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Environmental

Equipment Qualification
Test Report
Westinghouse LMD Motor Insulation
(Environmental Testing)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont)

1.0 OBJECTIVE

The objective of this qualification program is to demonstrate that the insulation system used on the Life Line D motors built by Westinghouse LMD and used on Westinghouse NSSS supplied auxiliary pumps meets or exceeds it's safety-related performance requirements while subjected to the normal, and simulated abnormal environmental and seismic service conditions specified in Section 3.

The motor insulation system is the critical component necessary for motor performance. Hence, verification of the motor's qualified life is obtained by insulation system testing.

2.0 EQUIPMENT TESTED

The equipment tested was a 450HP motor stator manufactured by Westinghouse LMD, Buffalo, N.Y. [

].a,c

3.0 PERFORMANCE SPECIFICATIONS

3.1 MOTOR PERFORMANCE REQUIREMENTS

1. During normal plant operation, the motors must function intermittently and continuously while exposed to the environments of Figure 1 (Condition 2 - Ventilation Normal).

2. During loss of ventilation the motors must function for 12 hours at the extreme temperature and humidity conditions of Figure 1(Condition 3 - Loss of Ventilation or non Class 1E Air Conditioning).

3. Pump motors used for post-accident recirculation must function during and after being exposed to a normal and post-accident radiation dose of 4.3×10^7 Rads.

4. The motors must function during and after the design basis earthquake (DBE) of 2.1gs in three directions.

3.2 INSULATION SYSTEM TESTS REQUIREMENTS

These insulation system tests are to show that the motor meets the performance requirements listed above.

1. The insulation resistance must be greater than 5.0 megohms after thermal aging to an equivalent life greater than 3.8 years.

2. The insulation system must not short to ground during a high potential test after being exposed to 100% relative humidity for 48 hours.

3. The insulation resistance must be greater than 5.0 megohms after radiation testing to 5.0×10^7 Rads.

4. The insulation system must maintain its structural integrity after the following seismic tests. The stator is tested using an umbrella seismic response spectrum (Figure 2) with a peak acceleration of approximately 4.75gs for all safe shutdown earthquake (SSE) tests. The peak acceleration for the operating basis earthquake (OBE) test is approximately 2.9gs as shown in Figure 3. The required response spectrum (RRS) along the control accelerometer axis is increased by $\sqrt{2}$ to account for the orientation of the stator at a 45 degree angle to the test table. Ten percent margin is also added to the RRS.

4.0 DESCRIPTION OF THE TEST FACILITY AND EQUIPMENT

4.1 TEST FACILITY

All environmental and seismic tests were performed at Westinghouse Advanced Energy Systems Division (AESD) in Large, Pa. with the exception of radiation aging. The radiation aging was performed at the Isomedix Inc. plant at Parsippany, N.J.

4.2 TEST EQUIPMENT

A list of all test equipment used during testing appears in Table 1.

4.3 MOUNTING

4.3.1 THERMAL AGING

Thermal aging was performed in a high temperature chamber. The stator was placed on four pipe sections to raise it from the lower heaters. The heaters were attached to the floor and walls of the inner chamber, and insulation was placed between the inner and outer chamber walls. An insulated lid was then added. Figure 4 shows the chamber. Figure 5 shows the stator as it was mounted in the chamber.

4.3.2 RADIATION AGING

Radiation aging was performed in the irradiator at Isomedix using a Cobalt-60 source.

4.3.3 VIBRATION AGING

Vibration aging was performed on the 6' x 6' biaxial test machine at AESD. The stator was mounted to the test table using four 3/4" - 10 bolts. The stator was mounted such that the motion of the test table was at right angles to the plane of the coils, as shown in Figure 6.

4.3.4 SEISMIC TEST

Seismic testing was performed on the 6' x 6' biaxial test machine at AESD. The stator was mounted at a 45° angle relative to the horizontal table motion. The hydraulic piston driving the table was at a 35° angle to the horizontal plane of the table. This orientation produced equal motion in three mutually perpendicular directions. Figure 7 shows a schematic of the test setup. Figures 8, 9, 10 and 11 show the orientation of the stator for test positions 1, 2, 3 and 4 respectively.

4.3.5 HUMIDITY AND HIGH POTENTIAL TESTS

The humidity test was performed in the environmental chamber at AESD. Figure 12 shows the stator sitting on wooden blocks in the environmental chamber. The High Potential Tester is shown in the foreground.

4.4 CONNECTIONS

The HV Megometer was connected to the stator leads during resistance measurements. The High Potential Tester was connected to the stator leads during the High Potential Test.

5.0 TEST PROCEDURES

5.1 ELECTRICAL CHECK

Before testing and after each major test sequence, the resistance of the stator insulation was measured and the ambient temperature was recorded. A 2500 VDC Megger was used to measure the insulation resistance. This measurement was made with the stator leads connected together. The voltage was applied for 10 minutes and resistance measurements were recorded at 15, 30, 45, 60, 90, and 120 seconds and at one minute intervals thereafter to the completion of testing. Although not required for motor qualification, two additional measurements were made. The winding resistance and the resistance of the RTD's was measured.

5.2 THERMAL AGING

The stator was placed in the high temperature chamber and thermally aged for [ ]^{b,c} This is equivalent to a projected qualified life of 3.8 years of motor operation at a motor operating temperature of 130^{o}C. The activation energy of [ ]^{b,c} (Figure 34), used to calculate motor life, was derived from tests performed as required by IEEE-275-1966. Following the aging, the stator was allowed to reach room temperature before the electrical checks of Section 5.1 were performed.

5.3 RADIATION AGING

The stator was exposed to a total accumulated radiation dosage of [ ]^{b,c} gamma radiation using a Cobalt-60 source. The rate of exposure was [ ]^{b,c} The stator was rotated [ ]^{b,c} hours to ensure uniform exposure. Following the radiation exposure, the electrical checks of Section 5.1 were performed.

5.4 VIBRATION AGING

The stator was mounted on the biaxial test machine as described in Section 4.3.3. The input for the vibration aging consisted of a continuous sinusoidal input of 1.5g at 60 Hz as described in IEEE 275-1966, servocontrolled from vertical table accelerometer A3. The duration of the test was one hour. Upon completion, the electrical checks of Section 5.1 were performed.

5.5 SEISMIC TESTING

The stator was mounted as described in Section 4.3.4. Prior to seismic testing, a resonant frequency search was performed, consisting of a continuously sinusoidal input wave form swept in frequency from 1 Hz to 70 Hz to 1 Hz at a sweep rate of one octave per minute. The input acceleration was held above 0.1g, servocontrolled from horizontal table accelerometer A1. The stator was then rotated 45° to test position 1. Nine Kulite piezoresistive accelerometers were used to measure accelerations of the test machine and stator. Figure 8 shows table accelerometers A1 to A3, and Figures 13 and 14 show stator accelerometers A7 to A12. Accelerometers A4 to A6 were mounted on motorettes tested at the same time and described in a separate report.The input for the seismic simulation testing was in the form of a 14-channel FM tape. The signals from the tape were sent through a 14-channel attenuator/summer. A displacement signal was then obtained by twice integrating the summed tape signal. This displacement signal provided the input to the hydraulic controller which resulted in table motion corresponding to the desired acceleration levels. A block diagram of this set-up is shown in Figure 15.

In test position 1, five OBE's were performed and one SSE was performed. An additional SSE was then performed in each of the remaining three test positions. The output from horizontal accelerometer A1 was fed into a shock spectrum analyzer. The result of the analysis was plotted on acceleration versus frequency coordinates. All accelerometer outputs were recorded on strip charts and FM tape. A block diagram of the accelerometer data acquisition equipment is shown in Figure 16. Following the SSE in test position 4, the electrical checks of Section 5.1 were performed.

5.6 HUMIDITY AND HIGH POTENTIAL TEST

The stator was placed in the environmental chamber at AESD and subjected to an environment of [ ]b,c relative humidity at [ ]b,c After [ ]b,c hours and while the stator was still wet from exposure, the insulation resistance was measured. After the insulation resistance was measured and while the stator was still wet, a voltage of [ ]b,c was applied to the stator for [one]b,c minute as shown in Figure 12. The stator leads were connected together for this high voltage test. This test is similar to the test described in IEEE 275-1966.

6.0 TEST DATA AND ACCURACY

6.1 THERMAL AGING RESULTS

The stator was aged for [ ]^{b,c} All thermocouples used were checked prior to testing by connecting them to a L+N Millivolt Potentiometer and putting the fused end in boiling water. Subsequent to aging, the four thermocouples located on the stator windings were checked and found to read between -.03°C and +.87°C at 0°C and between 98.75°C and 99.6°C at 100°C. The data is shown in Table 2.

6.2 RADIATION AGING RESULTS

The stator was exposed to a total accumulated dosage of [ ]^{b,c} gamma radiation using a Cobalt-60 source.

6.3 VIBRATION AGING RESULTS

The stator was vibrated for one hour at a level of 1.5g at 60 Hz.

