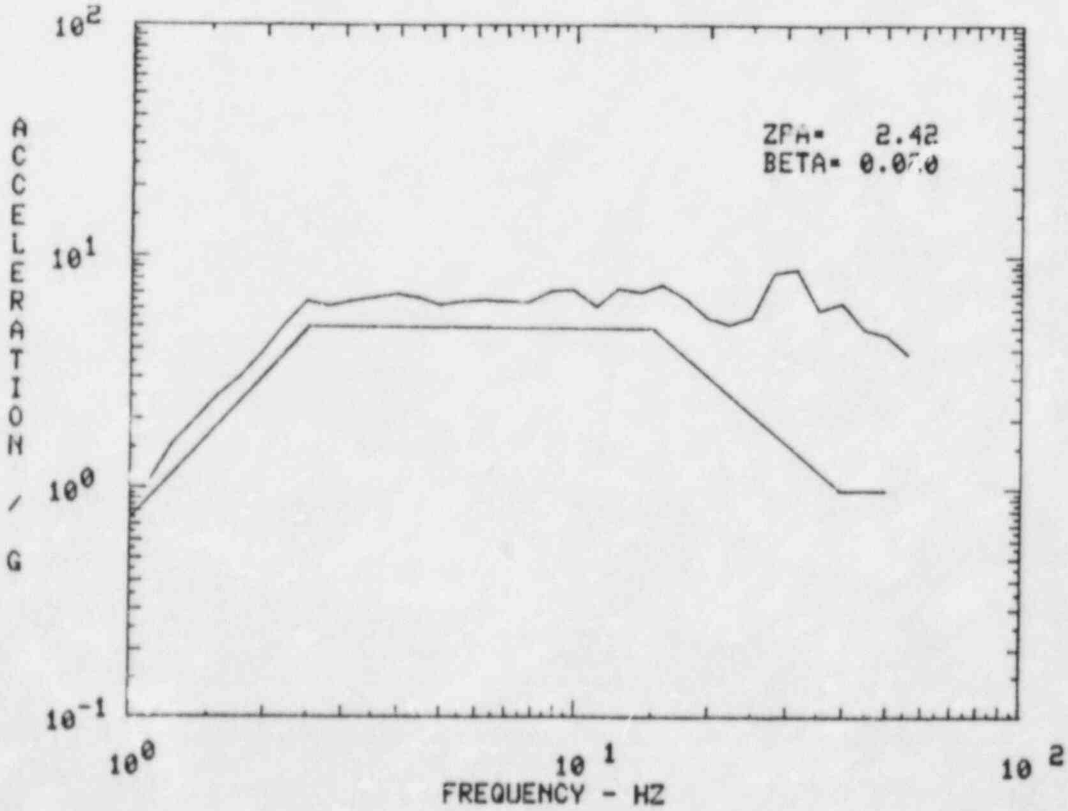


Figure 10.95 RUN OBYZ2 Accelerometer Location 9H

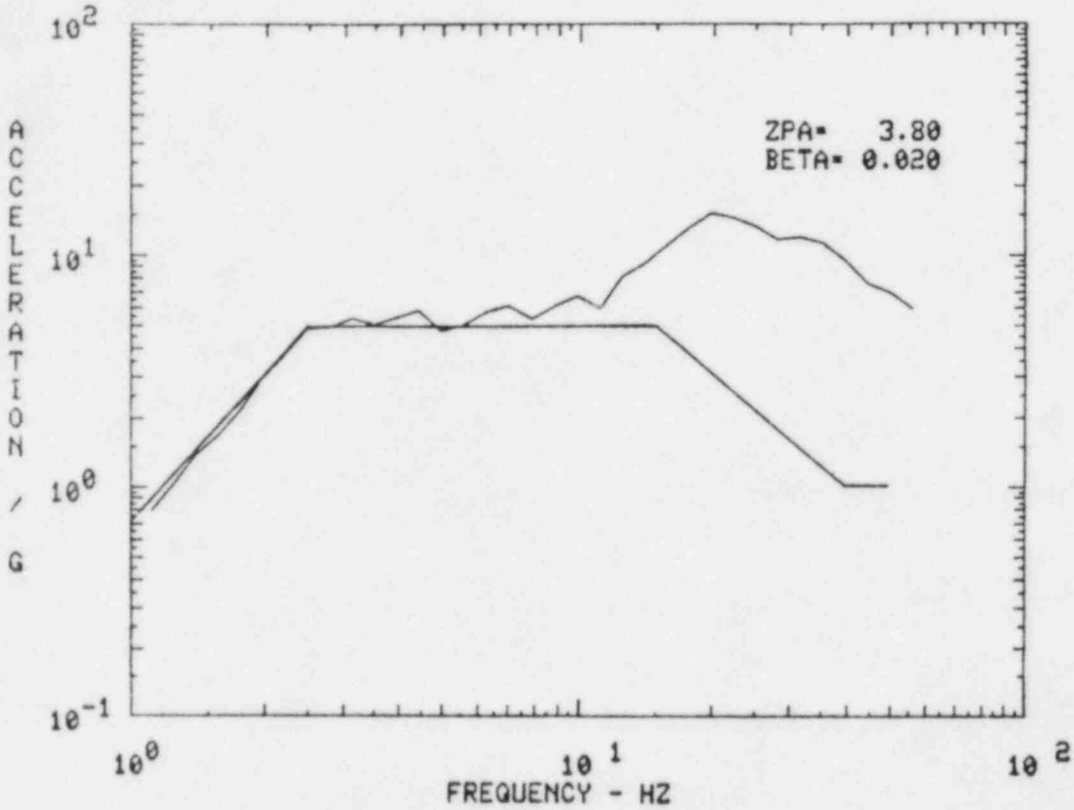


Figure 10.96 RUN OBYZ2 Accelerometer Location 10H

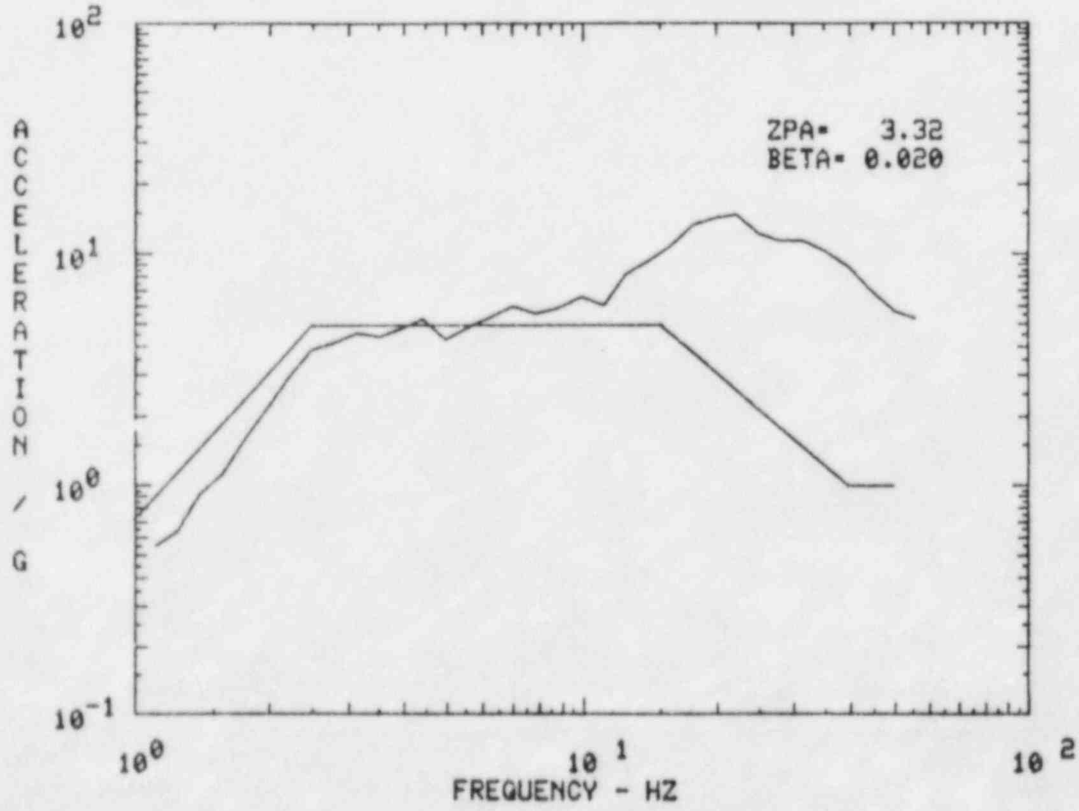


Figure 10.97 RUN OBYZ3 Accelerometer Location 1H

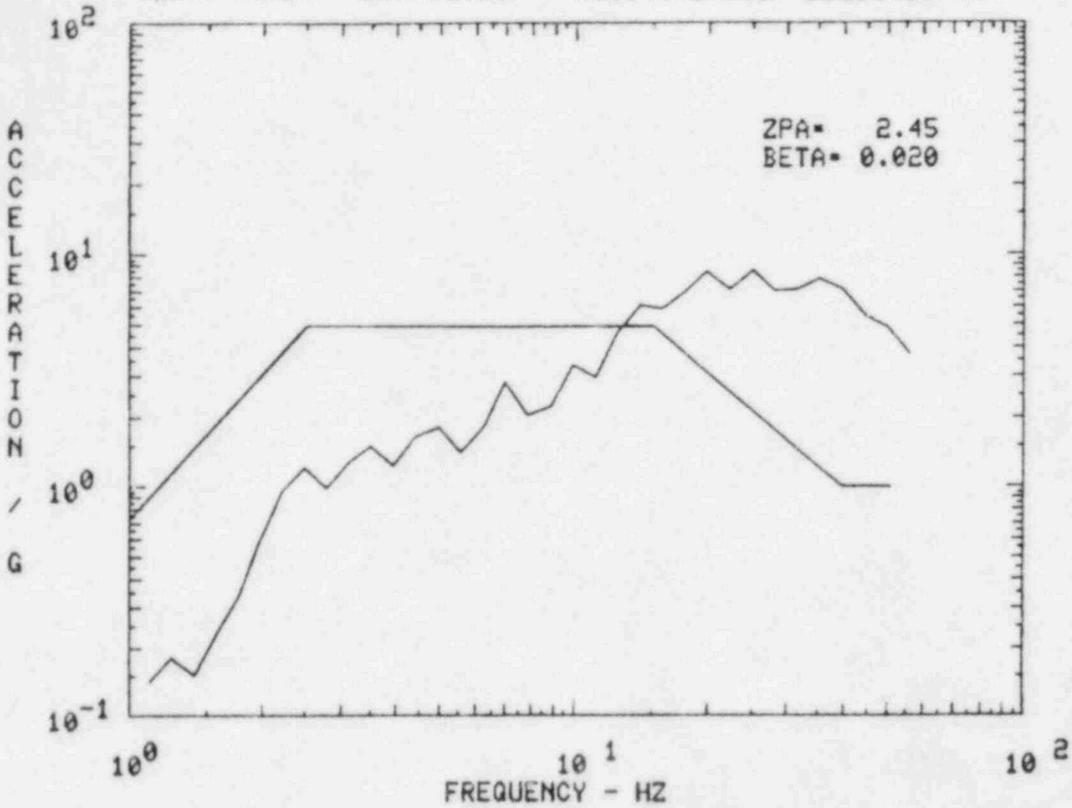


Figure 10.98 RUN OBYZ3 Accelerometer Location 2V

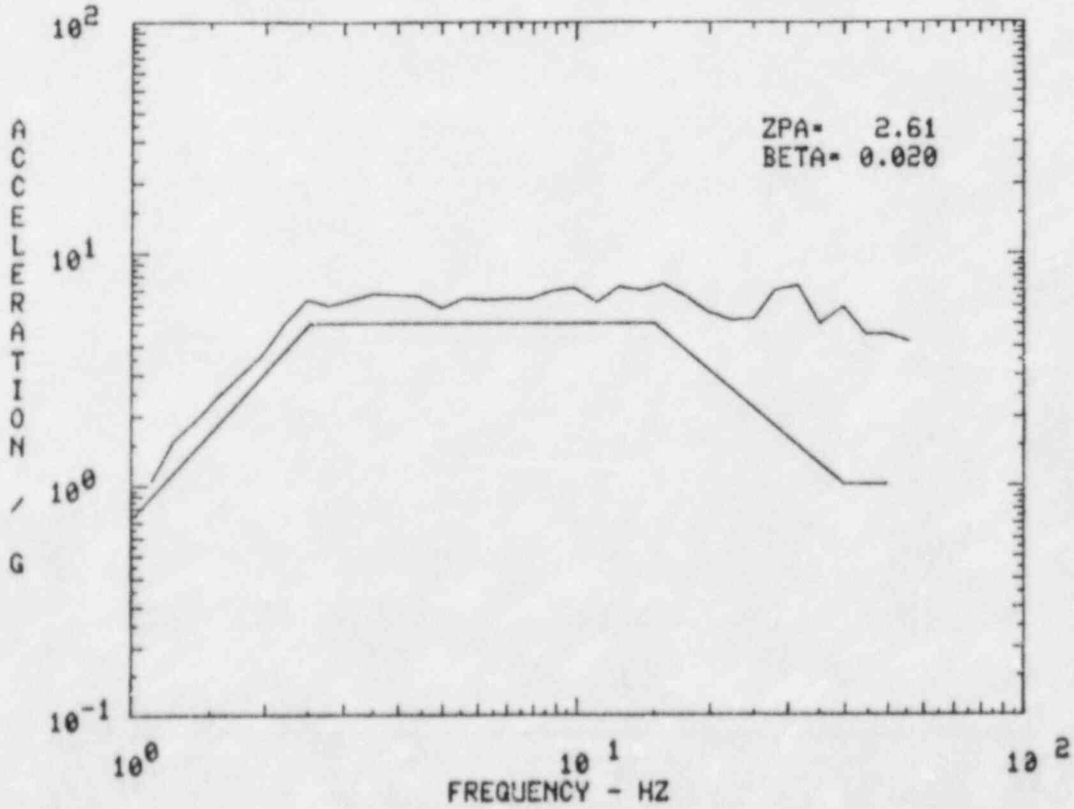


Figure 10.99 RUN OBYZ3 Accelerometer Location 3H

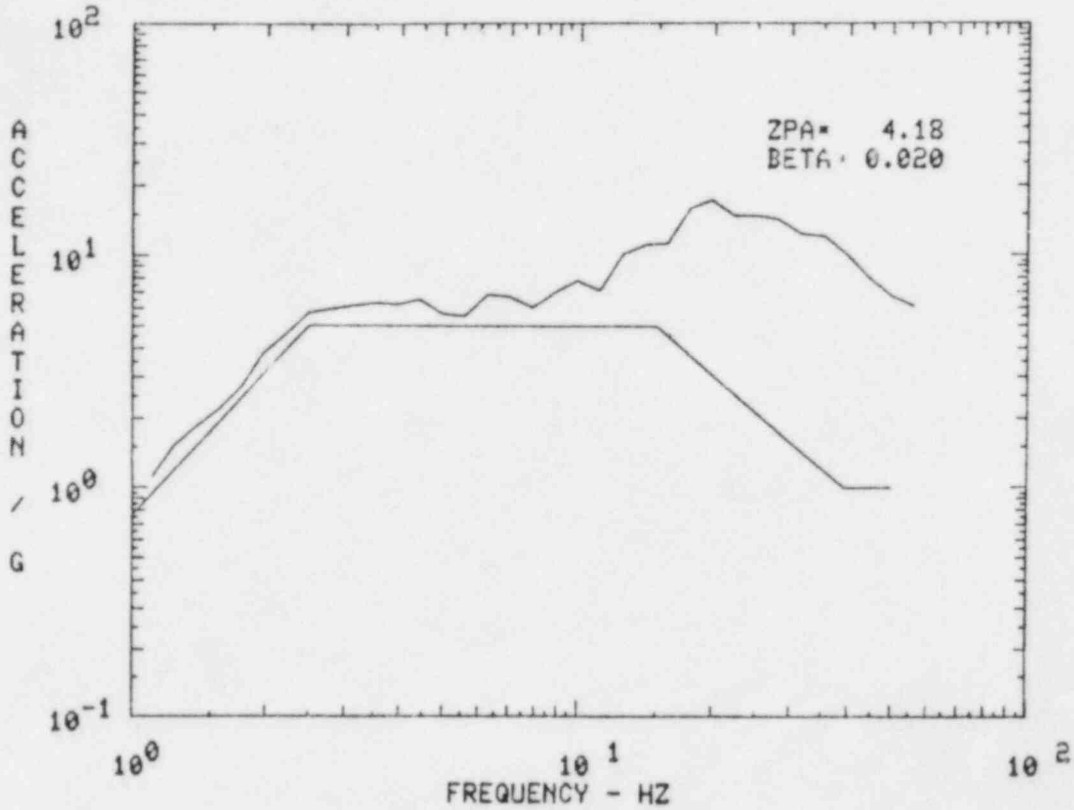


Figure 10.100 RUN OBYZ3 Accelerometer Location 4V

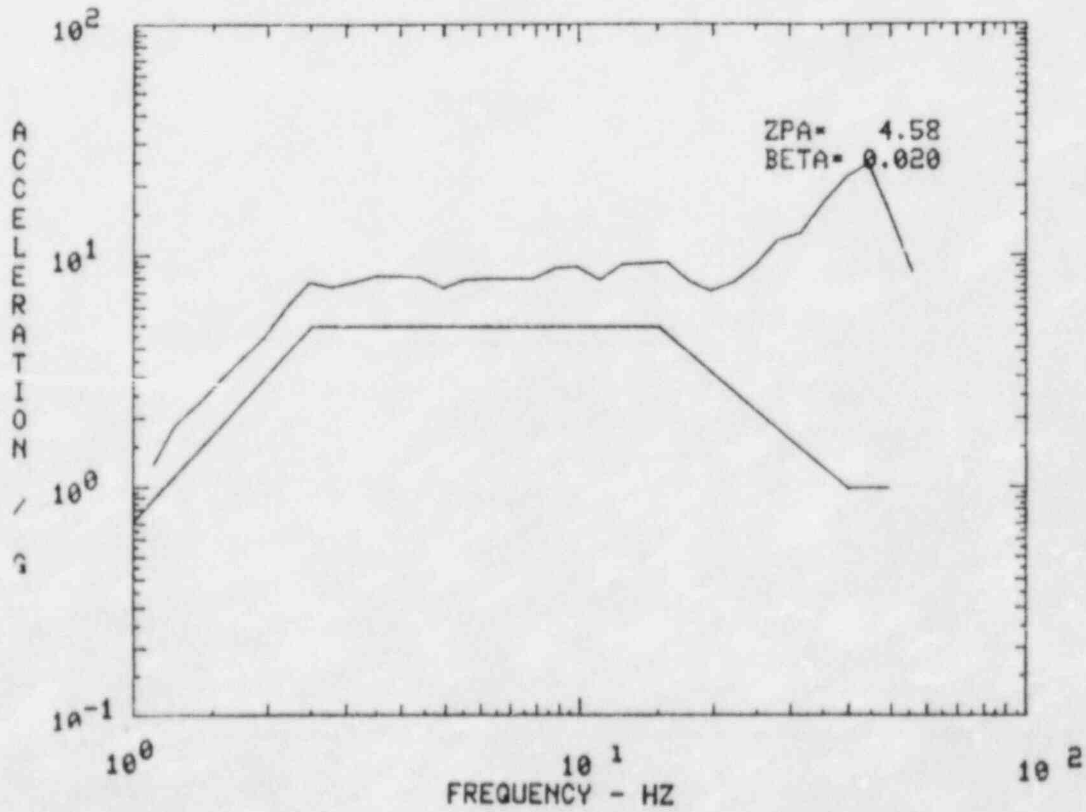


Figure 10.101 RUN OBYZ3 Accelerometer Location 5H

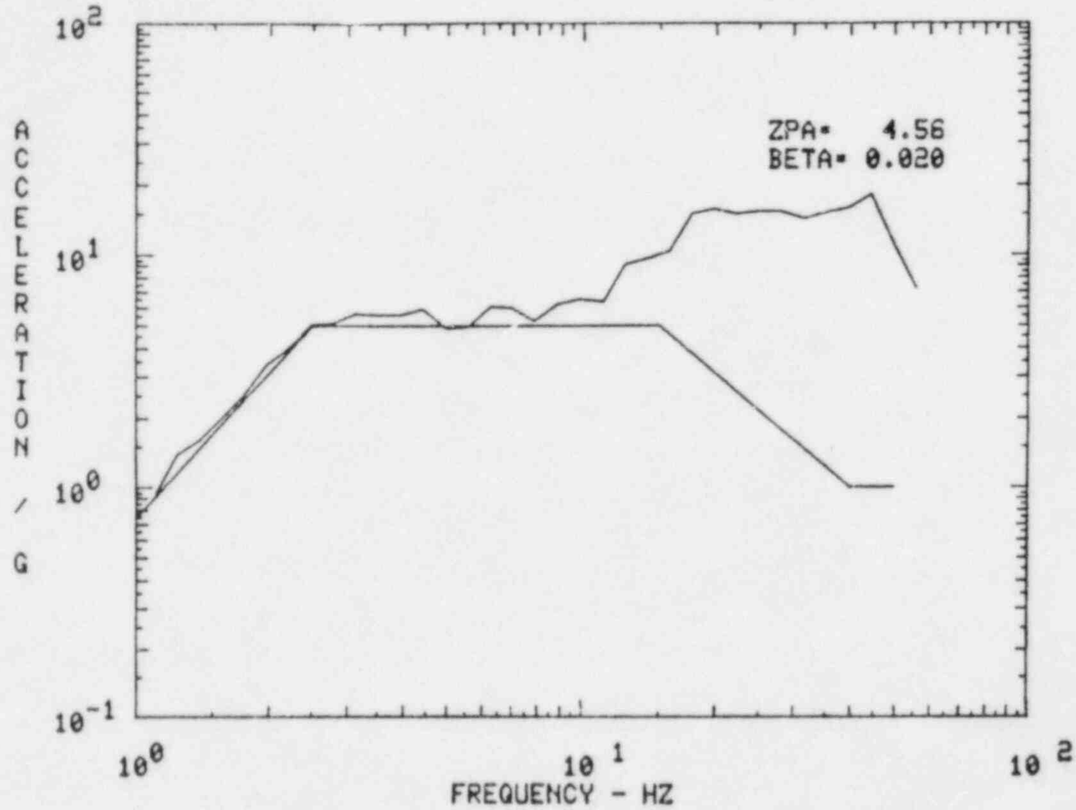


Figure 10.102 RUN OBYZ3 Accelerometer Location 6V

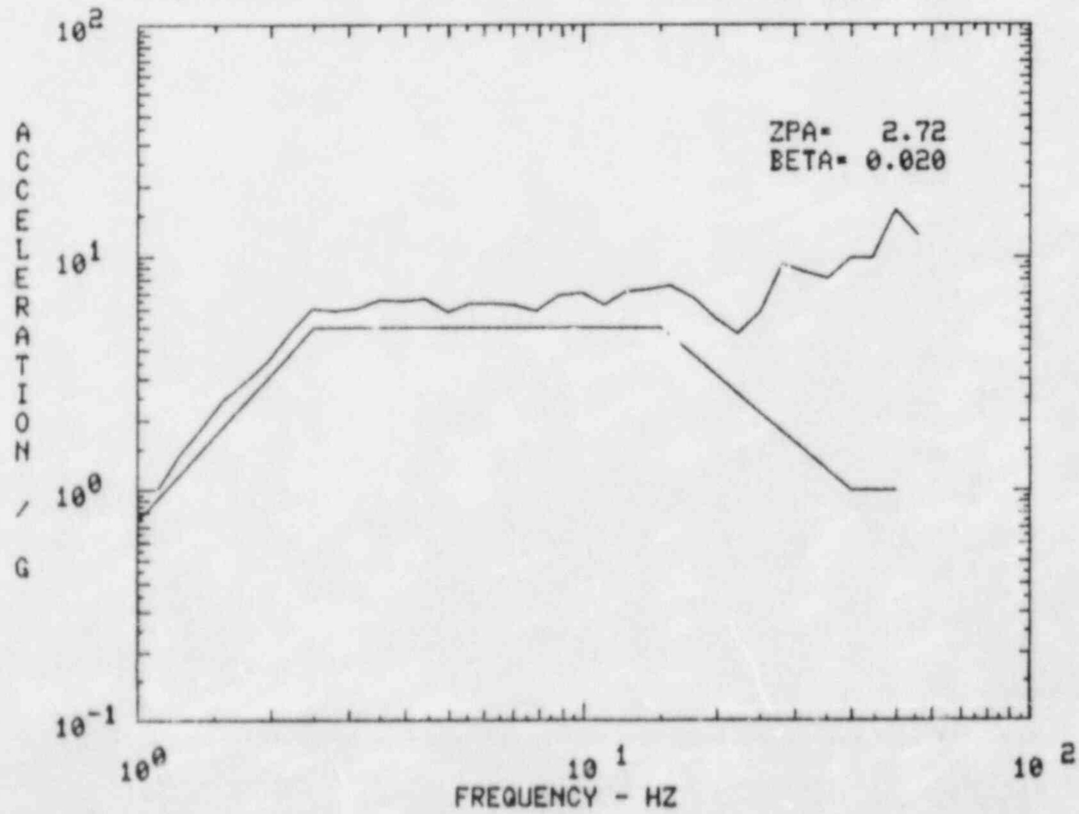


Figure 10.103 RUN OBYZ3 Accelerometer Location 7H

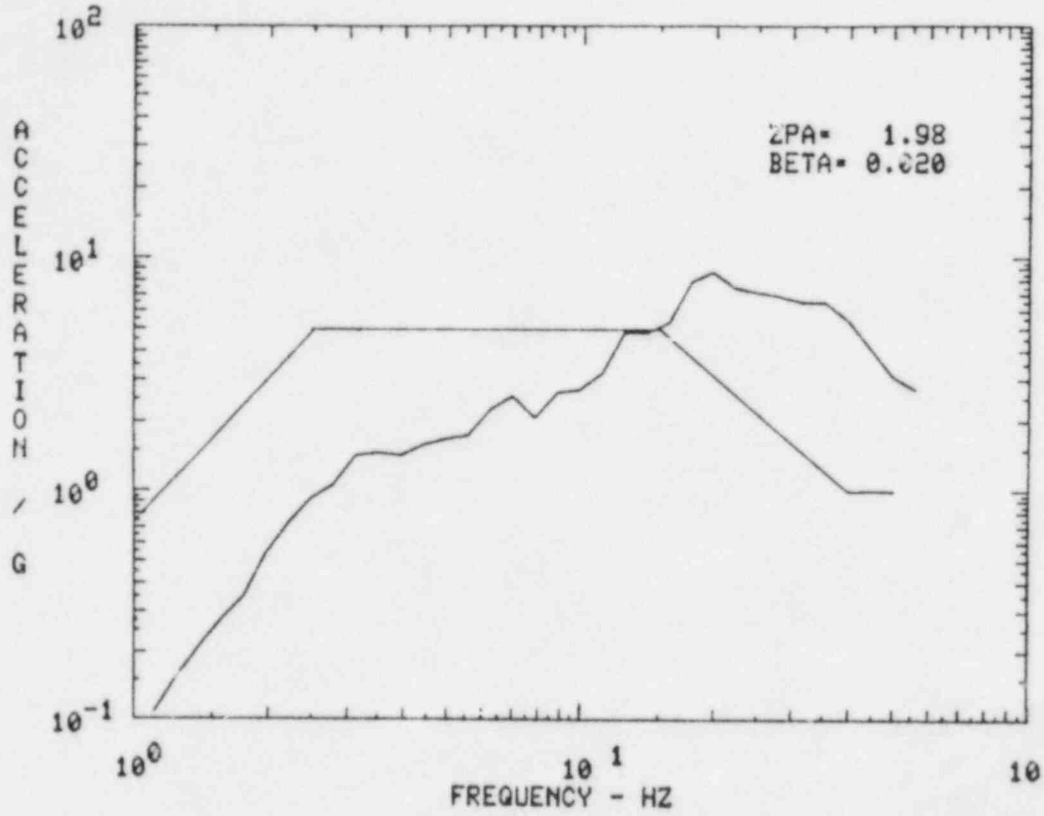


Figure 10.104 RUN OBYZ3 Accelerometer Location 8V

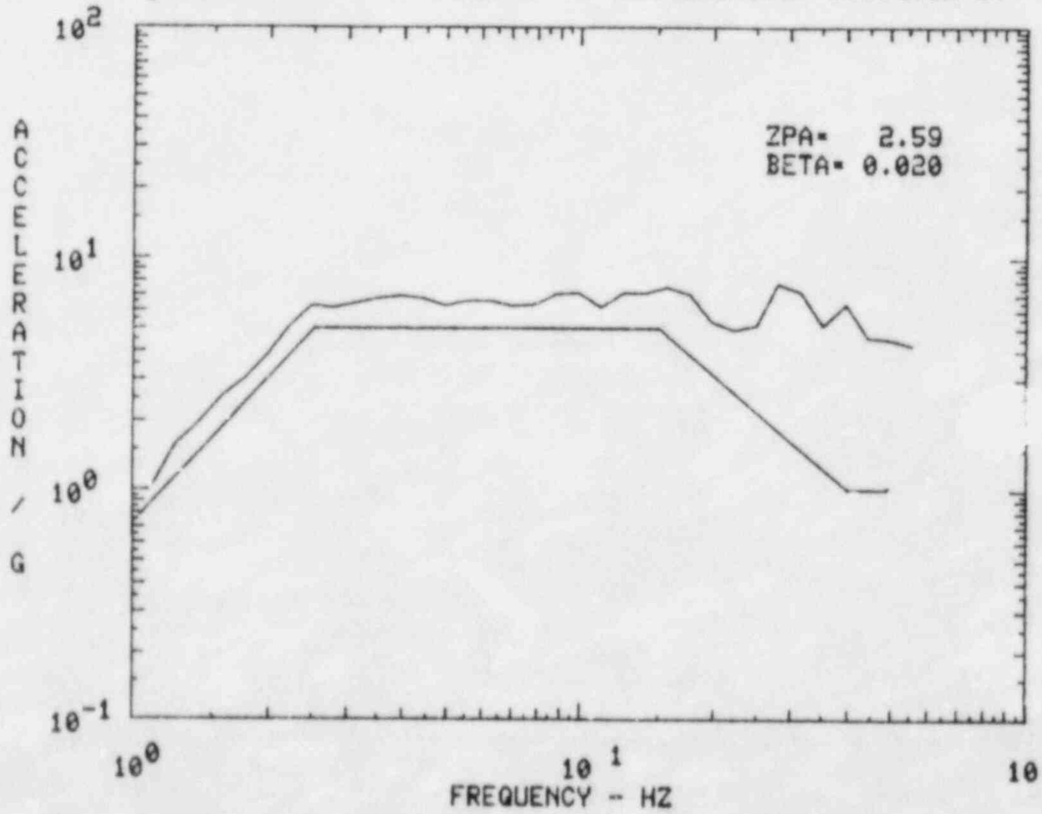


Figure 10.105 RUN OBYZ3 Accelerometer Location 9H

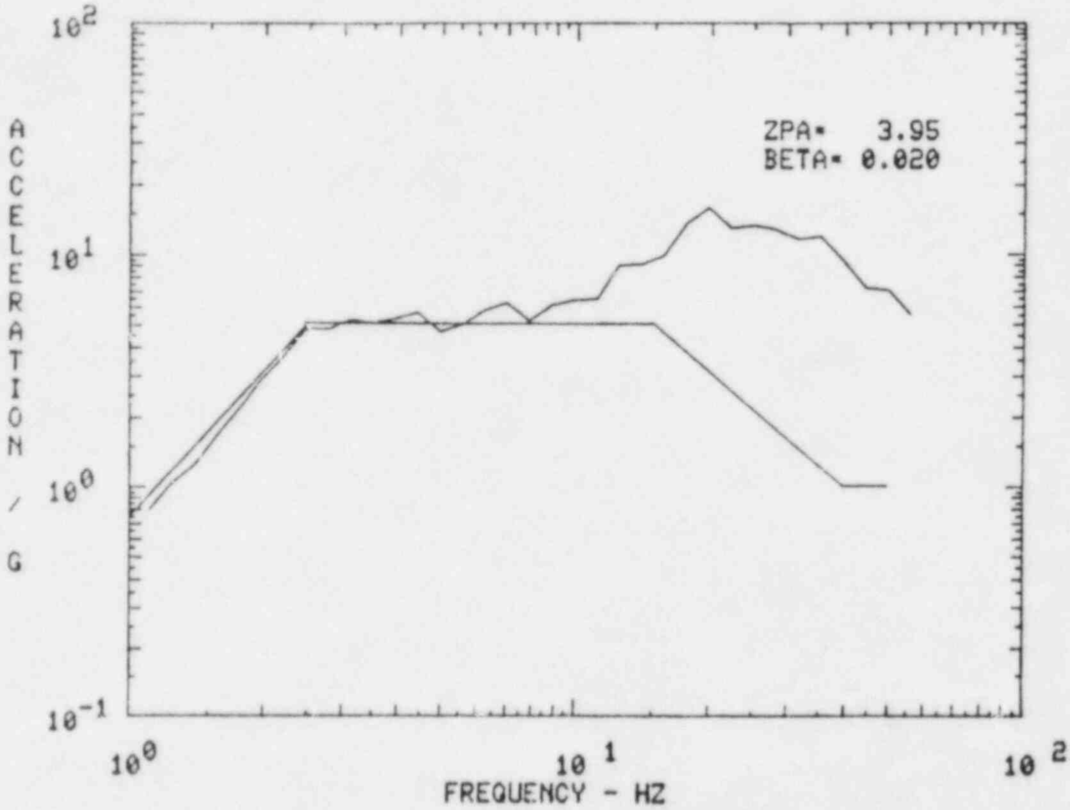


Figure 10.106 RUN OBYZ3 Accelerometer Location 10H

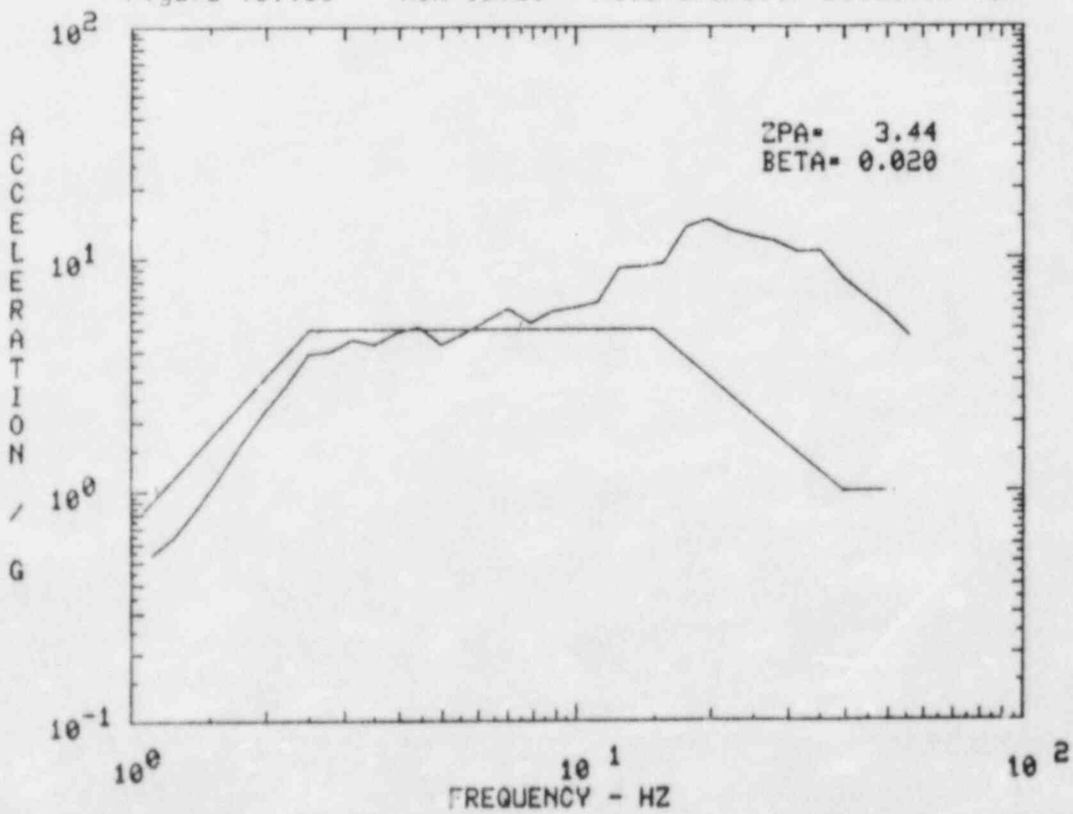


Figure 10.107 RUN OBYZ4 Accelerometer Location 1H

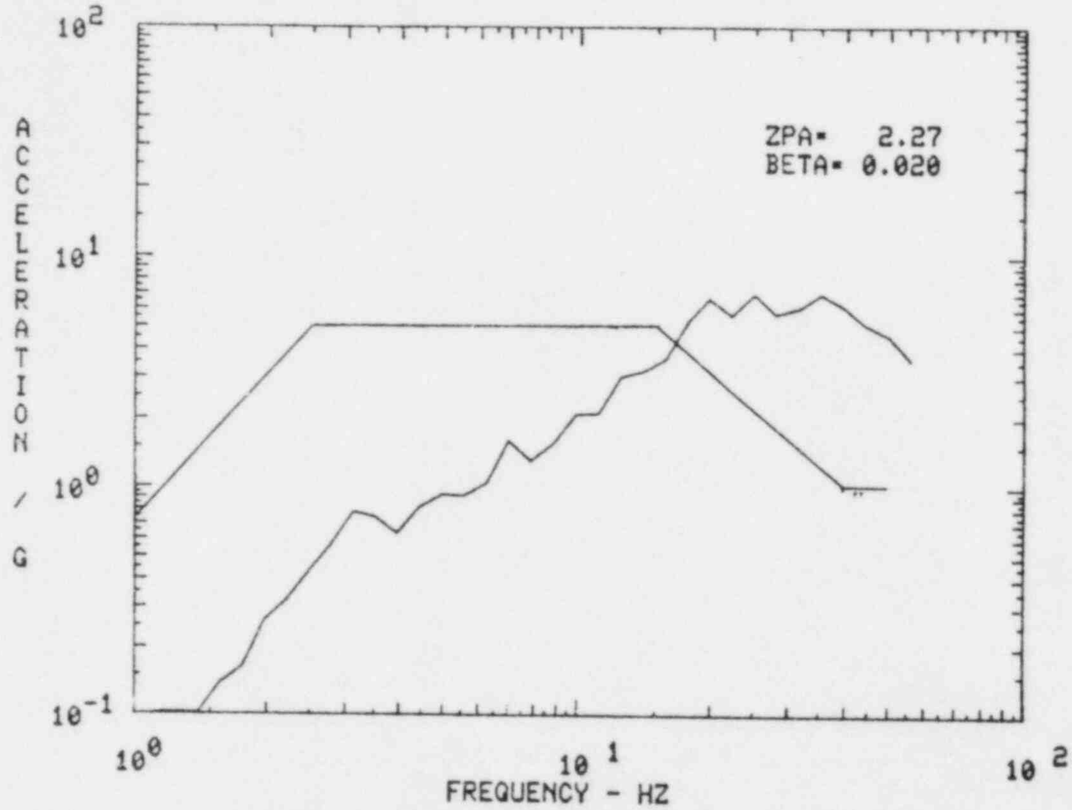


Figure 10.108 RUN OBYZ4 Accelerometer Location 2V

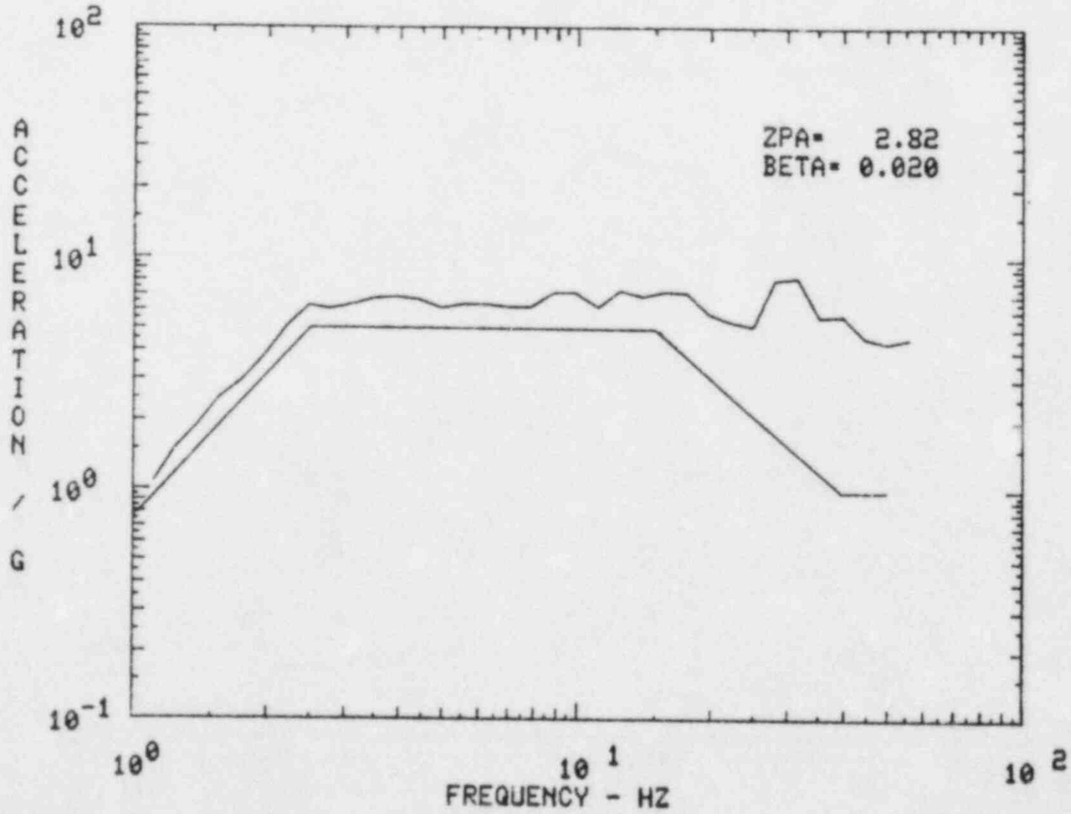


Figure 10.109 RUN OBYZ4 Accelerometer Location 3H

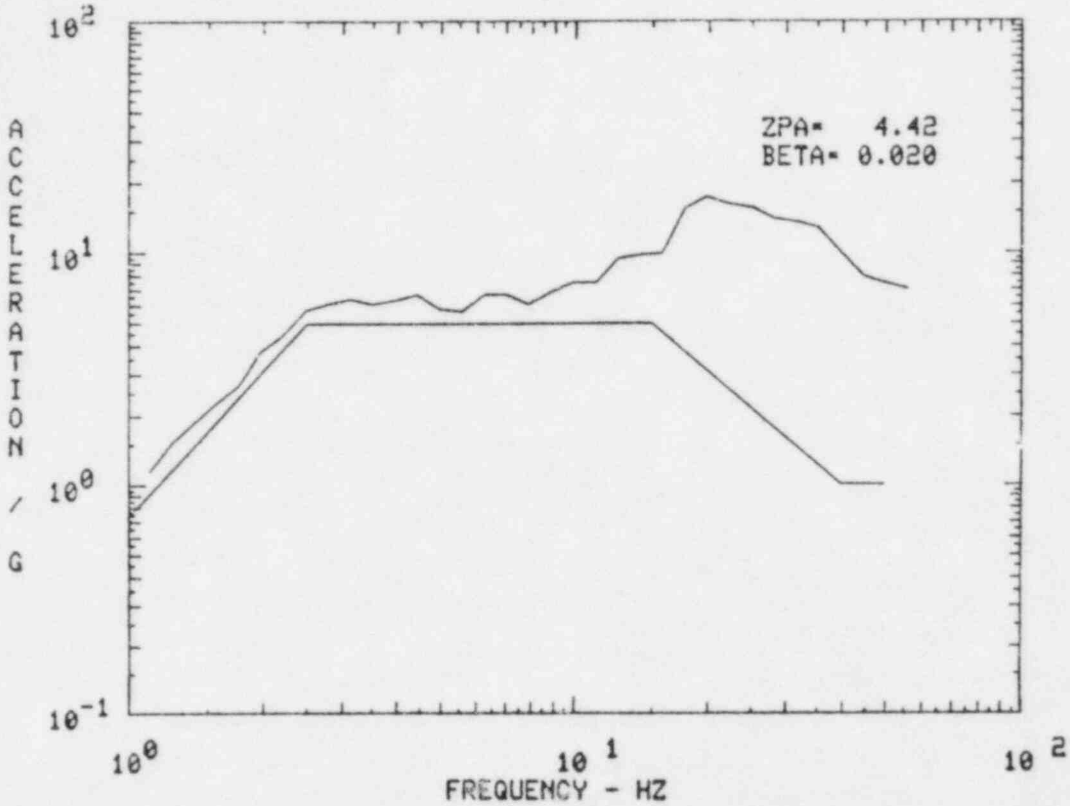


Figure 10.110 RUN OBYZ4 Accelerometer Location 4V

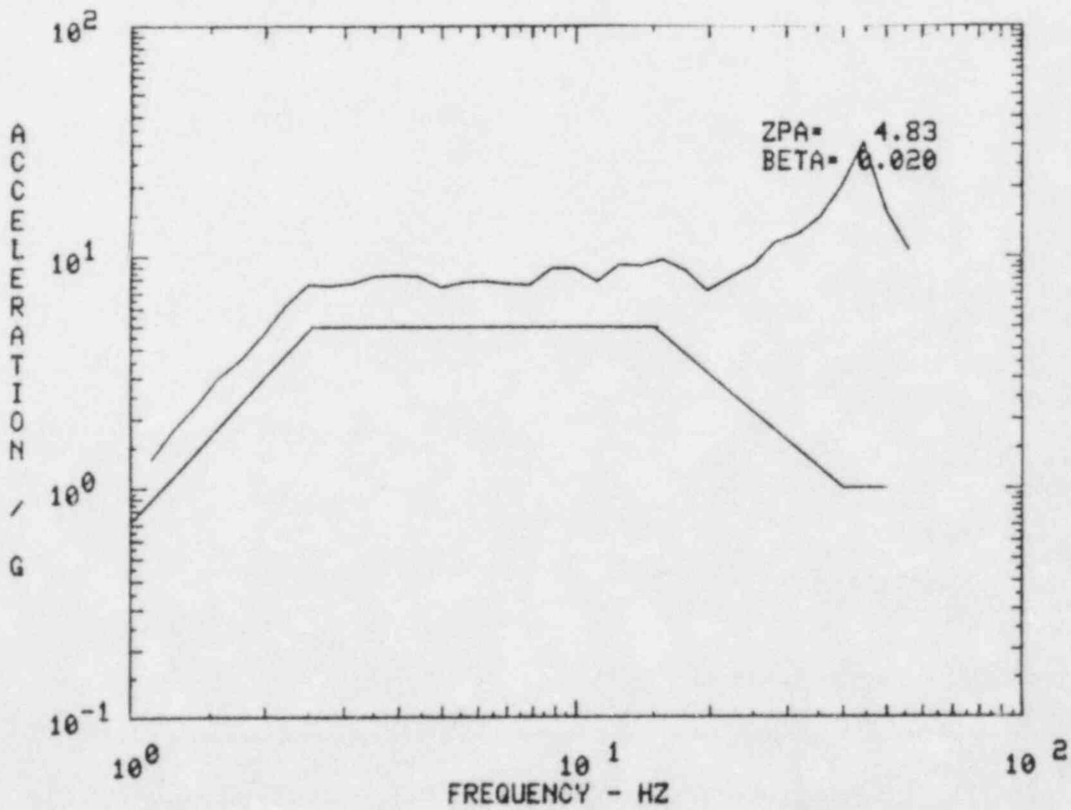


Figure 10.111 RUN OBYZ4 Accelerometer Location 5H

