This memorandum reports the results of Design Verification Testing on the Array E Antenna Aiming Mechanism.

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Introduction

The objective of the aiming mechanism design verification test program was to verify that the mechanism (P/N 2362400) was capable of surviving and successfully performing throughout the range of environments specified in the Performance/Design and Product Configuration Requirements Specification (Reference 1).

In exterior configuration and material composition, the aiming mechanism for Array E is sufficiently similar to the aiming mechanism used on previous arrays that analysis and conclusions reached relative to some specific environments for that previous mechanism are applicable to the Array E design. These environments are: relative humidity, sand and dust, acceleration, radiation, meteoroids, and acoustics.

The conclusions reached on the effects of these environments are documented in Reference 2. However, the design is sufficiently distinct that the following environments were considered necessary to evaluate: Vibration (random and sine), temperature (high and low), shock, and thermal-vacuum (with high and low temperature). These environmental tests are discussed in Section II of this report.

In addition to environmental tests, functional testing was also performed to verify that the environments had not degraded the operational characteristics of the mechanism.

The engineering model of the Array E Antenna Aiming Mechanism is presented in Figures 1a through 1e.

I. Functional Tests

Functional testing of the aiming mechanism consisted of evaluating the following operational characteristics:

A. Torque Requirements:

The torque required for continuous rotation of each adjustment knob was recorded using a 0-10 inch-lb torque wrench and torque wrench adapters which fit over the adjustment knobs. The torque required for disengaged and engagement using each override control knob was recorded in a similar manner.

B. Freedom of Travel:

The ability of the mechanism to gimbal or rotate throughout its entire range without interference or binding was checked. The ranges to be checked were: $\pm 60^\circ$ longitude, 0-45° latitude, $\pm 15^\circ$ shadow adjustment, and $\pm 10^\circ$ leveling in each axis.

C. Accuracy:

The pointing accuracy of the mechanism was checked in 20° and 15° intervals for longitude and latitude respectively. The measuring device was a plumb bob-precision protractor combination (shown in Figure 2) which was capable of measuring the actual mechanism pointing angle to ± 15 minutes. This tool was also used to measure the total backlash for the longitude and latitude gimbals. The backlash in the shadow adjustment control was measured with a dial indicator located at the pitch diameter of the worm wheel.

D. Interfaces:

The engagement of the mechanism on the antenna mast and the antenna in the mechanism was checked for ease and positiveness. The force required for antenna insertion into the mechanism (to the detent or locked position) was measured with a push-pull force gage.

Initial pre-test inspection and functional testing of the mechanism revealed that it had been painted with white semi-gloss enamel rather than the required thermal paint. All operational characteristics were within specification values, although the maximum pointing error for the latitude gimbal was close to the allowable limit of 66 minutes (the summation of the specification limits for manufacturing calibrations, interface misalignments, scale setting, and backlash errors). The pre-test functional characteristics are summarized below:

A. Torque requirements

1. Adjustment knobs: .3 in-lbs maximum
2. Override knobs: 2 in-lbs maximum

B. Freedom of Travel

No binding observed throughout the specified range of travel.

C. Accuracy

1. Longitude: 38 minutes of arc maximum error.
2. Latitude: 59 minutes of arc maximum error.
3. Shadow Adjustment: < 10 minutes of arc maximum error.

D. Interfaces

Both antenna mast and antenna interfaces functioned properly. Force Required for antenna engagement was 5 lbs.

II. Environmental Tests

In order to verify the engineering model aiming mechanism's ability to comply with Reference 1, the following sequence of environmental and functional tests were performed:

1. Functional test (receiving inspection).
2. High temperature
3. Functional test
4. High temperature (second cycle)
5. Functional test
6. Low temperature
7. Functional test
8. Low temperature (second cycle)
9. Functional test
10. Thermal/Vacuum (low temperature)
11. Functional test
12. Thermal/vacuum (high temperature)
13. Functional test
14. Vibration test (random and sine)
15. Functional test
16. Shock test
17. Functional test

These environmental tests are described below:

A. High Temperature Test

The high temperature test set-up consisted of instrumenting the aiming mechanism with four thermal couples (to be used for monitoring the conditioning rates and thermal equilibrium), placing the mechanism on a stand and mounting the assembly in a conditioning oven (See Figure 3.).

The mechanism was slowly heated (5°F per minute) to a temperature of 250°F (the maximum required survival temperature) and held there for four hours. Following this period, the mechanism was slowly cooled (5°F per minute) to 160°F and held there for 1 hour while a functional test was performed. This temperature represents the upper limit of the mechanisms operational temperature limit (see Reference 1). During the functional test there were no indications of binding throughout each adjustment range of travel and the torque required for manipulating of each adjustment knob and override control had not increased from the values obtained during the receiving functional test. Antenna and mast interfaces were engaged satisfactorily (4 lbs force required for antenna engagement) and pointing errors were unchanged indicating no measurable thermal distortion had occurred.

The high temperature test and the functional test at high temperature associated with it were repeated for a complete second cycle with nearly identical results to those described above.

The only anomaly noted during these tests was that the mechanism's white paint had turned a slight off-white or cream color. This is attributed to oxidation which occurs in the paint at high temperatures in an oxygen atmosphere and has no detrimental effect on the visibility of the visual alignment clues or the thermal characteristics of the mechanism.

B. Low Temperature Tests

The instrumentation of the aiming mechanism in the low temperature test was identical to that described above for the high temperature test. The test set up (shown in Figures 4 and 5) consisted of placing the mechanism in a polyurethane box into which gaseous/liquid nitrogen was carefully metered. Using this set up, the mechanism was slowly cooled (5°F per minute) to a temperature of -320°F (the minimum required survival temperature).

This temperature was maintained for four hours. Following this period, the mechanism was slowly warmed to -65°F and held there for 1 hour while a functional test was performed. This temperature represents the lower limit of the mechanism's operational temperature limit.

During the functional test there were no indications of binding throughout each adjustment's range of travel and the torque required for the manipulation of each adjustment knob had not significantly increased from the values obtained during the receiving functional test (3 in-lb maximum torque recorded for leveling screws).

The shadow adjustment override knob required 4 in-lbs of torque for manipulation, while the longitude and latitude override knobs required as high as 15 in-lbs of torque (compare with the specification limit of 9.6 in-lbs of torque) for complete clutch disengagement. There was also a tendency for these clutches to "stick" with only partial engagement. This "sticking" disappeared when the mechanism warmed to -25°F and complete clutch engagement was then obtained.

Antenna and antenna mast interface were also checked out and found to be satisfactory with 6 lbs of force required for antenna engagement. There were no measurable increases in pointing errors or indications of thermal distortions.

The low temperature test and the functional test associated with it were repeated for a second complete cycle. The results of this functional test were nearly identical to those described above with the exception that axial play had developed in the longitude gimbal worm shaft which in turn resulted in an increase in that gimbal's pointing error to 1° 13'.

Both the high torque required for clutch operation and the longitude gimbal pointing error were in excess of the allowable limits specified in reference 1. The cause of these discrepancies is discussed in detail in Section III.

C. Thermal/Vacuum (Low Temperature)

For thermal vacuum testing the aiming mechanism was instrumented identically to previous tests. The mechanism was placed in a small copper container (cold wall) to which tubing was attached so that LN_2 could be pumped through it (see Figure 6). This entire assembly was placed in a 4 ft x 8 ft vacuum chamber (See Figure 7), which was then pumped down to 1×10^{-6} torr and held at that pressure while LN_2 was pumped through the cold wall. By controlling the flow of LN_2 the temperature of the mechanism was reduced to approximately -300°F. The conditions of low temperature and vacuum were maintained for 48 hours and then returned to ambient and the mechanism removed for functional testing. The results of functional testing revealed no significant changes from those obtained during the previous tests. As expected, since this test was performed at room temperature, the torque requirements had returned to nominal values (.5 in-lbs maximum for adjustment knob and 2 in-lbs maximum for override knobs).

D. Thermal/Vacuum (High Temperature)

The thermal/vacuum (high temperature) instrumentation and test set up was identical to that described above (Section C) with the exception that heated trichloroethylene was used as the conditioning agent instead of LN_2. After being heated to +250°F at 1 x 10^{-6} torr and held there for 48 hours, the mechanism was returned to ambient conditions and functionally tested. The results of this functional test were essentially identical to those obtained after the thermal/vacuum (low temperature) test.

E. Vibration Testing

The test setup for vibration testing consisted mounting a triaxial response accelerometer on the mechanism (as shown in Figure 1c) and placing the mechanism in a foam packing (shown in Figure 8). The packing was in turn placed in an aluminum container (P/N 2362404) and mounted on the shaker head (See Figure 9). This container (a new design) is sized such that the mechanism can be mounted in it when gimballed (i.e., pre-set) to any coordinate within its specified range. To prevent excessive movement during vibration, the container is pre-loaded with approximately 12 lbs of force using rubber pads.

The vibration axes (which are identical to those for the ALSEP subpacks) are defined in Figure 10. During vibration testing the mechanism was subjected, one axis at a time, to: a 1 g sine sweep from 5-500 Hz at a sweep rate of 1 oct/min, 5-100-5 Hz sinusoidal vibration at 3 oct/min (inputs shown in Figures 11 and 12), earth launch boost random vibration spectrum (inputs shown in Figures 13, 14, and 15), and lunar descent random vibration spectrum (inputs shown in Figures 16, 17, and 18.

After all three axes had been subjected to the above environments, the mechanism was removed from its container and inspected for damage and then functionally tested. Neither the inspection or the functions tests revealed any change in the mechanisms condition or performance. A review of the test data reveals that the aiming mechanism container assembly has a natural frequency of 28 Hz (most likely the first made in cantalever), and that no excessive responses occur with inputs that are as high or higher than those expected to be experienced during flight.

F. Shock Testing

The instrumentation and packaging of the aiming mechanism for the shock test was identical to that and for the vibration test. The mechanism containers assembly mounted to the shock generator is shown in Figure 19. Shock testing consisted of applying a 20g, 11 millisecond duration, terminal peak sawtooth shock pulse three times in each axis direction (plus and minus directions except for the x-axis which was plus direction only). At the completion of these tests, the mechanism was removed from its container, inspected for damage, and functionally tested. No changes in condition or performance were noted.

