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(Ground Test and Flight)

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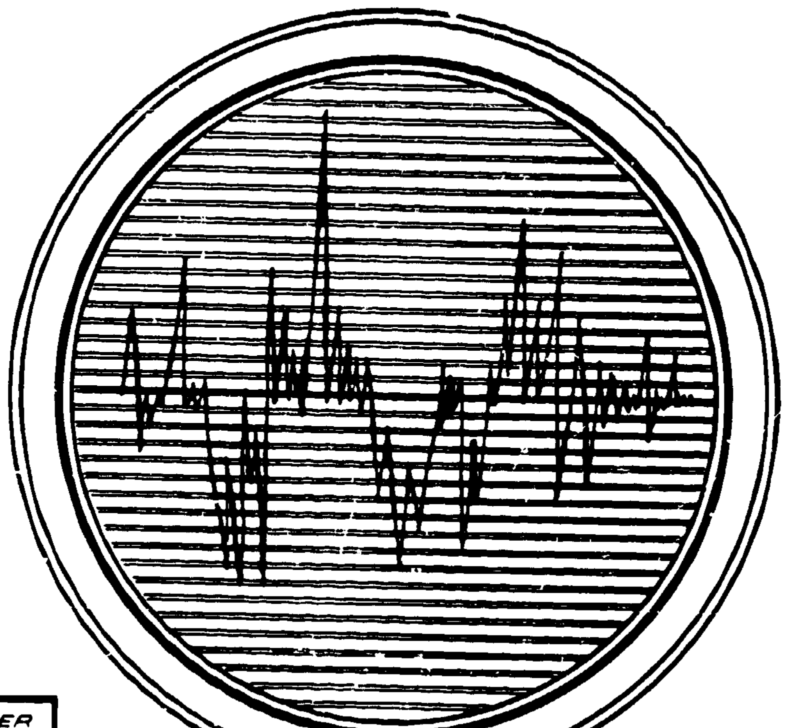

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for

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

FINAL REPORT

For

Aerospace Systems Pyrotechnic Shock Data (Ground Test and Flight)

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FOREWORD

The Martin Marietta Corporation, Denver Division performed a contract for the Goddard Spaceflight Center entitled "Aerospace Systems Pyrotechnic Shock Data (Ground Test and Flight)". This contract involved compilation and analysis of available industry wide pyrotechnic shock data. A total of 30 companies contributed. Because of the large volume of data available from Lockheed Missiles and Space Company, they were awarded a subcontract by the Martin Marietta Corporation to compile and analyze their data which are contained in Volumes IV and V. The results of these analyses have been included in the discussion contained in the summary document, Volume I. In addition, these analyses were considered in the preparation of the Design Guidelines Document, Volume VI.

SECTION NO. II.C

REPORT NO. 1315 AND 1336

SUBJECT:

PIN ACTUATORS

SECTION II.C

SUMMARY

Contained within this section are two reports which deal with pin puller shock. Report No. 1315 discusses qualification of a sub-satellite for both booster separation and sub-satellite pin puller separation. Dual pin pullers at each sub-satellite mounting lug provided the necessary overtest for qualification.

Report No. 1336 deals with pin puller tests which were conducted to test various isolation methods in an effort to reduce the shock environment at the Velocity Meter Accelerometer created by the nearby Horizon Sensor Bar Pin Puller. A number of techniques were devised to reduce the shock at the pin puller. Chief among them were: isolating silicon rubber washers, an energy absorbing snubber, and a force limiting spring bracket. The most successful method of shock reduction (factor of 10 reduction as measured at the velocity meter) was achieved with the force limiting bracket. In addition to the significant shock reduction, the bracket was simple to fabricate, easy to install, and maintained the necessary structural rigidity of the pin puller installation.

Also included in the two reports are a practical application of attenuation curves to predict peak g shock and a study of the repeatability of the bracket shock mount.

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SECTION NO. II.C.1

REPORT NO. 1315

SUBJECT:

QUALIFICATION OF A SUB-SATELLITE
FOR PYRO SHOCK WITH PIN PULLERS

SECTION II.C.1

SUMMARY

The intent of these tests was to qualify a sub-satellite for pyro shock which originates from the booster separation event as well as a sub-satellite pin puller event.

This was accomplished by attaching a dual set of pin pullers at each point where the sub-satellite attached to main structure. The resultant shock levels at reference measurements on the sub-satellite structure were compared to predicted booster separation shock levels.

A factor of 3.3 over test was achieved with the pin puller shock. Thus the test constituted qualification of the sub-satellite for the booster separation event. It also constituted qualification of the sub-satellite for the pin puller event as two pin pullers were used in place of the required one for flight vehicles.

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II.C.1.1 INTRODUCTION

This report documented the method of pyro shock qualifying a sub-satellite which is located on the aft rack for the booster separation event and pin puller event.

The test shock environment was created by pin pullers which were located in pairs at the four mounting lugs near the normal pin puller locations. Pin pullers were used to qualify the sub-satellite for booster separation because the shock environment from the pin puller event (sub-satellite separation) was thought to be higher than the environment from booster separation. To verify this, the booster separation peak g shock level at reference points on the sub-satellite was established using the shock attenuation curve for booster adapter separation joints. This peak g shock level was then reduced to account for the transmission loss across the lug pin joints. The transmission was determined from the measurements taken at either side of the pin joint during the pin puller pyro test.

The sub-satellite was then subjected to the shock of the eight pin pullers. All pin pullers were simultaneously fired from the same reference signal. Shock levels from accelerometers mounted on the sub-satellite structure reference points and other locations on nearby structure were then compared to the predicted shock levels from booster separation to establish qualification.

II.C.1.2 DISCUSSION AND ANALYSIS

II.C.1.2.1 Test Configuration and Instrumentation

The sub-satellite was suspended by bungee cords for this pyro shock test. Two pin pullers were attached to each set of angle brackets as shown in Detail 2 of Figure II.C.1.1. The angle brackets were bolted solidly to the four mounting lugs.

The actual flight configuration of the sub-satellite is shown in Figure II.C.1.2.

The accelerometers were located in the positions shown in Figure II.C.1.1 and as indicated in Table II.C.1.1. Accelerometers 1, 2 and 7, located twelve inches from the lugs on solid structure, were the refrence measurements.

II.C.1.2.2 Test Results

Results are presented in the form of oscillograms in Figure II.C.1.4. A summary of peak g levels is presented in Table II.C.1.1. The sub-satellite was inspected following the test and no structural or equipment failures were noted.

II.C.1.2.3 Analysis

The distance from the separation joint to the closest lug of the sub-satellite was 48 inches. The closest reference measurement at which the shock levels were compared was 12 inches inboard the sub-satellite from the lug (accelerometer 7, Figure II.C.1.1). Thus the total distance from the separation joint to the nearest reference measurement was 60 inches. At 60 inches from the separation joint, the booster adapter attenuation curve of Figure II.C.1.3 predicts a peak g level of 130 g's. To determine the predicted peak g shock level on the sub-satellite at the nearest reference point due to booster separation, it was first necessary to determine the transmission loss across the lug pin joints. This was accomplished during the test by locating accelerometers immediately on either side of the pin joint and comparing the measured pin puller shock at these two locations. Since the accelerometers were located very close to each other, distance attenuation was ignored and the ratio of the two shock levels yields the transmission.

Table II.C.1.1 indicates a peak g reading on the separation joint side of the pin joint of 10,600 g's (accelerometer 10) and a peak g reading of 732 g's (accelerometer 9) on the sub-satellite side of the pin joint.

The transmission is: 732/10,600 = 7 percent.

Thus the expected peak g shock level from booster separation at the nearest reference accelerometer location would be .07 x 430 = 30 g's. It was then necessary to compare this estimated booster separation peak g level with the actual shock level which was obtained at the reference locations during the pin puller shock to determine if the sub-satellite was qualified to sufficiently high levels. Table II.C.1.1 indicates that the peak g levels at measurement locations 1, 2 and 7, the reference locations were 361, 101 and 270 g's respectively.

Thus, using the most conservative value, the shock level from the pin puller test was a factor of 101/30 = 3.3 times higher, a sufficient overtest.

II.C.1.3 CONCLUSIONS

The pin puller test constituted qualification of the subsatellite for the booster separation event. The test also constituted qualification of the sub-satellite for the pin puller event since two pin pullers (as compared to only one in the flight configuration) were used at each location. (The squib grain size of the test pin pullers and the flight pin pullers was equivalent.)

TABLE II.C.1.1

ACCELEROMETER LOCATIONS AND PEAK G READINGS

Accelerometer No.	Direction	Location	Distance to nearest Shock Source (inches)	Peak G Reading
1	Z	Motor mount	13	361
2	Y	Motor mount	13	101
3	Z	Motor mount	12	63
4	[illegible]	Motor mount	12	105
5	Y	Normal to damper	17	49
6	Y	Normal to damper	27	37
7	Y	12 inches above lug	13	270
8	X	Just above lug	2	No data
9	Y	Just above lug	2	732
10	Y	On pin puller angle bracket	1	10,600
11	Z	On pin puller angle bracket	1	No data

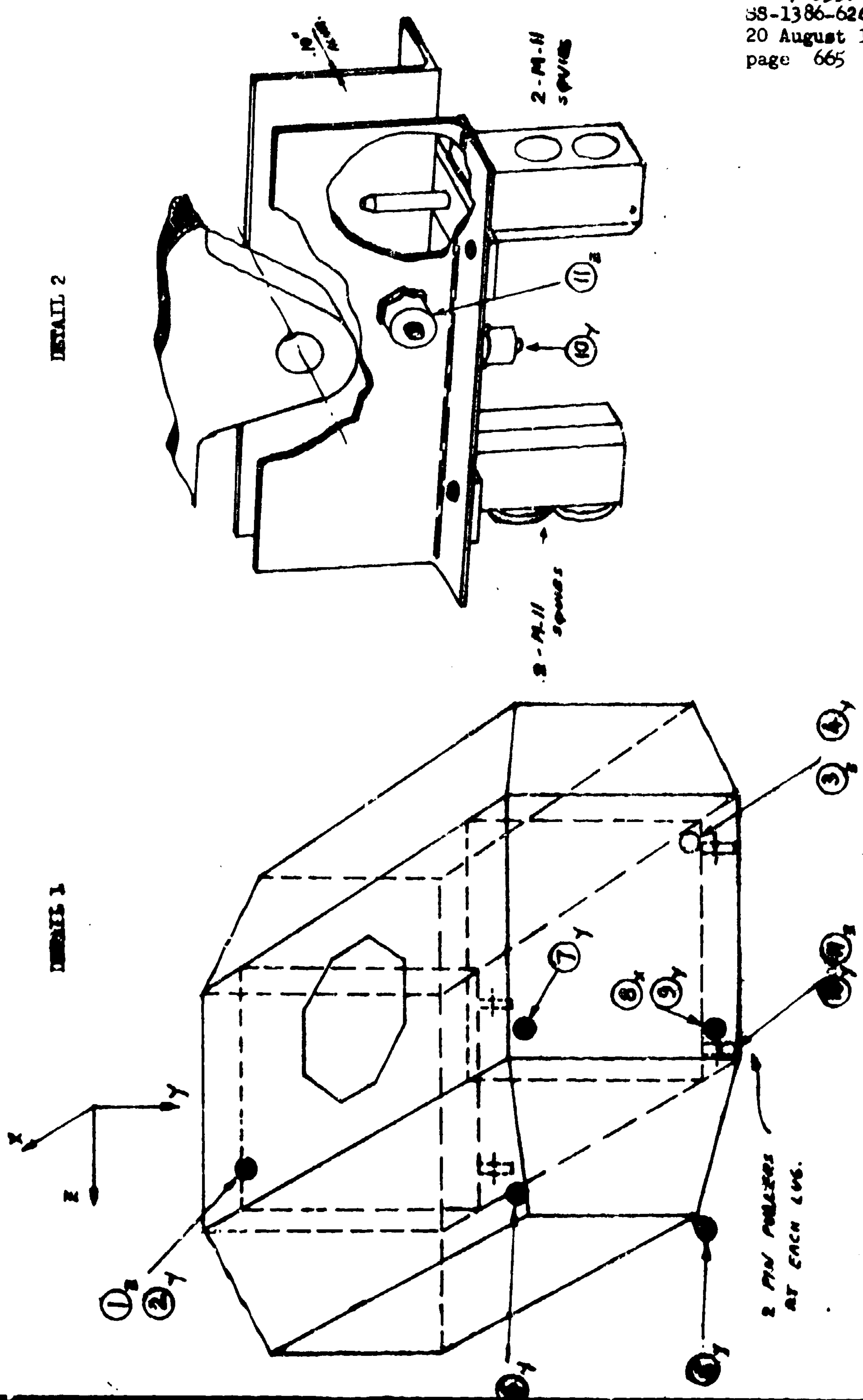


Figure II.C.1.1 TEST CONFIGURATION AND INSTRUMENTATION

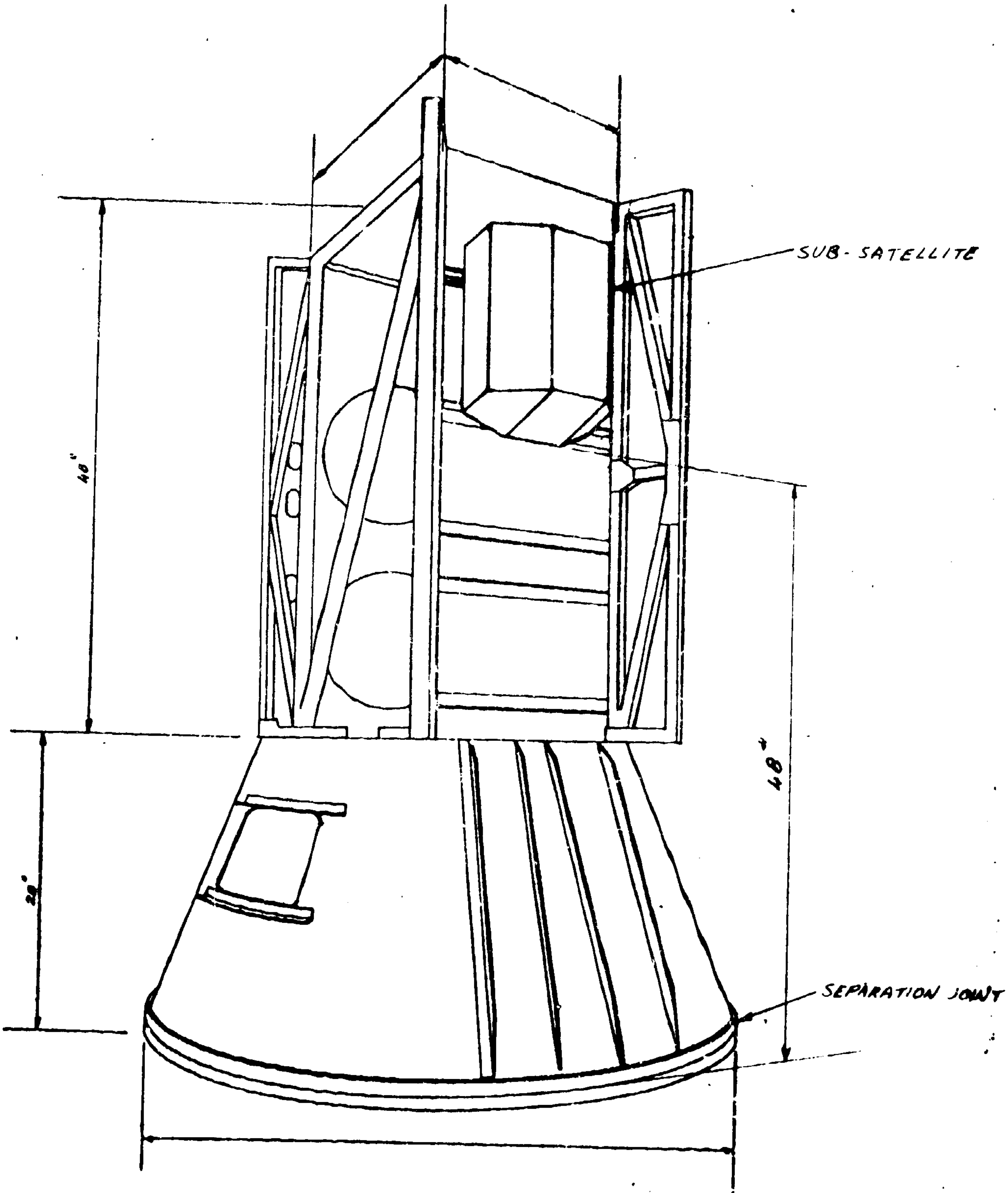


Figure II.C.1.2 FLIGHT CONFIGURATION

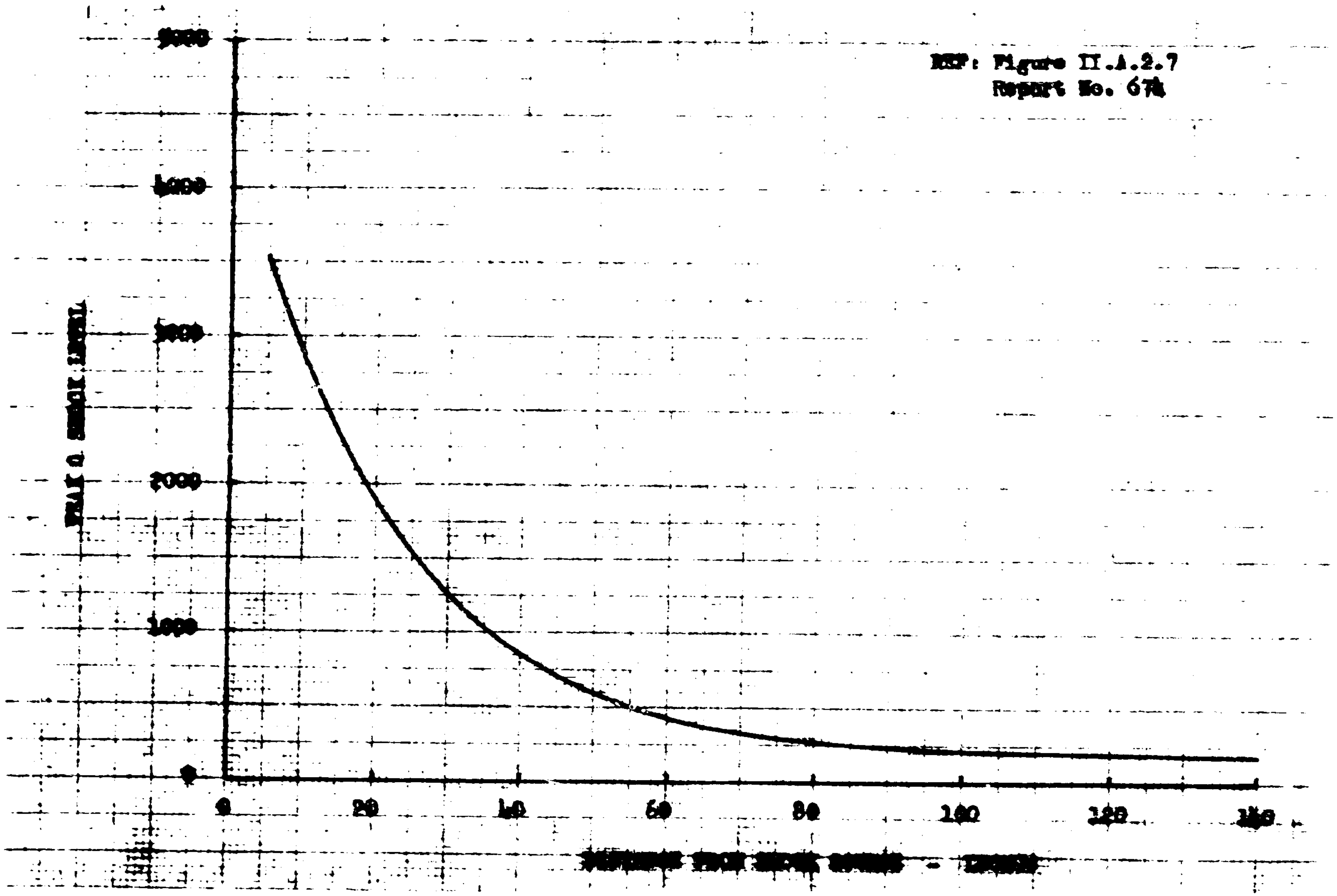
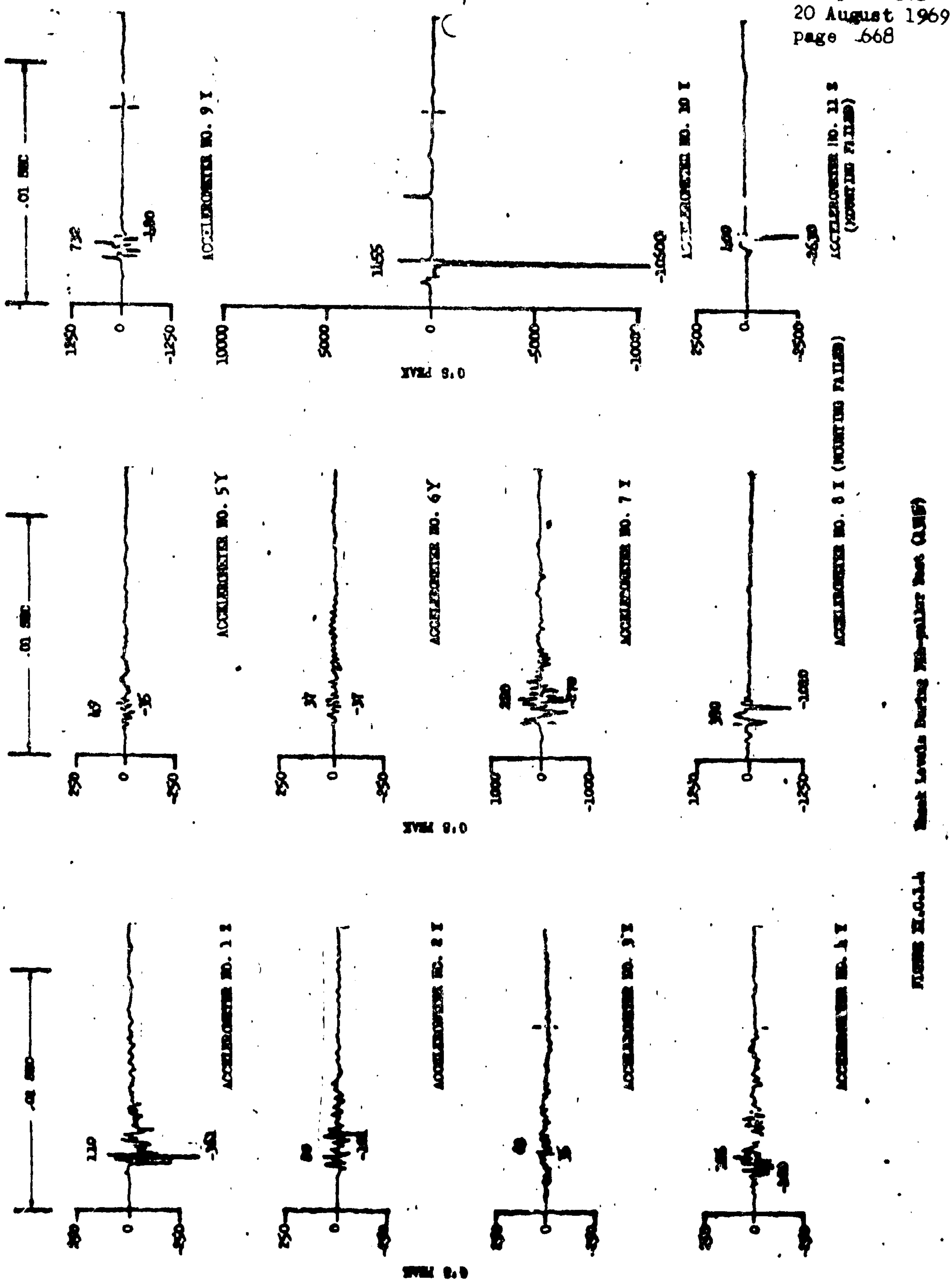


Figure II.C.I.3 BOOSTER SEPARATION PEAK G ATTENUATION CURVE


.01 SEC
ACCELEROMETER NO. 9 X
ACCELEROMETER NO. 10 X
ACCELEROMETER NO. 5Y
ACCELEROMETER NO. 6Y
ACCELEROMETER NO. 7 X

SECTION NO. II.C.2

REPORT NO. 1336

SUBJECT:

PIN PULLER ISOLATION STUDY

SECTION II.C.2

SUMMARY

The pin puller tests were conducted with the intent of reducing the shock environment at the Velocity Meter

During the study, three methods of isolation were attempted. In the first method, silicon rubber washers were placed between the pin puller and its mounting location on the Guidance Module. Although early development tests indicated a good reduction could be obtained by this method, later tests at the SCTB facility did not bear this out. The shock was reduced by only a factor of 4 at the Velocity Meter in the Y axis. This factor is an average over the frequency range of 100 to 2500 Hz. In addition to the poor shock reduction, the silicon washer arrangement reduced the structural rigidity of the pin puller installation and was difficult to install correctly.

In the second attempt, a snubber was designed to lessen the pin impact by slowing the pin at the end of its travel with a series of copper washers encased in a housing. Very little shock reduction was achieved with the snubber alone . (Average reduction was a factor of 3.4 at the Velocity Meter in the Y direction.) Silicone rubber isolators, similar to those installed in the SCTB test, were installed in an attempt to gain the needed shock reduction. The shock was reduced significantly (by a factor of 10.5 at the Velocity Meter Y axis measurement location) however the installation was much too flimsy and it was decided to develop another method of shock reduction.

The final, and most successful method of shock reduction was achieved with a bracket isolator. Not only was this configuration easy to install, it maintained the needed structural rigidity and reduced the shock considerably at all locations. Typical of the shock reduction was the 10:1 reduction at the Velocity Meter Y axis location. This kind of shock reduction was obtained consistently in a series of seven demonstration tests.

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SECTION II.C.2

II.C.2.1 INTRODUCTION

This report is the result of a study which was undertaken to determine the detrimental effects of pin puller pyro shock on the Digital Velocity Meter. Subsequently a method was sought to isolate the shock at its source; the horizon sensor bar pin puller. This pin puller is located on the same structure and just a few inches distant from the Velocity Meter. When the pin puller was activated, the resultant shock transmitted through the common mounting structure and disrupted the Velocity Meter counting mechanism. The result was a loss of pulse counts and a bias in the counting rate. This in turn caused event sequencing (which was controlled by the Velocity Meter) to be displaced in time.

Basically three methods of shock isolation were explored here: Figure II.C.2.1 illustrates the first configuration which was tested for its isolating properties in Tests 2 and 6 at SCTB. Silicon rubber isolators were inserted at the pin puller base at the mounting holes (Detail B).

The second isolating mechanism, displayed in Figure II.C.2.1, Detail B, is referred to as a snubber. The intent here was to dissipate the shock by gradually arresting the pin before impact. To accomplish this, a snubber which contained alternating large and small soft copper washers, was installed to absorb the energy of the pin by deformation (Test 15). This configuration was also tested with the silicon rubber washers inserted at the base of the pin puller (Test 13). These tests were conducted at the Sunnyvale plant.

The third isolation technique is also illustrated in Figure II.C.2.1. The pin puller is mounted on an aluminum bracket. The bracket deflects to allow cancellation of the pin puller momentum. Test 27 was one of seven tests conducted at Sunnyvale to collect information on the final bracket isolator configuration. Tests 2, 6A and 7 were conducted to collect data from hard mounted pin puller firings which could be used as a basis for comparison. A summary of the pin puller tests is presented in Table II.C.2.3.

II.C.2.2 DISCUSSION AND ANALYSIS

II.C.2.2.1 Test Set-Up and Instrumentation

The pin puller and Velocity Meter both mount on the Guidance Module which, in turn, mounts in the forward rack as shown in Figure II.C.2.2. The forward rack and guidance module were equipped with flight-type hardware to provide typical load and dynamic simulation of a flight vehicle installation.

Details of the pin puller are shown in Figure II.C.2.1. When the squibs are ignited, gas is created which expands through the pin puller port-holes and forces the pin upward against its stop. The major shock is created when the pin strikes the stop (5000 g's, 0 - peak, at 5000 Hz).

Instrumentation locations are shown in Figure II.C.2.2 for both the SCTB tests and the Bldg. 102, Sunnyvale tests. A breakdown of the instrumentation locations and accelerometer types is given in Tables II.C.2.1 and II.C.2.2. A schematic of the data acquisition system is shown in Section V.

II.C.2.2.2 Test Conditions and Results

II.C.2.2.2.1 SCTB Tests

Test 2 - Test 2 was conducted at Santa Cruz Test Base. The purpose of this test and Test 1 was to collect data which could be used as a basis for comparison with later tests in which the pin puller was to be isolated and to determine the shock environment at the Velocity Meter to evaluate the relative severity of these shock levels with those from other pyro events such as shroud separation and fairing ejection. The pin puller was hard-mounted in the normal fashion to the Guidance Module casting as shown in Detail D of Figure II.C.2.2. The torque tube, which is controlled by a damped spring mechanism, was rotated to bear against the pin puller pin as it does in flight. The cocked position, which is illustrated in Detail C of Figure II.C.2.2, results in a side load on the pin. This side load was applied in all tests. The pendulum output of the Velocity Meter was monitored to record any anomalous pulsing resulting from the shock. The test set-up also included a pulse counter/printer to record the pulse periods and determine any bias shift.

The results of this test are presented in Figures II.C.2.6 to II.C.2.12 as real time oscillograms and shock spectra at a Q of 25. Peak g levels from the oscillograms of this test are summarized in Table II.C.2.4. The pendulum output recording indicated that 13 pulses were missed beginning at the time the pin puller fired. The bias shift was negligible and within specification.

Test 6 - Prior to Test 6 and concurrent with Test 2, various schemes for pin puller isolation were under investigation at another test location. Satisfactory results had been obtained by mounting the pin puller with a set of silicon rubber isolators. This isolation scheme is illustrated in Detail B of Figure II.C.2.1. The smubber at the top of the pin puller was not used in this scheme. A compression of the bottom washers of 10 percent had been determined to result in the optimum shock reduction.

Five tests were conducted at SCTB using this configuration. Test 6 was selected for presentation in this report. The results of Test 6 agree well with those of the other tests of this shock isolator configuration.

Results of the test are presented in the form of real time oscillograms and shock spectra in Figures II.C.2.13 to II.C.2.20. A comparison is made with Test 2, the hard-mount test, in Figures II.C.2.21 to II.C.2.24 and Figures II.C.2.54 to II.C.2.56. A summary of the peak g readings from the oscillograms is presented in Table II.C.2.4. The pendulum output recording indicated that an average of 13 pulses were missed for Tests 5, 6 and 7. The bias shift was again within specification.

Test 6 shock spectra from two representative locations have been compared in Figures II.C.2.3 and II.C.2.4 to shock spectra from a hard-mounted pin puller test in which measurements were made in the same locations by octave bands. The isolator effectiveness was determined by ratioing the hard-mounted pin puller shock spectrum to the Test 6 spectra. Figures II.C.2.3 and II.C.2.4 illustrate that this configuration was ineffective in reducing the shock levels in most frequency bands. Although studies and tests were conducted to determine the inconsistency between these tests and the isolator development tests, which showed a significant reduction, no satisfactory conclusion was reached. Rather than embark on a new series of tests of variations of the same isolation scheme, the decision was made to develop a more effective and a more fool-proof isolation method.

II.C.2.2.2.2 Sunnyvale Isolator Tests

A large number of isolation schemes were suggested. Two of these were selected for further development. They are shown in Details B and C of Figure II.C.2.1. The first scheme, the snubber of Detail B, consisted of a series of alternating large and small diameter soft copper washers which were contained in a steel cap. The steel cap was fixed to the end of the pin puller and adjusted so that the pin penetrated as many of the washers as possible without bottoming. The object was to reduce the shock by absorbing the momentum of the pin gradually.

The snubber tests were conducted with and without the silicone washers which had been previously tested at SCTB (Tests 13 and 15 of this report, respectively).

The second scheme is illustrated in Detail C of Figure II.C.2.1 The bracket isolates the shock because it allows the pin puller body to move freely when it is fired. Thus the pin momentum is cancelled by the pin puller body momentum and very little shock is transferred through the bracket. The bracket allows the pin puller to move in translation and in three directions of rotation. At the same time it also provides the necessary structural rigidity to survive vehicle flight dynamic environments. This was demonstrated in a series of dynamic tests of the pin puller bracket assembly which simulated the vehicle dynamic environment.

To determine the proper dimensions, materials, etc., that had to be used to build a bracket which would allow the pin puller to cancel its own momentum with the least sacrifice in rigidity, a mathematical model of the pin puller and a computer program were developed. This program modeled the dynamics of the pin puller assembly. (Refer to Addendum of this report for application of the model and program to this particular problem as well as other applications)

A series of development tests resulted in an effective bracket which was demonstrated in seven tests. One of these tests, Test 26, is presented in this report.

Prior to conducting tests of the bracket it was again necessary to conduct baseline firings with hard-mounted pin pullers which could be used to compare the data from the bracket tests to determine the bracket effectiveness.

At the time both ASI and M11 pin pullers were available for testing. M11 pin pullers had been used in the flight configuration but there was some evidence that the ASI pin puller might yield lower shock levels. This was based on the observation that ASI pin pullers did not deform the end plug as the M11 pin puller did (the pin impacts the end plug when it is fired). Thus it was deducted that the end velocity of the ASI pin must be less than that of the M11 pin and this could conceivably mean lower shock levels.

To verify this, tests were conducted at SCTB to determine the end velocity of the two pins of the M11 and ASI pin pullers. High speed photography was used to determine the velocity. At the same time, tests were conducted in Sunnyvale of both the hard-mounted ASI and M11 pin pullers. Tests 6A and 7 of this report are of the ASI and M11 hard-mounted pin pullers respectively.

Test 6A

This test established baseline data for the ASI pin puller. The feet of this pin puller were rotated 90 degrees from their normal position so that the pin puller could be mounted directly to the Guidance Module.

The shock spectra and oscillograms from this test are shown in Figures II.C.2.25 to II.C.2.28 and are compared to the spectrums from the hard-mounted pin puller test, Test 7, in Figures II.C.2.33 to II.C.2.36. The comparison indicates that the shock from both pin pullers is very comparable. In addition, results from the pin velocity determination tests which were conducted at SCTB showed that the end velocity of the two pins was the same. Therefore, the ASI pin puller was not used in any subsequent testing.

Test 7

An M11 pin puller was hard-mounted in the normal fashion for this test. Shock spectra with oscillograms are presented in Figures II.C.2.29 to II.C.2.32. This data was compared with data from the isolator tests to determine isolator effectiveness.

Test 13

This was the first successful test of the snubber device illustrated in Figure II.C.2.1, Detail B. In addition to the snubber, the pin puller was mounted on one-half inch diameter, one-quarter inch thick silicon isolators.

Examination of the snubber after the test showed that the pin had penetrated most of the copper washers as desired. The results of this test are presented in Figures II.C.2.37 to II.C.2.40 in shock spectrums and oscillograms. The shock spectrums from this test are also compared to spectrums from Test 7, the baseline test, and Test 15, another snubber test without the silicon washers, in Figures II.C.2.45 to II.C.2.48.

A summary of peak g's from the oscillograms are presented in Table II.C.2.4. The effectiveness of this isolation method is indicated in Figures II.C.2.3 and II.C.2.4. These figures indicate that this isolator configuration was most effective of any of the isolator configurations tested in reducing the shock levels. The average reduction factor over the frequency spectrum, based on Test 7 of the hard-mounted M11 pin puller, was 5.2 for the pin puller Y axis measurement and 10.5 for the velocity meter Y axis measurement.

The snubber was not intended for use with the silicon isolators, but up to this test very little isolation had been achieved with the snubber alone. Even though Test 13 showed very good isolation, the snubber/isolator washer configuration was very flexible due to a combination of a heavy mass at the end of the pin puller and a flexible base. The assembly exhibited extreme susceptibility to vibrations such as occur during vehicle boost flight.

Test 15

In Test 13 the optimum copper washer arrangement had been devised which provided maximum pin penetration. Test 15 was conducted with the same copper washer arrangement to determine how much shock isolation could be gained by use of the snubber alone. The pin puller with snubber was hard-mounted to the module.

Shock spectra and oscillograms from this test are presented in Figures II.C.2.41 to II.C.2.44. The peak g's are summarized in Table II.C.2.4. In Figures II.C.2.45 to II.C.2.48, the shock spectra from this test are compared with the baseline test, Test 7, and the snubber/isolator washer test, Test 13. These figures indicate that the snubber by itself was not nearly as effective as the snubber with silicon washers in reducing the shock and that some measurements show almost no reduction in shock below the baseline test. Figures II.C.2.3 and II.C.2.4 show the isolator effectiveness by octave bands.
Tables II.C.2.5 and II.C.2.6 indicate that the average reduction factors for this configuration are 1.4 and 3.4 for the pin puller Y axis and Velocity Meter Y axis location, respectively.

Test 26

Test 26 was one of a series of seven demonstration tests of the bracket shock mount which is illustrated in Detail C of Figure II.C.2.1. This bracket had been developed in an earlier series of tests in which brackets of other dimensions were tested to determine the optimum configuration which would allow the necessary deflection when the pin puller was fired, yet maintain maximum structural rigidity. Ease of assembly was also an important factor of consideration in the design of the bracket isolator.

It was necessary to lengthen the pin puller pin slightly for these tests since the use of the bracket increased the distance between the pin puller and the module casting which also decreased the engagement length between the pin and the horizon sensor bar arm (see Detail C of Figure II.C.2.2).

Results of Test 26 are presented in Figures II.C.2.49 to II.C.2.53 in the form of shock spectra and real time oscillograms. Peak g's from the oscillograms are summarized in Table II.C.2.4. The pendulum output was monitored for this test. The pendulum output recording indicated that only 3.5 pulses were missed (compared to 13 pulses missed in earlier hard-mount and silicon washer isolator tests). Shock spectra from this test have been compared to spectra from baseline Test 7, the SCTB silicon washer isolator test, Test 6, and the SCTB baseline test, Test 2, in Figures II.C.2.53 to II.C.2.56. Figures II.C.2.3 and II.C.2.4 show that this configuration was very effective in reducing the shock. Tables II.C.2.5 and II.C.2.6 show the average reduction over the frequency spectrum to be a factor of 5.1 for the pin puller Y axis measurement and 10.1 for the velocity meter Y axis measurement. Thus the bracket isolator provided the necessary shock reduction with little or no sacrifice to structural rigidity.

The seven demonstration tests showed that the isolator bracket provided repeatable results. (See Figure II.C.2.5 for 99th percentile, 50th percentile, and maximum envelope shock spectra for each measurement locations.)

II.C.2.2.3 Data Analysis

Most analysis of the pin puller was accomplished by comparison of shock spectra. This is covered, where appropriate, in other sections of this report.

In Figures II.C.2.3 and II.C.2.4 the different isolators have been compared by means of an effectiveness ratio, which is the ratio of baseline test shock spectrum g response levels to shock spectrum g response levels from the isolator tests. The pin puller Y axis and Velocity Meter Y axis were selected to give an idea of the isolator effectiveness at the source and at the Velocity Meter. Figures II.C.2.3 and II.C.2.4 were derived, as shown in Tables II.C.2.5 and II.C.2.6, by averaging the 1/3 octave data into octave bands for the baseline test, Test 7, and the isolator tests, Tests 6, 13, 15 and 26. Since the Velocity Meter had internal resonances below 2500 cps, only the frequency range between 100 cps and 2500 cps was considered. The octave band response g levels from each of the isolator tests were then ratioed to the octave band g levels from Test 7, a baseline test, to determine the isolator effectiveness in each octave band. These values were then plotted in Figures II.C.2.3 and II.C.2.4. The octave band values were also averaged for each isolator test over the frequency spectrum and are presented in Tables II.C.2.5 and II.C.2.6.

Figure II.C.2.5 indicates the repeatibility of the seven bracket isolator demonstration tests. The maximum shock spectra are an envelope of the seven demonstration tests for each measurement location. The 99th and 50th percentile spectra are the result of a statistical analysis of the seven tests. The analysis assumed a log-normal distribution of the values since the measurements were found to correlate to the positive skew log-normal distribution.

II.C.2.3 CONCLUSIONS

The pin puller shock levels at the Velocity Meter were reduced on an average by more than a factor of 10 over the 100 to 2500 Hz range by the bracket isolator. The effect of the shock from the pin puller on the Velocity Meter was reduced sufficiently to allow operation of the Velocity Meter within specification. There is no sacrifice of structural rigidity.

The silicon washer isolators tested at SCTB did not exhibit the isolation properties which a similar isolator configuration had demonstrated in earlier tests.

Silicon rubber isolators were too flexible for the pin puller application to be used with confidence. This was especially obvious in the snubber/silicon washer configuration

The snubber did not significantly lower the shock levels unless it was used with the silicon rubber washers.

Results of pin velocity tests and pin puller firings indicated that the ASI and M11 pin pullers produce the same shock levels.

The bracket demonstration tests were very repeatable as illustrated by a statistical analysis of the seven demonstration tests.

TABLE II.C.2.1

ACCELEROMETERS AND LOCATIONS

SCTB TESTS 2 AND 6

Accelerometer No.	Box	Direction	Location	Distance to Shock Source (inches)	Accelerometer Type
A	Velocity meter	X	Box	9.0	GLENITE A314TM
B	Velocity meter	Y	Box	4.5	GLENITE A314TM
C 1	Velocity meter	Z	Box	4.5	GLENITE A314TM
D 1	Pin puller	Y	Frame	1.0	ENDEVCO 2225
E	Velocity meter electronics	X	Box	4.5	GLENITE A314TM
F 1	Velocity meter electronics	Y	Box	5.0	ENDEVCO 2225
F 2	Velocity meter electronics	Y	Box	5.7	ENDEVCO 2211
G	Statham bolt	X	Box	4.0	GLENITE A314TM
H	Module frame	X	Frame	11.0	GLENITE A314TM

TABLE II.C.[illegible]

ACCELEROMETERS AND [illegible]

SUNNYVALE TESTS 6A, 7, 13, [illegible], 26

Accelerometer No.	Box	Direction	Location	Distance to Shock Source (inches)	Accelerometer Type
A	Velocity meter	X	Box	9.[illegible]	ENDEVCO 2225
B	Velocity meter	Y	Box	4.5	ENDEVCO 2225
C 1	Velocity meter	Z	Box	4.5	ENDEVCO 2225
[illegible]	Pin puller	Y	Frame	1.0	ENDEVCO 2225
D 2	Pin puller	Y	Frame	1.0	ENDEVCO 2225

TABLE II.C.2.3

SUMMARY OF TESTS

Test No.	Explosive Size	Test Purpose	Shock Isolation
2	2 Gr. *	Development	None
6	2 Gr. *	Development	Silicon Washers
6A	2 Gr. *	Development	None, Baseline - AS1
7	2 Gr. *	Development	None, Baseline - MB1
1[illegible]	2 Gr. *	Development	Silicon Washers and Snubber
15	2 Gr. *	Development	Snubber
26	2 Gr. *	Development	Bracket

* 2 SQUIBS - 1.0 Gr. Explosive Each

TABLE II.C.2.4

OSCILLOGRAM PEAK G READINGS

ACCELEROMETER No.	SCTB 2	SCTB 6	Sunnyvale 6A	Sunnyvale 7	Sunnyvale 13	Sunnyvale 15	Sunnyvale 26
A	-	160	1050	830	30	60	117
B	595	442	550	566	110	190	150
C 1	344	410	700	664	100	100	115
D 1	6720	1555	-	-	375	700	745
D 2	-	-	2900	3460	-	-	-
E	700	520	-	-	-	-	-
F 1	5120	-	-	-	-	-	-
F 2	-	333	-	-	-	-	-
G	230	155	-	-	-	-	-
H	270	200	-	-	-	-	-
I	-	-	-	-	-	-	-

Table II.C.2.5

DERIVATION OF ISOLATOR EFFECTIVENESS RATIOS, VELOCITY METER Y AXIS MEASUREMENT

VELOCITY METER Y AXIS, MEASUREMENT B

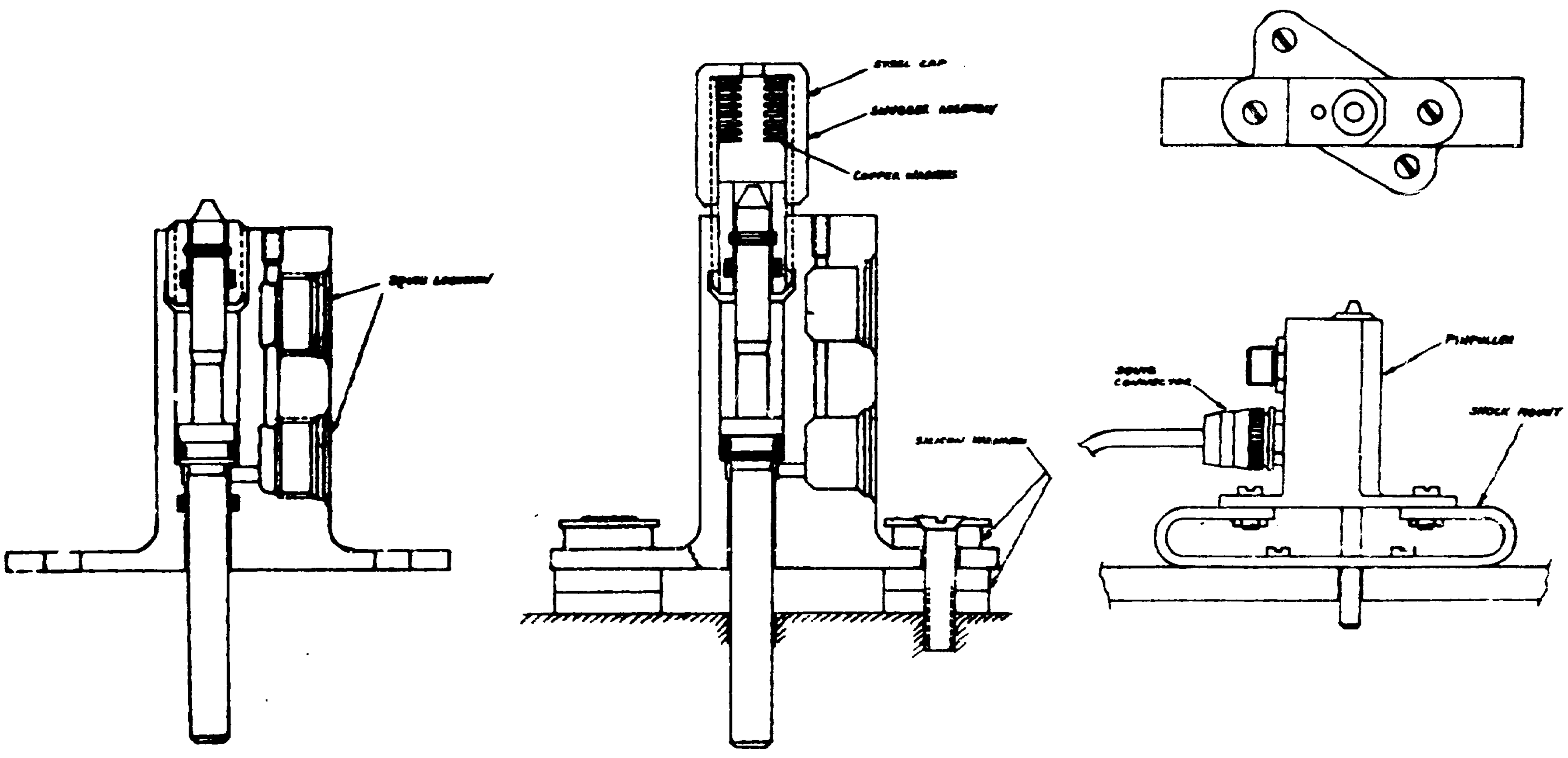
1/3 Octave Band Center Frequency	Octave Band Center Frequency	Test 7, Sunnyvale (Baseline) 1/3 Octave	Test 7 Octave Average	Test 6, SCTB (Silicon Washers) 1/3 Octave	Test 6 Octave Average	Test 7 / Test 6	Test 13, Sunnyvale (Silicone Washer & Snubber) 1/3 Octave	Test 13 Octave Average	Test 7 / Test 13	Test 15, Sunnyvale (Snubber) 1/3 Octave	Test 15 Octave Average	Test 7 / Test 15	Test 26, Sunnyvale 1/3 Octave	Test 26 Octave Average	Test 7 / Test 26
100		131		10			5			12			5		
125	125	167	171	14	15.0	11.4	8	7.3	23.3	21	22.7	7.5	6	9.3	18.3
160		215		21			9			35			17		
200		271		33			15			59			18		
250	250	335	338	94	67.7	5.0	38	55.0	6.1	93	99.3	3.4	30	34.3	9.3
315		408		114			112			146			61		
400		447		355			47			197			62		
500	500	481	497	1437	851	0.6	71	68.3	7.3	285	297	1.7	106	108	4.6
630		594		744			87			408			155		
800		736		943			107			531			194		
1000	1000	597	677	938	912	0.7	97	128	5.2	369	359	1.9	139	151	4.4
1250		679		887			181			477			121		
1600		965		671			245			528			141		
2000	2000	1582	1114	557	590	1.9	148	173	6.5	412	466	2.4	88	108	18.3
2500		794		242			145			457			102		
Spectrum Average						3.9			10.5			3.5			10.1

Table II.C.2.6

DERIVATION OF ISOLATOR EFFECTIVENESS RATIO - PINPULLER Y AXIS

PIN PULLER Y AXIS, MEASUREMENTS [illegible], [illegible]

1/3 Octave Band Center Frequency	Octave Band Center Frequency	Test 7, Sunnyvale (Baseline) 1/3 Octave	Test 7 Octave Average	Test 6, SCTB (Silicon Washer) 1/3 Octave	Test 6 Octave Average	Test 7 / Test 13	Test 13, Sunnyvale (Silicone Washer & Snubber) 1/3 Octave	Test 13 Octave Average	Test 7 / Test 13	Test 15, Sunnyvale (Snubber) 1/3 Octave	Test 15 Octave Average	Test 7 / Test 15	Test 26, Sunnyvale 1/3 Octave	Test 26 Octave Average	Test 7 / Test 26
100		66		38			70			70			[illegible]		
125	125	78	74.3	94	65.0	1.1	43	46.3	1.6	43	46.9	1.4	83	31.0	2.4
160		79		[illegible]			86			86			[illegible]		
200		68		151			80			[illegible]			87		
250	250	206	112	320	375	0.48	121	108	1.7	130	205	[illegible]	183	[illegible]	0.74
315		183		685			154			344			485		
400		394		1440			238			579			280		
500	500	903	920	2846	2605	0.35	394	320	2.8	830	1076	0.84	467	438	2.1
630		1444		3730			375			1019			358		
800		2180		4695			253			1346			439		
1000	1000	3378	3466	5122	4843	0.70	400	311	11	2700	2950	1.4	540	477	7.3
1250		4899		5732			280			[illegible]			485		
1600		4898		3009			406			3257			475		
2000	2000	6788	5748	3862	3491	1.6	497	650	8.8	1979	2449	2.2	338	442	13
2500		5519		4738			647			2170			483		
Spectrum Average						0.85			5.2			[illegible]			5.1



DETAIL A   DETAIL B   DETAIL C

Figure II.G.2.1 PIN PULLER AND PIN PULLER ISOLATION TECHNIQUES

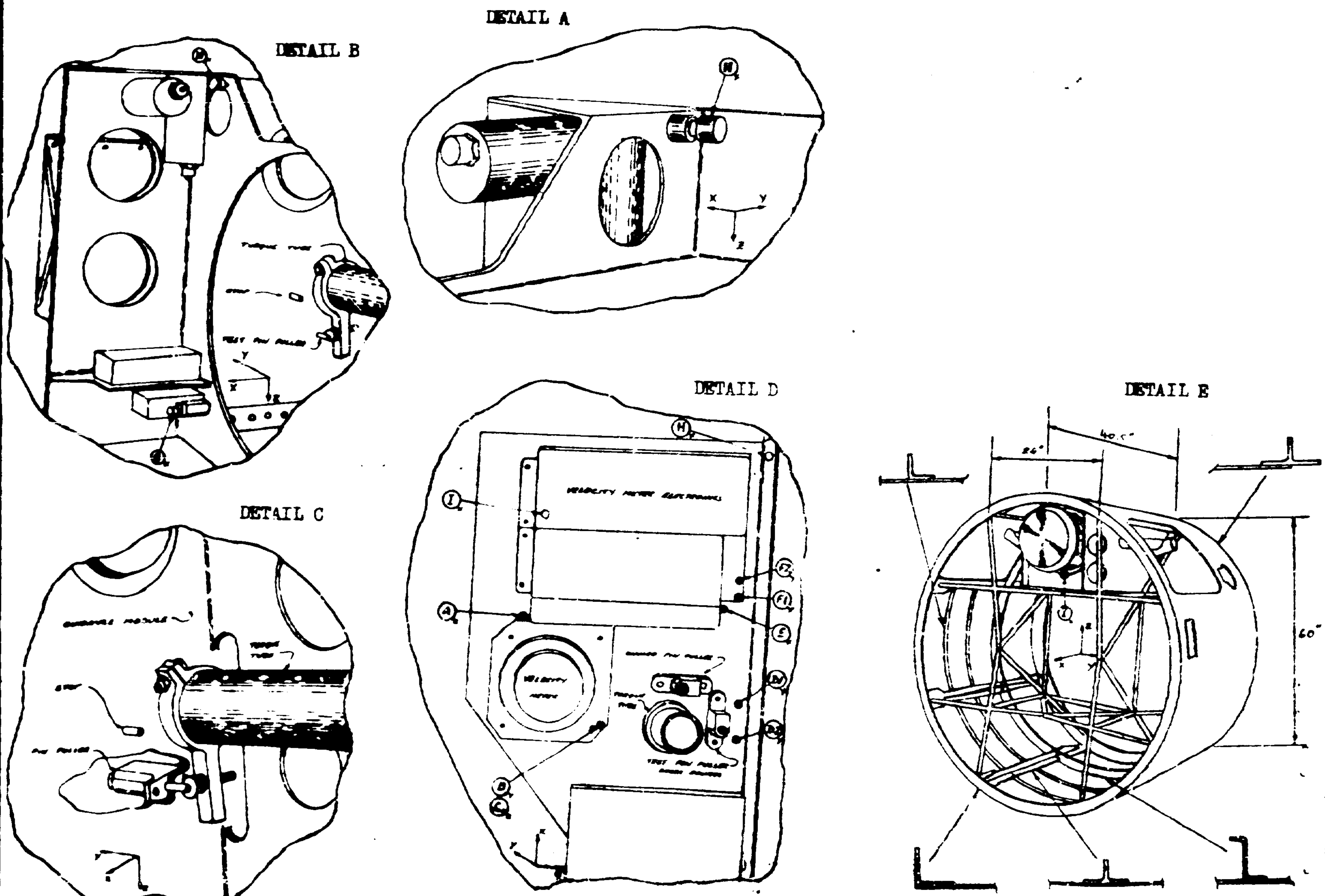


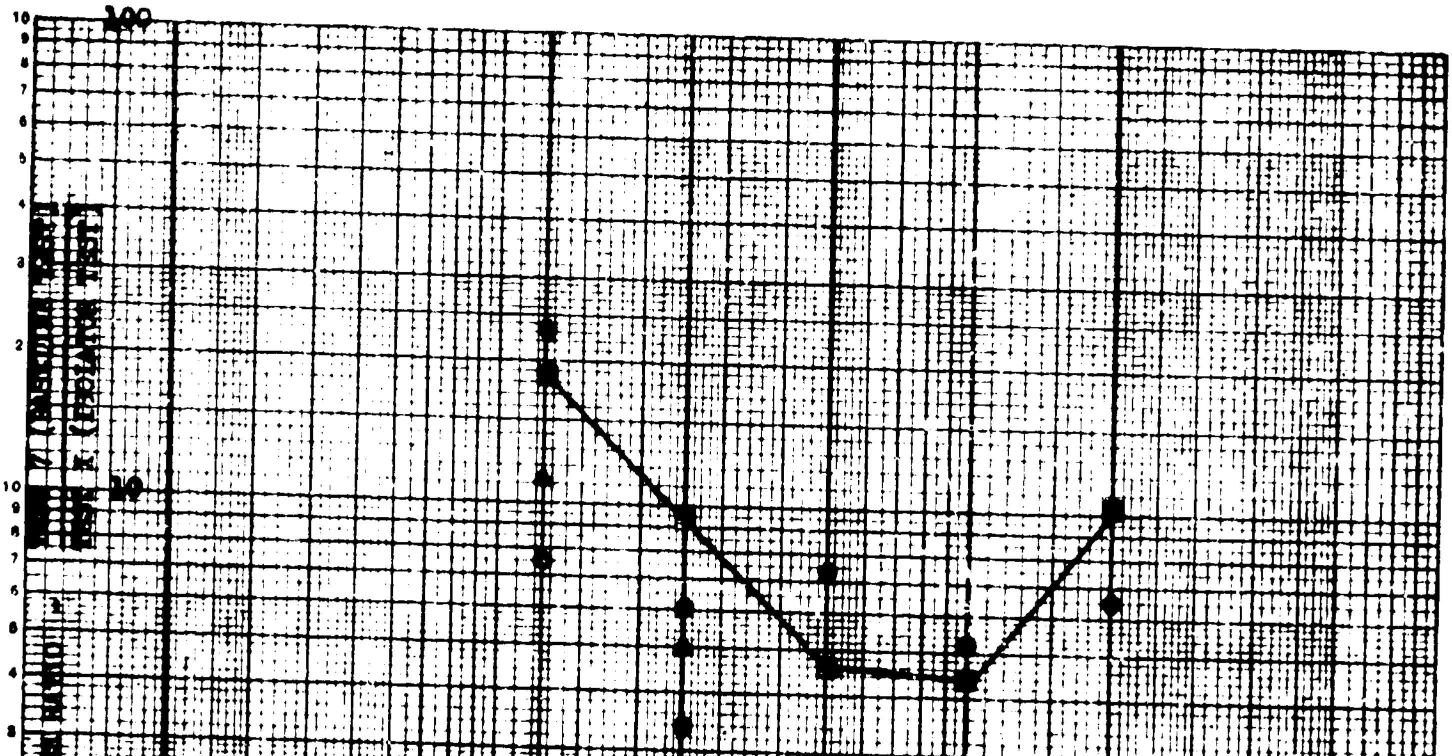
Figure II.C.2.2 TEST SPECIMEN AND INSTRUMENTATION LOCATIONS