6.4 RESONANCE SEARCH RESULTS

Table 3 shows the accelerations measured by each accelerometer versus frequency for the 1 Hz to 70 Hz to 1 Hz search. A1 is the control accelerometer.

6.5 SEISMIC TEST RESULTS

6.5.1 Test Position 1

Run 1 subjected the stator to a seismic simulation which did not envelope the OBE. Figure 17 is the test response spectrum (TRS) obtained from table accelerometer A1.

Runs 2-6 subjected the stator to five (5) successful simulations at the OBE RRS as shown below:

Run	OBE Number	5% Damping Figure	2% Damping Figure
2	1	18	19
3	2	20	21
4	3	22	23
5	4	24	25
6	5	26	27

Run number 7 subjected the stator to a seismic simulation at the SSE RRS. Figure 28 is the TRS obtained from accelerometer A1.

6.5.2 Test Position 2

Run 1 subjected the stator to a seismic simulation which did not envelope the SSE. Figure 29 is the TRS obtained from accelerometer A1.

Run 2 subjected the stator to a successful seismic simulation at the SSE RRS. Figure 30 is the TRS obtained from accelerometer A1. The TRS is slightly below the RRS between 2.1 and 3.4 Hz, however it is acceptable since the RRS contains considerable margin at those frequencies and it was decided not to subject the stator to an excessive number of SSE's. In addition, figure 31 shows the TRS of run #2 analyzed at both 2% damping and 5% damping. The TRS at a damping of 4% can be interpolated and shown to be above the RRS. The required damping for mechanical equipment is 4% for the SSE.

6.5.3 Test Position 3

Run 1 subjected the stator to a seismic simulation at the SSE RRS. Figure 32 is the TRS obtained from accelerometer A1.

6.5.4 Test Position 4

Run 1 subjected the stator to a seismic simulation at the SSE RRS. Figure 33 is the TRS obtained from accelerometer A1.

6.5.5 Inspection Following Seismic Testing

The stator withstood the seismic simulation and maintained its structural integrity.

6.6 HIGH POTENTIAL TEST

[ ]^{b,c}

6.7 INSULATION RESISTANCE

The minimum measured resistance when subjected to the 2500 VDC megger test was greater than the required [5.0]^{b,c} megohms after all the insulation resistance tests as shown in Table 4.

6.8 RESISTANCE OF STATOR RTDS AND WINDING RESISTANCE

The resistance of the stator RTDs and the winding resistance is given in Tables 5 and 6 respectively. This data is included for information only.

7.0 SUMMARY

The results of the testing demonstrate the capability of the thermalastic epoxy insulation system used by Westinghouse LMD for Life Line D motors to perform satisfactorily with margin during normal and simulated abnormal service conditions (environmental, radiation, and seismic).

TABLE 1 (Sheet 1 of 4)

TEST EQUIPMENT

Device	Manufacturer	Model No.	Serial No. or McBee No.
Thermocouples	Thermal Electric	Type K	AP8 AJ8 2 HOJ8
Multimeter	Hewlett Packard	3490A	0471
Recorder	Kay Instrument	DIGISTRIP II	3160
Millivolt Potentiometer	Leeds & Northrup	8686	1386
Dosimeter	Applied Raidation Chemistry Group Harwell, Great Britain	4034 Red Perspex	---
Temperature and Humidity Chamber	Hot Pack	UUCI (1313)6-1	---
Controller	Technology Diversified	Weathersetter	---
Temperature & Humidity Chamber Recorder	Honeywell	Servoline 45	0362

TABLE 1 (Sheet 2 of 4)

TEST EQUIPMENT

Device	Manufacturer	Model No.	Serial No. or McBee No.
Accelerometers	Kulite	GAD-813-50	4145 4284 4283 2871 2244 2873 2874 4235 2226
Biaxial Test Machine #2, 6' x 6' Aluminum Table	---	---	---
Signal Conditioner	B&F Instruments	1C1613	4108 4133
Amplifier	B&F Instruments	10-800	0560 4201
Brush Recorder	Gould	Mark 200	2246 1722
FM Tape Recorder	Honeywell	101	AL31343

TABLE 1 (Sheet 3 of 4)

TEST EQUIPMENT

Device	Manufacturer	Model No.	Serial No. or McBee No.
FM Tape Recorder	Consolidated Electrodynamics	VR-2800	AL31134
Double Integrator	M-Rad	197D	3408
Attenuator & Summer	M-Rad	197SB	2900
Hydraulic Controller	MTS	442	AL31210
Sweep Oscillator	Spectral Dynamics	104A-5	1306
Servo Controller	Spectral Dynamics	105C	1168
Frequency Counter	Hewlett Packard	5323A	3537
Oscilloscope	Tektronix	502A	1090
Spectrum Analyzer	Spectral Dynamics	13231	2104
X-Y Plotter	Spectral Dynamics	320	0529
DC Power Supply	B&F Instruments	PS-15-1500	0813
Digital Volt Meter	Data Precision	1450	0683

TABLE 1 (Sheet 4 of 4)

TEST EQUIPMENT

Device	Manufacturer	Model No.	Serial No. or McBee No.
AC High Potential Tester	Westinghouse	1366[illegible]1-E	6782043
HV Megohmeter	American Test Systems (ASEA)	PM[illegible]00	---
High Temperature Chamber	---	---	---
Irradiator	---	---	---

STANDARDS LABORATORY

REPORT

For

Thermocouples Type K Numbered AP8, AJ8, 2, HOJ8
Degrees °C Millivolt Output Measured by Pot Box
McBee 1386; referenced to IPTS 68 T.C. Table

Nominal	0°C Read	100°C Read
TC-AP8	0°C	99.5°C
TC-AJ8	+.87°C	99.5°C
TC-2	-.03°C	99.6°C
TC-HOJ8	+.04°C	98.75°C

Table 2. Thermocouple Accuracy

b,c

Table 3 Resonance Search Data (Sheet 1 of 2)

b,c

Table 3 Resonance Search Data (Sheet 2 of 2)

TABLE 4

STATOR INSULATION RESISTANCE

(1000 MEGOHMS)

(EXCEPT POST HUMIDITY READING IS IN MEG OHMS)

b,c

TABLE 5 (Sheet 1 of 2)

RESISTANCE OF RTDs (OHMS)

b,c

TABLE 5 (Sheet 2 of 2)

RESISTANCE OF RTDs (OHMS)

TABLE 6

RESISTANCE OF STATOR WINDING (OHMS)

b,c

[ ]