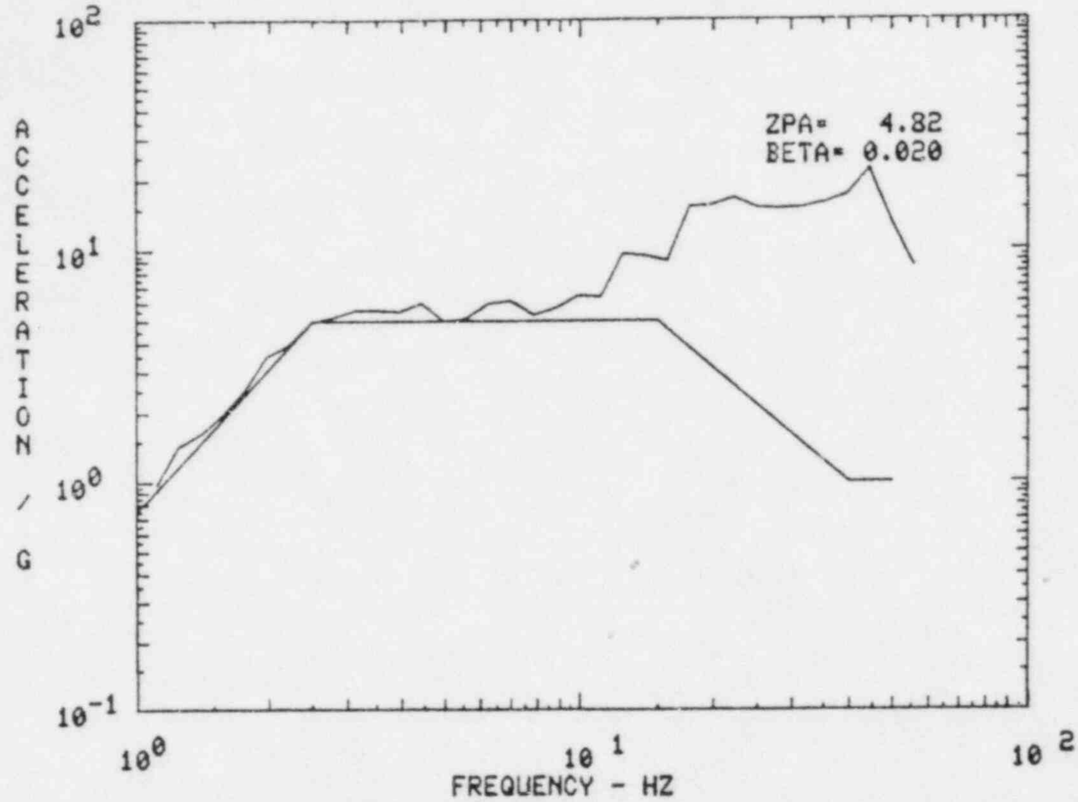


Figure 10.112 RUN OBYZ4 Accelerometer Location 6V

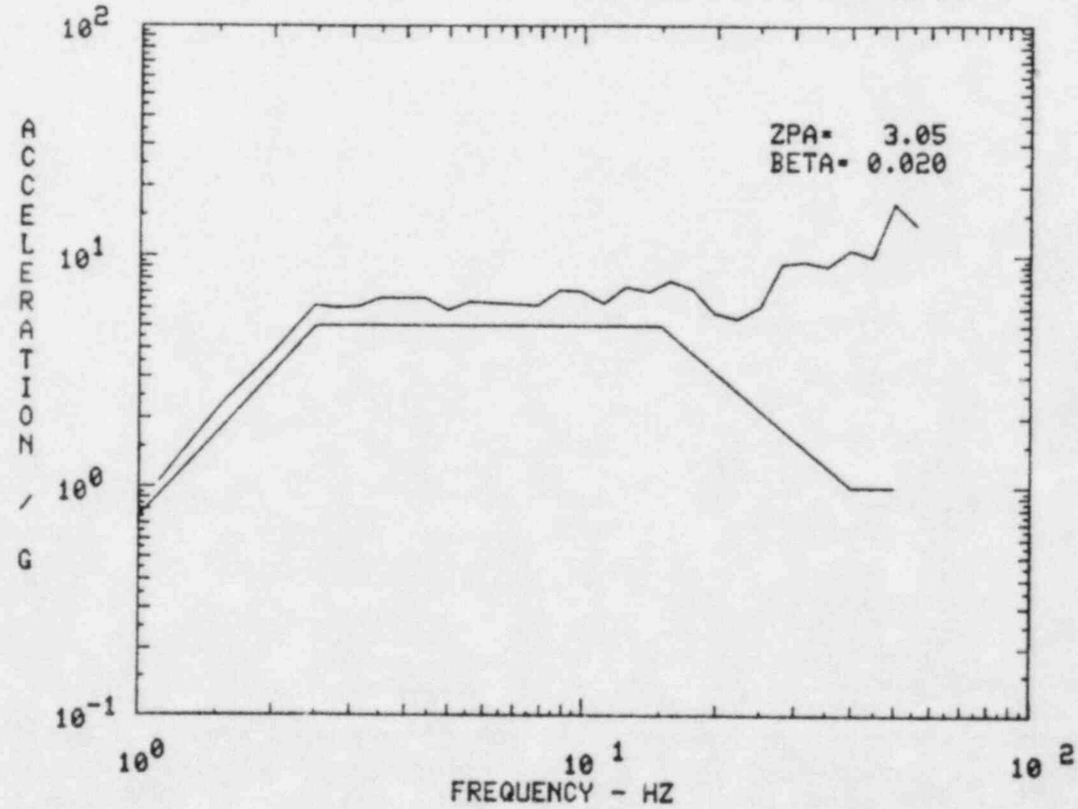


Figure 10.113 RUN OBYZ4 Accelerometer Location 7H

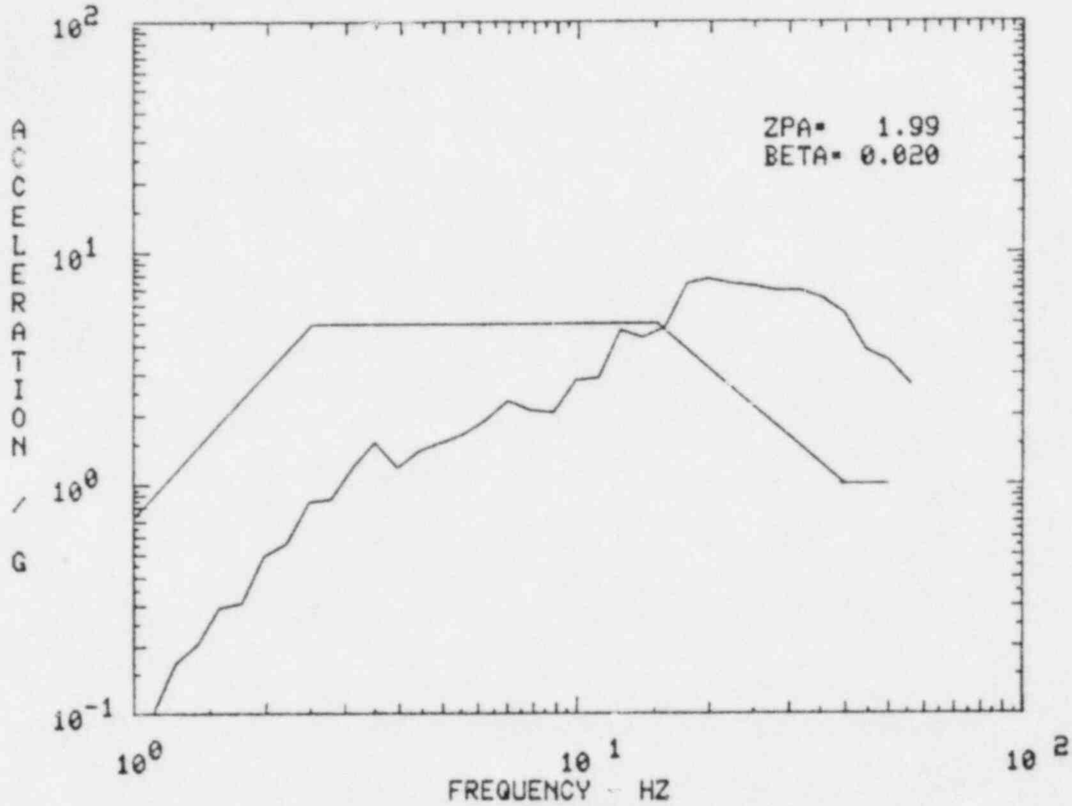


Figure 10.114 RUN OBYZ4 Accelerometer Location 8V

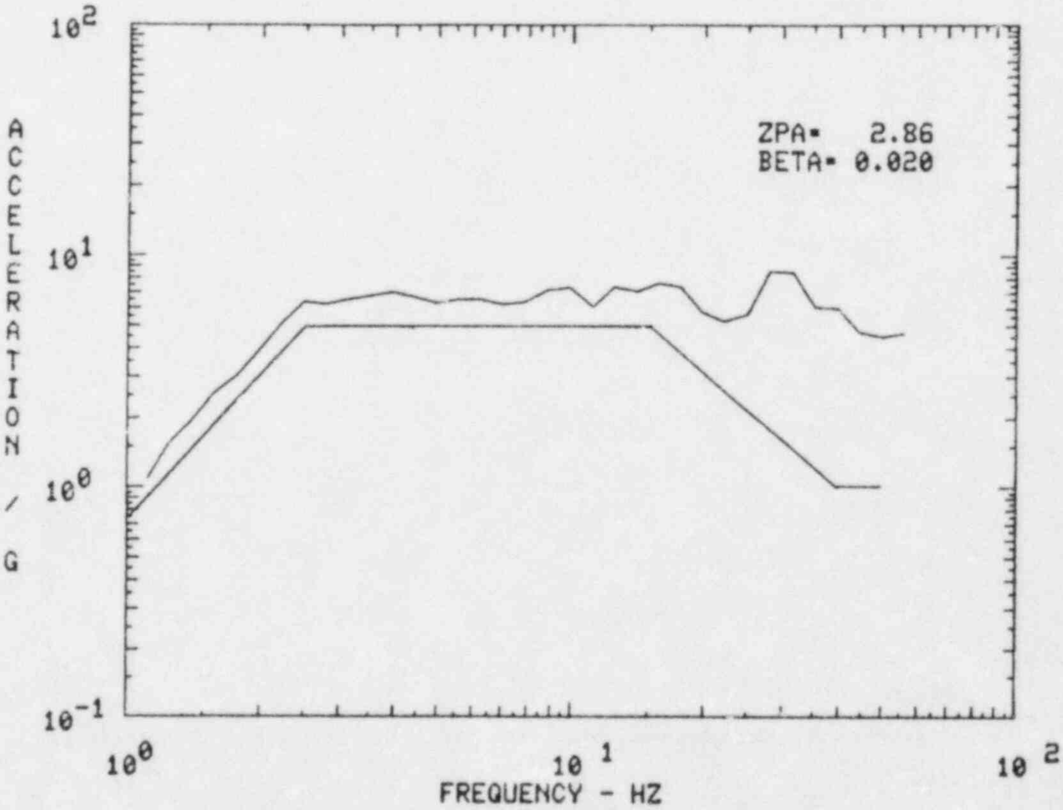


Figure 10.115 RUN OBYZ4 Accelerometer Location 9H

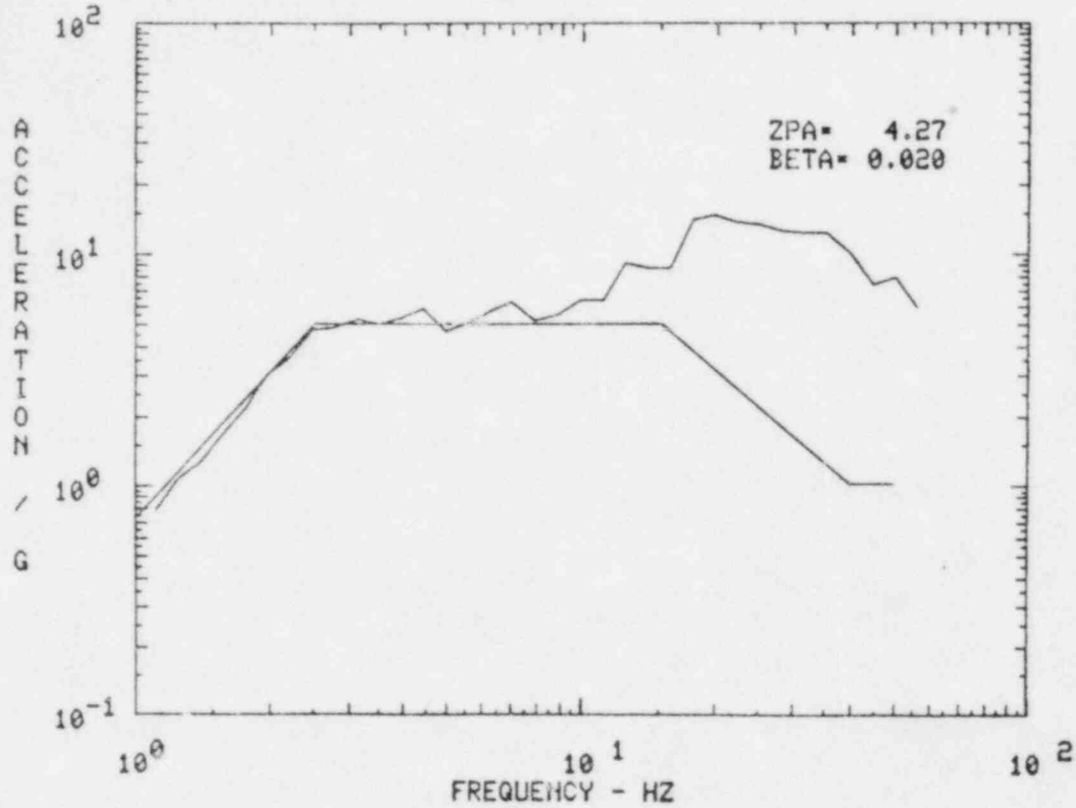


Figure 10.116 RUN OBYZ4 Accelerometer Location 10H

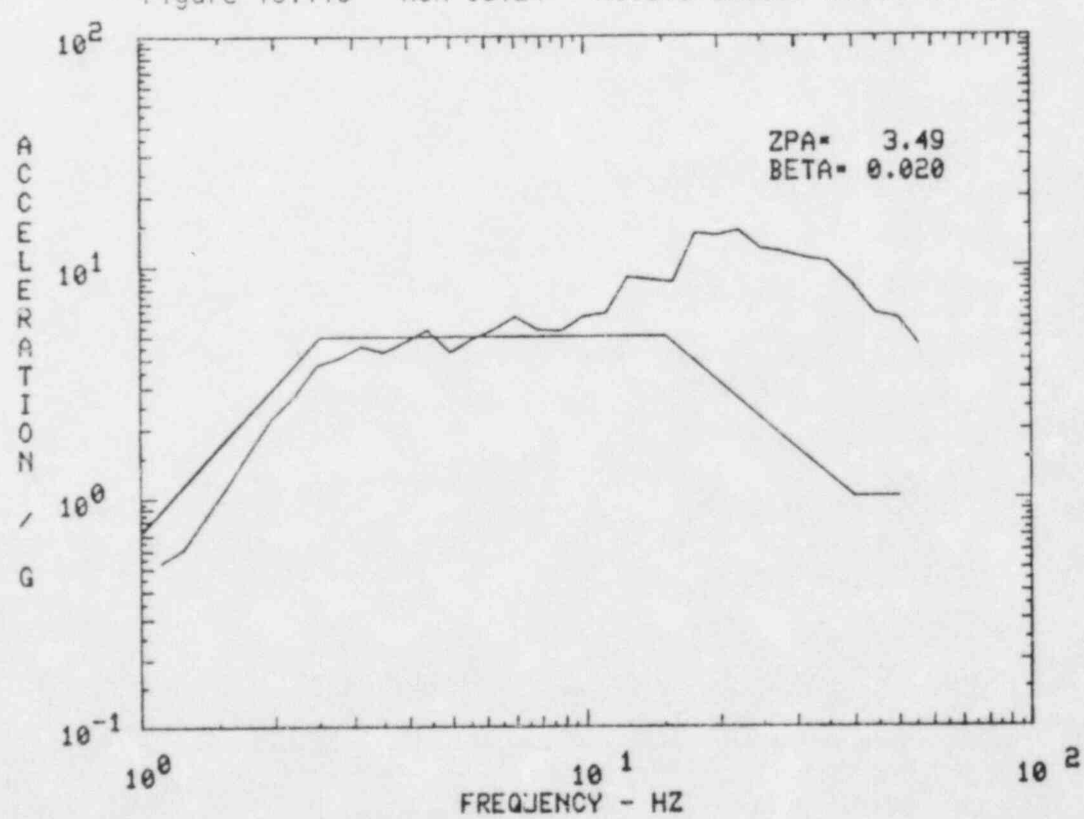


Figure 10.117 RUN OBYZ5 Accelerometer Location 1H

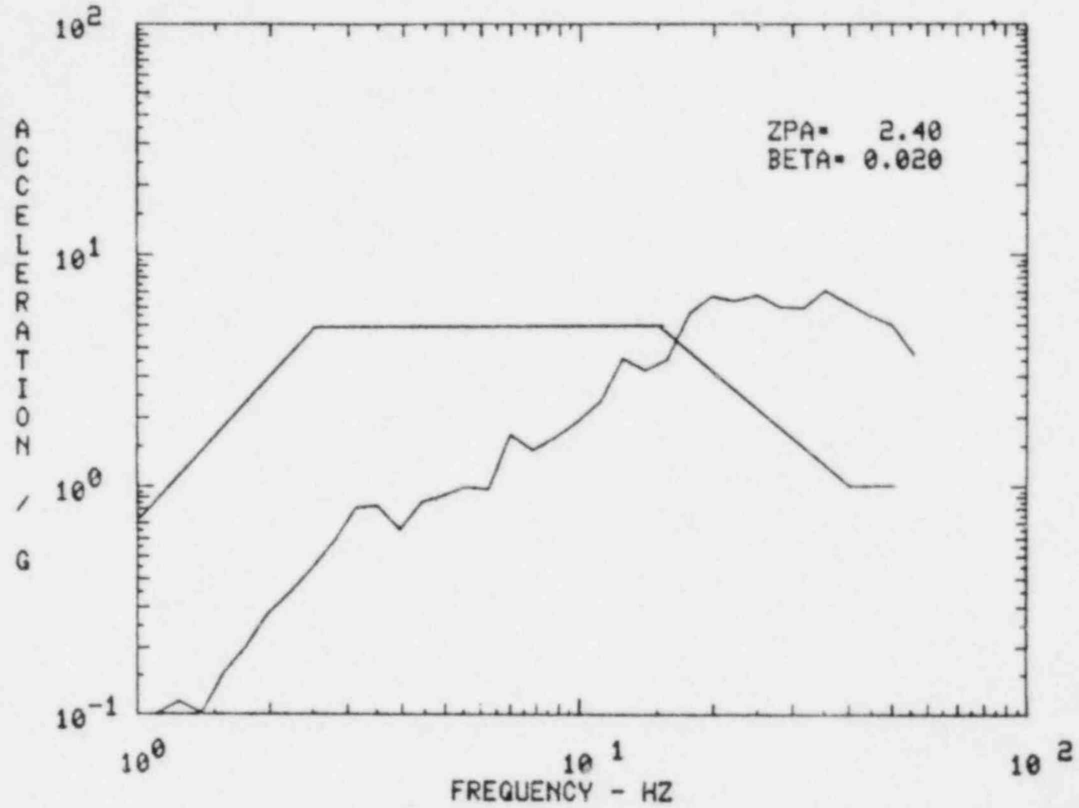


Figure 10.118 RUN OBYZ5 Accelerometer Location 2V

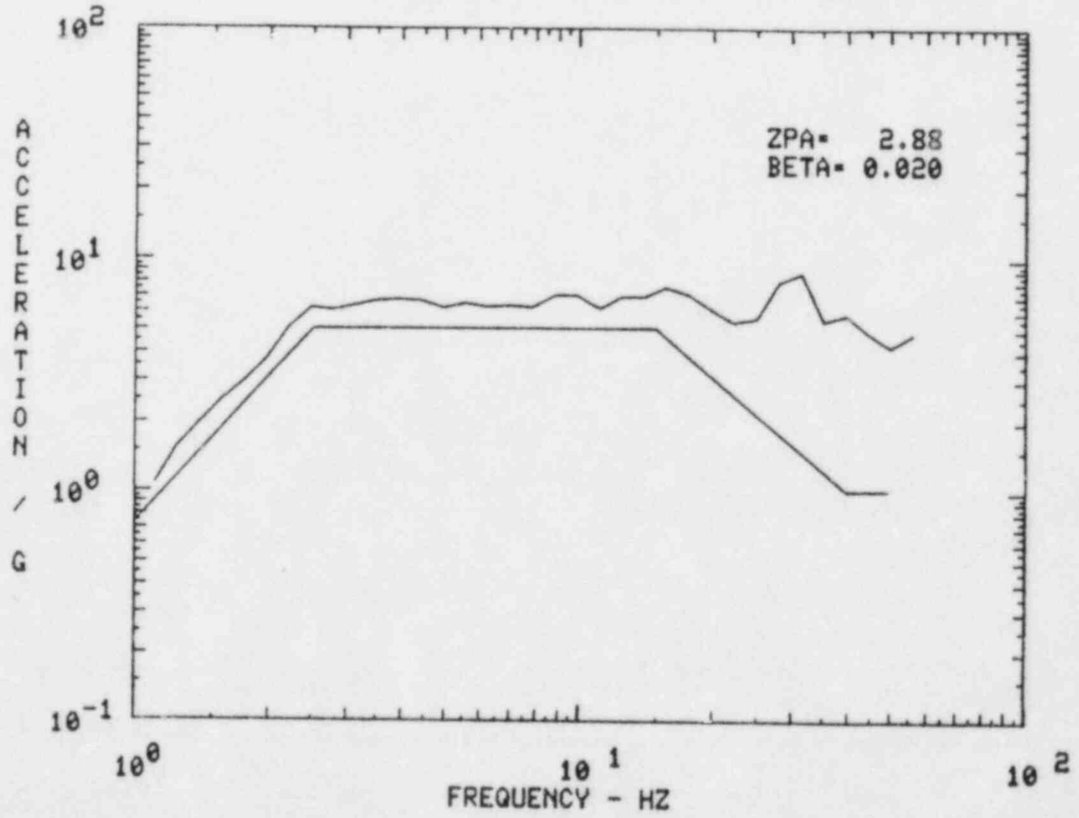


Figure 10.119 RUN OBYZ5 Accelerometer Location 3H

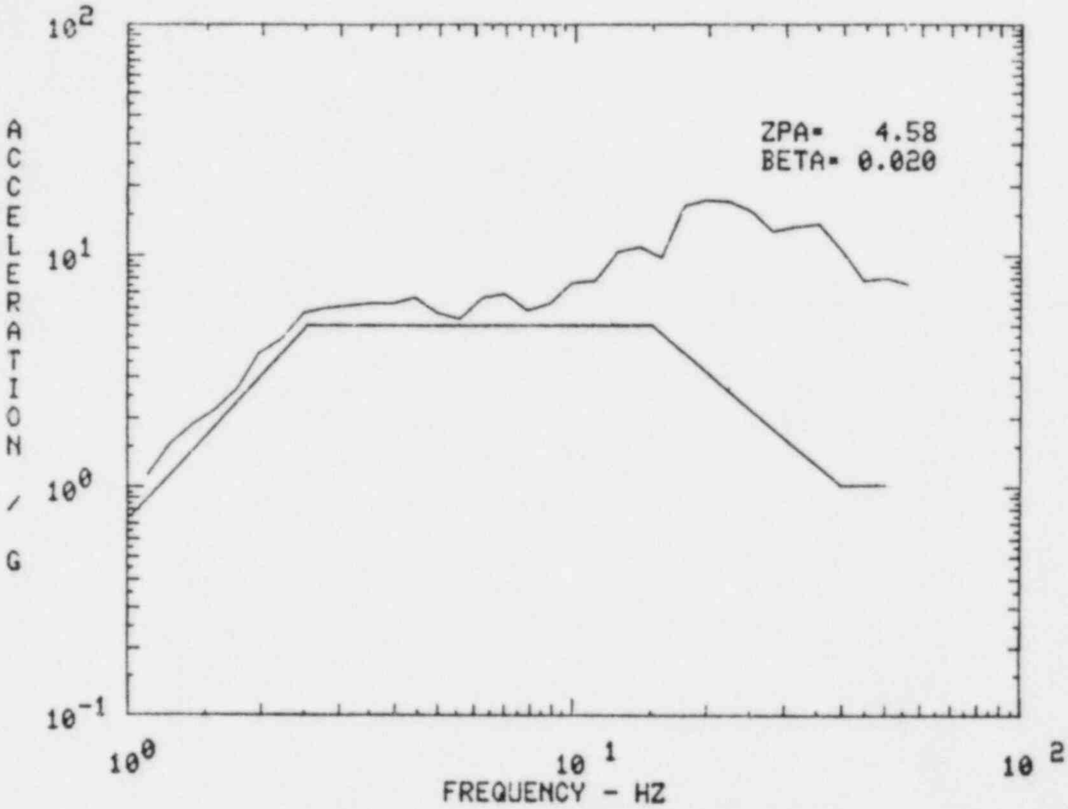


Figure 10.120 RUN OBYZ5 Accelerometer Location 4V

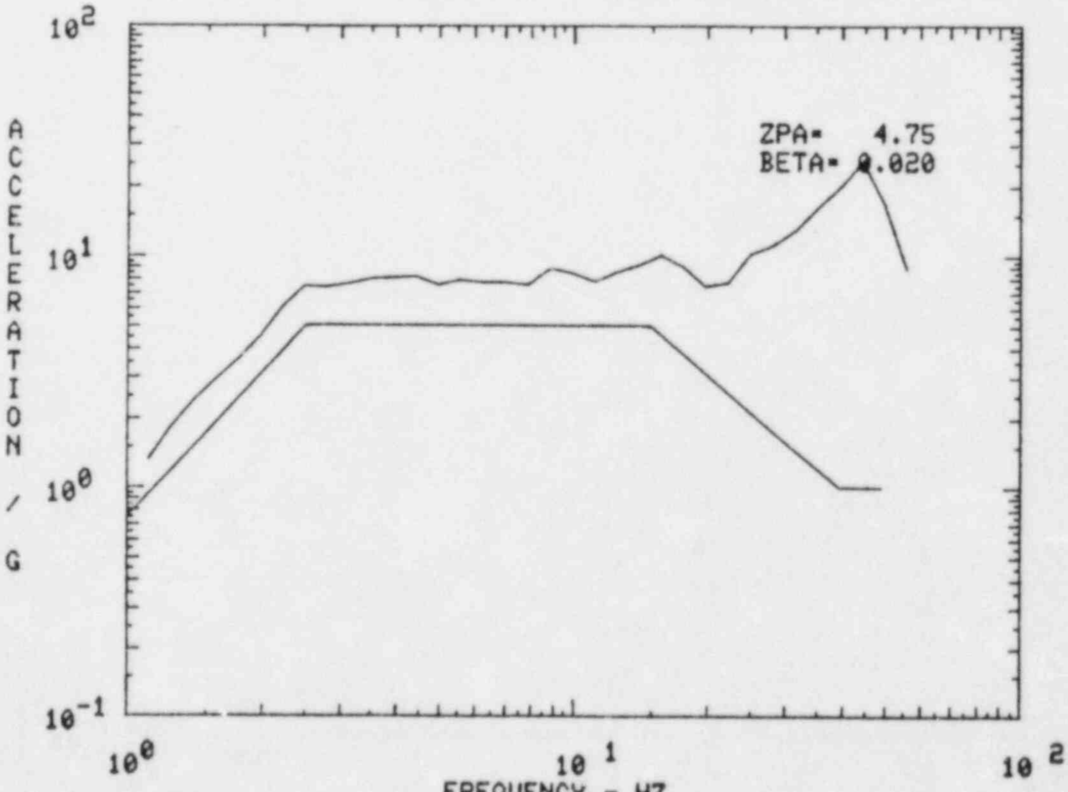


Figure 10.121 RUN OBYZ5 Accelerometer Location 5H

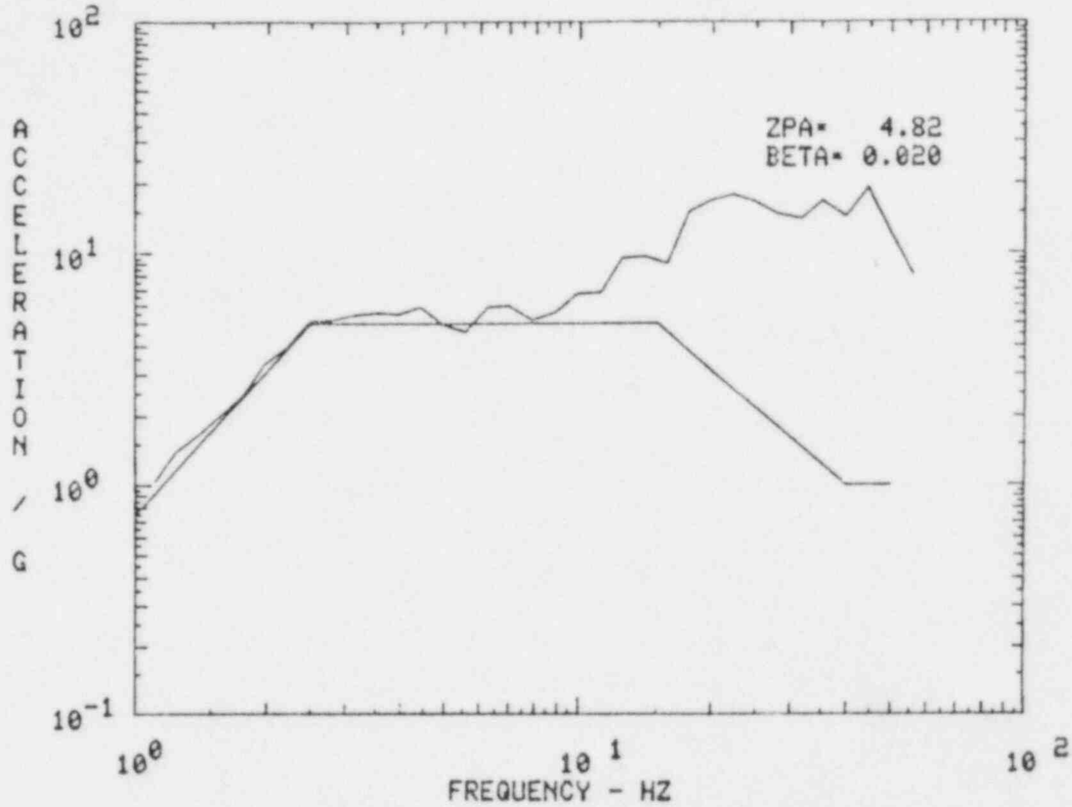


Figure 10.122 RUN OBYZ5 Accelerometer Location 6V

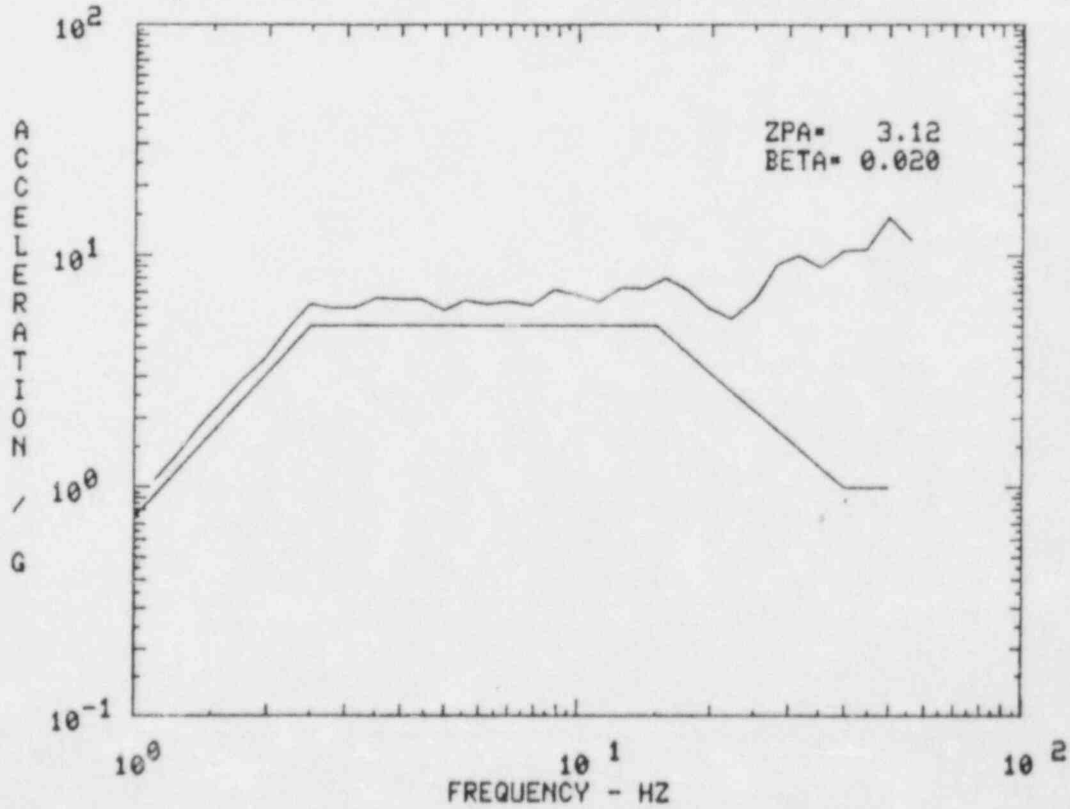


Figure 10.123 RUN OBYZ5 Accelerometer Location 7H

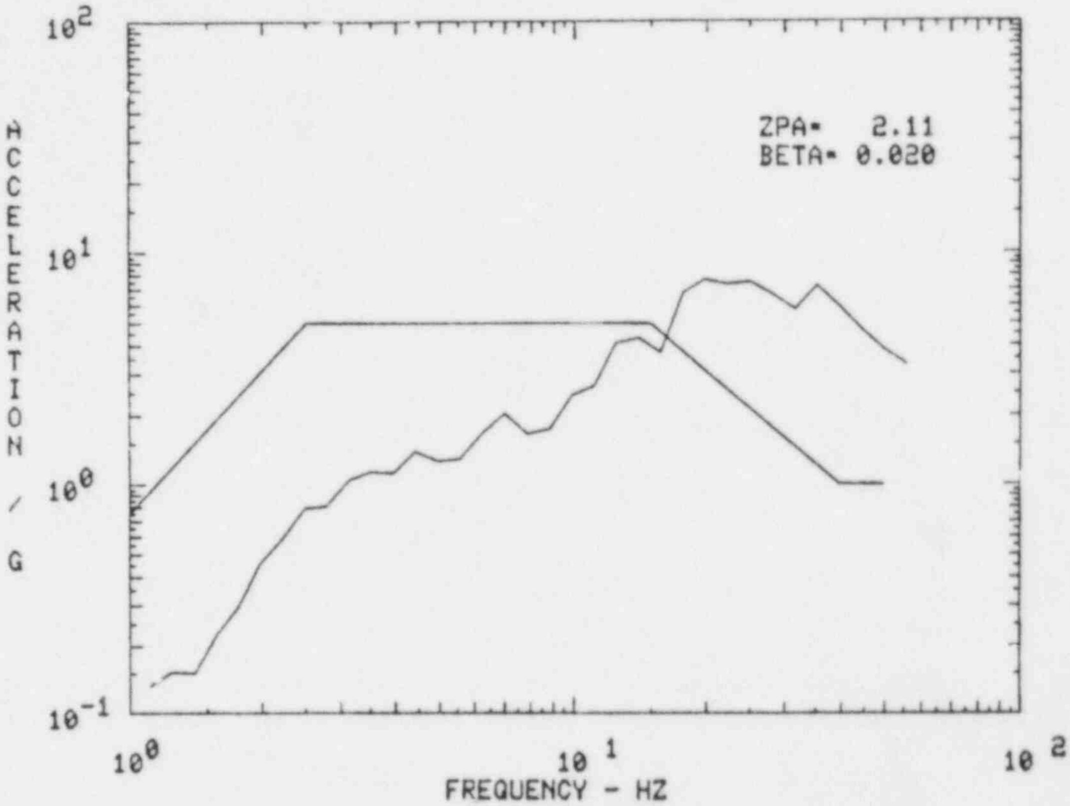


Figure 10.124 RUN OBYZ5 Accelerometer Location 8V

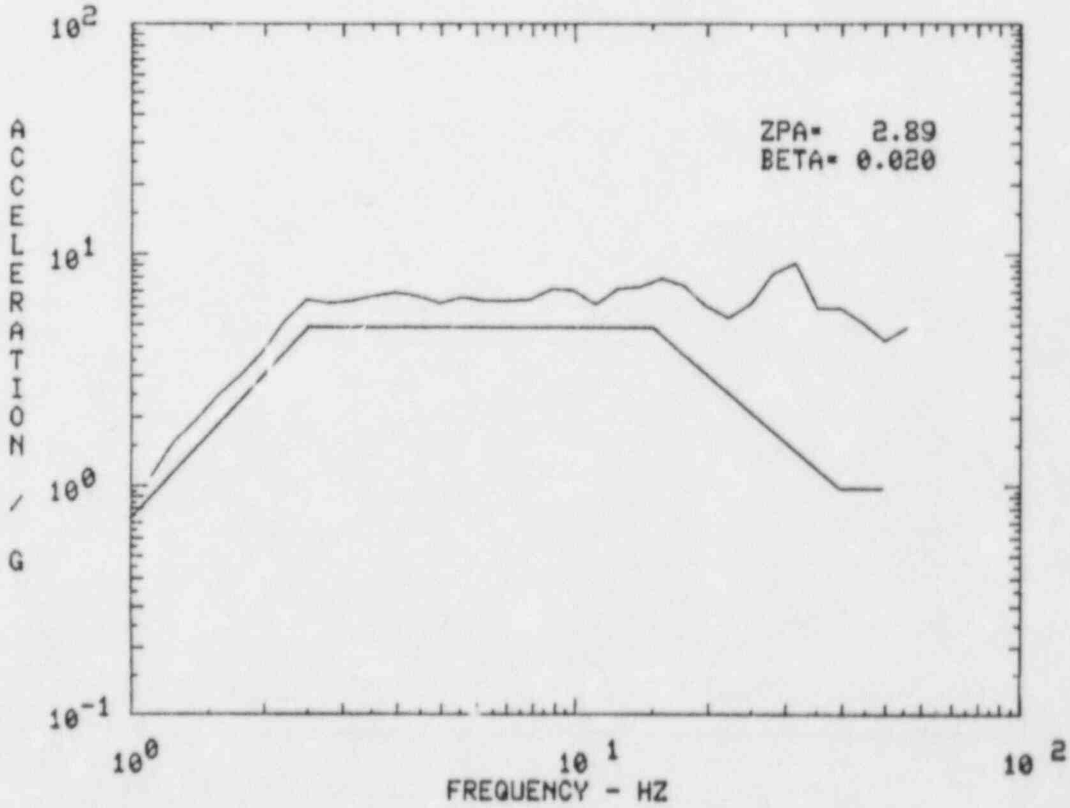


Figure 10.125 RUN OBYZ5 Accelerometer Location 9H

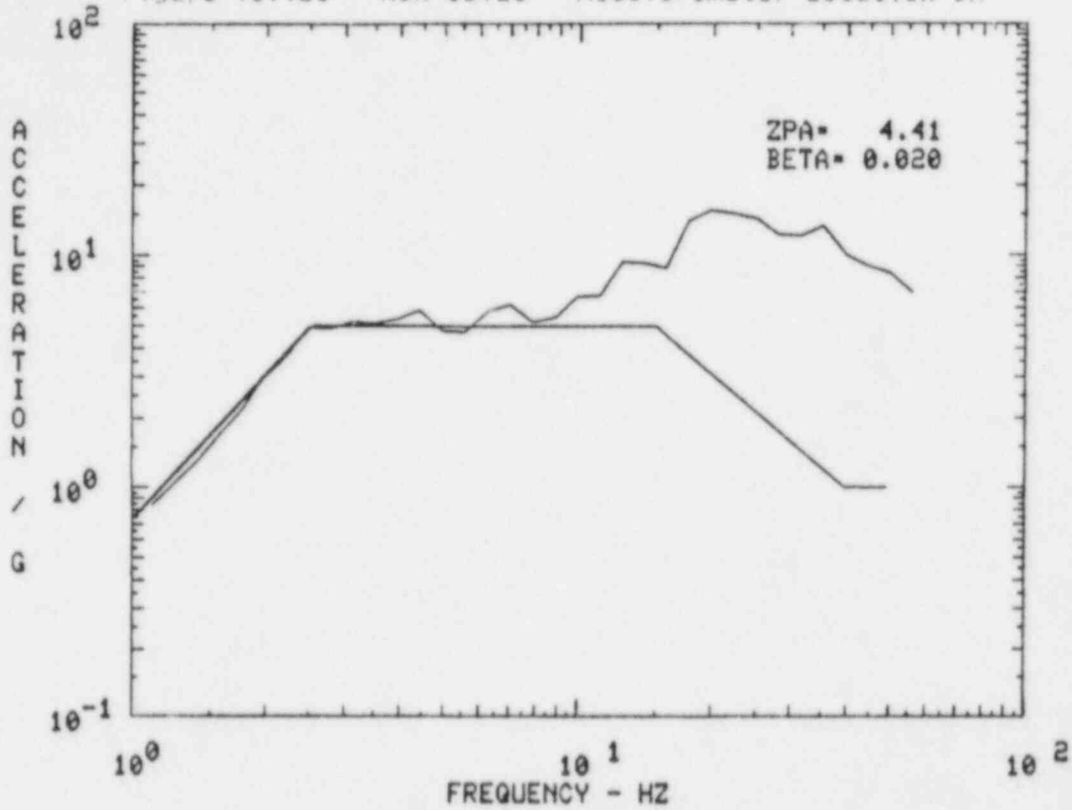


Figure 10.126 RUN OBYZ5 Accelerometer Location 10H

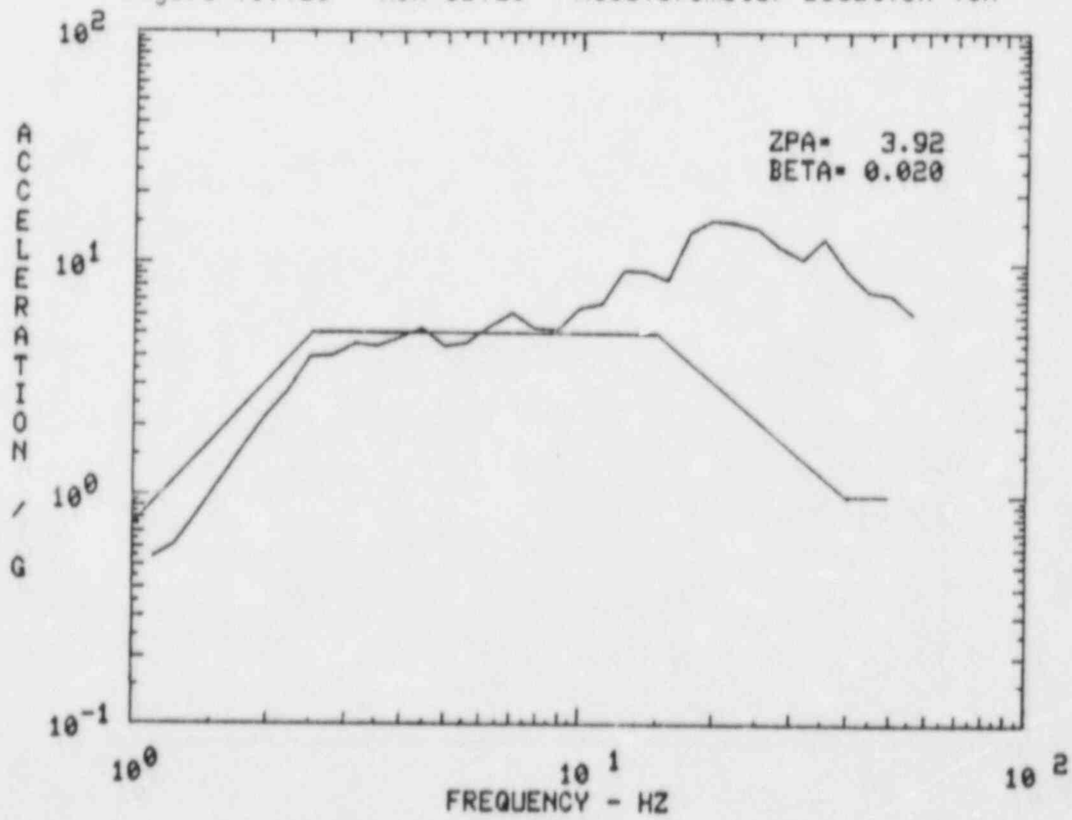


Figure 10.127 RUN SSYZ1 Accelerometer Location 1H

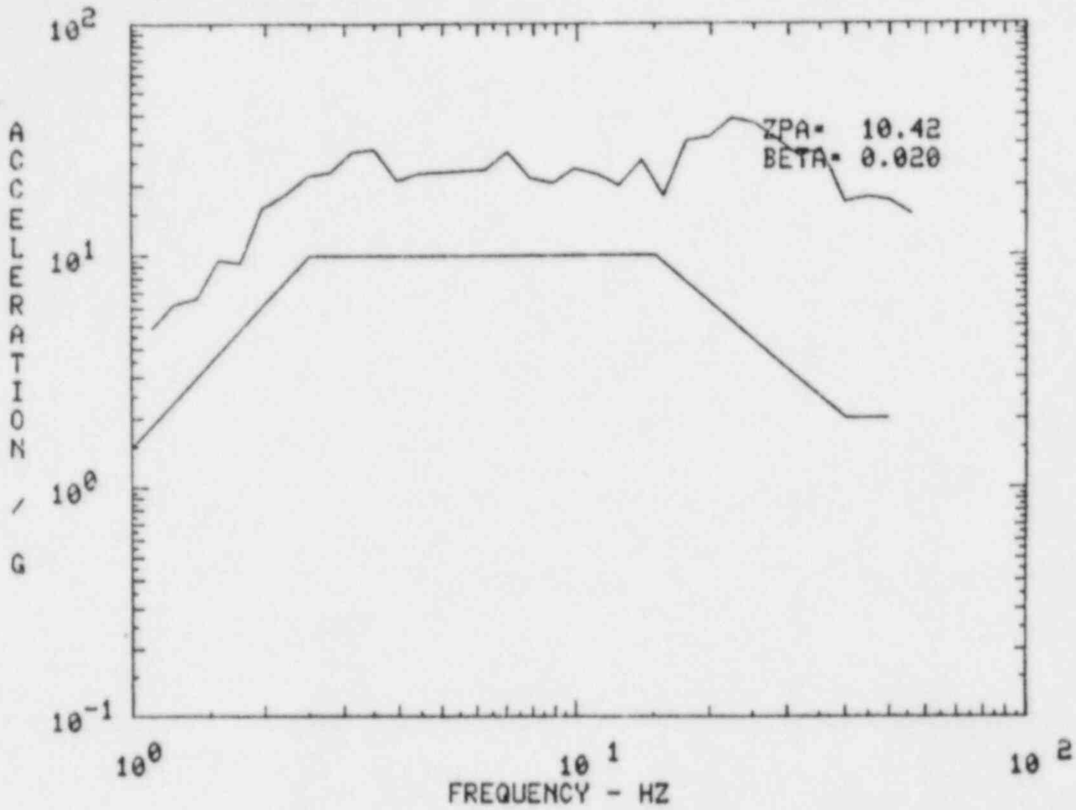


Figure 10.128 RUN SSYZ1 Accelerometer Location 2V