▲ TEST 6, SILICON WASHERS

● TEST 13, SILICON WASHERS AND SNUBBER

● TEST 15, SNUBBER

■ TEST 26, BRACKET



FREQUENCY - HZ -

FIGURE II.C.2.3 ISOLATOR EFFECTIVENESS - VELOCITY METER Y AXIS MEASUREMENT

▲ TEST 6, SILICON WASHERS

● TEST 13, SILICON WASHERS AND SNUBBER

● TEST 15, SNUBBER

■ TEST 26,

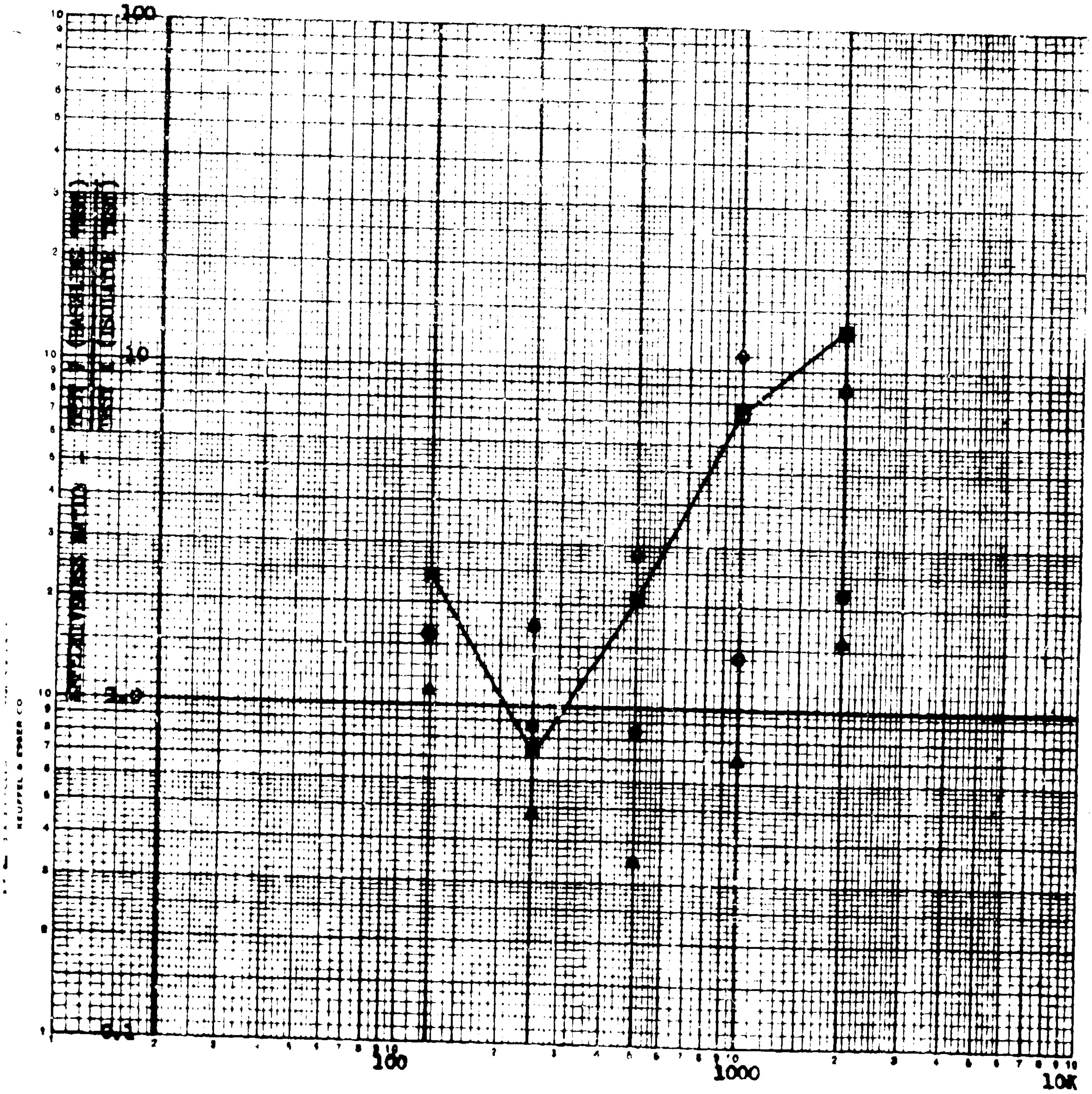


Figure IL.C.2.L ISOLATOR EFFECTIVENESS - PINPULLER Y AXIS MEASUREMENT

△ 99th PERCENTILE
○ MAXIMUM
□ MEAN (50th PERCENTILE)

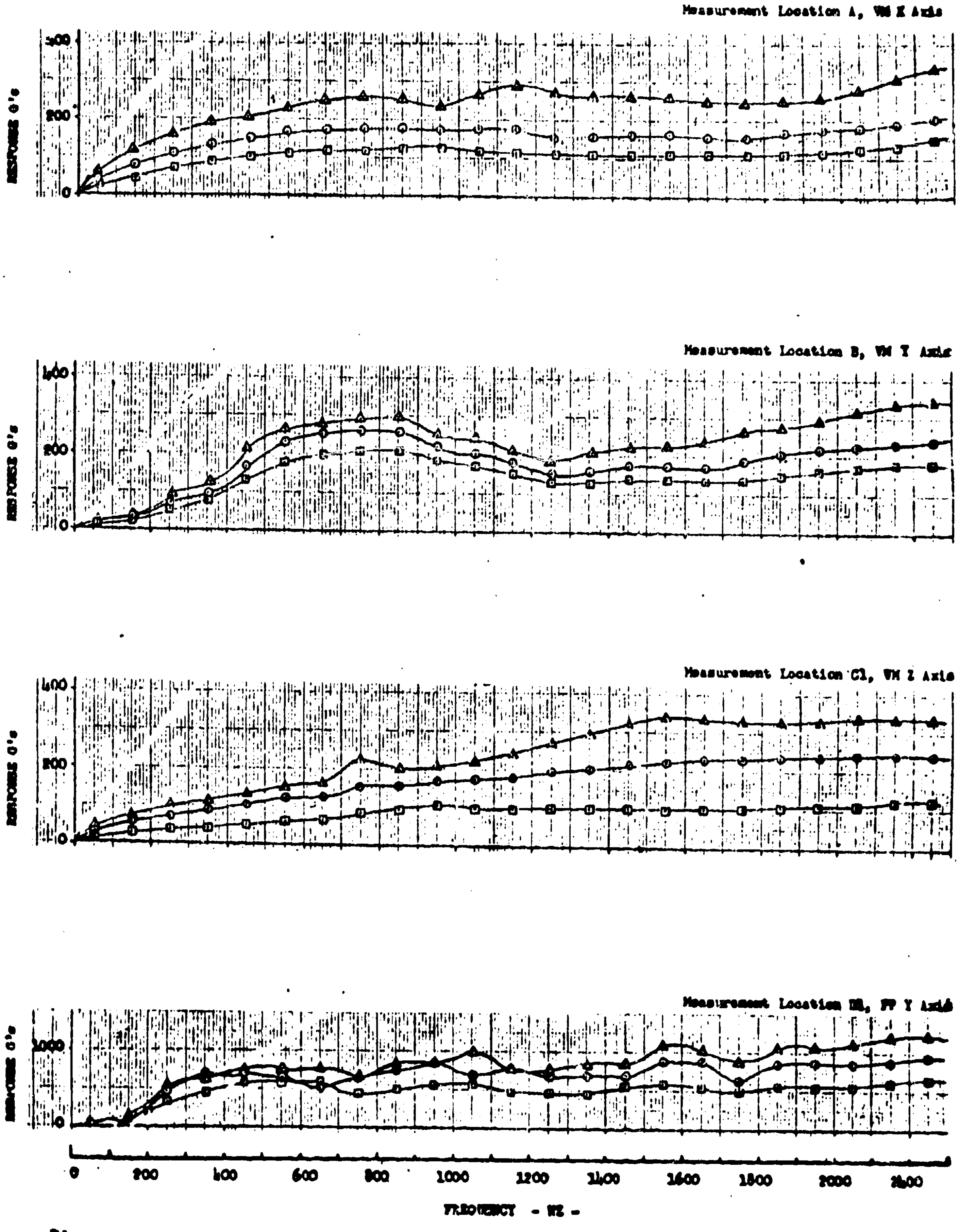


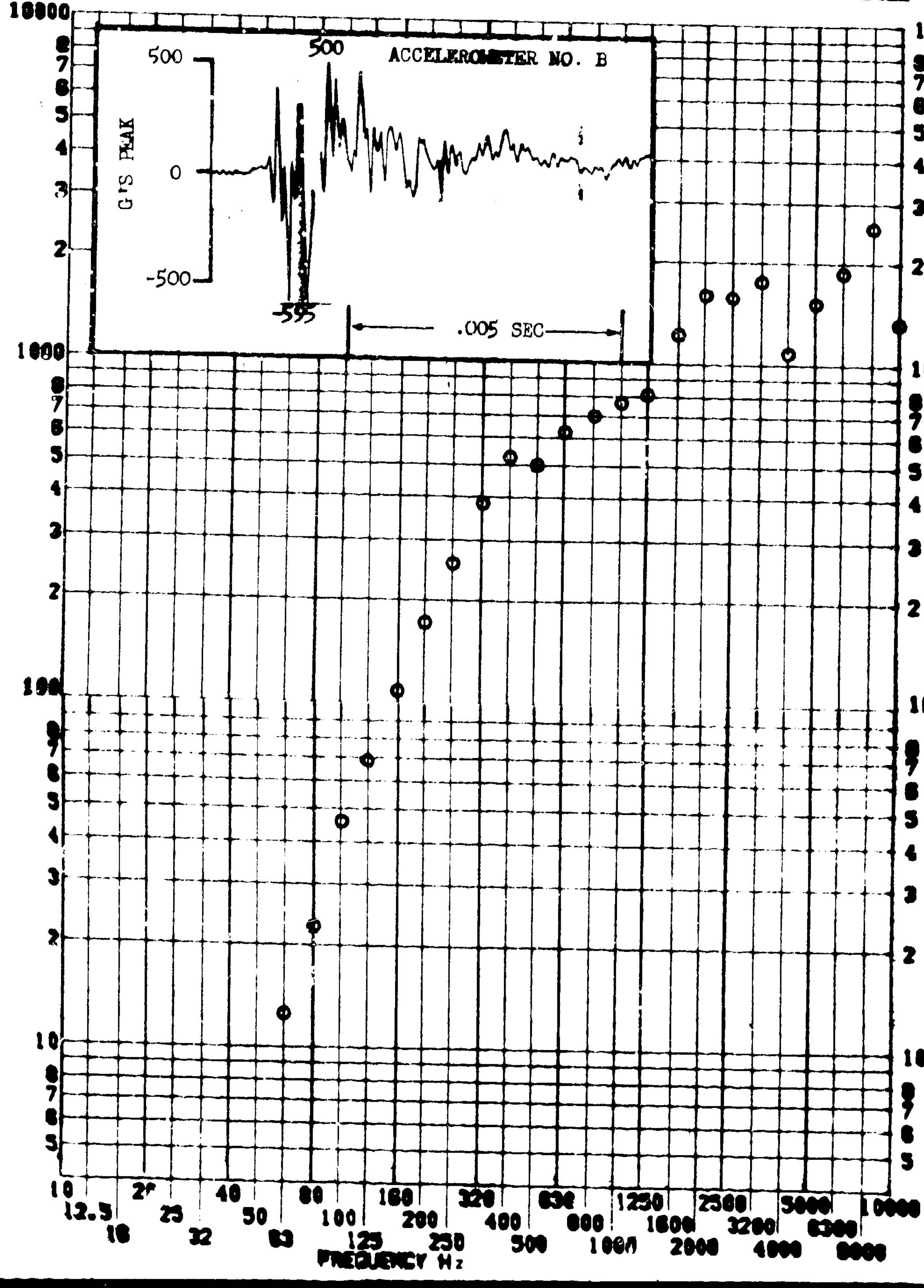
Figure: II.C.2.5 REPEATIBILITY OF SEVEN BRACKET PINPULLER TESTS

SHOCK TEST ANALYSIS DATA SHEET II.C.2.6

TEST ITEM 1336-193
SERIAL NO. ____
SHOCK AXIS Y

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2

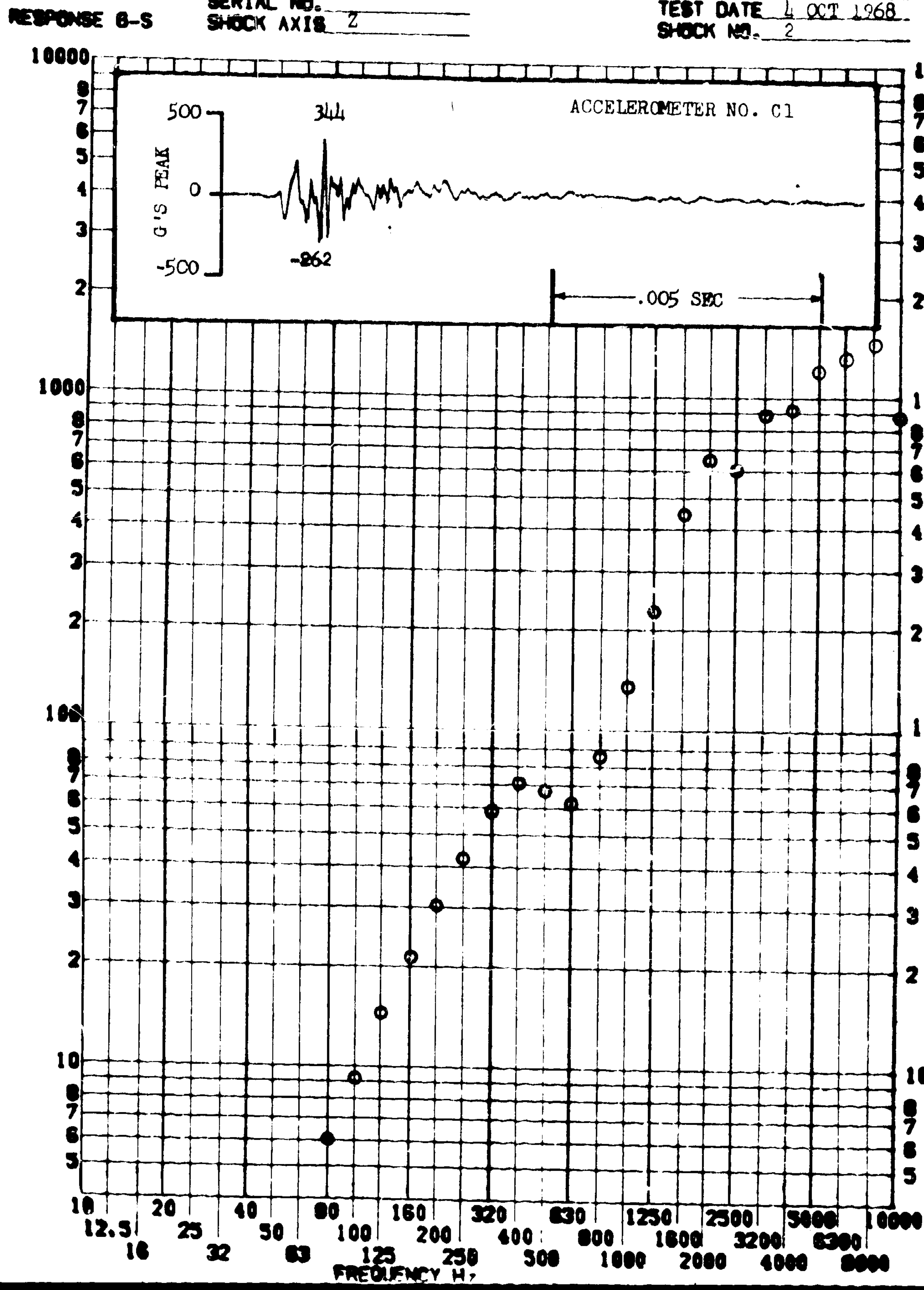
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.C.2.7

TEST ITEM 1336-194
SERIAL NO.
SHOCK AXIS Z

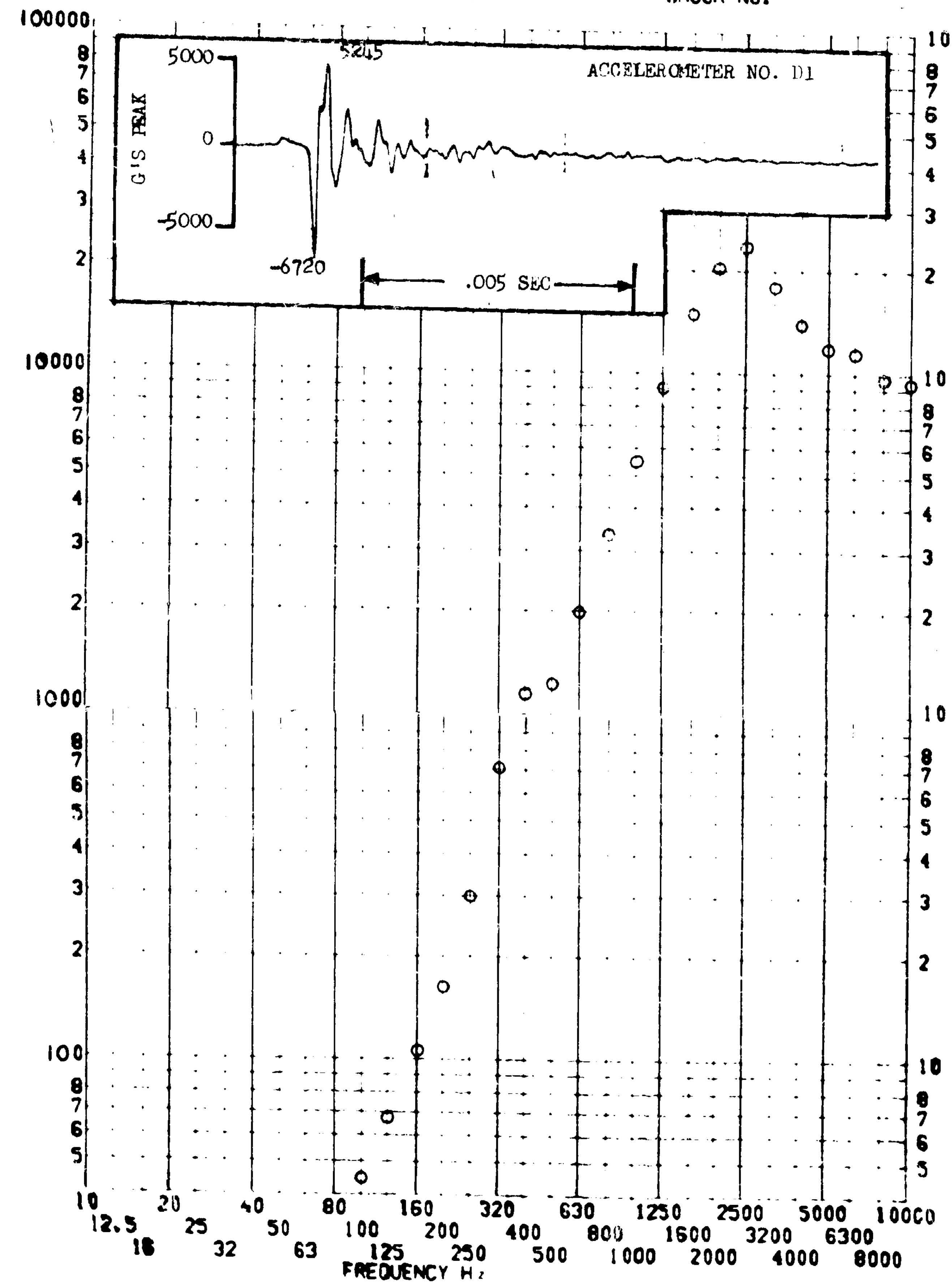
PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.C.2.8

TEST ITEM 1336-192
SERIAL NO.
SHOCK AXIS Y

PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 2

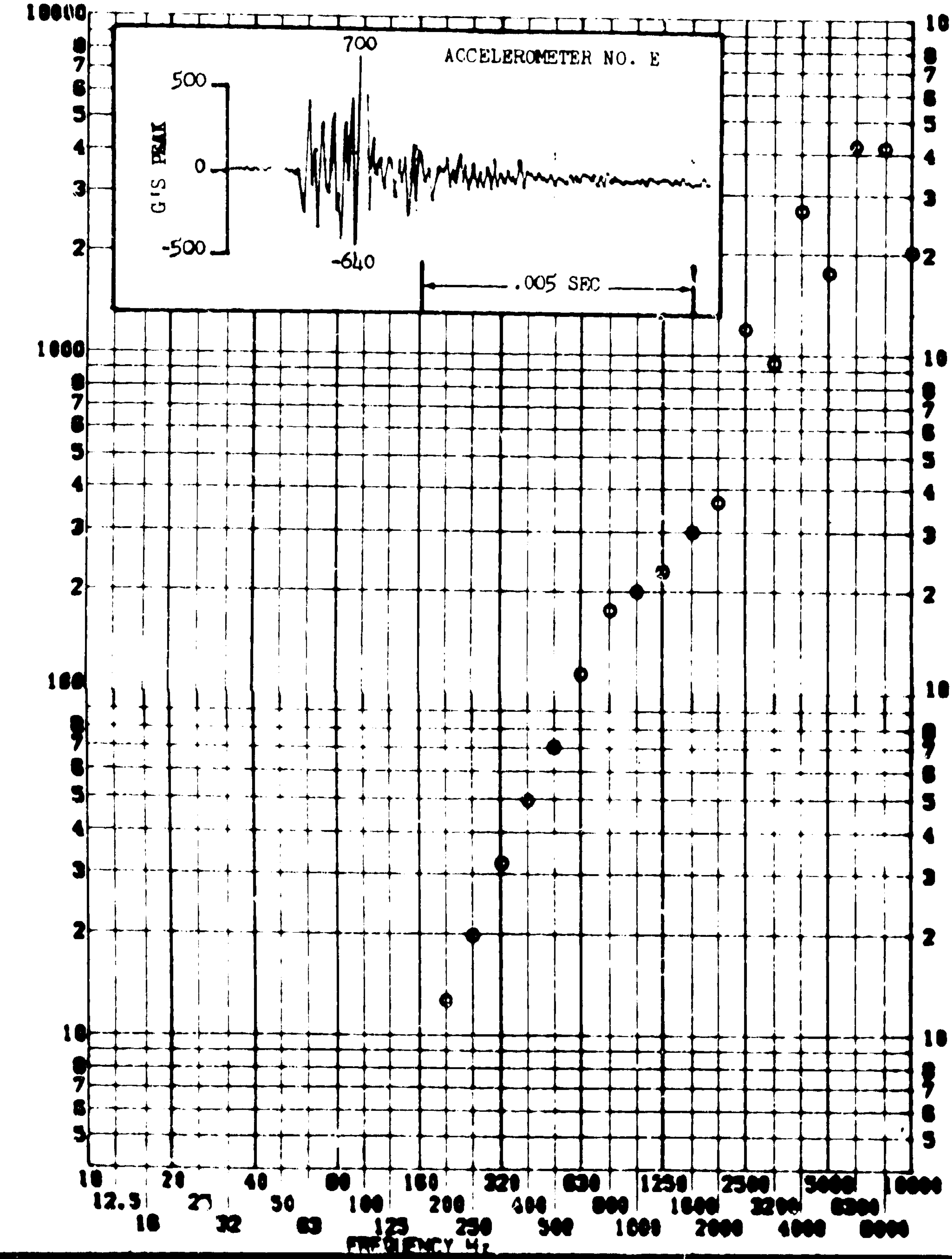


SHOCK TEST ANALYSIS DATA SHEET II.C.2.9

TEST ITEM 1336-195
SERIAL NO.
SHOCK AXIS X

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2

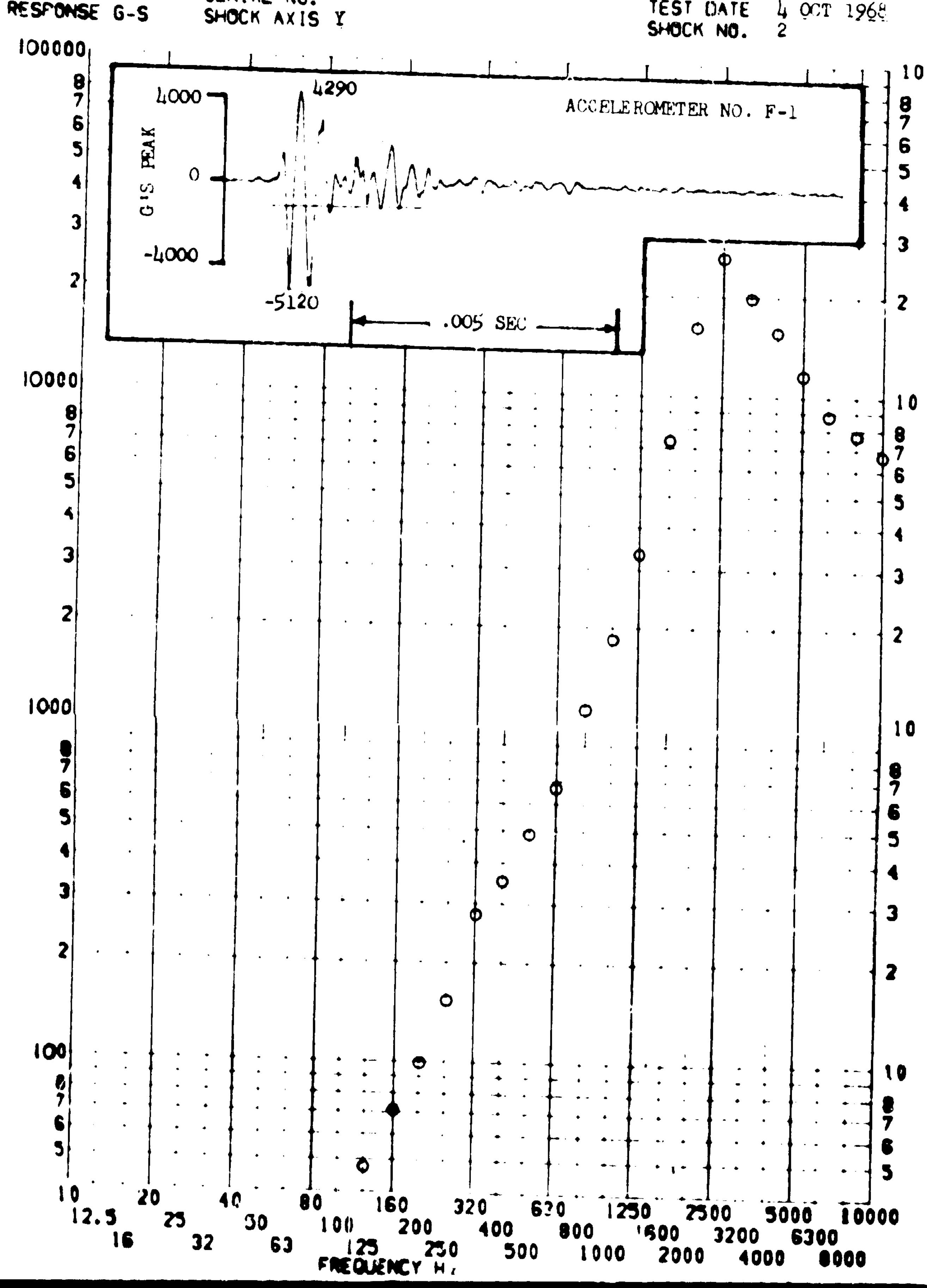
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.C.2.10

TEST ITEM 1336-196
SERIAL NO.
SHOCK AXIS Y

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2

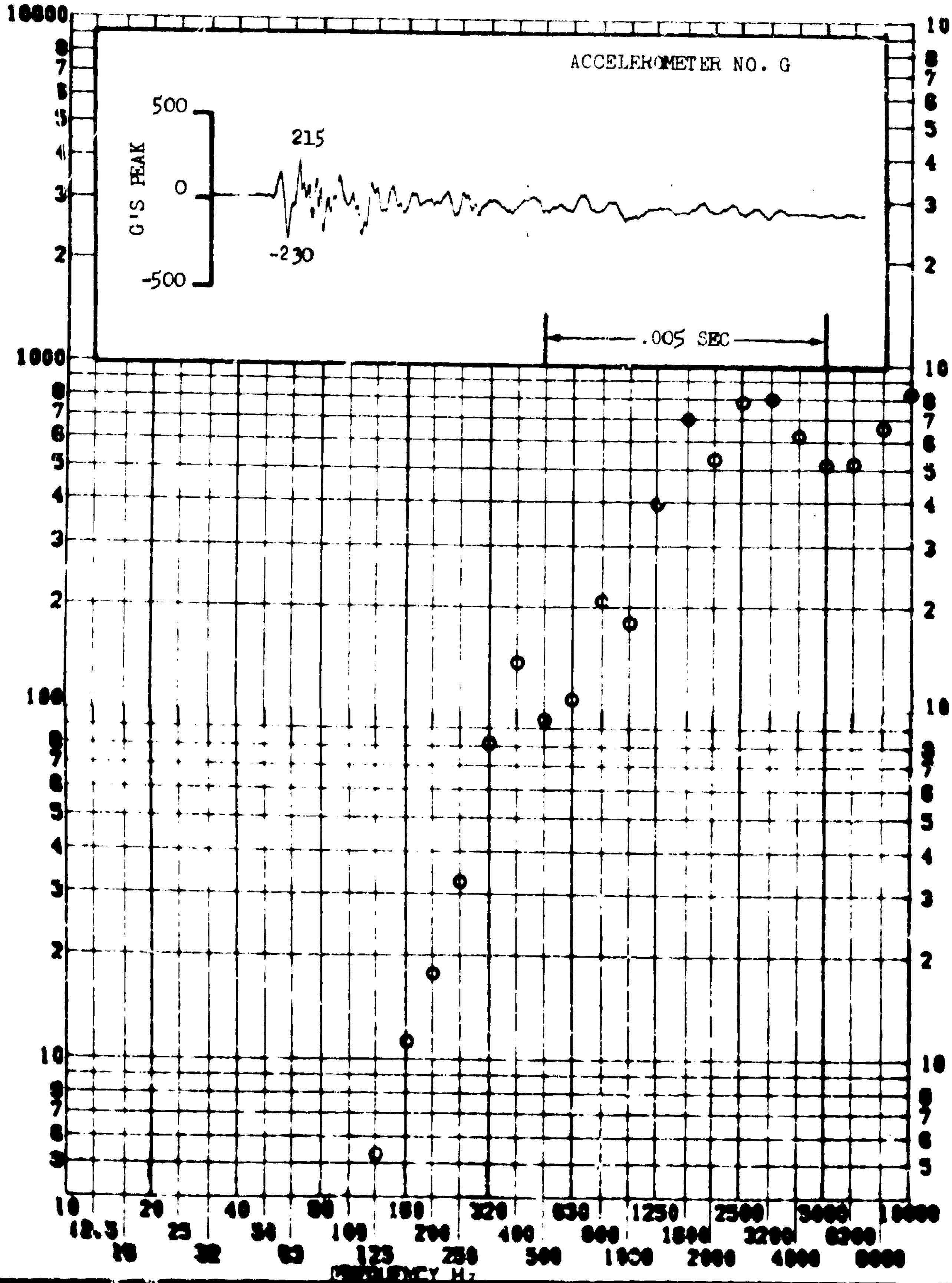


SHOCK TEST ANALYSIS DATA SHEET II.C.2.21

TEST ITEM 1336-198
SERIAL NO.
SHOCK AXIS X

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.C.2.12

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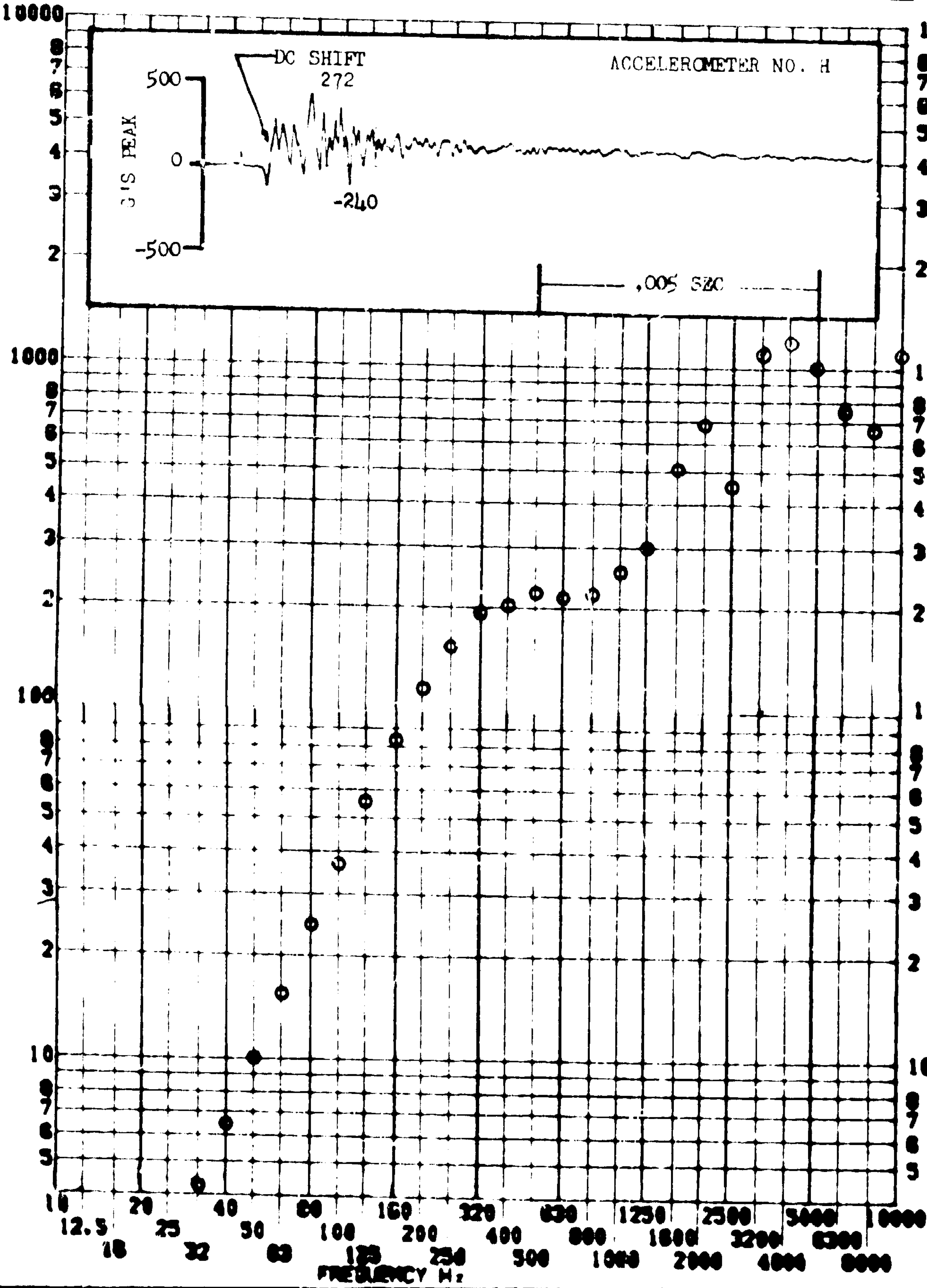
SERIAL NO.
SHOCK AXIS X

PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 2

RESPONSE G-S

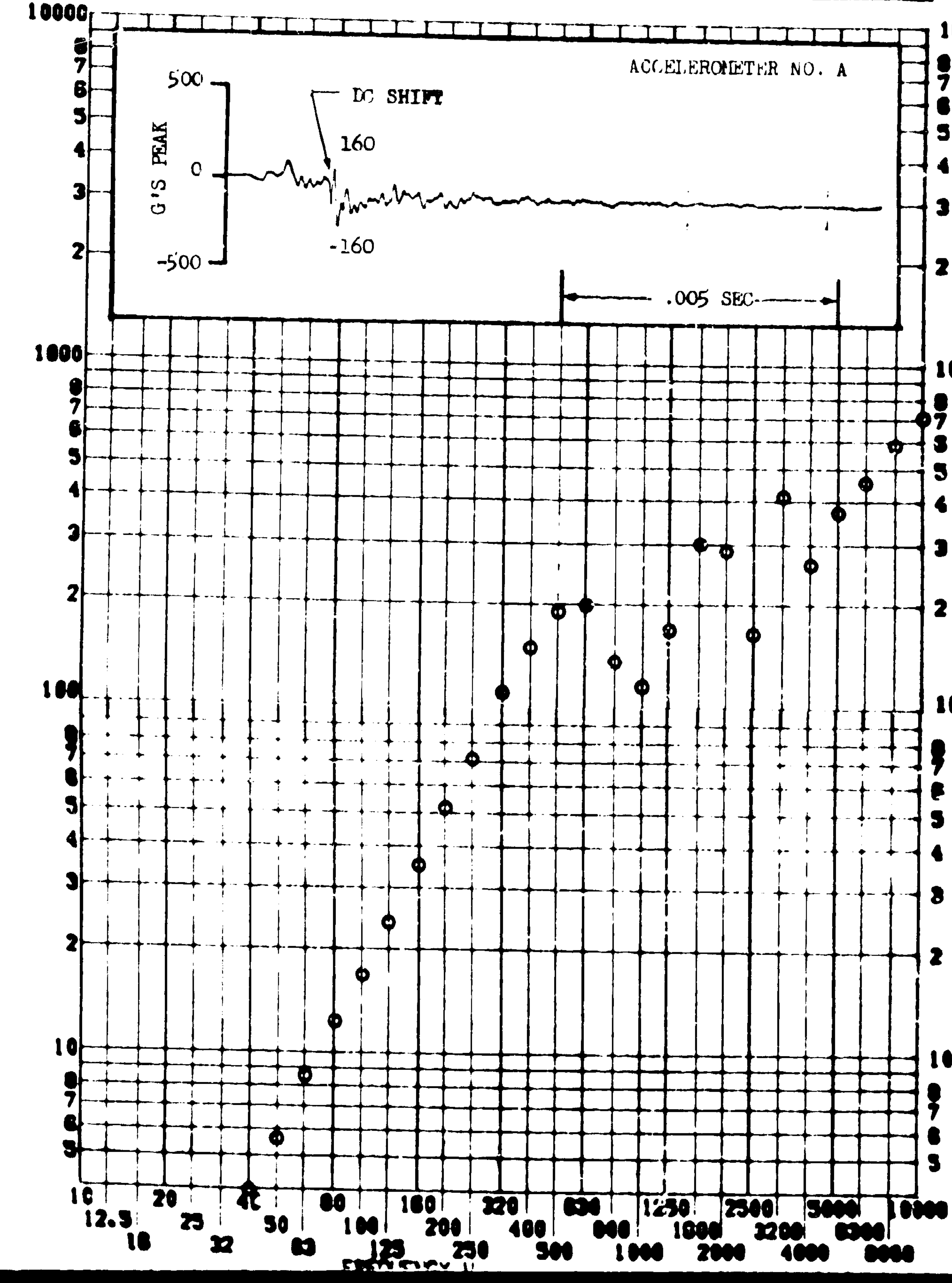


SHOCK TEST ANALYSIS DATA SHEET II.C.2.13

TEST ITEM 1336-200 PART NO. BOX

SERIAL NO. TEST DATE 4 OCT 1968

RESPONSE G-S SHOCK AXIS X SHOCK NO. 6

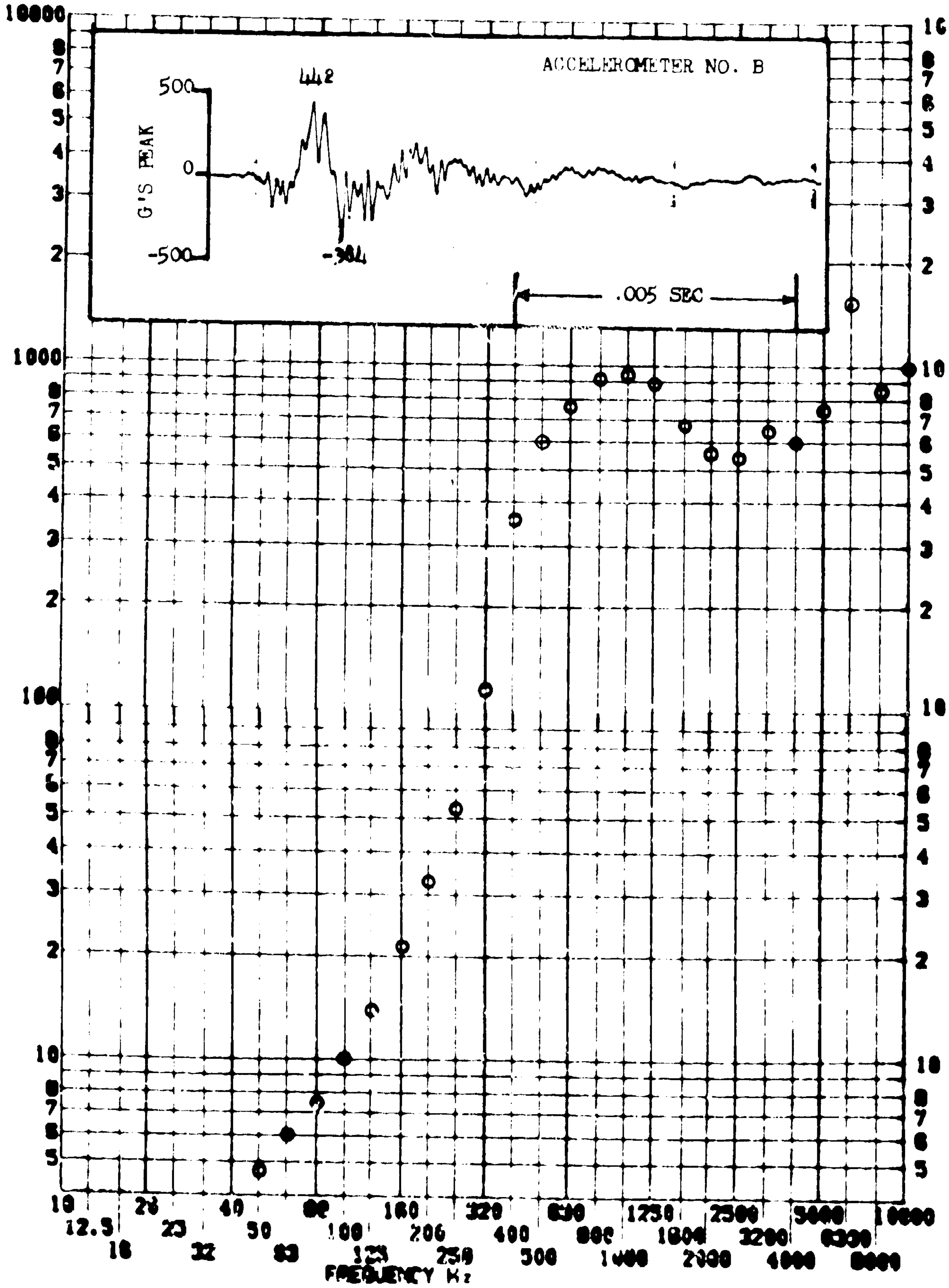


SHOCK TEST ANALYSIS DATA SHEET II.C.2.14

TEST ITEM 1336-201
SERIAL NO.
SHOCK AXIS Y

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6

RESPONSE G-S

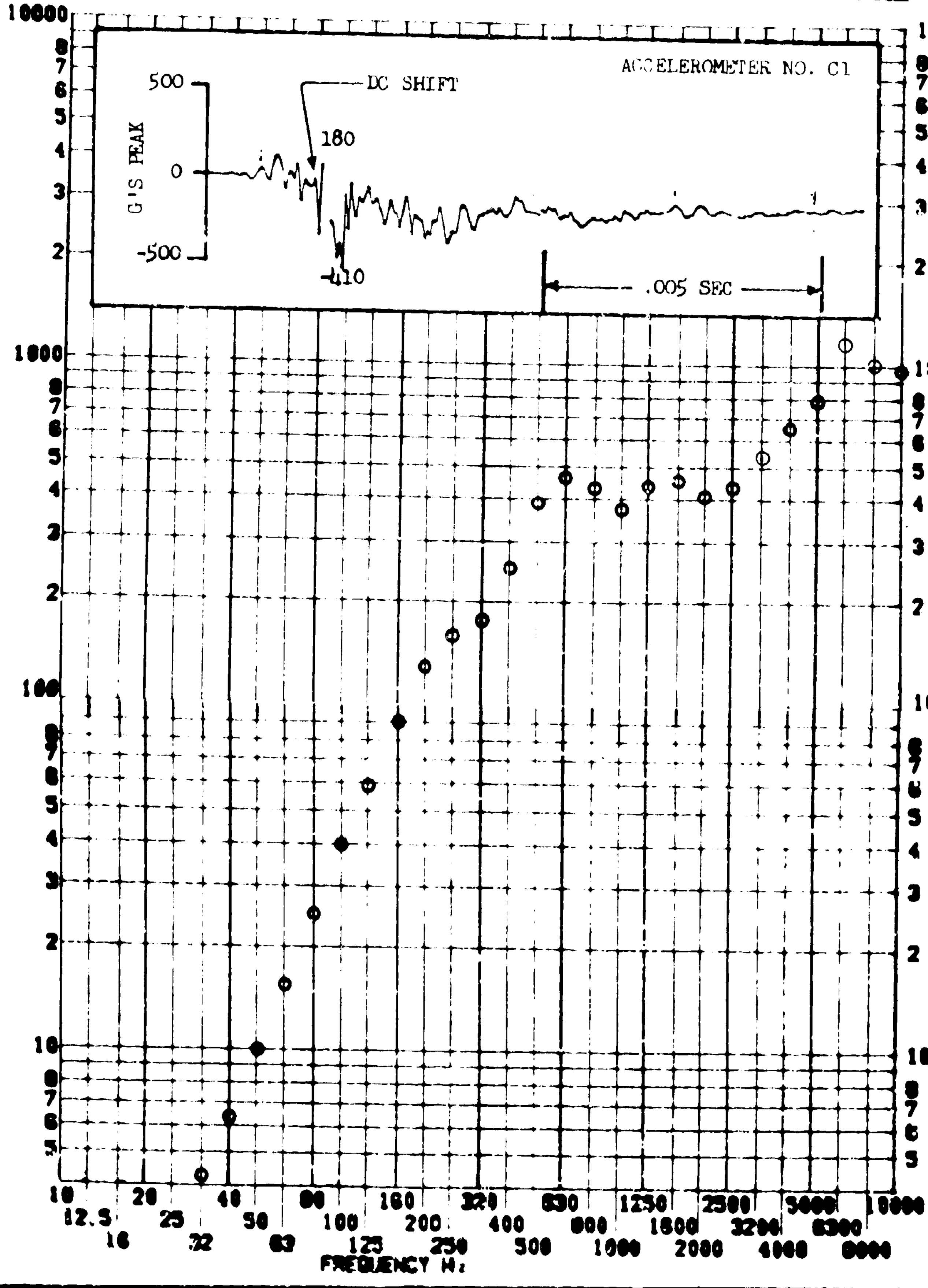


SHOCK TEST ANALYSIS DATA SHEET

RESPONSE G-S

TEST ITEM 1336-202
SERIAL NO.
SHOCK AXIS Z

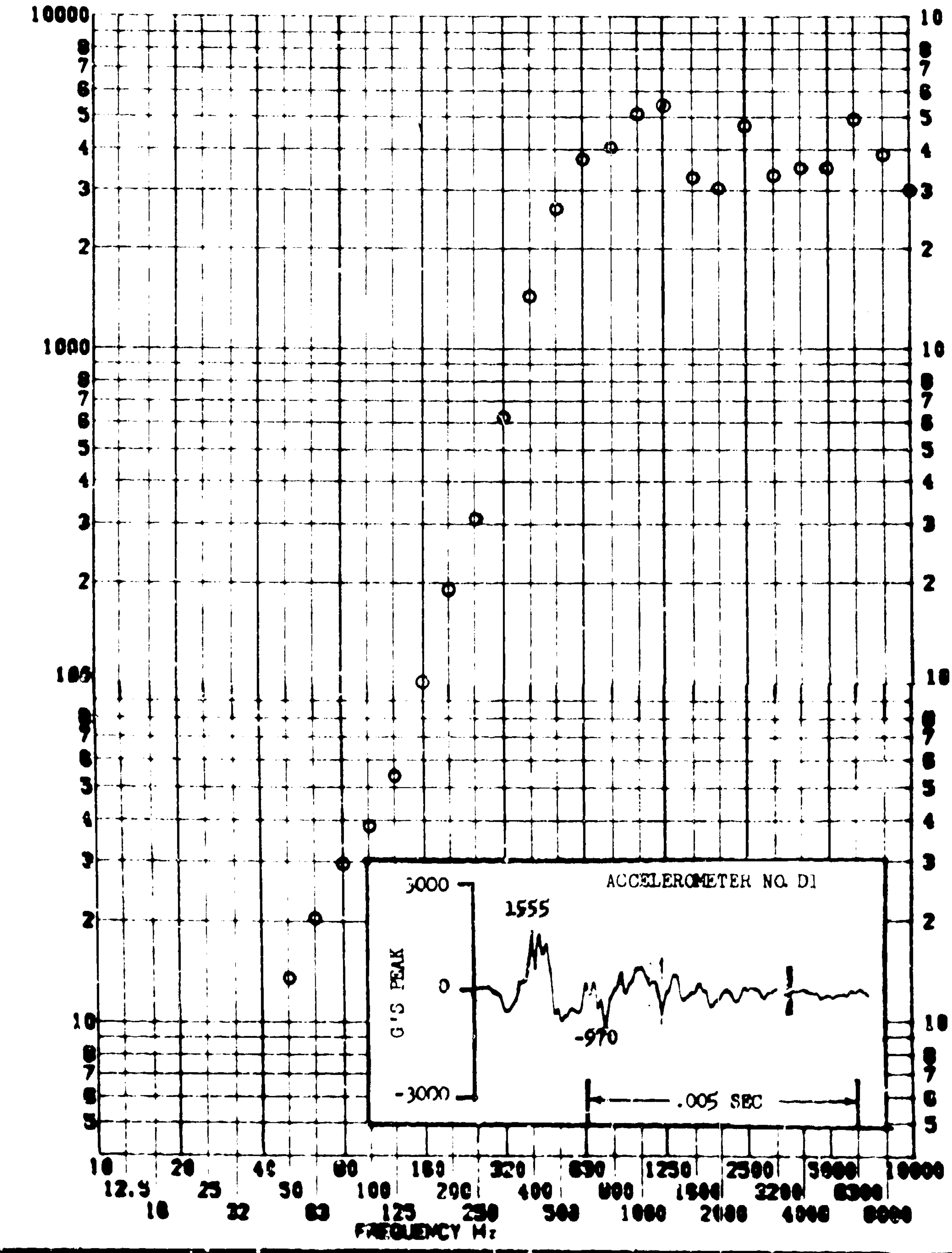
PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6



SHOCK TEST ANALYSIS DATA SHEET II.C.2.16

TEST ITEM 1336-199
SERIAL NO.
SHOCK AXIS Y

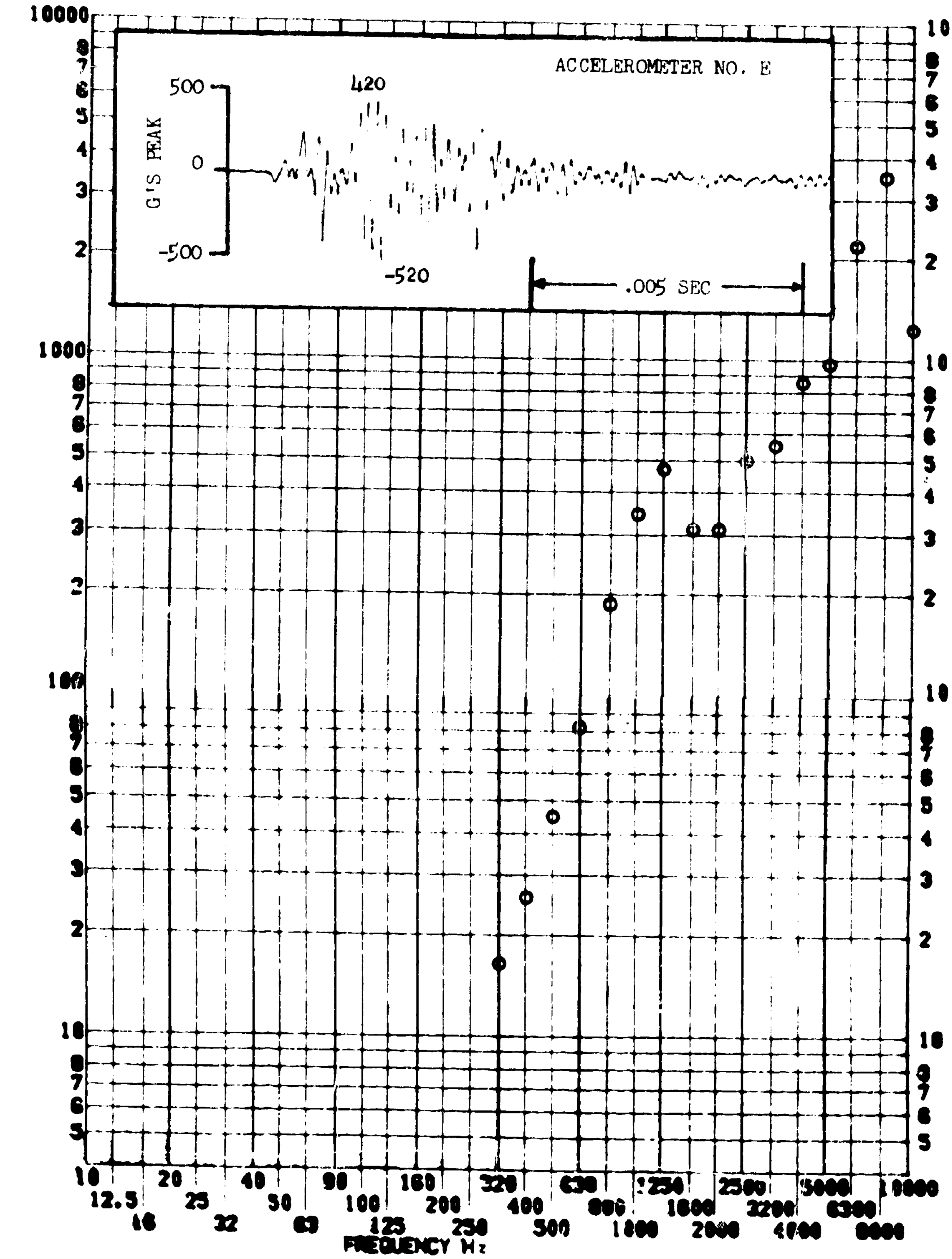
PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 6