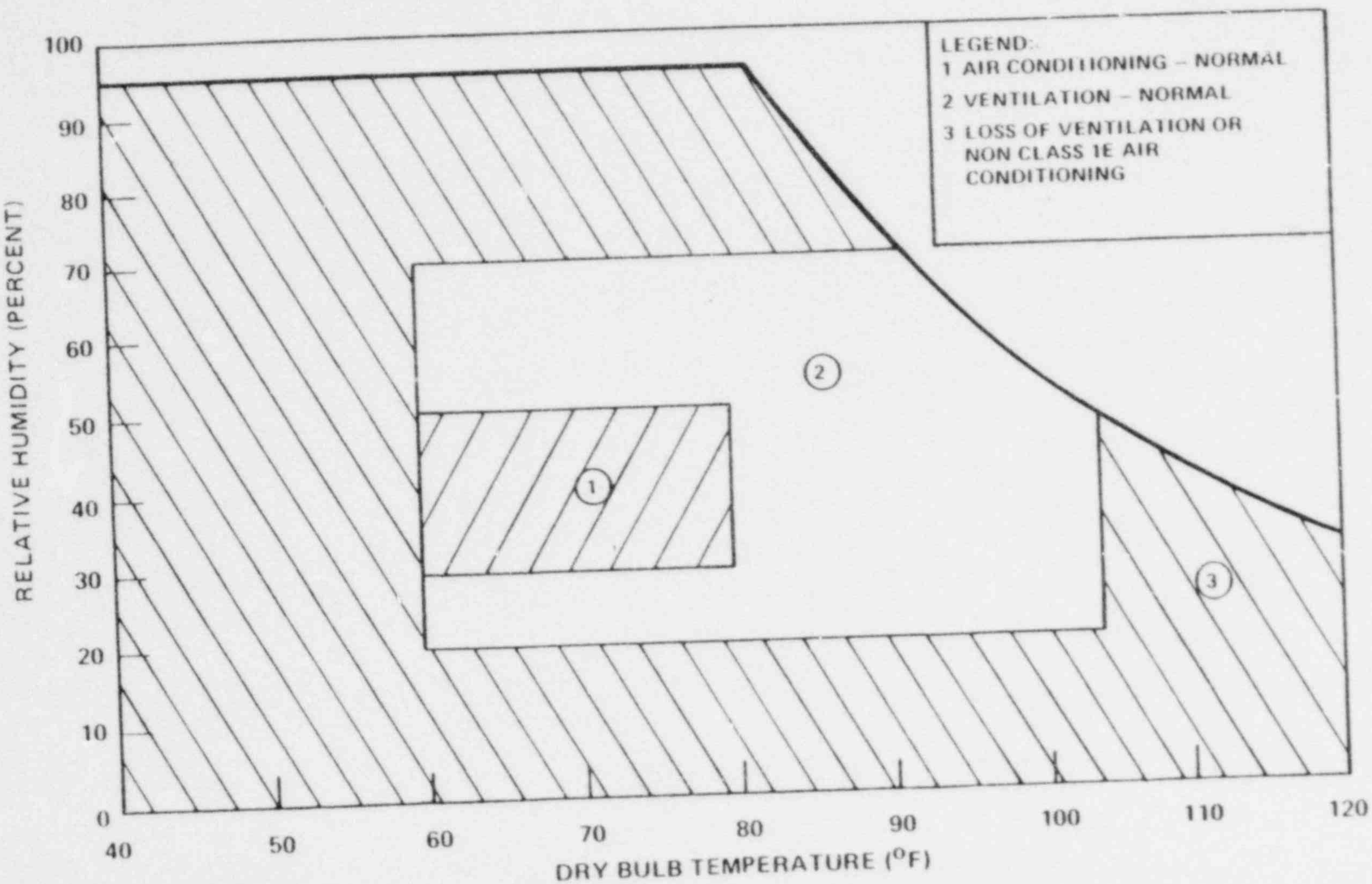

Figure 1. Temperature Versus Humidity-Enclosed Environments Outside Containment

SSE

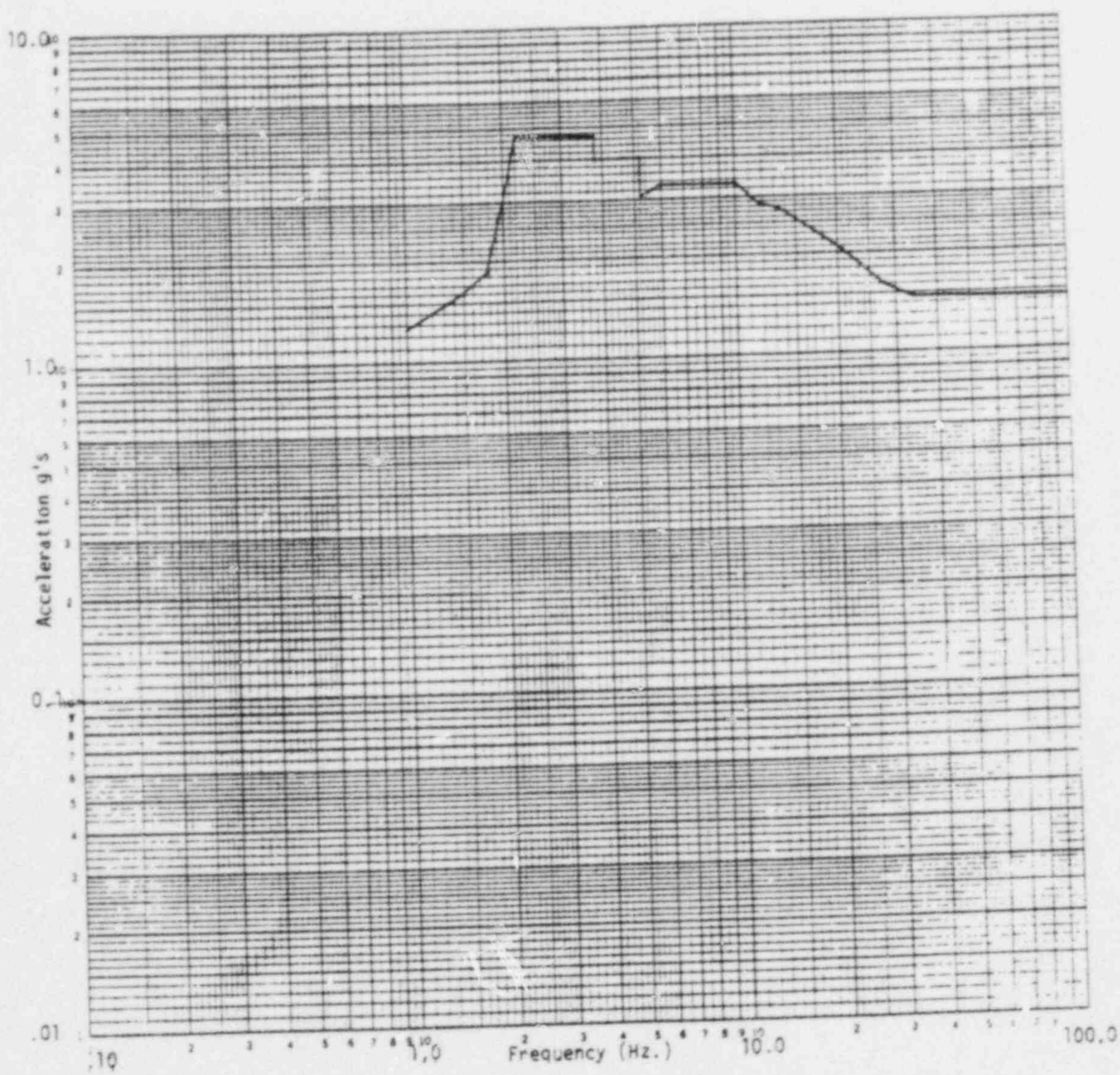

Figure 2 Required SSE Response Spectrum

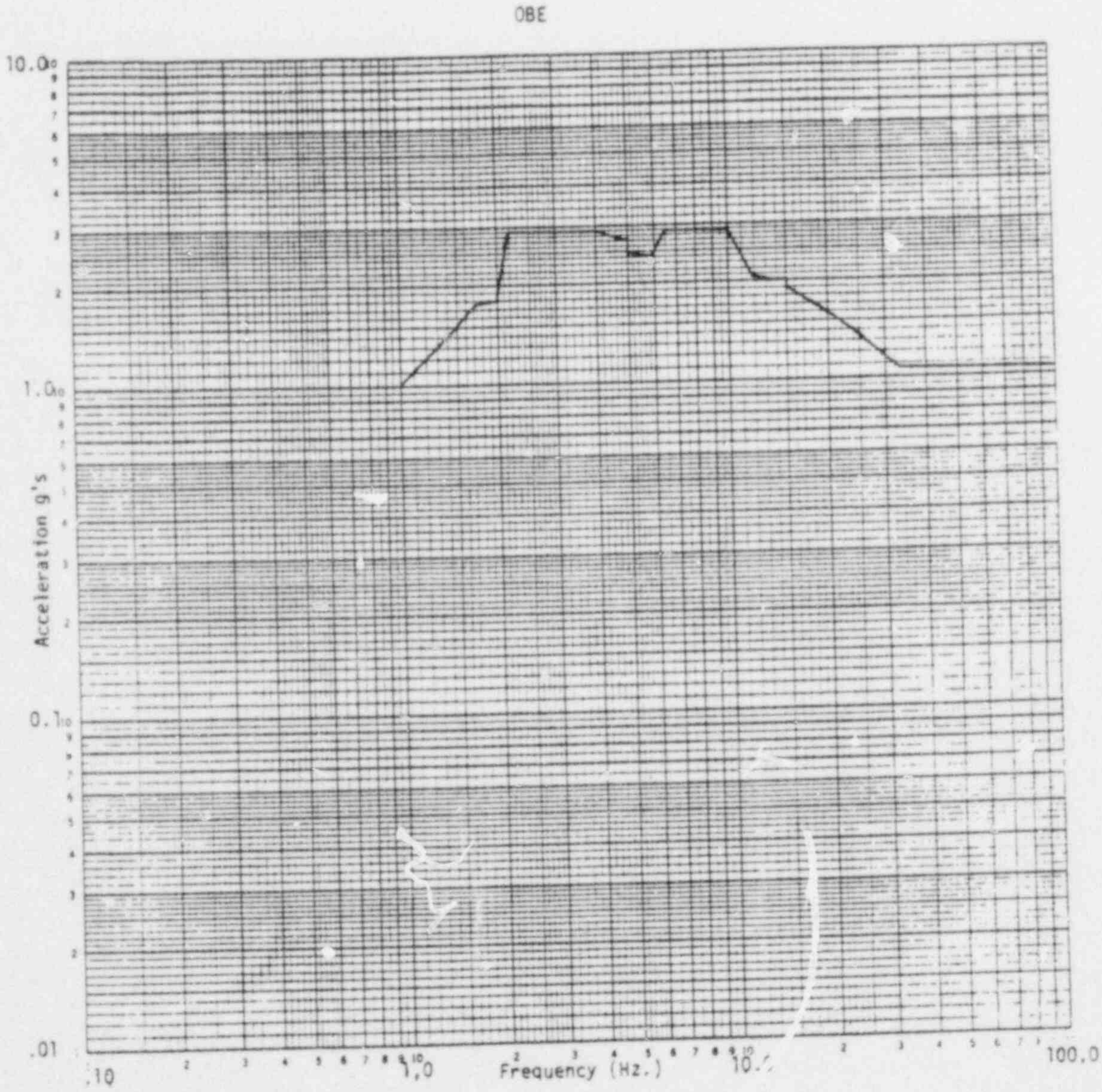