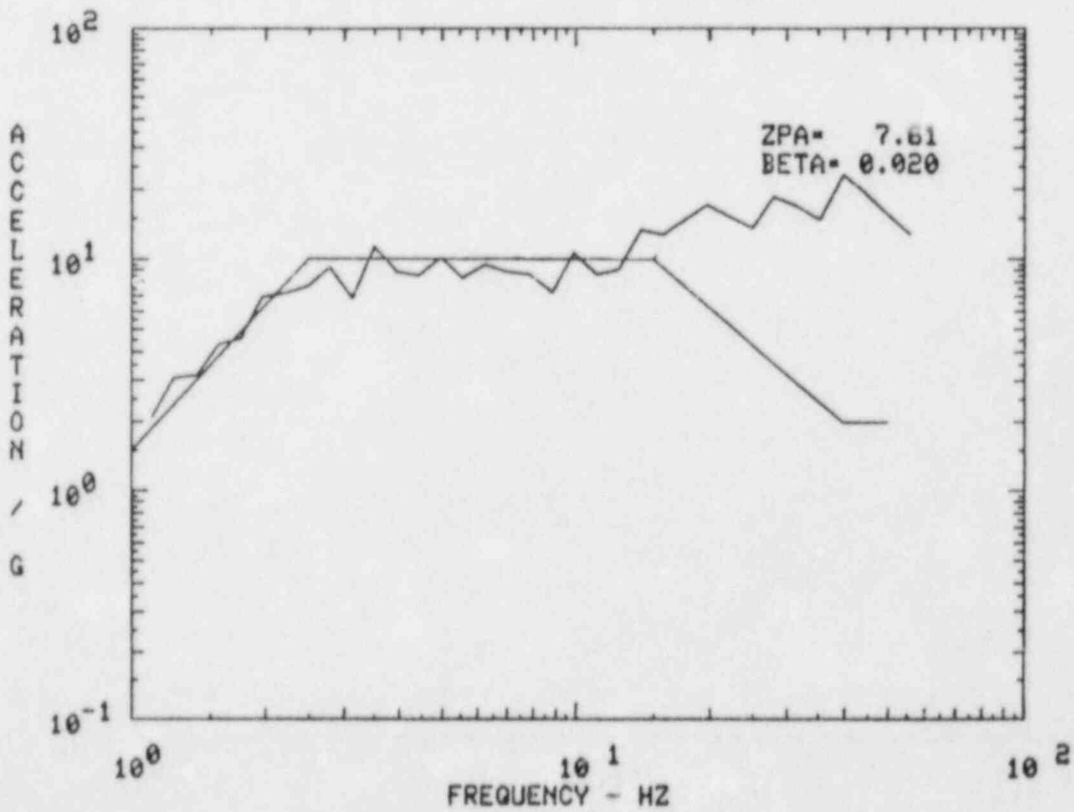


Figure 10.129 RUN SSYZ1 Accelerometer Location 3H

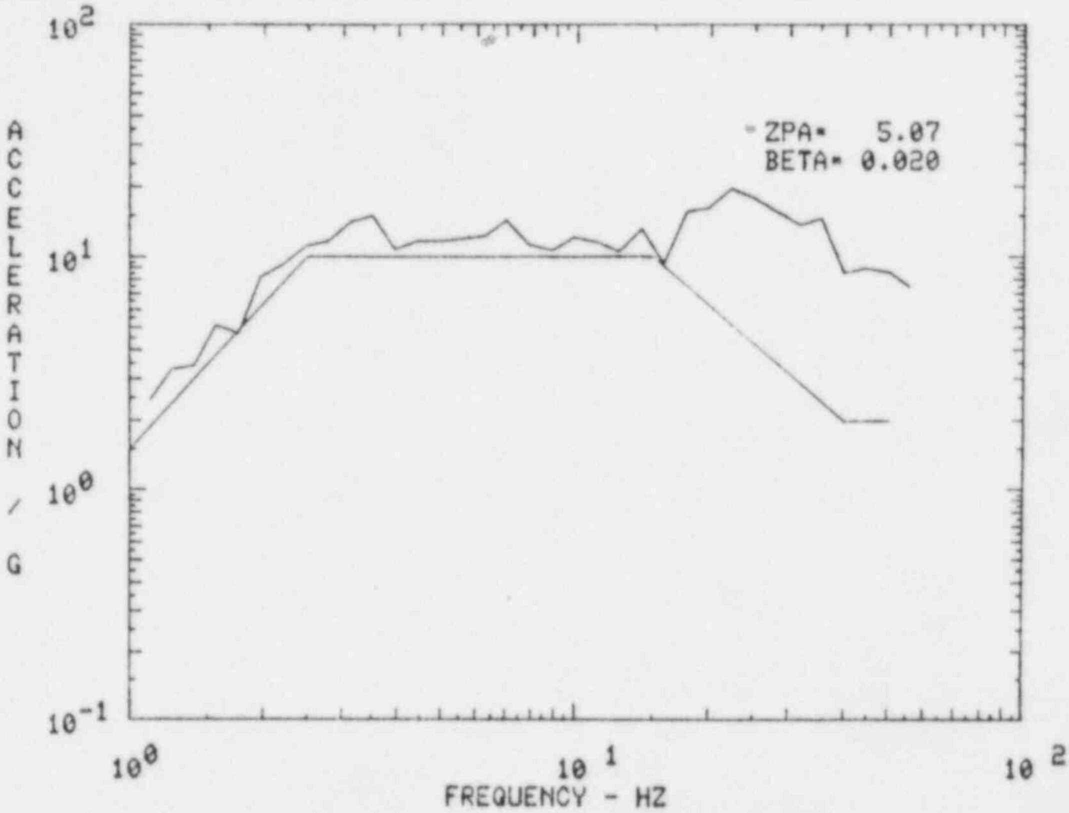


Figure 10.130 RUN SSYZ1 Accelerometer Location 4V

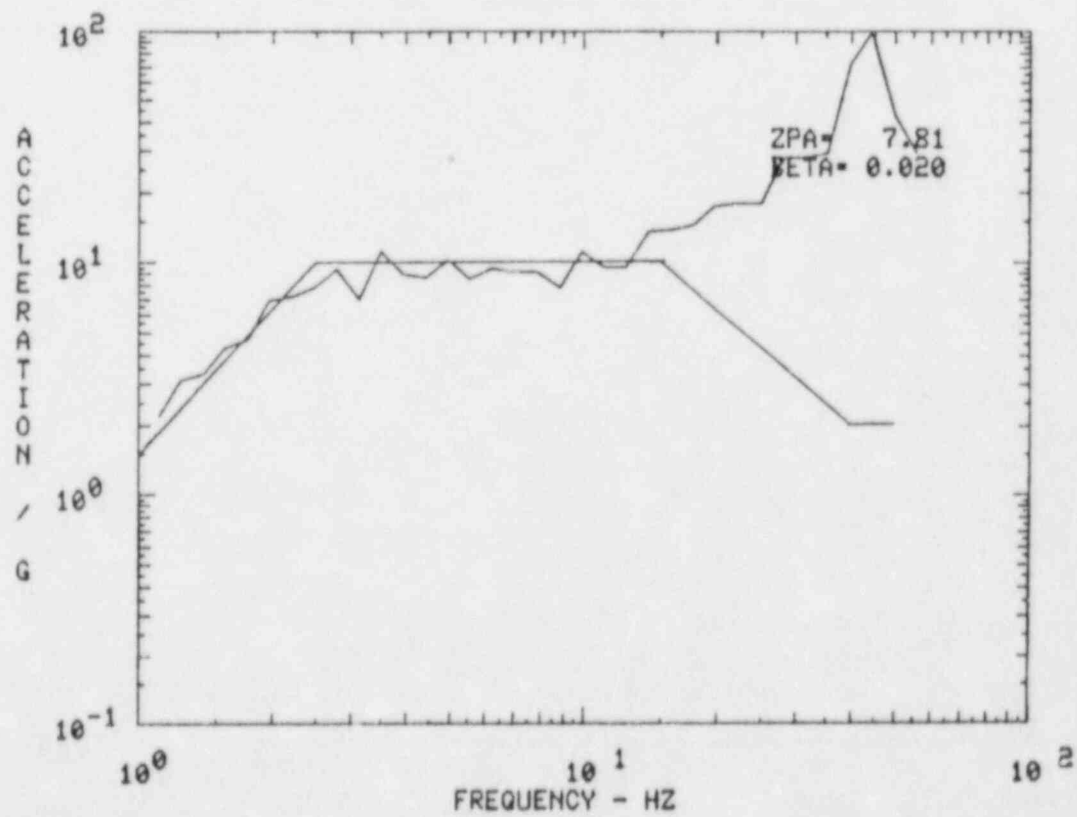


Figure 10.131 RUN SSYZ1 Accelerometer Location 5H

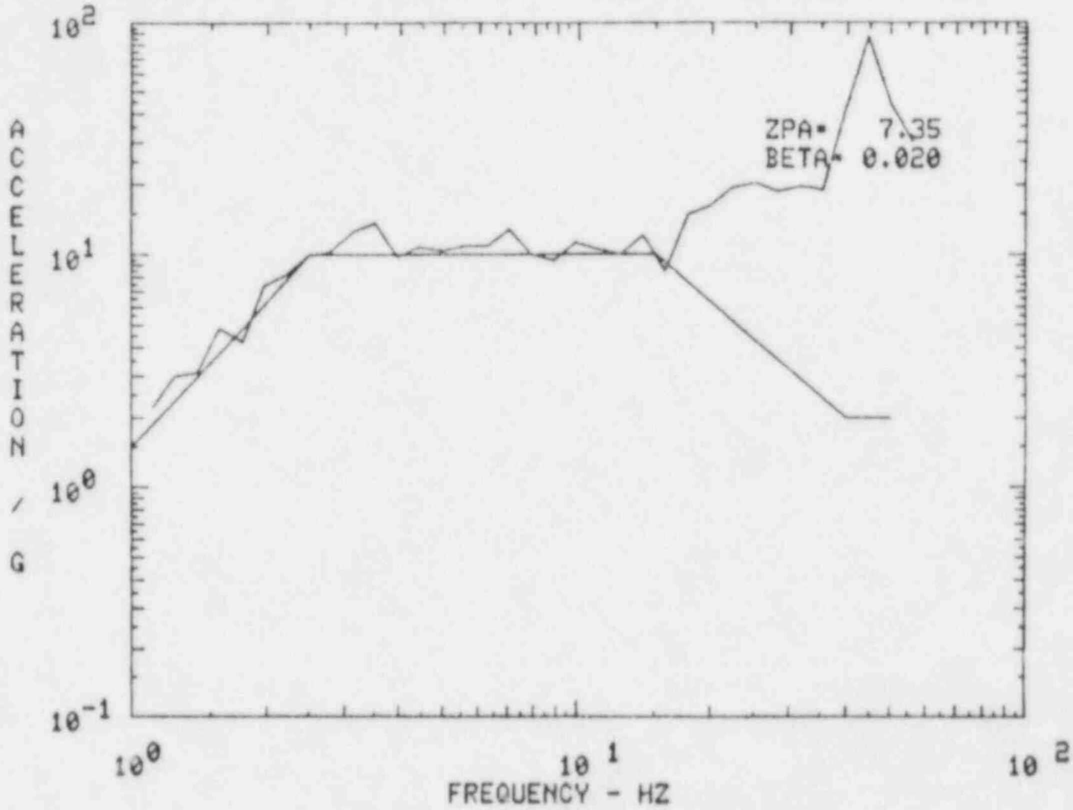


Figure 10.132 RUN SSYZ1 Accelerometer Location 6V

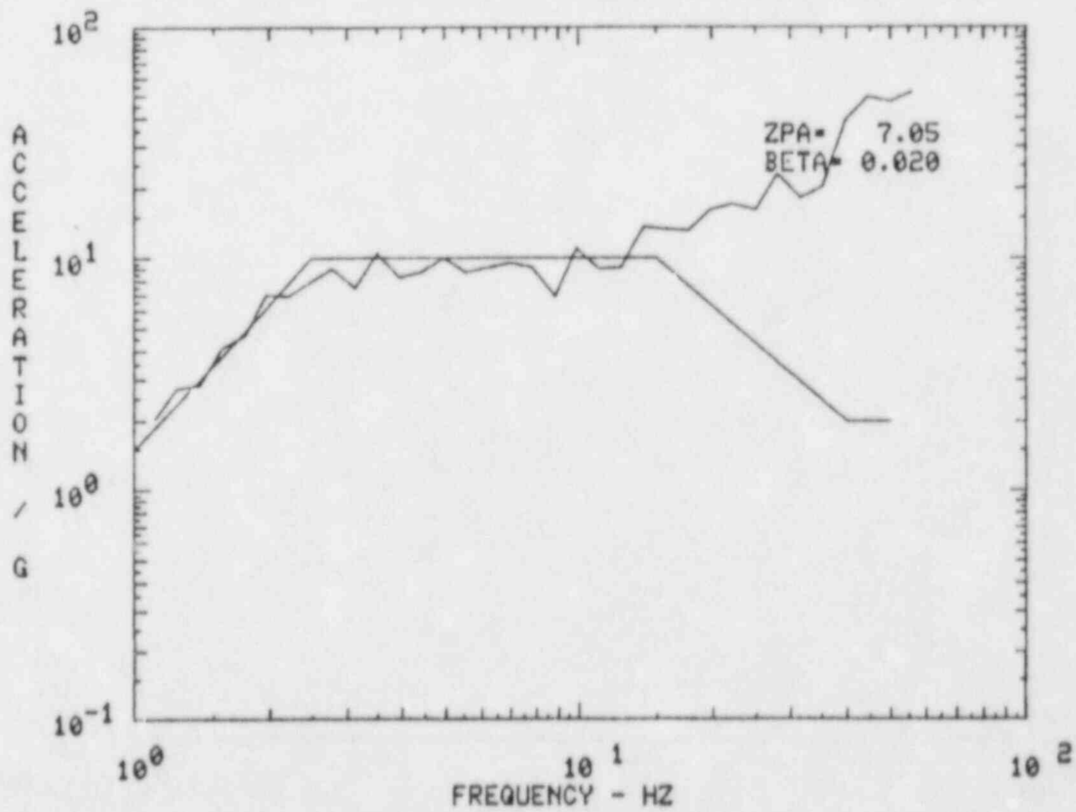


Figure 10.133 RUN SSYZ1 Accelerometer Location 7H

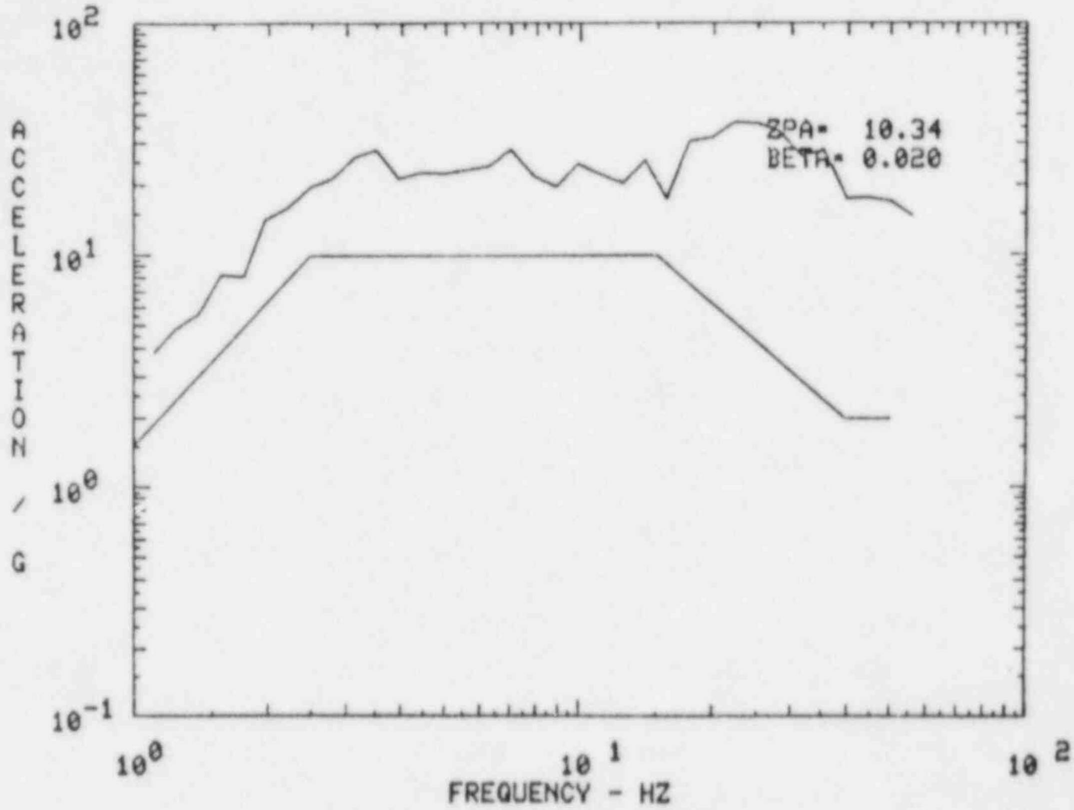


Figure 10.134 RUN SSYZ1 Accelerometer Location 8V

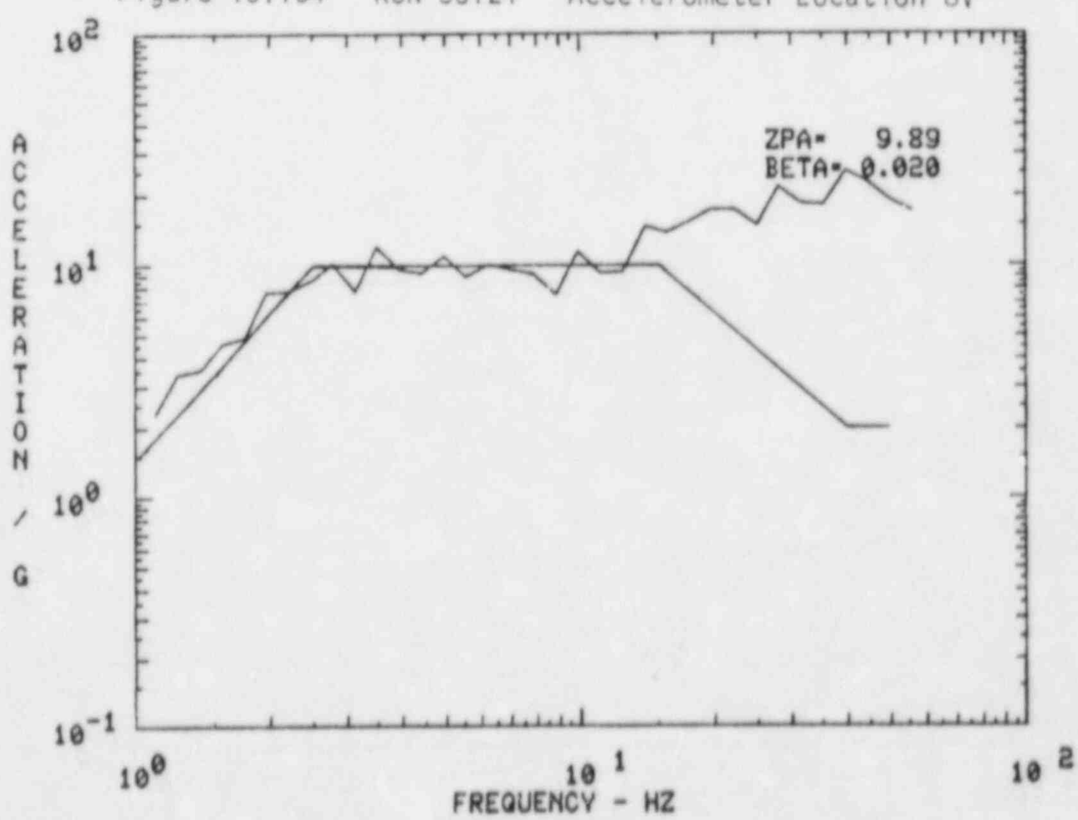


Figure 10.135 RUN SSYZ1 Accelerometer Location 9H

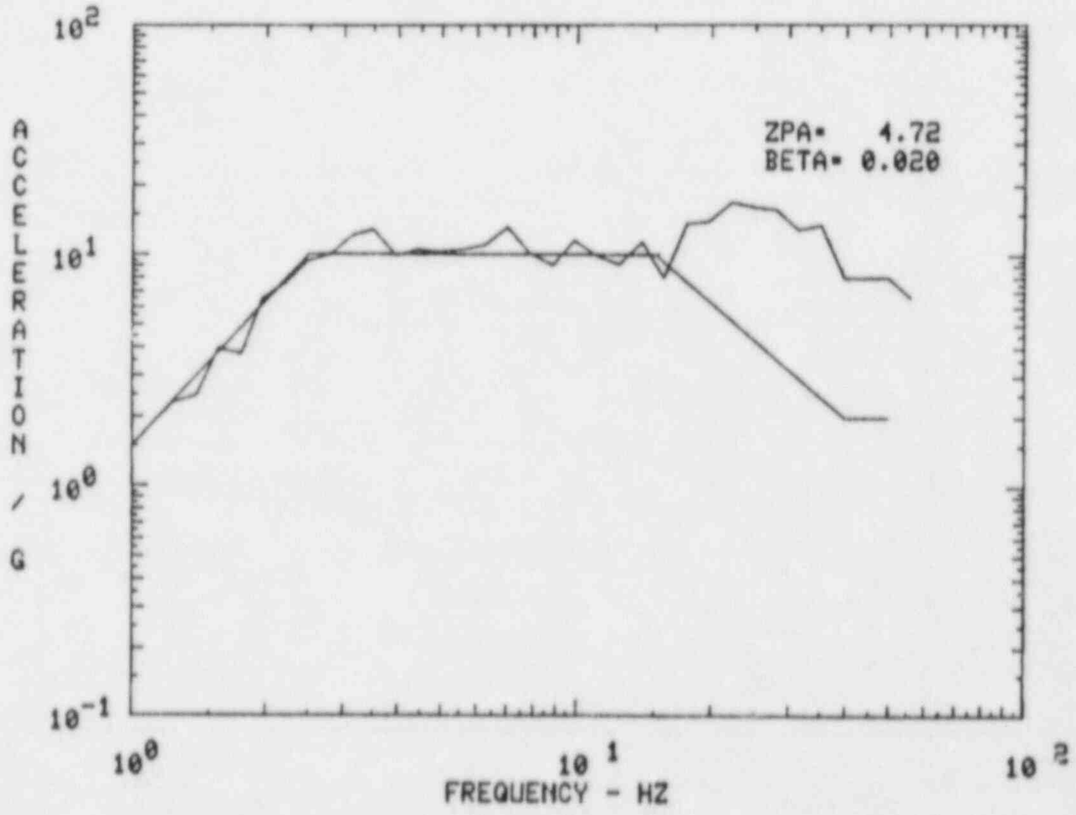


Figure 10.136 RUN SSYXA1 Accelerometer Location 1H

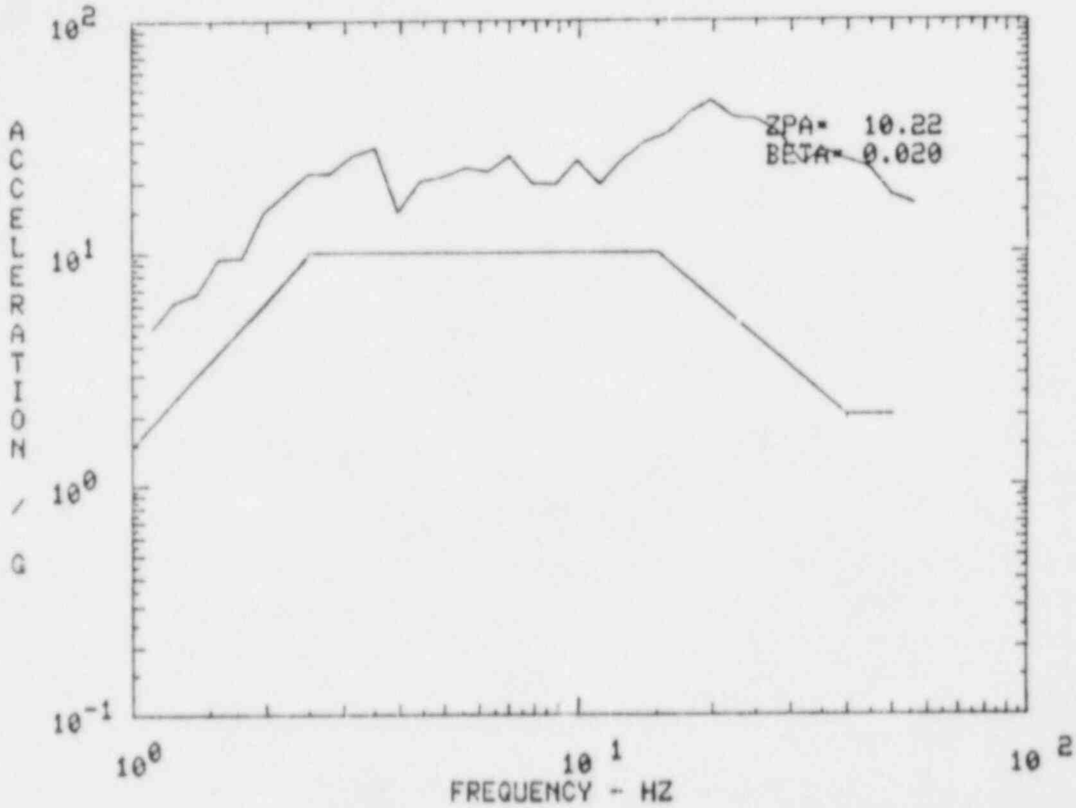


Figure 10.137 RUN SSYXA1 Accelerometer Location 2V

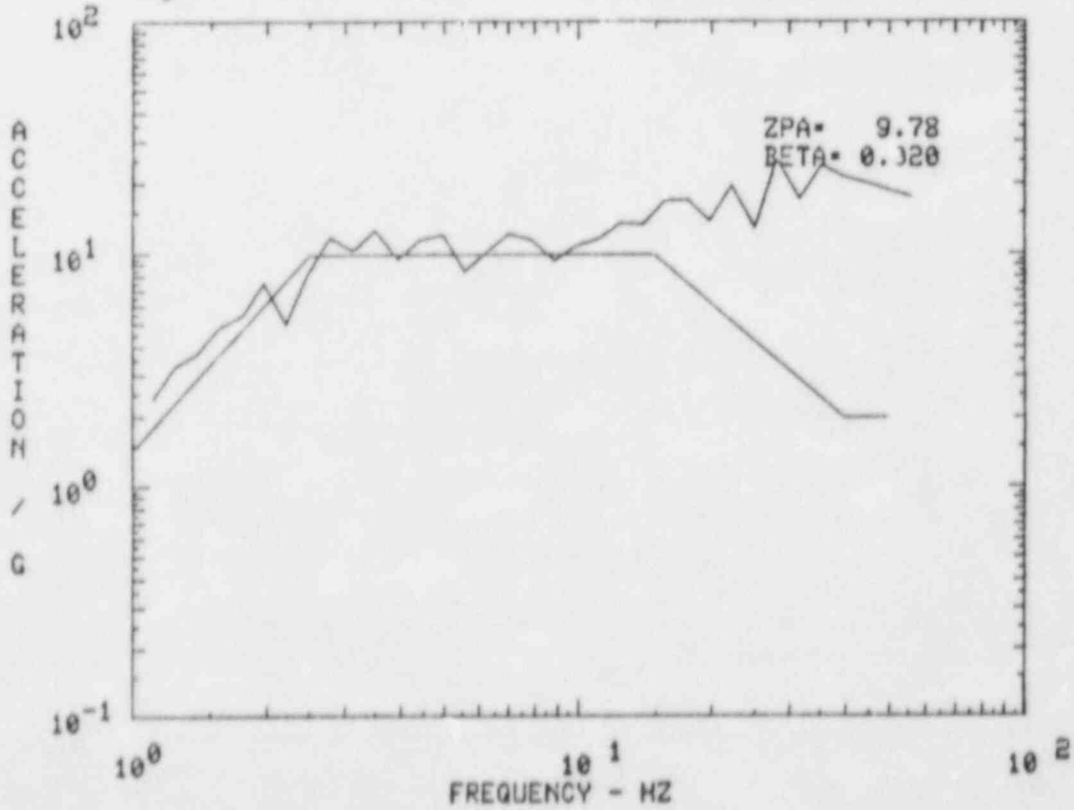


Figure 10.138 RUN SSYXA1 Accelerometer Location 3H

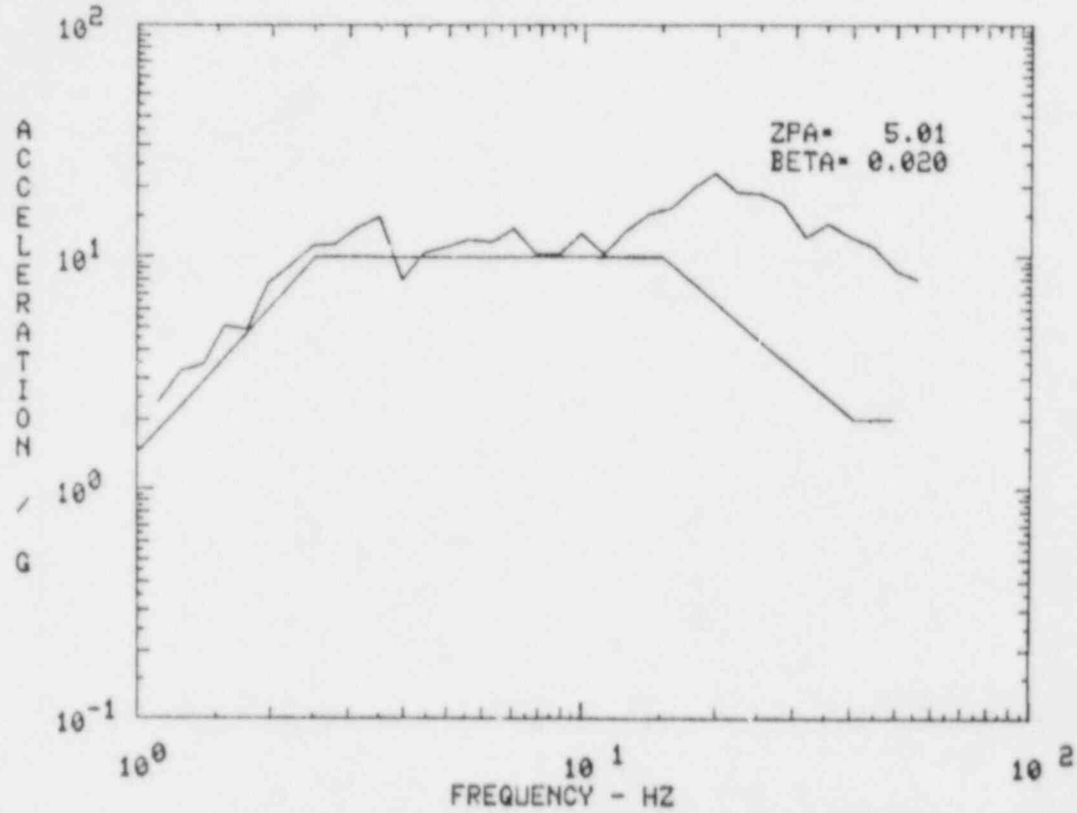


Figure 10.139 RUN SSYXZ1 Accelerometer Location 4V

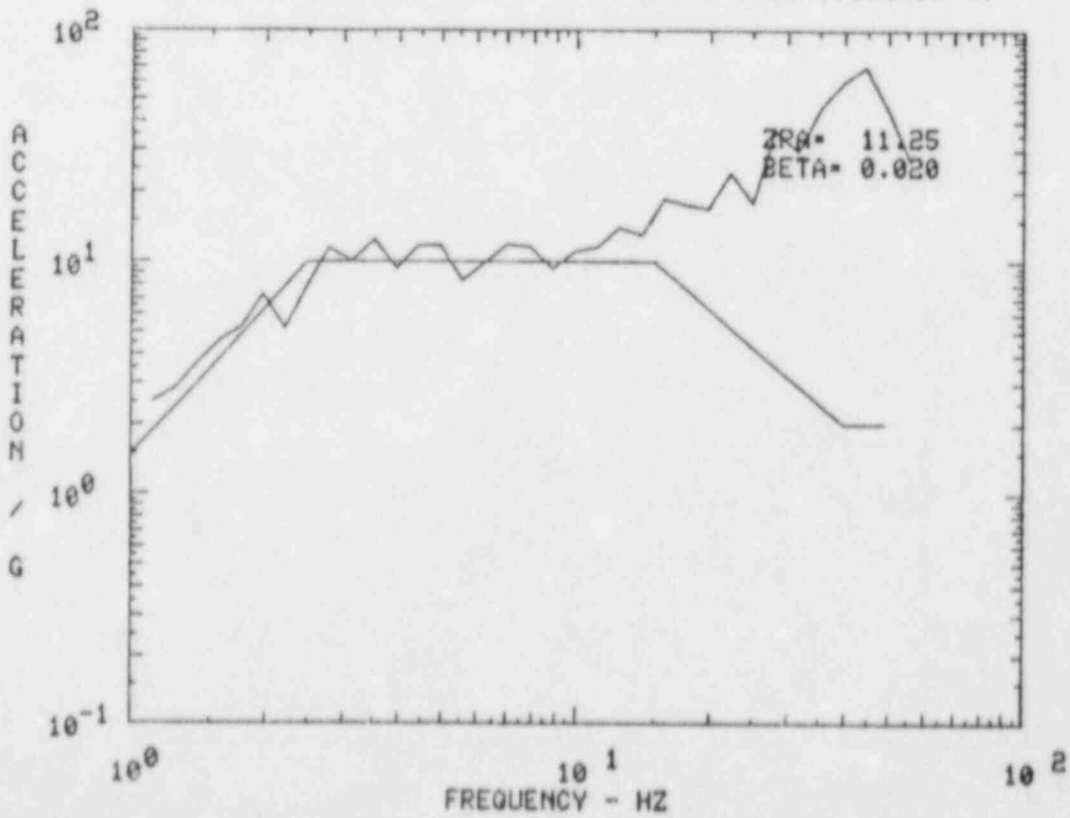


Figure 10.140 RUN SSYZA2 Accelerometer Location 5H

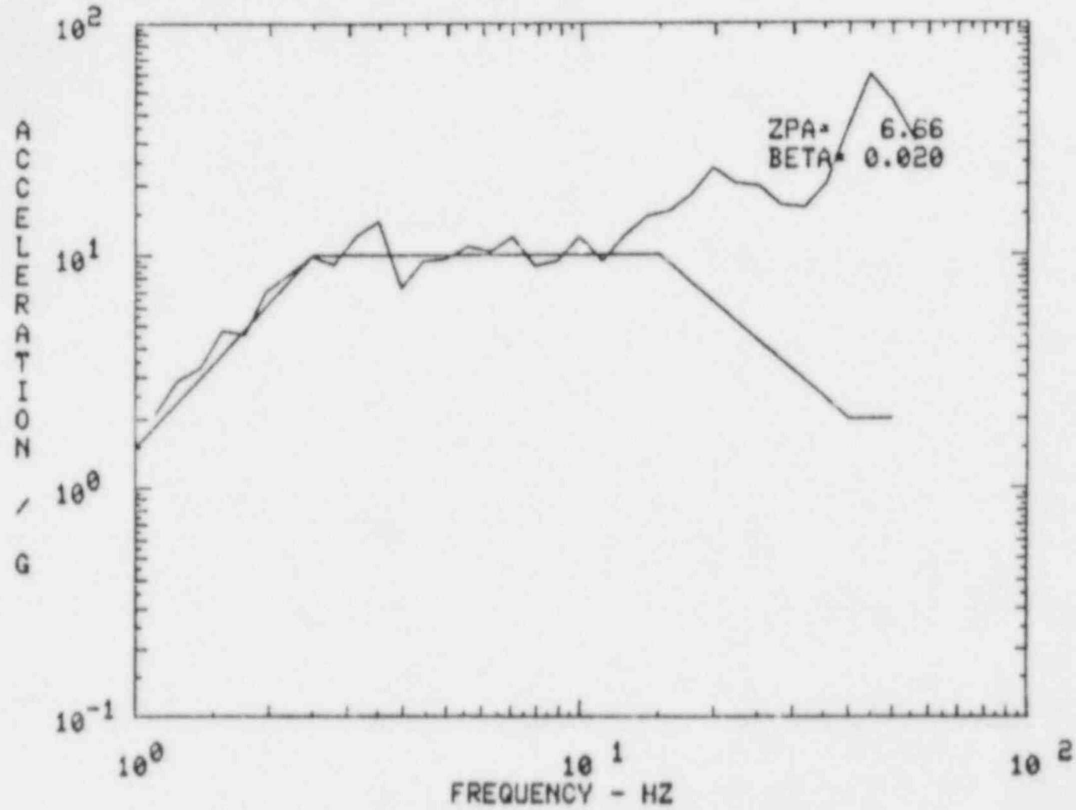


Figure 10.141 RUN SSYZA2 Accelerometer Location 6V

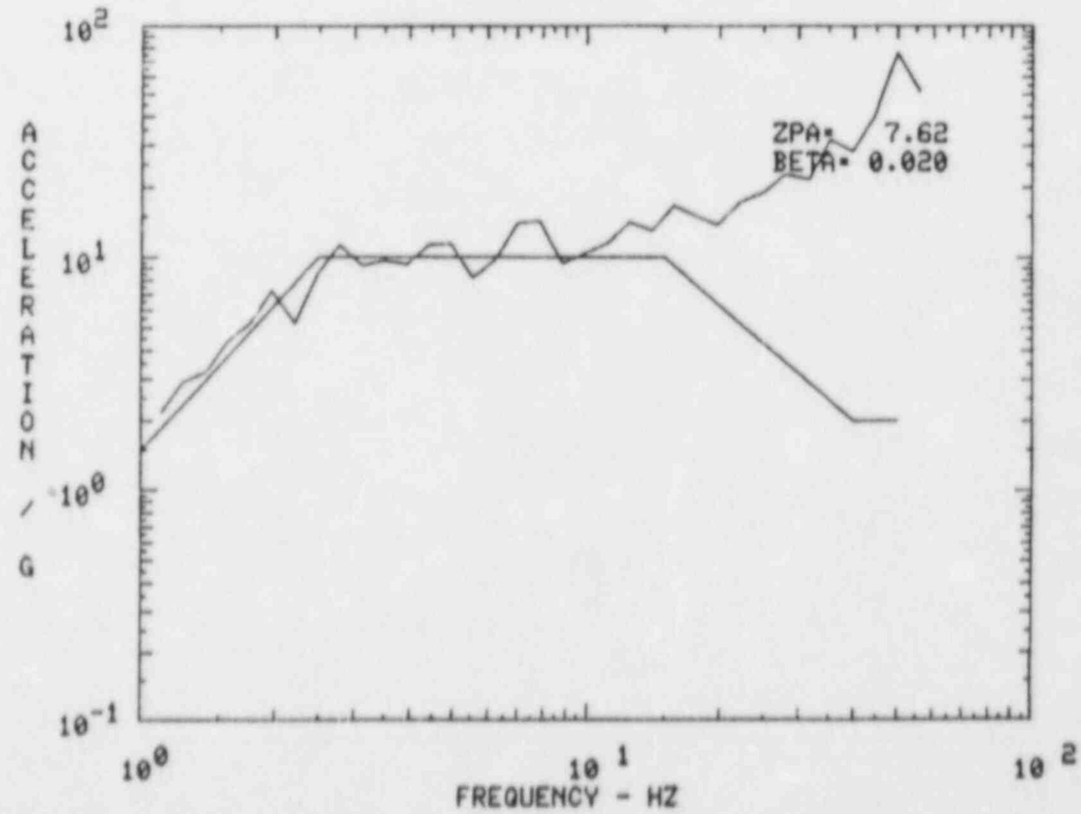


Figure 10.142 RUN SSYZA2 Accelerometer Location 7H

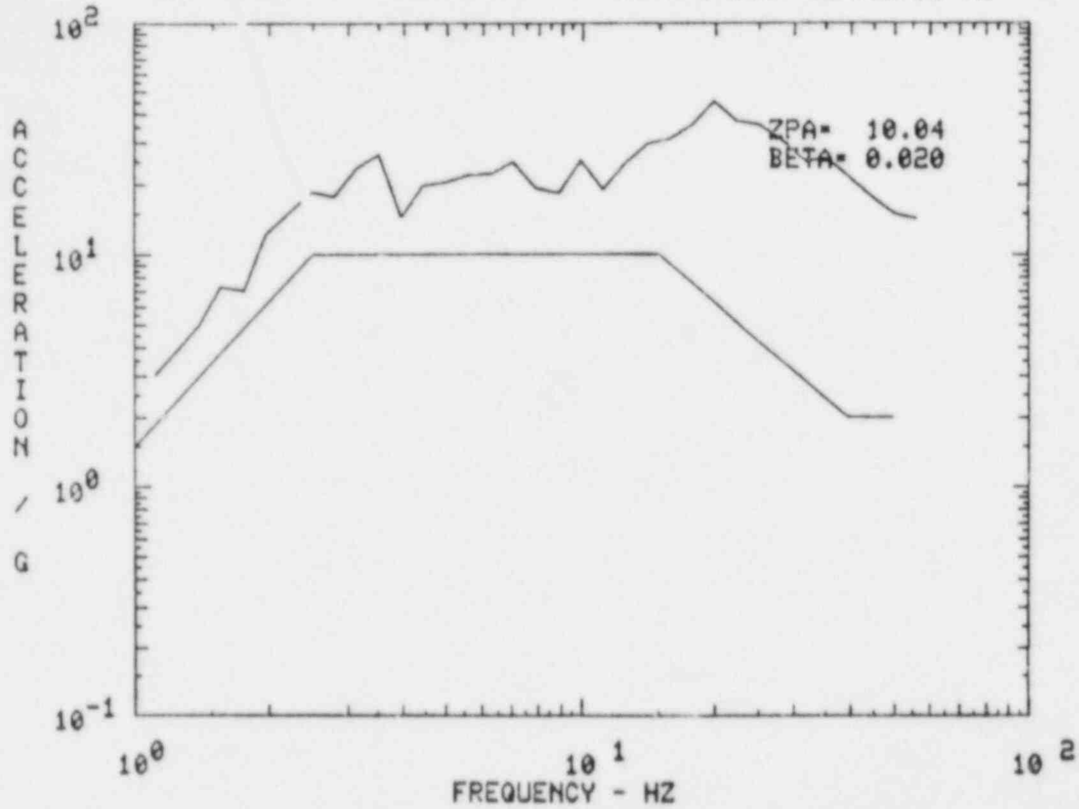


Figure 10.143 RUN SSYZA2 Accelerometer Location 8V

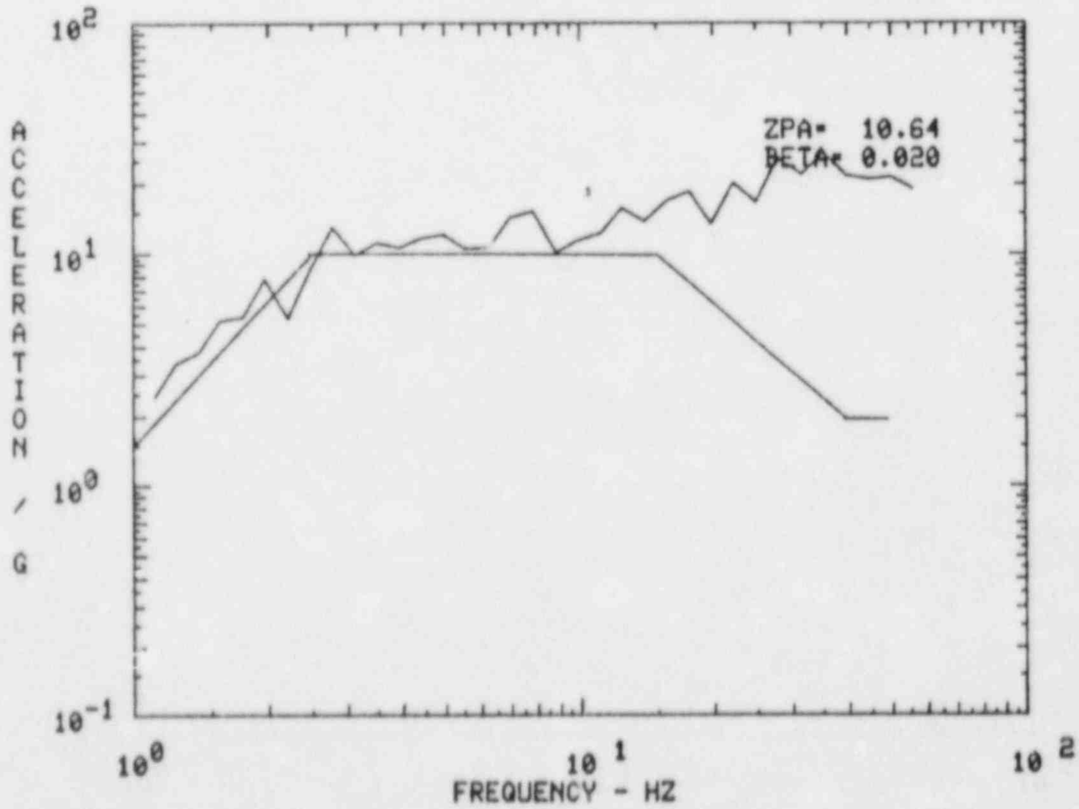


Figure 10.144 RUN SSYZA2 Accelerometer Location 9H

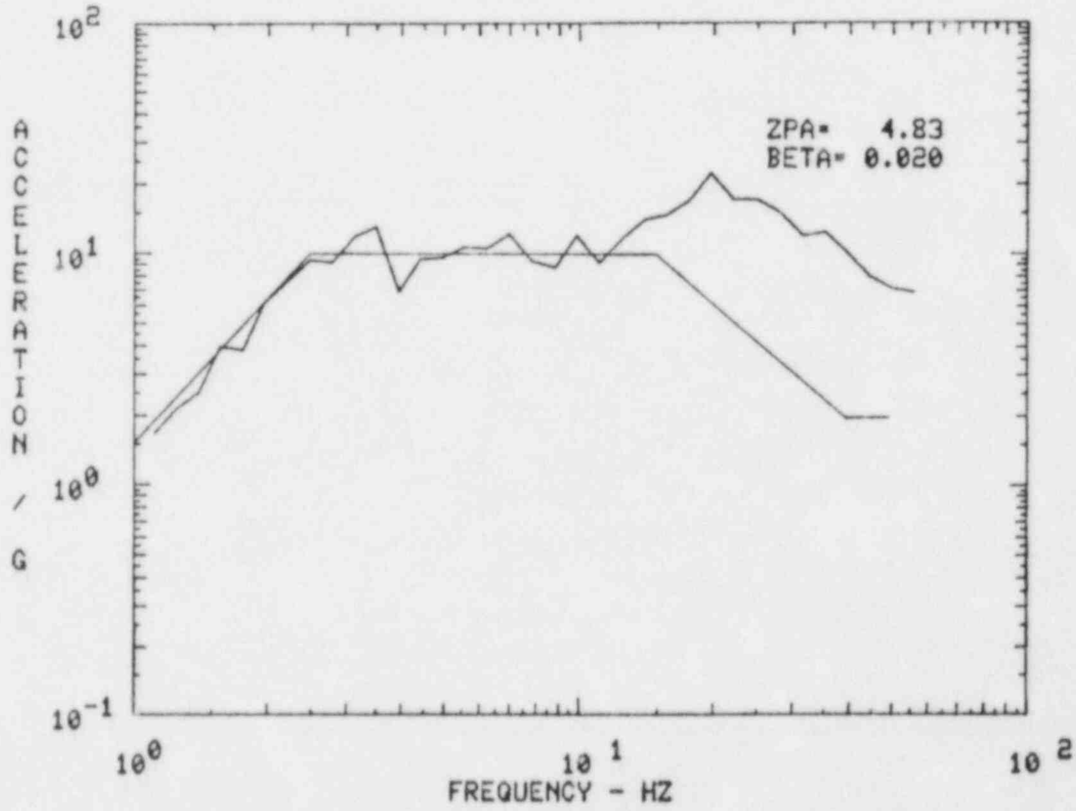


Figure 10.145 RUN SSYZB1 Accelerometer Location 1H

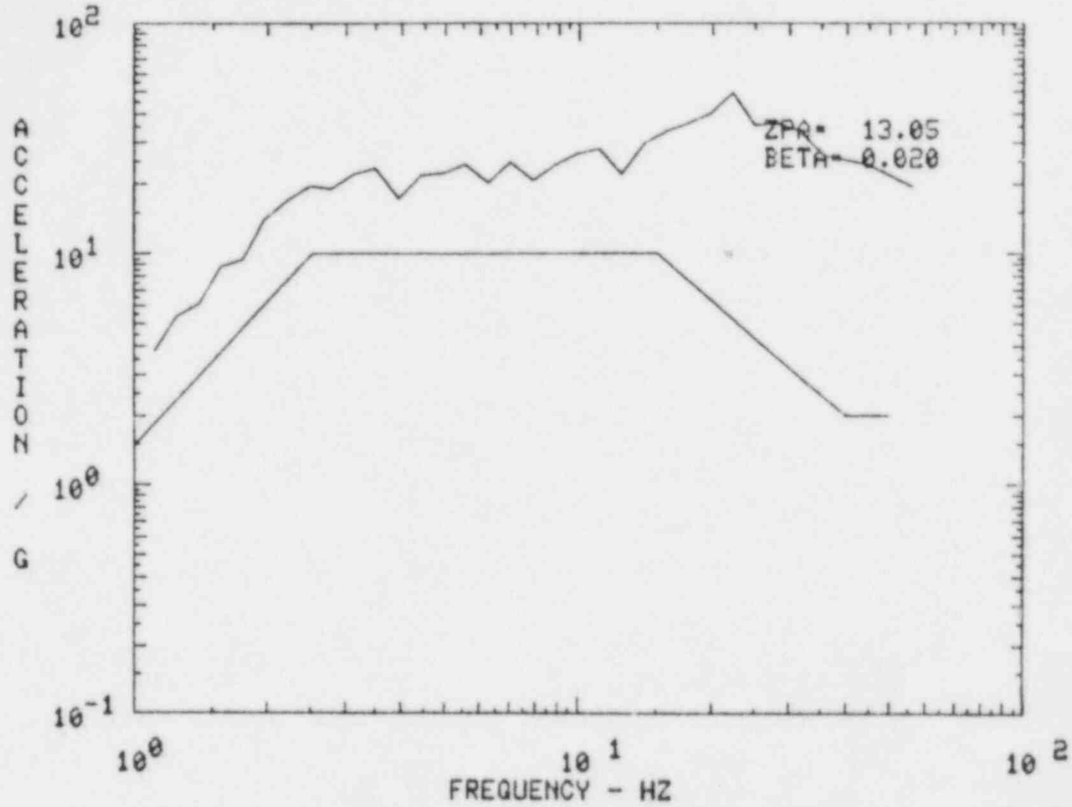