SHOCK TEST ANALYSIS DATA SHEET II.C.2.17

TEST ITEM 1336-203
SERIAL NO.
SHOCK AXIS X

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6



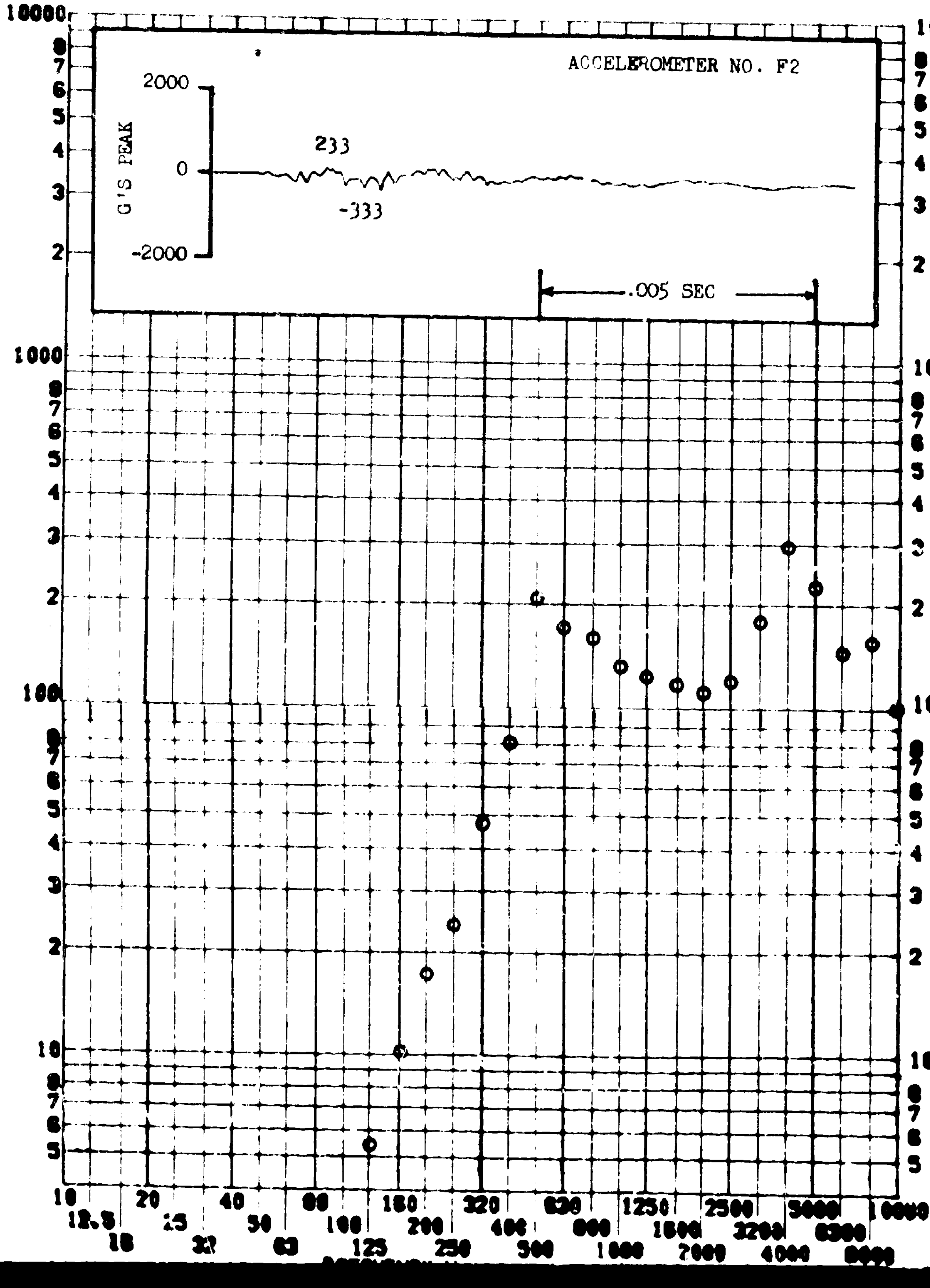
SHOCK TEST ANALYSIS DATA SHEET

II.C.2.18

TEST ITEM 1336-204
SERIAL NO.
SHOCK AXIS Y

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6

RESPONSE G-S

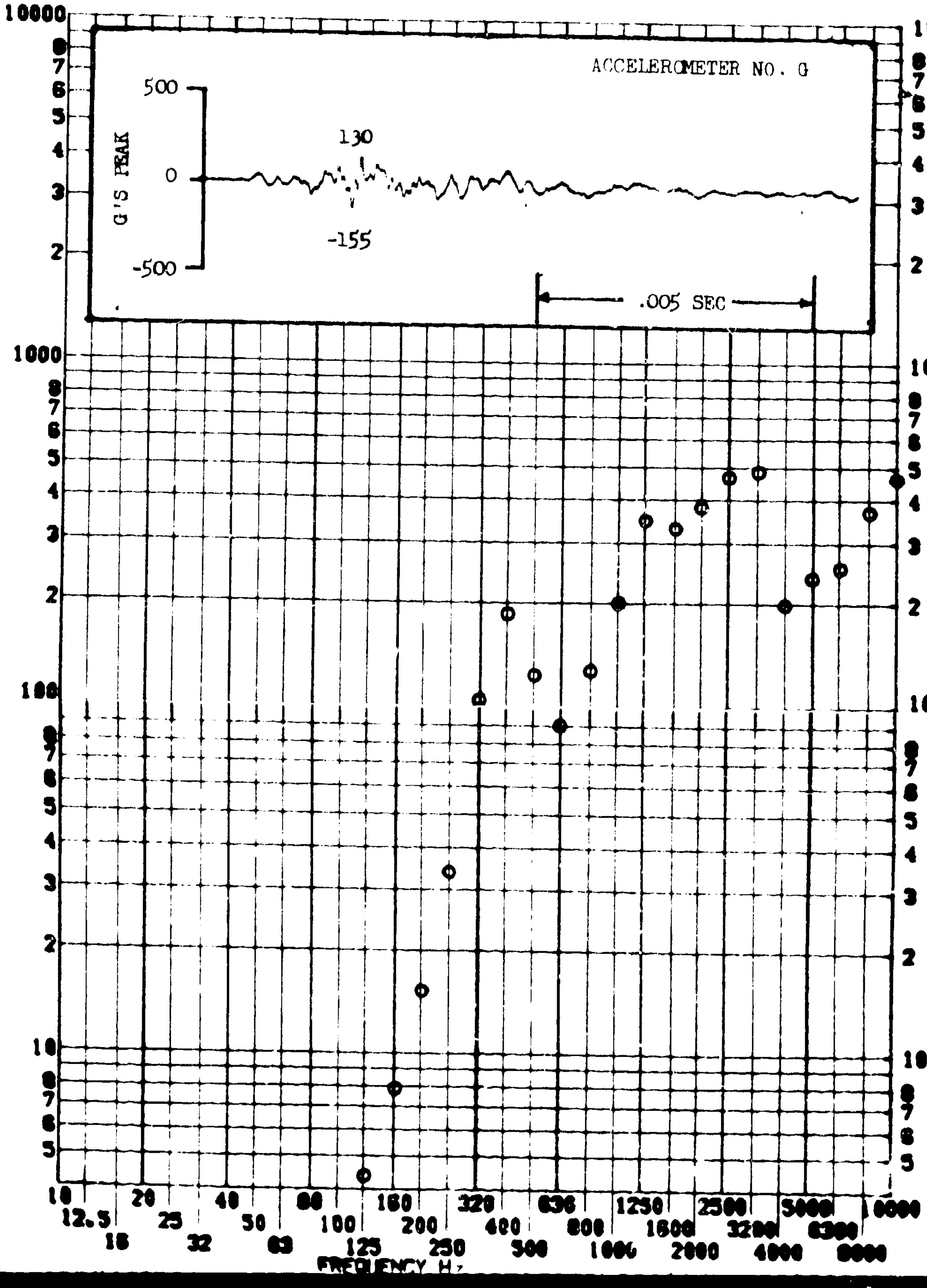


SHOCK TEST ANALYSIS DATA SHEET II.C.2.19

TEST ITEM 1336-206
SERIAL NO.
SHOCK AXIS X

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6

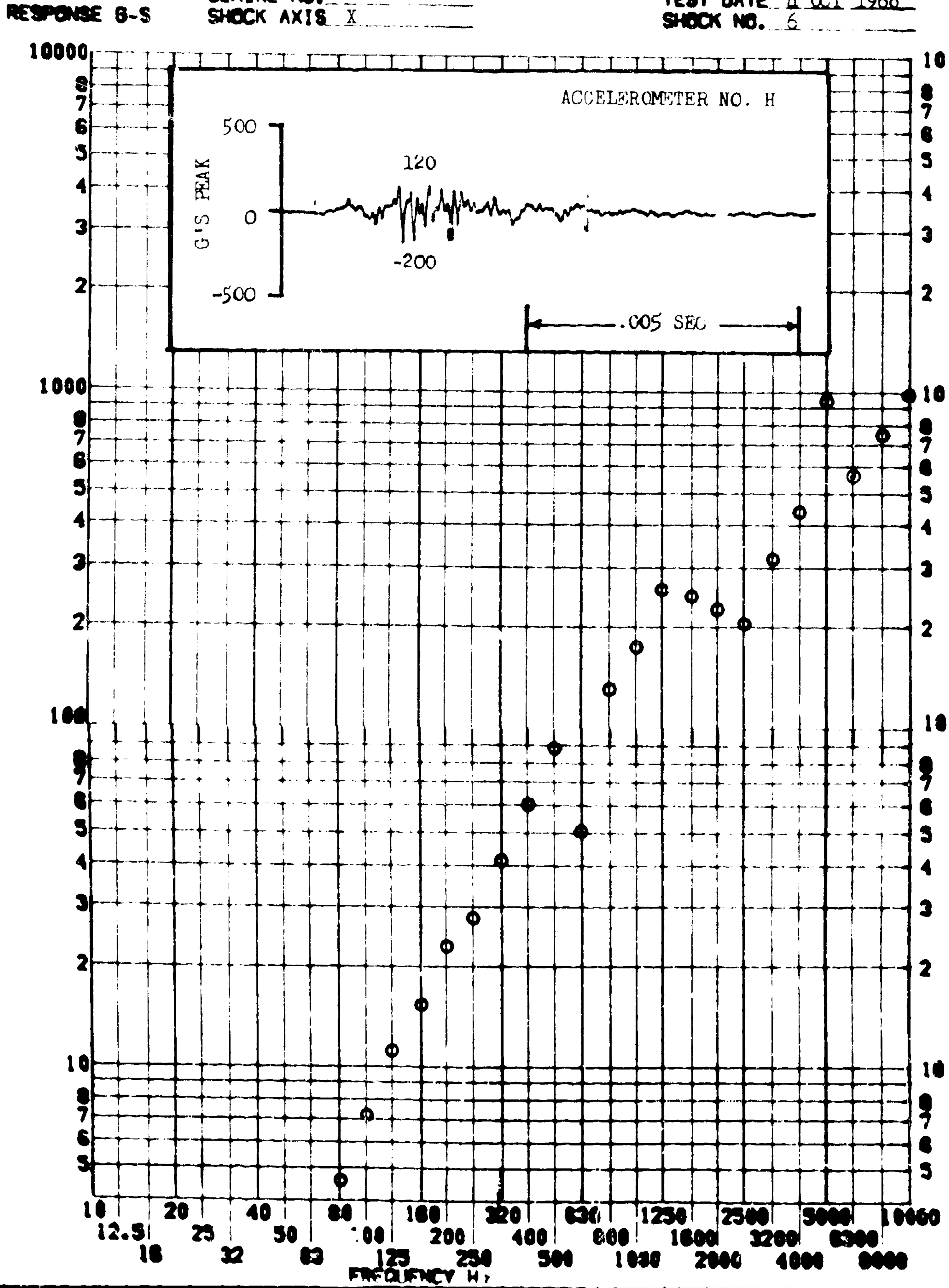
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.C.2.20

TEST ITEM 1336-205
SERIAL NO.
SHOCK AXIS X

PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 6

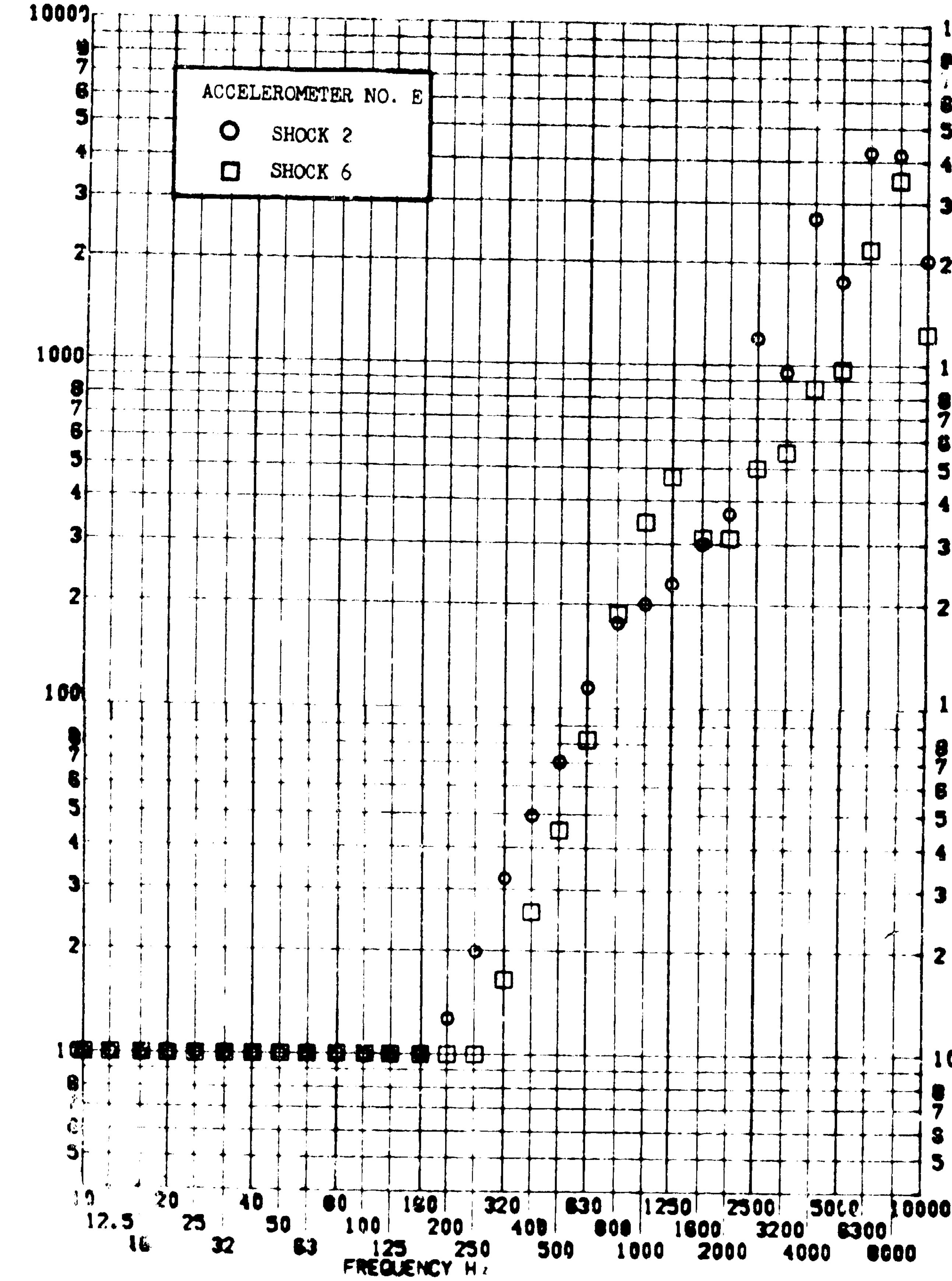


SHOCK TEST ANALYSIS DATA SHEET II.C.2.21

TEST ITEM 1336-195,203
SERIAL NO.
SHOCK AXIS X

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2,6

RESPONSE G-S

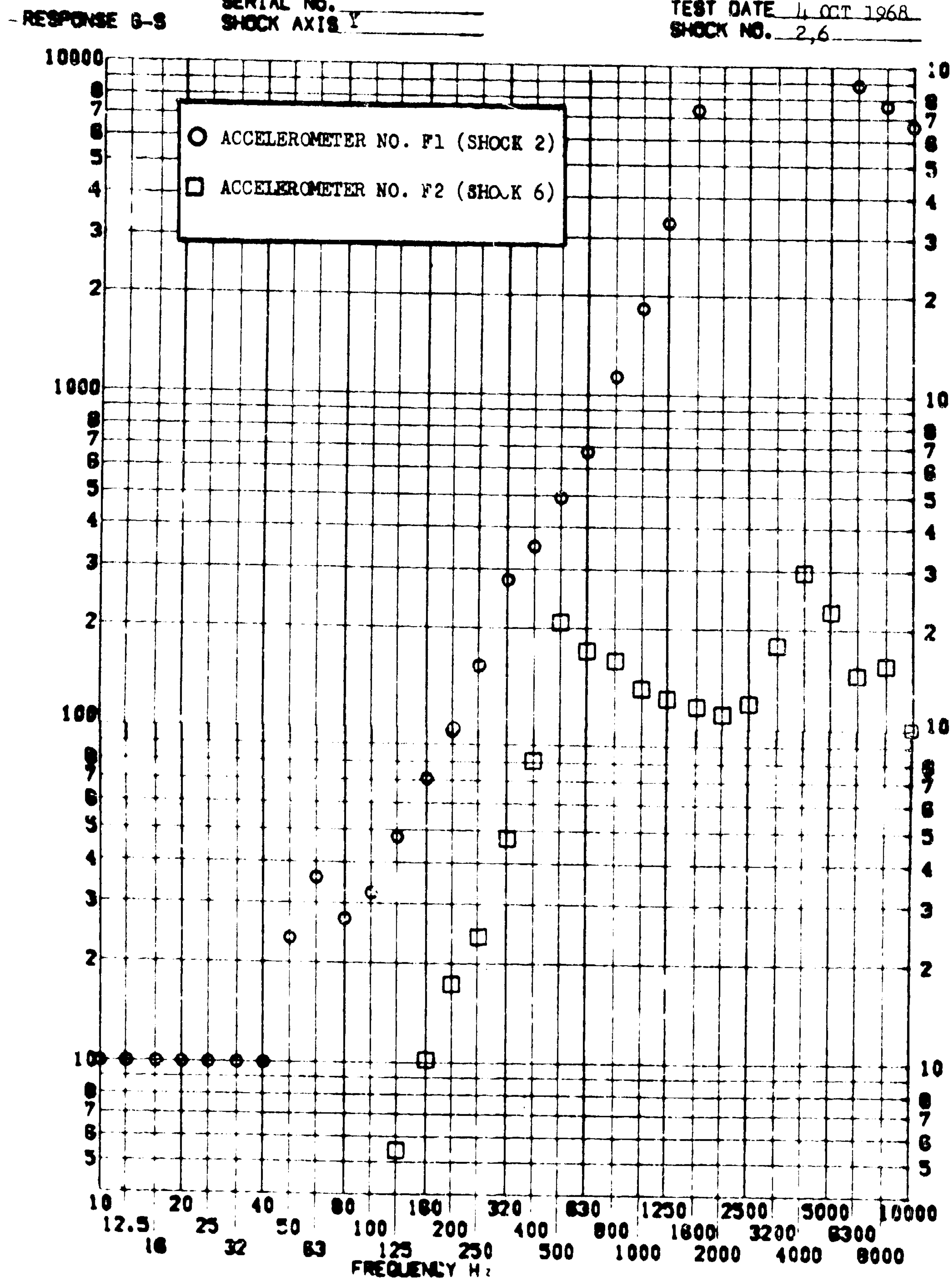


2

SHOCK TEST ANALYSIS DATA SHEET II.C.2.22

TEST ITEM 1336-196,204
SERIAL NO. ______
SHOCK AXIS Y

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2,6

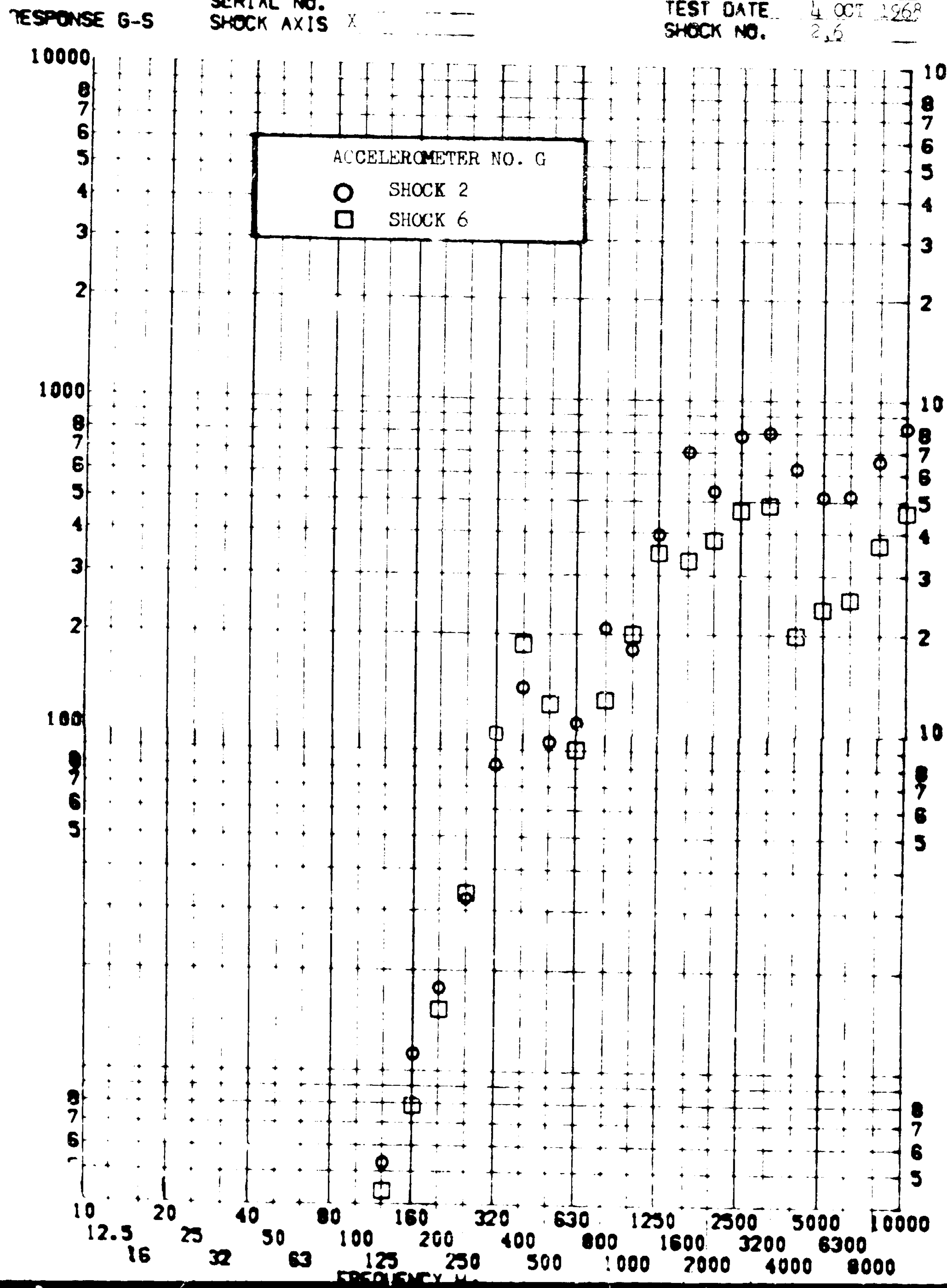


SHOCK TEST ANALYSIS DATA SHEET

II.C.2.23

TEST ITEM 1336-198,206
SERIAL NO.
SHOCK AXIS X

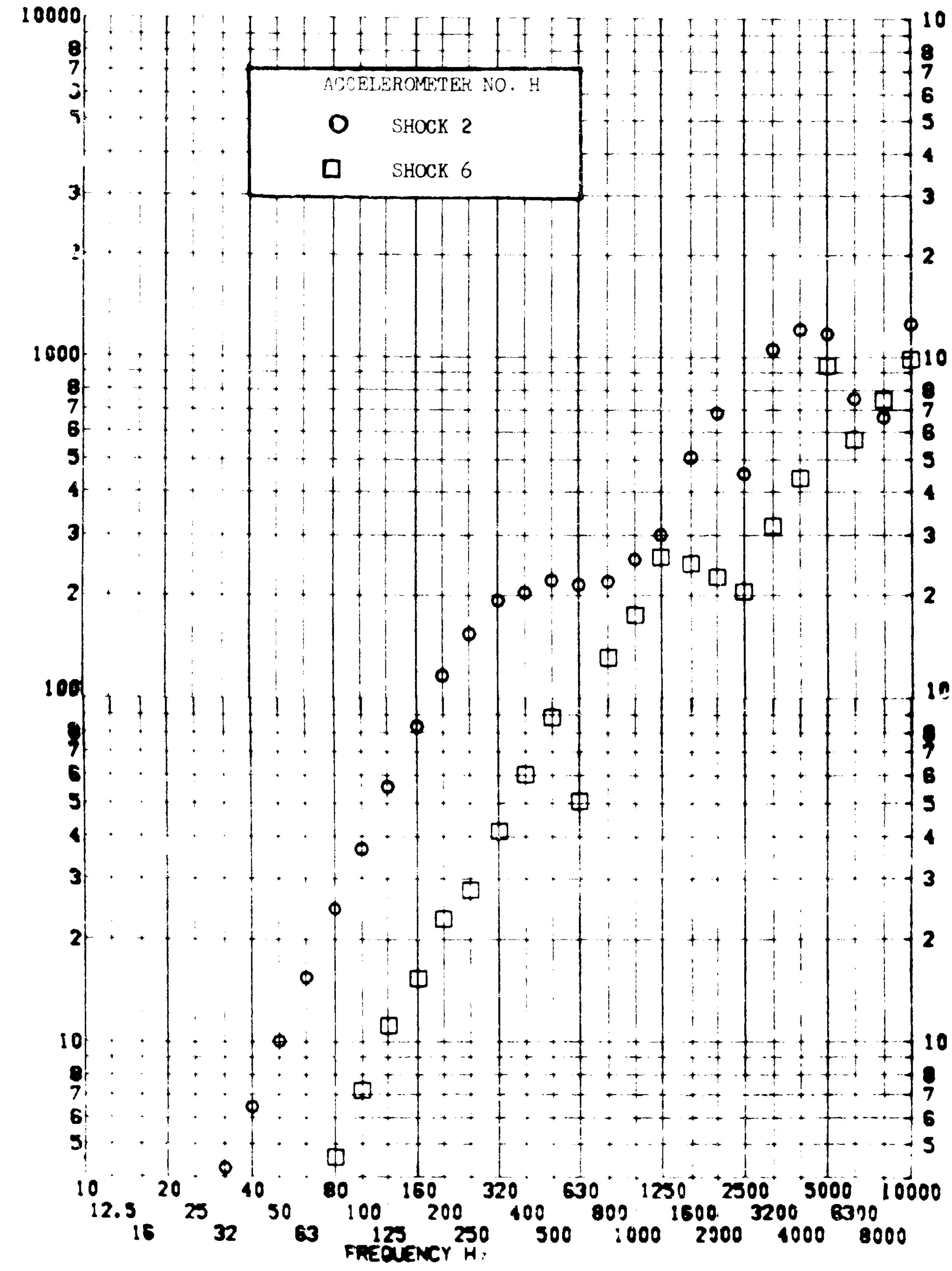
PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 2,6



SHOCK TEST ANALYSIS DATA SHEET II.C.2.24

TEST ITEM 1366-196,204
SERIAL NO.
SHOCK AXIS X

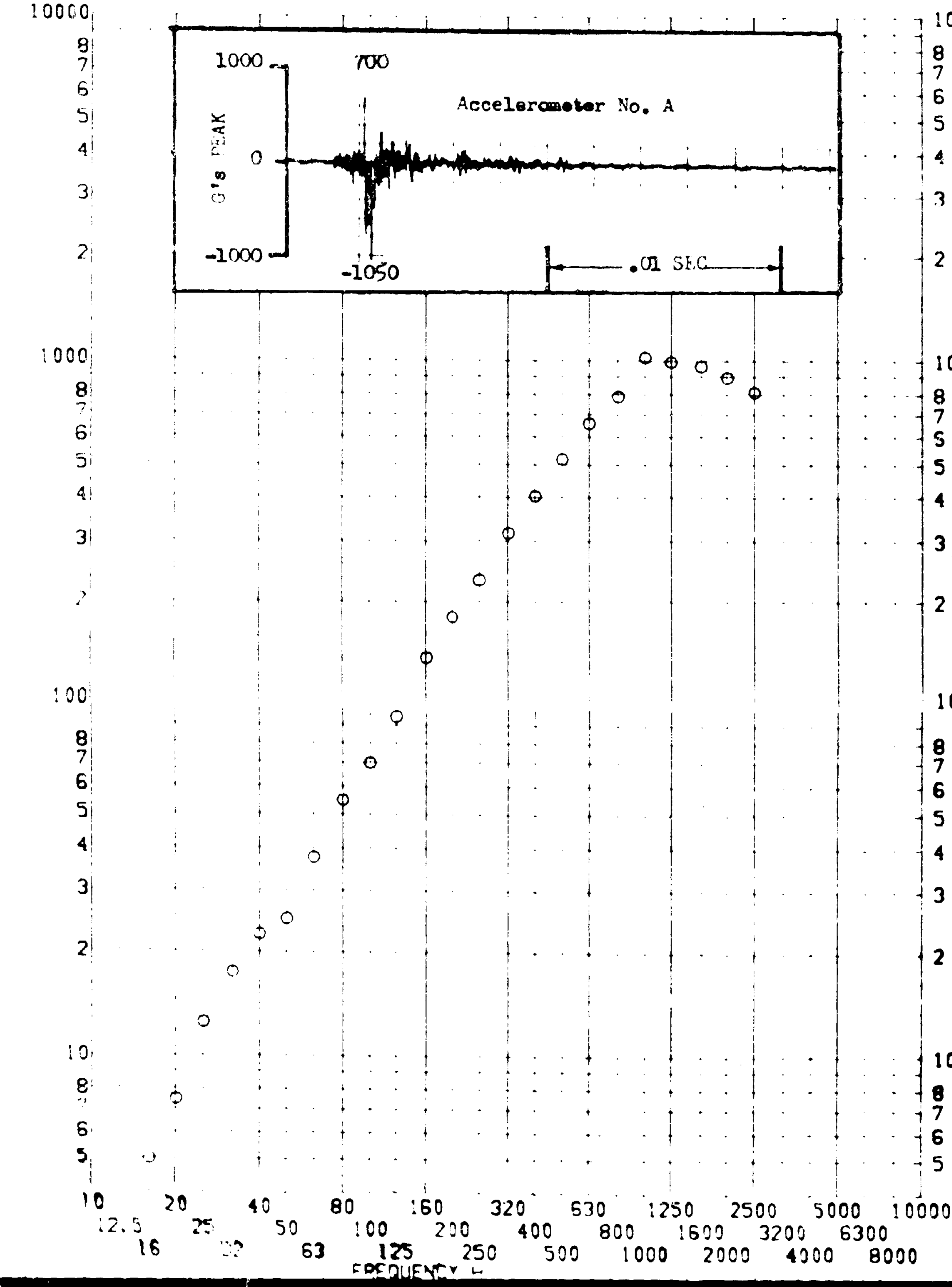
PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 2,6



SHOCK TEST ANALYSIS DATA SHEET II.C.2.25

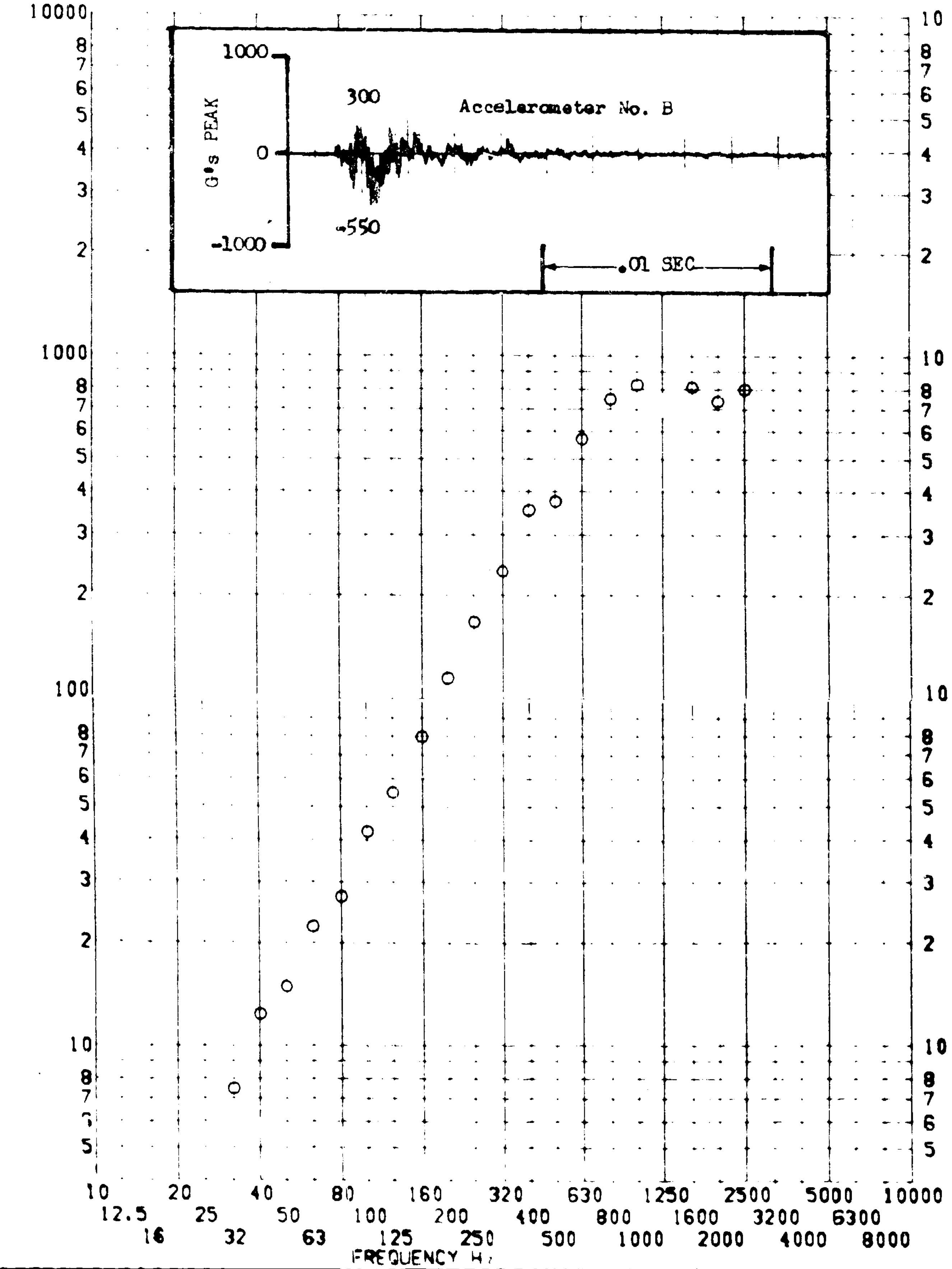
TEST ITEM 1336-218
SERIAL NO.
SHOCK AXIS X

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6A



SHOCK TEST ANALYSIS DATA SHEET II.C.2.?6

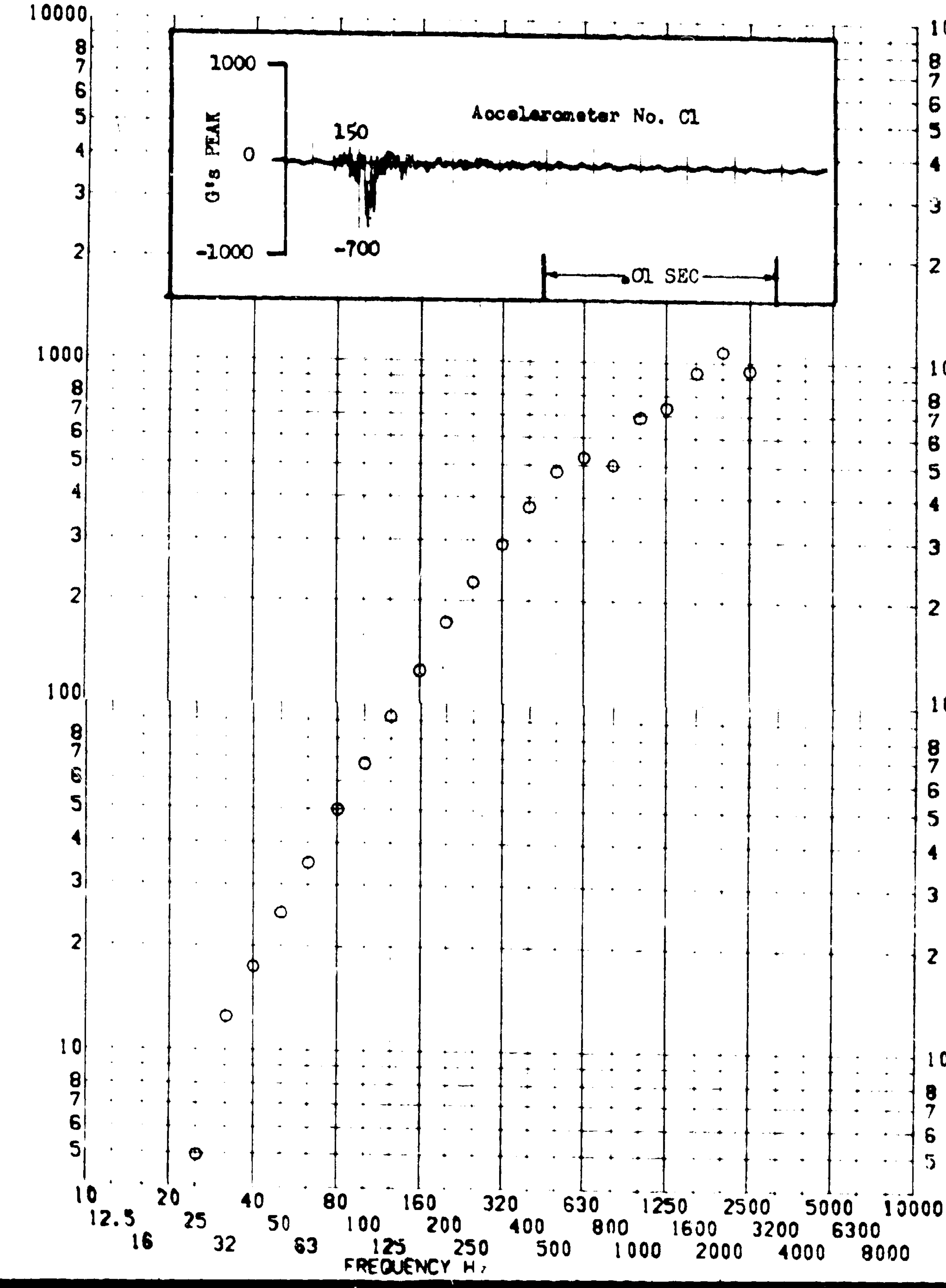
TEST ITEM 1336-220 PART NO. BOX
SERIAL NO. TEST DATE 4 OCT 1968
SHOCK AXIS Y SHOCK NO. 6A



SHOCK TEST ANALYSIS DATA SHEET II.C.2.27

TEST ITEM 1336-222
SERIAL NO.
SHOCK AXIS Z

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6A

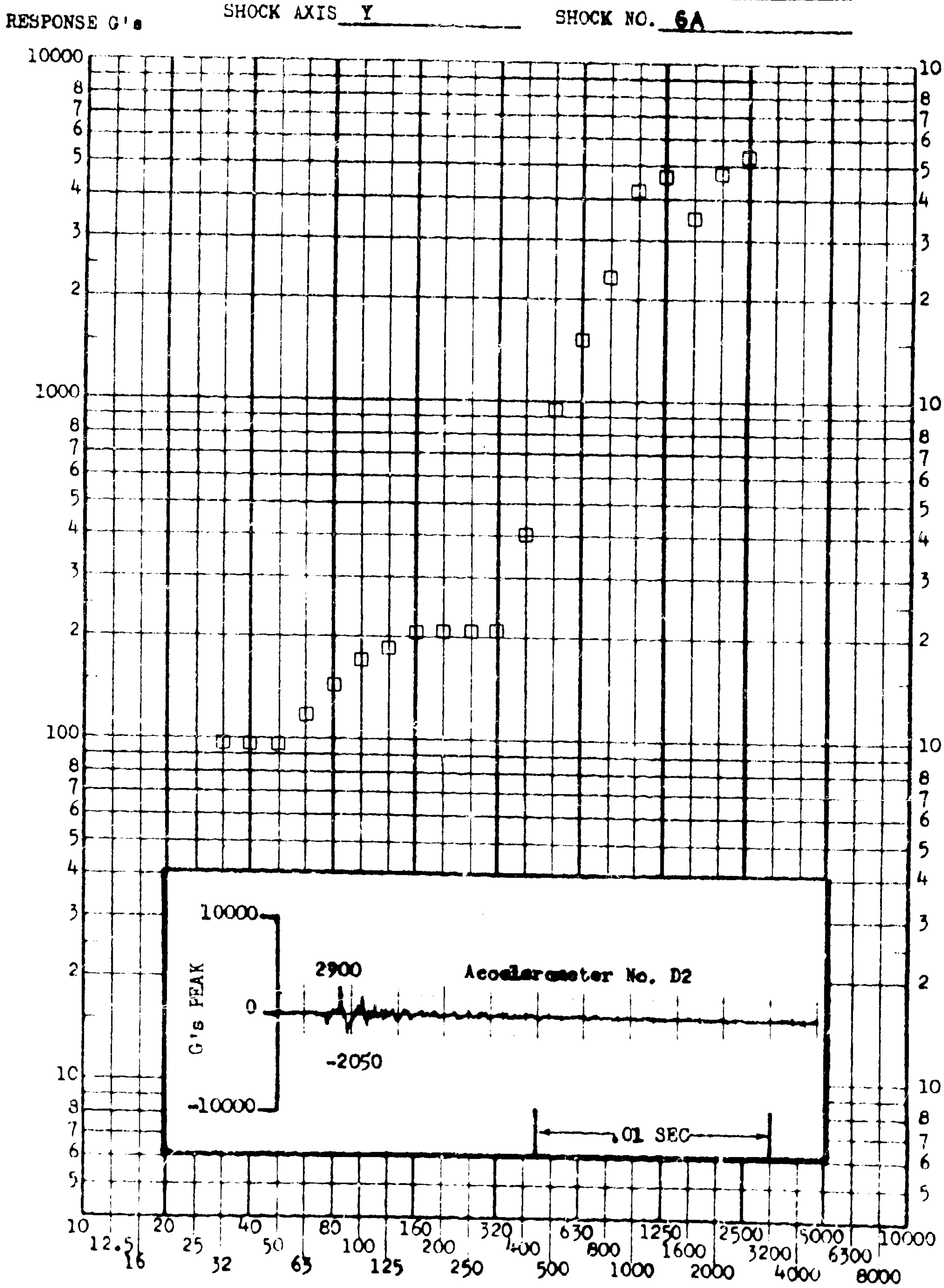


SHOCK TEST ANALYSIS DATA SHEET III.C.2.28

TEST ITEM 1386-216 PART NO. FRAME

SERIAL NO. TEST DATE 4 Oct 1968

SHOCK AXIS Y SHOCK NO. 6A



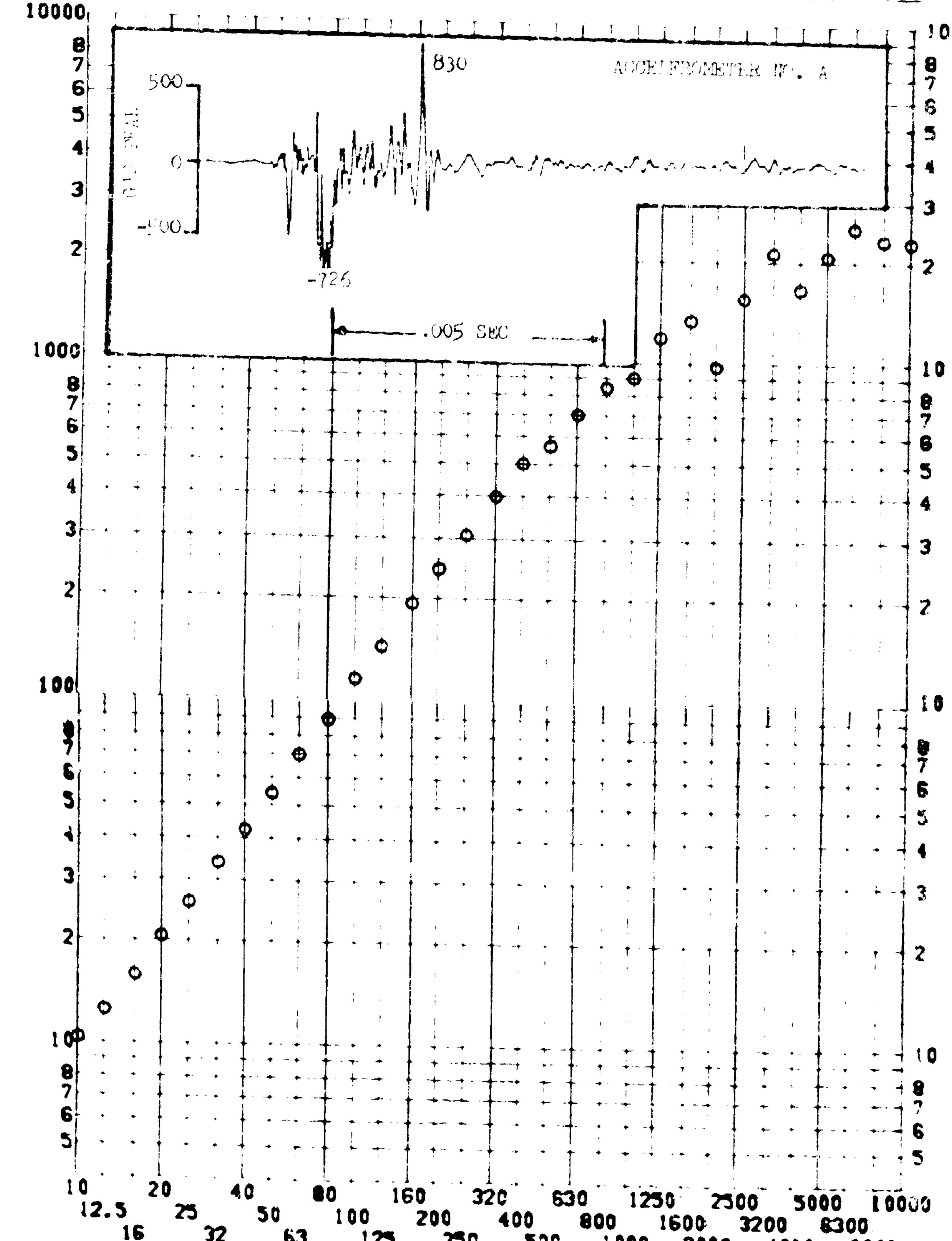
SHOCK TEST ANALYSIS DATA SHEET

11.C.2.29

TEST ITEM 1336-108
SERIAL NO.
SHOCK AXIS X

PART NO. BOX
TEST DATE [illegible] OCT 1968
SHOCK NO. 7

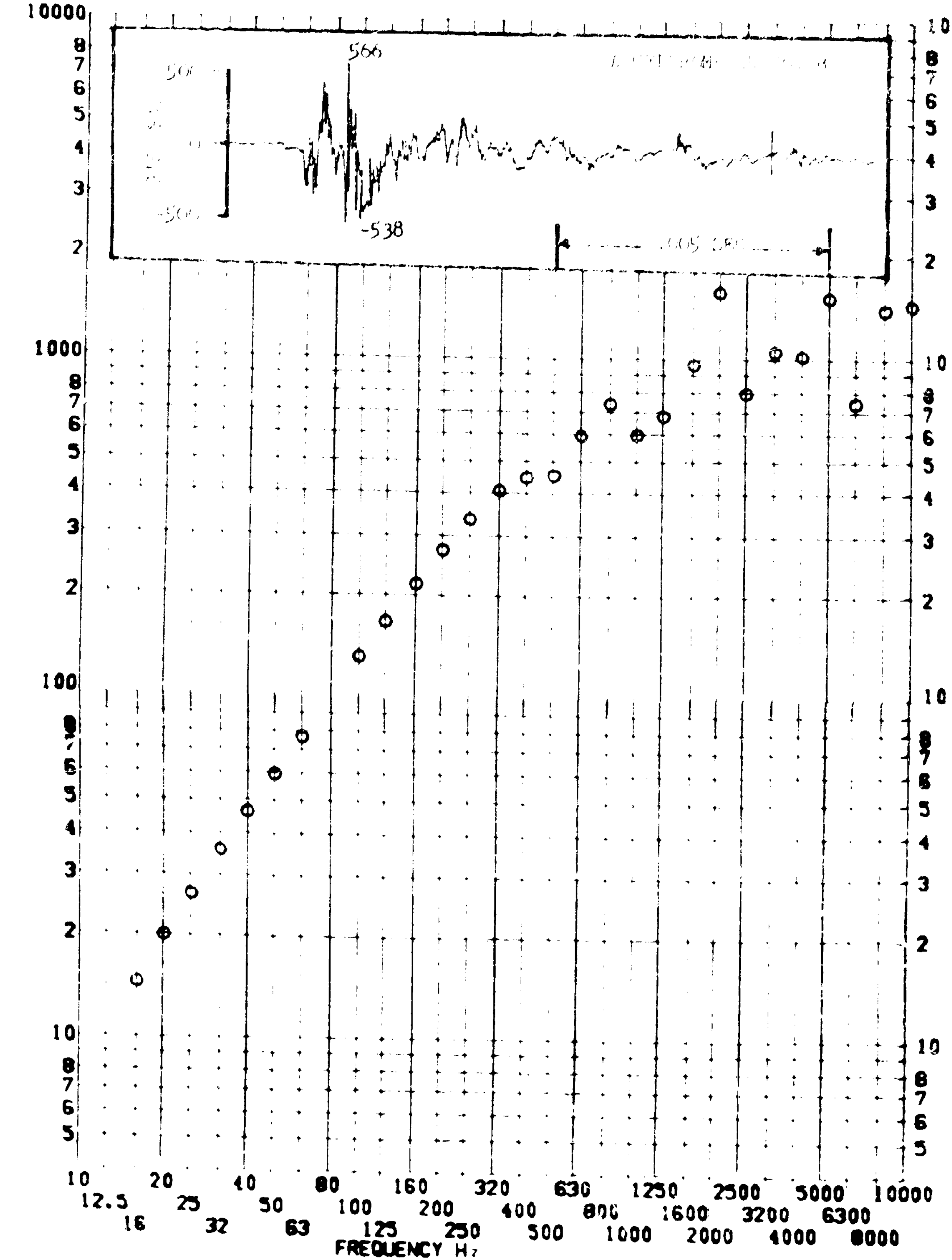
RESPONSE G S



SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM 1336-209
SERIAL NO.
SHOCK AXIS Y

PART NO.
TEST DATE
SHOCK NO.

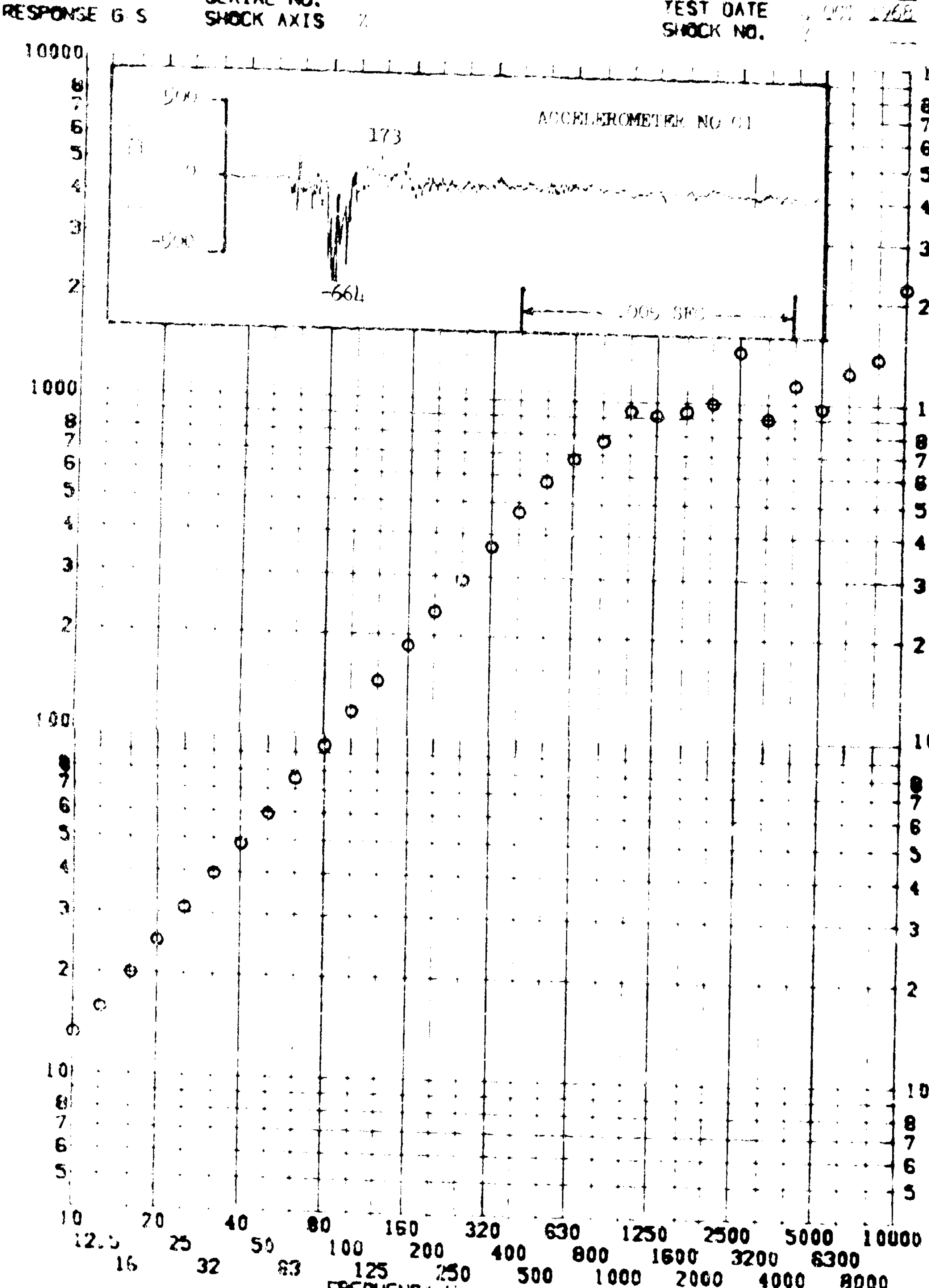


LMSC/A955909

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM 1336-10
SERIAL NO.
SHOCK AXIS Z

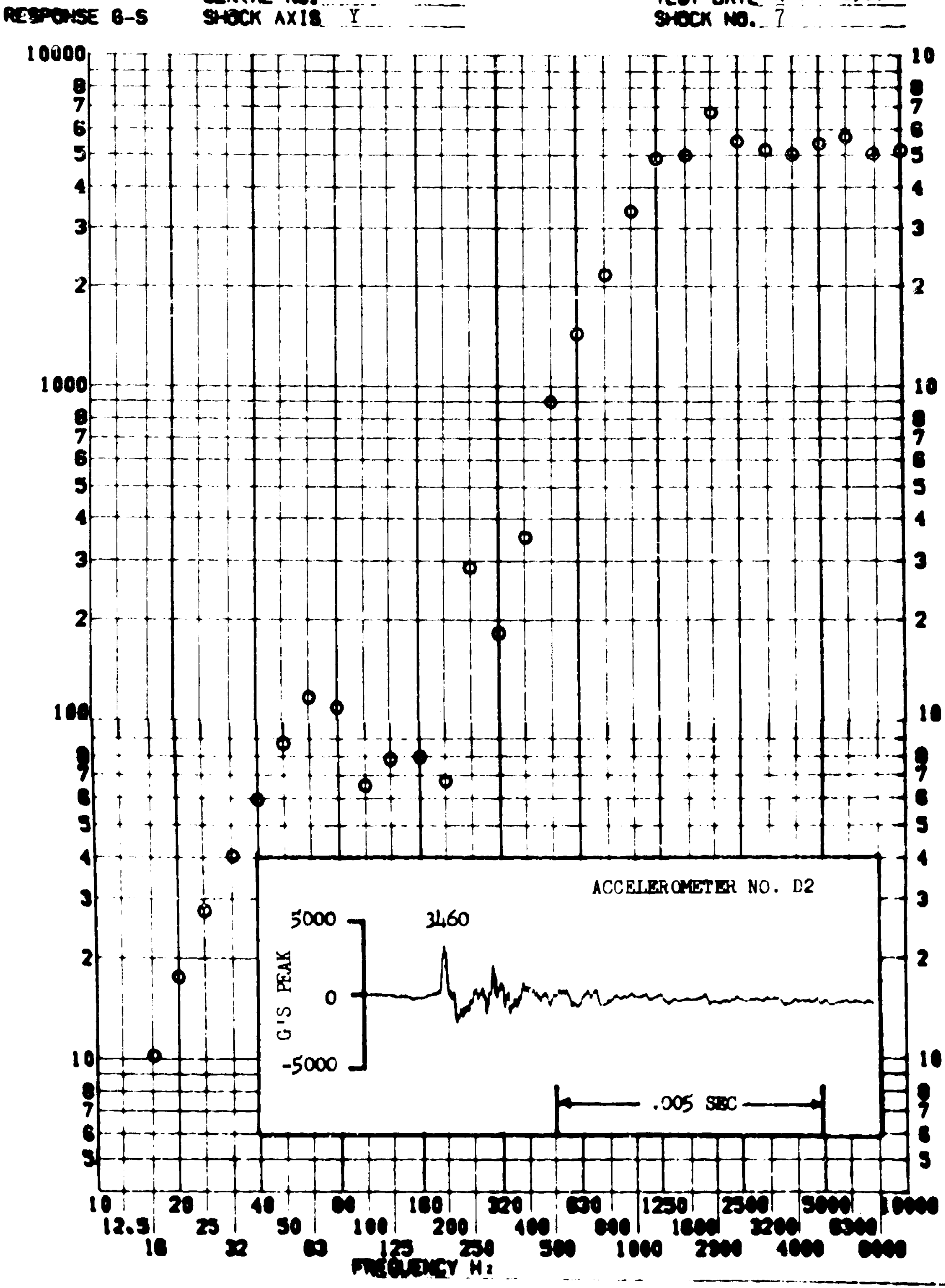
PART NO.
TEST DATE
SHOCK NO.