Figure 3 Required OBE Response Spectrum

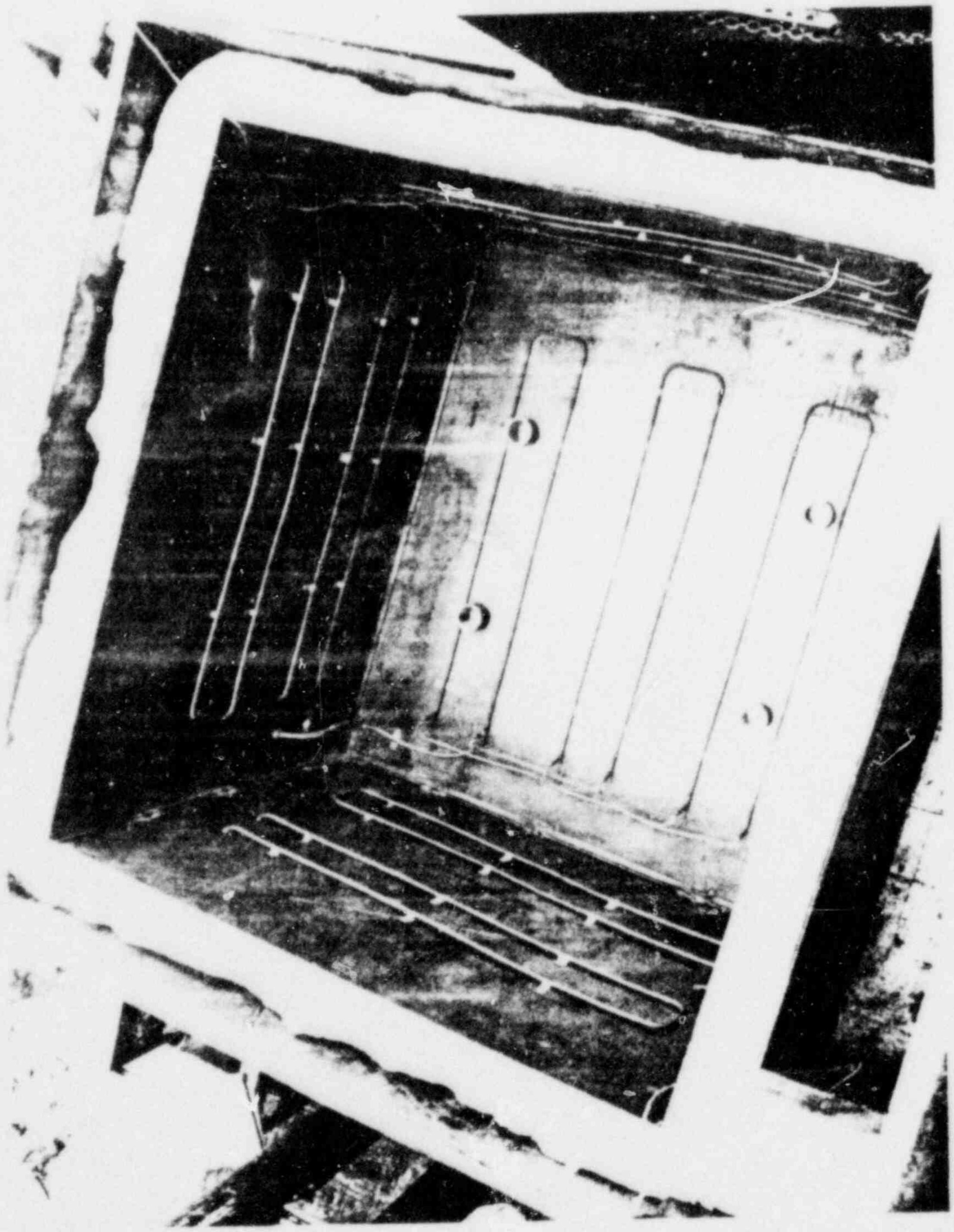

Figure 4. High Temperature Chamber

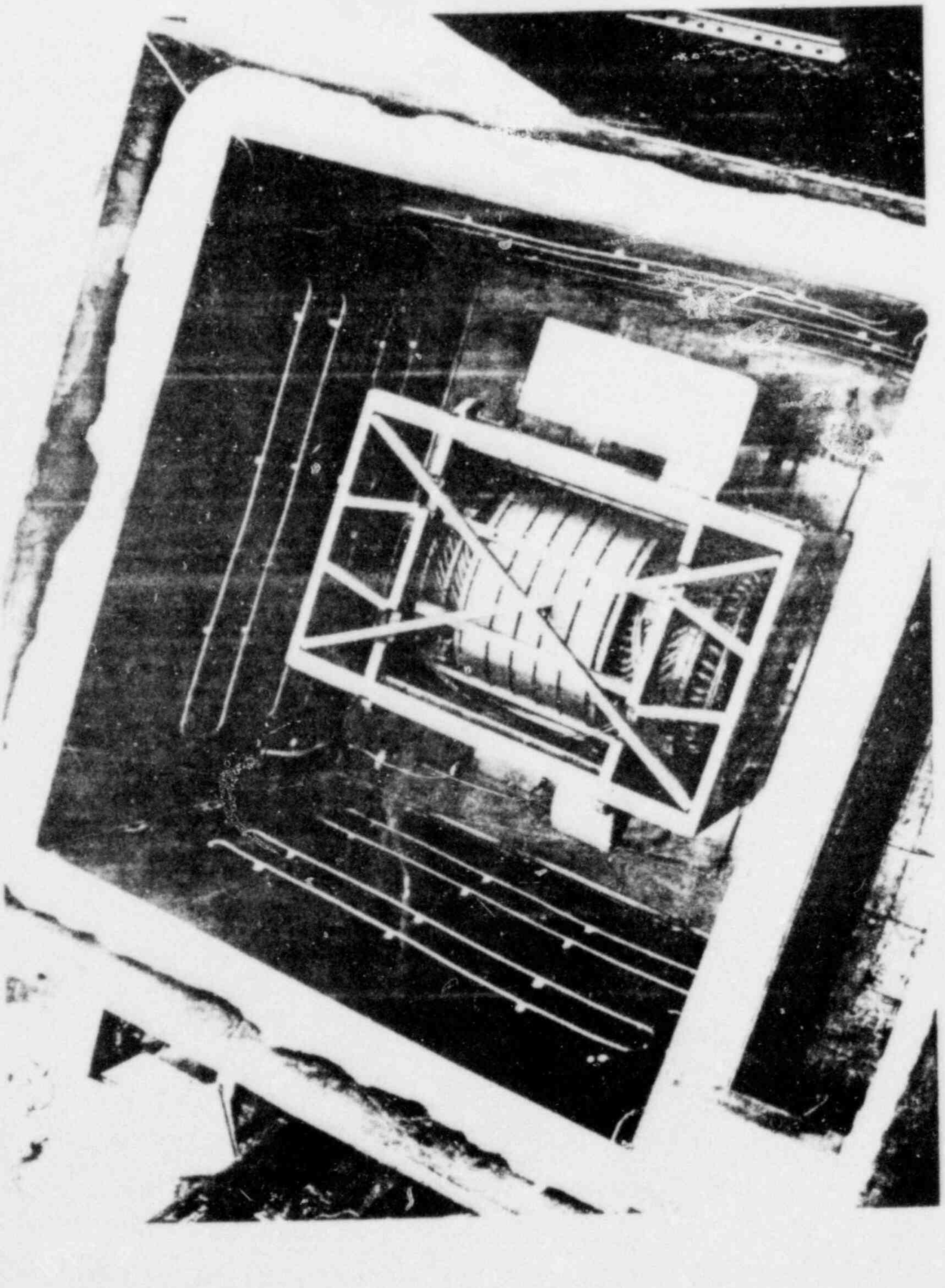

Figure 5. High Temperature Chamber With Stator Located Inside

POOR ORIGINAL