Figure 10.146 RUN SSYZB1 Accelerometer Location 2V

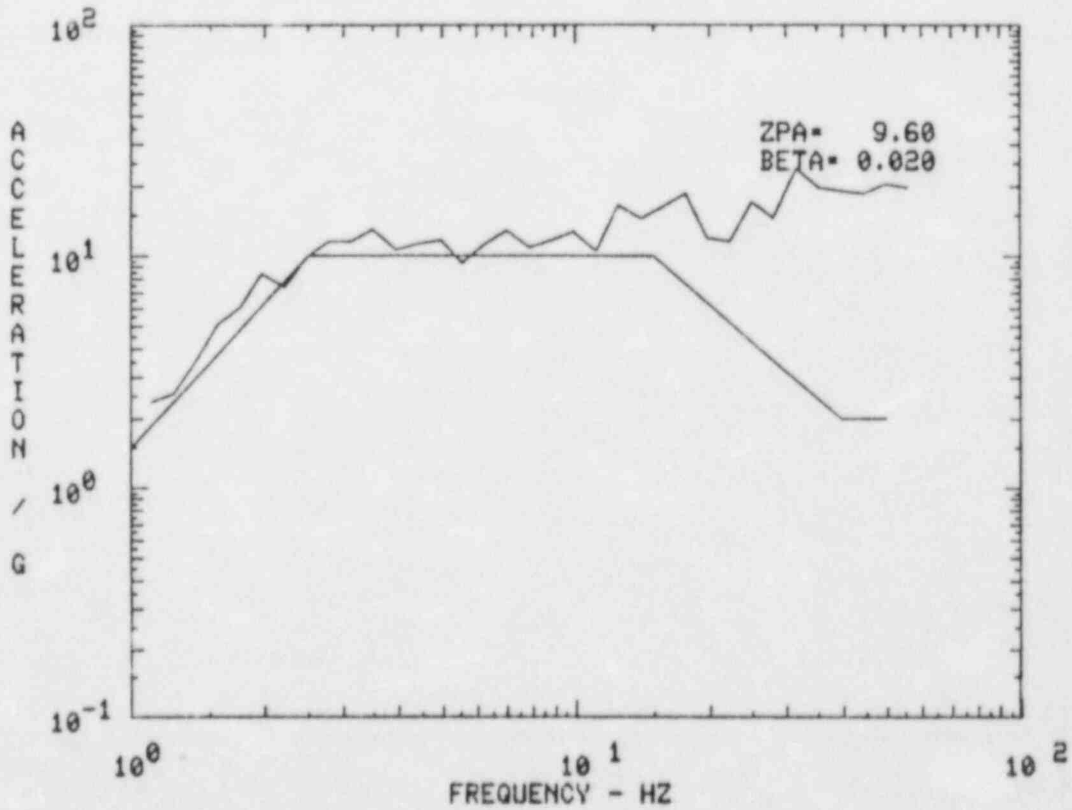


Figure 10.147 RUN SSYZB1 Accelerometer Location 3H

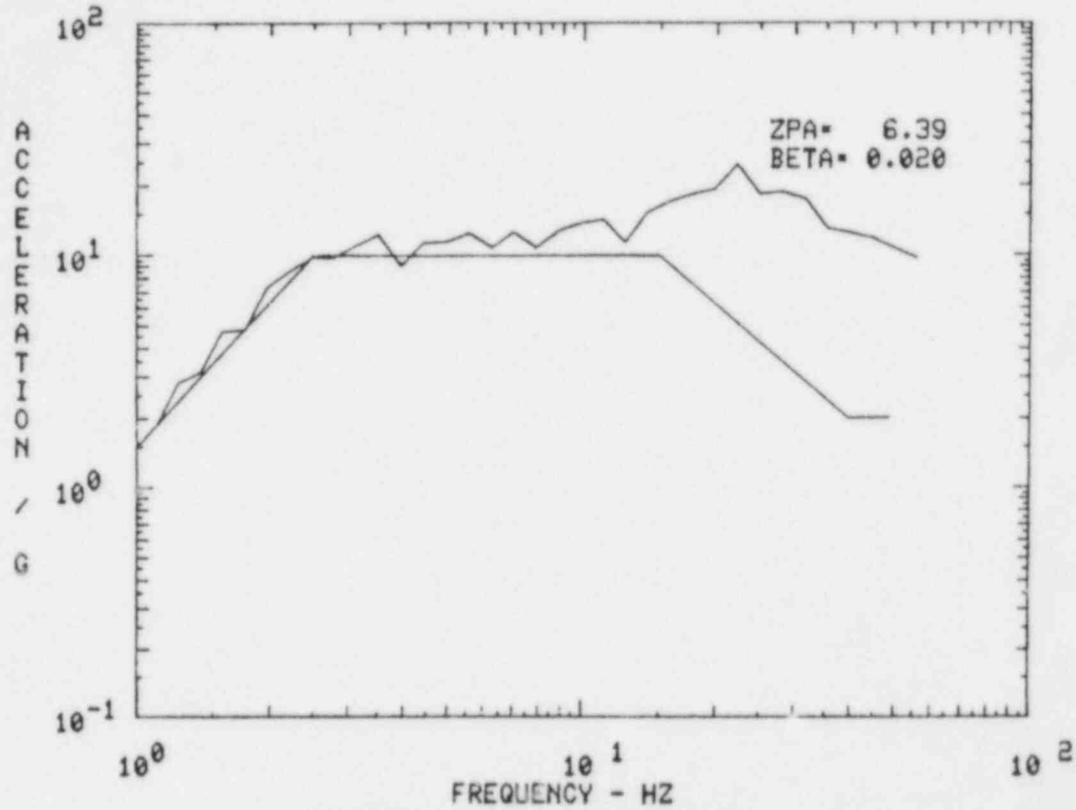


Figure 10.148 RUN SSYZB1 Accelerometer Location 4V

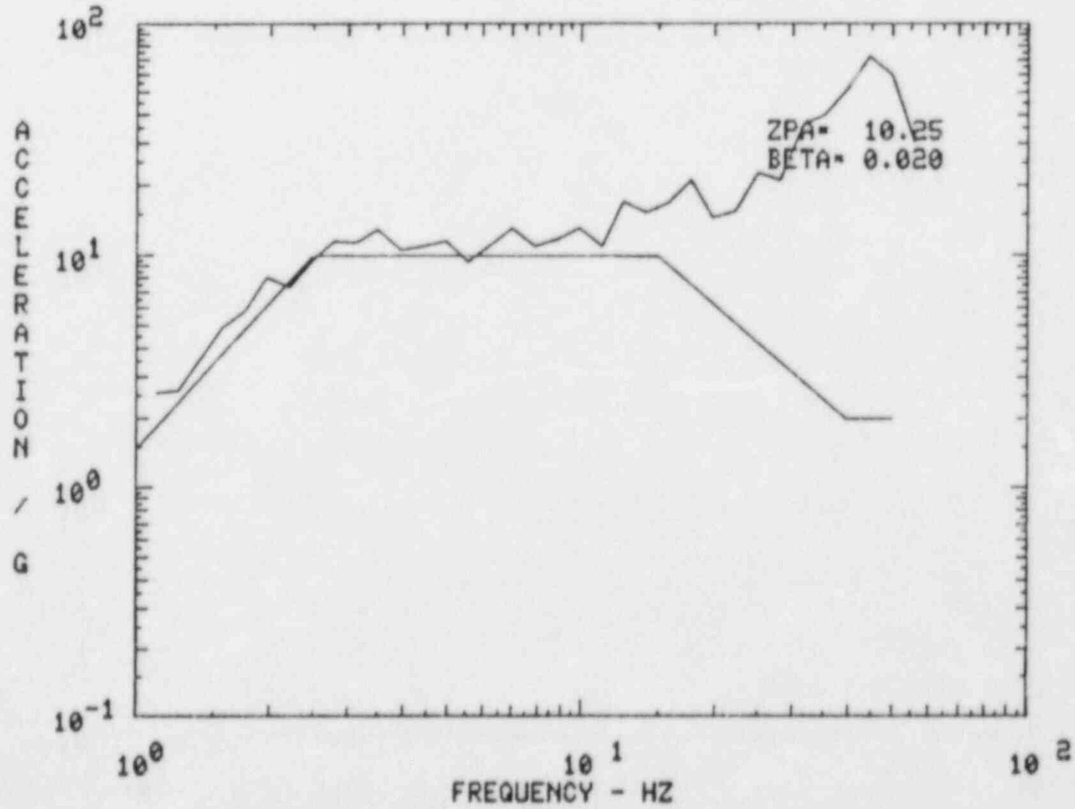


Figure 10.149 RUN SSYZB2 Accelerometer Location 5H

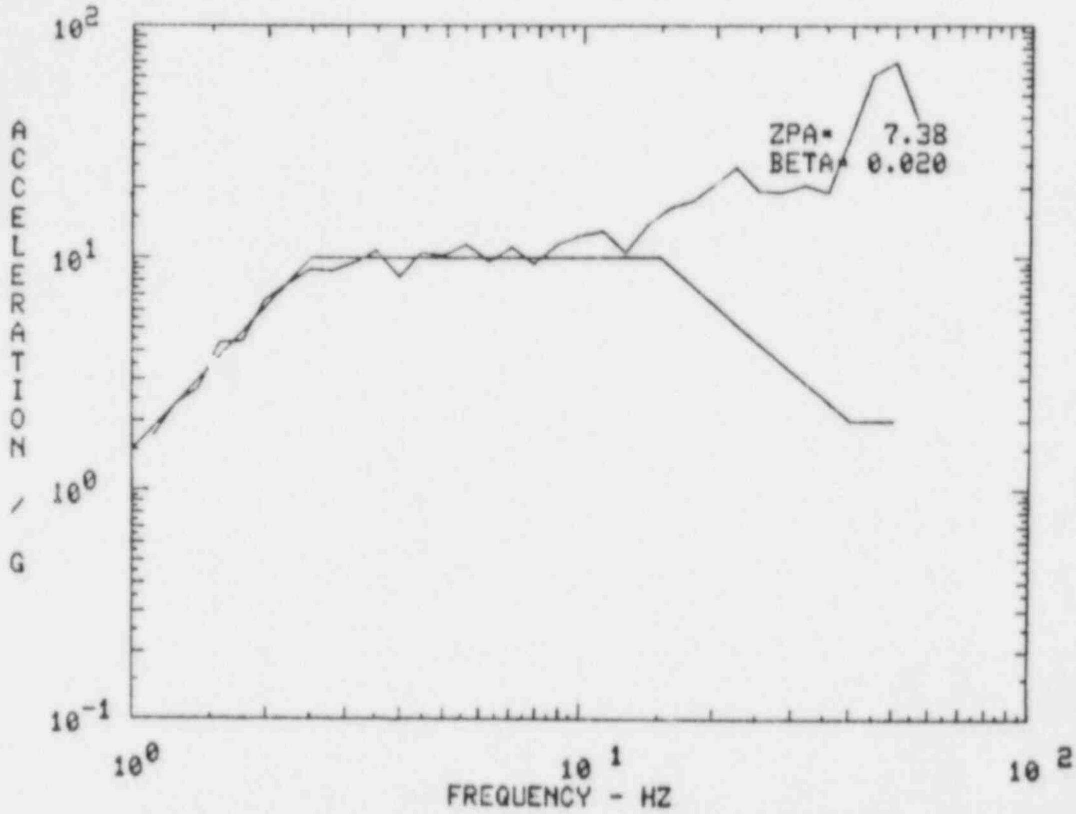


Figure 10.150 RUN SSYZB2 Accelerometer Location 6V

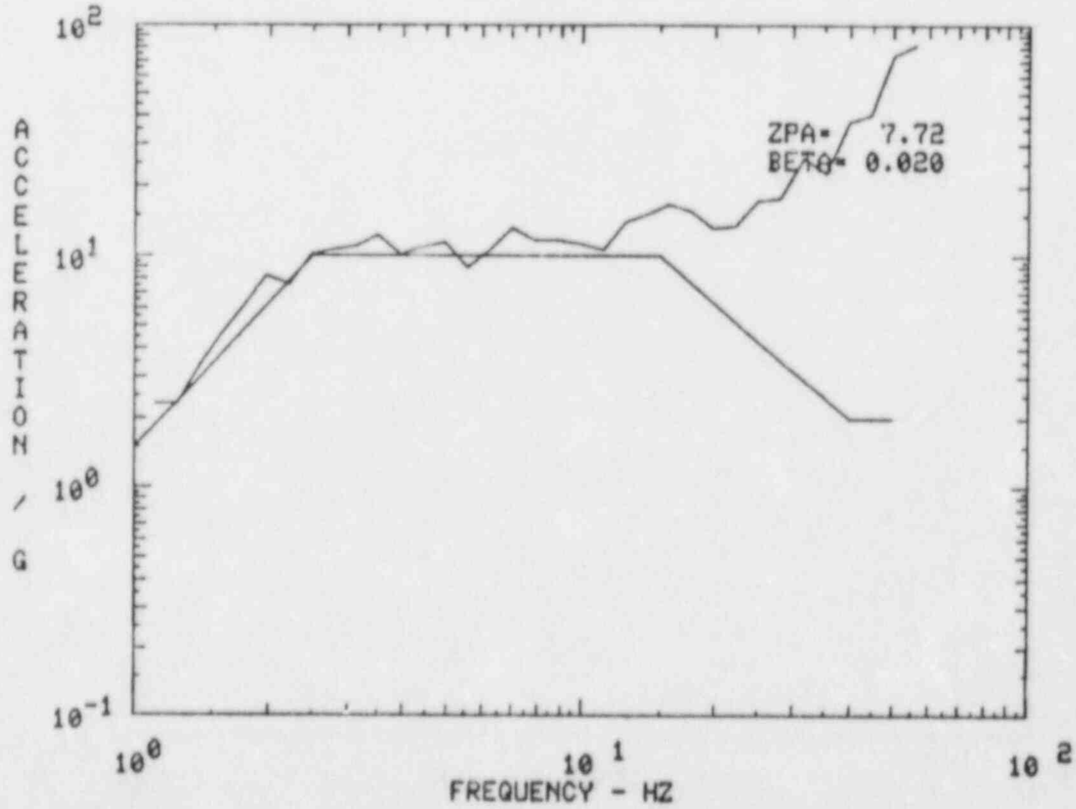


Figure 10.151 RUN SSYZB2 Accelerometer Location 7H

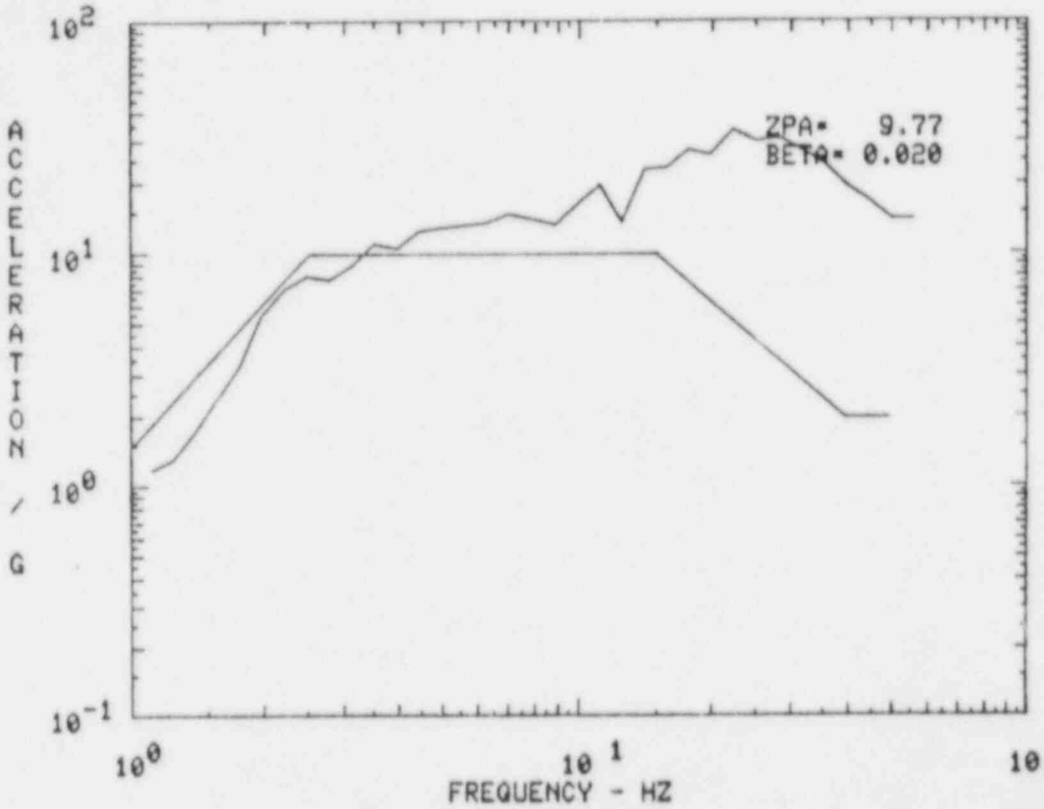


Figure 10.152 RUN SSYZB2 Accelerometer Location 8V

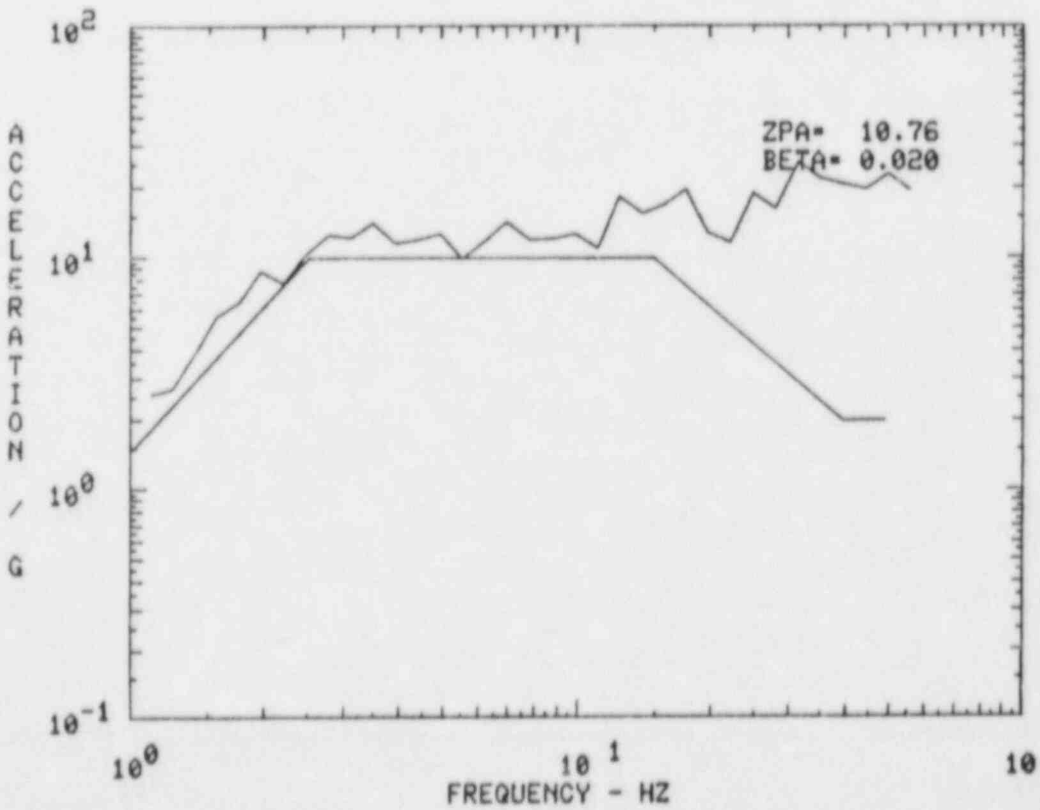


Figure 10.153 RUN SSYZB2 Accelerometer Location 9H

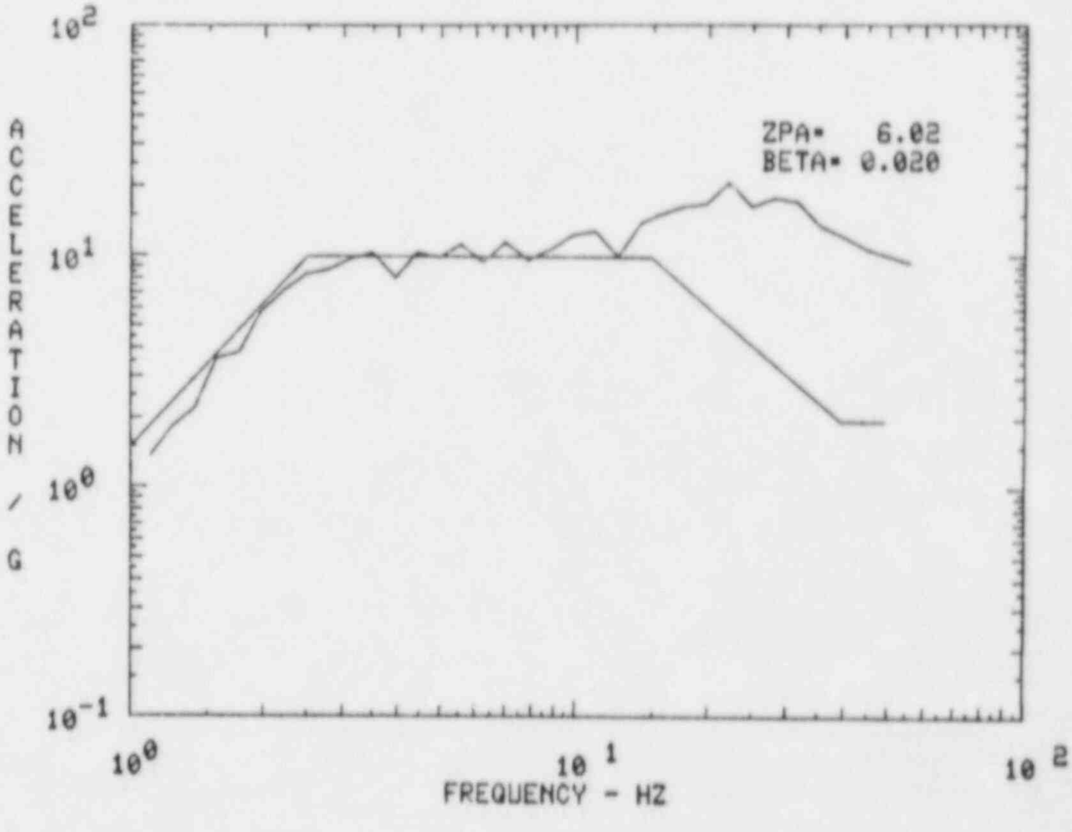


Figure 10.154 RUN SSXZ1 Accelerometer Location 1H

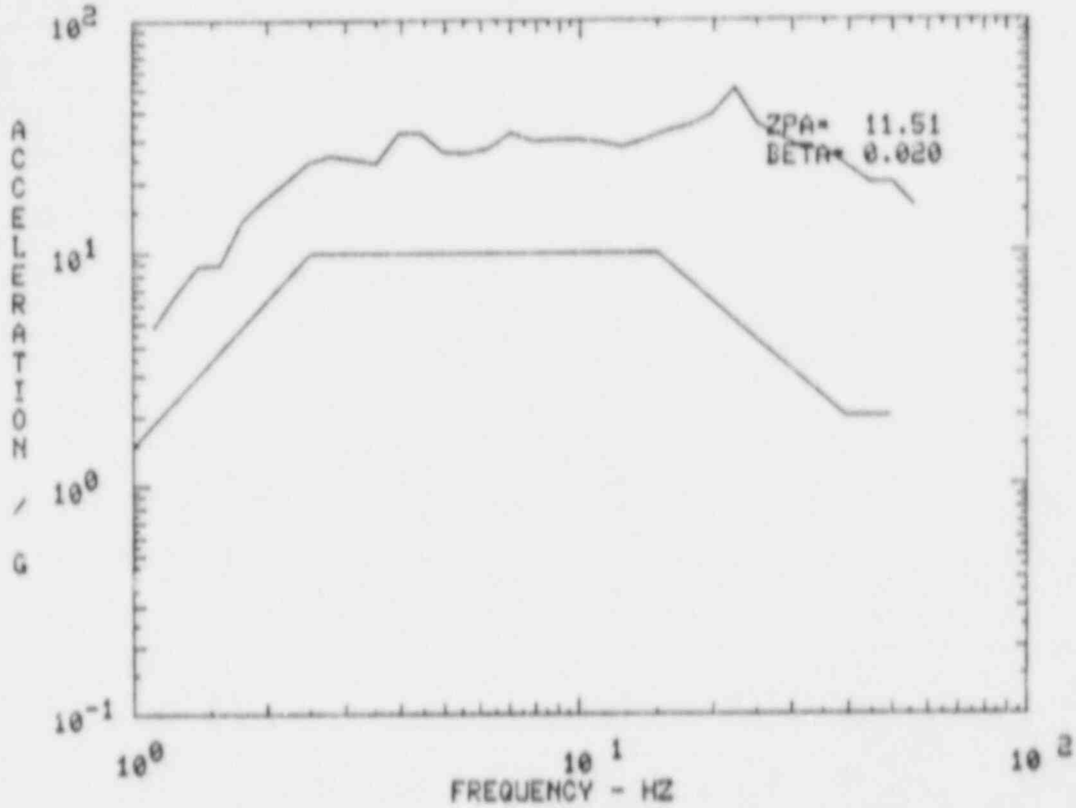


Figure 10.155 RUN SSXZ1 Accelerometer Location 2V

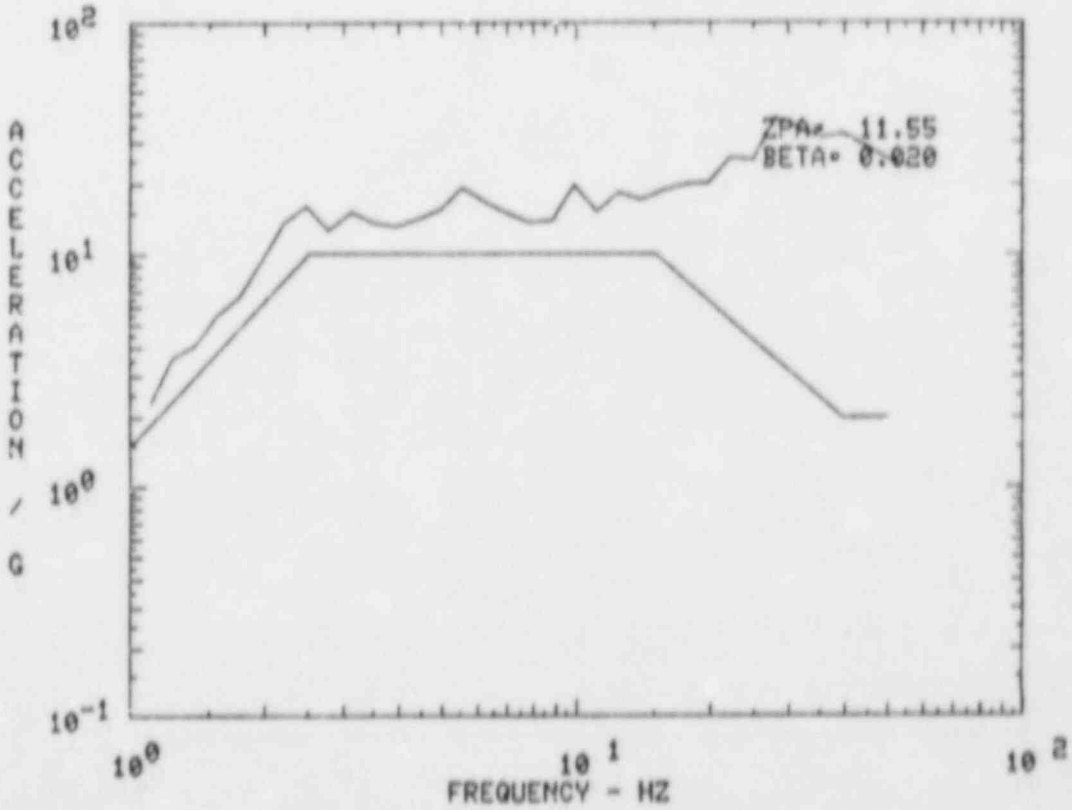


Figure 10.156 RUN SSXZ1 Accelerometer Location 3H

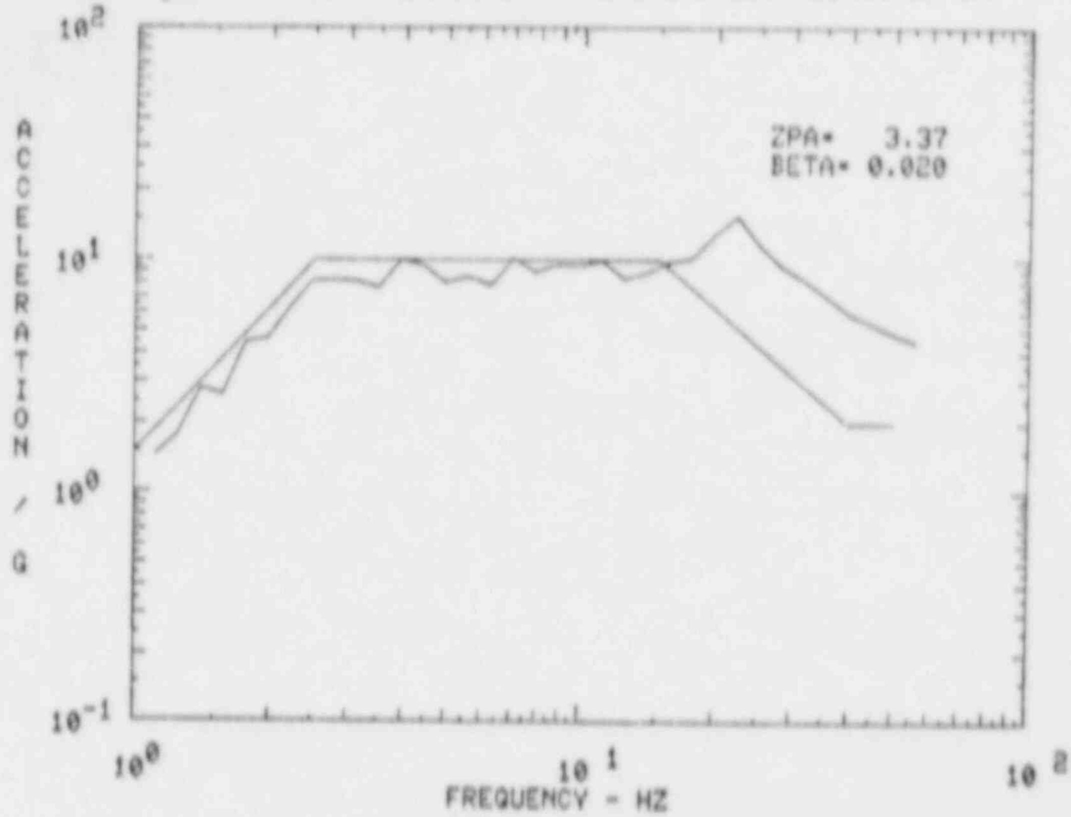


Figure 10.157 RUN SSXZ1 Accelerometer Location 4V

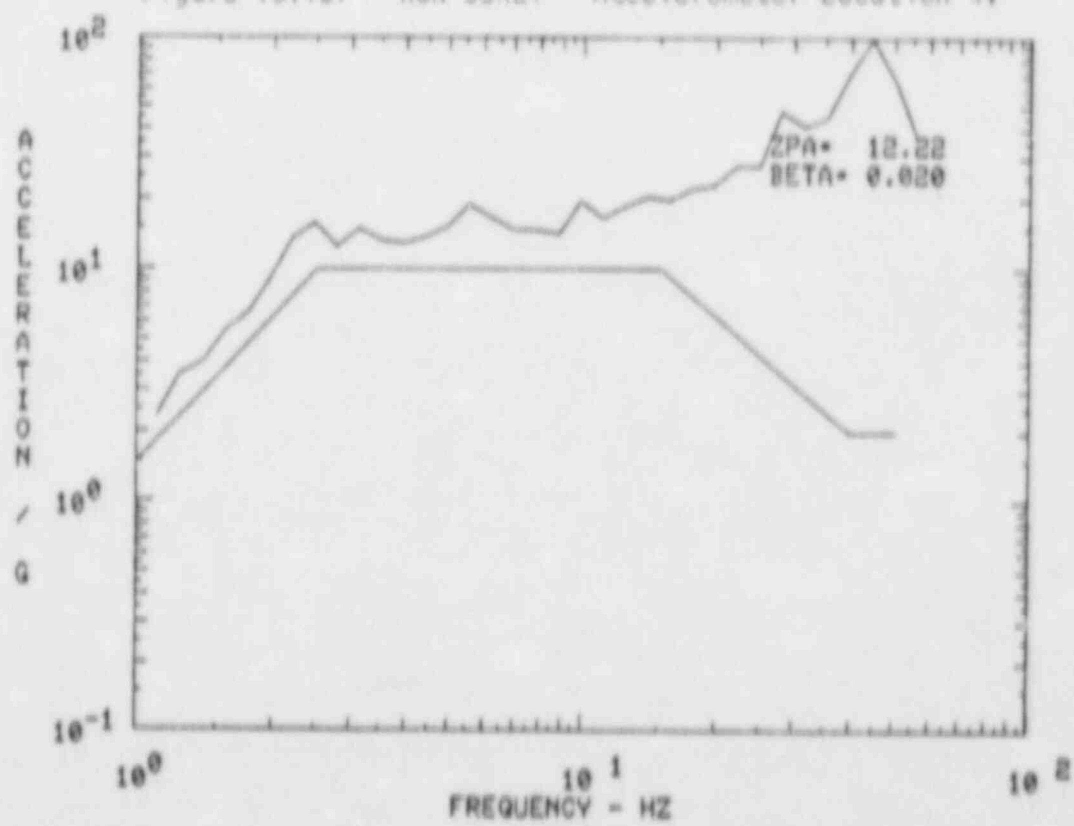


Figure 10.158 RUN SSXZ1 Accelerometer Location 5H

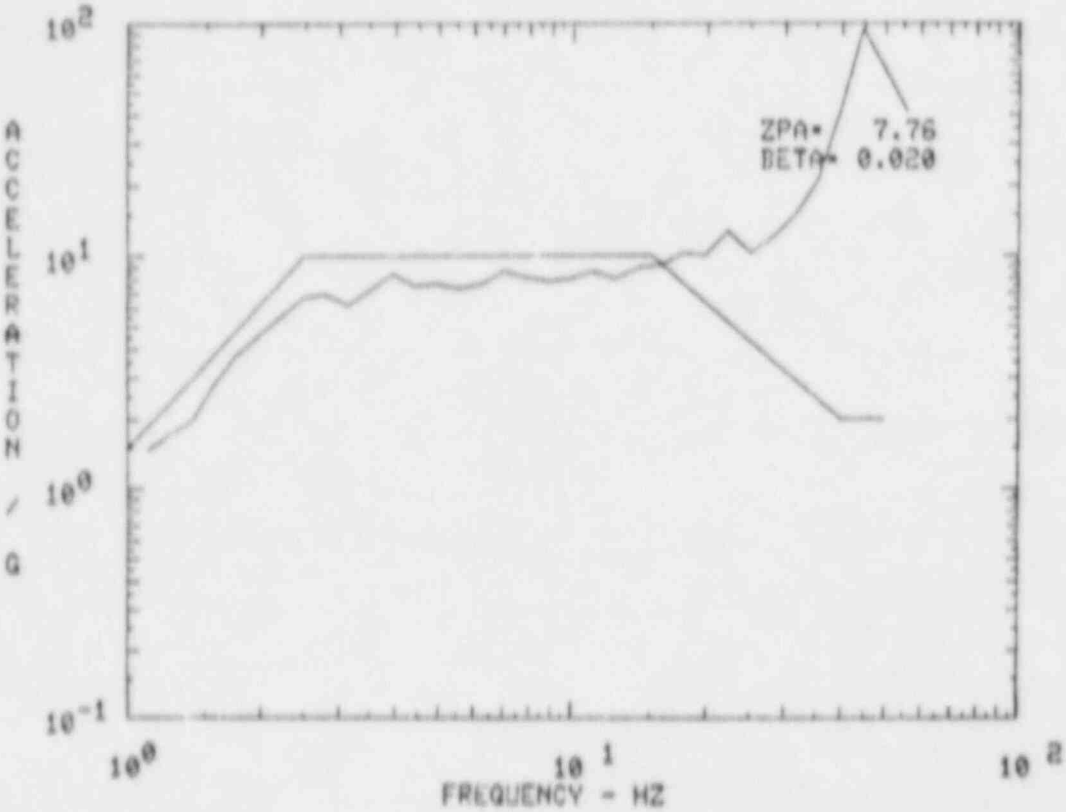


Figure 10.159 RUN SSXZ1 Accelerometer Location 6V

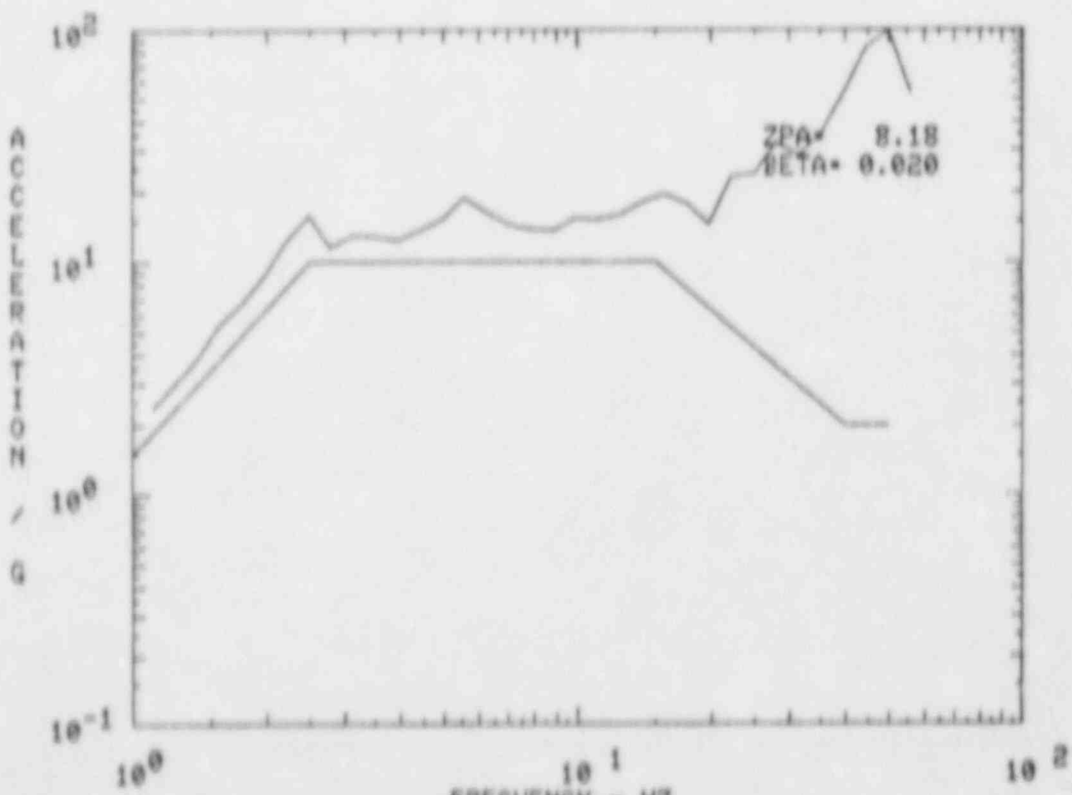


Figure 10.160 RUN SSXZ1 Accelerometer Location 7H

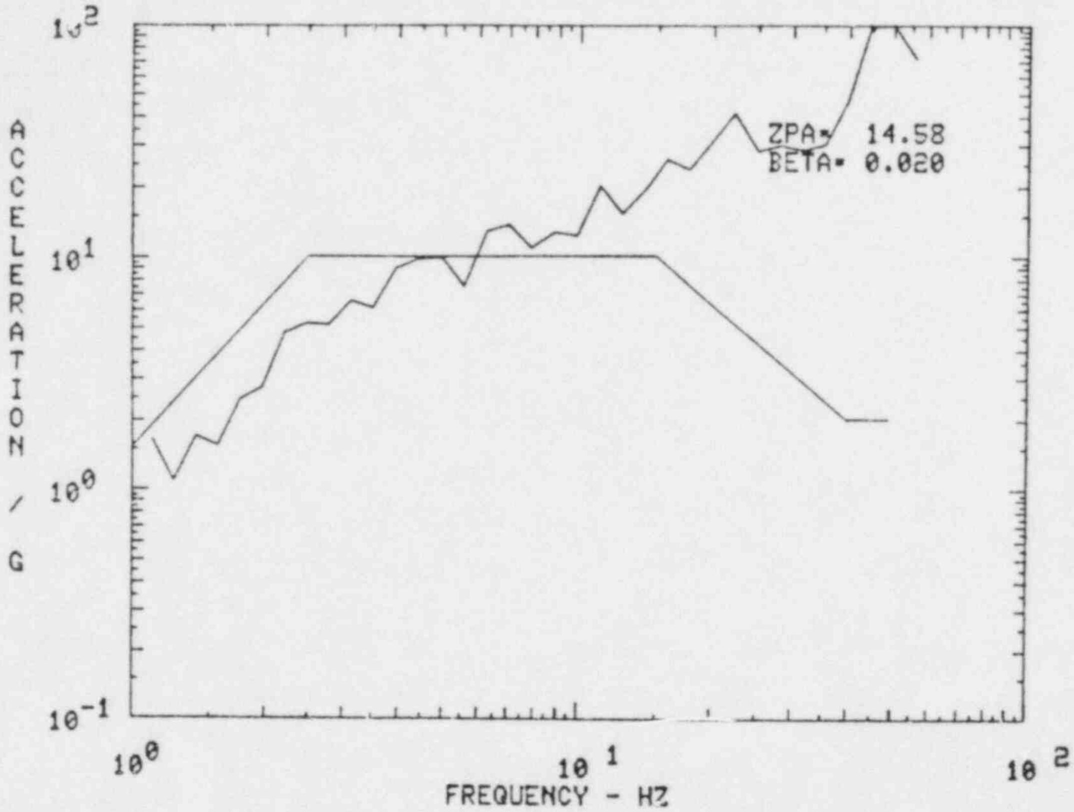


Figure 10.161 RUN SSXZ1 Accelerometer Location 8V

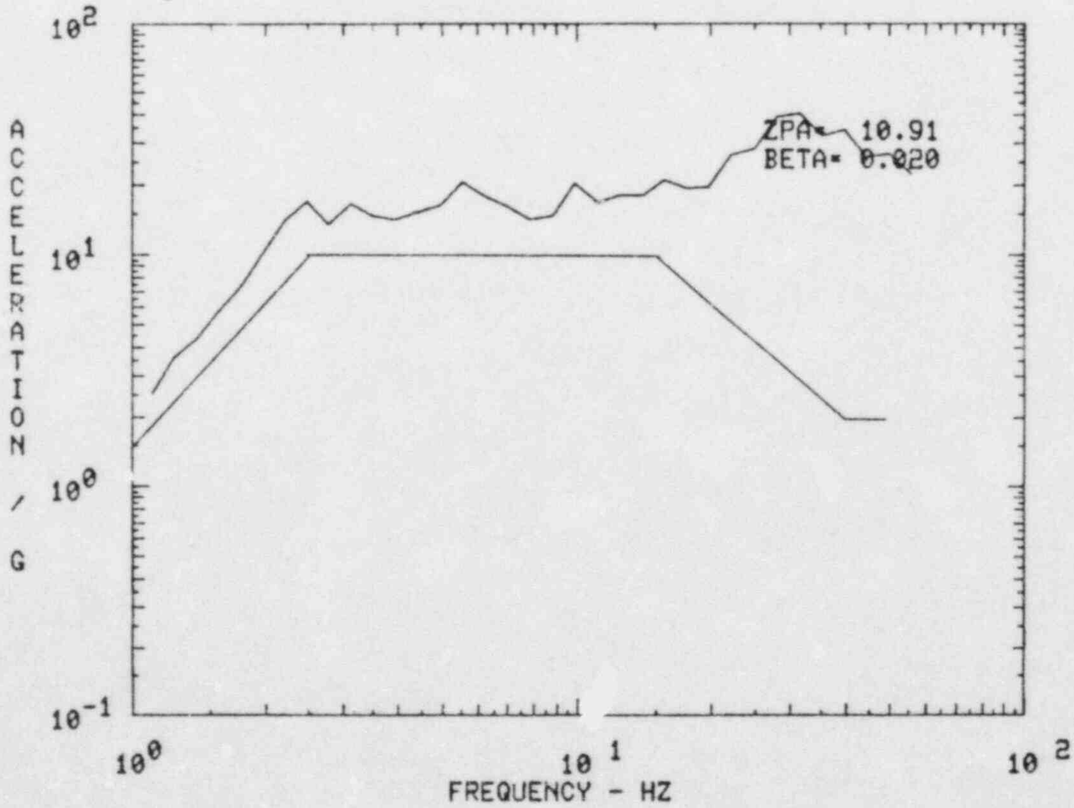
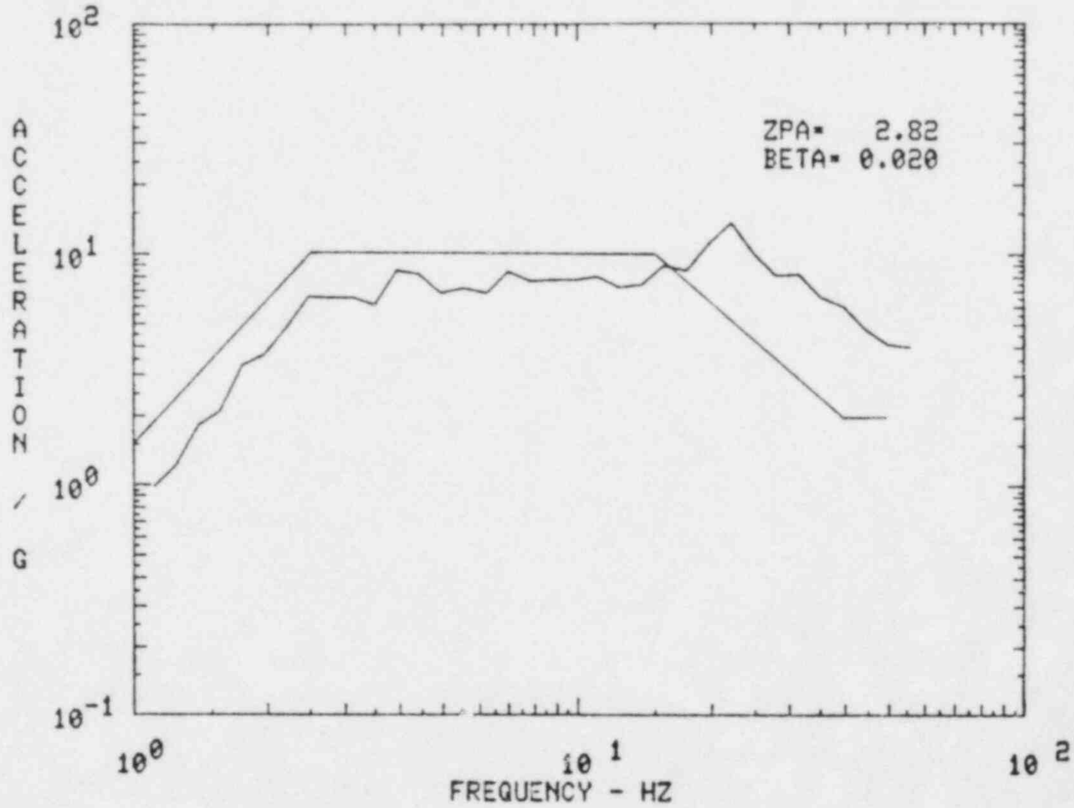


Figure 10.162 RUN SSXZ1 Accelerometer Location 9H