SHOCK TEST ANALYSIS DATA SHEET II.C.2.32

TEST ITEM 1336-207
SERIAL NO.
SHOCK AXIS Y

PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 7

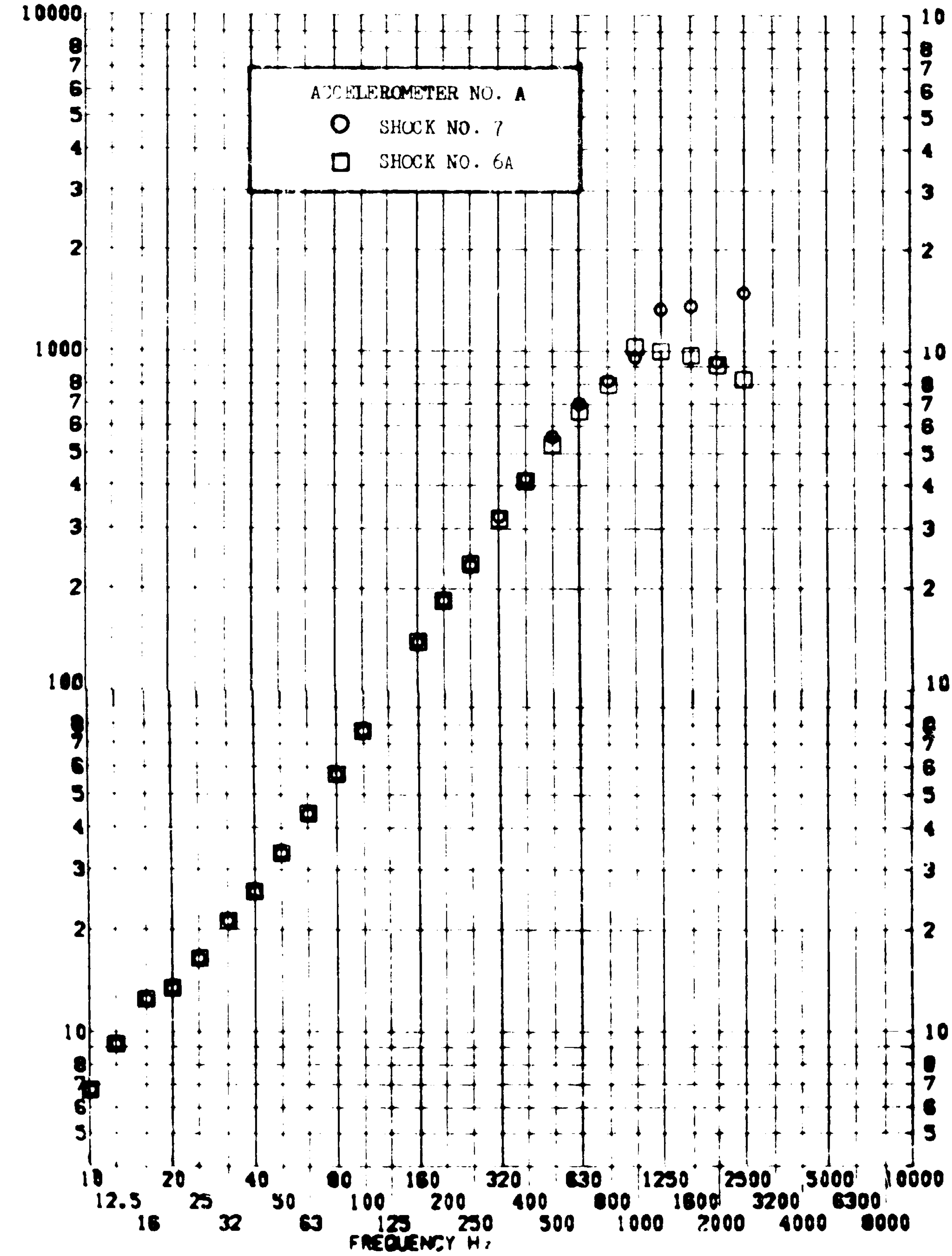


SHOCK TEST ANALYSIS DATA SHEET II.?.2.33

TEST ITEM 1336-217,218
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 6A & 7

RESPONSE G-S

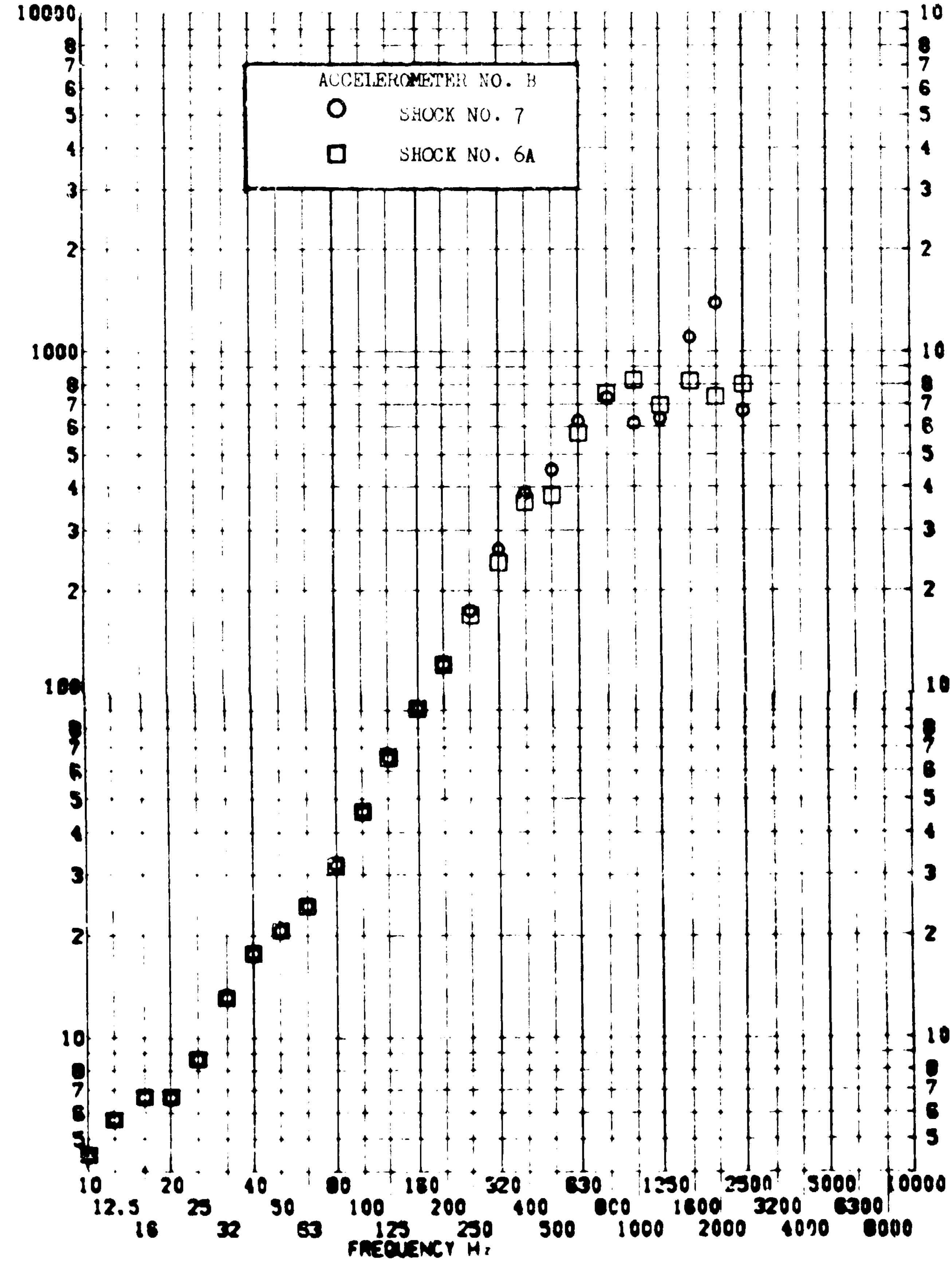


SHOCK TEST ANALYSIS DATA SHEET

II.C.2.34

TEST ITEM	1336-219,220	PART NO.	BOX
SERIAL NO.		TEST DATE	4 OCT 1968
SHOCK AXIS	Y	SHOCK NO.	6A & 7

ESPONSE G-S

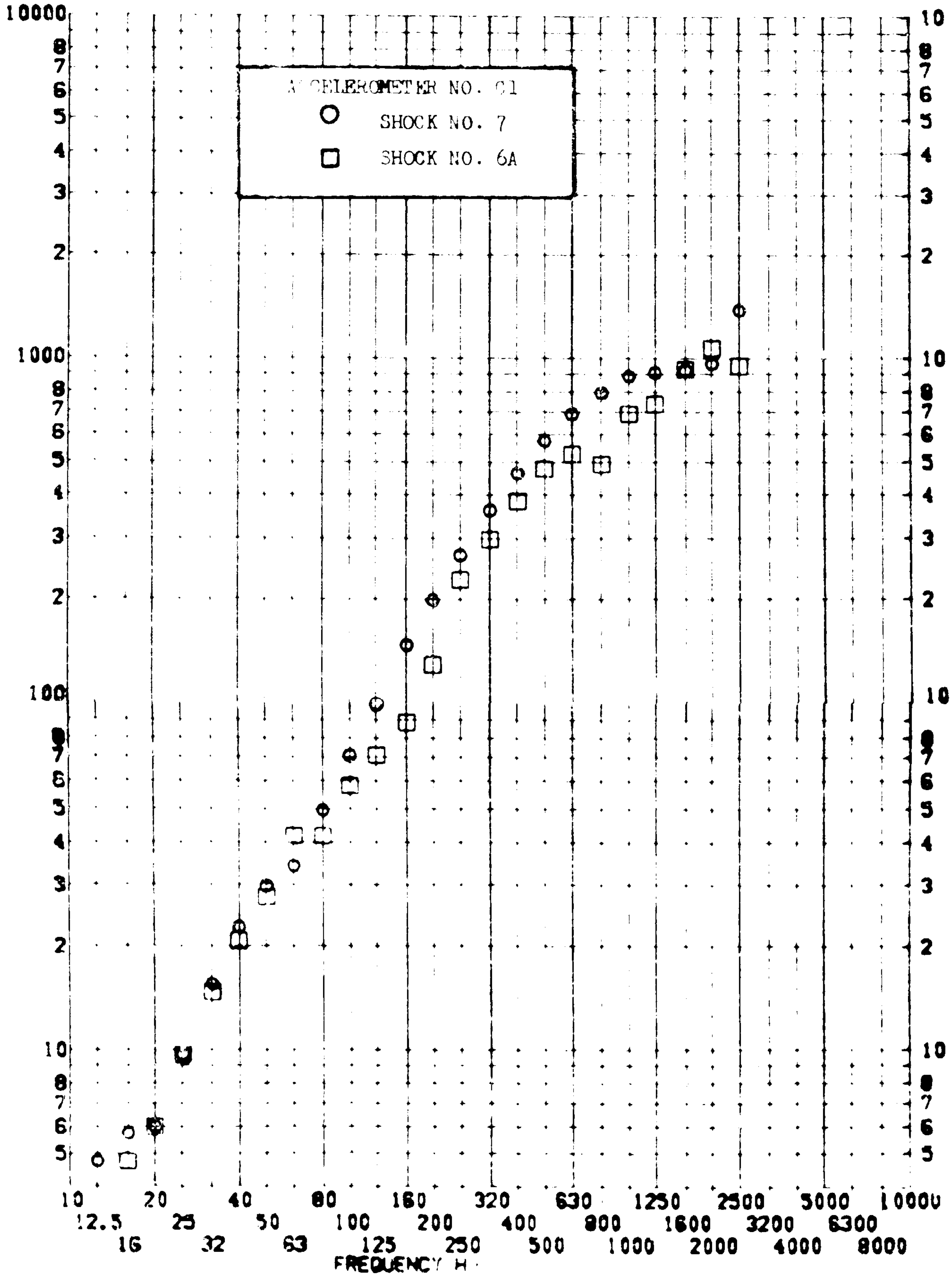


SHOCK TEST ANALYSIS DATA SHEET

II.?.2.35

TEST ITEM 1336-221,222
SERIAL NO.
SHOCK AXIS 7

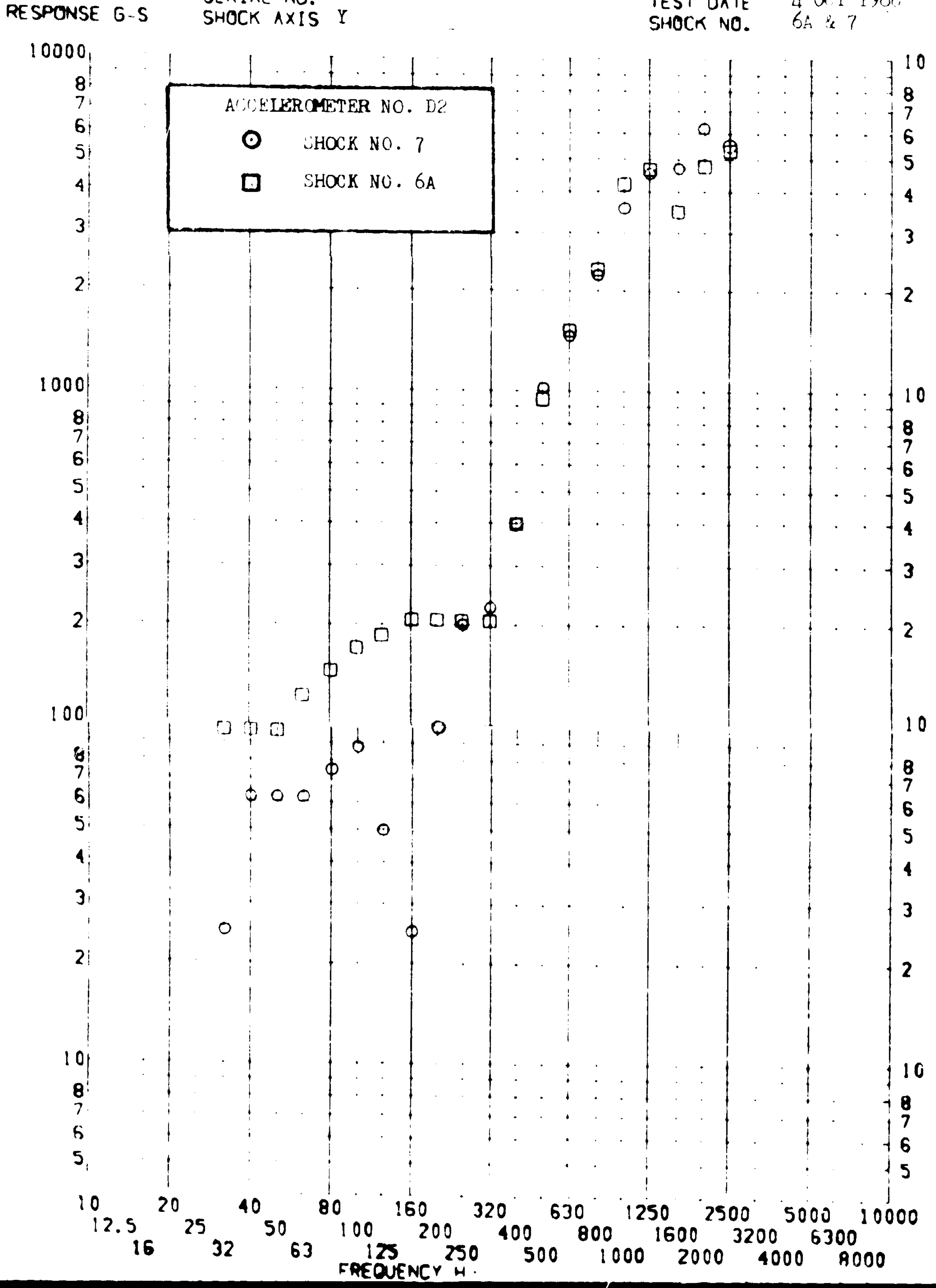
PART NO. BOX
TEST DATE 1 OCT 1968
SHOCK NO. 6A & 7



SHOCK TEST ANALYSIS DATA SHEET II.C.2.36

TEST ITEM 1336-215,216
SERIAL NO.
SHOCK AXIS Y

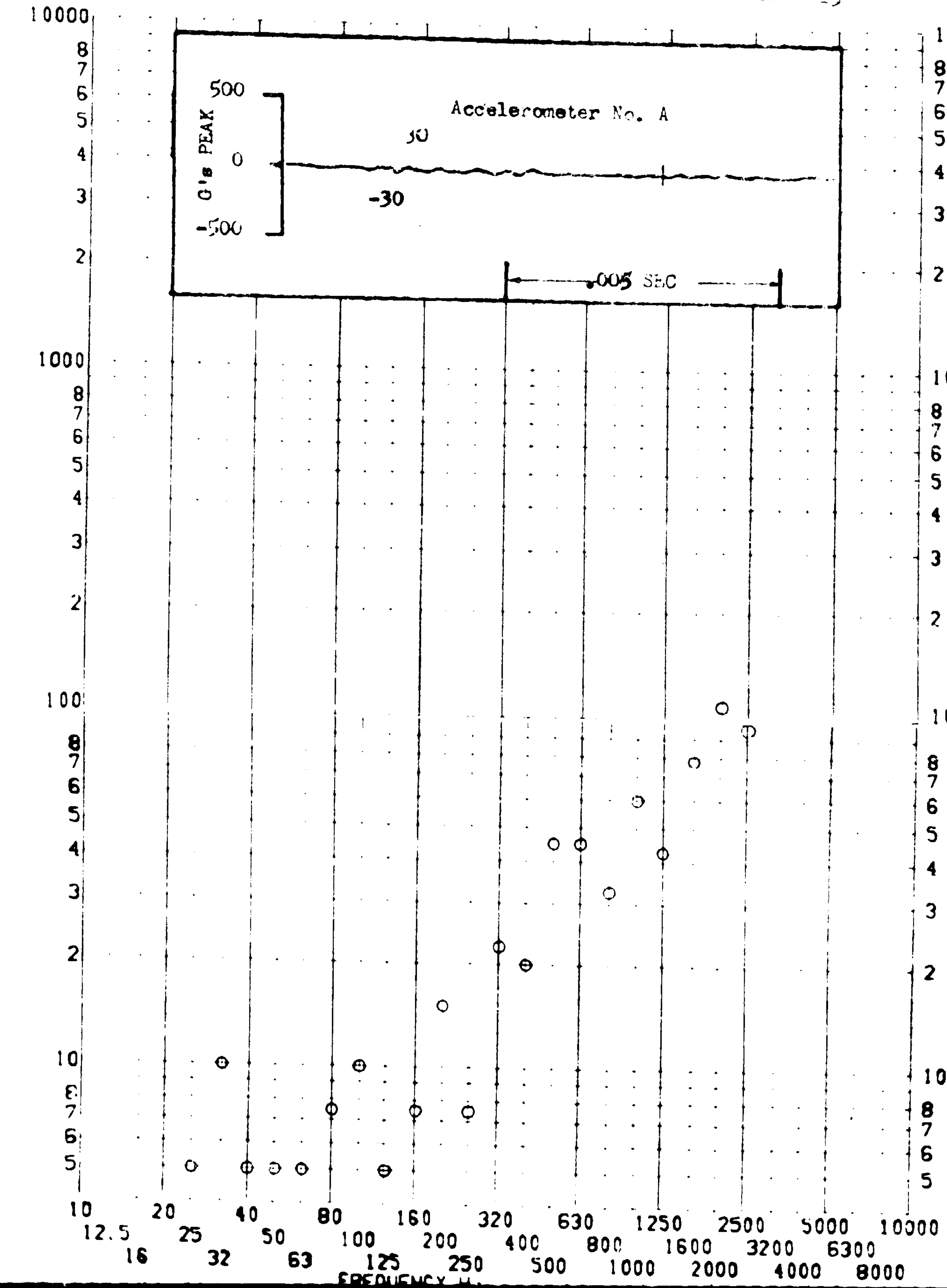
PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 6A & 7



SHOCK TEST ANALYSIS DATA SHEET 11.0.2.37

TEST ITEM 1336-228
SERIAL NO.
SHOCK AXIS X

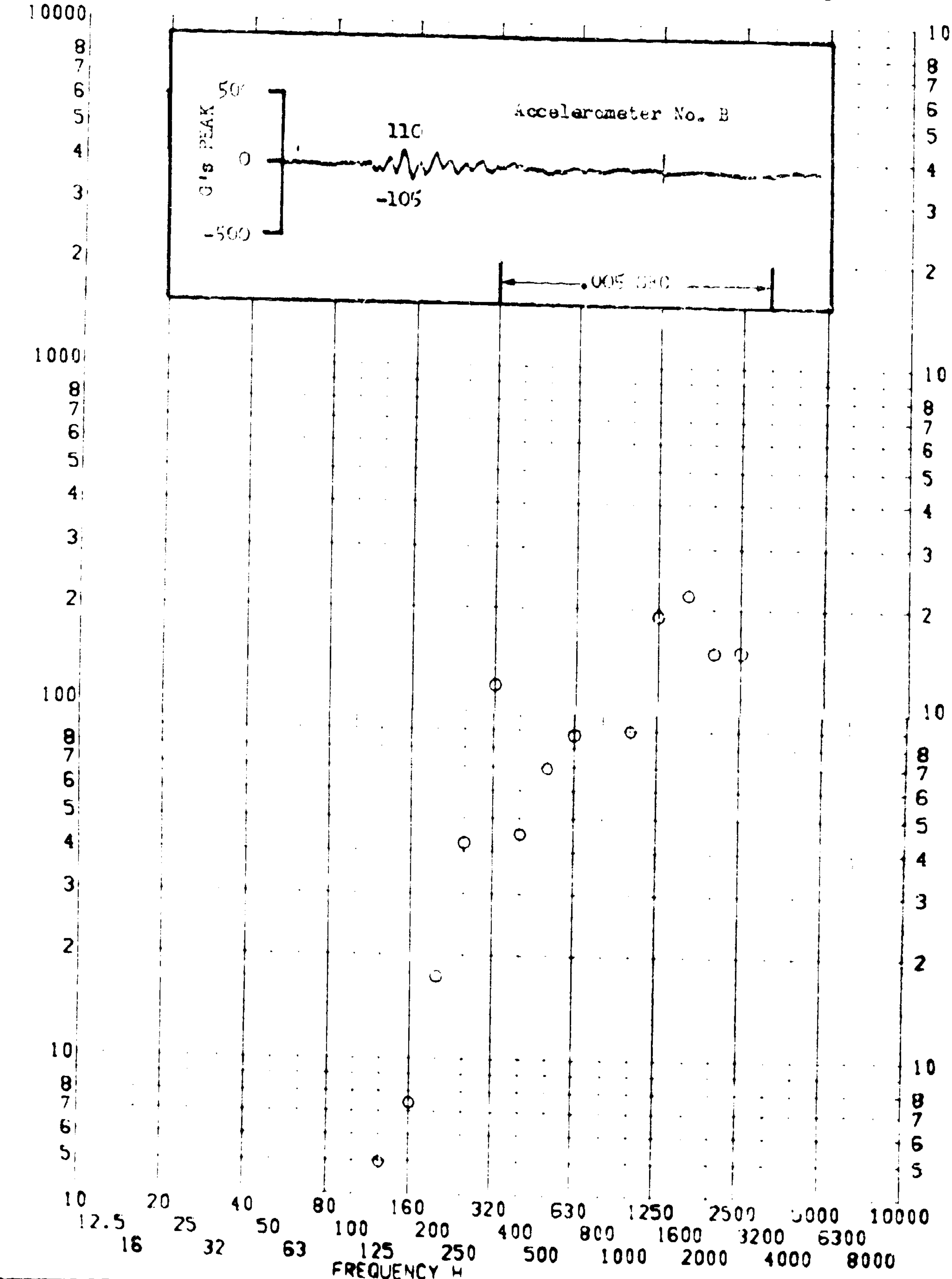
PART NO. BOX
TEST DATE 1 OCT 1968
SHOCK NO. 23



SHOCK TEST ANALYSIS DATA SHEET II.C.2.39

TEST ITEM 1336-231
SERIAL NO.
SHOCK AXIS Y

PART NO. 80A
TEST DATE 4 OCT 196
SHOCK NO. 13



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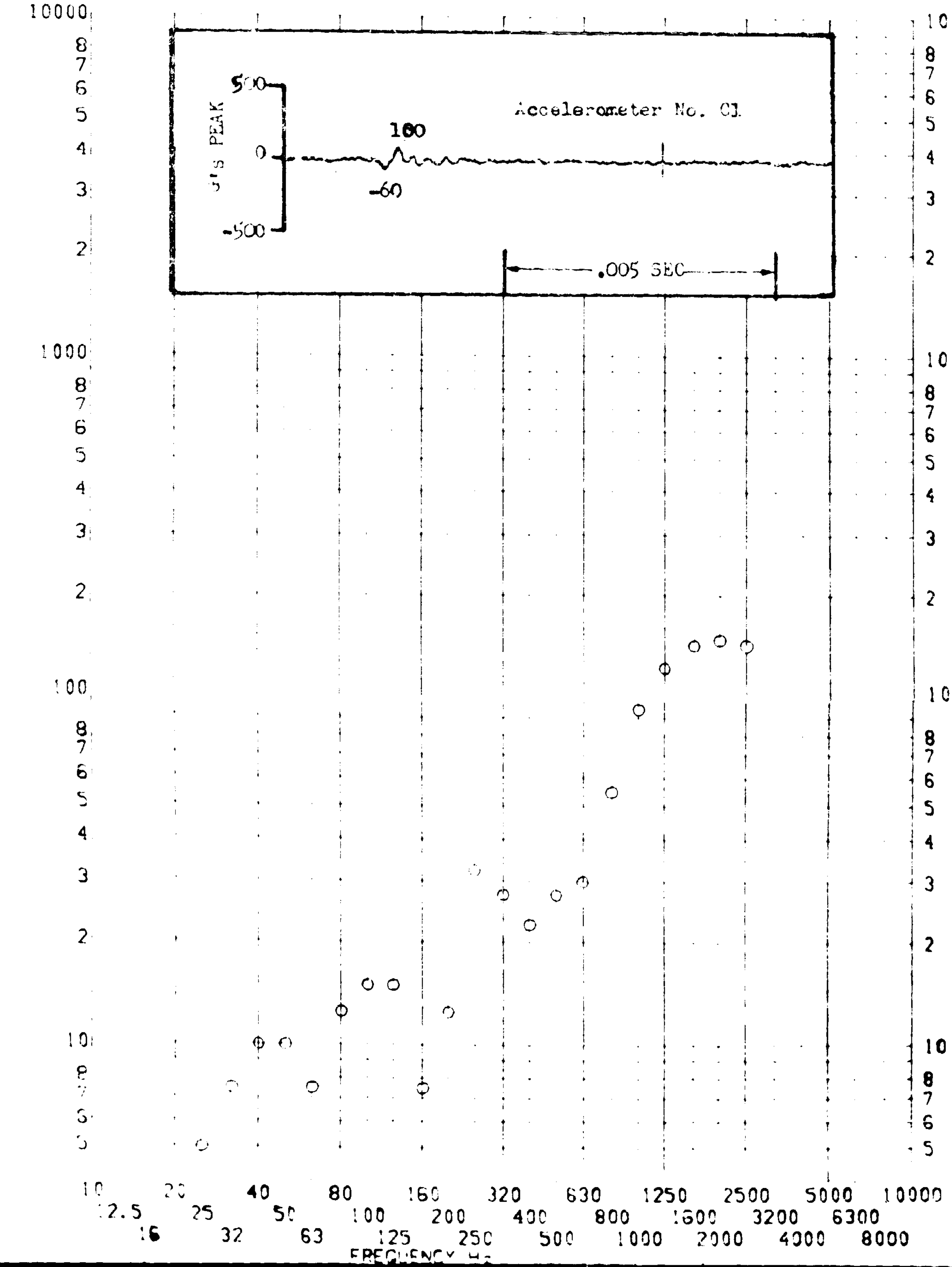
SHOCK AXIS

PART NO.
TEST DATE
SHOCK NO.



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PART NO. FRAME
TEST DATE ? OCT 1968
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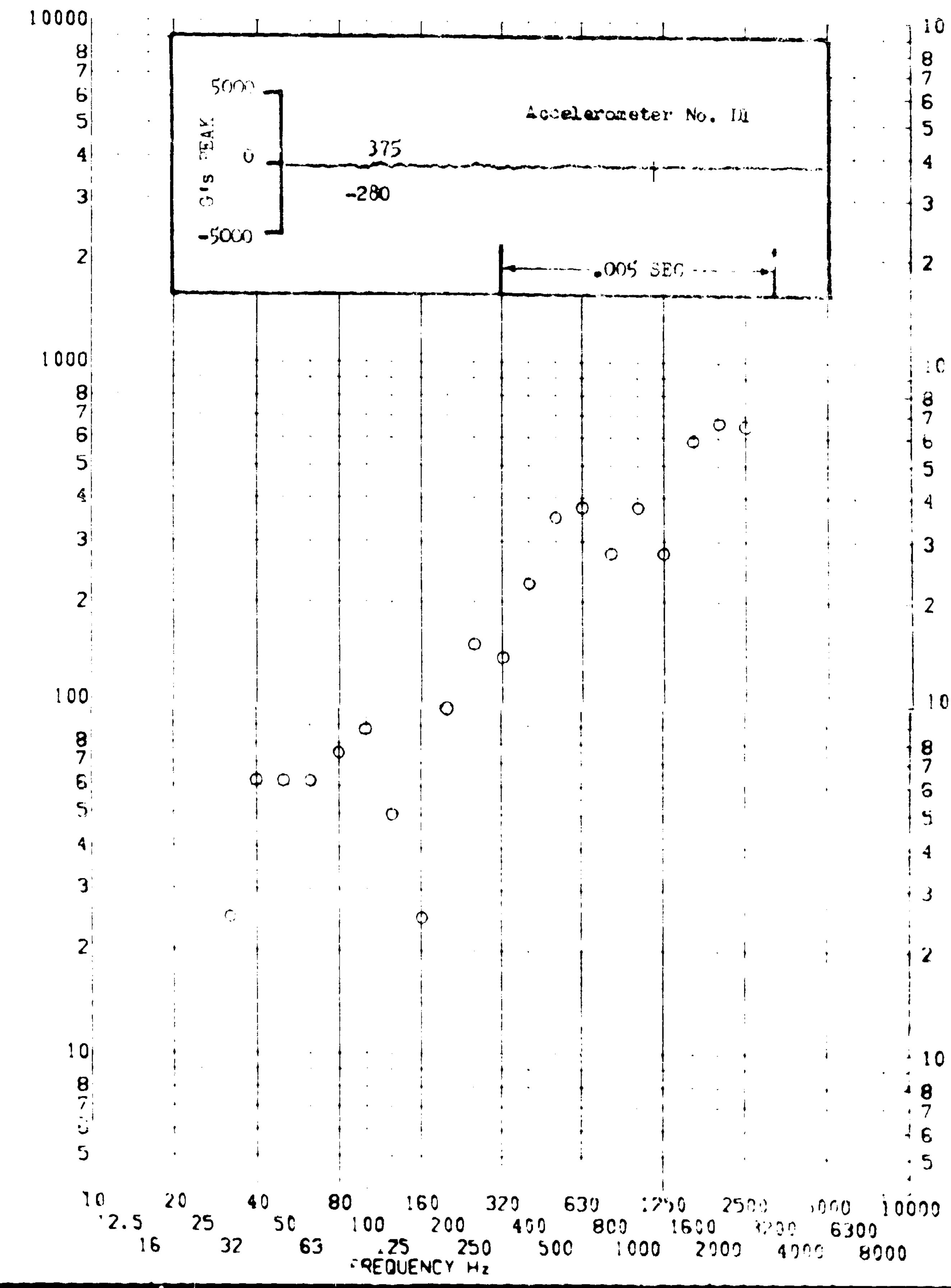

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PART NO.
TEST DATE
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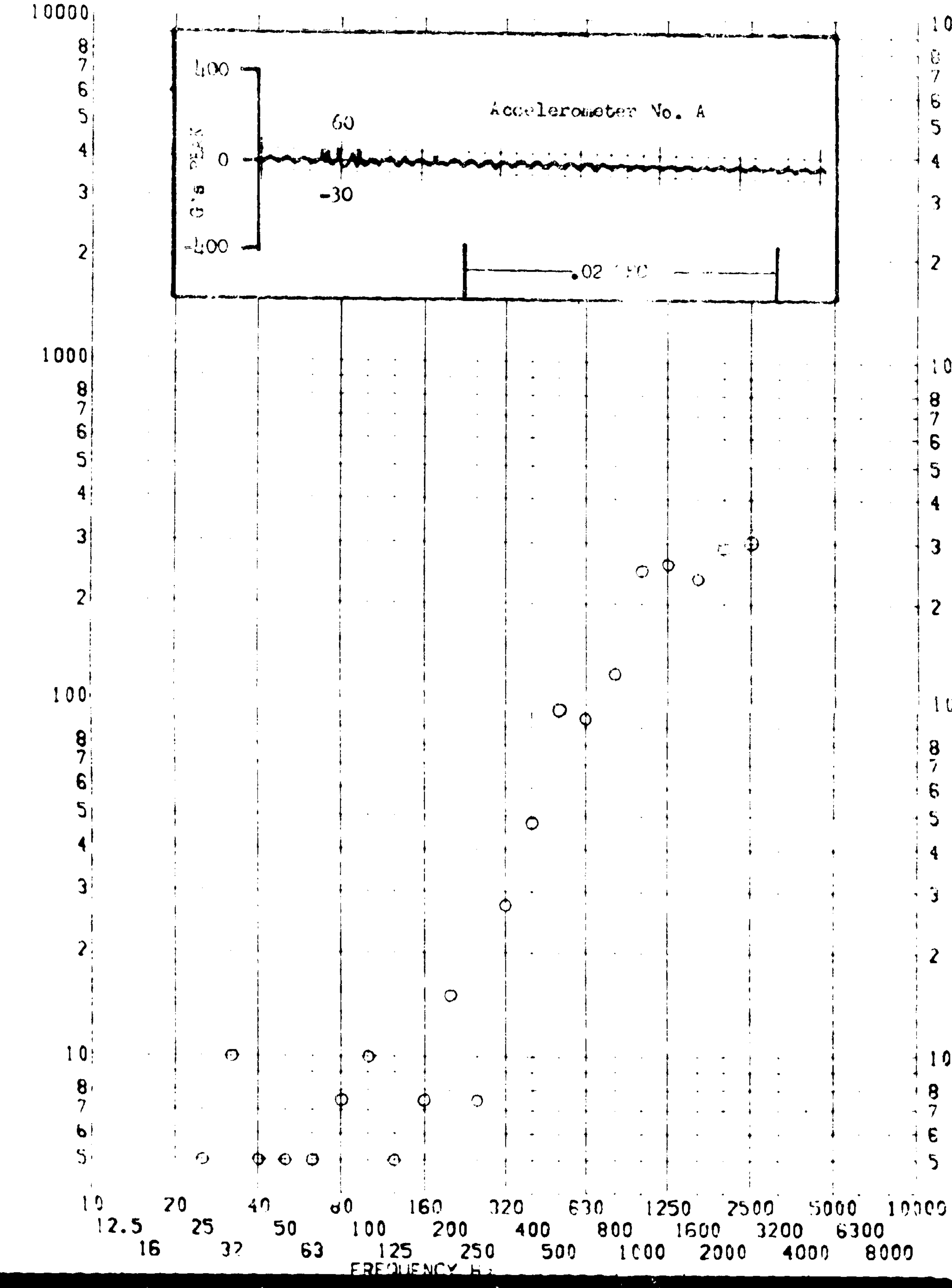

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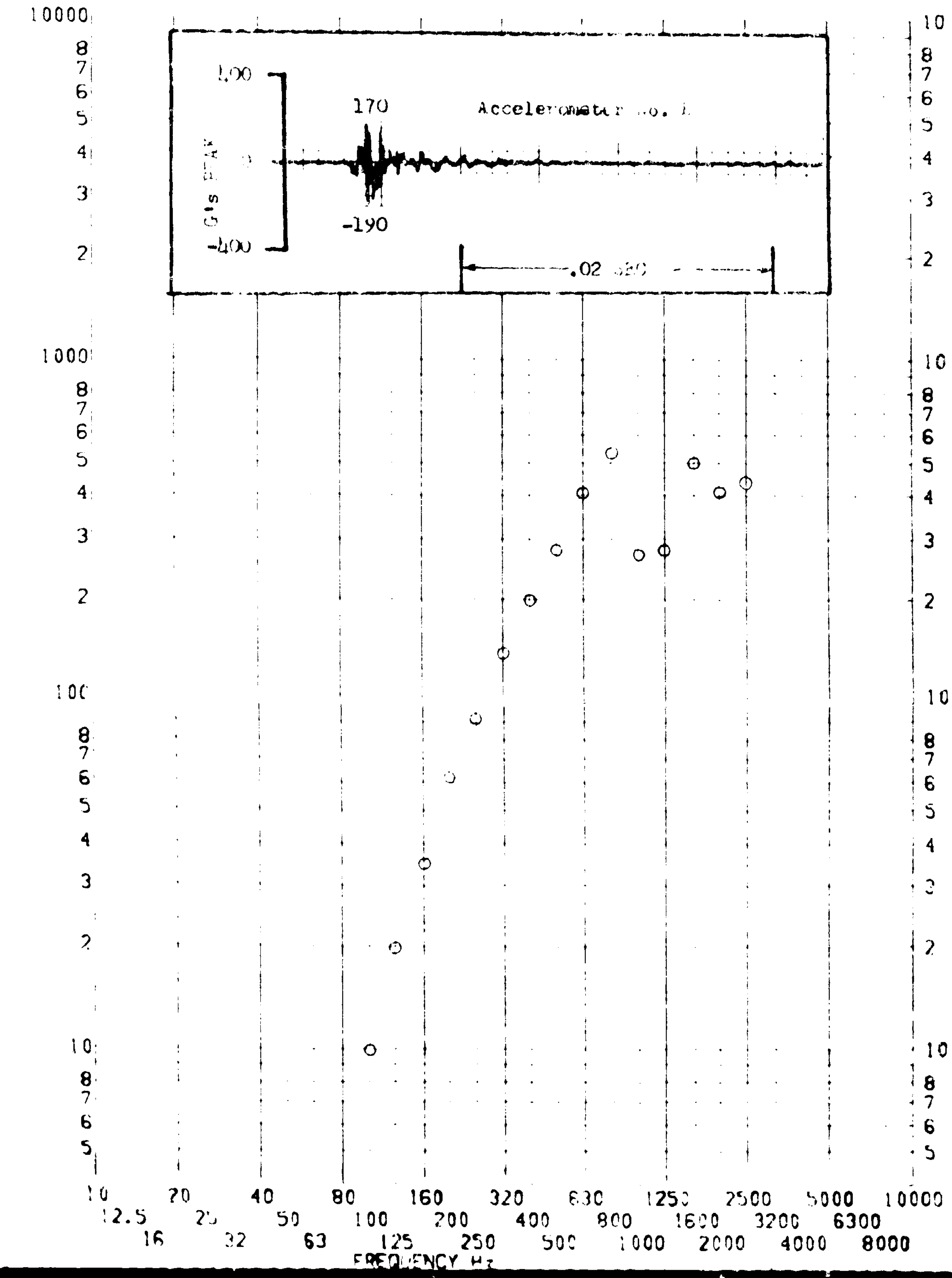
PART NO.
TEST DATE
SHOCK NO.



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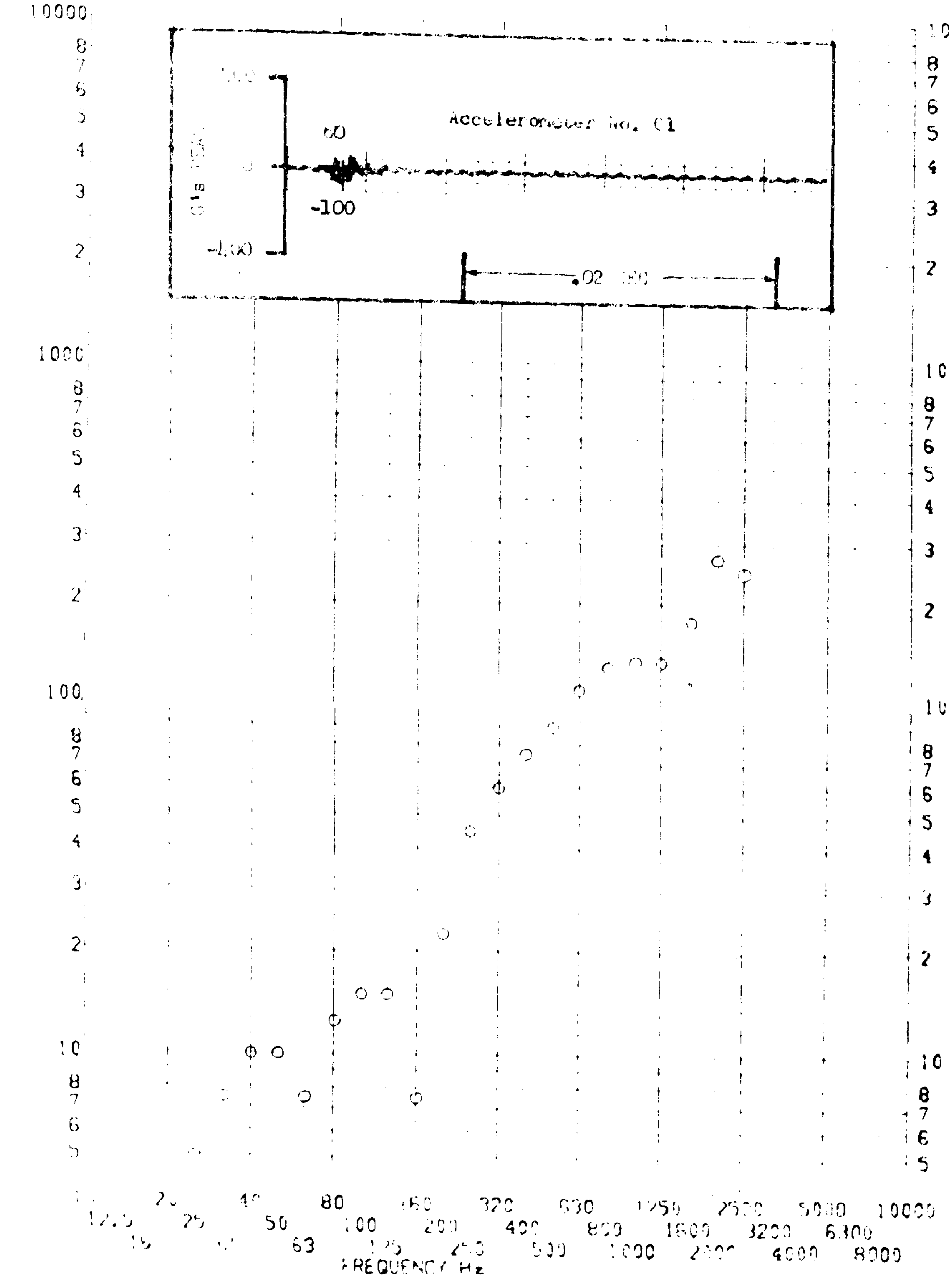
TEST ITEM 1386 2.. PART NO.
SERIAL NO. TEST DATE
SHOCK AXIS SHOCK NO.

RESPONSE G'S



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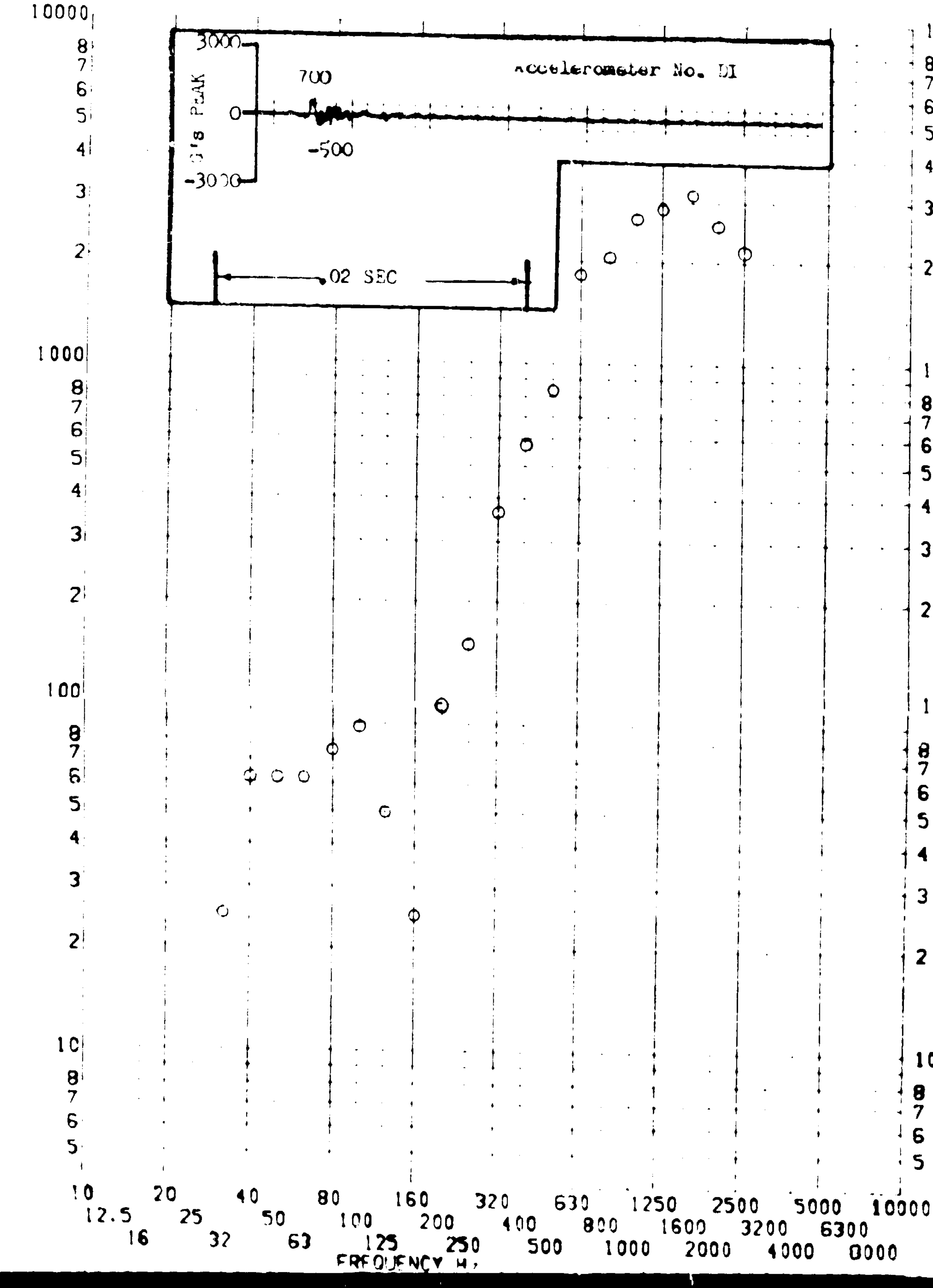

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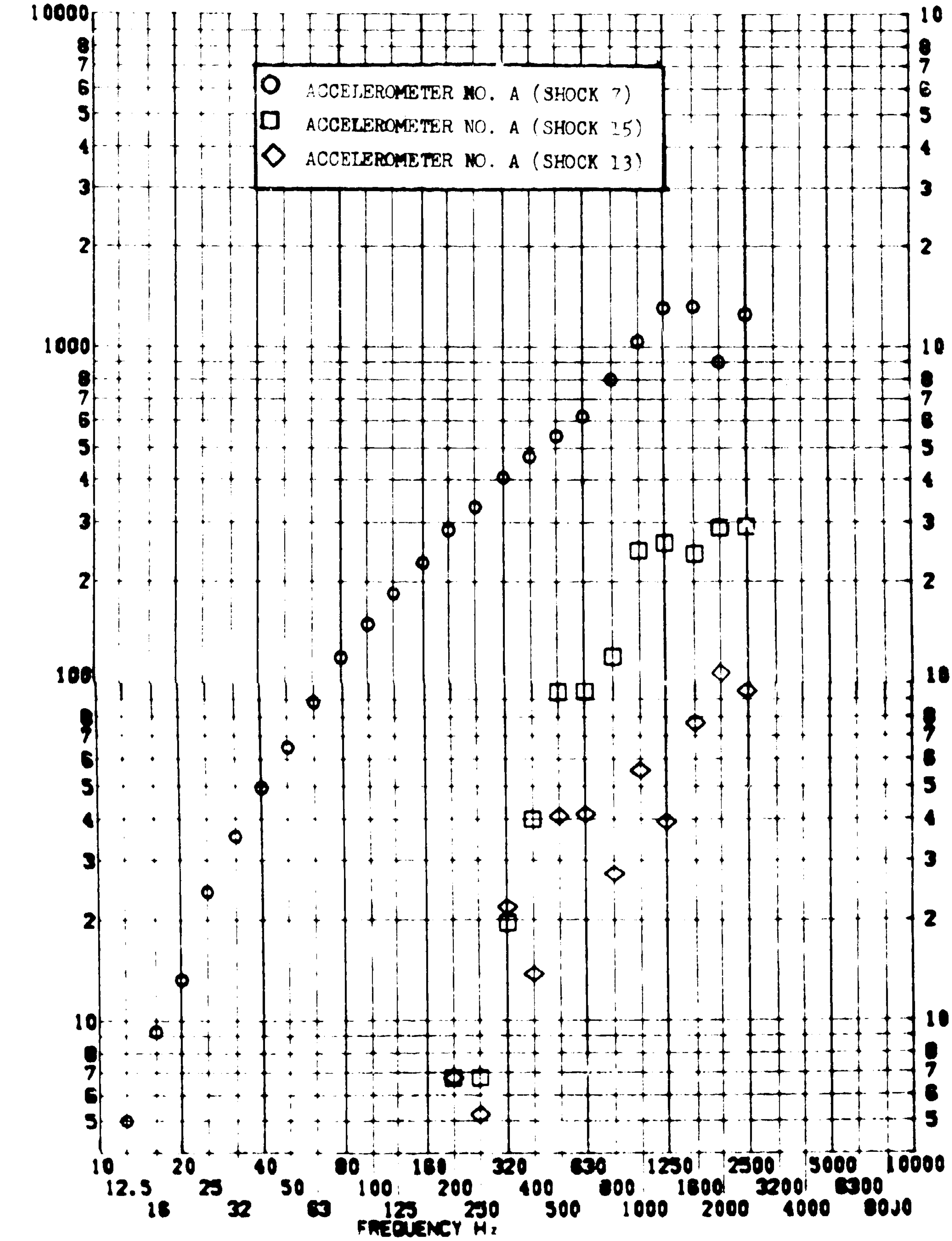

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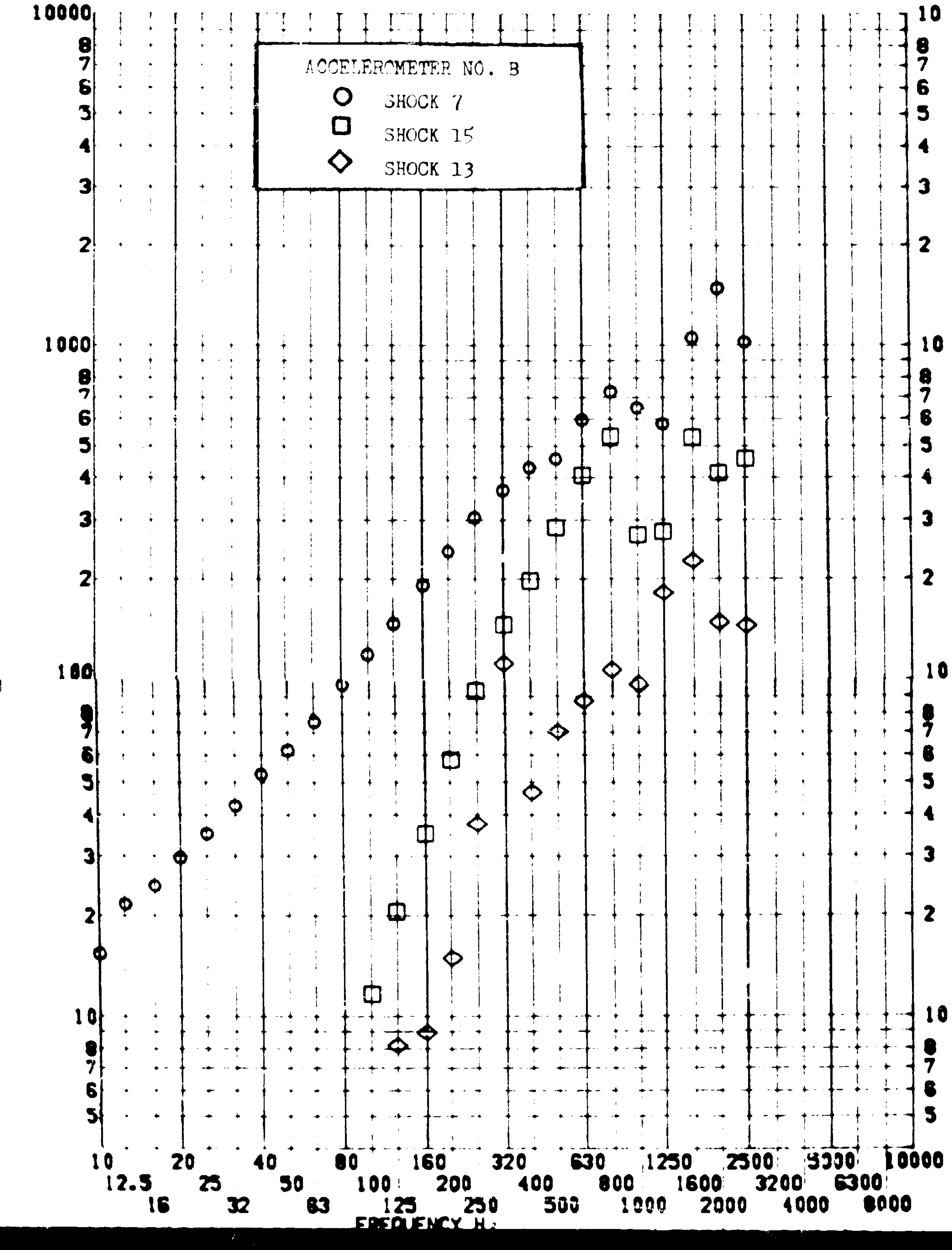

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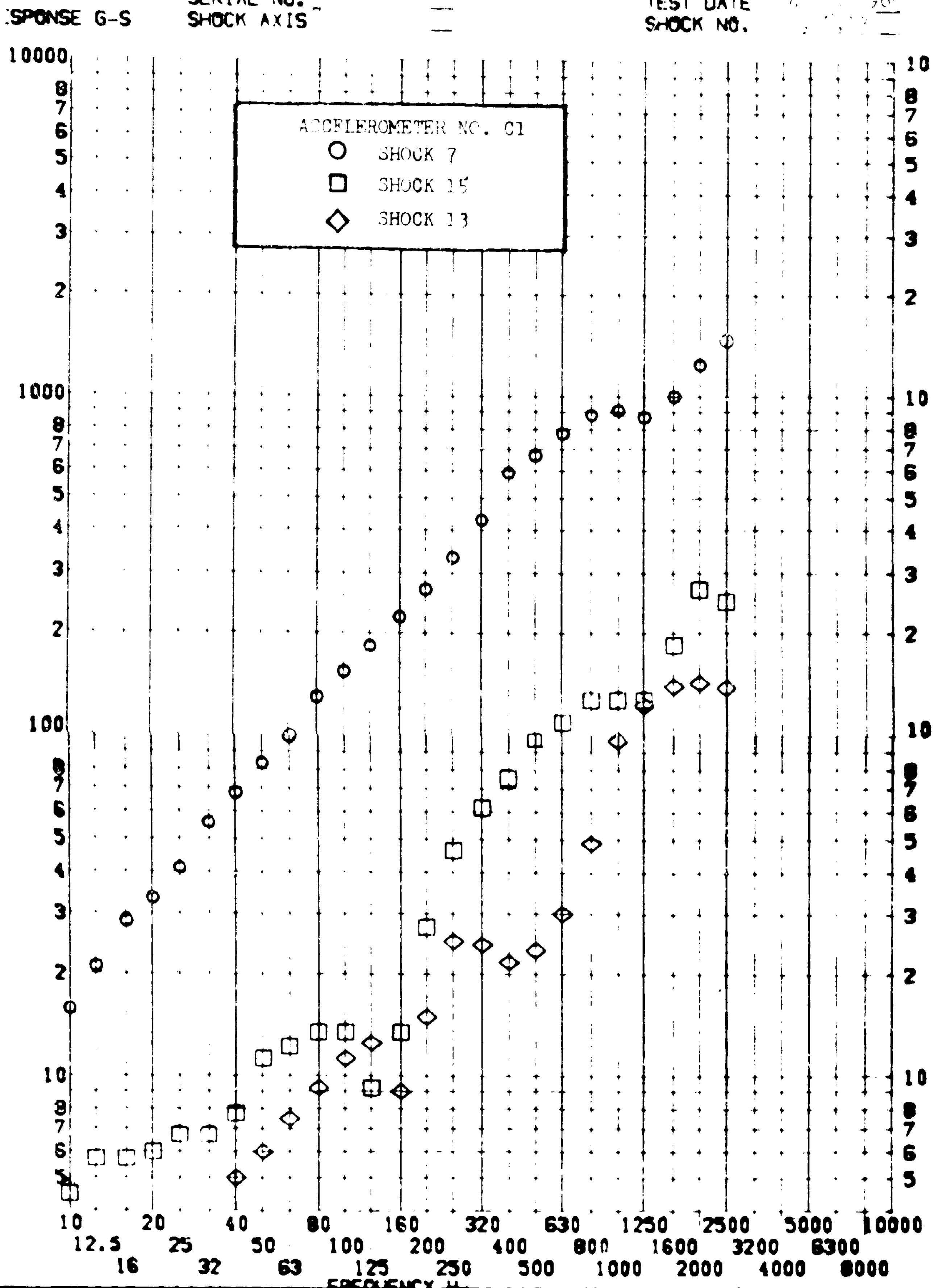

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II.?.2.18

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SHOCK AXIS Y —

PART NO. FRAME
TEST DATE 1 OCT 1968
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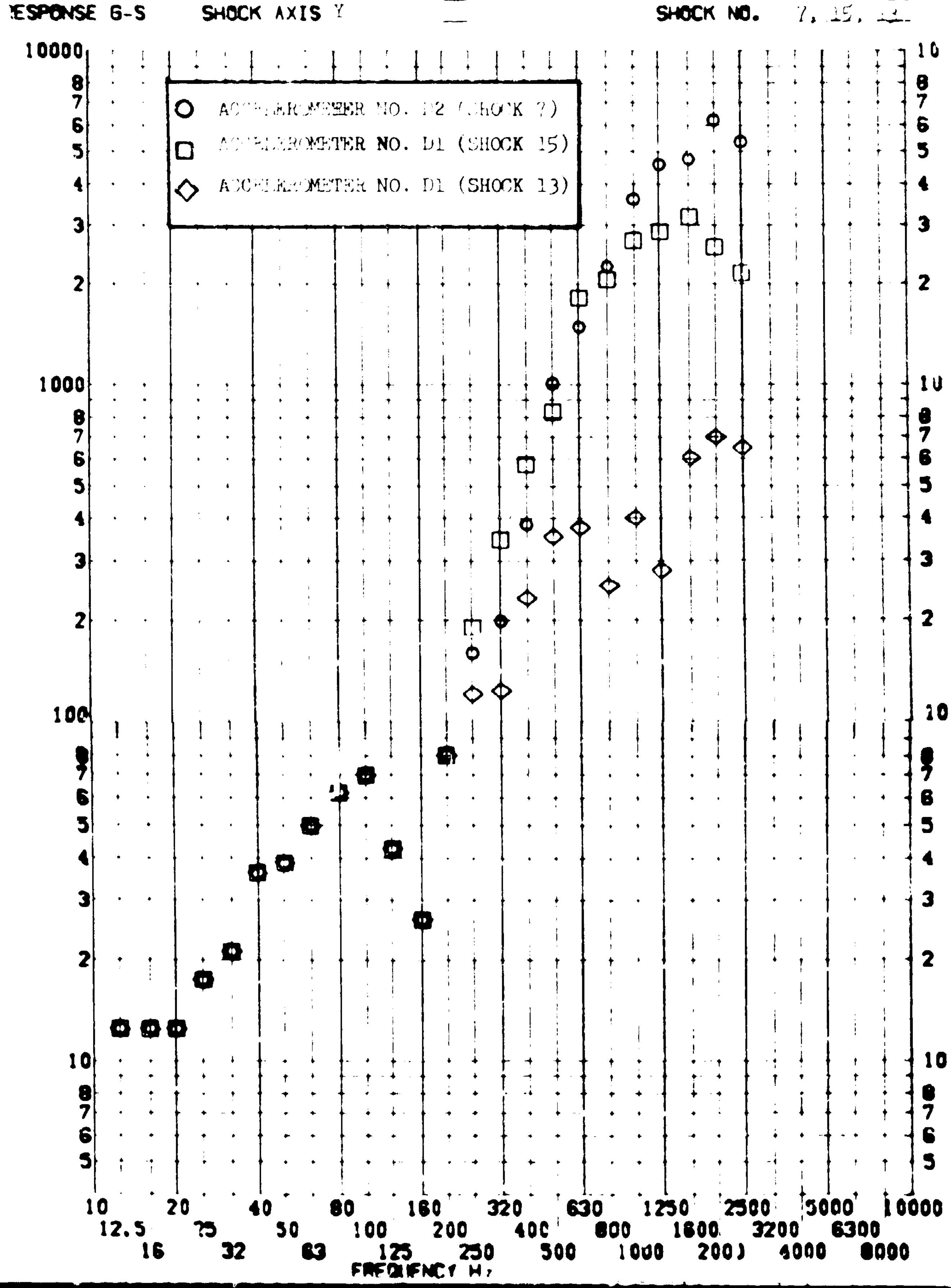