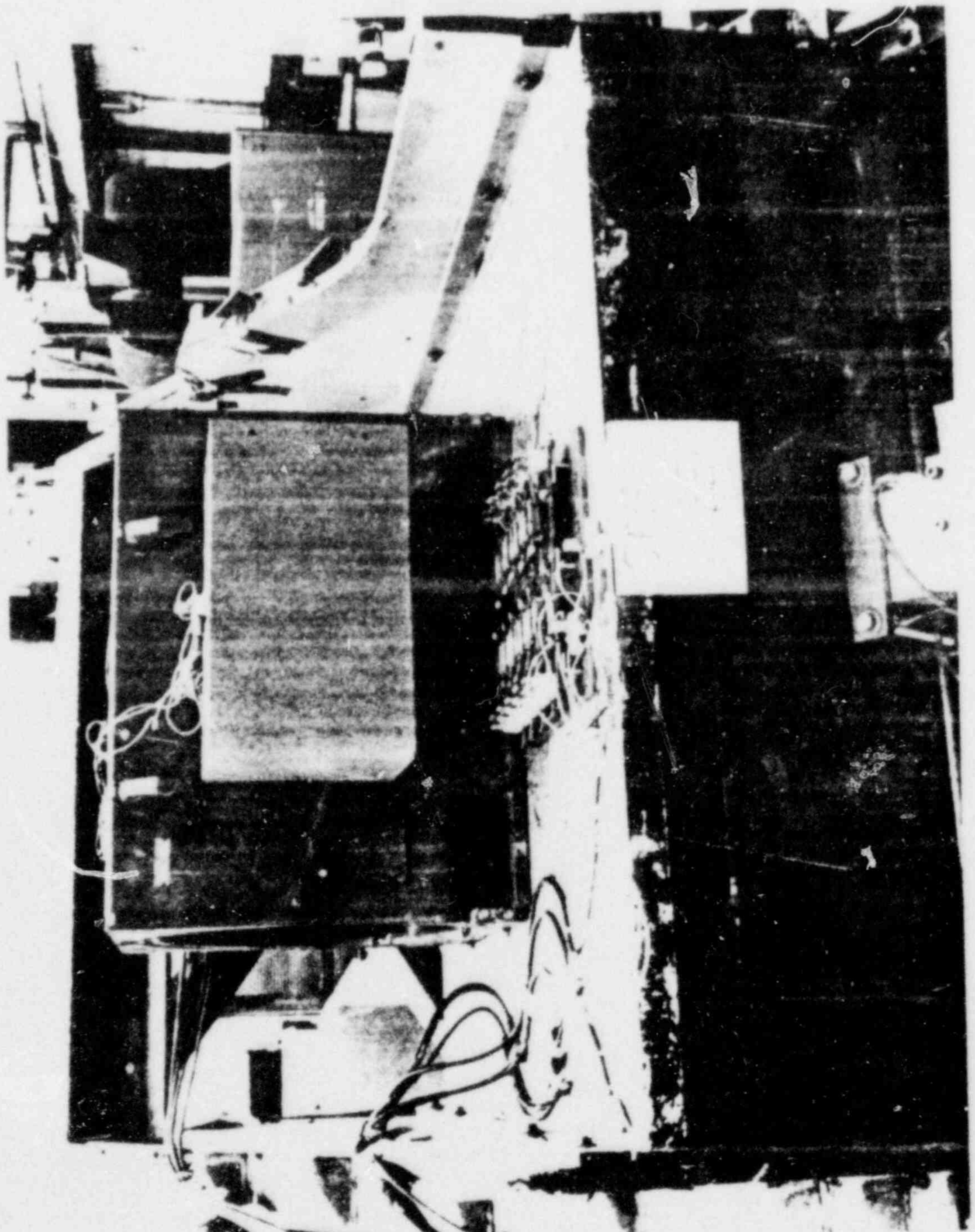

Figure 6. Stator Mounted for Vibration Aging and Resonance Search

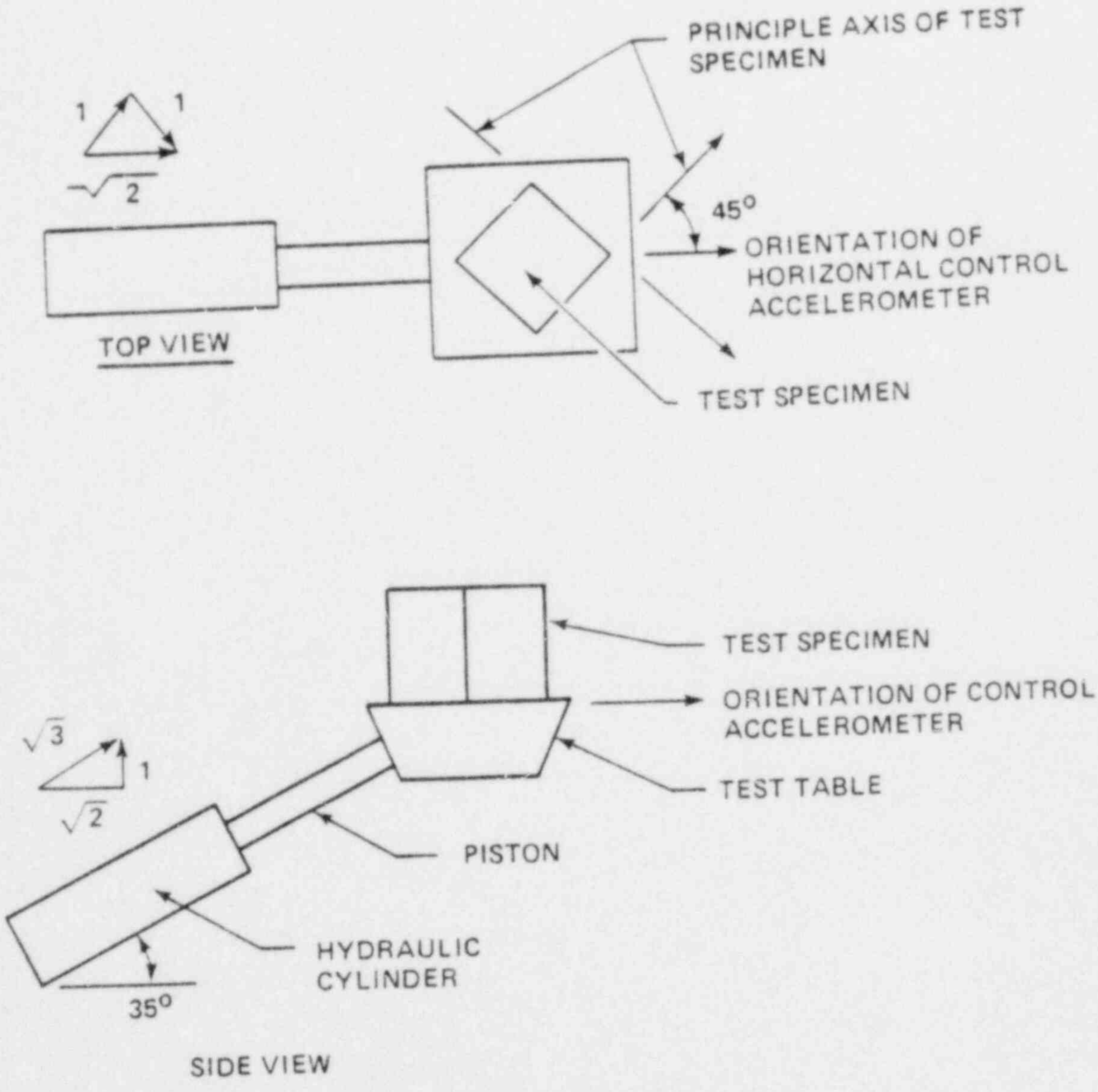

Figure 7. Schematic of Biaxial Test Setup

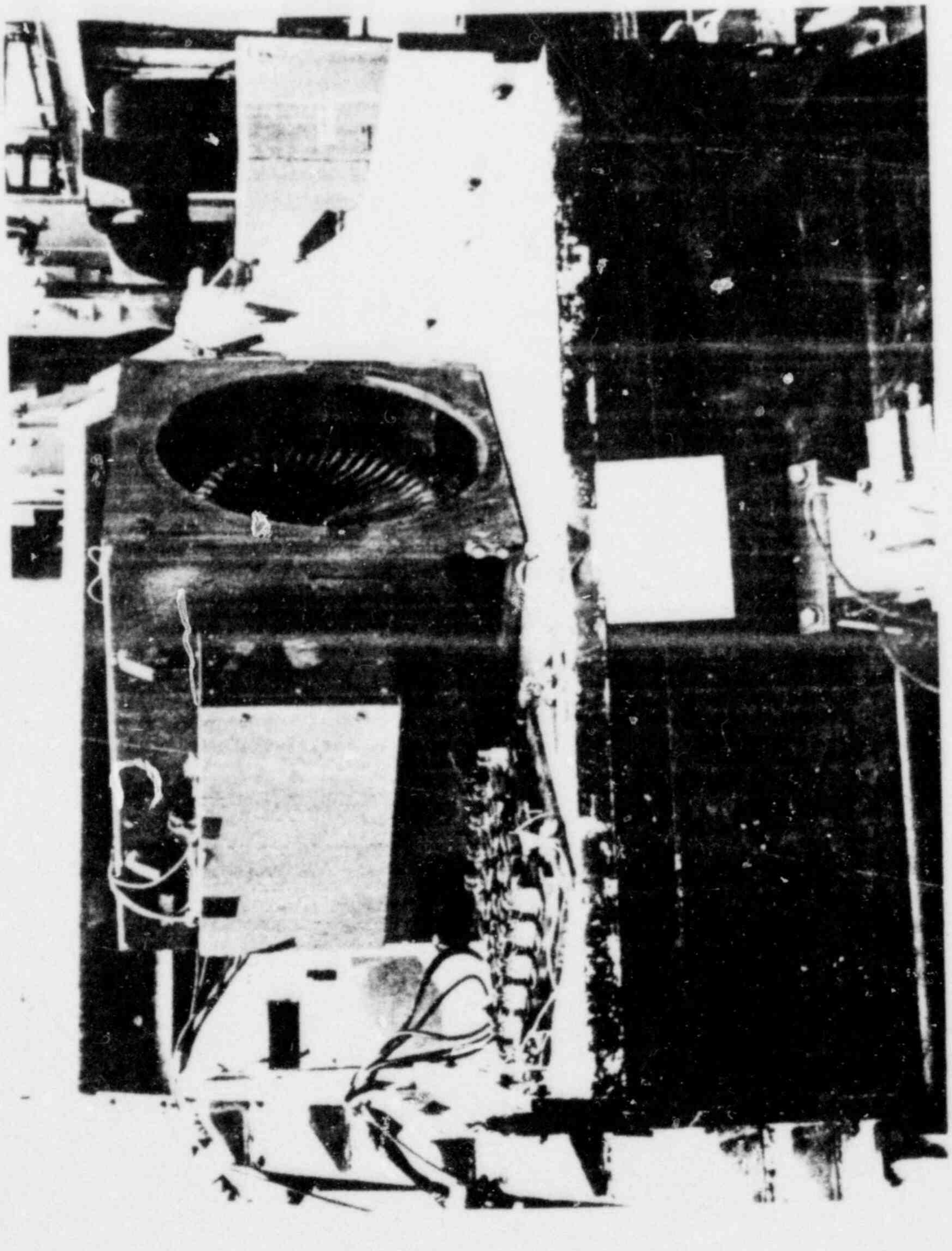