SECTION 11.0

SwRI LABORATORY DATA LOGS

SOUTHWEST RESEARCH INSTITUTE

LABORATORY DATA LOG

TEST ITEM IDENT. SANDIA (10 Pressure switches) PAGE 1 OF 4

TEST PROCEDURE REF. FIN A1355 Rev. 4

TEST NAME Unaged DBE TEST, SEISMIC PROJECT NO. 02-7279-001

DATE	TIME	OBSERVATIONS
9-27-82	11:00	Calibrate the following Accelerometers to 1gp/1gpk as per XII-EE-101-3 using Kistler 808K/5651T as standard.
		Eastman Accelerometers with Amp. card, Accells model EAC-50CDS-2C SwRI I.D. # 93, 94, # 96, # 97, # 25, # 95, # 26, # 28. Also the following Piezo electric accelerometers were called as above in pairs (Amp + Accel.) # 41 & # 11, # 43 & # 18.
		The accelerometers are numbered as follows for test:
		1) 93 6) 95
		2) 94 7) 26
		3) 96 8) 28
		4) 97 9) 41 & 11
		5) 25 10) 43 & 18
9-28-82	8:45	Put 1gpk @ 10Hz calibration signal on all 12 channels of Ampex FR1300A through 49.9kΩ series in line resistors on all channels with tape speed at 3¾ ips. Calibration signal is from 72-98 on tape.
	9:05	Place Accelerometers on Pressure Switches as follows:
		1) Horizontal response on Barksdale B2T-M12SS (Item #1)
		2) Vertical response on Barksdale B2T-M12SS
		3) Horizontal on Spring 12N-AA4X-X3 s/n# 82-5-1537 #1
		4) Vertical on Barksdale D2H-A150SS #1
		5) Horizontal on Barksdale D2H-A150SS #1
		6) Vertical Response on Barksdale D2H-150SS (Item #2)
		7) Horizontal Response on Barksdale D2H-150SS (Item #2)
		8) Vertical Response on Barksdale B2T-M12SS (Item #2)
		9) Horizontal Response on Barksdale B2T-M12SS (Item #2)

Tests Conducted By: S. K. Wilson, [signature] Witness SwRI Govt