Shock testing completed the environmental testing sequence.

III. Disassembly and Post Test Inspection

Following completion of environmental testing, the mechanism was completely disassembled and inspected. The inspection revealed that wear of moving parts had been minimal and that Dow 17 coating on the mating parts had not been degraded. Also revealed were the following discrepancies (which are attributable to fabrication, rather than test environments).

1. The cam pin in both clutches had broken through to the I.D. of the clutch bore. The area where the pin had broken through was badly scratched and scored during de-burring. It is also apparent that the de-burring was incomplete on the longitude clutch or the bore had been distorted as a .0001 inch undersize plug gage would only go half way through the clutch bore.

2. The latitude clutch was .0002 to .0004 inch smaller than allowable. The required dimension is $.0950 \begin{smallmatrix}+0000\\-0002\end{smallmatrix}$).

3. The snap ring on the longitude worm shaft was found to have pulled out of its groove. Inspection of all worm shaft snap ring grooves revealed that they were discrepant and did not allow proper seating of the snap rings and hence, resulted in loose assemblies. No other significant discrepancies were found.

These discrepancies are considered to be the cause of the two out of specification conditions noted during environmental and functional testings; namely excessive torque required for clutch operation at low temperatures (caused by discrepancies 1 and 2) and excessive backlash in longitude and latitude gimbal assemblies (caused primarily by discrepancy 3 above). After the snap ring grooves on the worm shafts had been repaired and the mechanism reassembled, the total backlash for each gimbal assembly was found to be reduced to approximately 13 minutes (maximum total pointing error was less than 43 minutes for each axis).

Conclusions

The EEM antenna aiming mechanism has successfully completed design verification testing during which there were no anomalies observed which were not the result of manufacturing discrepancies. This type of manufacturing discrepancy should not be experienced with flight and subsequent models as complete quality assurance and inspection procedures will be instigated which were not utilized on the engineering model.

References:

(1) AL 410210 Performance/Design and Product Configuration Requirements - Antenna Aiming Mechanism for Array E, ALSEP.

(2) Report No. 4037 (BRLD) Design Verification Report, ALSEP Antenna Aiming Mechanism.

ARRAY E ANTENNA AIMING MECHANISM

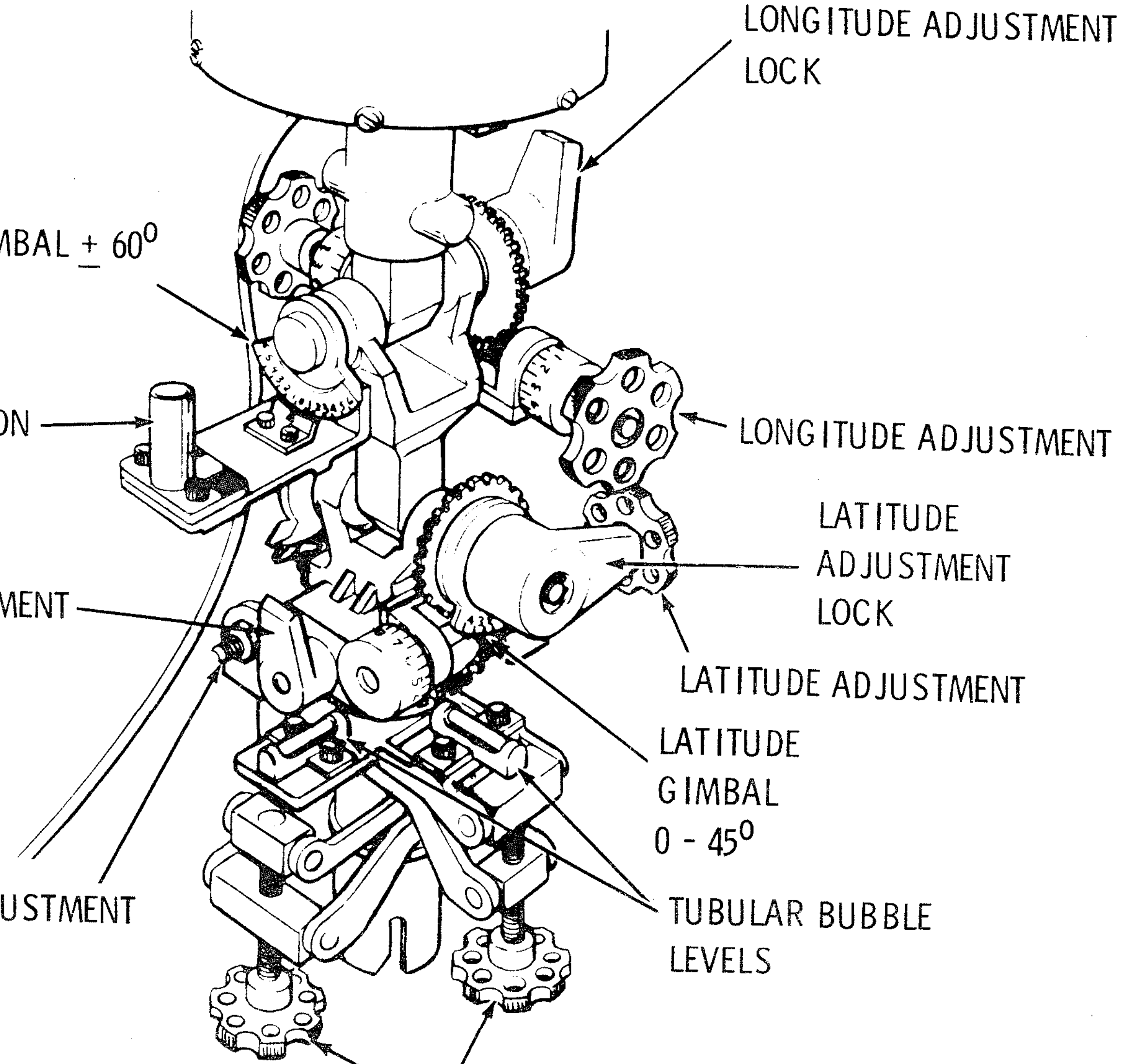


FIGURE 1a.

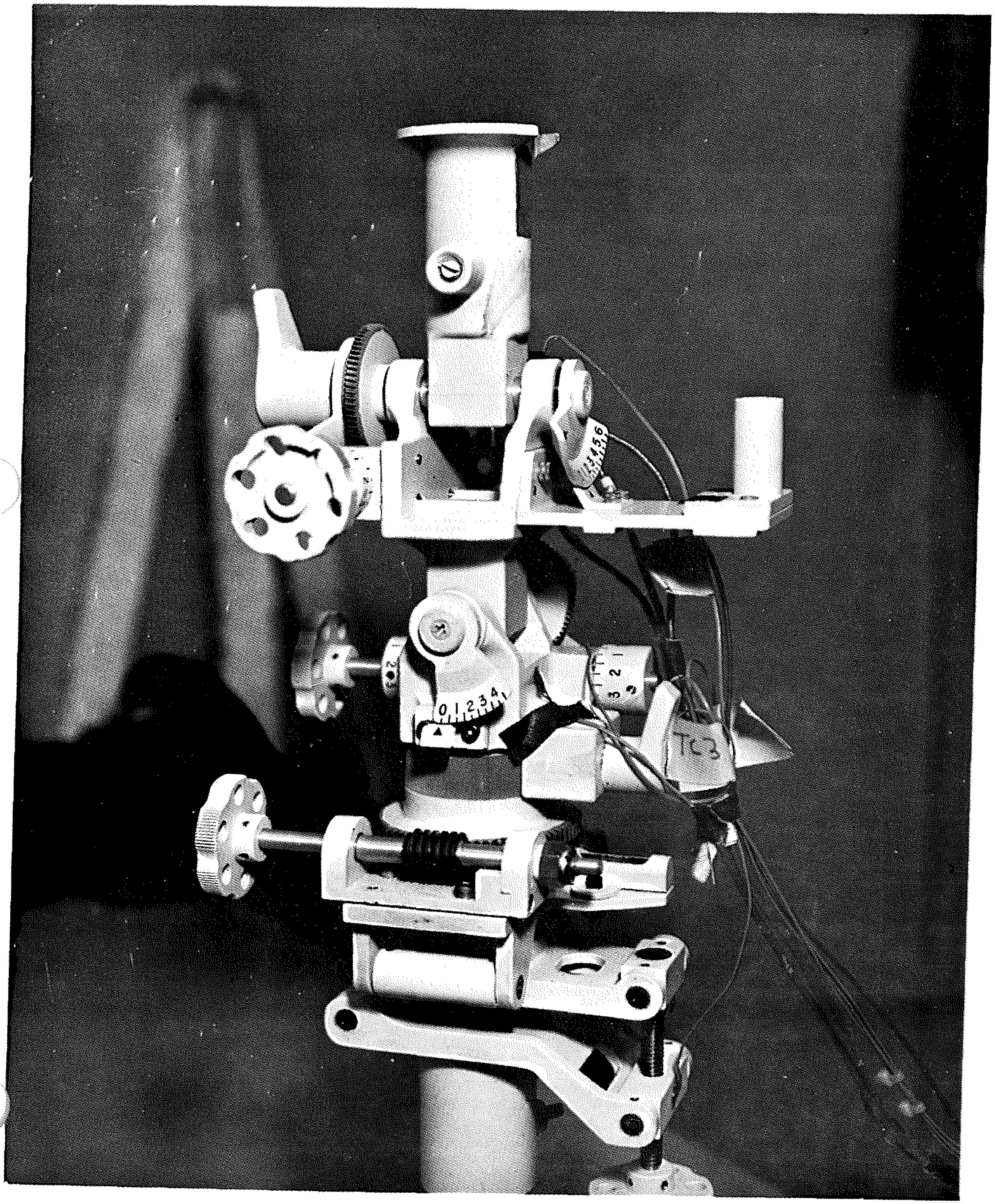


Figure 1b. Antenna Aiming Mechanism (cont'd).