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SHOCK AXIS X

PART NO. BOX
TEST DATE 4 OCT 1968
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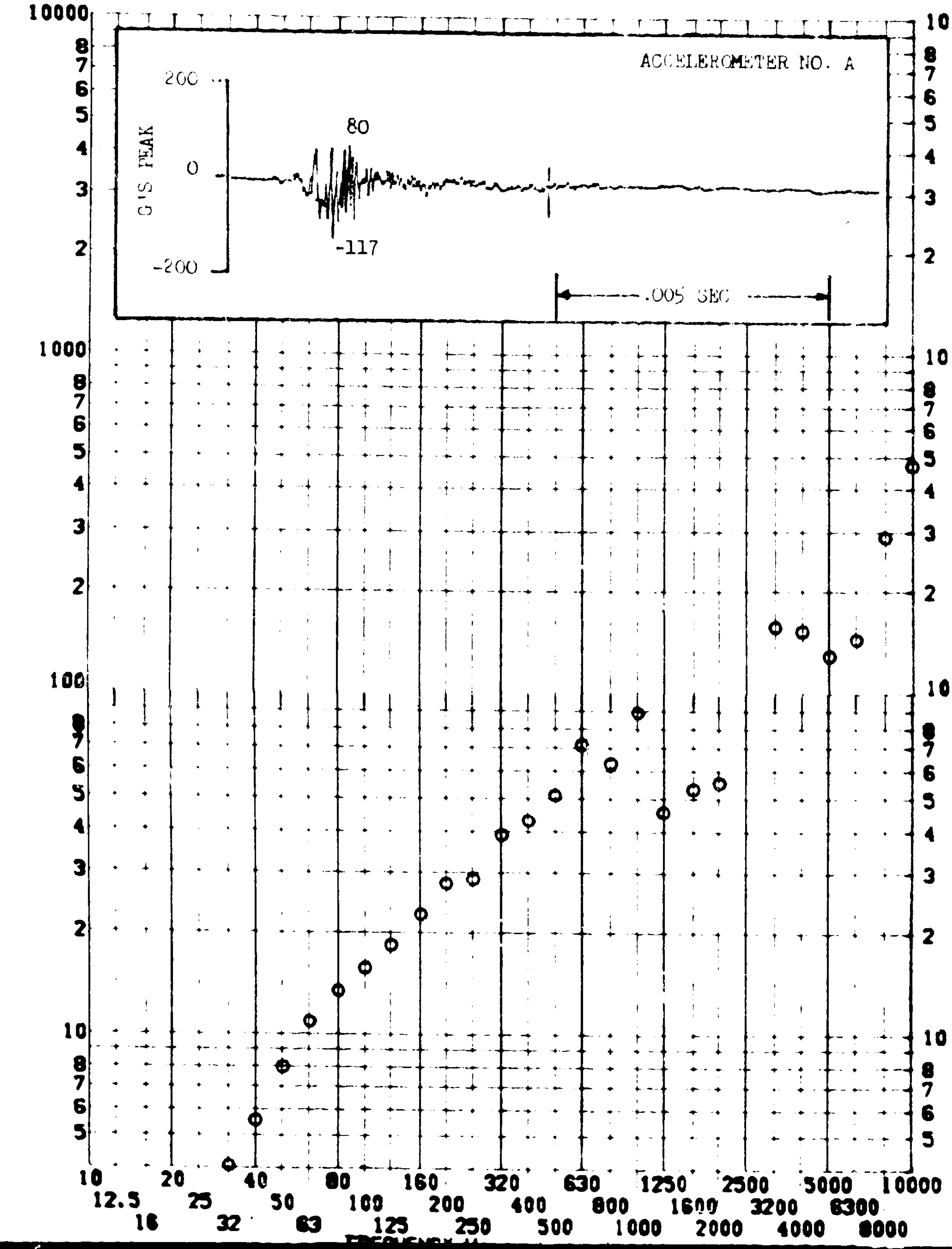

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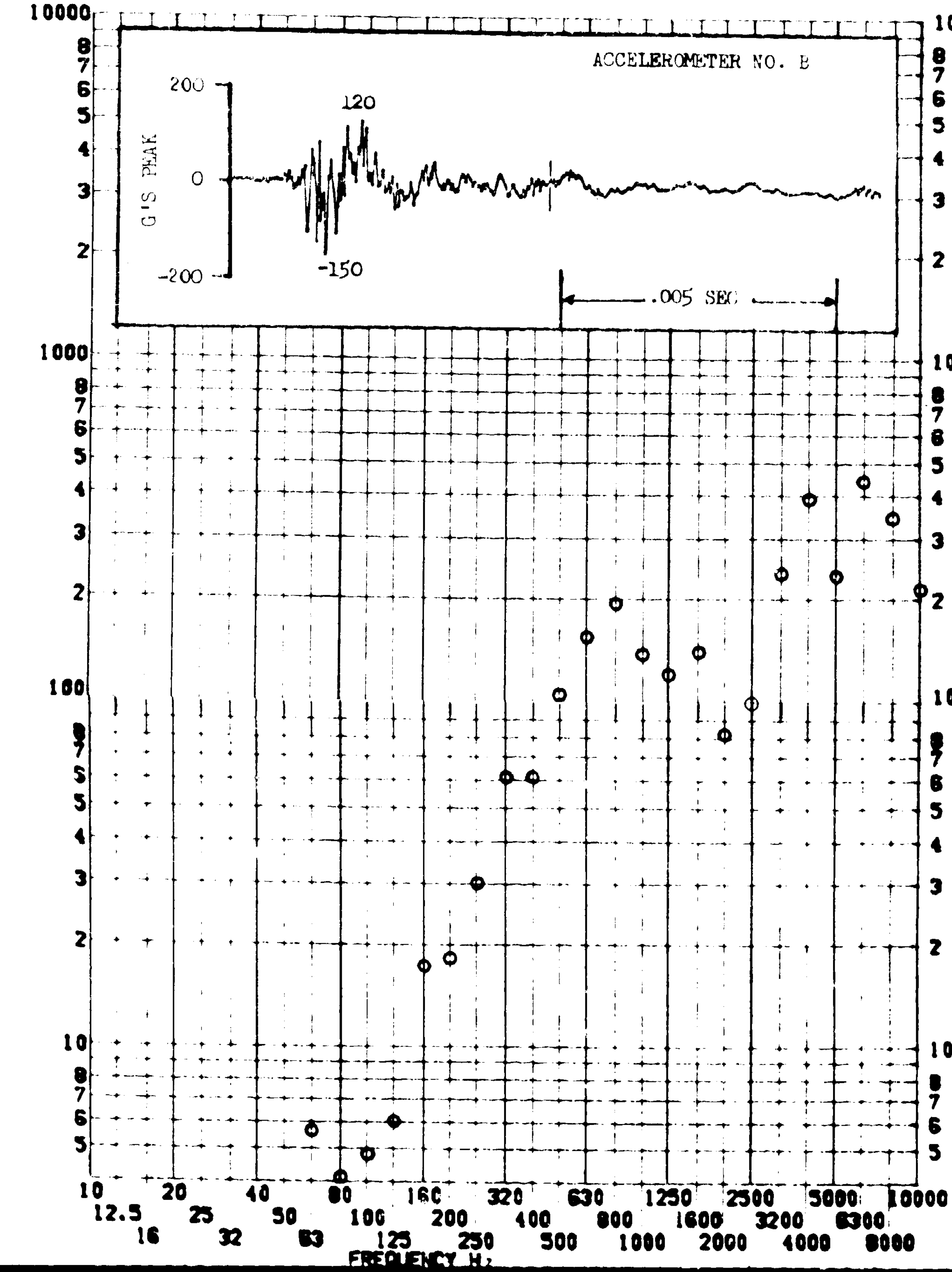
SHOCK AXIS LATERAL

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 26

RESPONSE G-S



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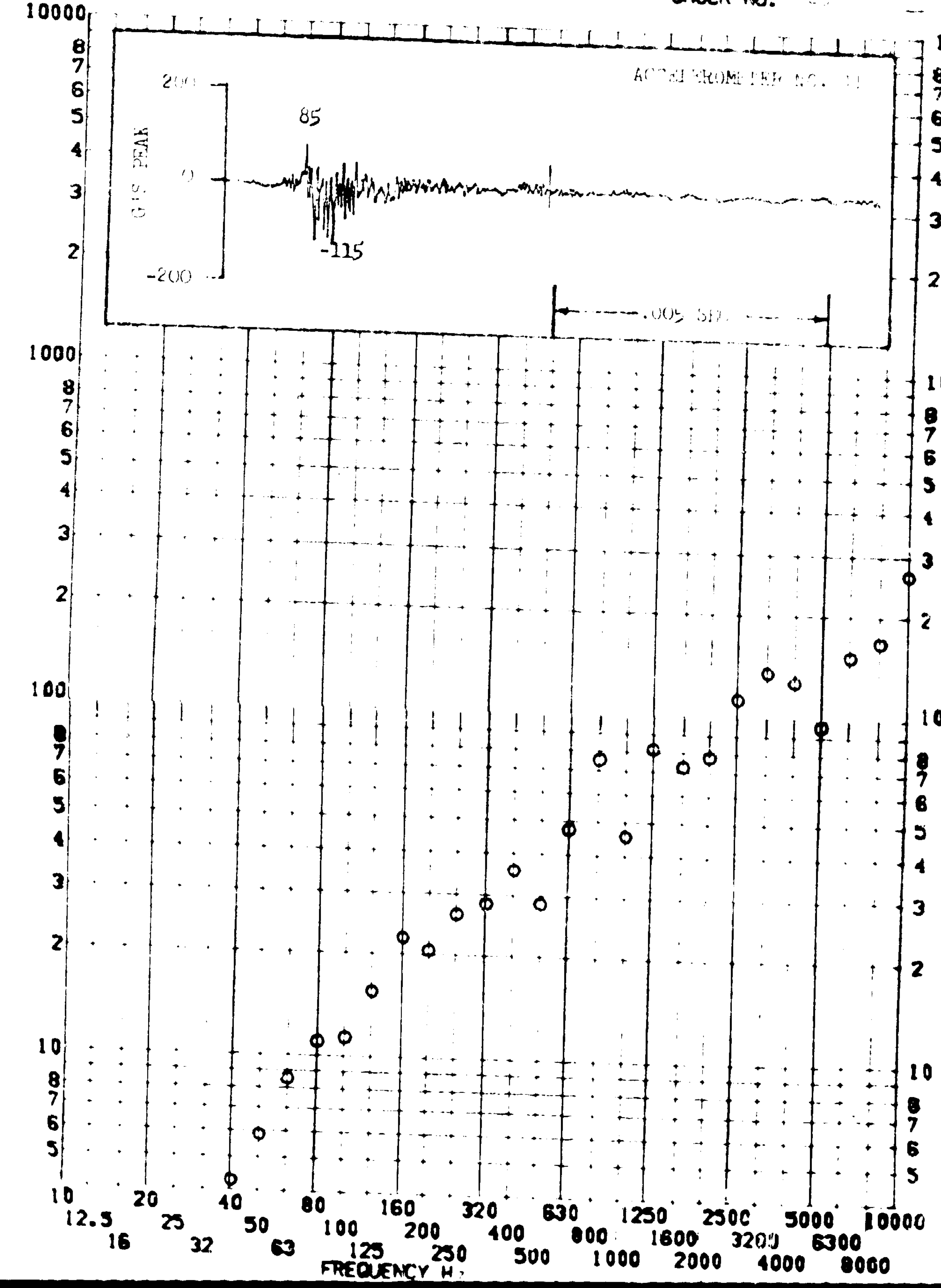
SHOCK AXIS Z

PART NO. BOX
TEST DATE 4 OCT 1968
SHOCK NO. 26



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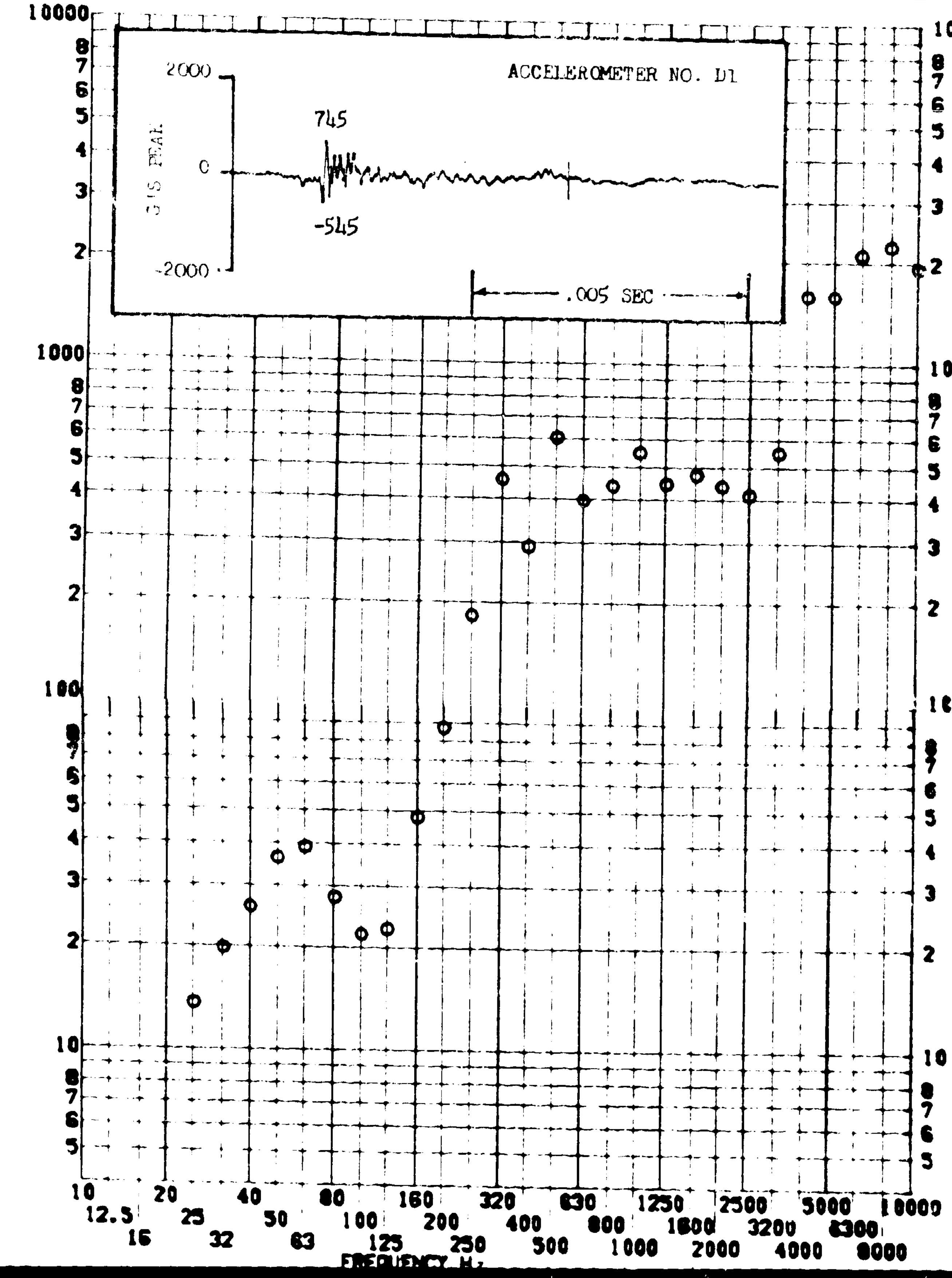
SHOCK AXIS X

PART NO. FRAME
TEST DATE 4 OCT 1968
SHOCK NO. 26

RESPONSE 6-S



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II.C.2.53

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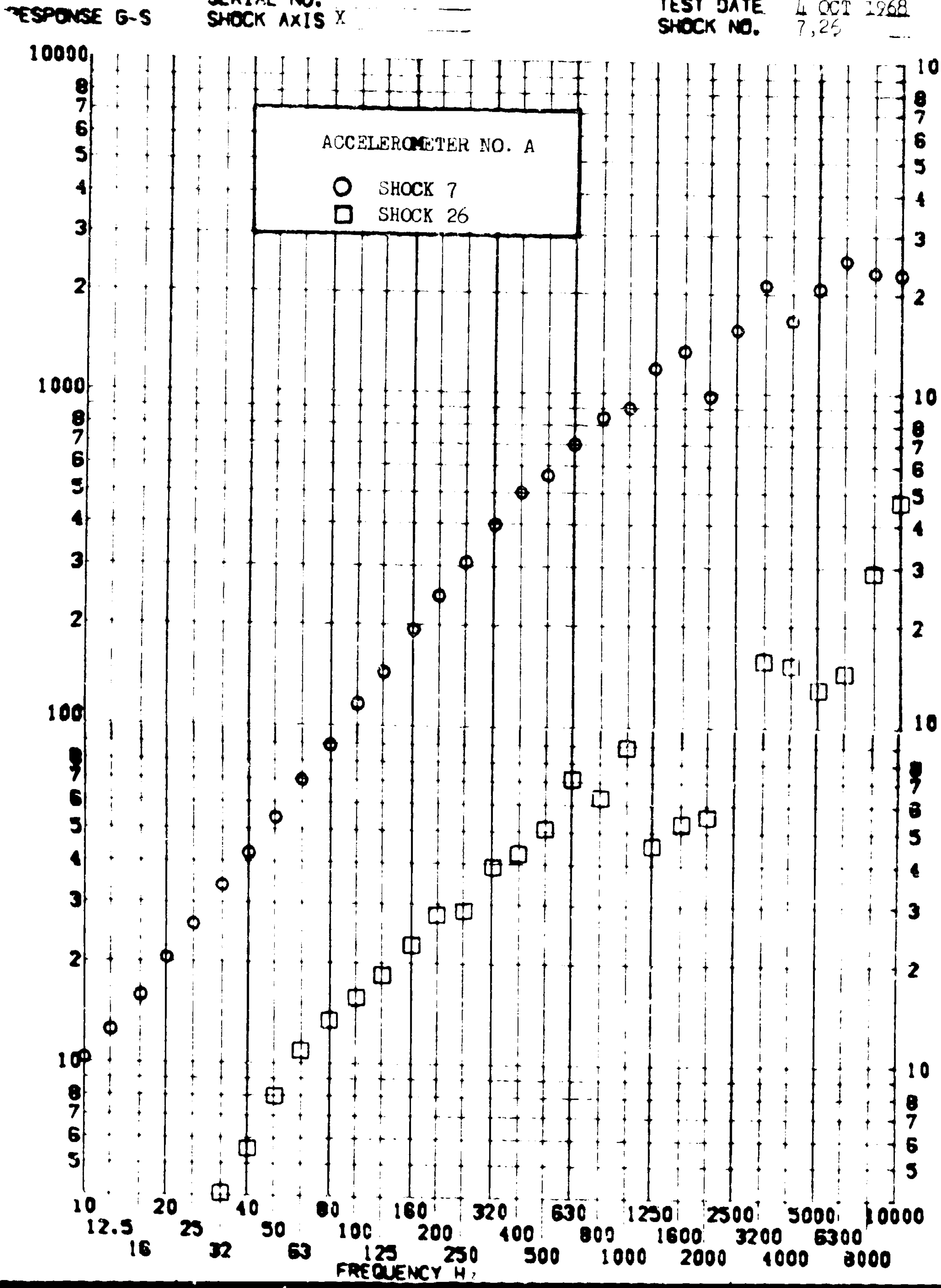

SHOCK TEST ANALYSIS DATA SHEET

11.C.2.5?

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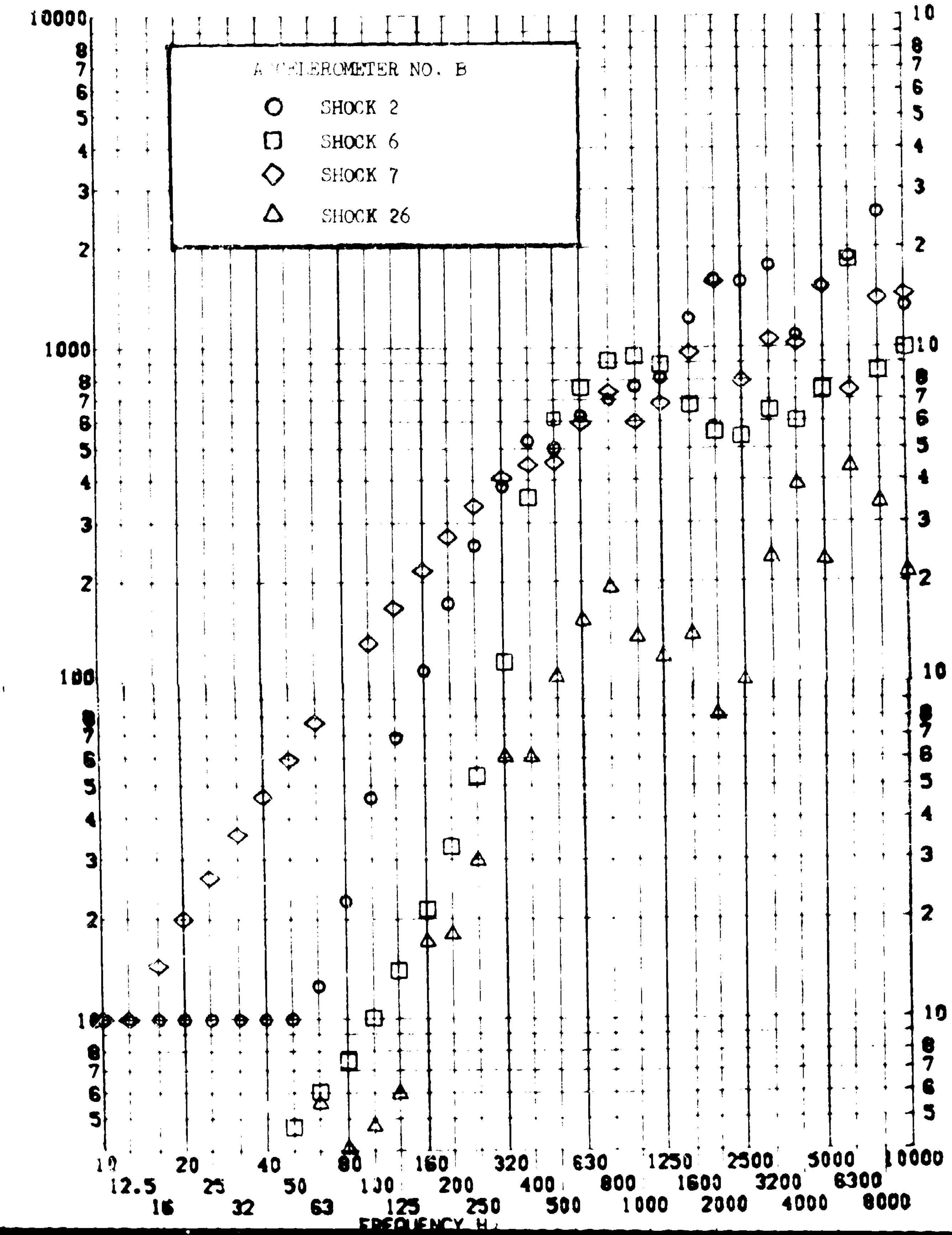

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II.C.2.85

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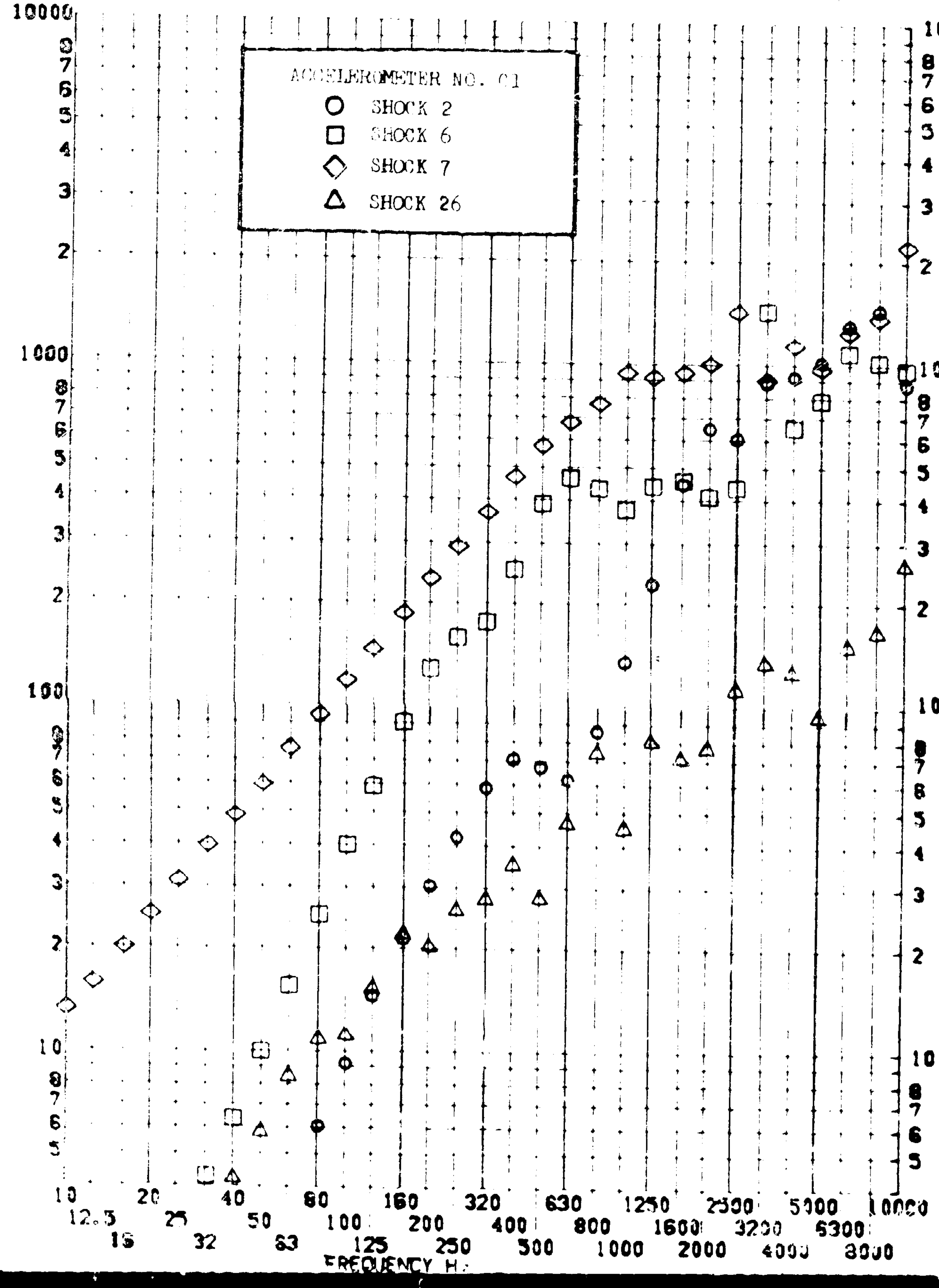

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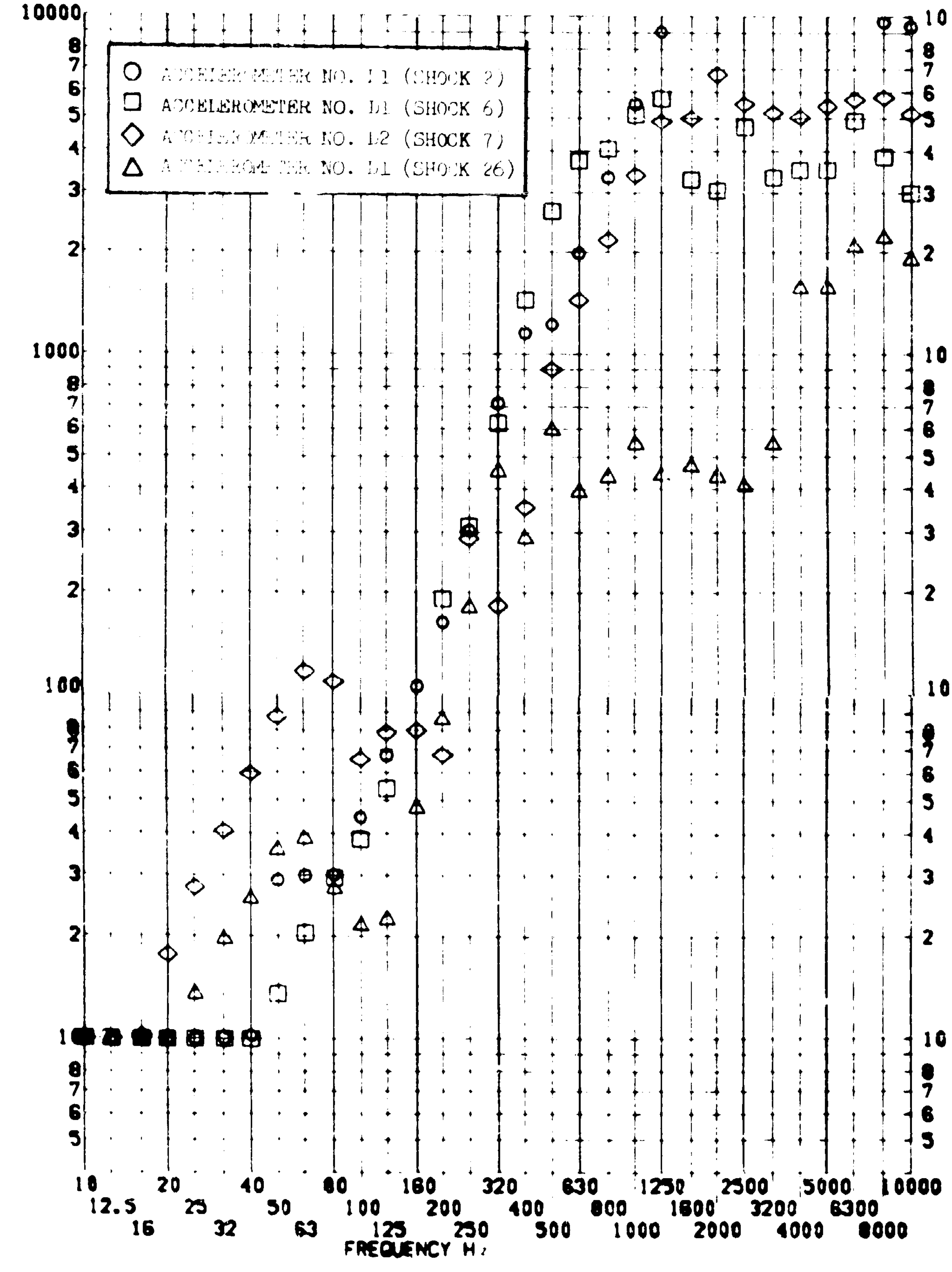
SHOCK AXIS Y

PART NO. FRAME
TEST DATE OCT 1968
SHOCK NO. 2,6,7,26



II.C.2.4 ADDENDUM

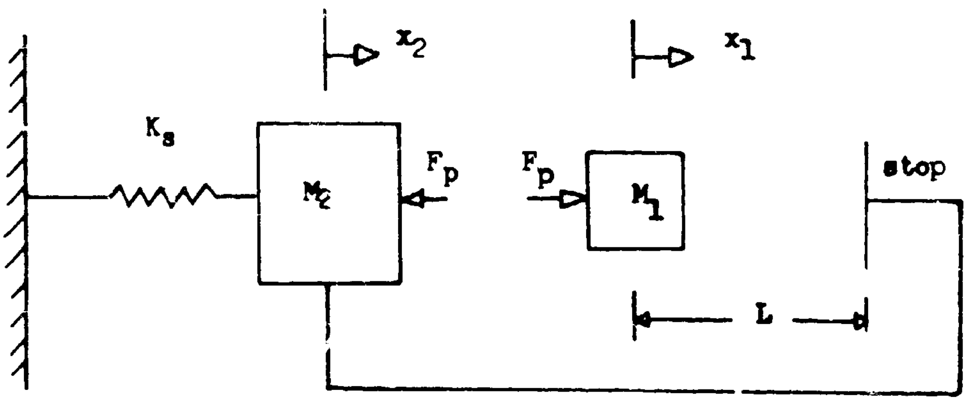
A preliminary analysis was made to model the pin puller. Initially this model was developed to evaluate the use of vibration isolators for the pin puller for reducing the peak response levels recorded on vehicle primary structure; however the model is general and may be used to analyze other parameters as well.

The reasoning used to derive the model was that detonation of the explosive causes the pin and the pin puller case to move in opposite directions. The pin acts as a free body (i.e. no interaction between pin and case) until it hits a stop on the case, which then acts against the mounting structure. The mounting structure was modeled as a simple spring attached to a fixed base (see Figure II.C.2.4.1). After contact with the stop both pin and case were assumed to act as a single rigid body. Initial conditions were determined by conservation of momentum.

For the purpose for which this model was derived, the spring rate between case and structure corresponded to the stiffness of the isolators. For the more general case where the casing is hard-mounted to structure this spring rate would represent the local structural deflection which could be obtained from analysis or tests.

Also shown in Figure II.C.2.4.1 is the shape assumed for the pressure force which results from detonation. This shape was assumed for simplicity in analysis, and also because it yielded results for pin deflection that agreed reasonably well with experimental data.

Figures II.C.2.4.2 and II.C.2.4.3 show the results of the analysis for which the model was originally derived. These figures plot the maximum deflection of the case, and the corresponding maximum force exerted on the structure by the case as a function of the spring rate. These results were used to pick an optimum isolation system for the pin puller. Similar analysis using this model could be used to obtain information relative to design parameters other than isolators. The model can easily be extended to include a more realistic forcing function as well as interaction forces, such as friction, between the pin and case.



K_s = Local Structural Spring Constant

F_p = Pin Puller Squip Pressure Force

M_1 = Mass of Pin

M_2 = Mass of Pin Puller Housing

L = Distance Pin Travels to stop

T_1 = Time M_1 Hits stop

τ = Pressure Force Rise Time

ASSUMED PRESSURE FORCE SHAPE

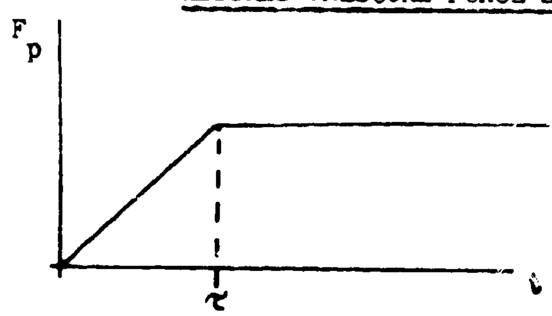


Figure II.C.2.4.1 PIN PULLER MODEL

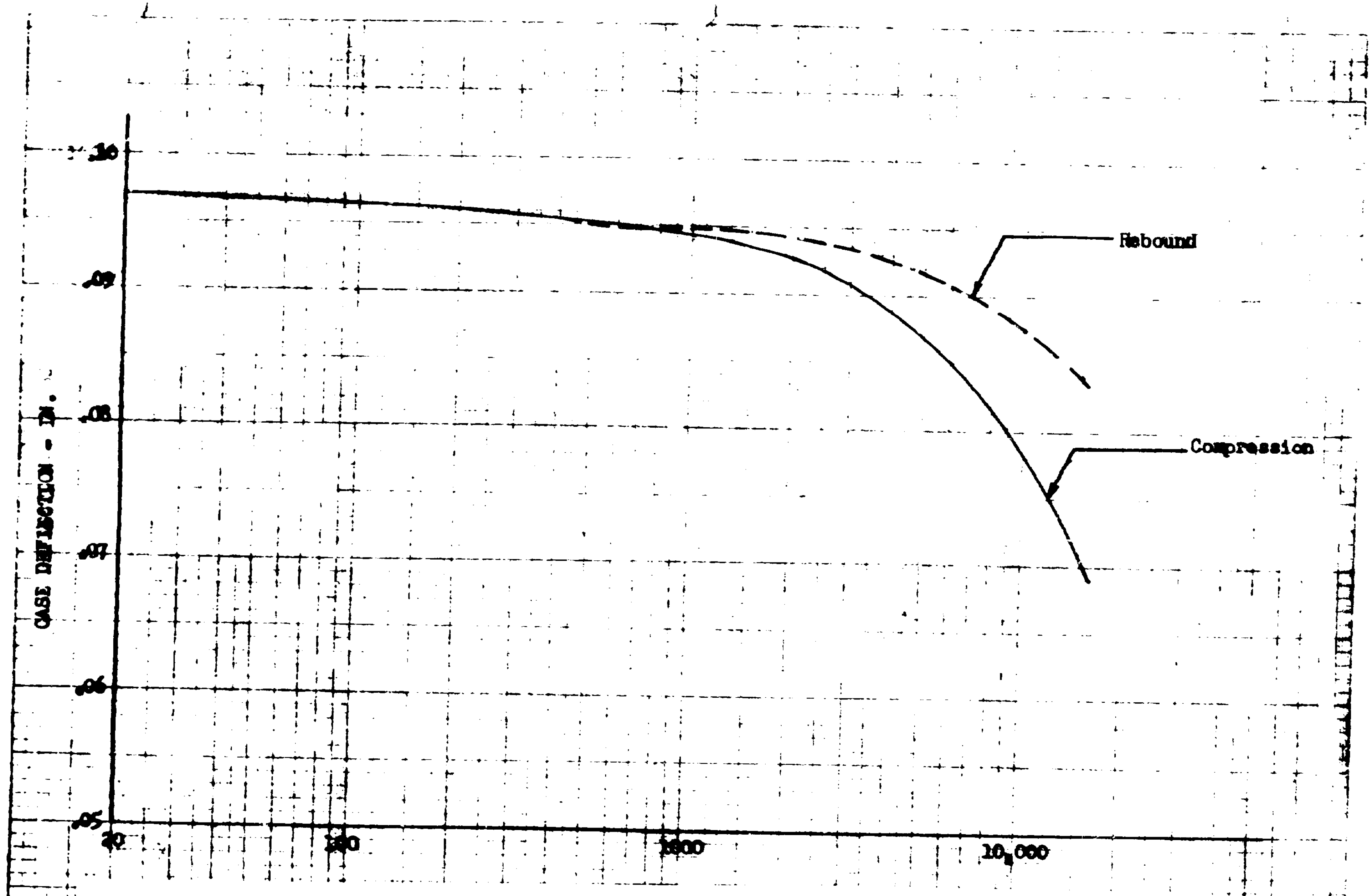


Figure II.C.2.4.2 MAXIMUM CASE DEFLECTION AS A FUNCTION OF BRACKET SHOCK MOUNT SPRING CONSTANT

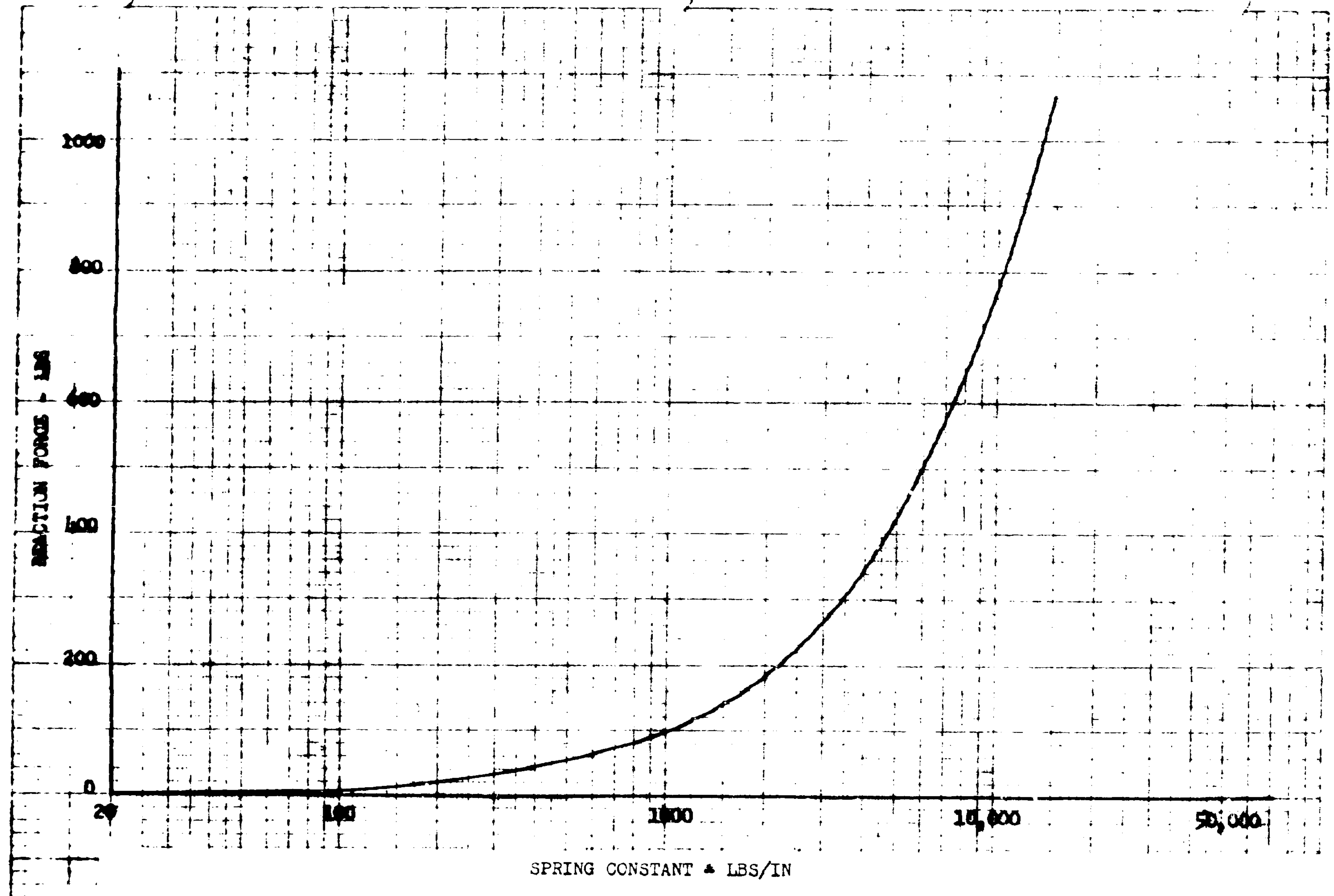


Figure II.C.2.4.3 MAXIMUM FORCE EXERTED ON GUIDANCE MODULE CASTING AS A FUNCTION OF BRACKET SPRING CONSTANT

II.C.3 ANALYSIS AND DISCUSSION

Pin pullers are used at LMSC as a means of qualifying or establishing flight confidence in equipments for a number of pyro shock events. The reason for this method of shock testing is obvious. Pin pullers are cheap to use, readily available, require little set-up time and satisfactorily simulate the pyro event. The sub-satellite of Report 1315 was an example of a case where the pin puller could be used successfully to establish qualification both for the booster separation event and the sub-satellite pin puller separation event since the pin pullers produced the more severe shock environment. It was only necessary to mount pin pullers at the sub-satellite mounting lugs and compare the resultant shock with the predicted shock from booster separation based on a peak g attenuation curve. The result was a factor of 3.3 overtest. This was considered enough of an overtest to qualify the sub-satellite.

A pin puller may be reckoned to a lion in sheeps clothing. It doesn't sound or look like it could do any harm, but the effects of pin puller shock can be devastating to sensitive equipments. Shock levels of several thousand g's in the high frequencies (1,000 to 10,000 Hz) are common in the near vicinity of the pin puller. Report 1336 documents a study which was conducted to investigate methods of isolating the pin puller when it was discovered that the shock from the horizon sensor bar pin puller was disrupting the magnetic timer of the nearby velocity meter. The resonant frequencies of the magnetic timer were in the high frequencies where the pin puller produced its highest shock levels. It was imperative that the pin puller shock levels be reduced by a very large factor.

After extensive testing of a number of different isolation schemes, an isolator was devised which maintained the structural rigidity of the pin puller installation. At the same time the "bracket" isolator allowed the pin puller to move freely when activated in such a manner that its momentum was cancelled and very little shock was transferred to the velocity meter. The fix requires very little modification of the pin puller and is easy to install.

An analysis of shock spectrum measurements at the velocity meter indicated an average reduction over the frequency range of 100 to 2500 Hz, the range of major concern, by a factor of 10. This was considered very satisfactory. A series of seven tests were conducted with the bracket isolator installation. These tests showed that use of the bracket resulted in consistently low shock levels. This was demonstrated by a statistical analysis of the repeatability of this data in which the 95th and 50th percentile shock spectrums were computed. Several vehicles have incorporated this fix, and have flown successfully.

II.C.4 CONCLUSIONS

The pin puller has been demonstrated to be a satisfactory method of qualifying sub-assemblies for pin puller events as shown by the pin puller tests of the sub-satellite of Report 1315.

The results of the sub-satellite pin puller test also condlusively demonstrated the capability of the sub-satellite to survive the booster separation event by virtue of the large overtest factor of 3.3 (based on peak g's).

Although the pin puller produces the same type of shock as a booster separation joint, it cannot, in general, be used to qualify equipments for the booster separation event because of different frequency and attenuation characteristics.

The pin puller tests of Report 1336 demonstrated the damage potential of pin pullers. Shock measurements made during these tests indicated that equipments located near pin pullers are subjected to high g levels with the most severe shock occurring in the 4000 to 7000 Hz range.

Normal isolation methods which were previously applied to isolate equipment from shock did not produce satisfactory results when applied to the pin puller. The bracket isolator reduced the shock level on an average over the frequency spectrum of 100 to 2500 Hz by a factor of 10. The bracket shock mount is sufficiently rigid to prevent excessive motion during the ascent phase of flight but allows the pin puller to move freely when fired such that its momentum is cancelled instead of transferred to the surrounding structure.

The bracket isolator tests demonstrated a specific application of a bracket shock mount. What was most importantly demonstrated, however, was application of the principle of an isolator that acts only under high g - high frequency excitation (i.e. pyro shock near or at the source), and is insensitive to low g - low frequency excitation (i.e. POGO and sine transients) or low g - medium high frequency excitation (i.e. acoustic excitation).

SECTION NO. II.D

REPORTS 429 AND 447

SUBJECT:

QUALIFICATION OF EXTERNAL PODS
FOR PYROSHOCK WITH BARREL TESTER

SECTION II.D

SUMMARY

The two tests which are documented in the two reports which follow were conducted for the purpose of qualifying two external pods for pyroshock on the SCTB barrel tester. Because of the extreme length of the pods, two barrels were mated together and hung in a test stand by bungee cords. Each pod was then mounted separately on the two barrels for testing.

Measurements were taken on the barrel structure at the standard reference location to determine qualification of the shocks. Other measurements were made on the pod structure and on pod equipment.

Measurements made on the fore, central and aft structure of the pod of Report 429 indicate that the shock transmission path is both through the slip joint and through the structure on which the pod is mounted. Normal attenuation/distance relationships which are used to predict peak shock levels thus should not be used for pod equipment because of peculiarities of the shock transmission path. Rather, the envelopes of equipment measurements as shown in Figure II.D.1 for both pods should be used to determine equipment qualification shock levels for each of the pods.

The pod qualification tests were accomplished successfully. These tests demonstrated the practicality of testing extended structures on mated barrels.

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SECTION NO. II.D.1

REPORT NO. 429

SUBJECT:

QUALIFICATION OF EXTERNAL POD
FOR PYROSHOCK WITH BARREL TESTER, POD 1

SECTION II.D.1

SUMMARY

The purpose of the test which this report documents was to qualify a pod for the booster separation event. The pod contained functional equipment.

Included in the analysis is a discussion of the shock transmission path through both the pod attachment and mounting structure.

The pod was subjected to sufficiently high shock levels to qualify both structure and equipment. An examination of the assembly after the test showed that no failures had occurred.

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SECTION II.D.1

* L - Longitudinal, R - Radial, T - Tangential

LIST OF FIGURES (Cont.)

SECTION II.D.1

* L - Longitudinal, R - Radial, T - Tangential

II.D.1.1 INTRODUCTION

When the booster adapter separates from the vehicle high shocks are generated and transmitted throughout the structure. These pyro-generated shocks can cause equipment and structural failures. It is thus necessary to subject vehicle equipment, or modules containing equipment (such as the pods), to shock levels above those which they would encounter in flight to establish their qualification.

II.D.1.2 DISCUSSION AND ANALYSIS

II.D.1.2.1 Test Configuration and Instrumentation

The pod is shown in Figure II.D.1.1 in its normal mounting location on the flight vehicle. To accommodate this long structure on the barrel tester, two barrels were mated together as shown in Figure II.D.1.3. The assembly was then suspended by bungee cords from one of the test stands. The pod was mounted to the barrel structure in the same manner as it is mounted on the flight vehicle. The only two pod attachment points are the sliding fit and the rigid attachment aft and forward ends as shown in Figure II.D.1.2. The test was performed with a 30 grain per foot primacord and a 0.190 inch magnesium thorium separation skin segment. Instrumentation locations were as shown in Figure II.D.1.3 and outlined in Table I.D.1.2.

II.D.1.2.2 Test Results and Analysis

Shock spectra of the 16 measurements for each of the two shocks are presented in Figures II.D.1.5 to II.D.1.35. Shock 1 is compared to shock 2 for each of the measurements in Figures II.D.1.36 to II.D.1.50 to show the repeatability of the barrel tester between the two tests. Figure II.D.1.4 presents the shock spectrums from the radial, tangential, and longitudinal barrel measurements. These are the reference measurements which are used to determine qualification of the shocks. The shocks were both sufficient to qualify the pod for pyroshock.

In Figure II.D.1.51 the envelope of the three shock spectra of the barrel reference measurements is compared to the envelope of the equipment measurements and the envelopes of structure measurements at both ends and the middle of the pod. The figure is significant in that it shows that the structure measurements from the end of the pod furthest from the separation joint produced shock spectrums of comparable level to the structure measurements from the end of the pod nearest the separation joint while the structure measurements at the middle of the pod are considerably less than the end measurements. The figure also indicates a large shock reduction between the reference location and the structure measurement locations. This indicates that the shock path is through both the slip joint and the structure on which the pod is mounted. The normal attenuation/distance relationships should not be applied to predict shock levels at pod equipments. Rather, the envelope of all the equipment measurements, as shown in Figure II.D.1.51, should be used to predict the pod equipment shock levels for this pod.

II.D.1.3 CONCLUSIONS

Testing was satisfactorily completed. The pod was subjected to qualification level pyroshock. No structural or equipment failures were found after the test.

This pod test shows that the shock transmission path is through both the slip joint and the structure on which the pod is mounted.

TABLE II.D.1.1

ACCELEROMETER LOCATIONS

ACCELEROMETER NO.	DIRECTION	LOCATION
1	L	Eighth Bulkhead Aft C/L (furthest Fwd Bulkhead)
2	R	Eighth Bulkhead Aft C/L (furthest Fwd Bulkhead)
3	T	Eighth Bulkhead Aft C/L (furthest Fwd Bulkhead)
4	L	Fifth Bulkhead Aft C/L(mid point of pod)
5	R	Fifth Bulkhead Aft C/L(mid point of pod)
6	T	Fifth Bulkhead Aft C/L(mid point of pod)
7	L	First Bulkhead C/L (Aft End)
8	R	First Bulkhead C/L (Aft End)
9	T	First Bulkhead C/L (Aft End)
10	L	Equipment No. 1
11	R	Equipment No. 2
12	T	Equipment No. 2
13	L	Equipment No. 2
14	R	Equipment No. 3
15	T	Equipment No. 3
16	L	Equipment No. 3

L - Longitudinal   R - Radial   T - Tangential

TABLE II.D.1.2

ACCELEROMETER INFORMATION

ACCELEROMETER NO.	STATION	DIRECTION	DISTANCE TO SHOCK SOURCE (Inches)	ACCELEROMETER TYPE
1	307	L	86	ENDEVCO 2220
2	307	R	86	ENDEVCO 2220
3	307	T	86	ENDEVCO 2220
4	360	L	33	ENDEVCO 2220
5	360	R	33	ENDEVCO 2220
6	360	T	33	ENDEVCO 2220
7	383	L	10	ENDEVCO 2220
8	383	R	10	ENDEVCO 2220
9	383	T	10	ENDEVCO 2220
10	355	L	38	ENDEVCO 2220
11	378	R	15	ENDEVCO 2220
12	378	T	15	ENDEVCO 2220
13	378	L	15	ENDEVCO 2220
14	378	R	15	ENDEVCO 2220
15	378	T	15	ENDEVCO 2220
16	378	L	15	ENDEVCO 2220
A2*	378	L, R, T	15	3 ENDEVCO 2225

* A2 BARREL STANDARD SOURCE MEASUREMENT

** L - Longitudinal R - Radial T - Tangential

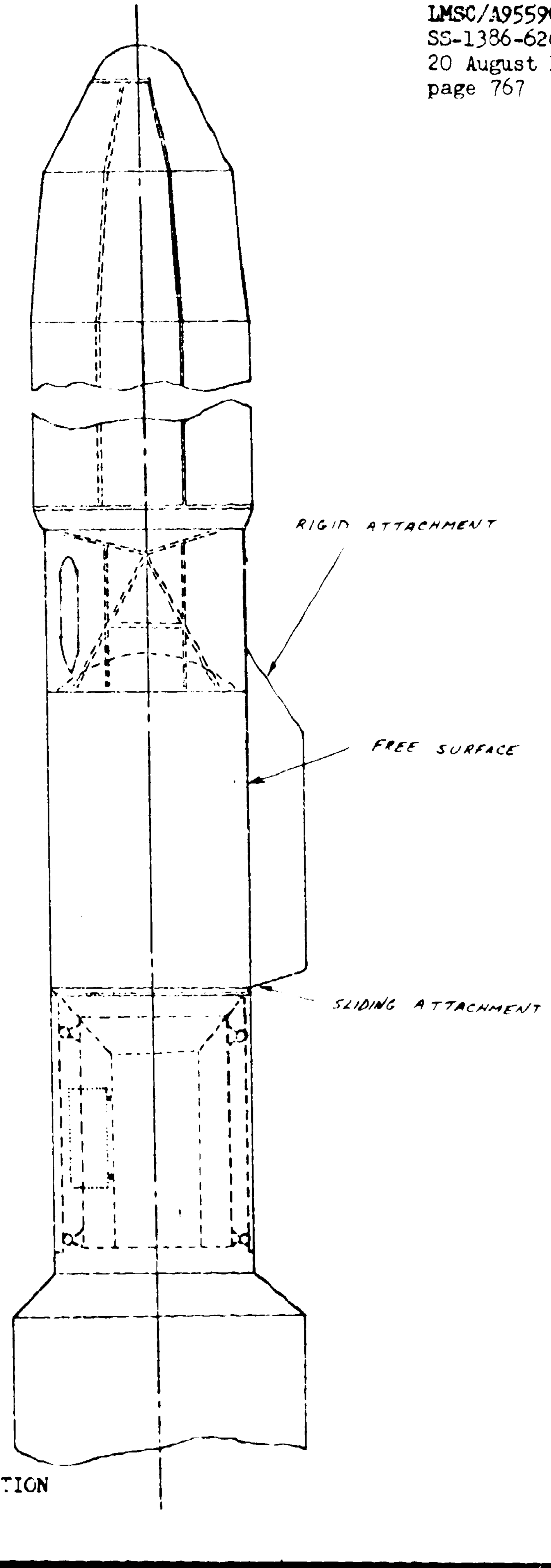


Figure II.D.1.1 FLIGHT CONFIGURATION

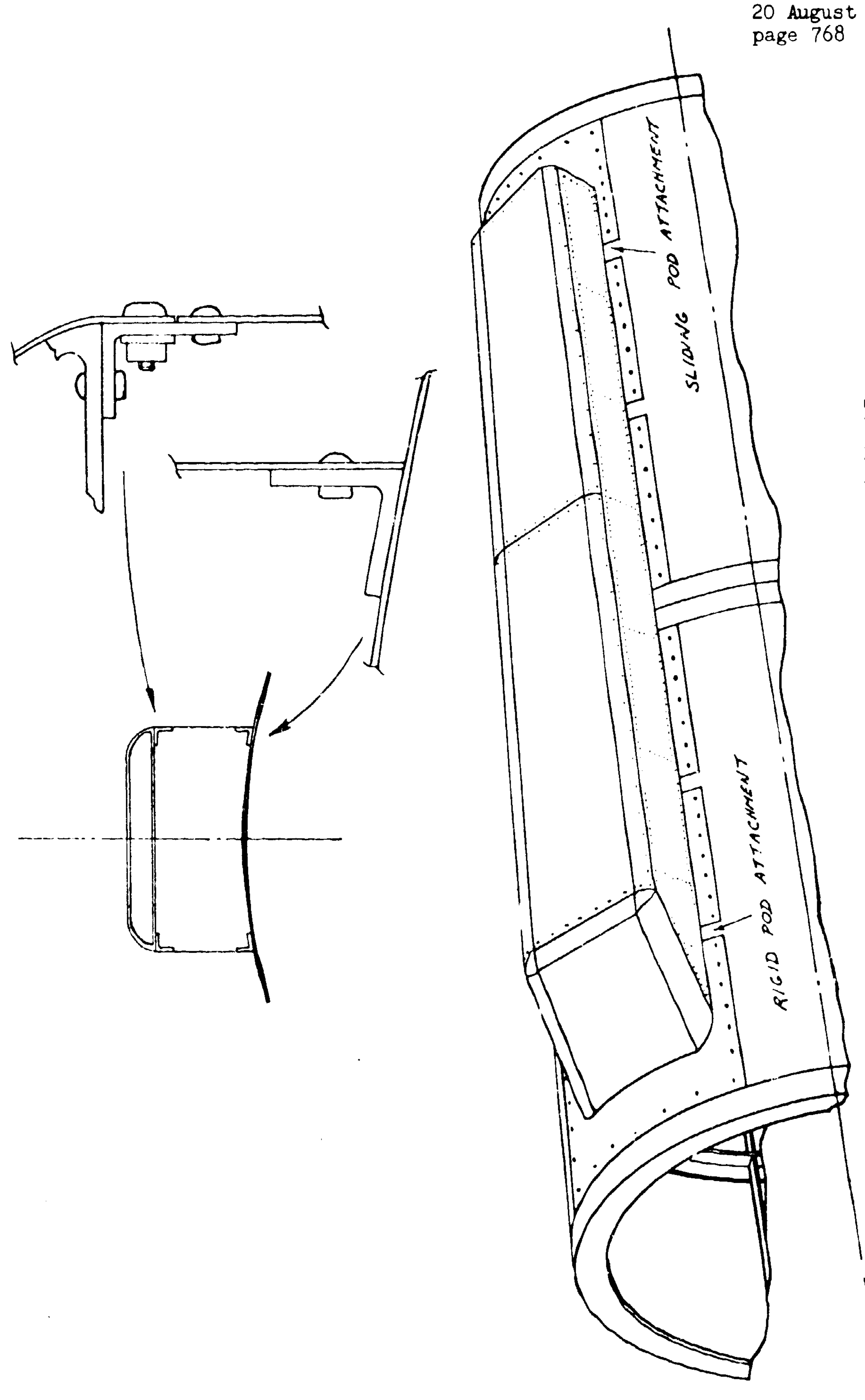


Figure II.D.1.2 DETAILS OF POD ATTACHMENT

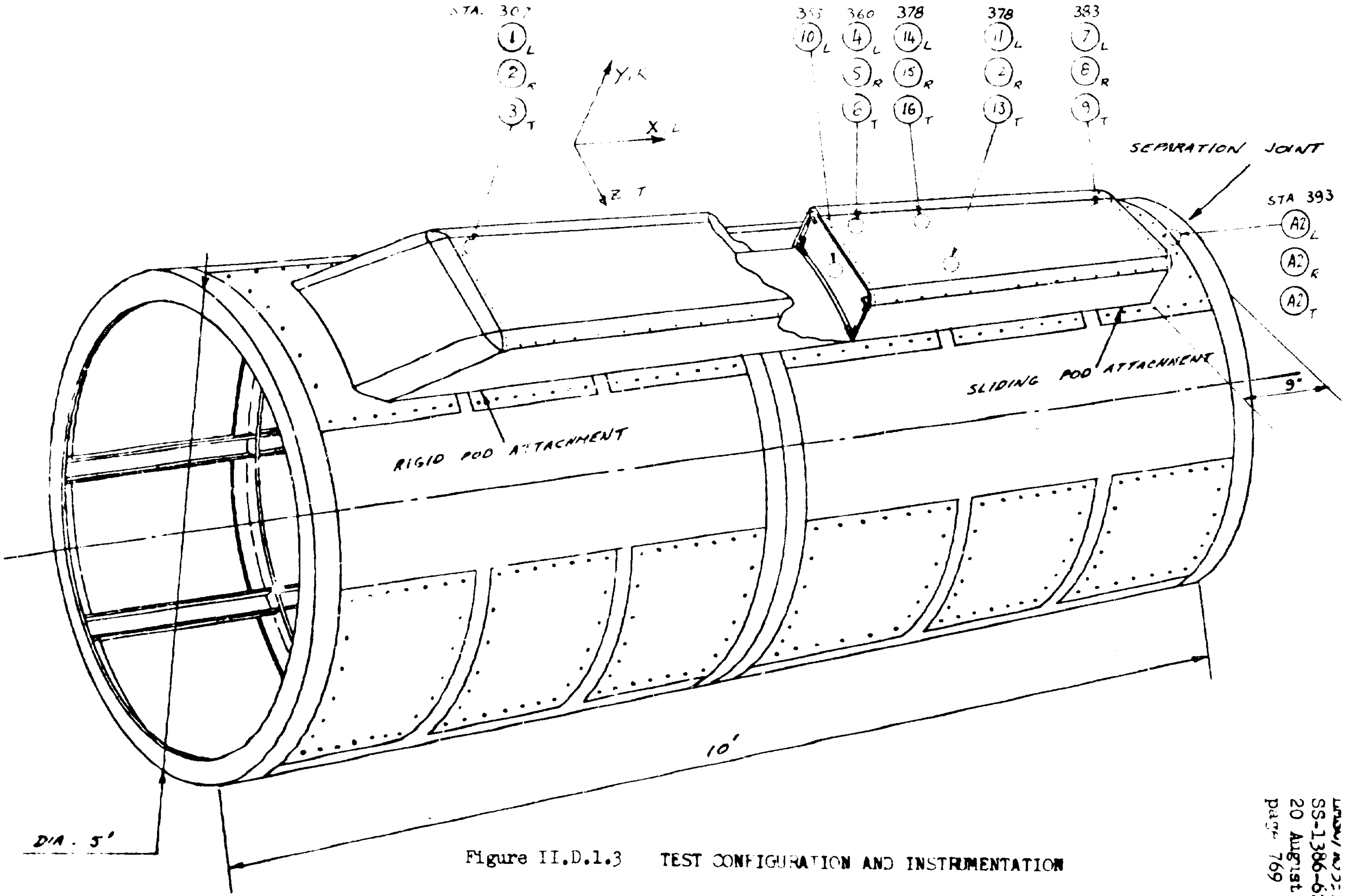


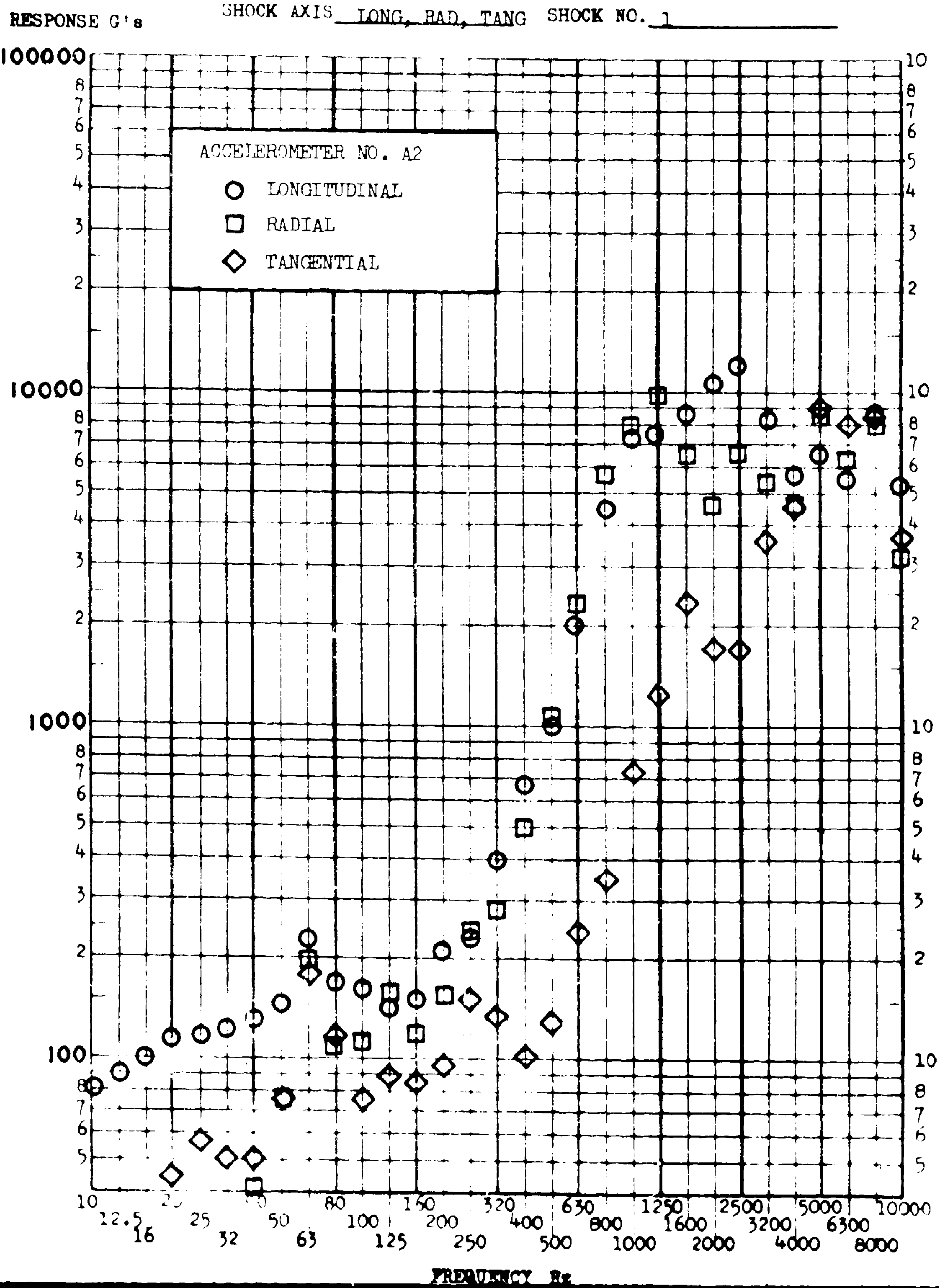
Figure II.D.1.3 TEST CONFIGURATION AND INSTRUMENTATION