SOUTHWEST RESEARCH INSTITUTE

LABORATORY DATA LOG

TEST ITEM IDENT. SANDIA (10 Pressure switches) PAGE 2 OF 4

TEST PROCEDURE REF. FIN A1355 REV. 4

TEST NAME SEISMIC (UNAGED ITEMS) PROJECT NO. 02-7279-001

DATE	TIME	OBSERVATIONS
9-28-82		10) Horizontal Response on SOR inc. 12N-AA4X-X3 sn# 82-5-1635
		Set-up tape recorder with channel inputs as follows:
		Channel # Information
		1 Horizontal Table Accelerometer
		2 Vertical Table Accelerometer
		3 Response Accel # 1, Horizontal on Barksdale BZT-M12SS
		4 Response Accel # 2, Vertical on Barksdale BZT-M12SS
	Response Item # 1	5 Response Accel # 3, Horz. on SOR inc. 12N-AA4X-X3 sn# 82-5-1637
		6 Response Accel #4, Vertical on Barksdale D2H-A150SS
		7 Response Accel #5, Horizontal on Barksdale D2H-A150SS
		8 Response Accel #6, Vertical on Barksdale D2H-150SS
	Response on Item # 2	9 Response Accel #7, Horz. on Barksdale D2H-150SS
		10 Response Accel #8, Vertical on Barksdale BZT-M12SS
		11 Response Accel #9, Horizontal on Barksdale BZT-M12SS
		12 Response Accel #10, Horz. on SOR inc. 12N-AA4X-X3 sn# 82-5-1635
	12:20	The following Equipment was used to perform these tests:
		#4, 10, 11, 18, 25, 26, 29, 41, 43, 57, 65 in cal, 66 in cal, 67
		in cal, 68 in cal, #77, 78, 79, 80 in cal, #83 in cal, 87 in cal,
		#93, 94, 95, 96, 97, 105, 128, 129. Also used were:
		SwRI Amplifier card Power supply (no serial #)
		Hard Copy Tektronix 4611
		Terminal Tektronix 4051
		The locations of the Pressure switches along with type
		& model are shown on Page 1A along with Accel. locations.
		A Baseline functional check was performed on the