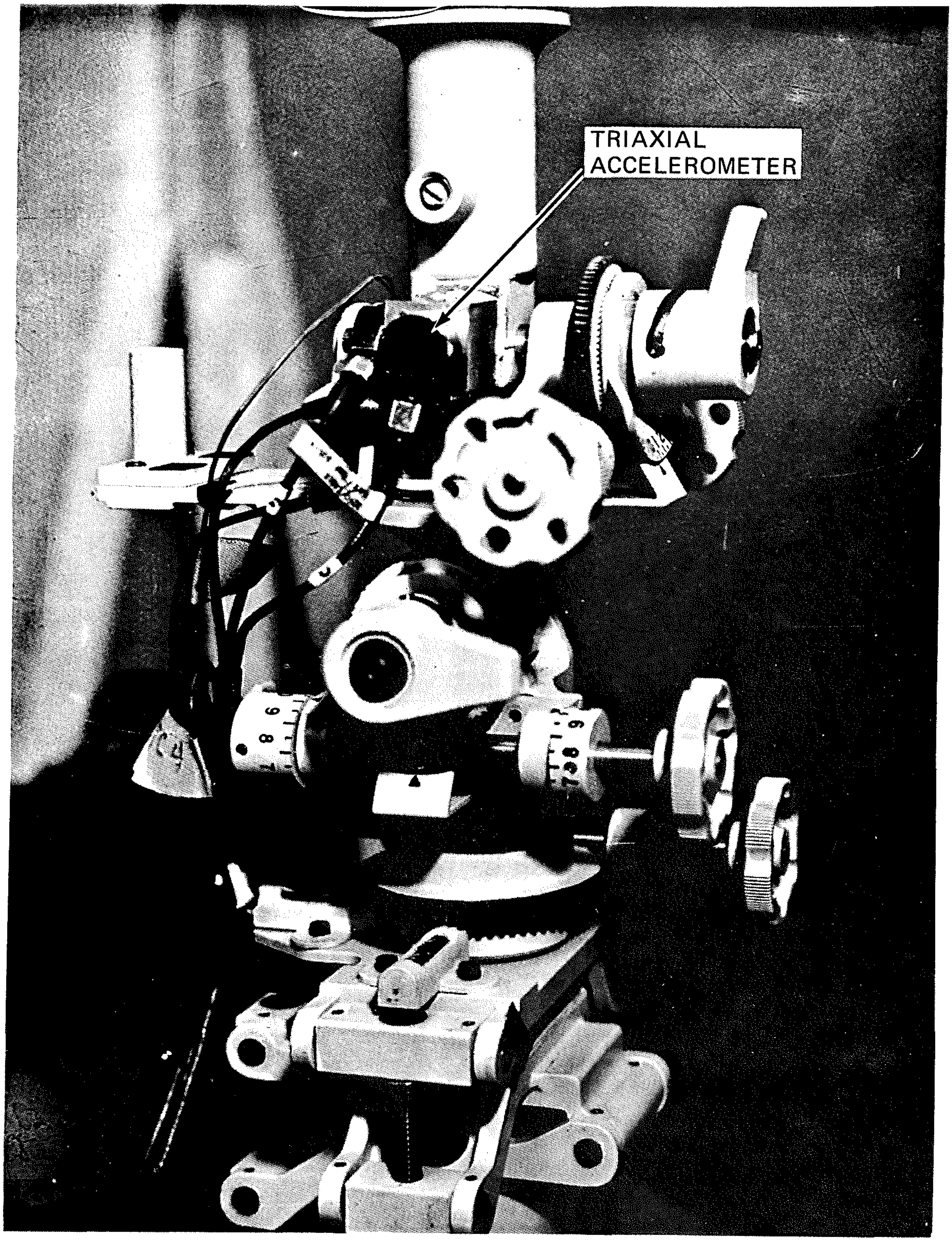


Figure 1c. Antenna Aiming Mechanism (cont'd).

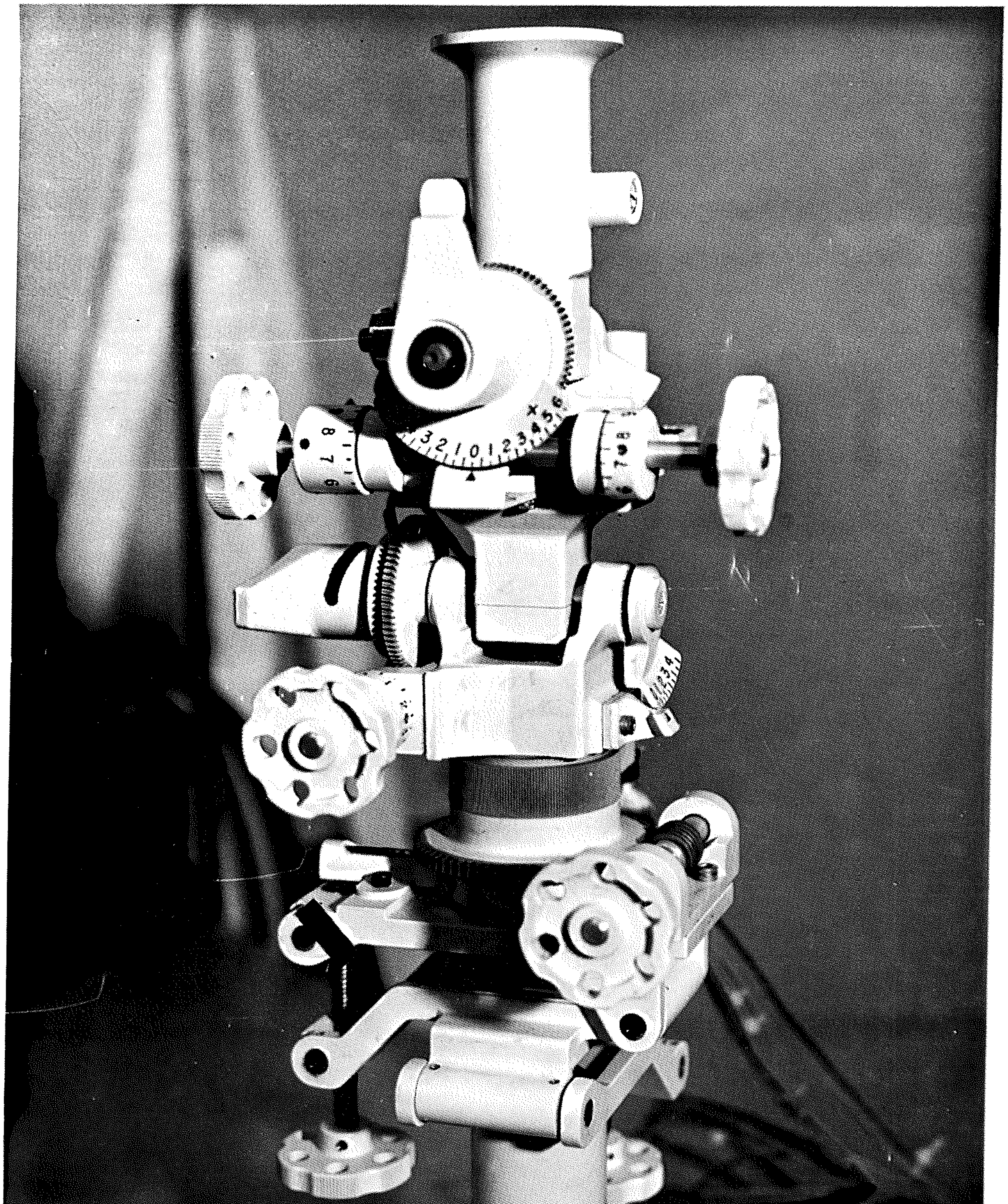


Figure 1d. Antenna Aiming Mechanism (cont'd).