SHOCK TEST ANALYSIS DATA SHEET II.D.1.4

TEST ITEM 429 PART NO. STRUCTURE

SERIAL NO. ______ TEST DATE 7 MAR 1968

SHOCK AXIS LONG, RAD, TANG SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.D.1.5

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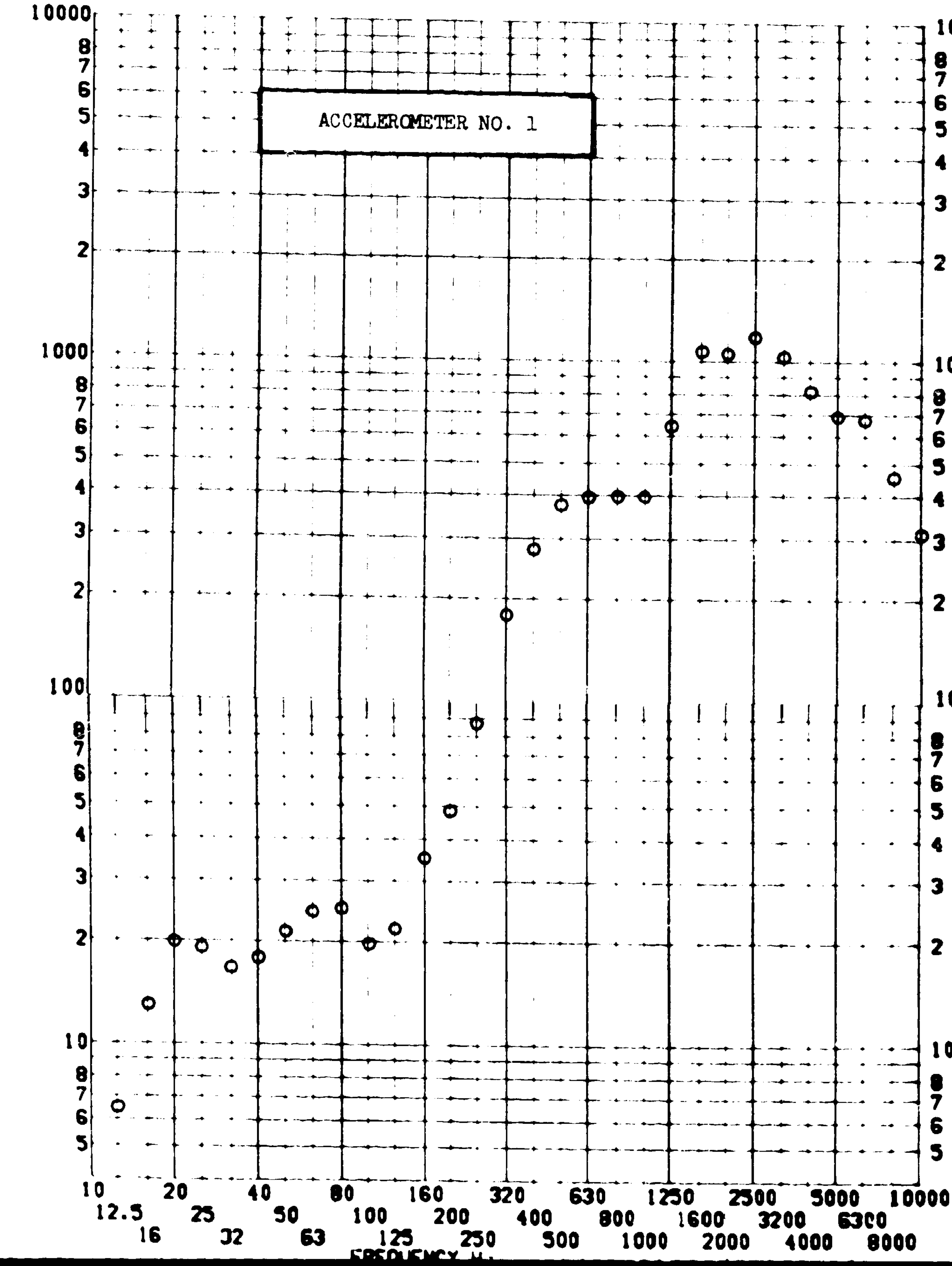
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.1.6

TEST ITEM 429-305
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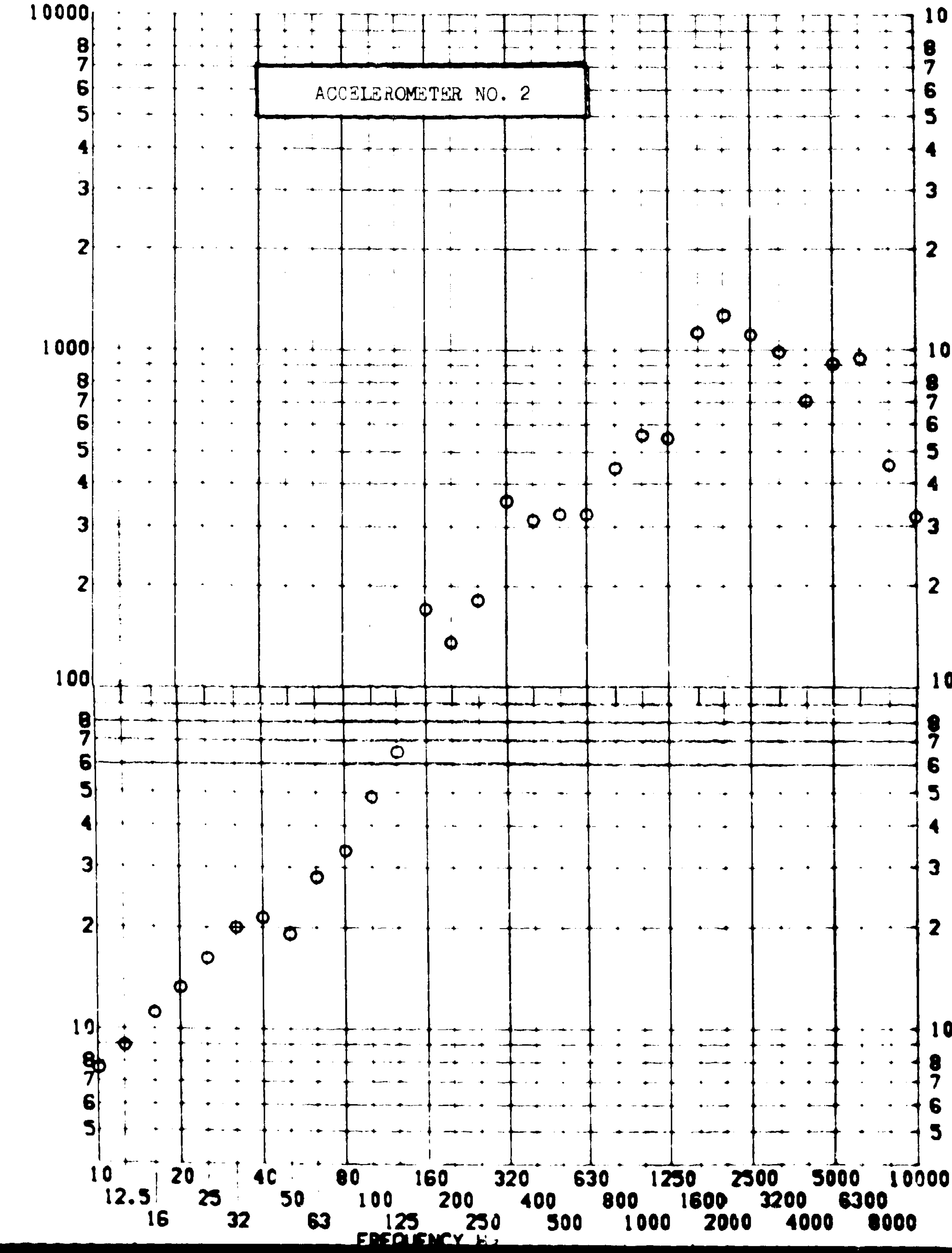
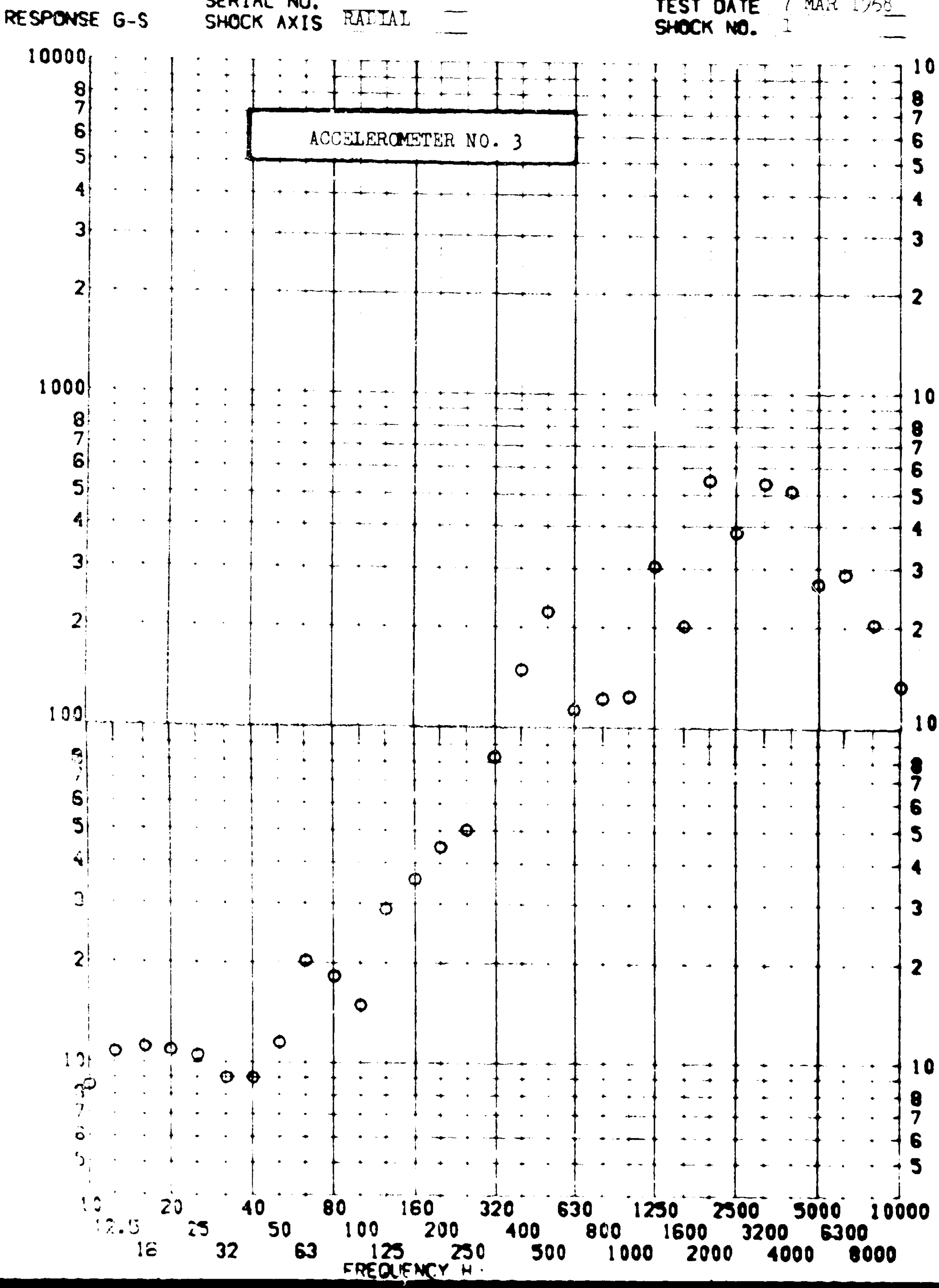
SHOCK AXIS TANGENTIAL
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.D.1.7

TEST ITEM 429-303
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.D.1.8

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SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
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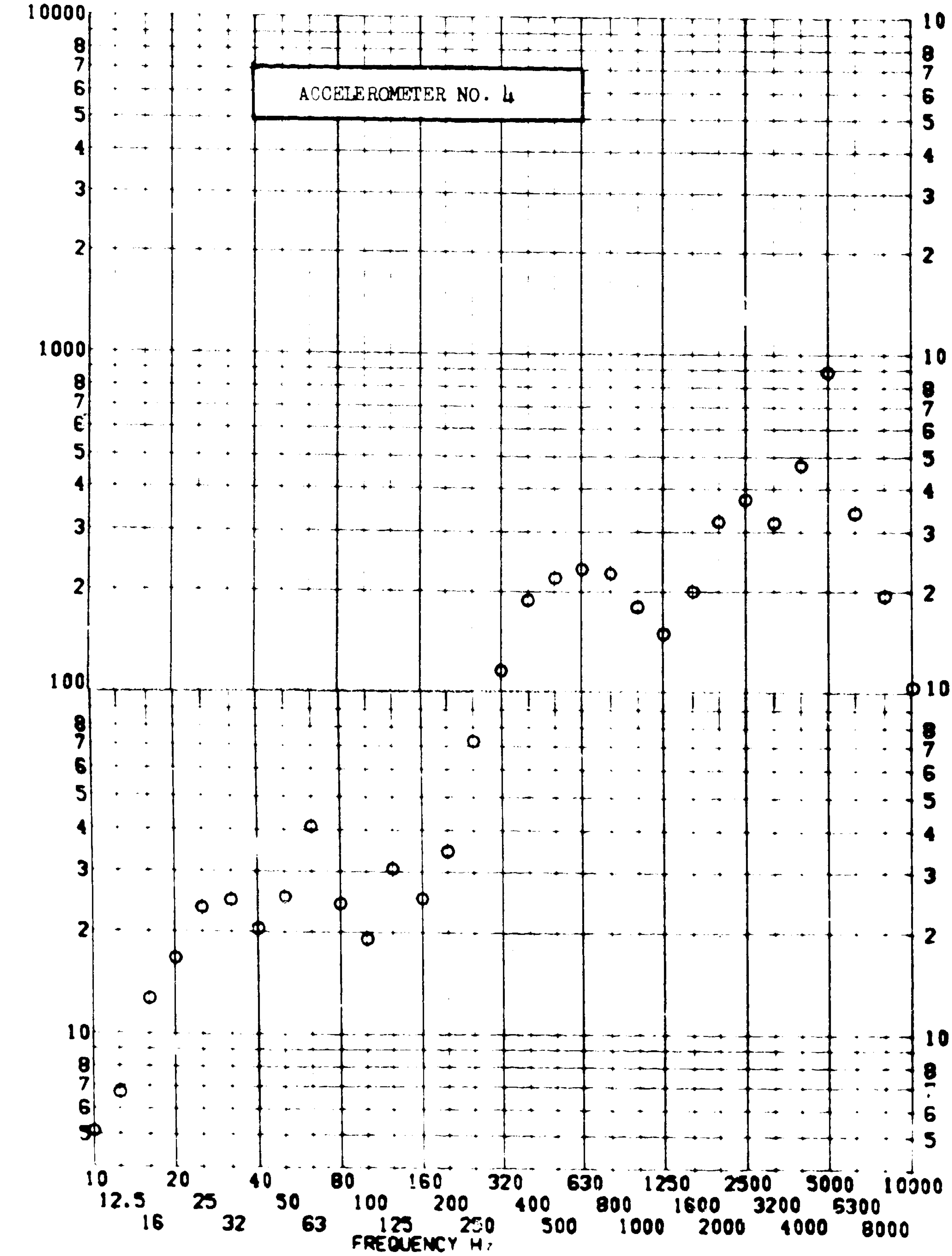

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SERIAL NO. TEST DATE 7 MAR 1968
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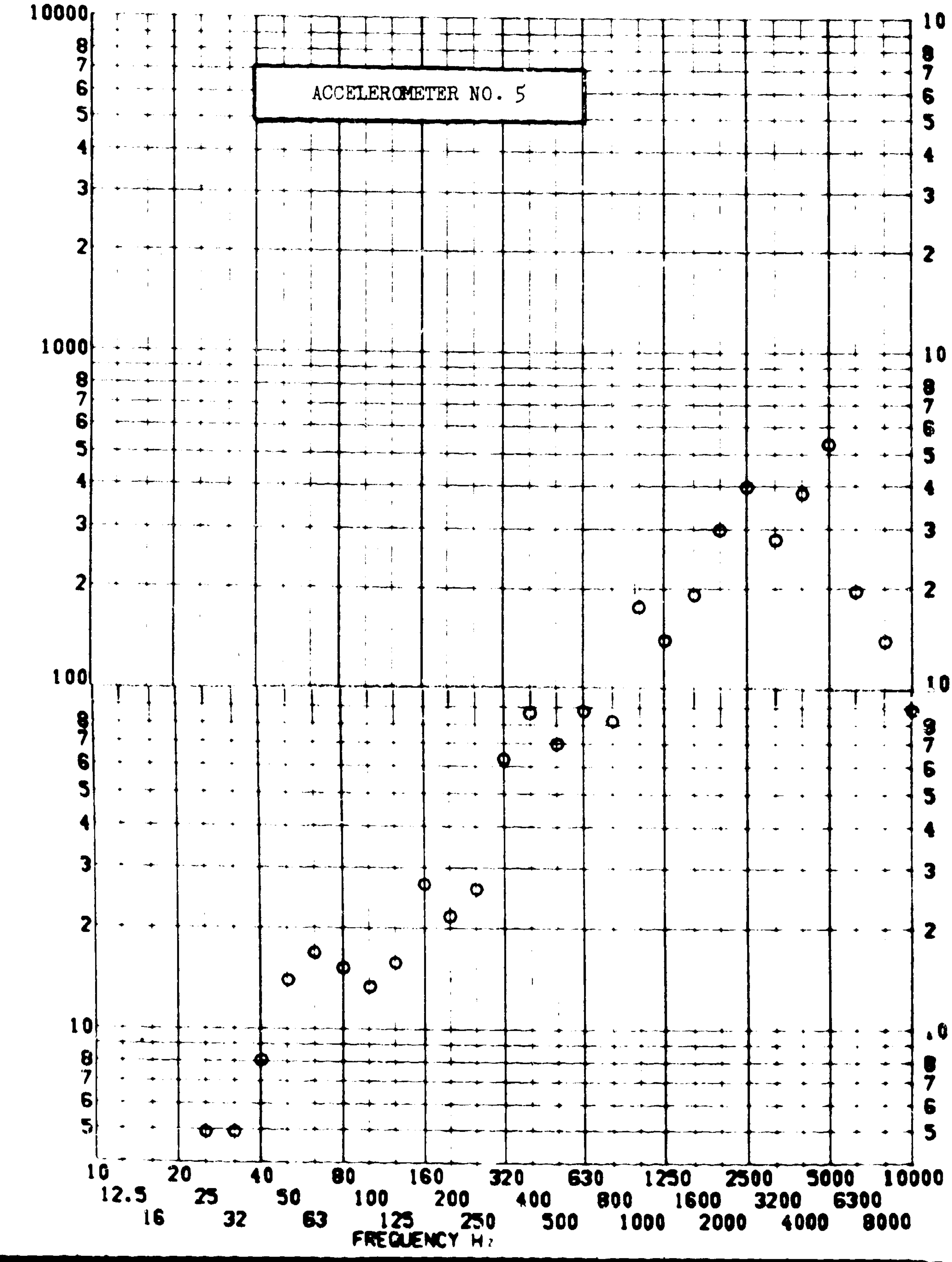

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PART NO. STRUCTURE
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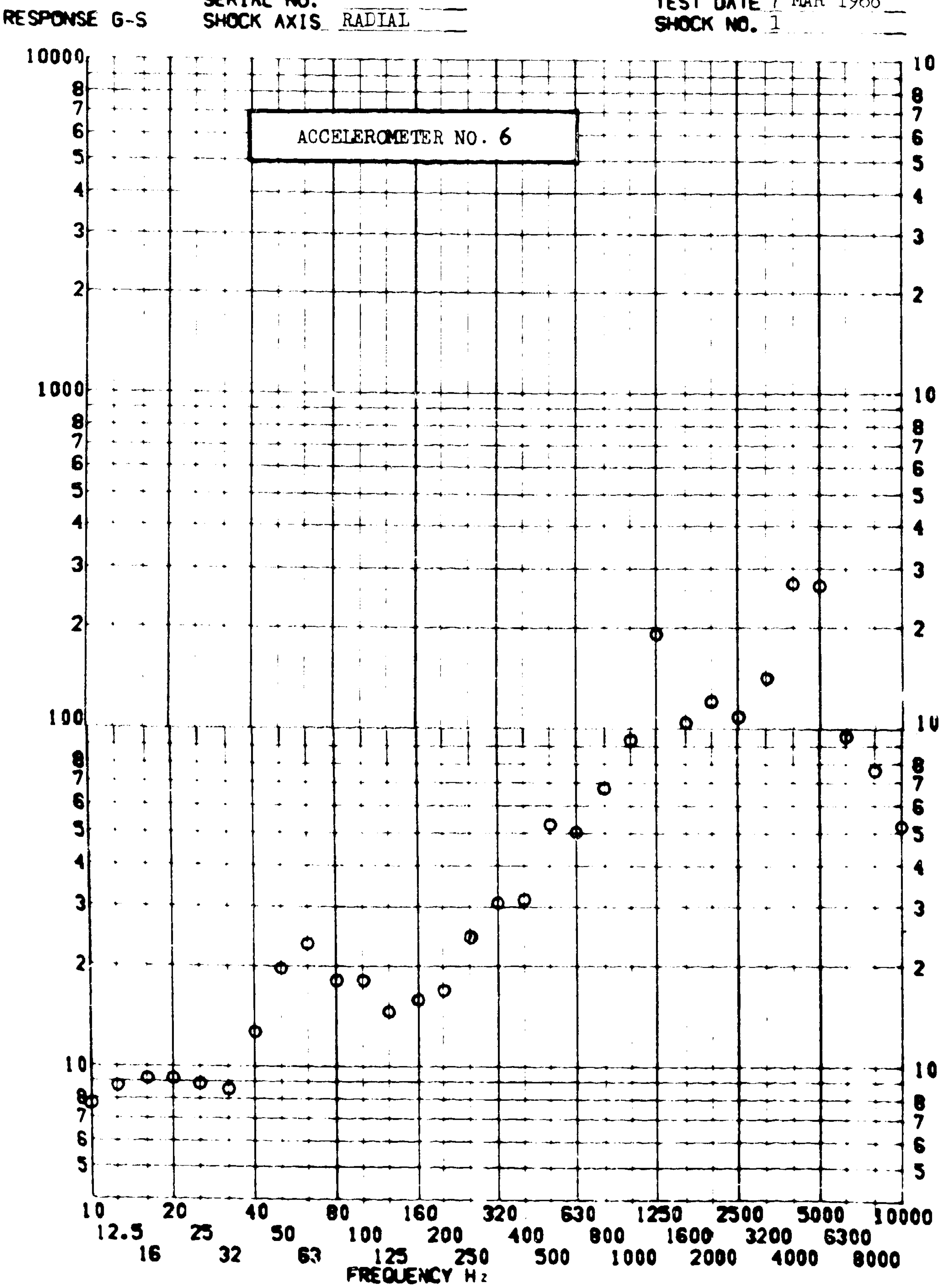
SHOCK NO. 1



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PART NO. STRUCTURE
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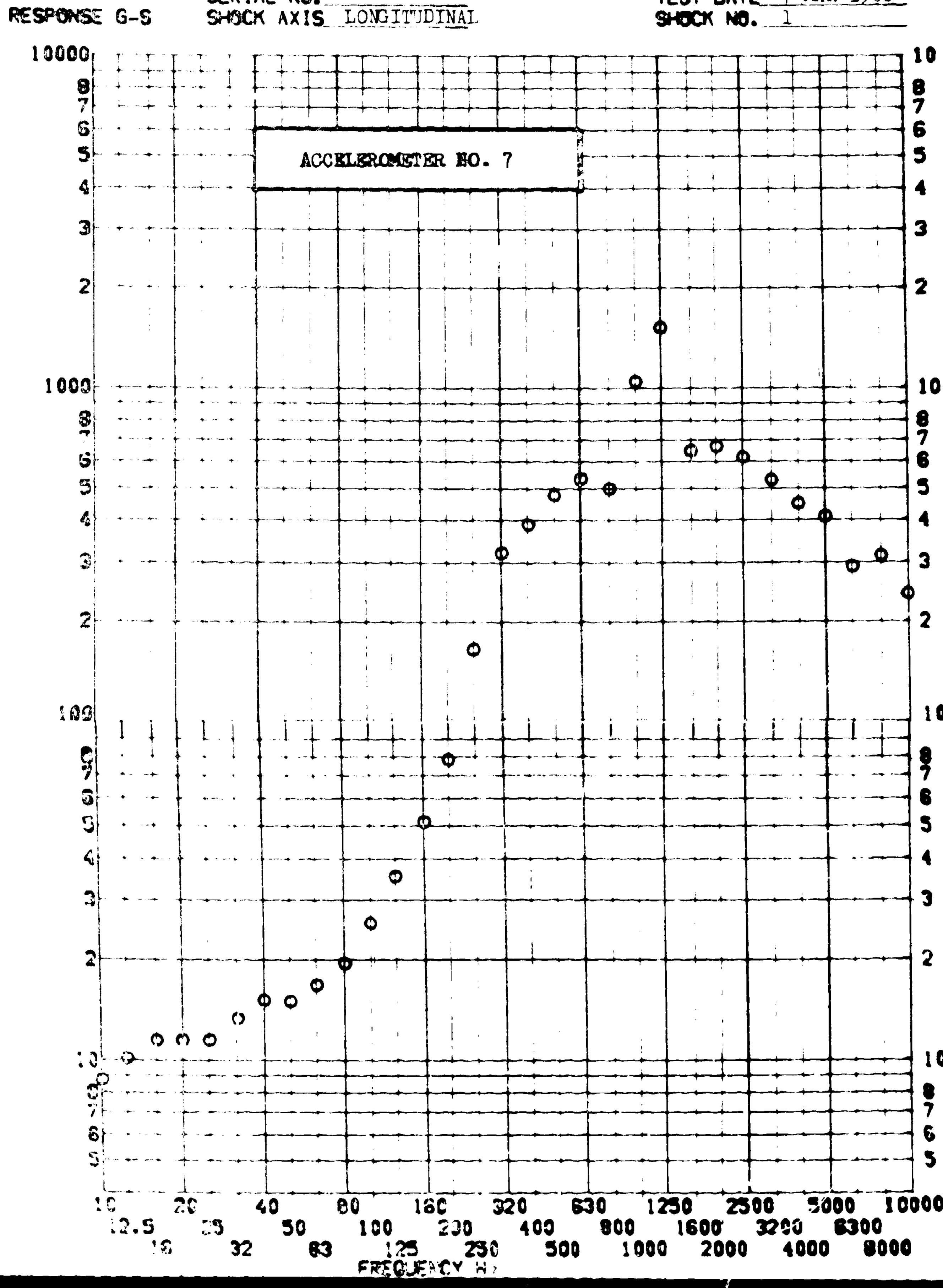

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SHOCK AXIS TANGENTIAL

PART NO. STRUCTURE
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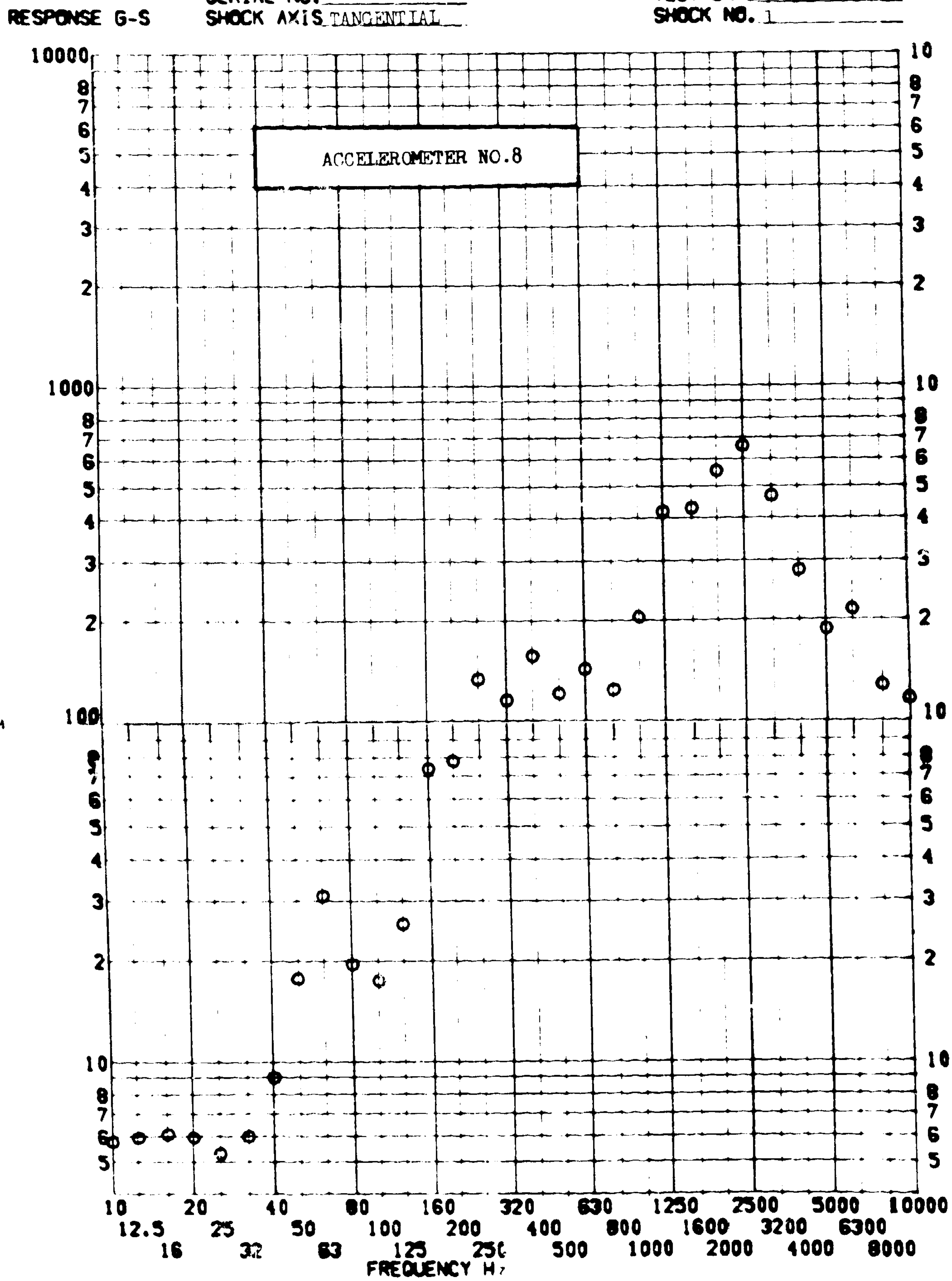

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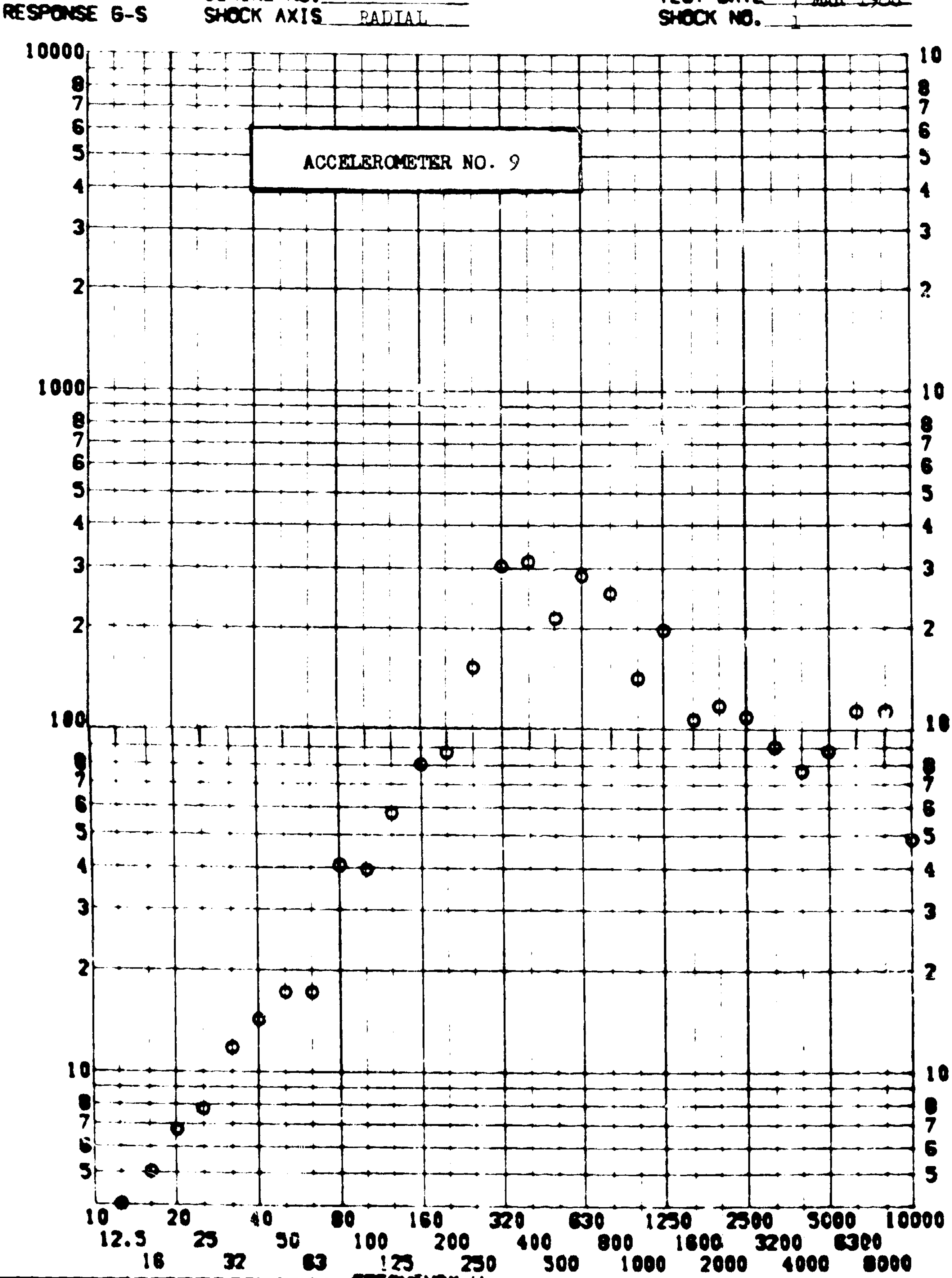

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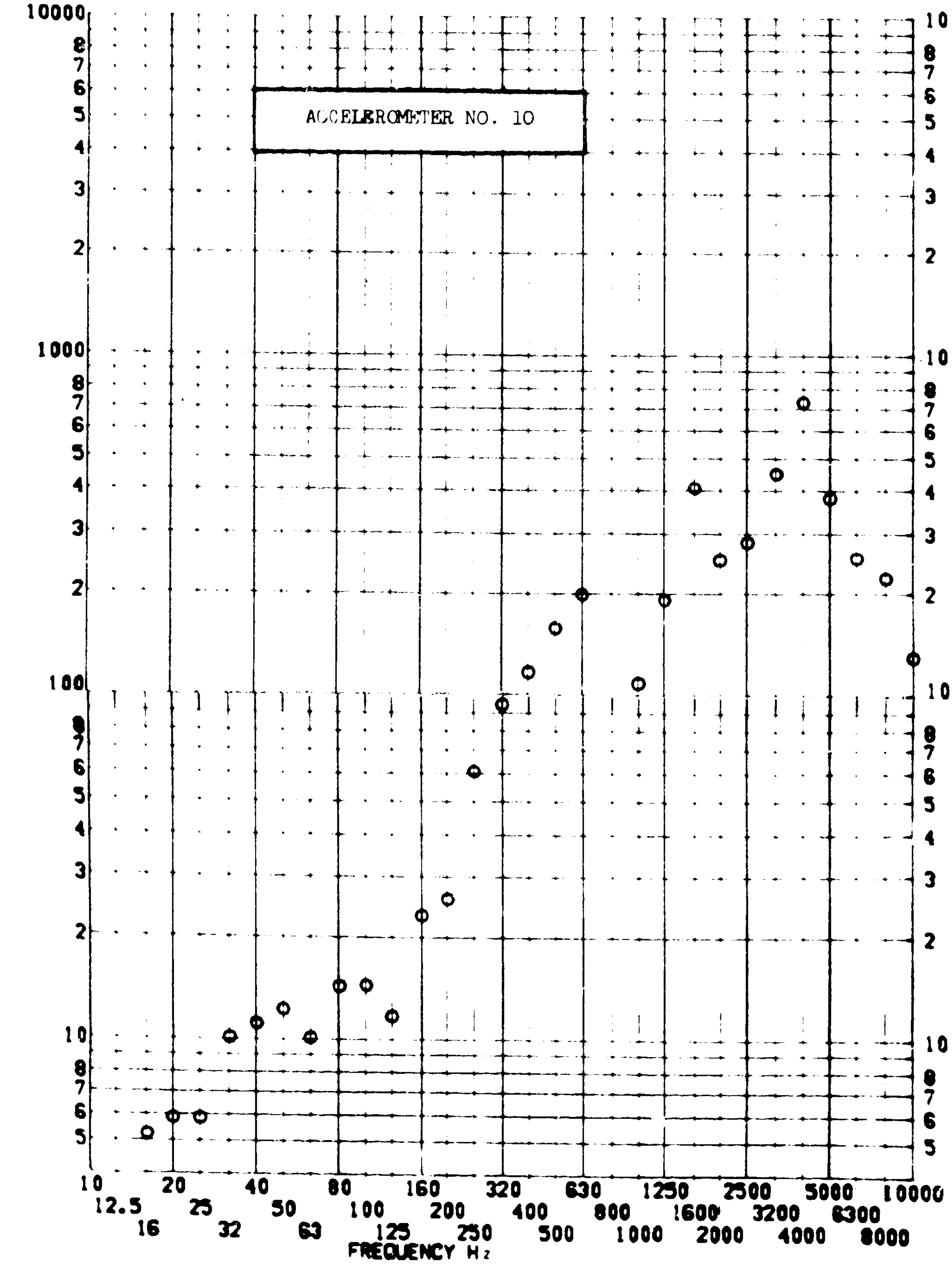
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1969
SHOCK NO. —



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PART NO. STRUCTURE
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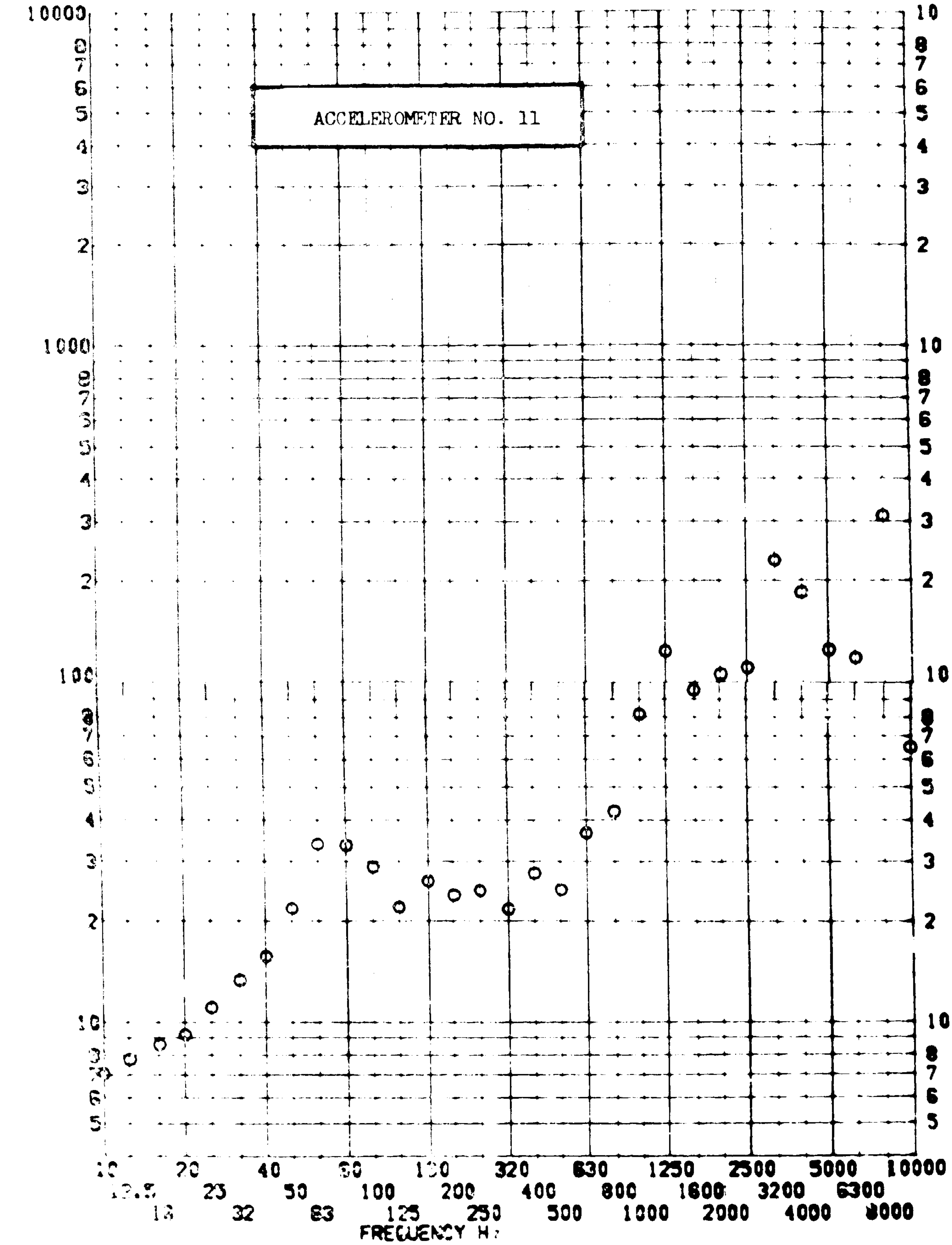
SHOCK NO. 1



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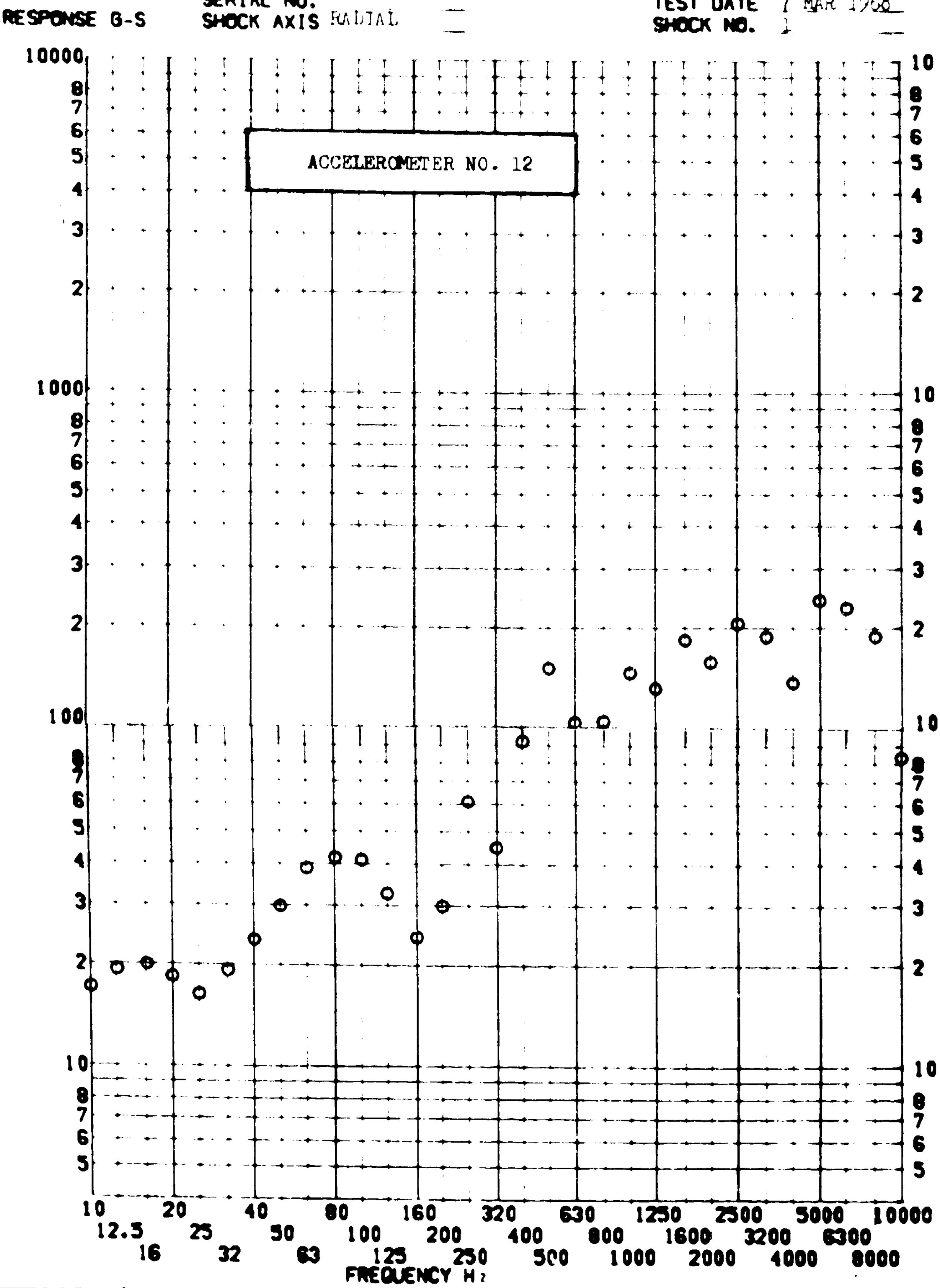
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1



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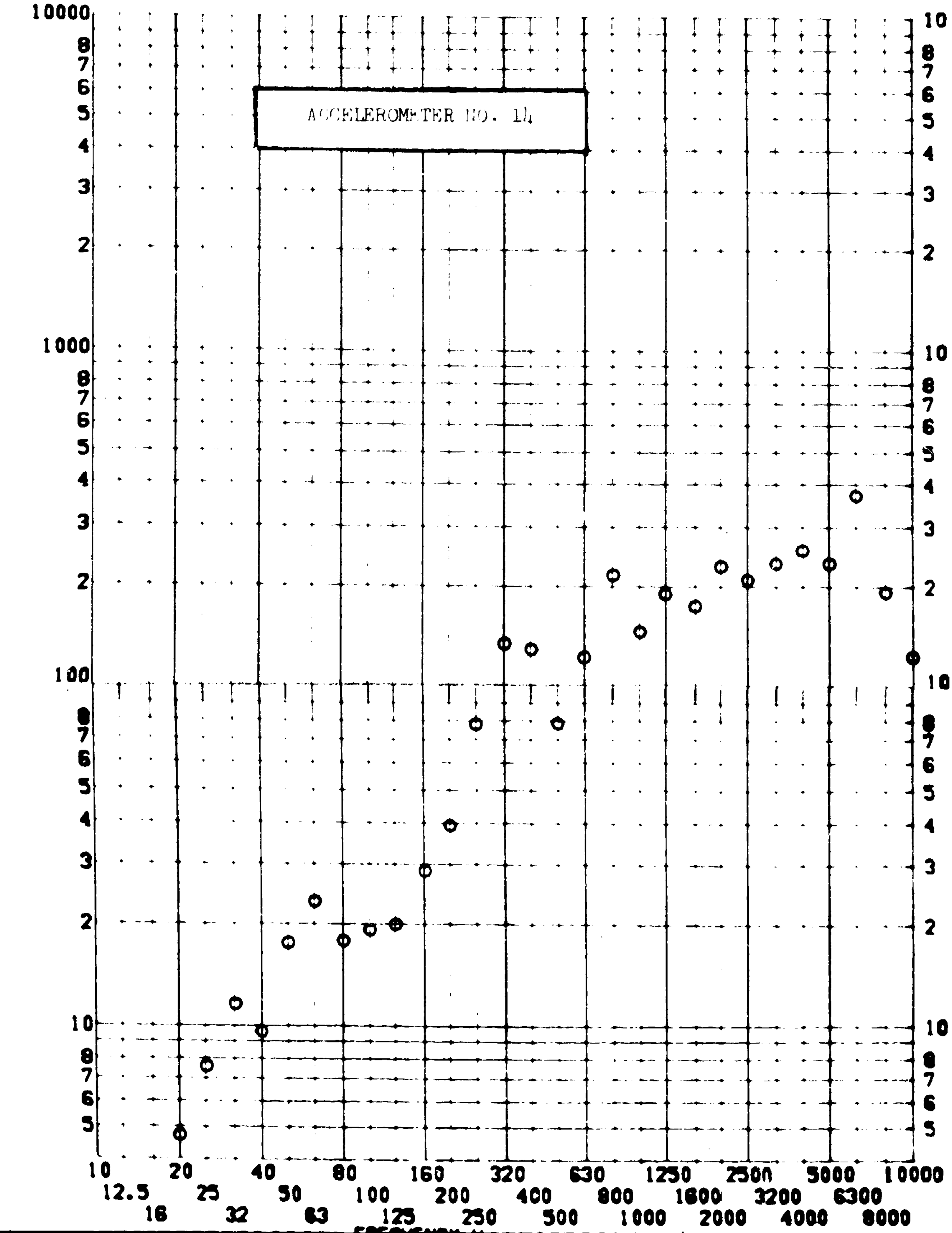
SERIAL NO.		TEST DATE	7 MAR 1968
SHOCK AXIS	TANGENTIAL	SHOCK NO.	