		test items by SANDIA personnel prior to the start
		of seismic tests.

Tests Conducted By: S.K. Nelson Witness SwRI Goals

[signature]

SOUTHWEST RESEARCH INSTITUTE

LABORATORY DATA LOG

TEST ITEM IDENT. SANDIA (10 Pressure Switches) PAGE 3 OF 4

TEST PROCEDURE REF. FIN A1355 Rev. 4

TEST NAME SEISMIC (UNAGED ITEMS) PROJECT NO. 02-7279-001

DATE	TIME	OBSERVATIONS
9-28-82	12:48	OBE X-Z No. 1 (change amps. for Accels. 9 & 10 were
		TAPE 98-123 not on; All other channels O.K.)
		OBE X-Z No. 2
	1305	TAPE 123-151
	1317	OBE X-Z No. 3
		TAPE 151-177
	1328	OBE X-Z No. 4
		TAPE 177-203
	1342	OBE X-Z No. 5
		tape 203-228
	13:50	Rotate test items 90° counterclockwise for Y-Z OBE Tests.
		Also RE-orient accelerometers. All Accelerometers on
		same test items as before. Changed mount to round
		plates in the middle of test item with one bolt.
		(SEE sheet 1B for 90° ROTATION).
	1440	OBE Y-Z No. 1
		TAPE 228-254
	1451	OBE Y-Z No. 2
		TAPE 254-278

Tests Conducted By: S. K. Wilson Witness [illegible]

[illegible signature]

SOUTHWEST RESEARCH INSTITUTE

LABORATORY DATA LOG

TEST ITEM IDENT. SANDIA (10 Pressure switches) PAGE 4 OF 4

TEST PROCEDURE REF. FIN A1355 Rev. 4

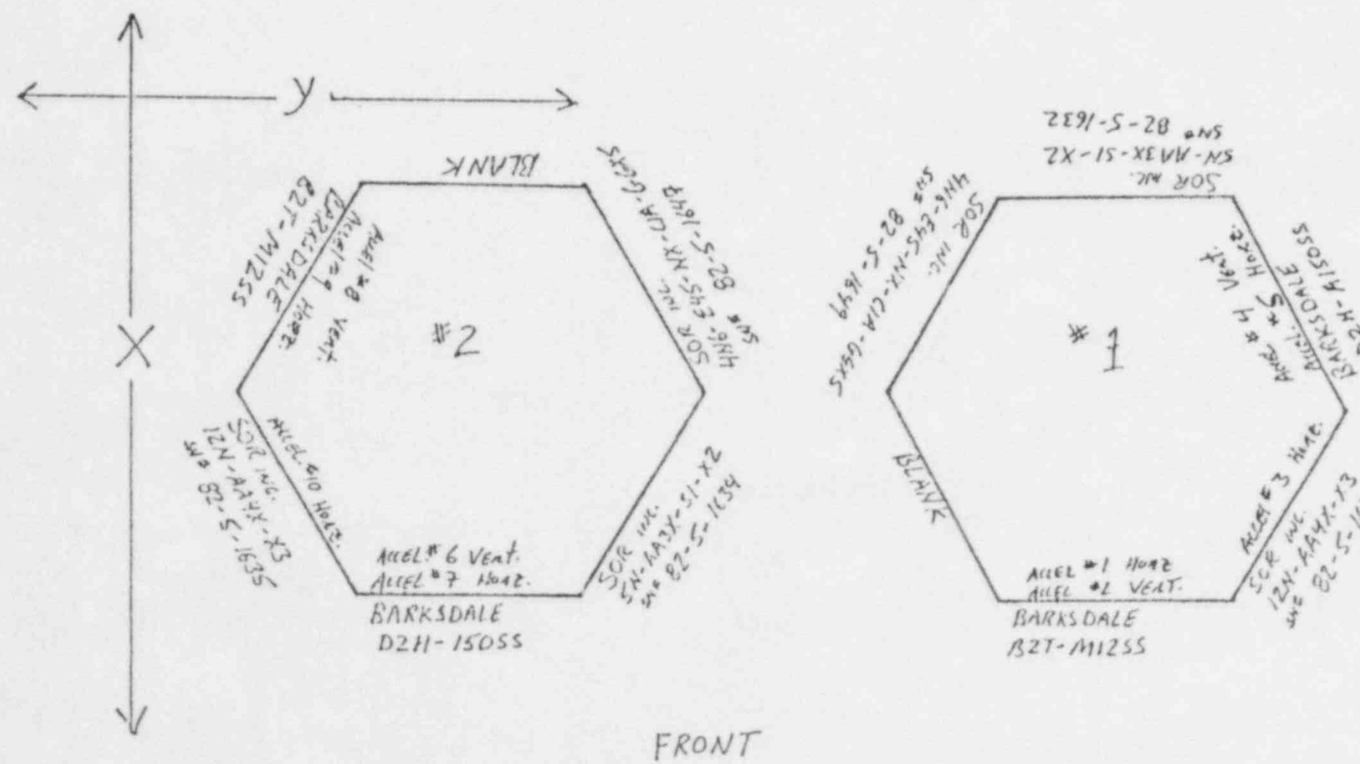
TEST NAME Seismic (Unaged Items) PROJECT NO. 02-2279-001

DATE	TIME	OBSERVATIONS
9-26-82	1503	OBE Y-Z No. 3 Tape 278-306
	1515	OBE Y-Z No. 4 Tape 306-333
	1528	OBE Y-Z No. 5 Tape 333-358
9-29-82	8:30	SANDIA Personnel perform functional check on all Pressure switches, All functioned properly.
	1021	SSE Y-Z No. 1 Tape 358-385
	1040	SSE Y-Z No. 1A tape 385-413
	1100	SSE Y-Z No. 1B Tape 413-439