Figure 8. Stator Mounted for Seismic Testing in Test Position 1

POOR ORIGINAL

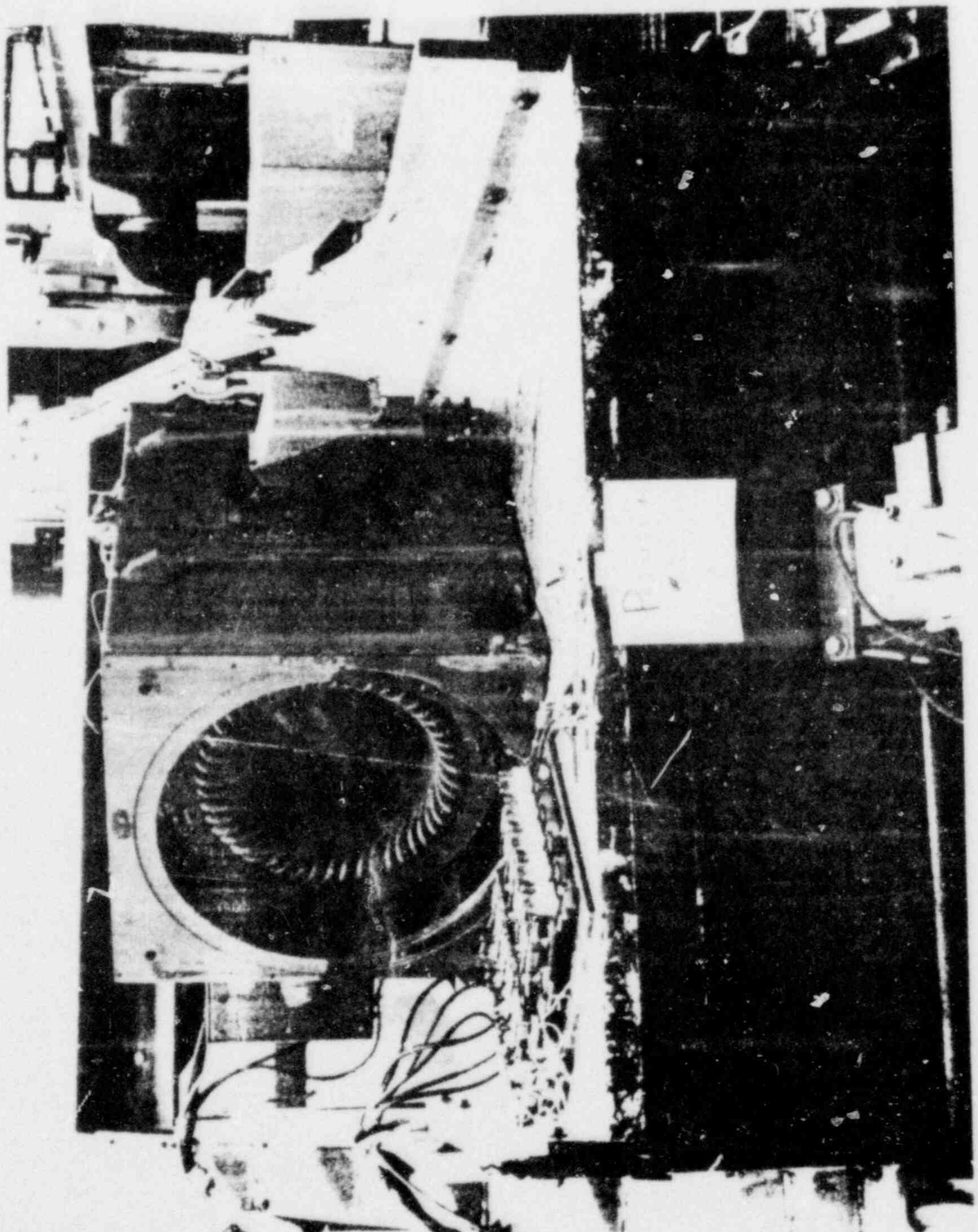

Figure 9. Stator Mounted for Seismic Testing in Test Position 2

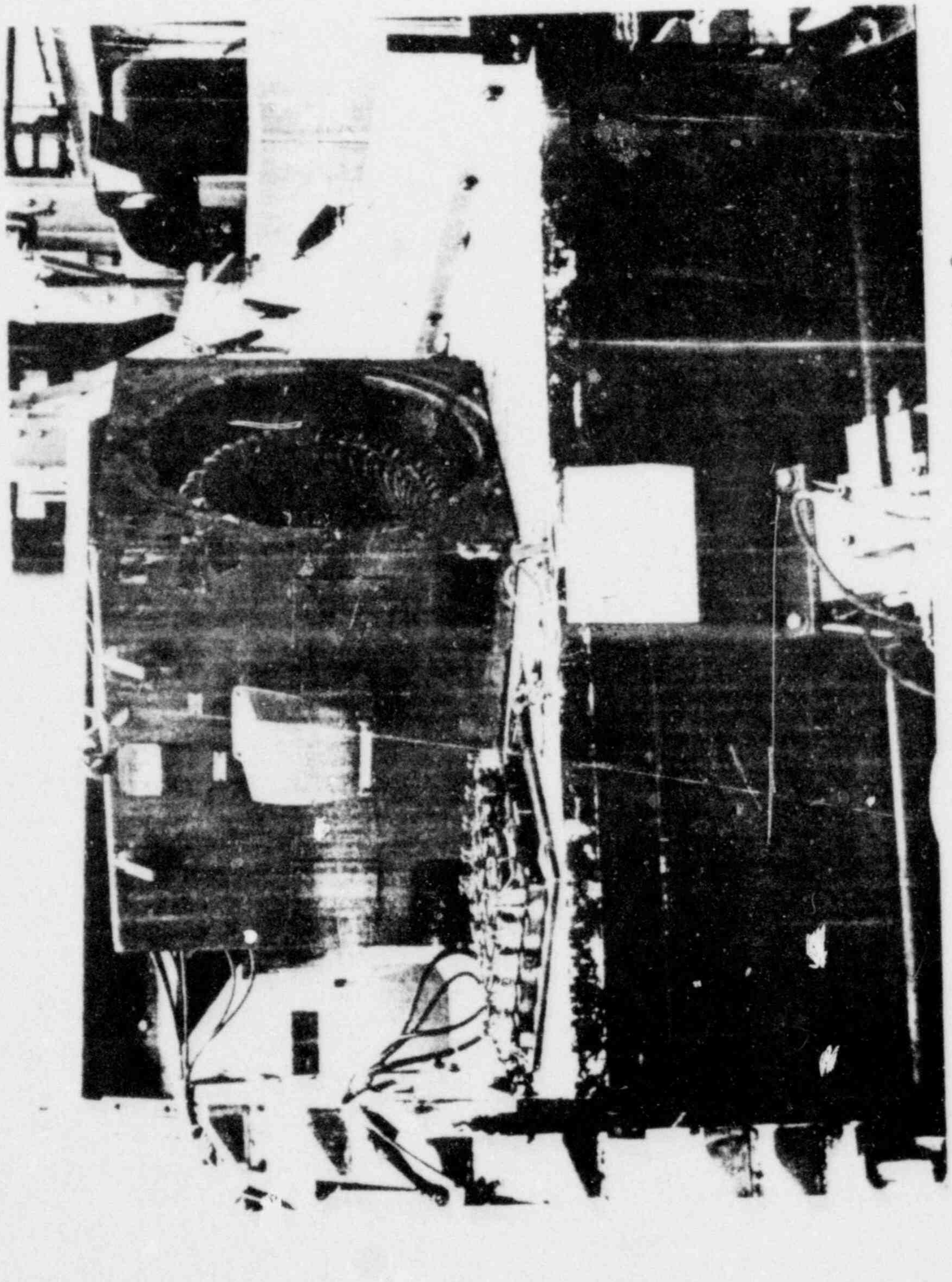

Figure 10. Stator Mounted for Seismic Testing in Test Position 3