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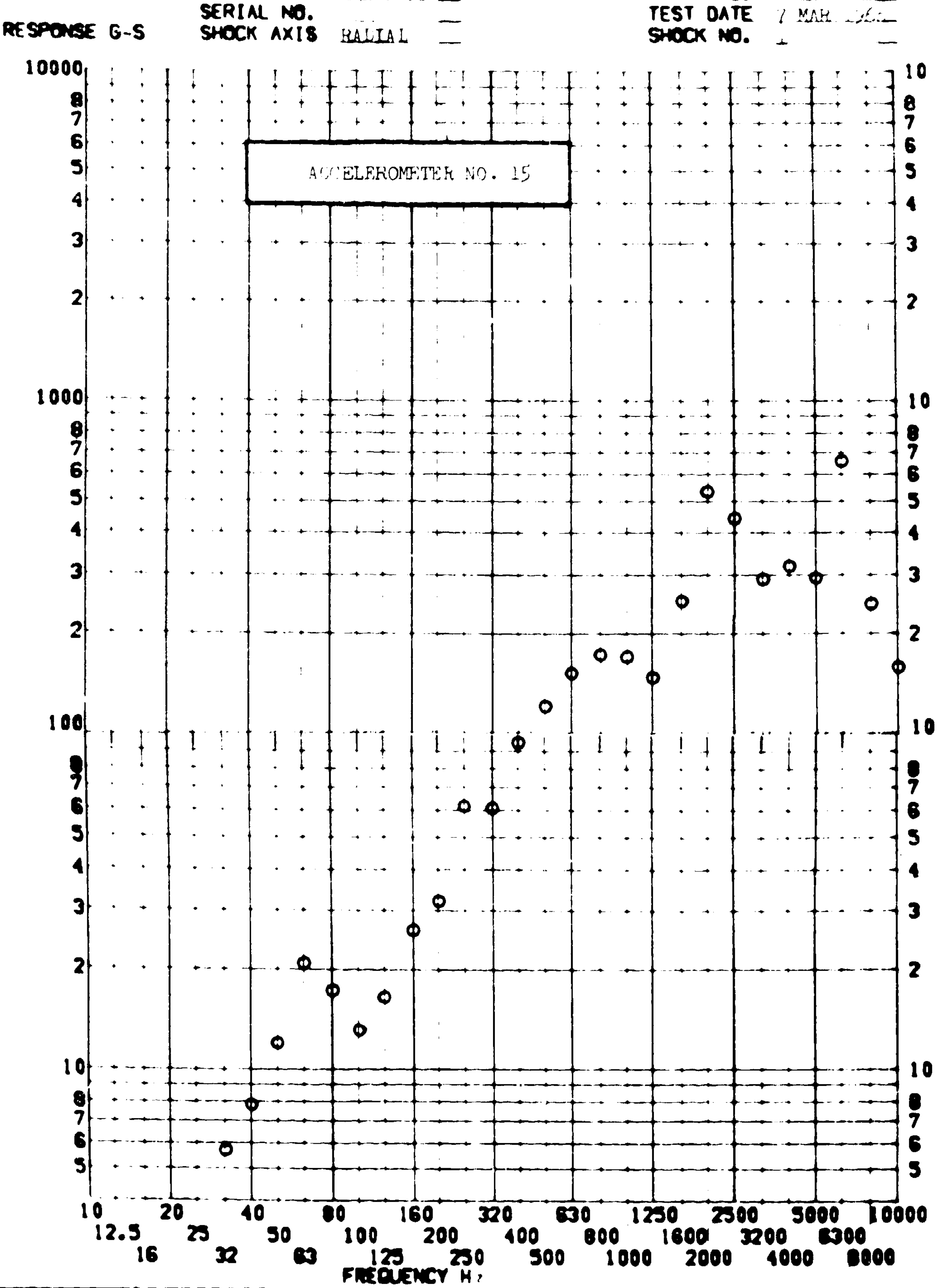

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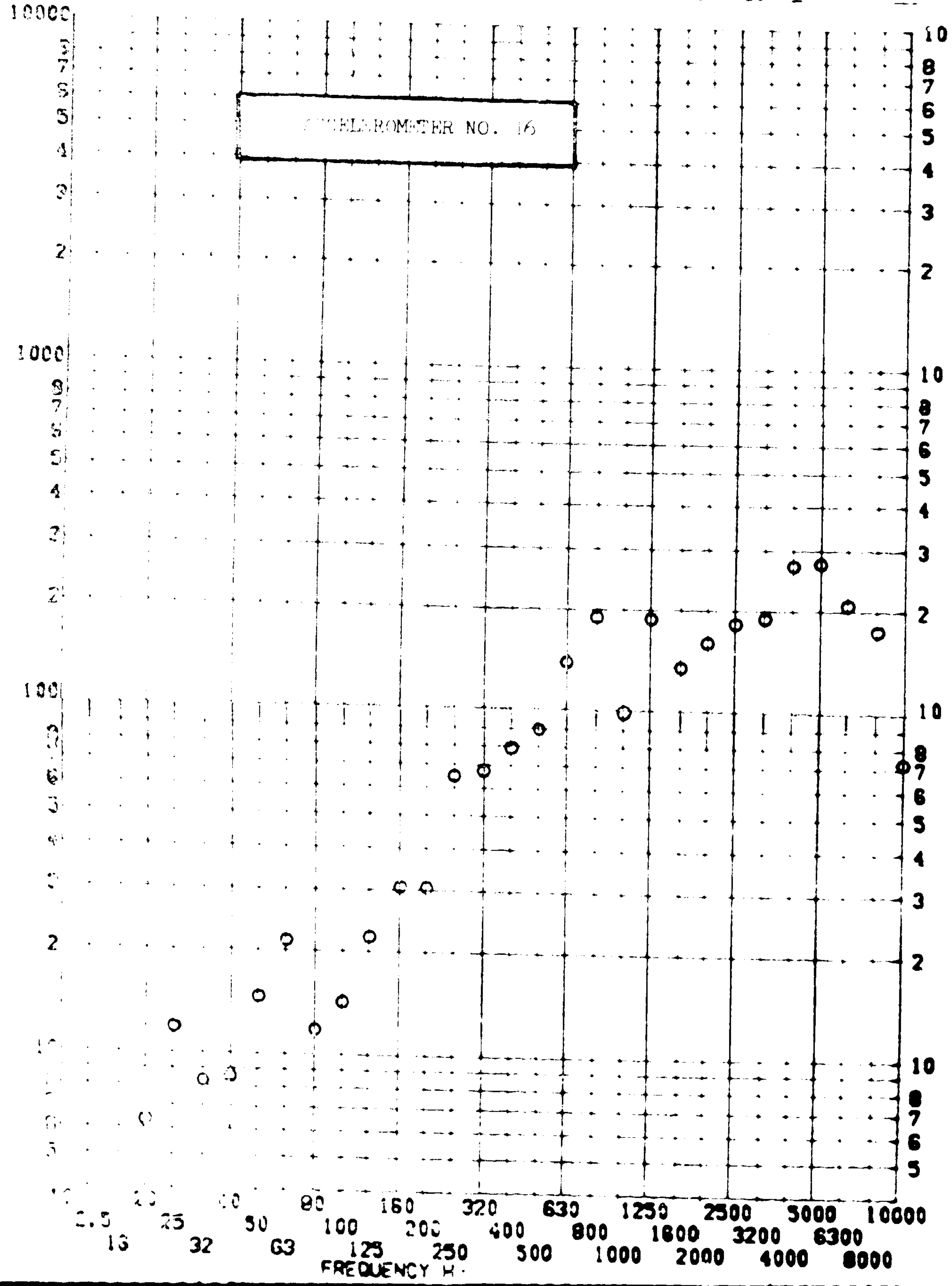
PART NO. [illegible]
TEST DATE 7 MAR [illegible]
SHOCK NO. —



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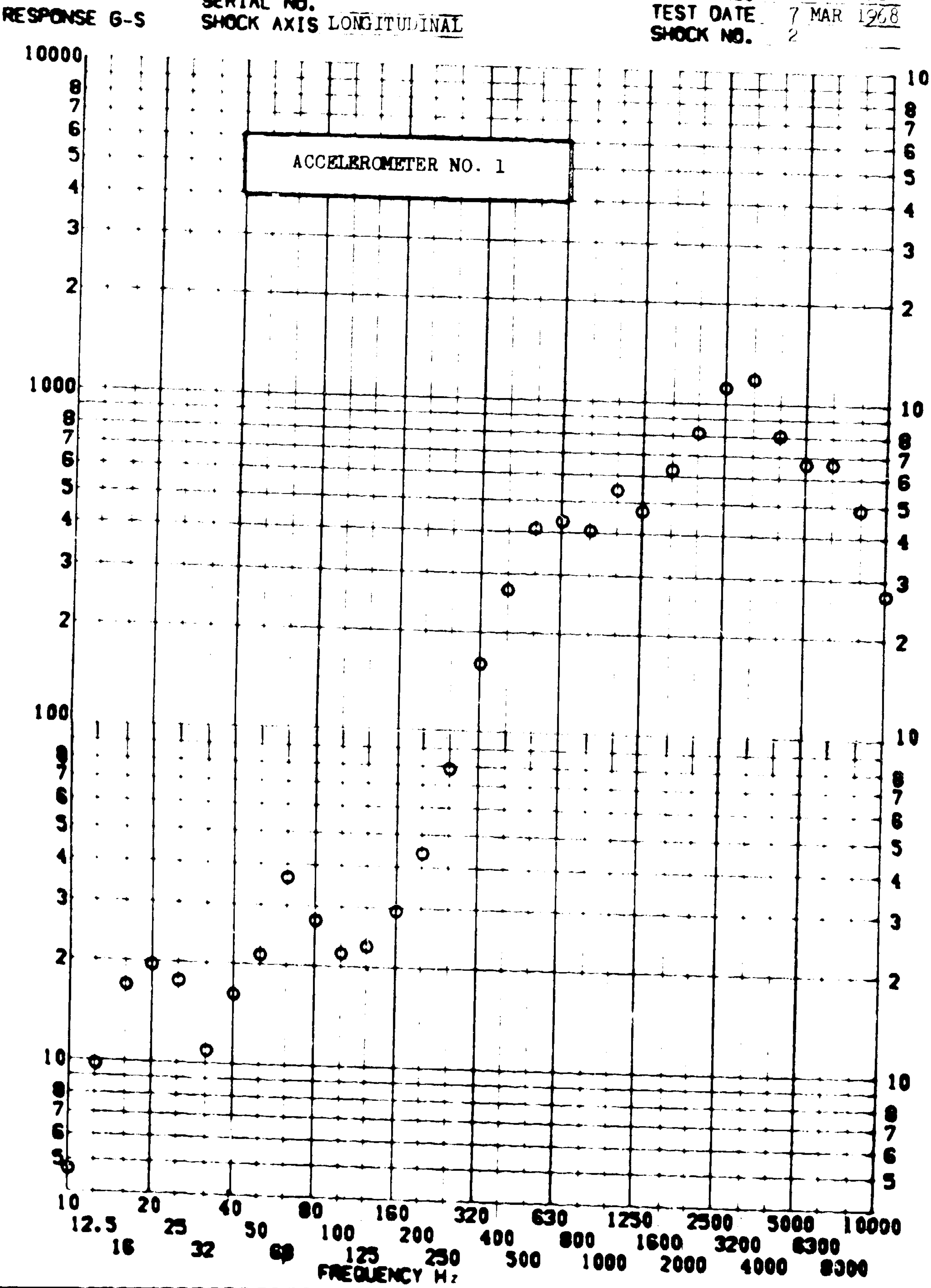
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



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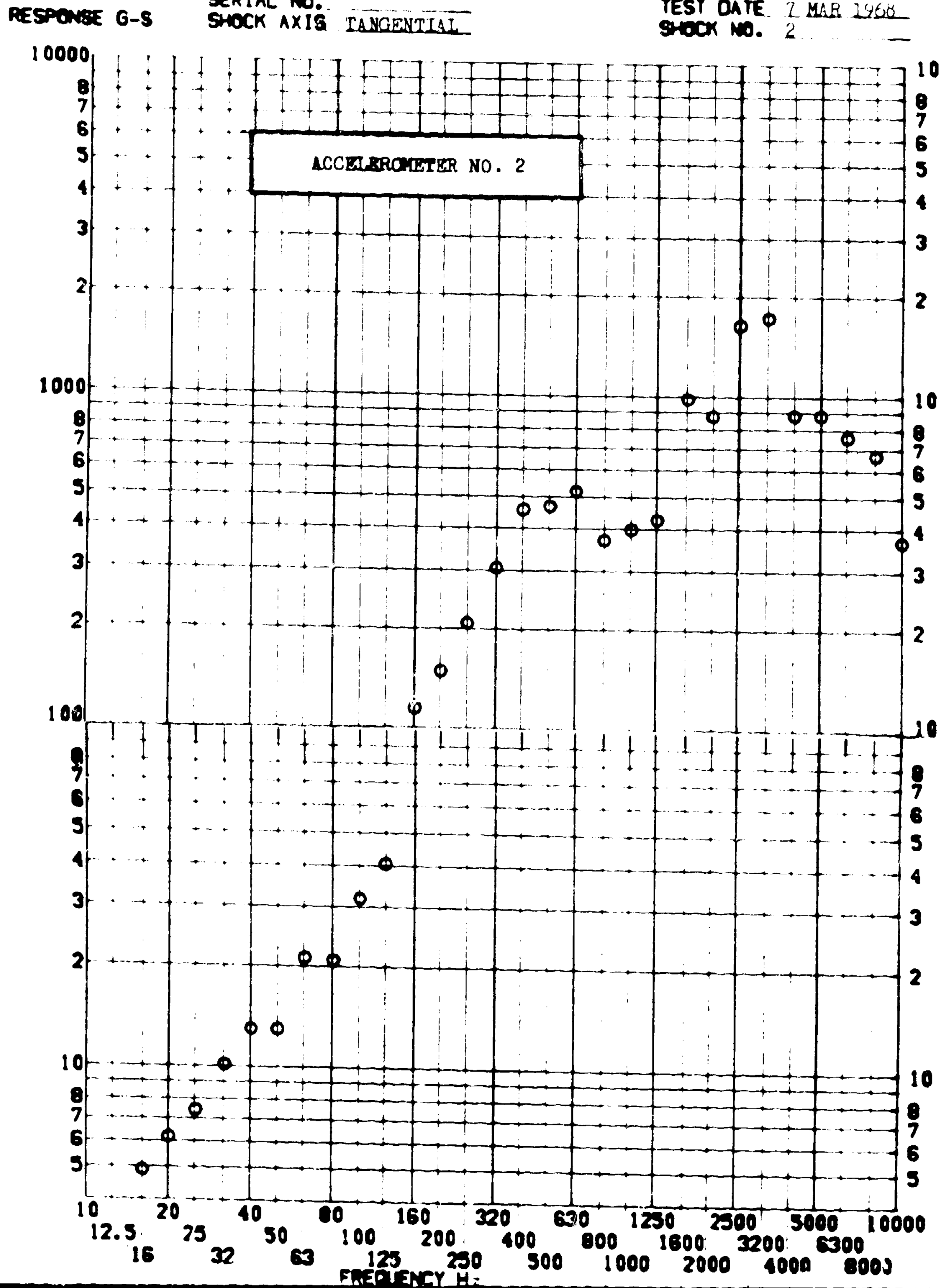
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



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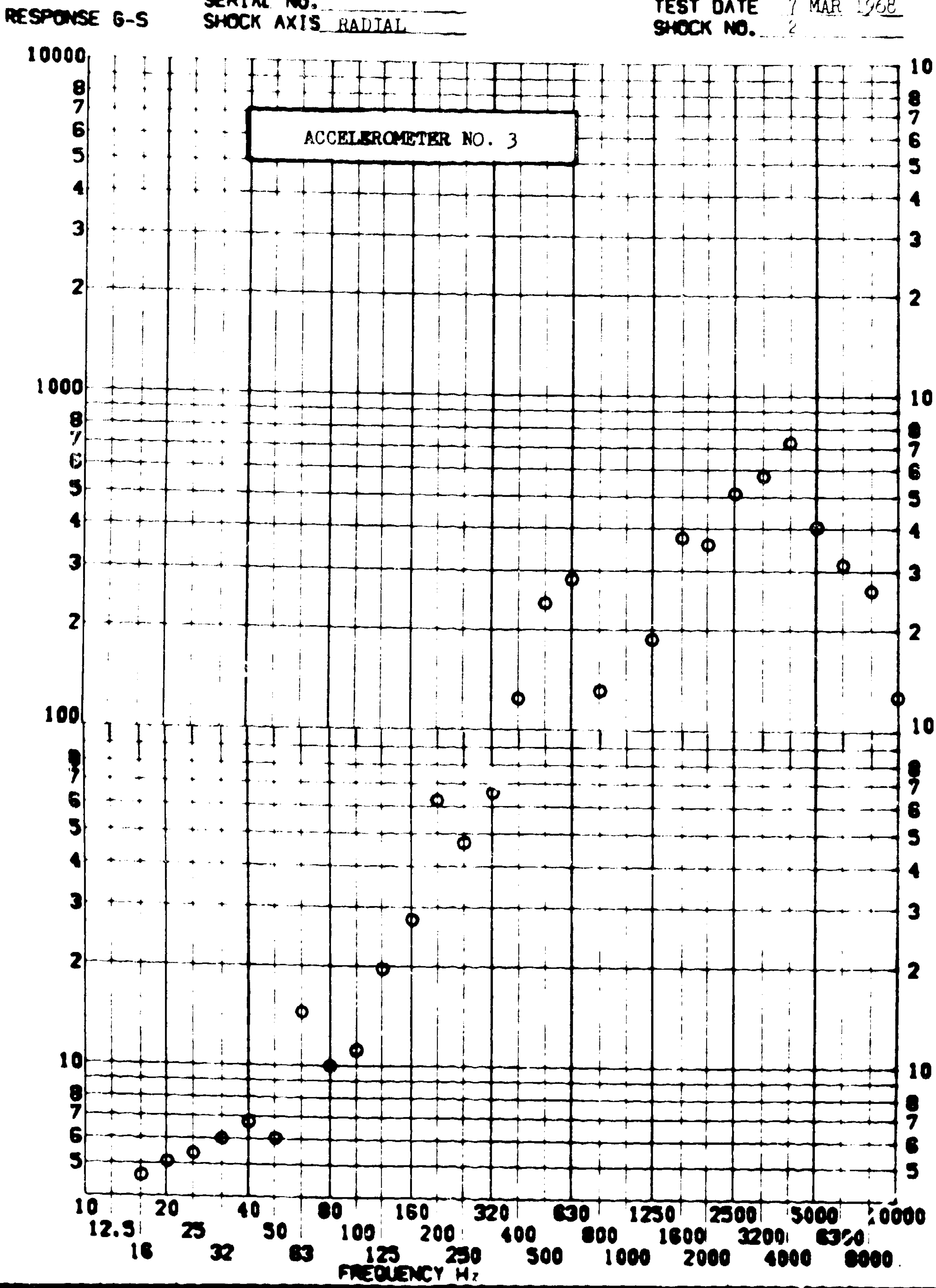
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET

II.D.1.23

TEST ITEM 429-300
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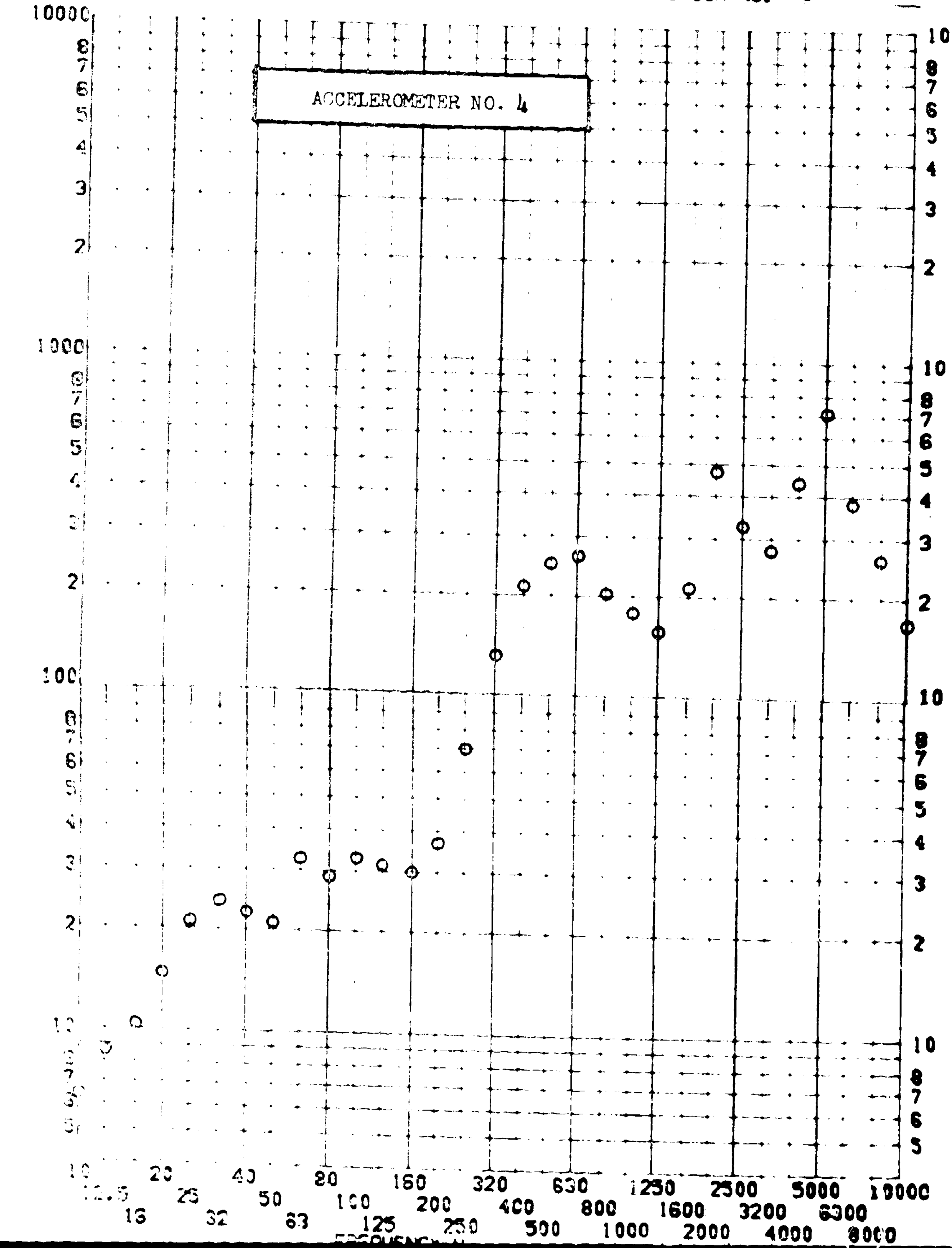
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



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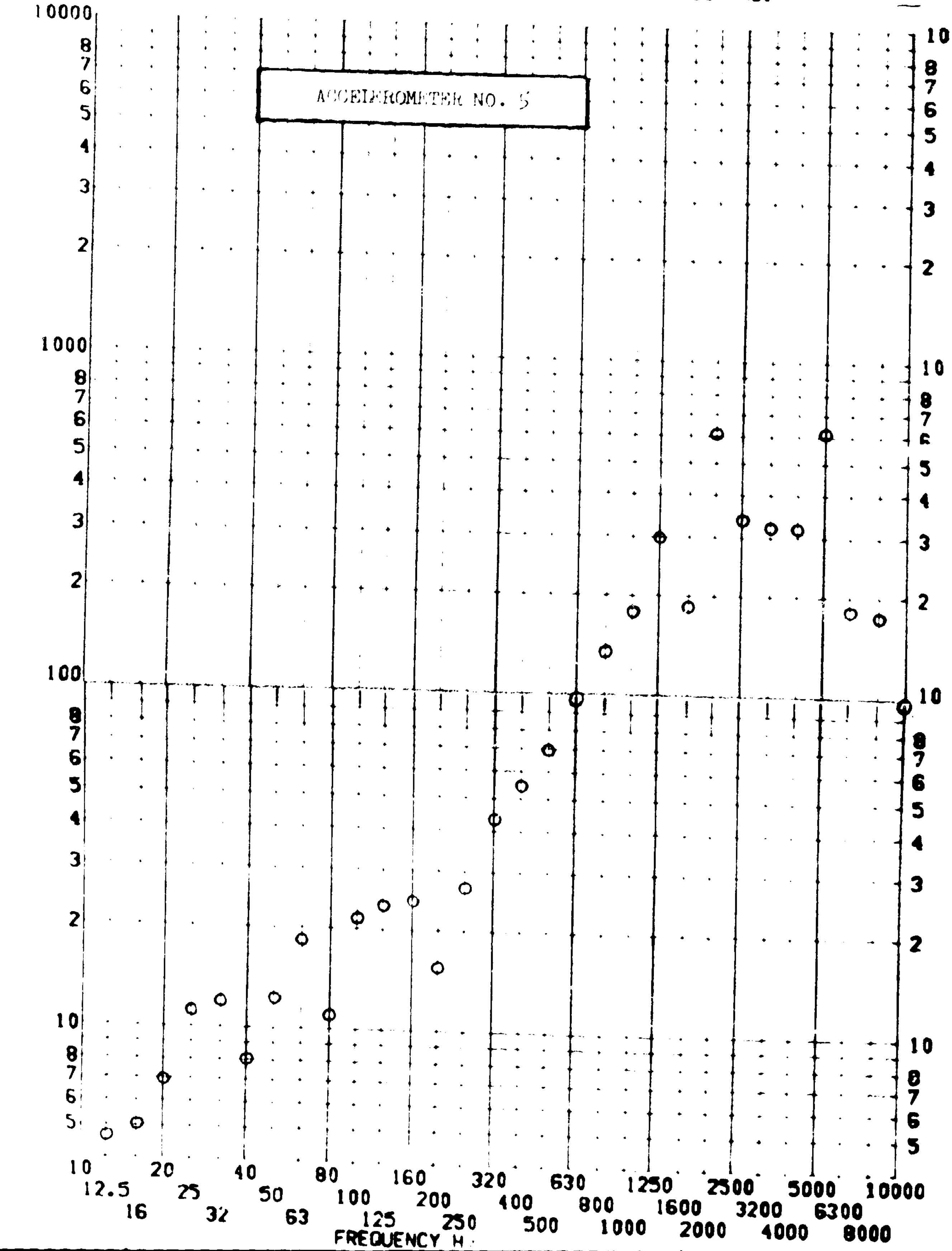
SHOCK NO.



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TEST ITEM 429-302
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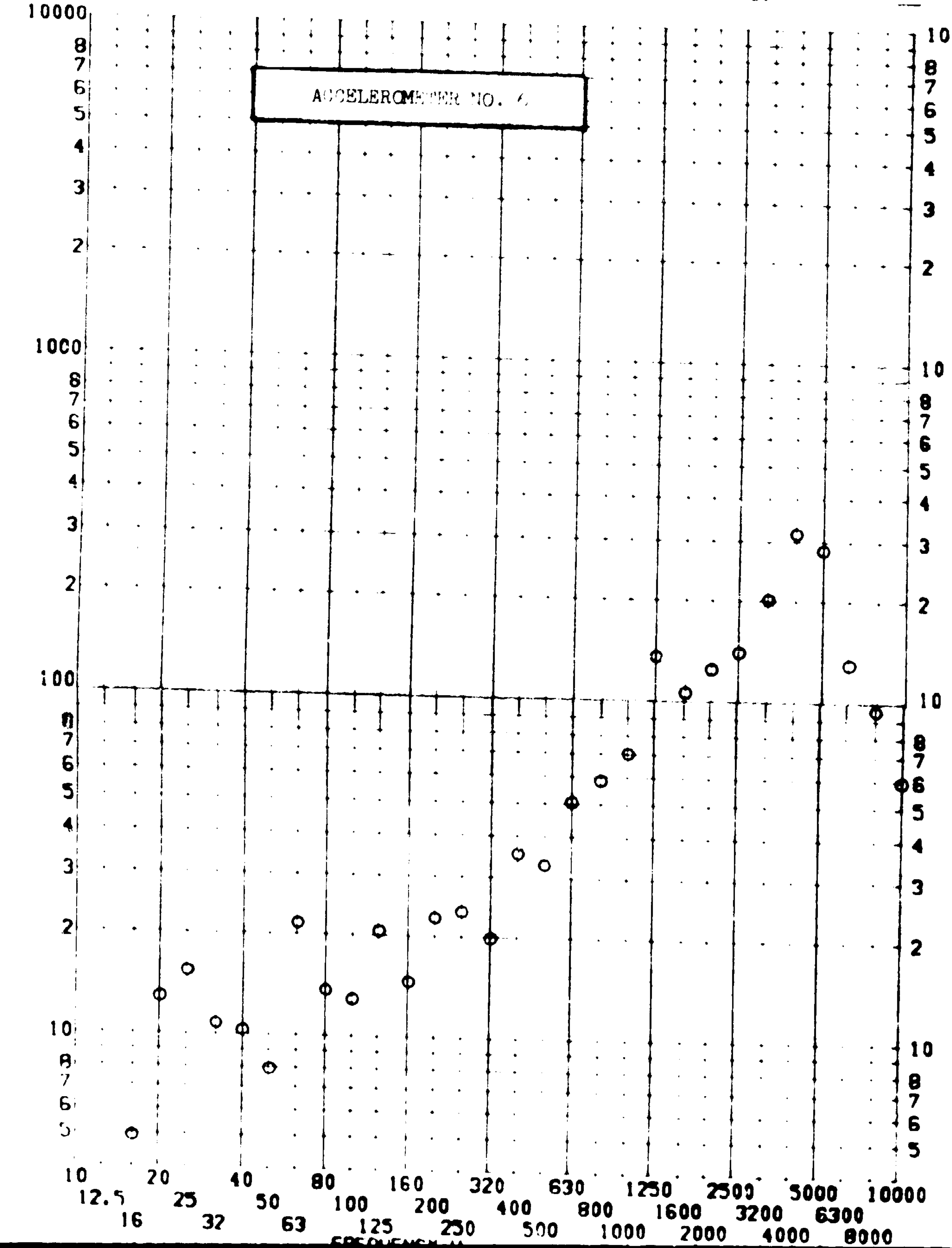
SHOCK AXIS RADIAL

PART NO.
TEST DATE
SHOCK NO.



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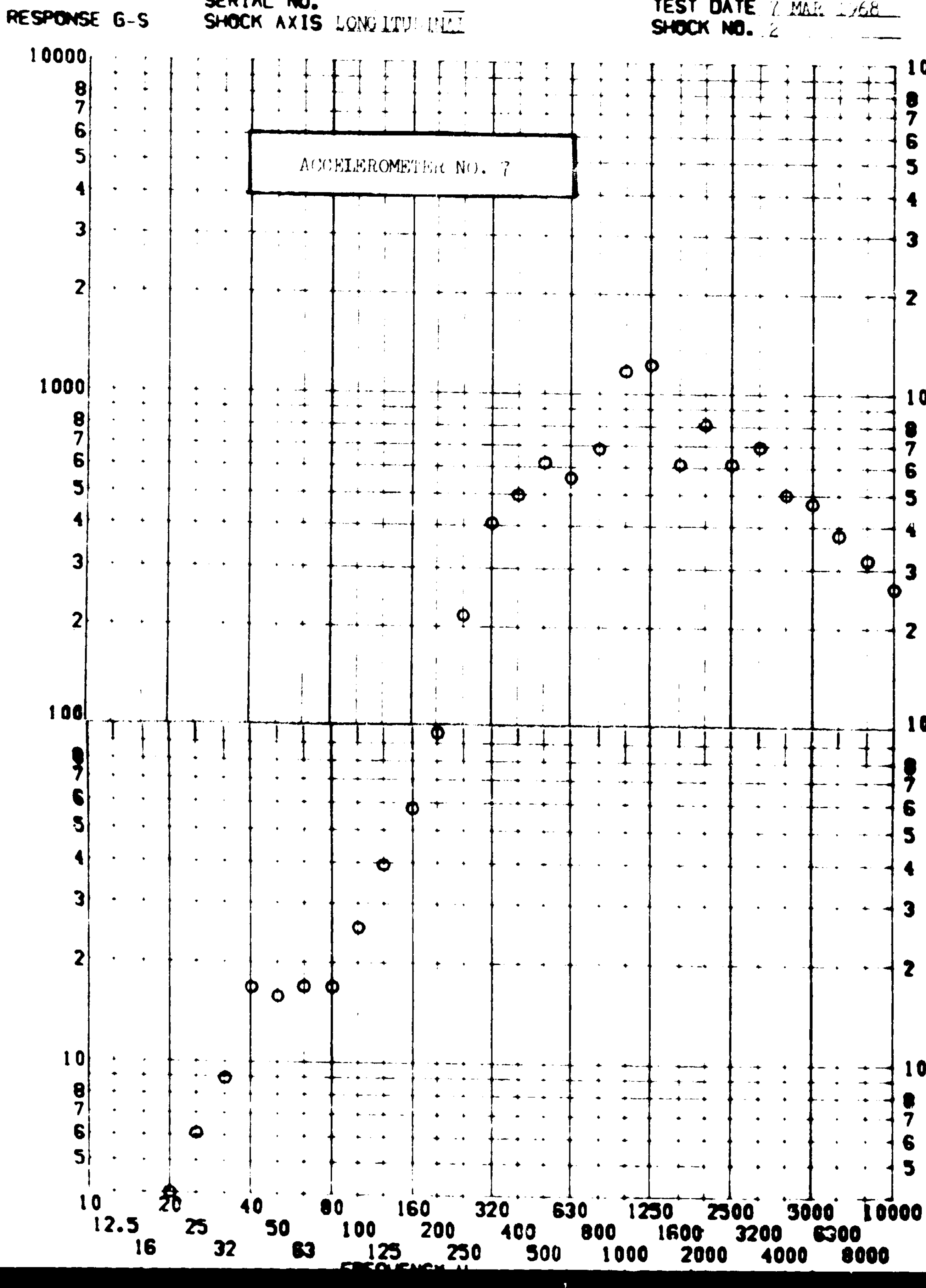
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



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PART NO. STRUCTURE
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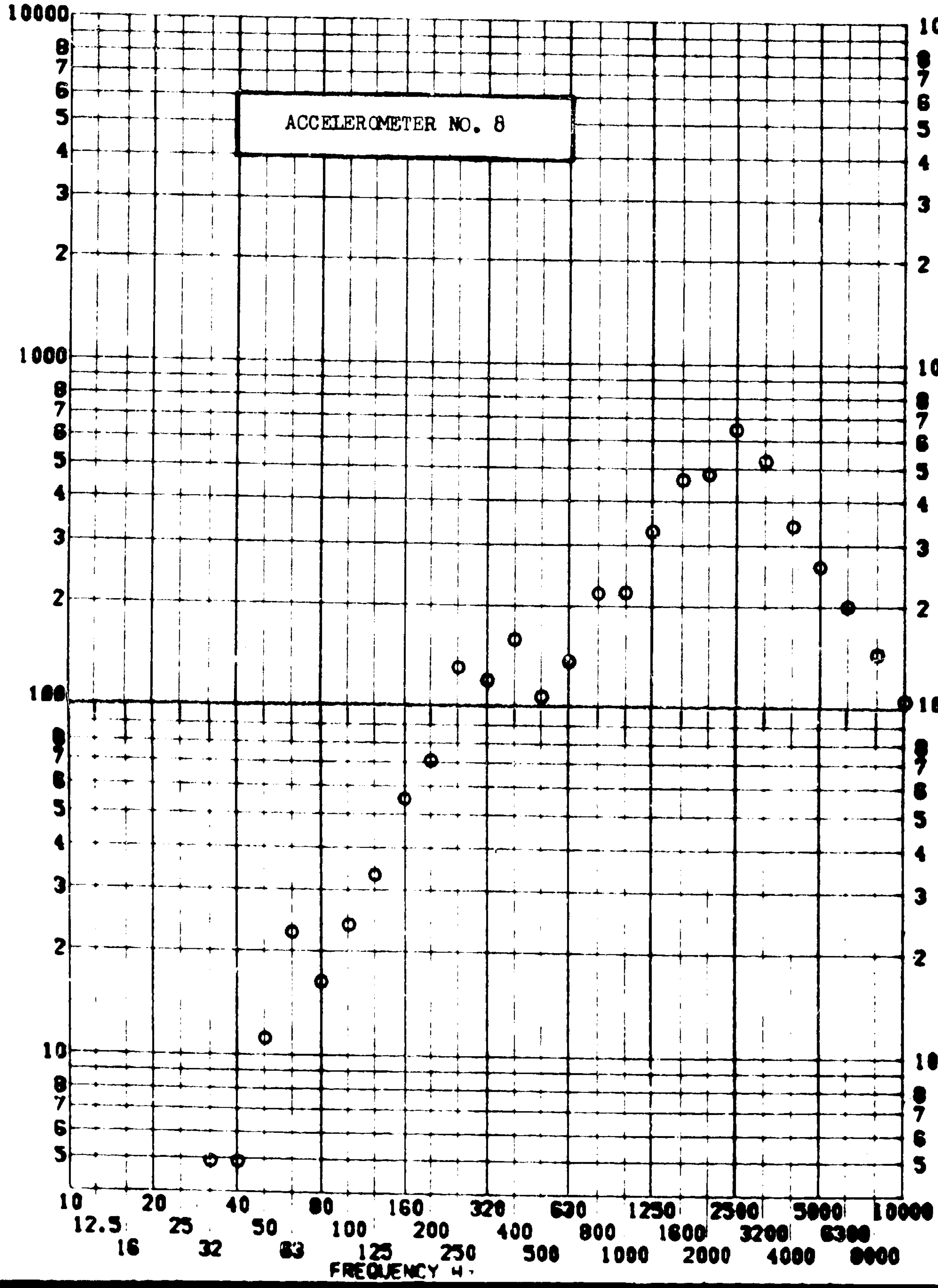
RESPONSE G-S



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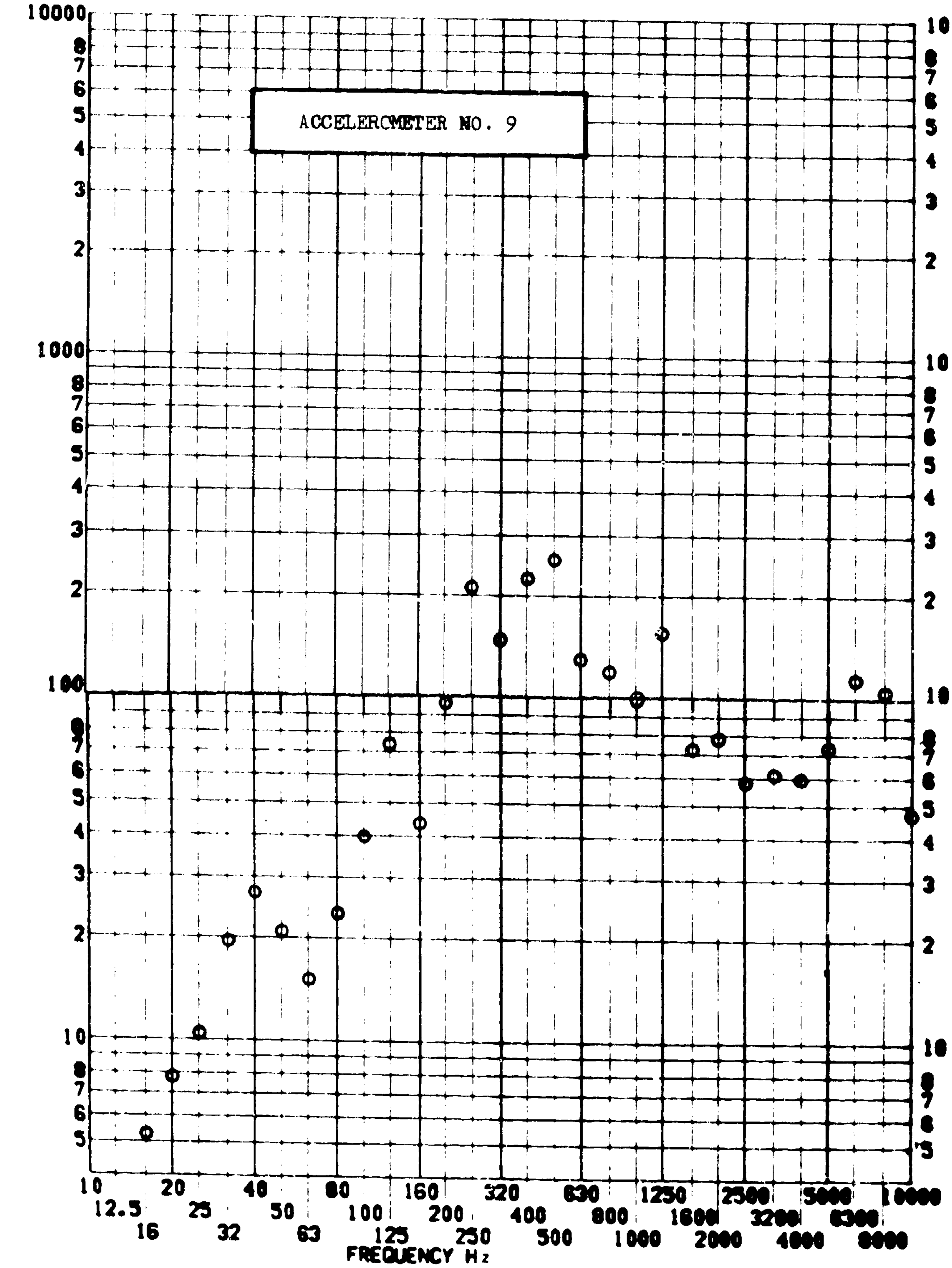
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.D.1.29

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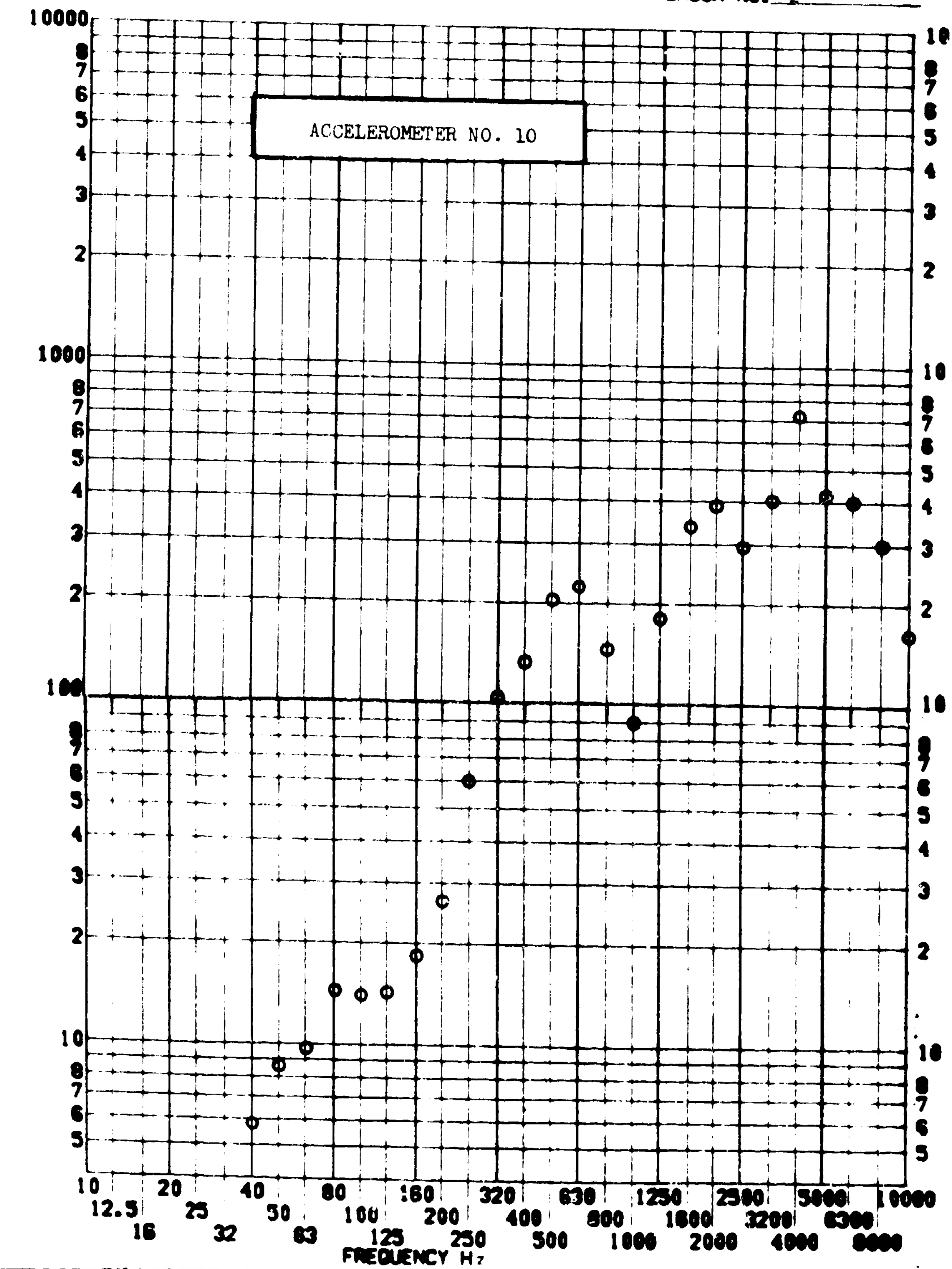
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.1.30

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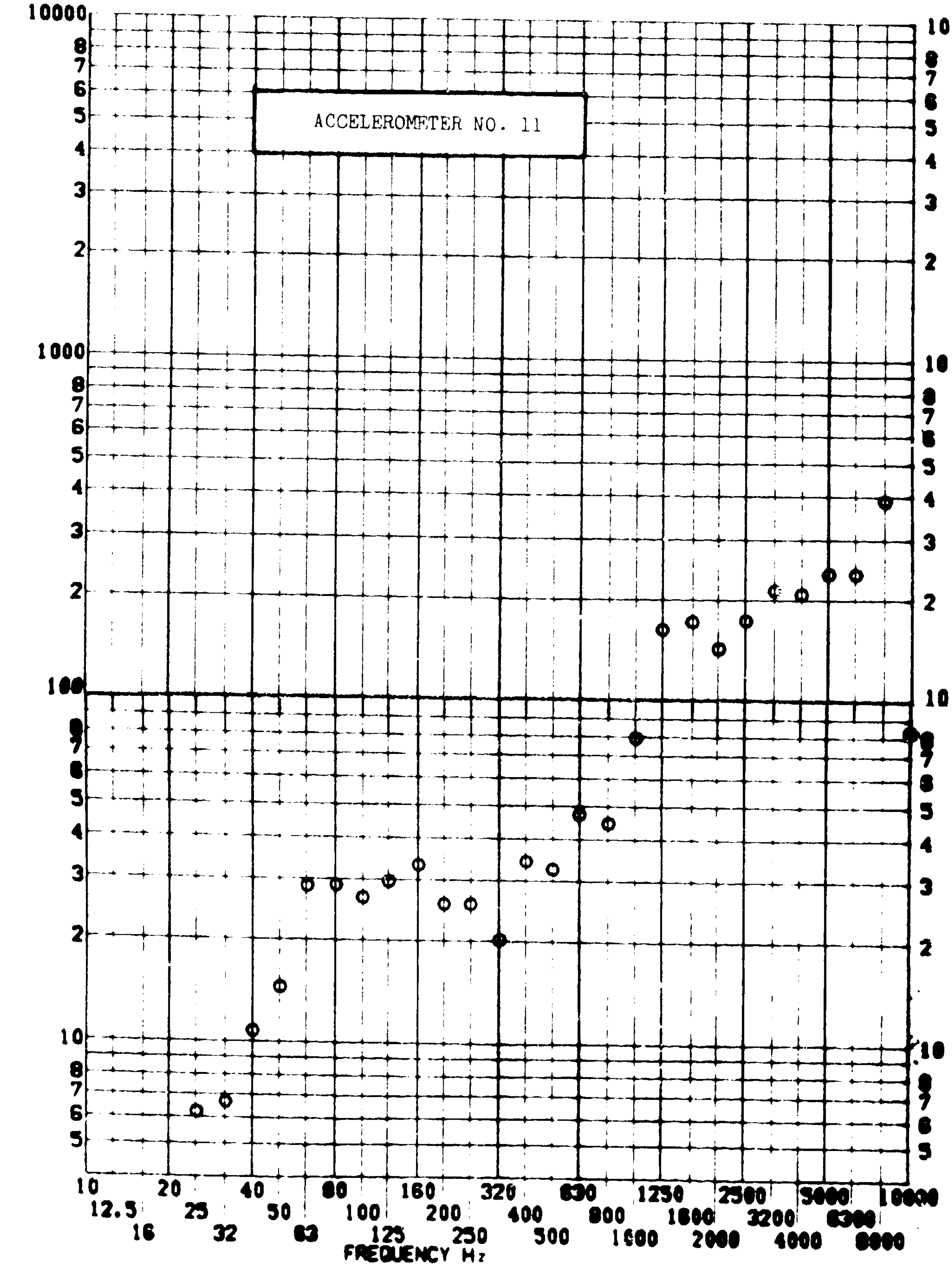
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



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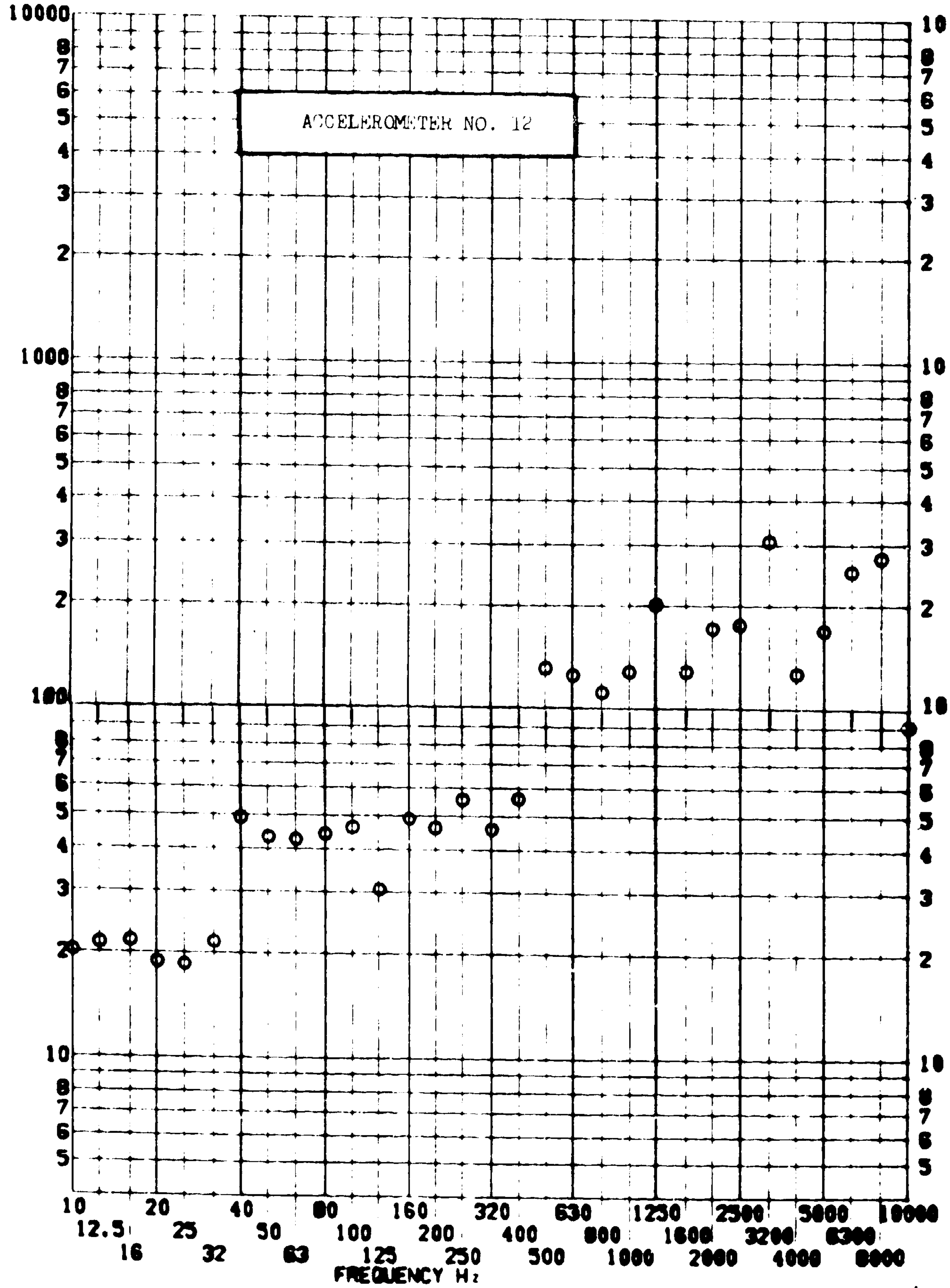
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2

RESPONSE G-S



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SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
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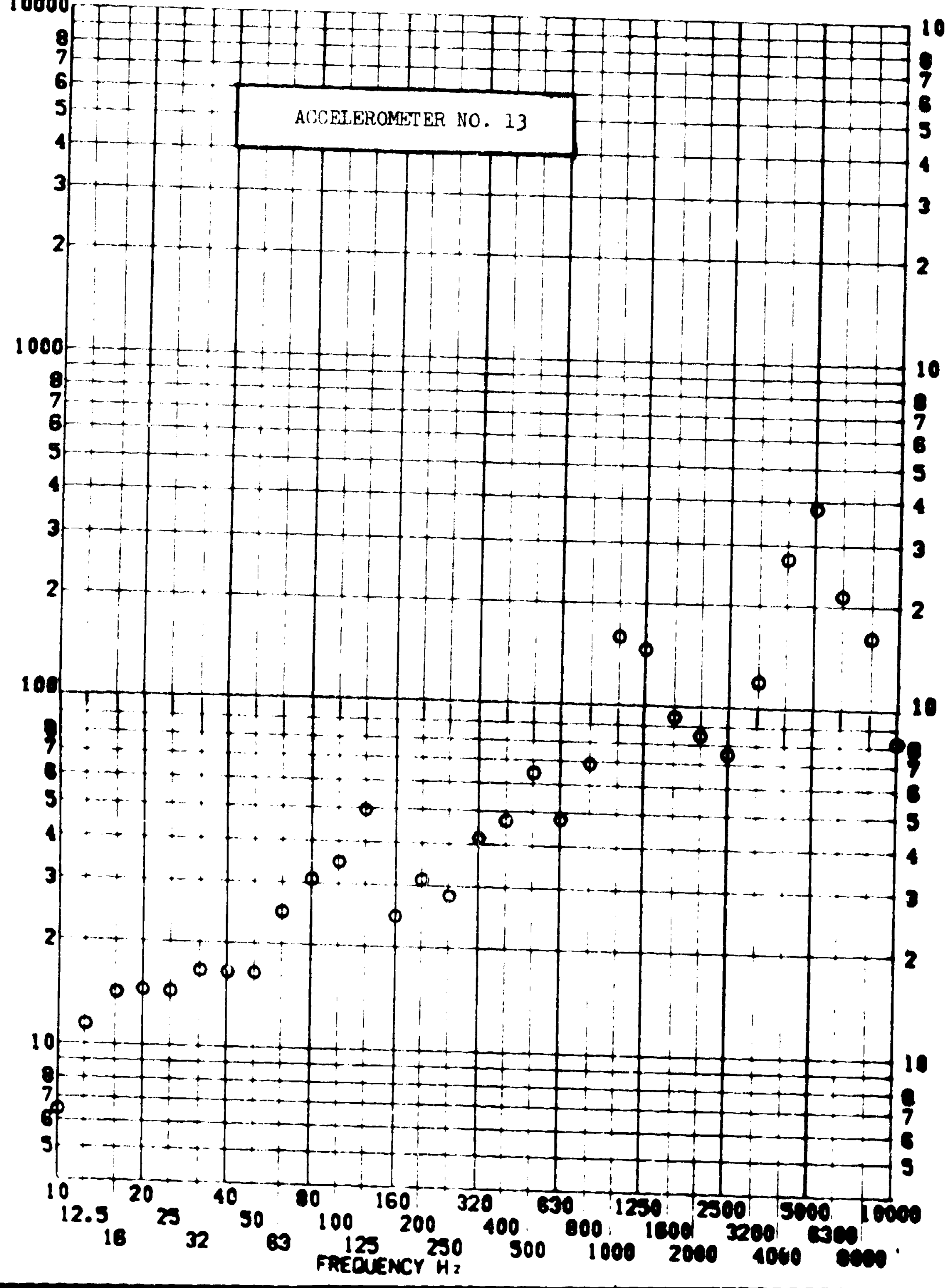
RESPONSE G-S



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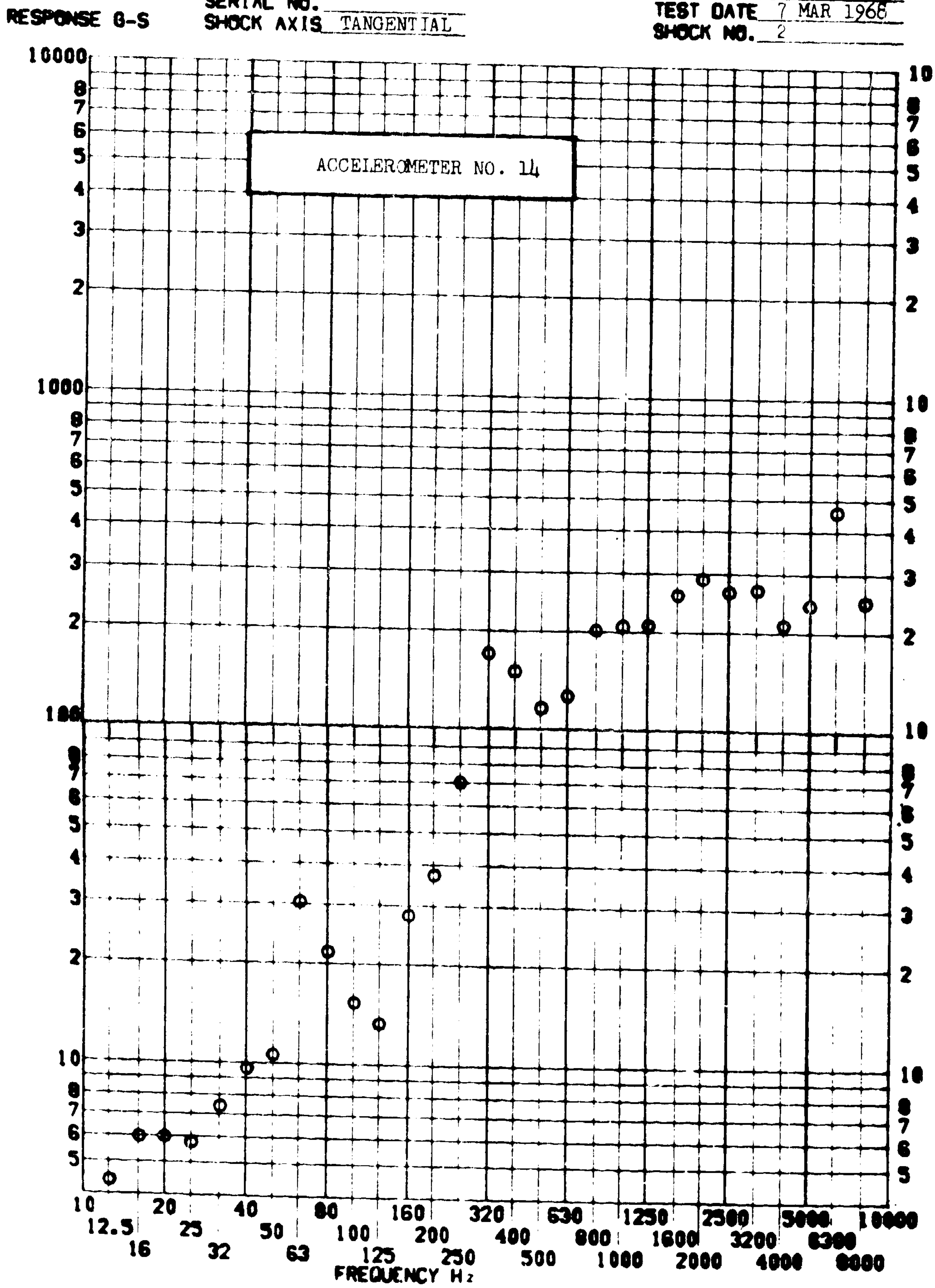
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET

II.D.1.34

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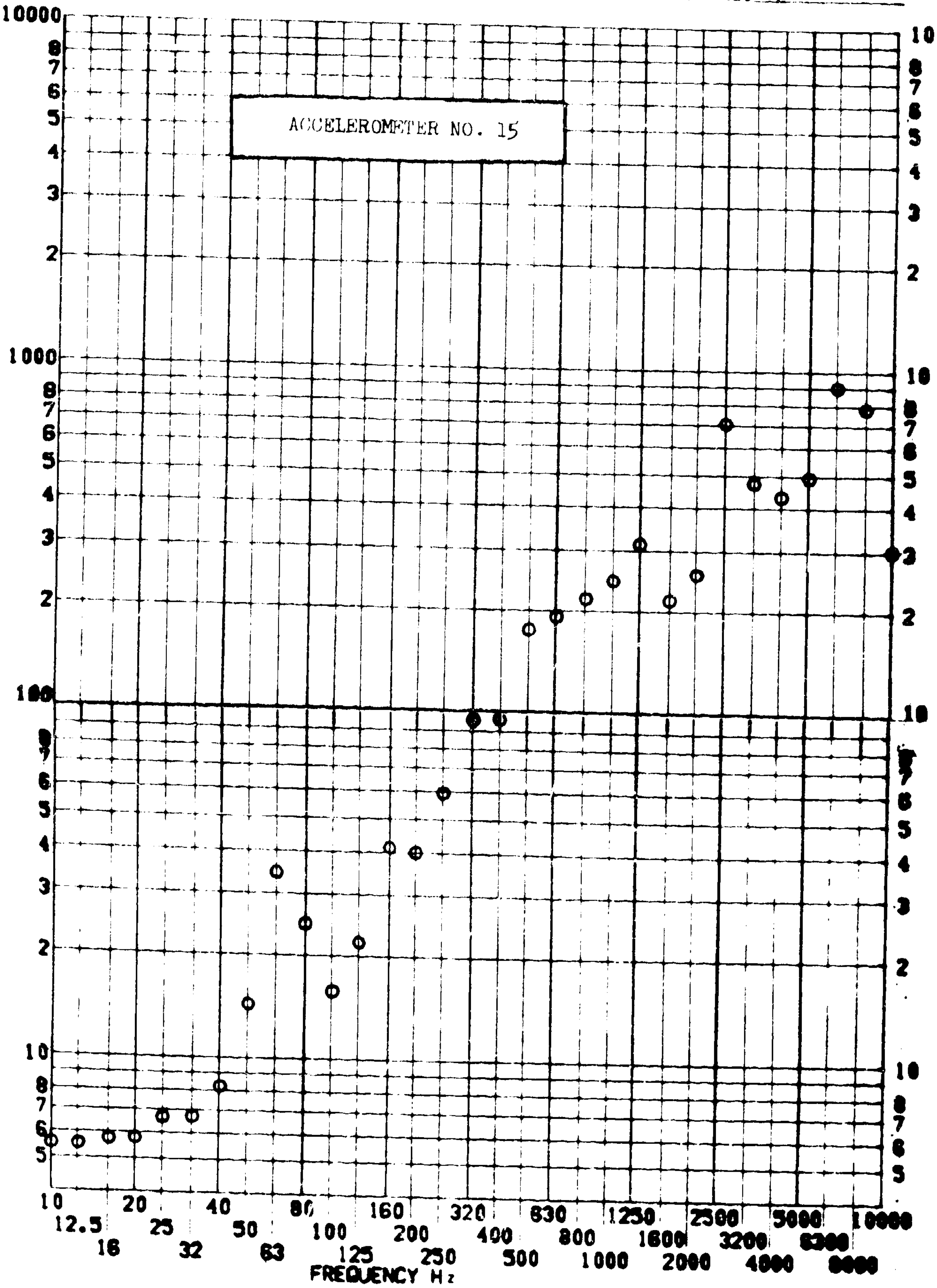
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 2