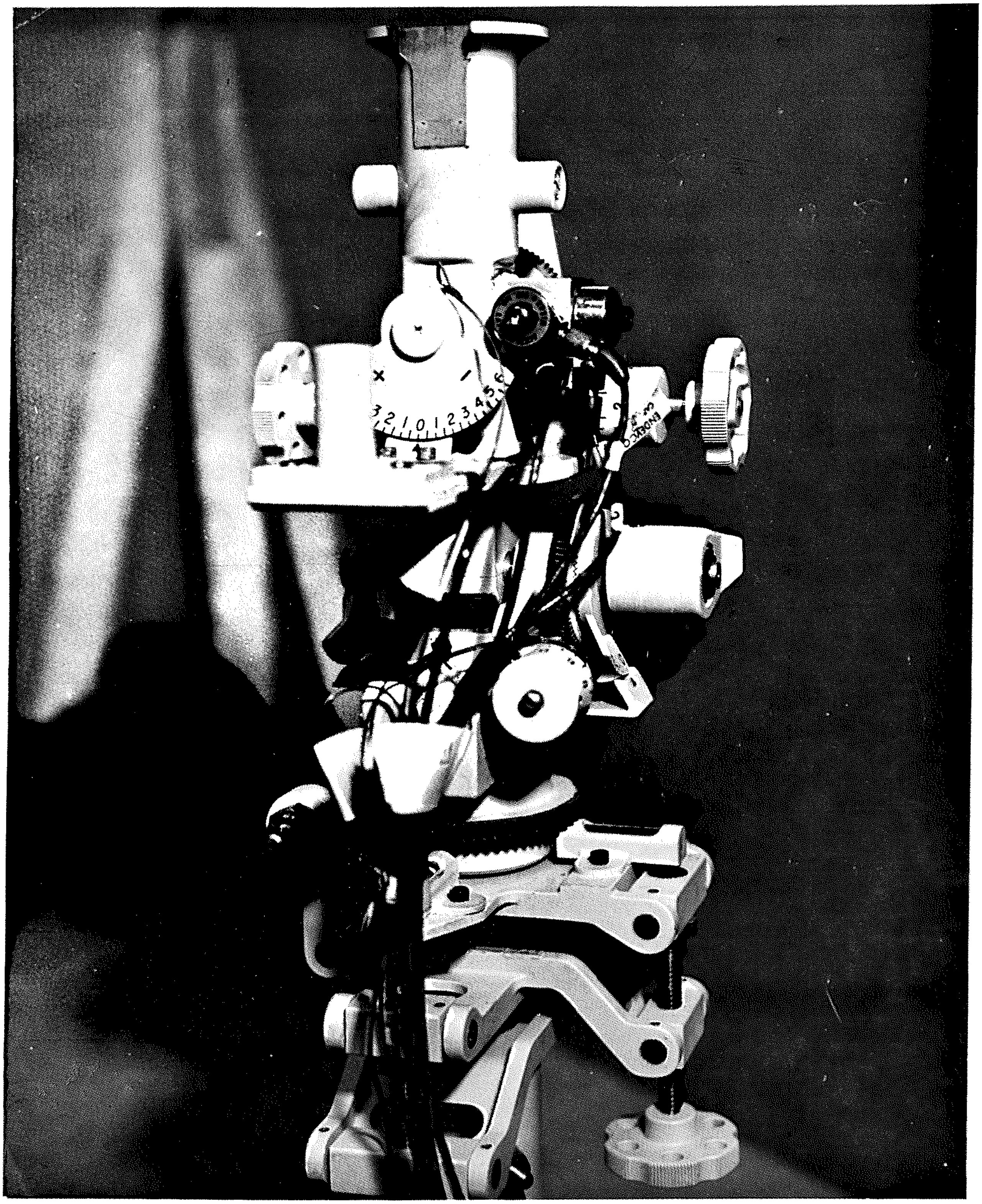


Figure 1e. Antenna Aiming Mechanism (cont'd).

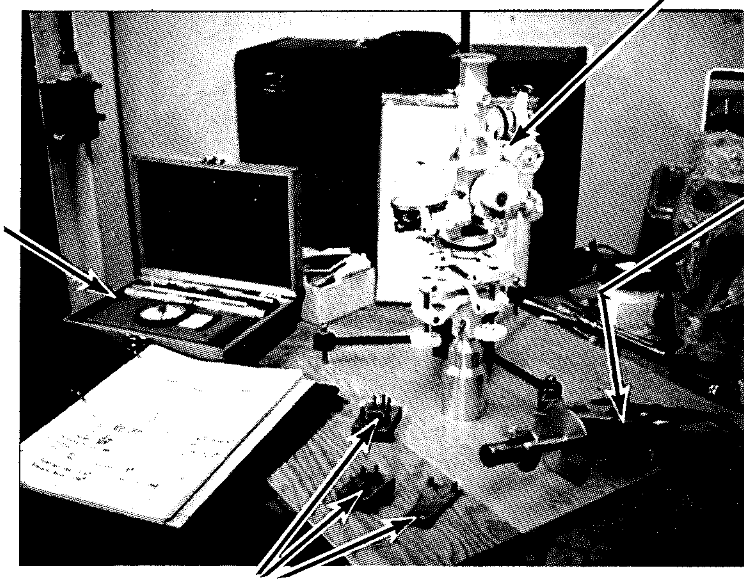


Figure 2. Functional Test Equipment

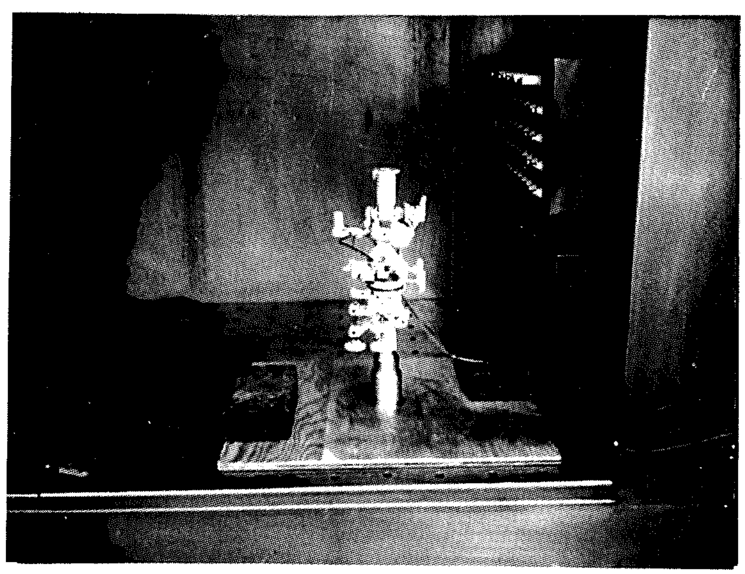


Figure 3. Aiming Mechanism Setup in Oven for High Temperature Test.

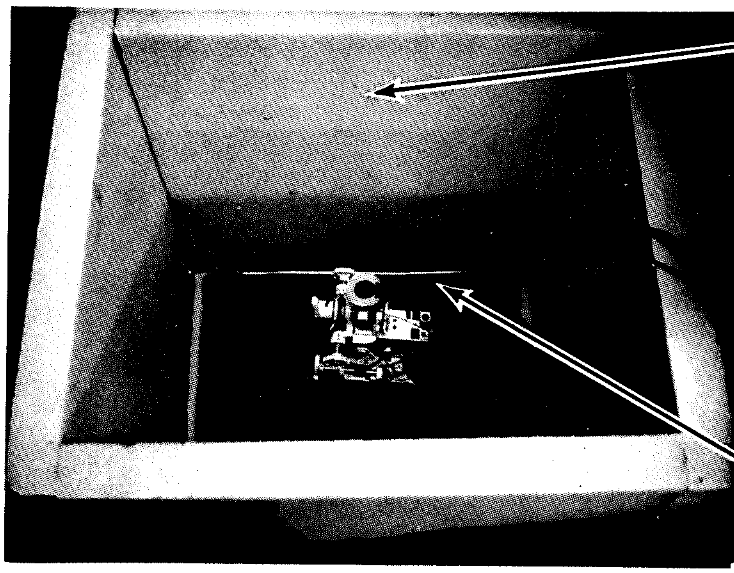


Figure 4. Aiming Mechanism Setup in Low Temperature Test Cell (Cover Removed).

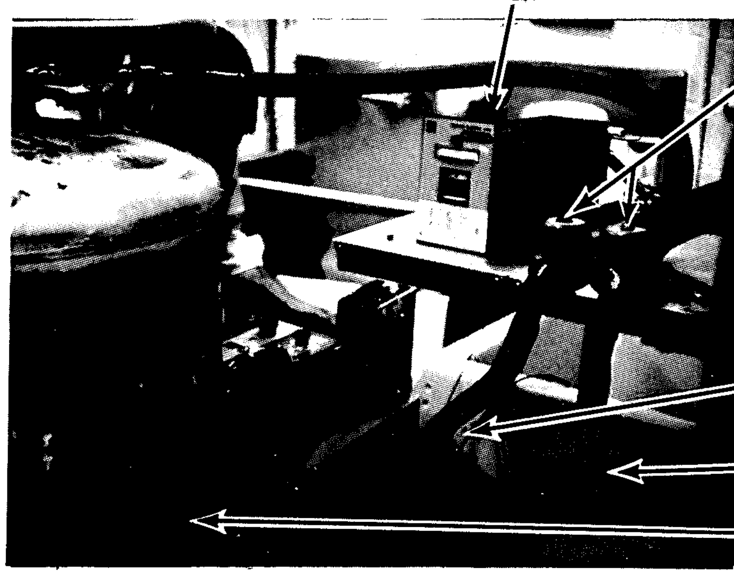


Figure 5. Low Temperature Test Support Equipment.

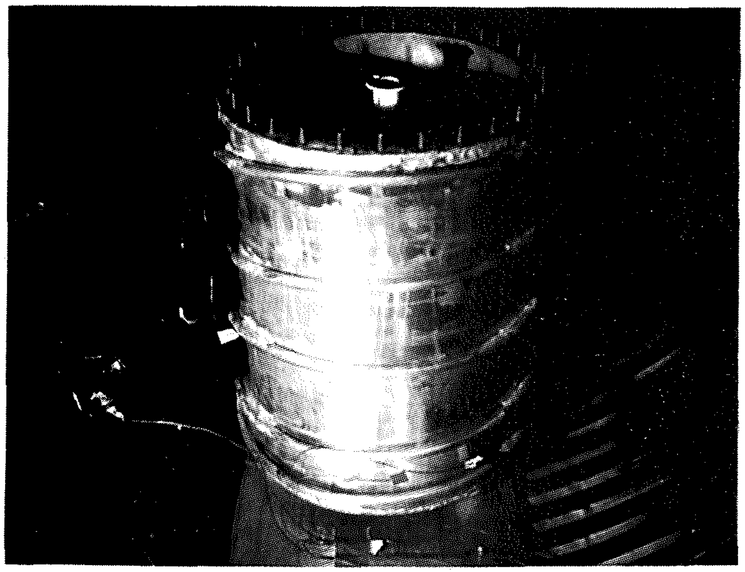


Figure 6. Aiming Mechanism Mounted in Cold Wall Container.

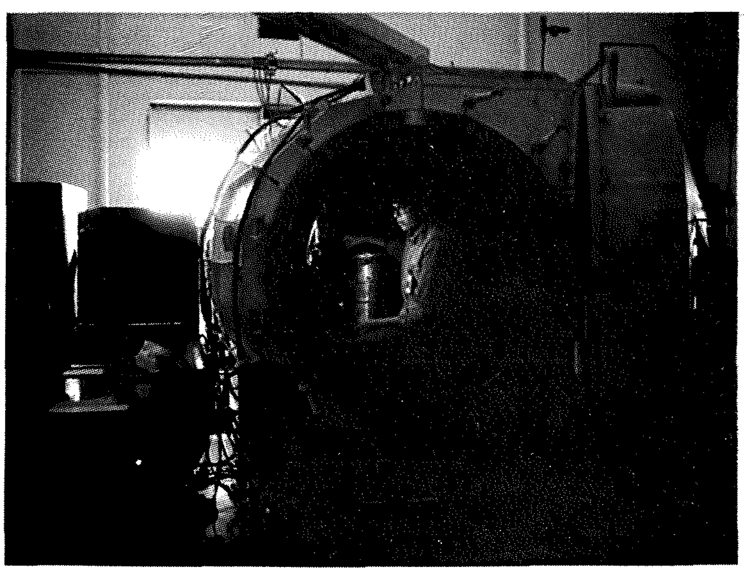


Figure 7. Aiming Mechanism and Cold Wall Set Up in 4 x 8 Vacuum Chamber.