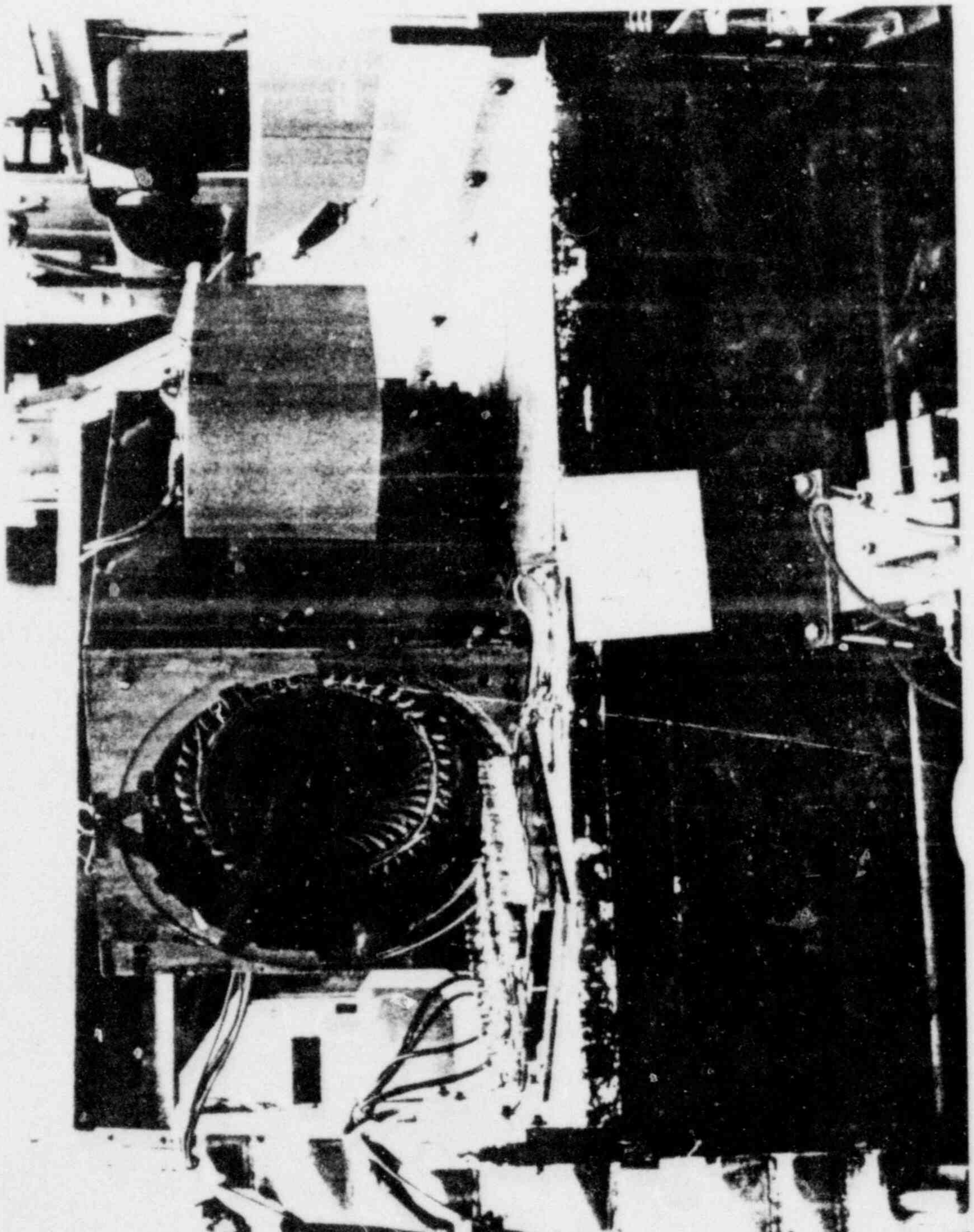

Figure 11. Stator Mounted for Seismic Testing in Test Position 4

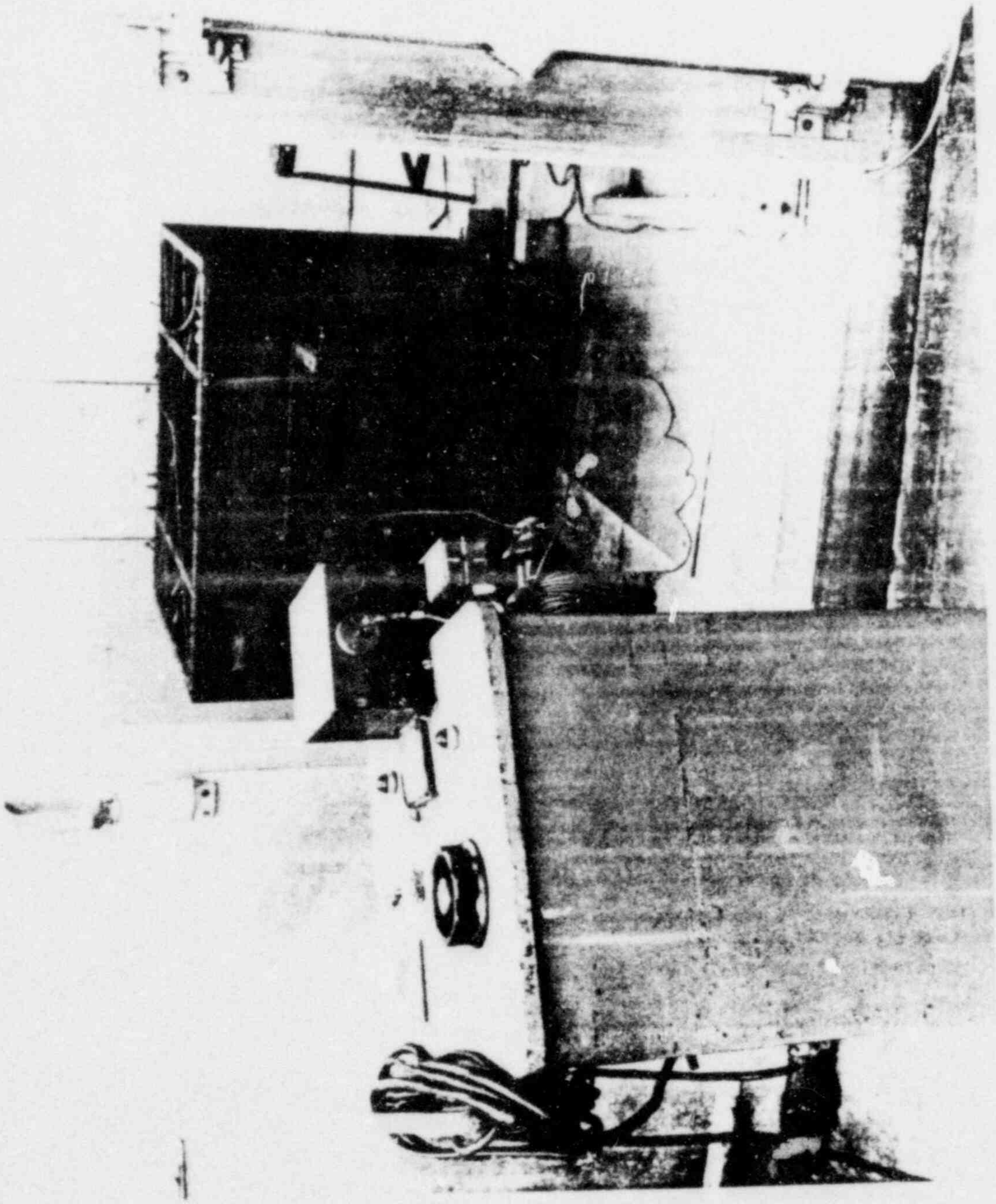

Figure 12. Stator Located in Environmental Chamber High Potential Tester in Foreground