	11:13	Turn test items 90° and reorient accelerometers.
	1128	SSE X-Z No. 1 Tape 439-465
	12:35	SANDIA Personnel performed functional checks at the Completion of seismic tests.

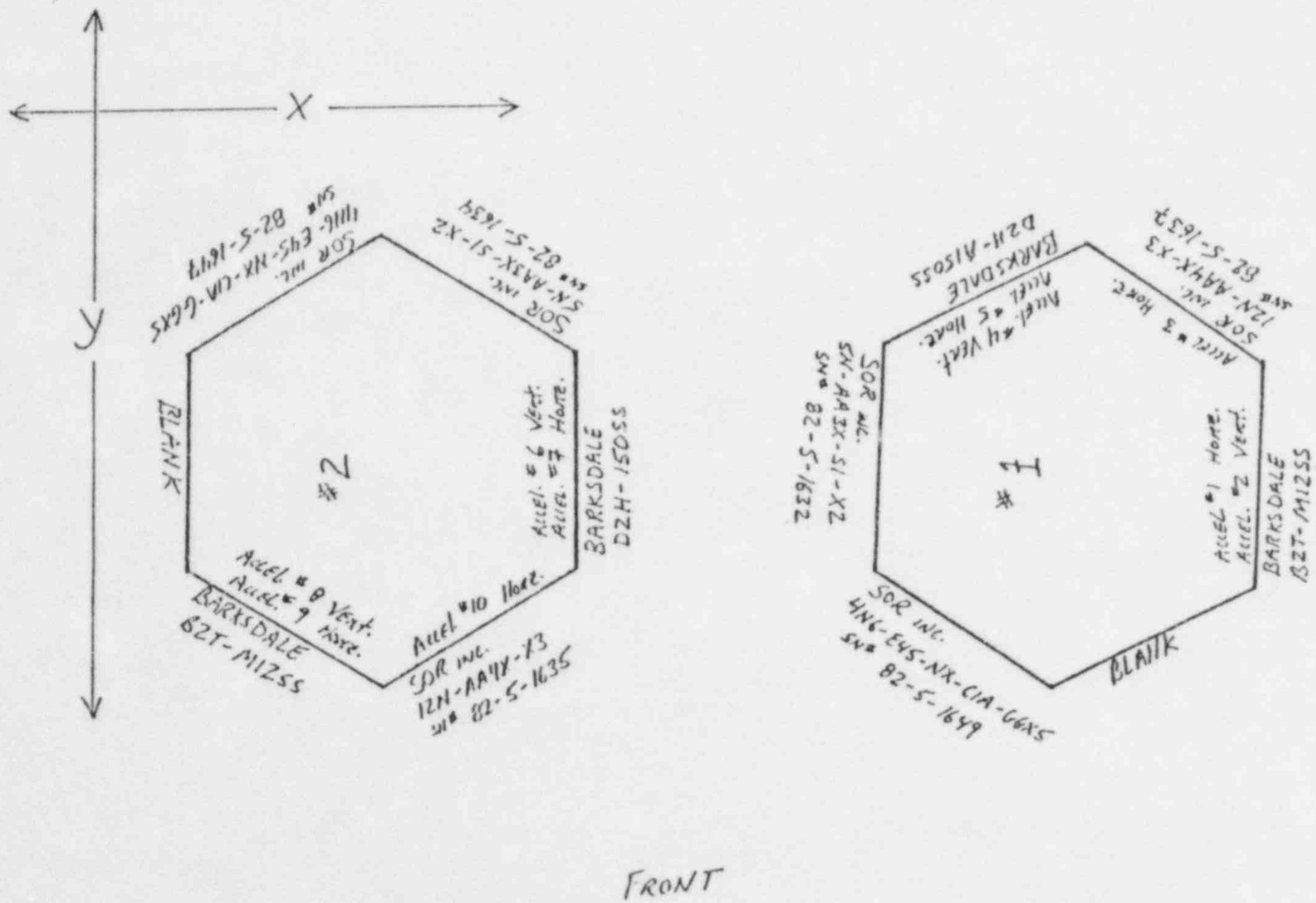
Tests Conducted By: [signature] Witness SwRI Cust.

Sheet 1A

ORIENTATION OF TEST ITEMS FOR SEISMIC TESTING 02-7279-001
AND ACCELEROMETER LOCATIONS FOR X-Z AXIS.



Sheet 1B ORIENTATION OF TEST ITEMS FOR SEISMIC TESTING 02-7279-001
AND ACCELEROMETER LOCATIONS FOR Y-Z AXIS.



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13. SUPPLEMENTARY NOTES

14. ABSTRACT (200 words or less)

Pressure switches, two each of five different models from two manufacturers, were tested in baseline evaluation tests typical of IEEE-323 (1974) suggested profiles as part of the NRC-sponsored Equipment Qualification Methodology Research Test Program (A-1355). The tests incorporated generic seismic and loss-of-coolant accident (LOCA) environments to assess the functional capabilities of unaged equipment. During the baseline evaluation tests, the seismic environment did not affect the functionality of the pressure switches, but the LOCA environment caused numerous functional failures and extensive physical damage in four of five models tested. As a result, eight other switches of the same make and model as those used in the baseline evaluation tests were tested in a follow-up test. In the follow-up test (a discrete-step pressure ramp LOCA environment) erratic functional behavior or complete failure was observed in all the equipment early in the test.

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