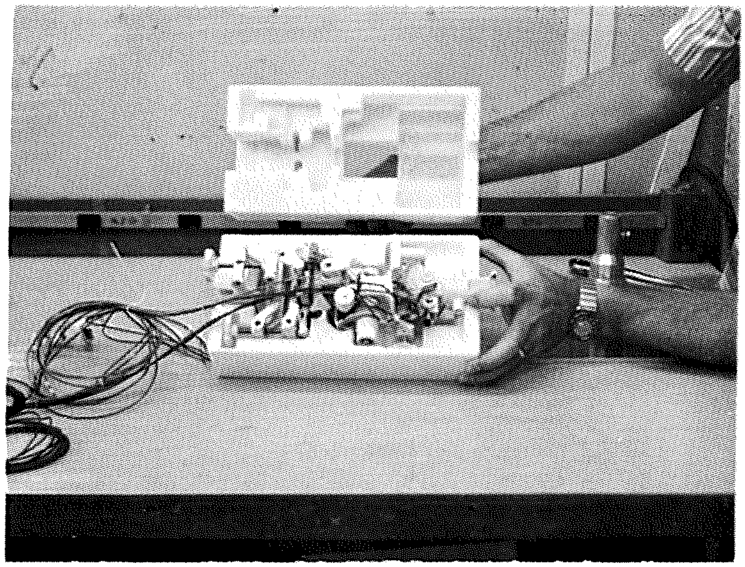


Figure 8. Aiming Mechanism Mounted in Foam Packing Prior to Placing it in its Container.

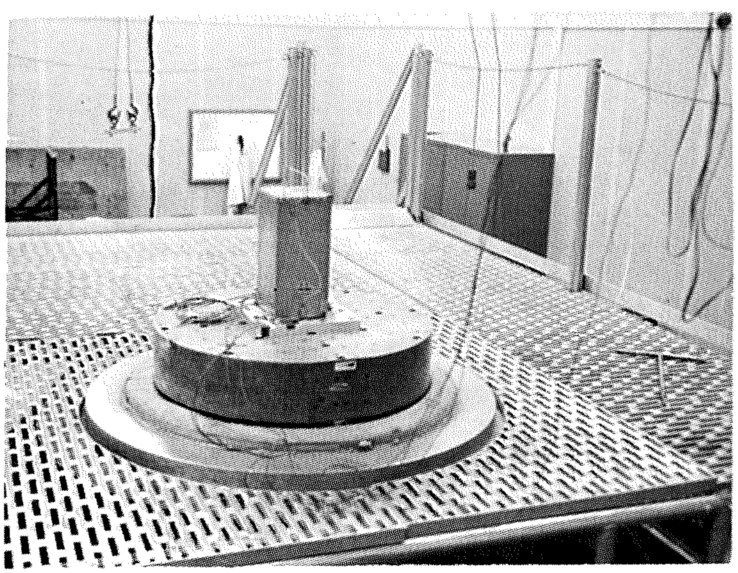


Figure 9. Aiming Mechanism and Container Mounted to Shaker Head for Vibration Testing.

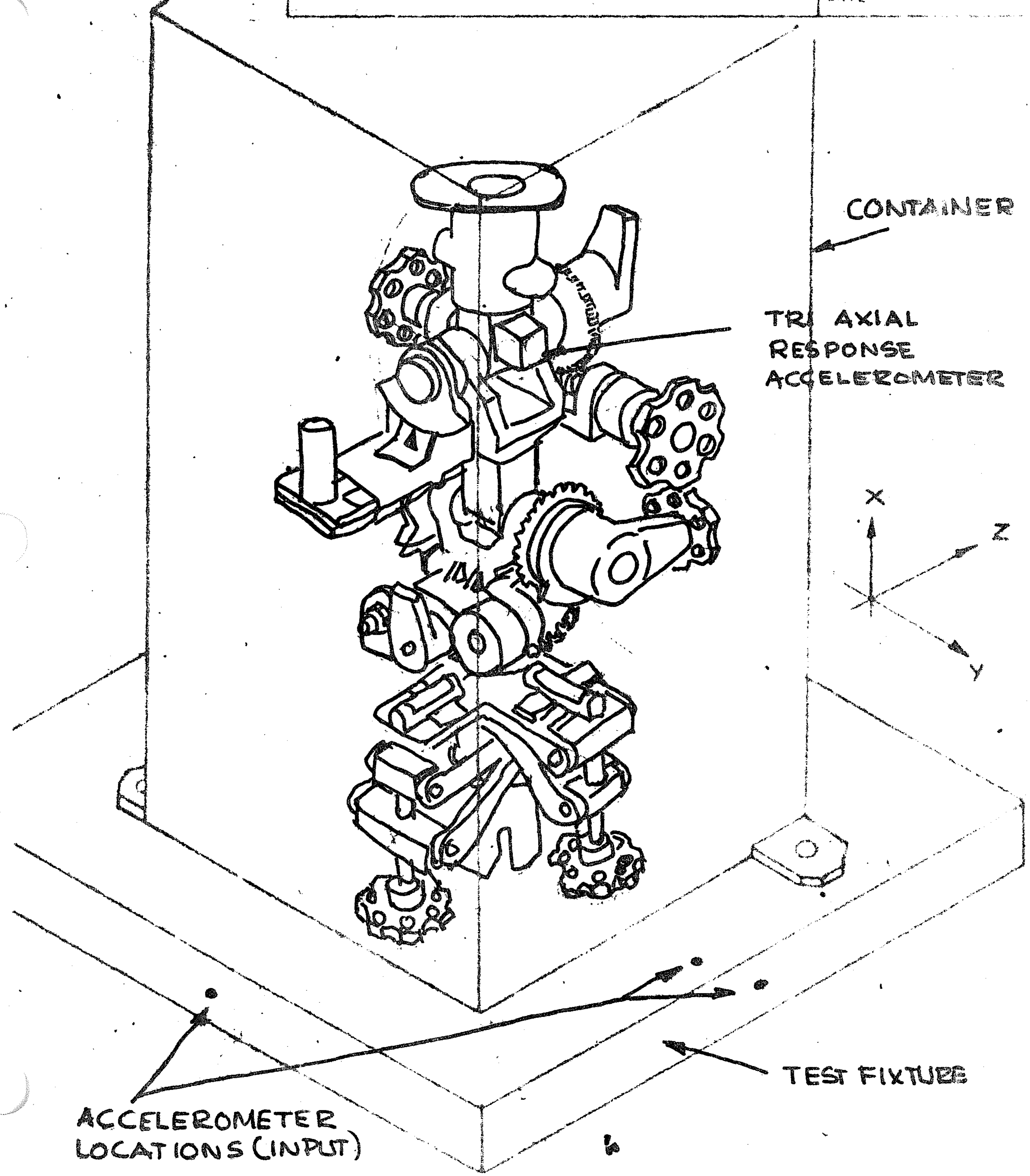
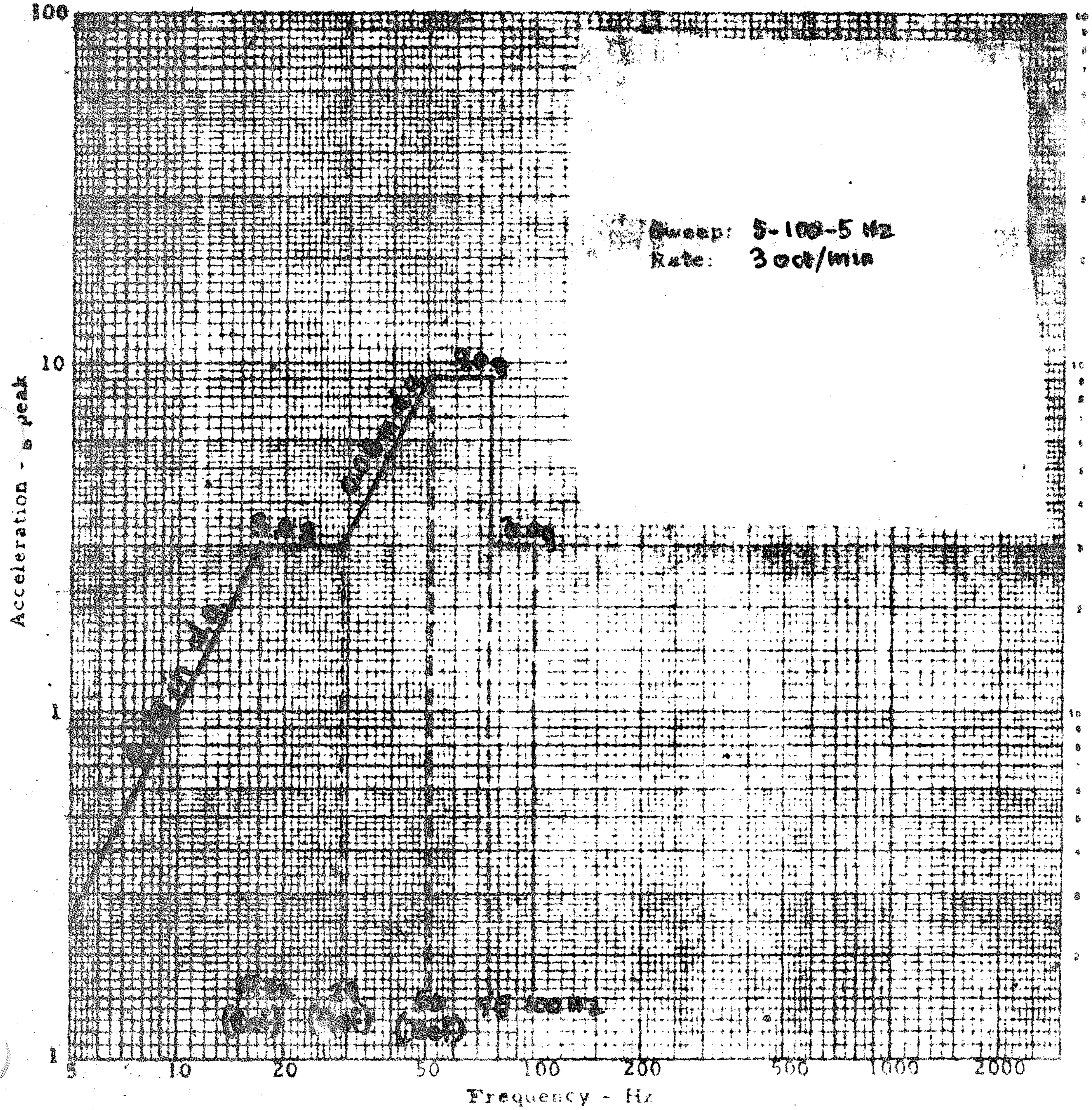