WESTINGHOUSE CLASS 3

a,c

WESTINGHOUSE CLASS 3

a,c

Figure 14. Accelerometer A10 to A12

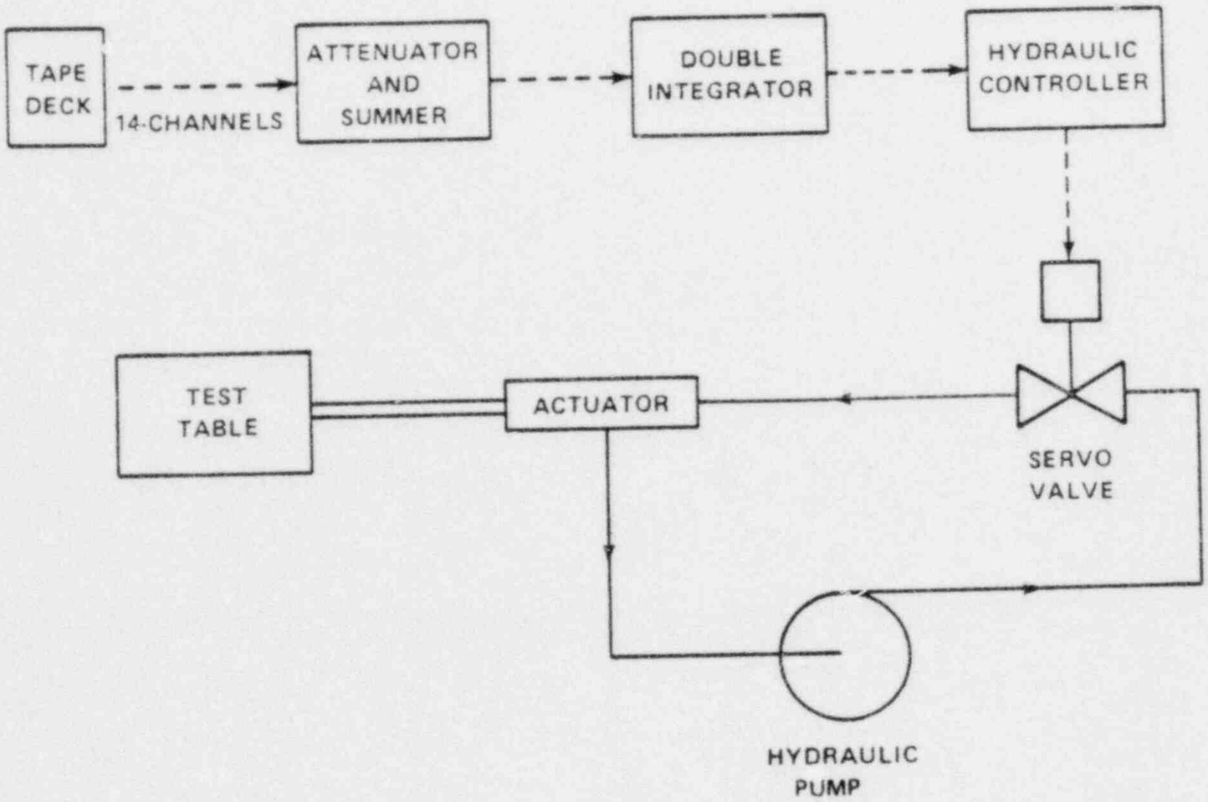

Figure 15. Input Signal Flow Path

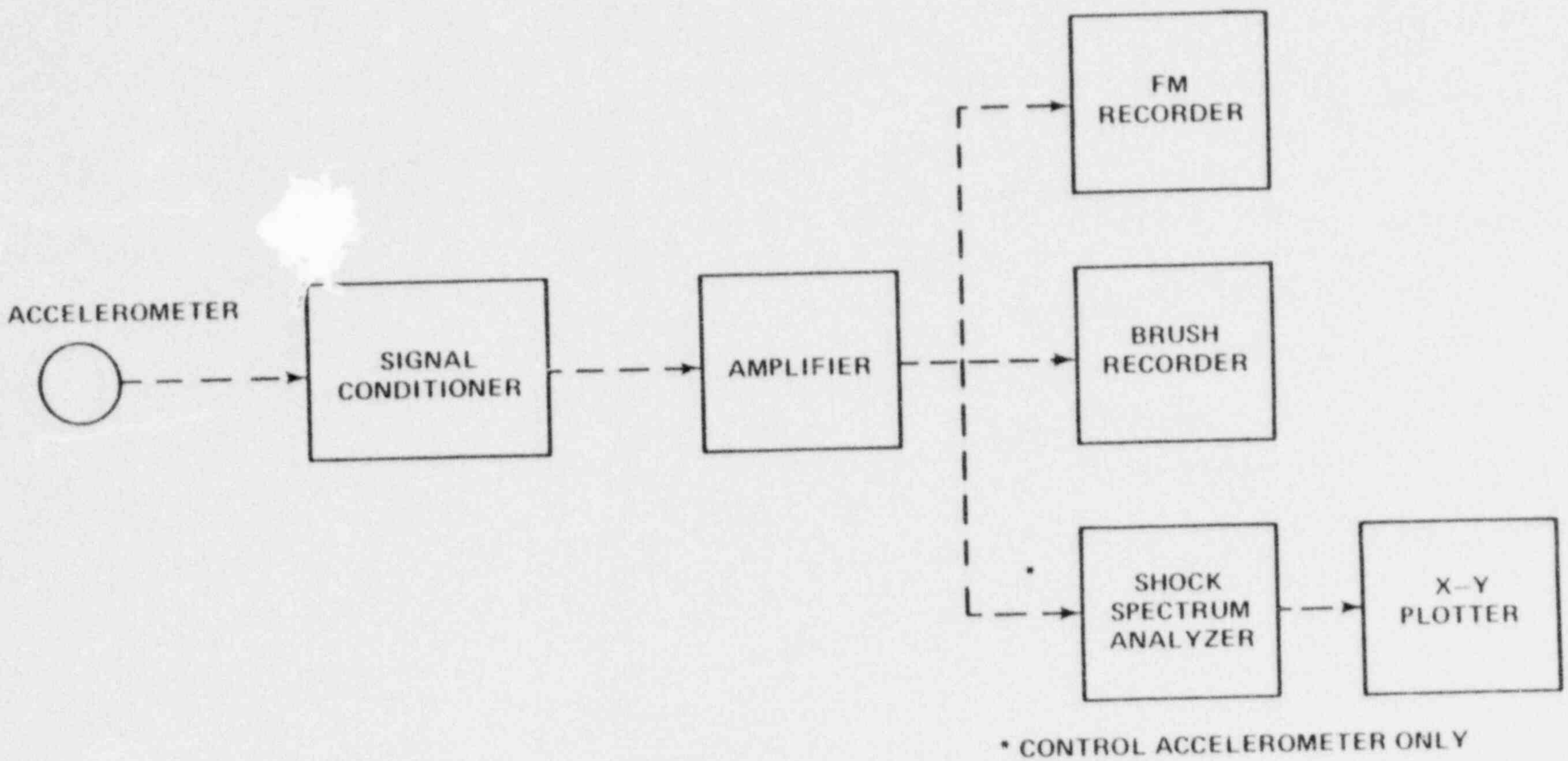

Figure 16 Accelerometer Signal Flow Path

b,c,e

Figure 17 Stator Try For Obe Test Response Spectrum Control Accelerometer a,c,e

Figure 18 Stator-OBE No. 1 Test Response Spectrum
Control Accelerometer 5% Damping

b,c,e

[ ]

Figure 19. Stator-OBE No. 1 Test Response Spectrum
Control Accelerometer 2% damping

b,c,e

Figure 20. Stator-OBE No. 2 Test Response Spectrum
Control Accelerometer 5% damping

b,c,e

Figure 21. Stator-OBE No. 2 Test Response Spectrum
Control Accelerometer 2% damping

b,c,e

[ ]

Figure 22. Stator-OBE No. 3 Test Response Spectrum
Control Accelerometer 5% damping

b,c,e

Figure 23. Stator-OBE No. 3 Test Response Spectrum
Control Accelerometer 2% damping

b,c,e

Figure 24. Stator-OBE No. 4 Test Response Spectrum
Control Accelerometer 5% damping

,c,e

Figure 25. Stator-OBE No. 4 Test Response Spectrum
Control Accelerometer 2% damping

b,c,e

[ ]

Figure 26. Stator-OBE No. 5 Test Response Spectrum
Control Accelerometer 5% damping

,c,e

Figure 27. Stator-OBE No. 5 Test Response Spectrum
Control Acclerometer 2% damping

b,c,e

Figure 28. Stator-SSE Position No. 1 Test Response Spectrum Control Accelerometer 5% damping

b,c,e

Figure 29. Stator-SSE Position No. 2 Test Response Spectrum Control Accelerometer 5% damping

b,c,e

Figure 30. Stator-SSE Position No. 2 Test Response Spectrum Control Accelerometer 5% damping

b,c,e

Figure 31. Stator-SSE Position No. 2 Test Response Spectrum
Control Accelerometer 5% and 2% damping

b,c,e

Figure 32. Stator-SSE Position No. 3 Test Response Spectrum Control Accelerometer 5% damping

b,c,e

Figure 33. Stator-SSE Position No. 4 Test Response Spectrum Control Accelerometer 5% damping

b,c,e

Figure 34. Arrhenius Plot for Thermalastic Epoxy Insulation