CONTAINER
TRI AXIAL RESPONSE ACCELEROMETER
X
Z
Y
TEST FIXTURE
ACCELEROMETER LOCATIONS (INPUT)

FIGURE 10

Sinusoidal Vibration X-AXIS



440-8 A

Figure 11

[illegible] Z & Y AXIS

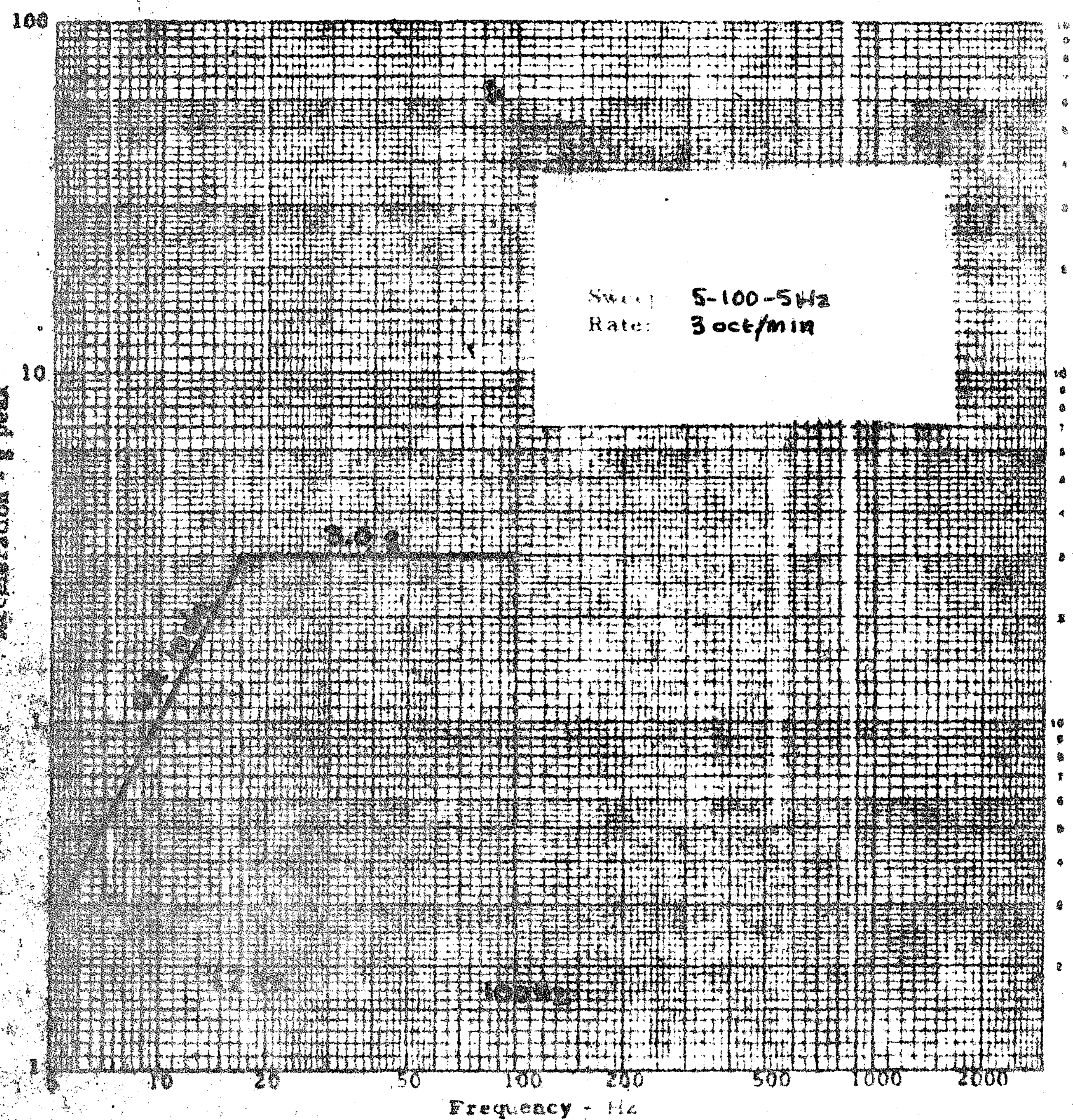
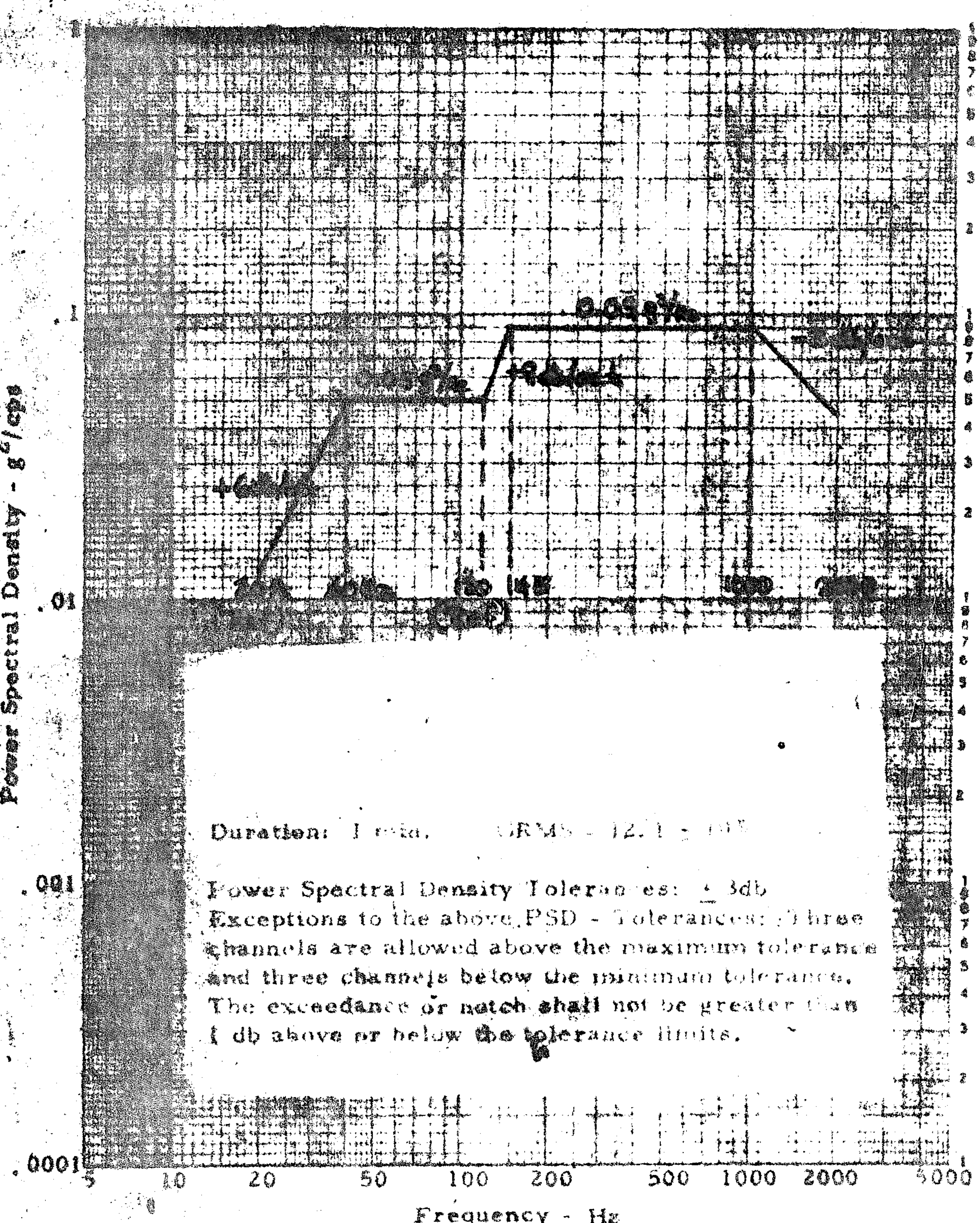


Figure 12

440-8 A

Earth Launch Boost Random Vibration Spectrum

X-Axis



Duration: 1 min. GRMS = 12.1

Power Spectral Density Tolerances: ± 3db
Exceptions to the above PSD - Tolerances: Three channels are allowed above the maximum tolerance and three channels below the minimum tolerance. The exceedance or notch shall not be greater than 1 db above or below the tolerance limits.

Earth Launch Boost Random Vibration Spectrum

Y-Axis

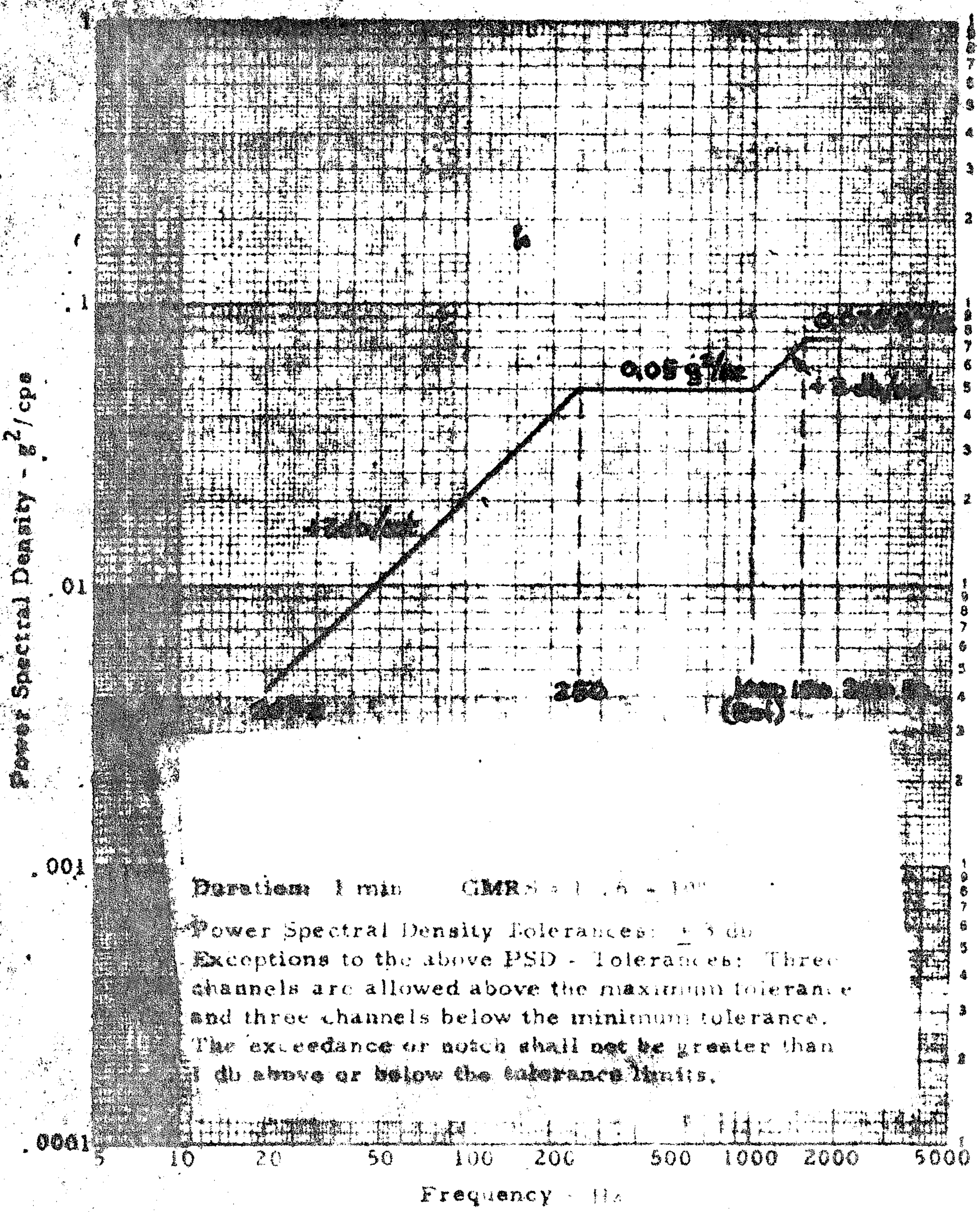


Figure 14

Earth Launch Boost Random Vibration Spectrum

Z- Axis

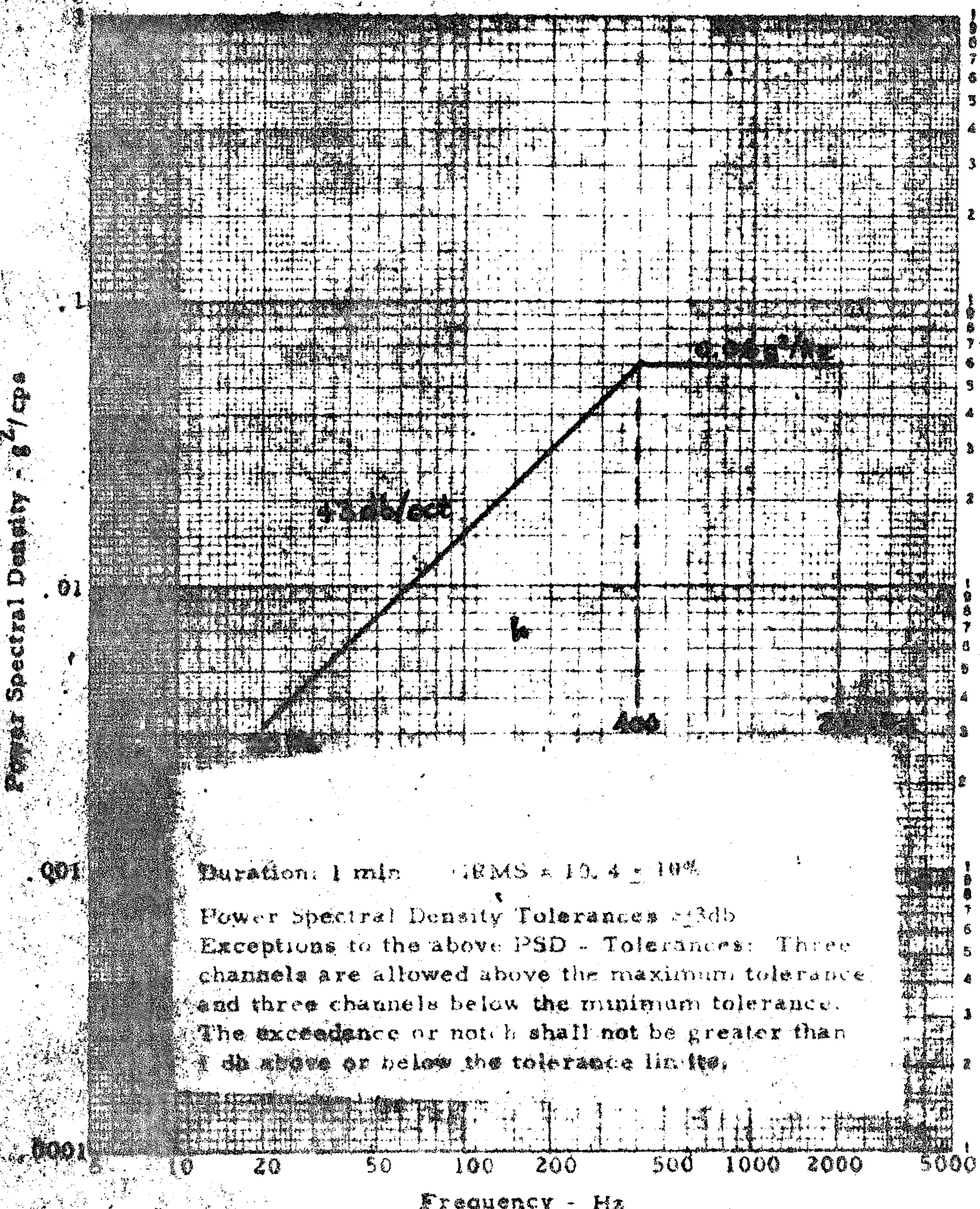


Figure 15

Lunar Descent Random Vibration Spectrum

X-AXIS

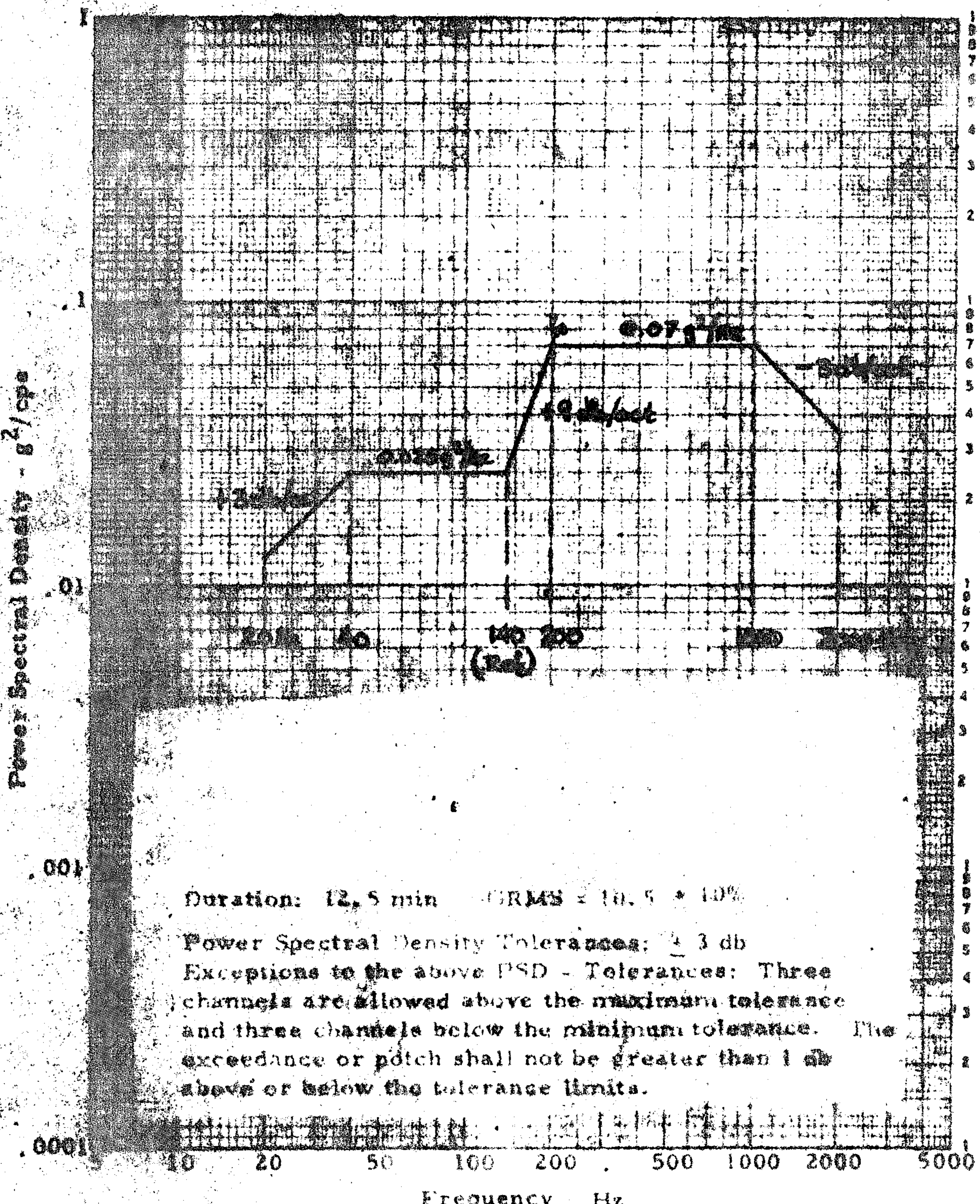
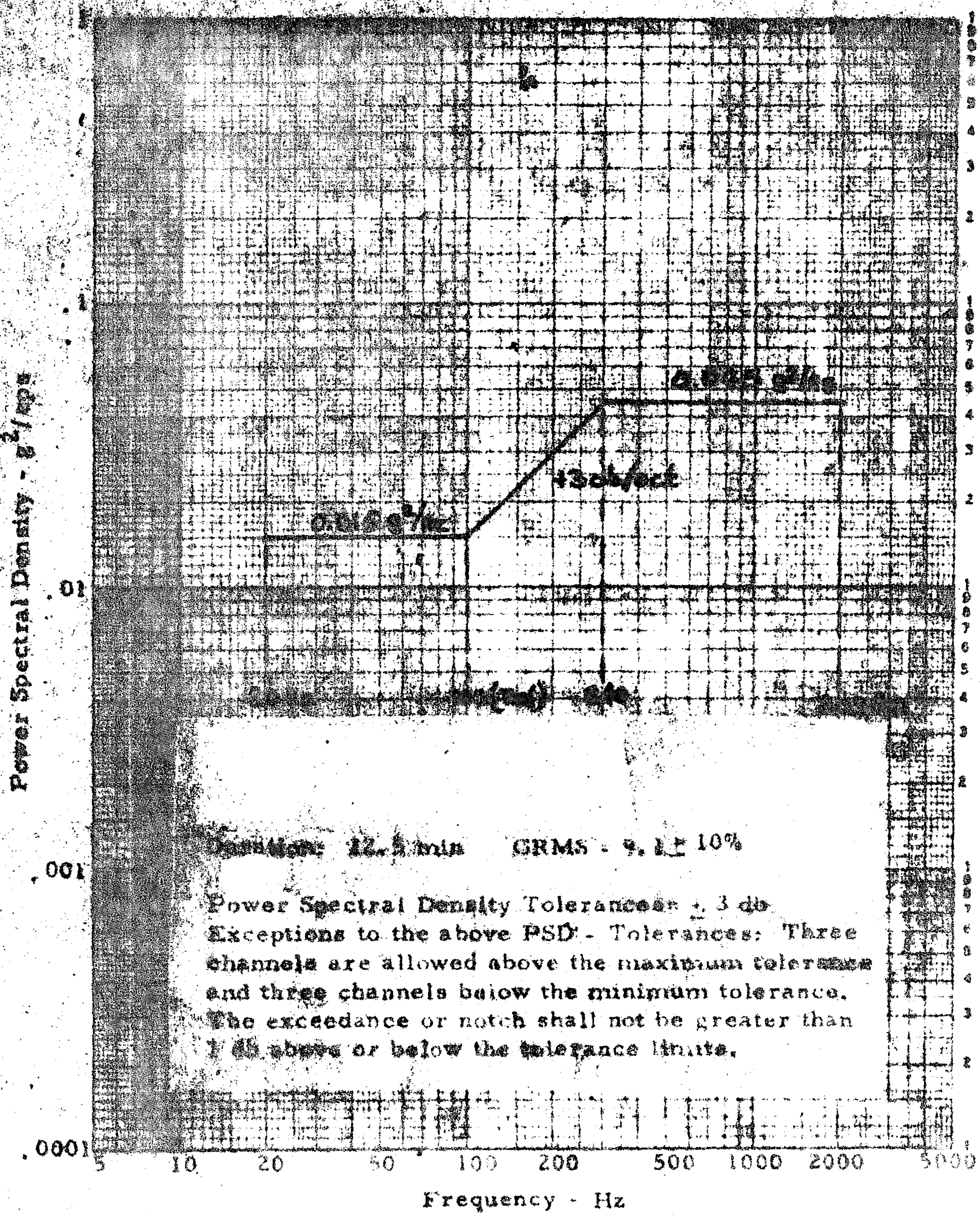


Figure 16

Lunar Descent Random Vibration Spectrum

Y-Axis



Figure

Lunar Descent Random Vibration Spectrum

Z- Axis

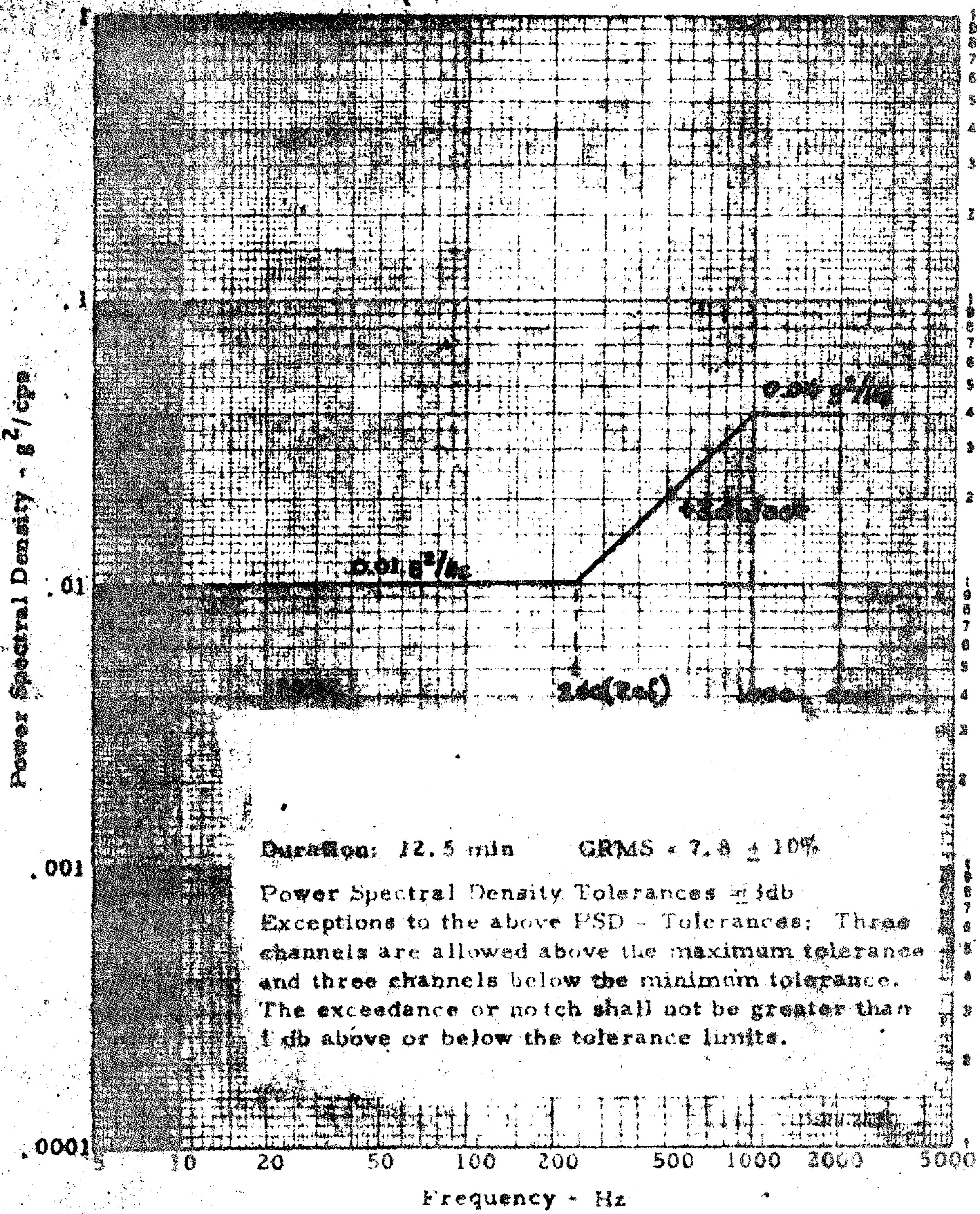


Figure [illegible]

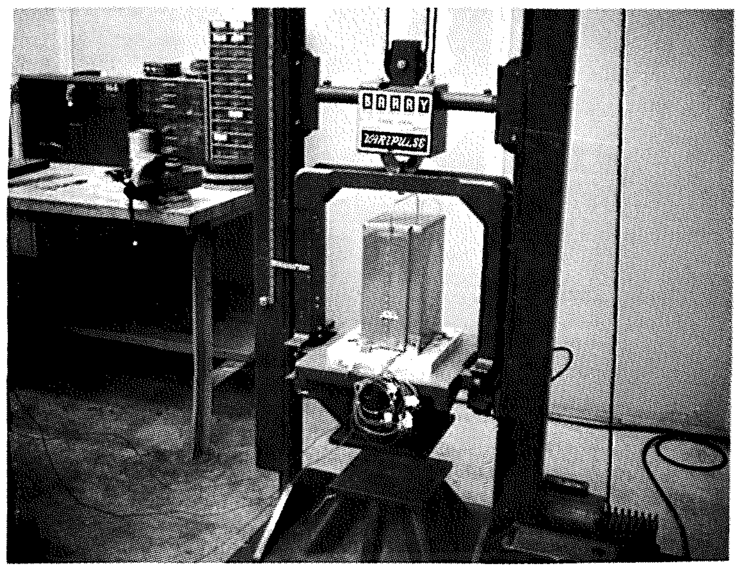


Figure 19. Aiming Mechanism and Container Mounted to Shock Generator.