RESPONSE G-S



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PART NO. STRUCTURE
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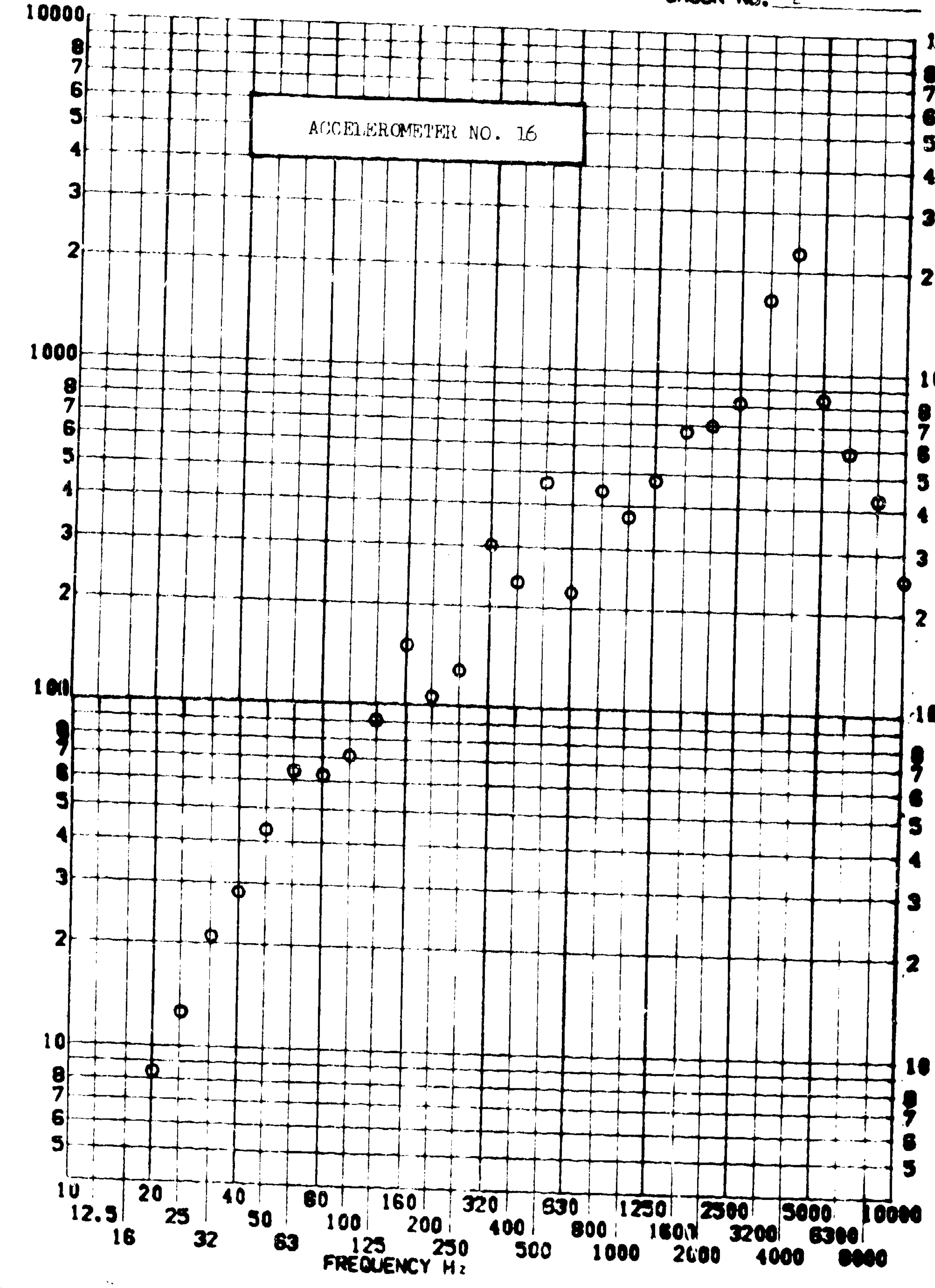
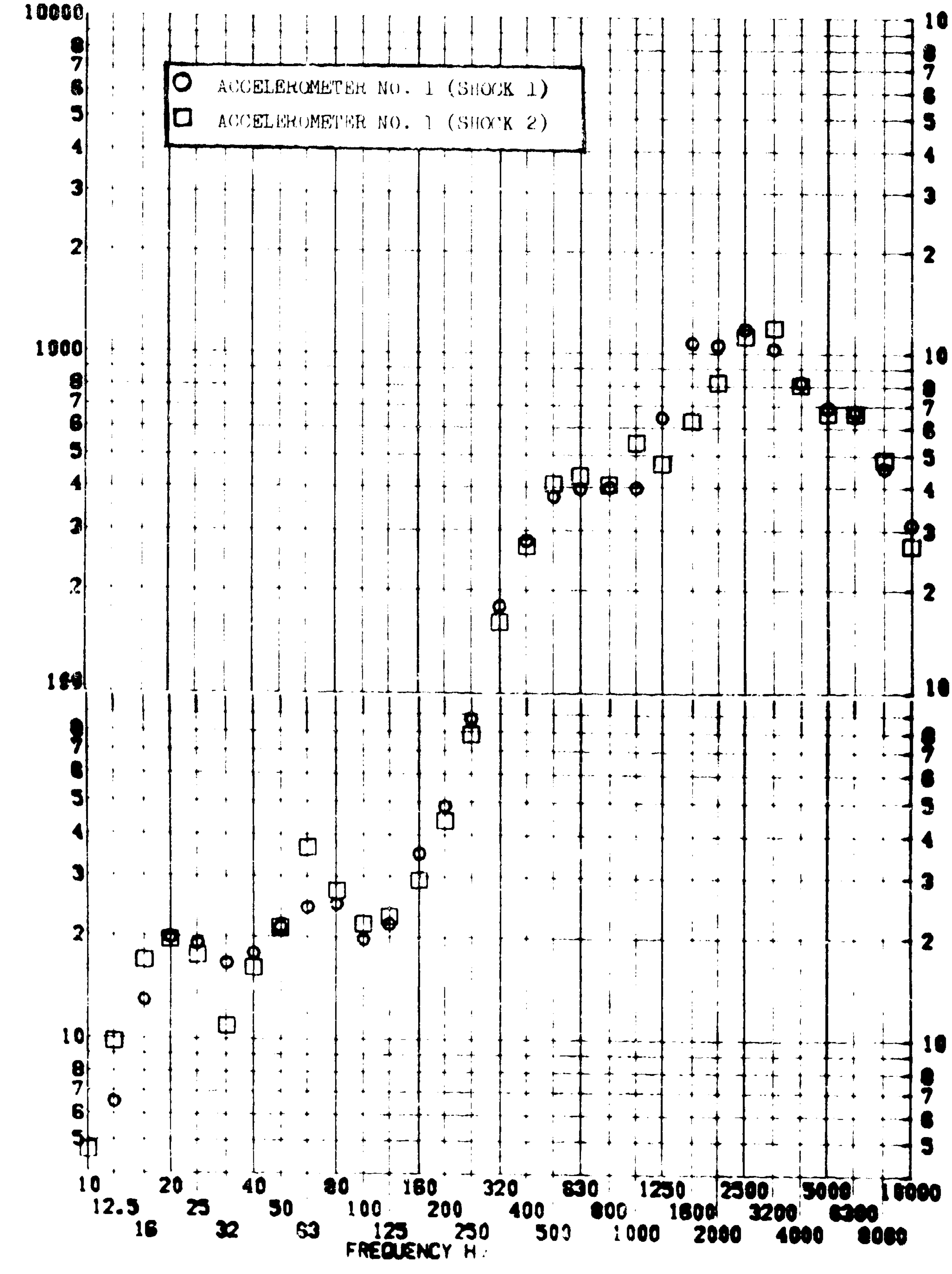


SHOCK TEST ANALYSIS DATA SHEET

II.D.1.36

TEST ITEM 429-304,307
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2



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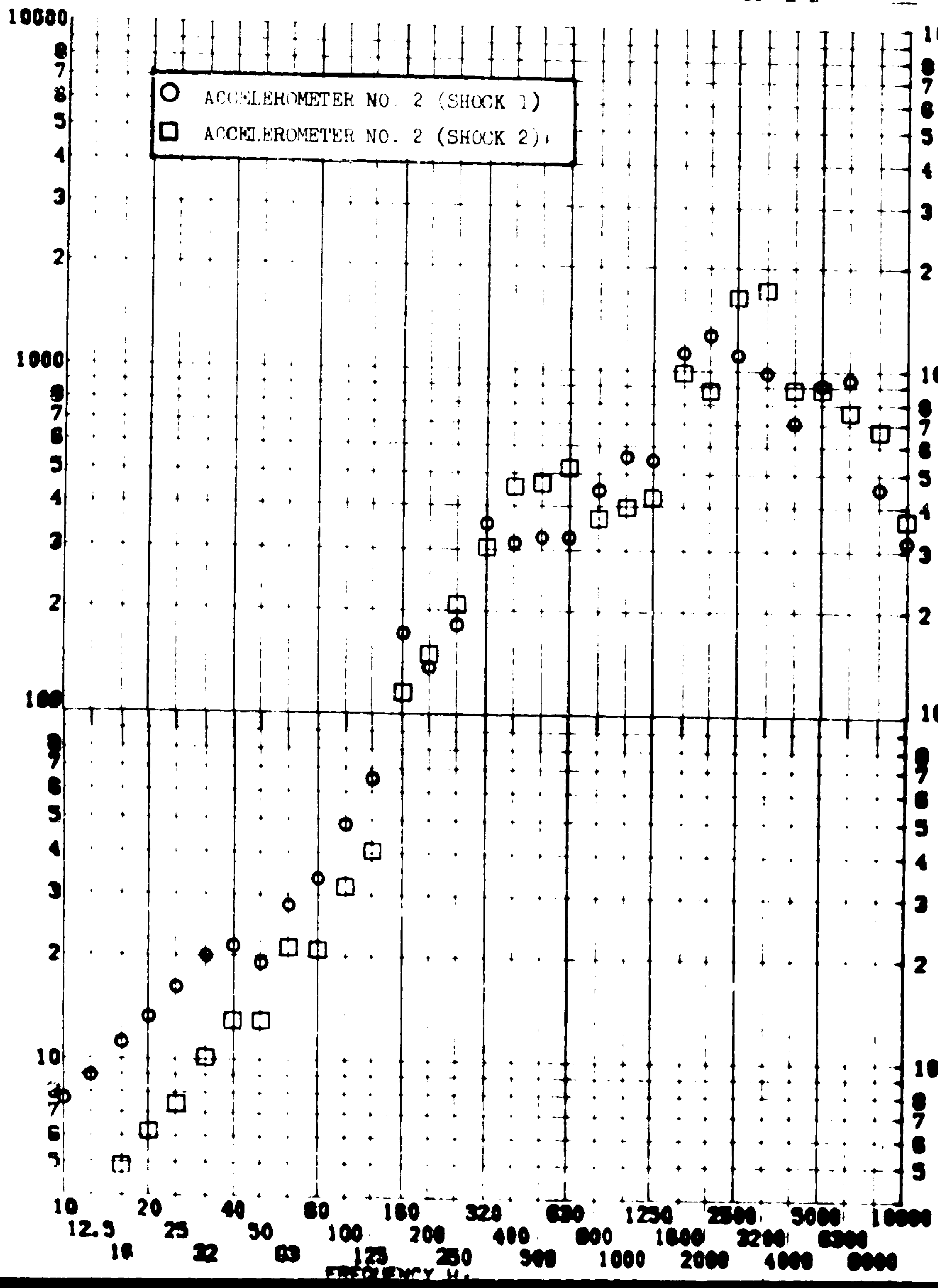
SHOCK AXIS TANGENTIAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2



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TEST ITEM 429-303,304
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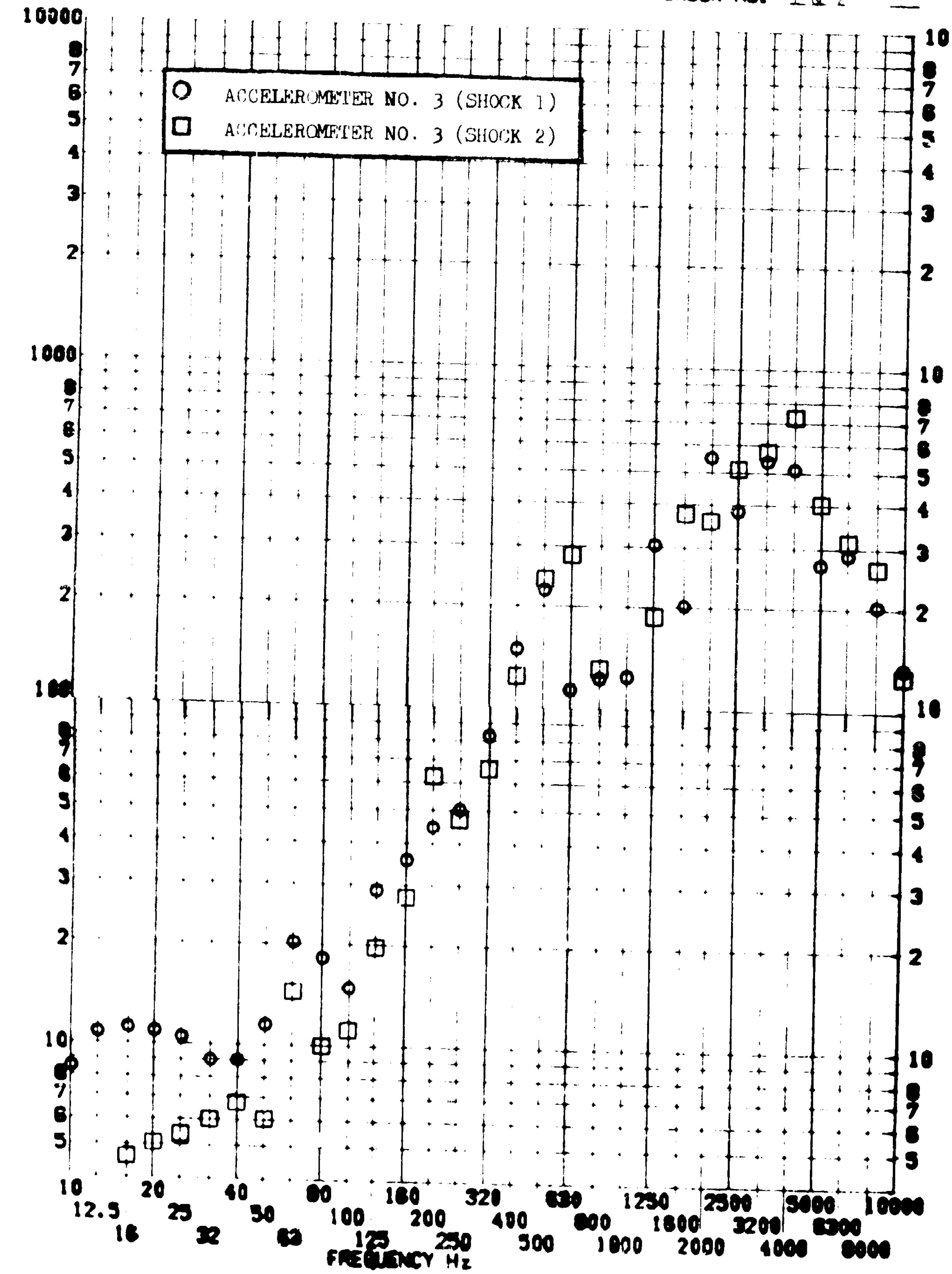
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET

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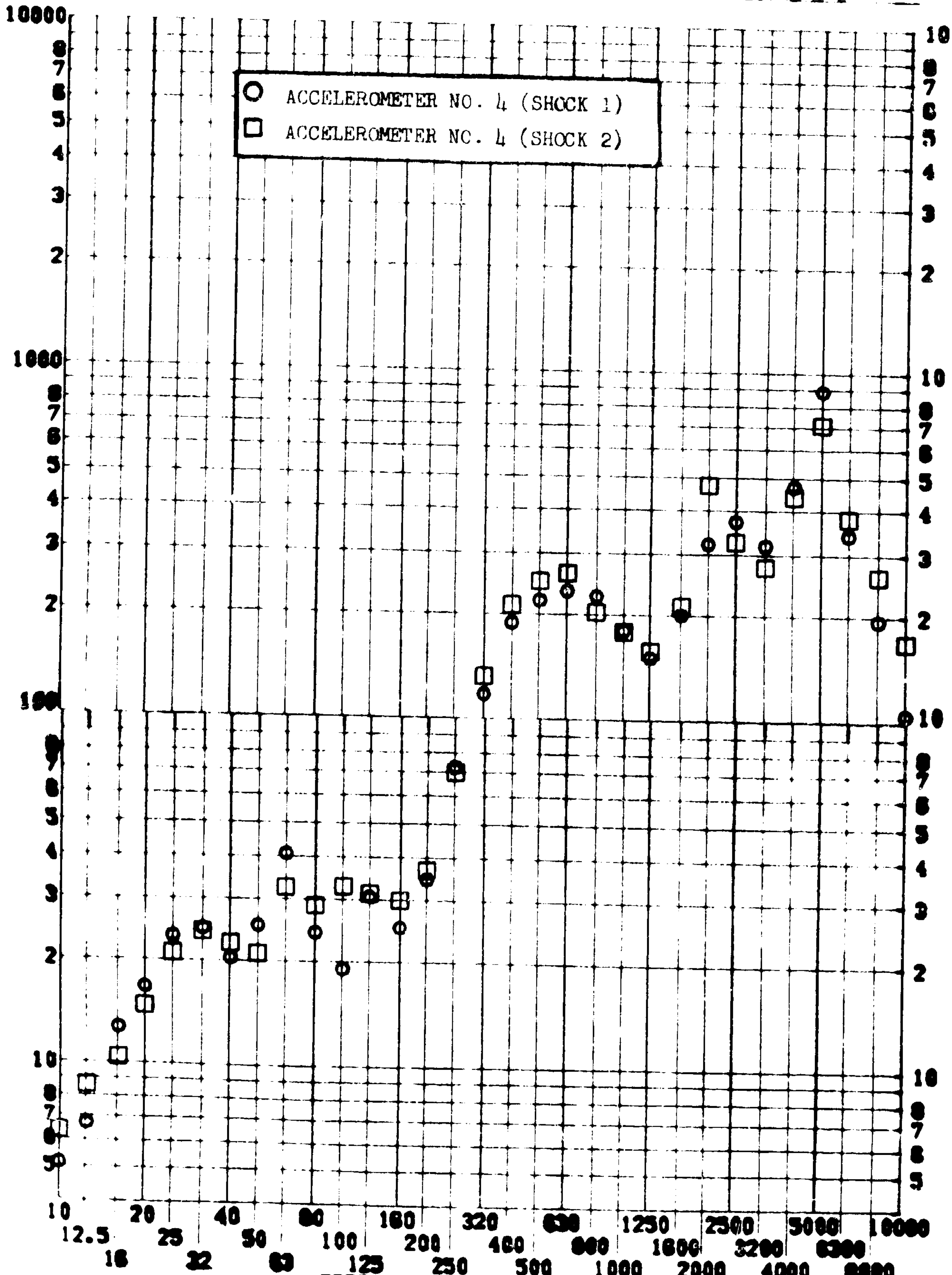
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2



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PART NO. STRUCTURE
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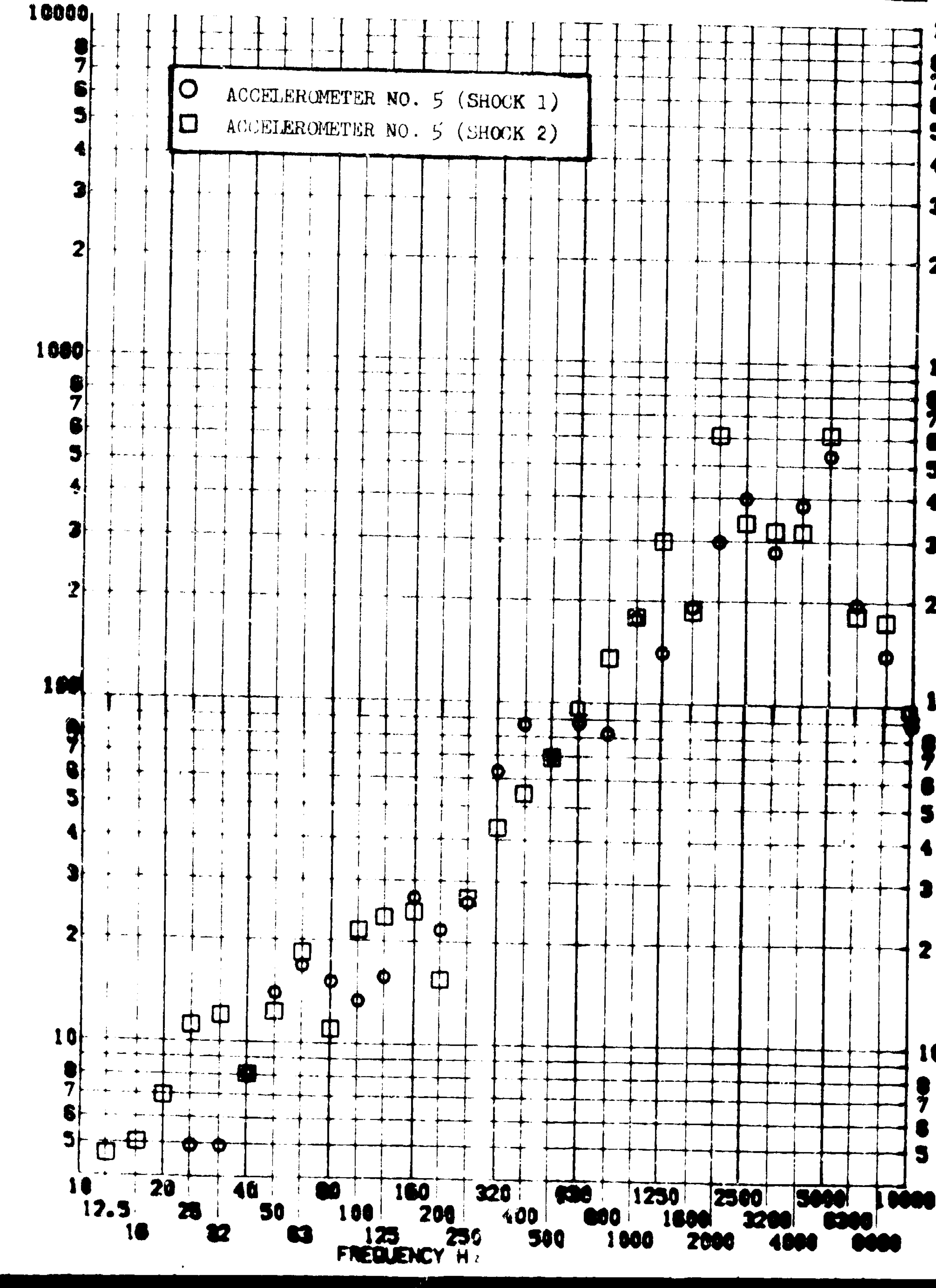

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PART NO. STRUCTURE
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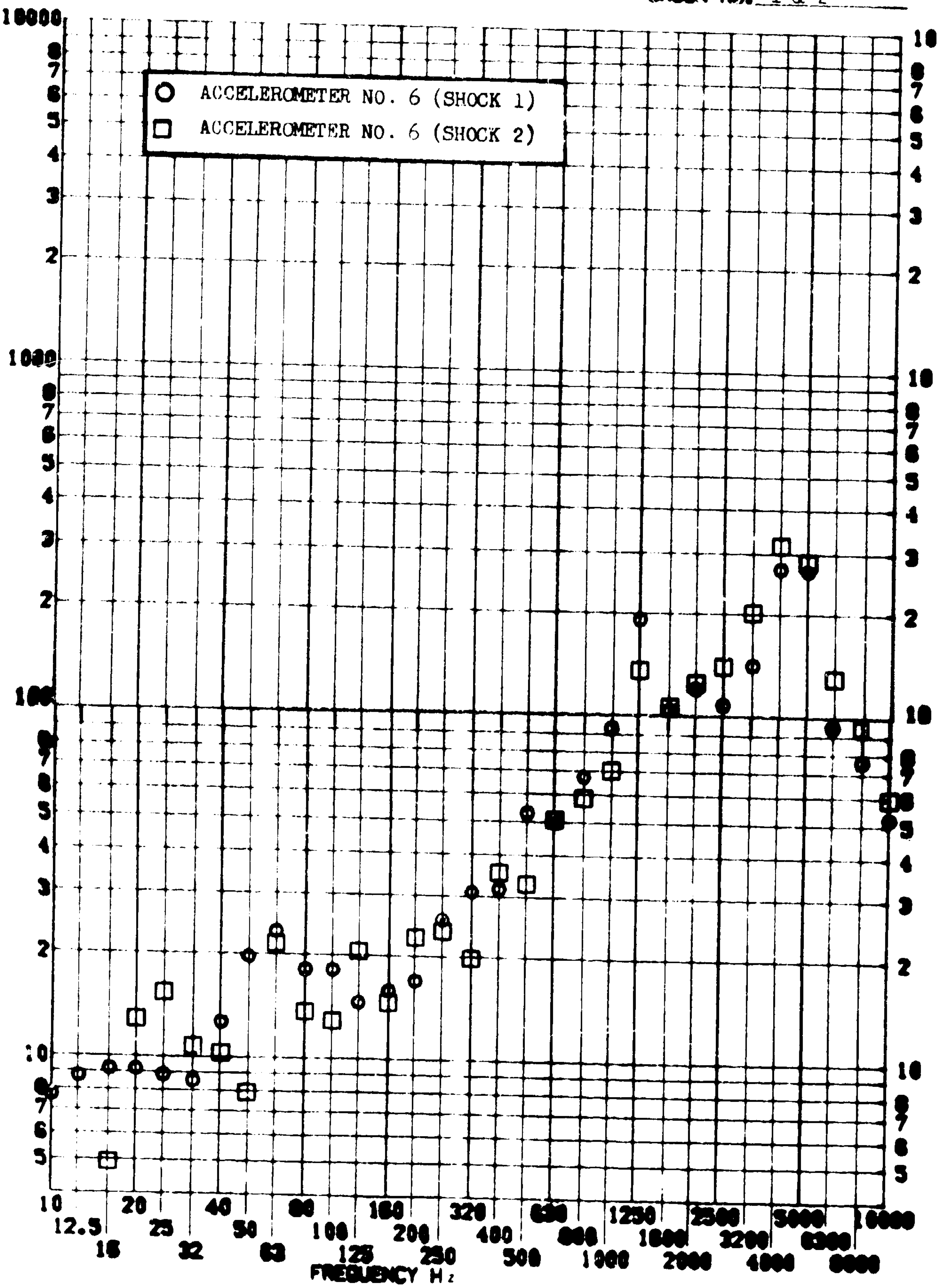
SHOCK NO. 1 & 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.1.42

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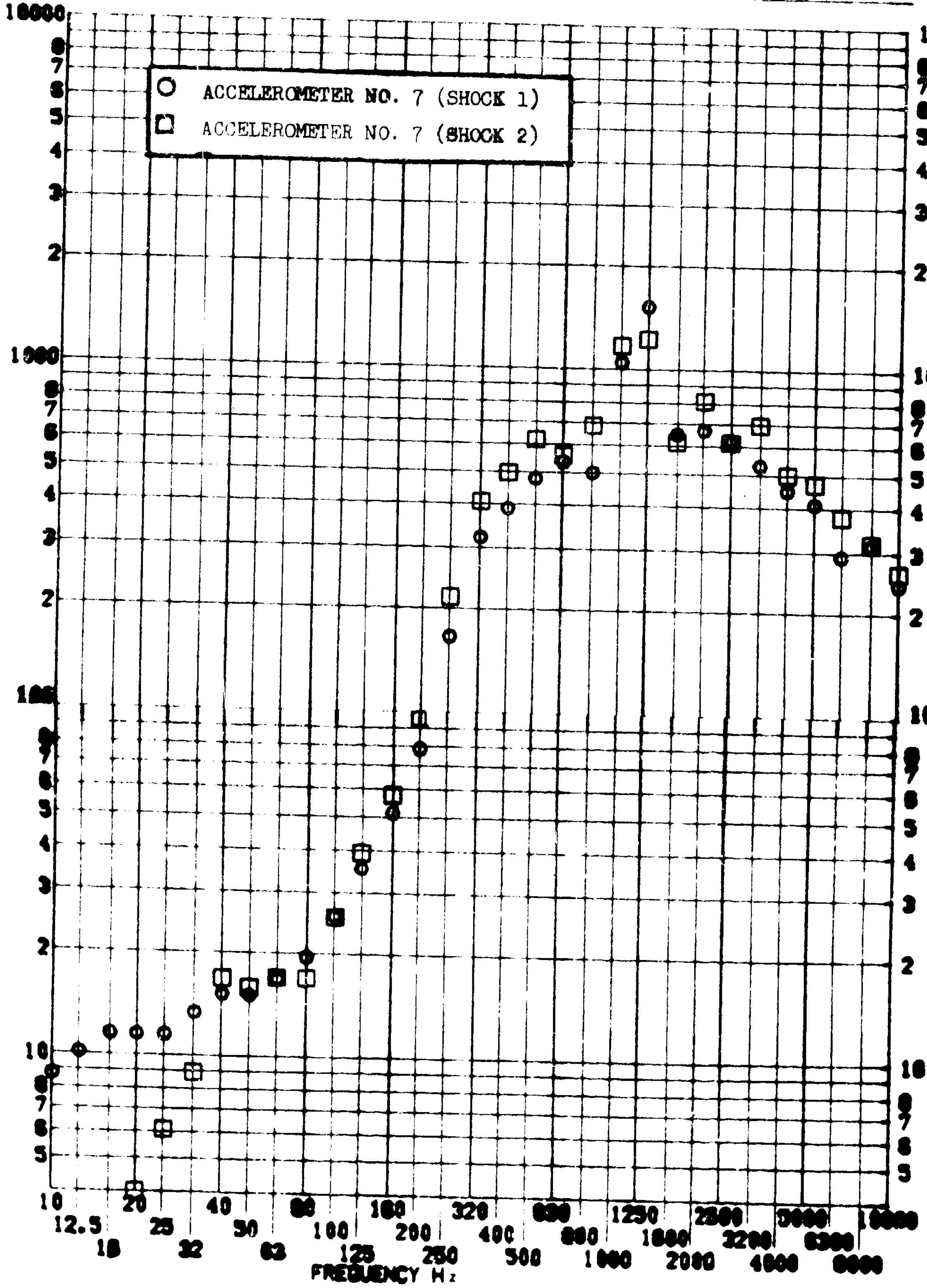
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.1.43

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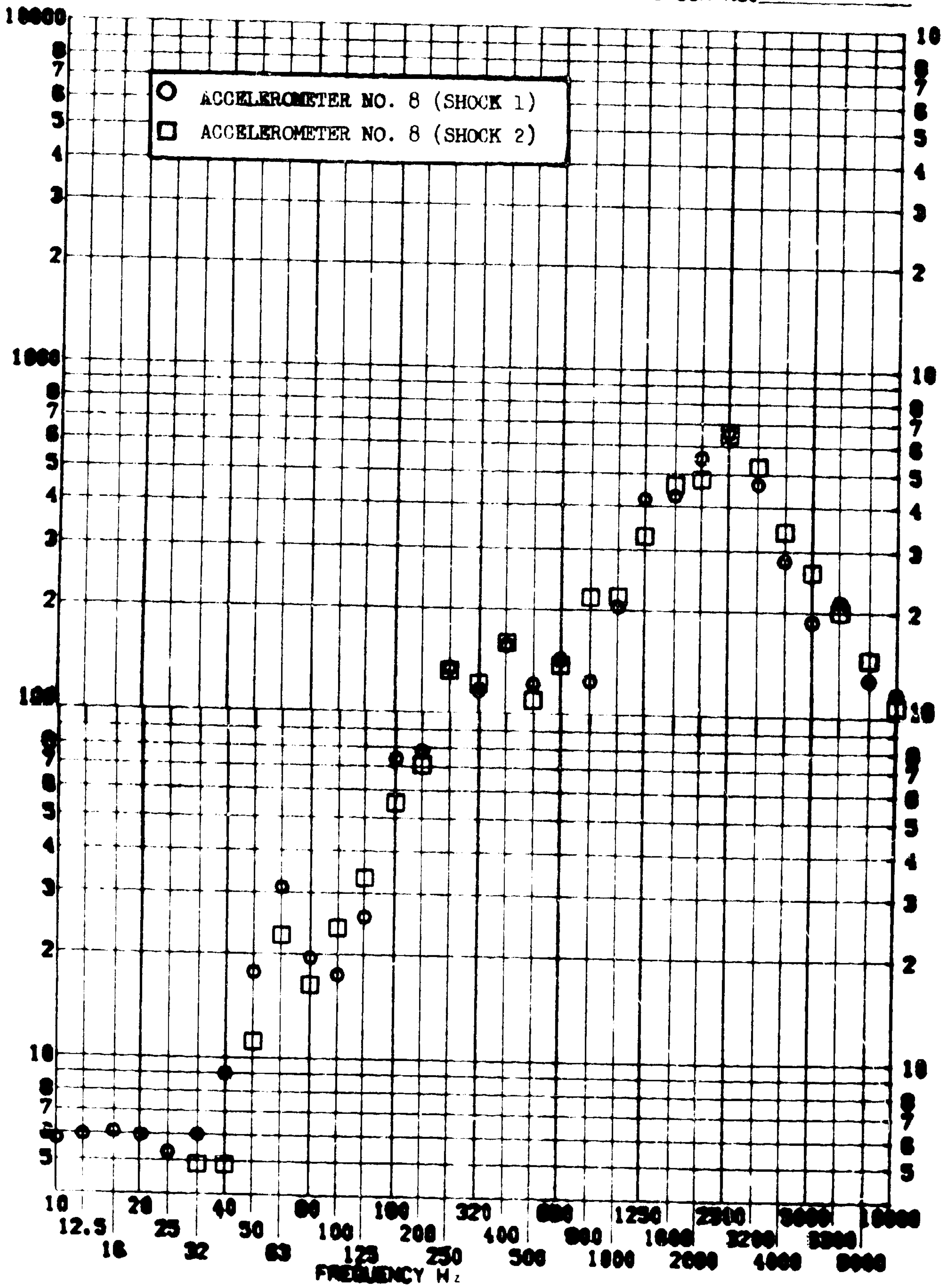
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2

SPONSE 8-8



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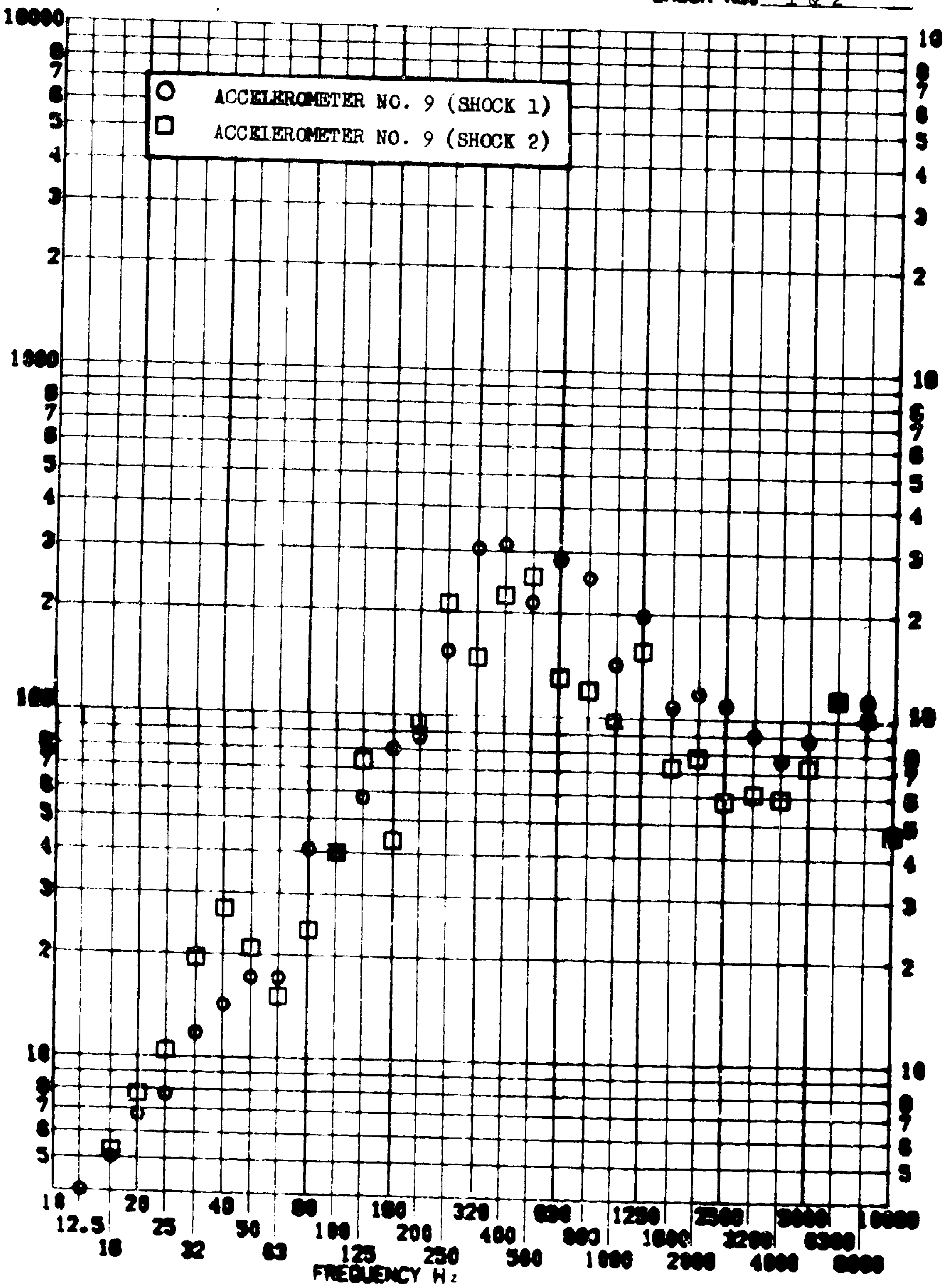
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2

RESPONSE G-S



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SPONSE 6-8

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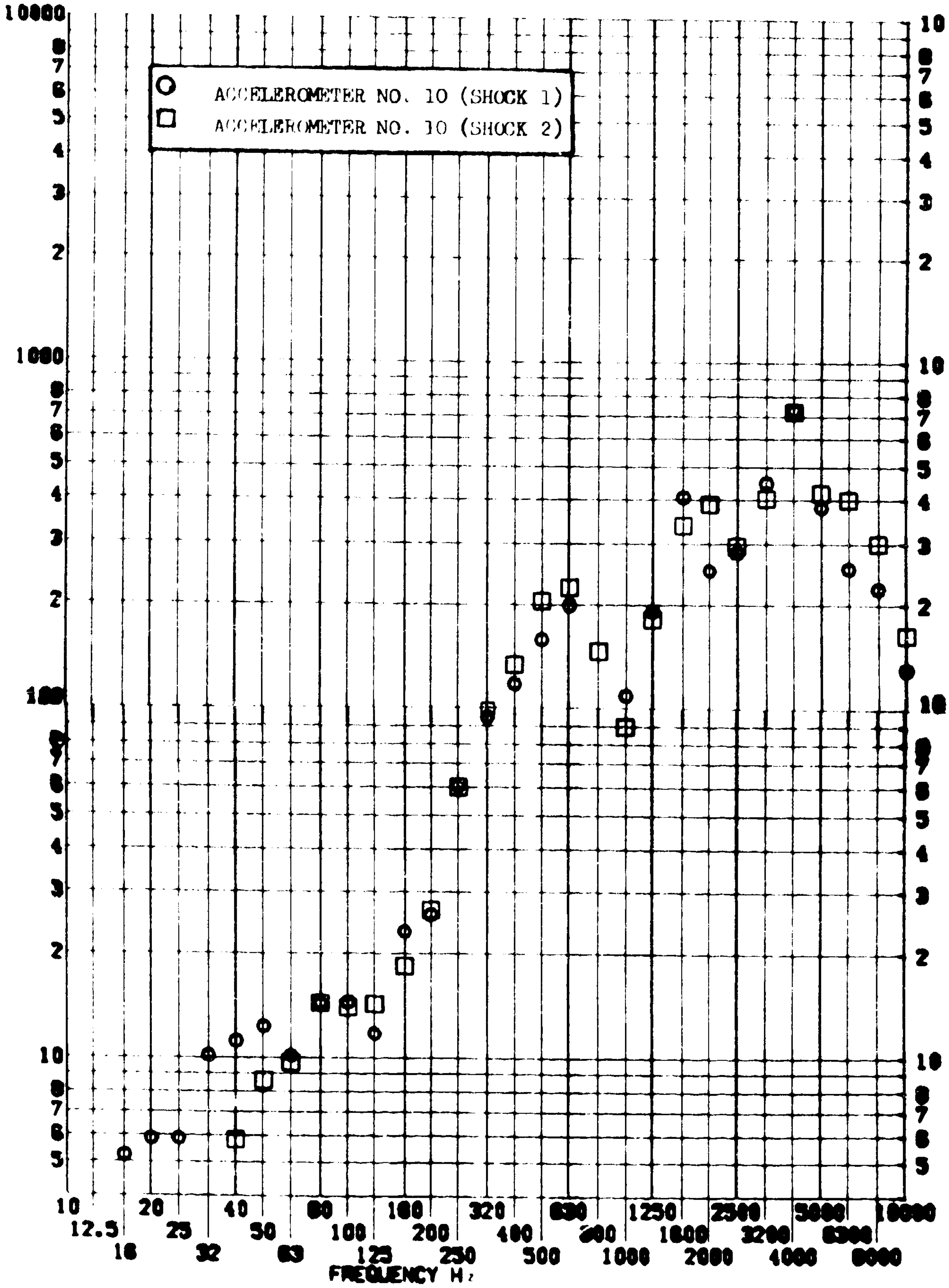
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2



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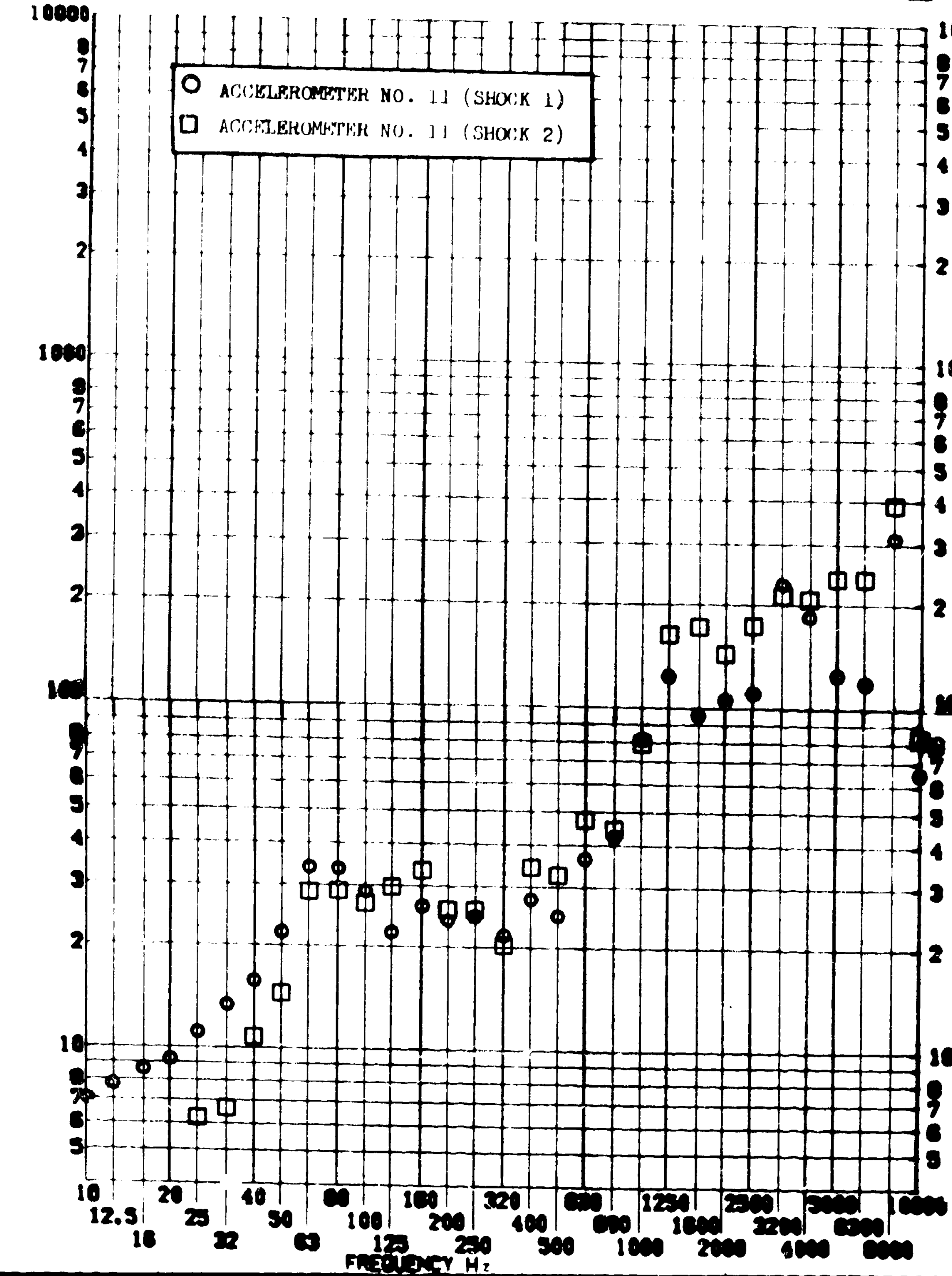
PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET T.D.1.47

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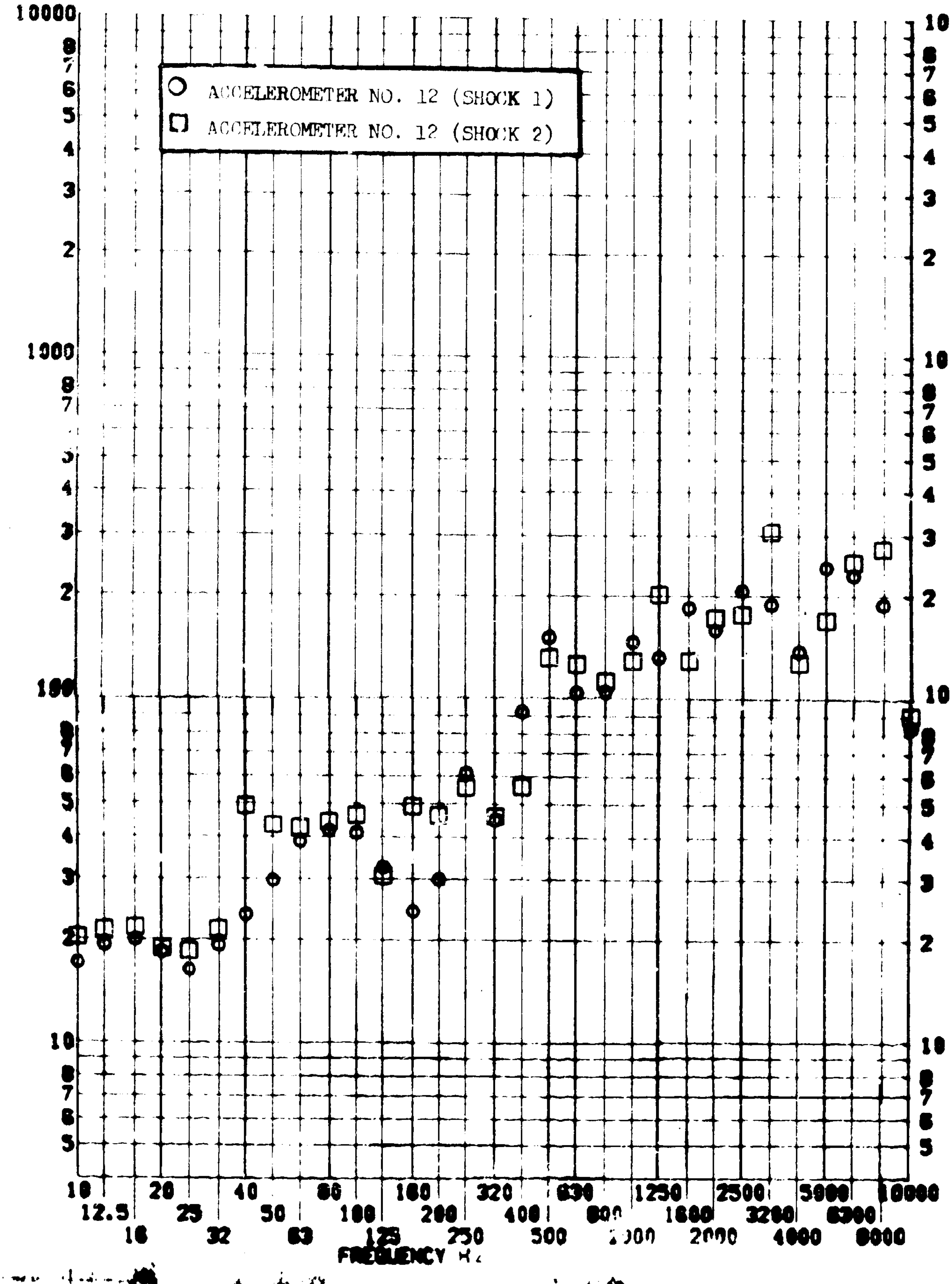
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 7 Mar 1968
SHOCK NO. 1 & 2



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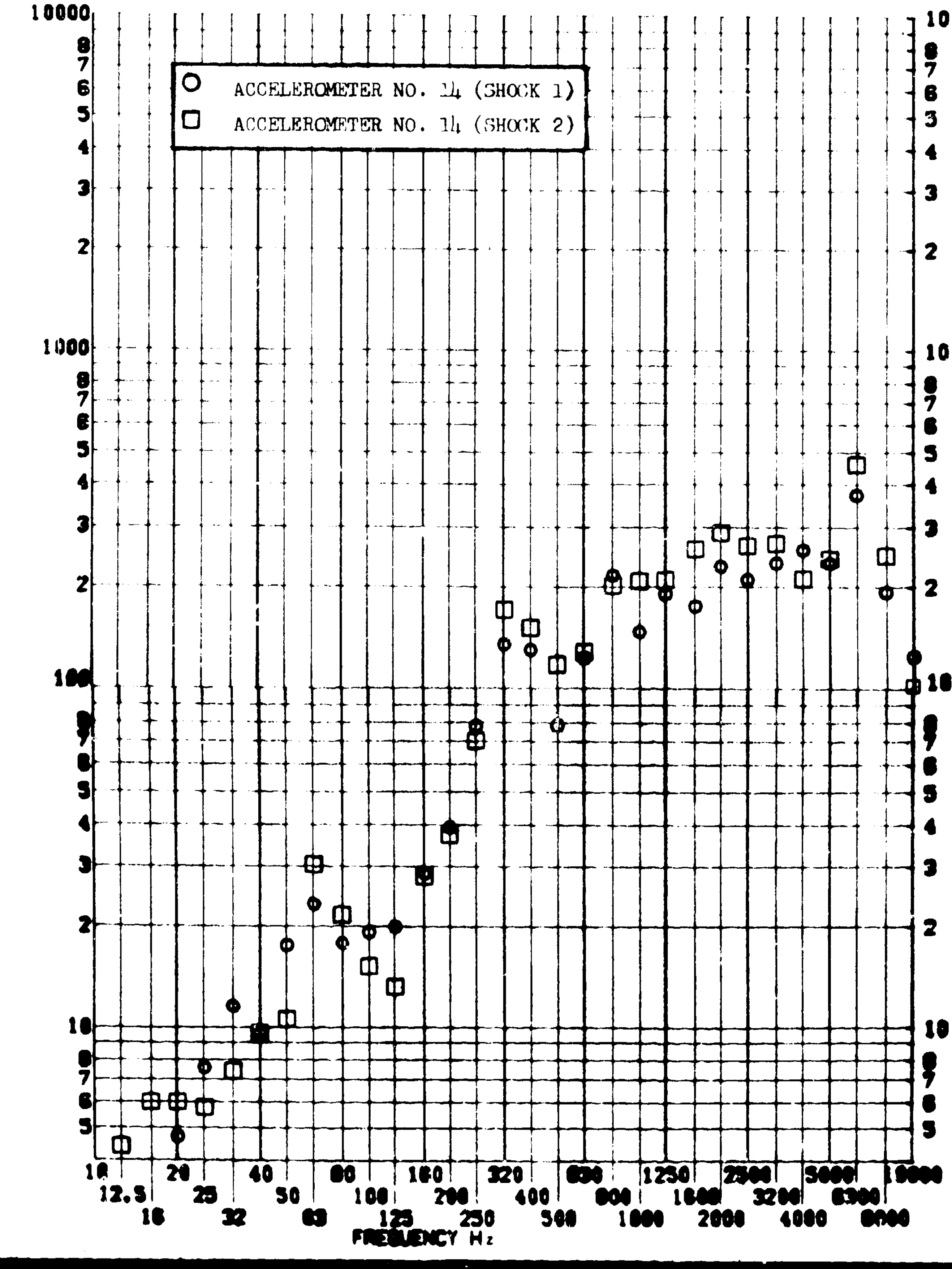
SHOCK AXIS TANGENTIAL

PART NO. STRUCTURE
TEST DATE 7 MAR 1968
SHOCK NO. 1 & 2



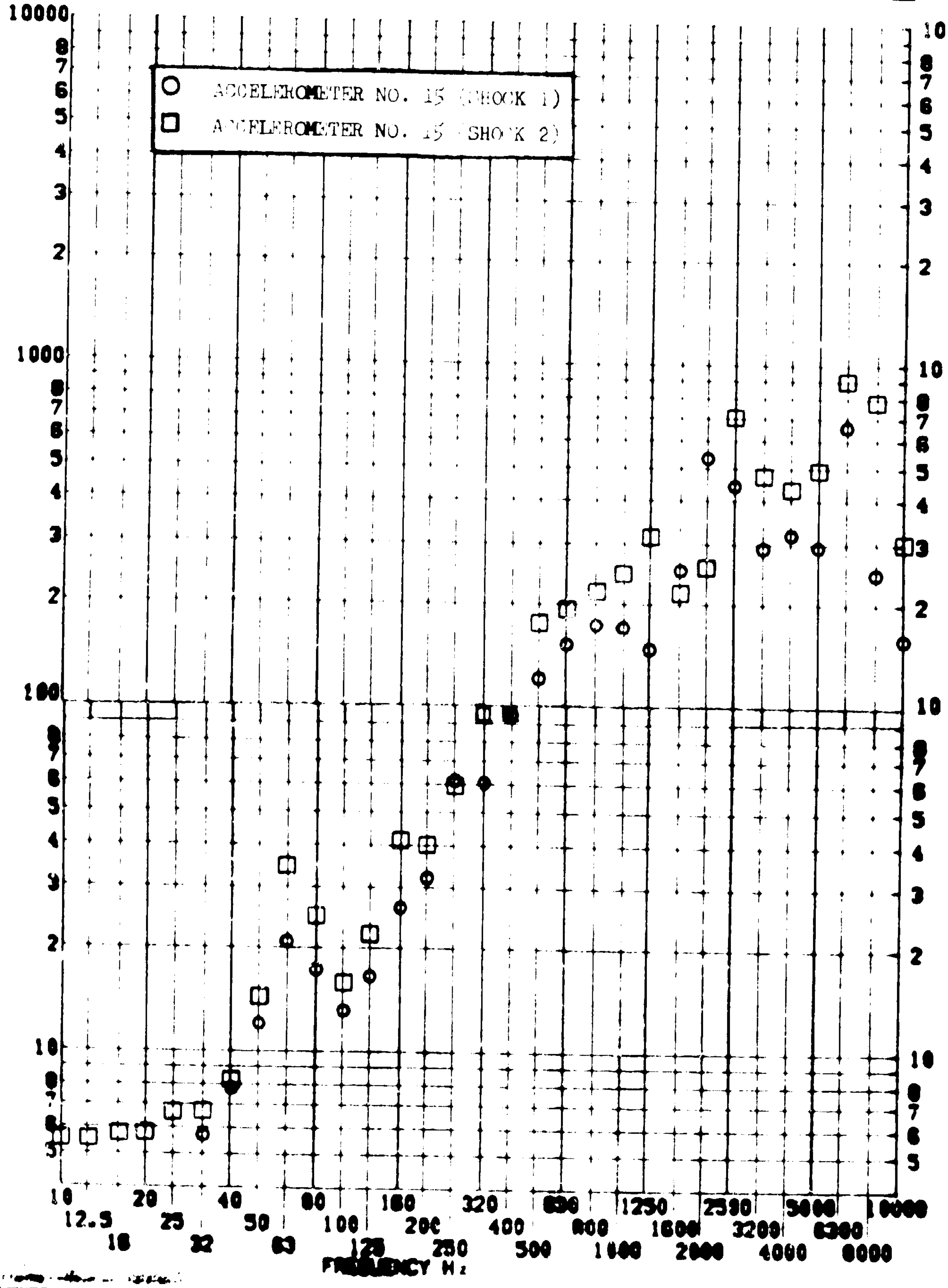
SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM 429-323,326 — II.D.1.

SERIAL NO. — PART NO. STRUCTURE

SHOCK AXIS RADIAL — TEST DATE MAR 68

SHOCK NO.

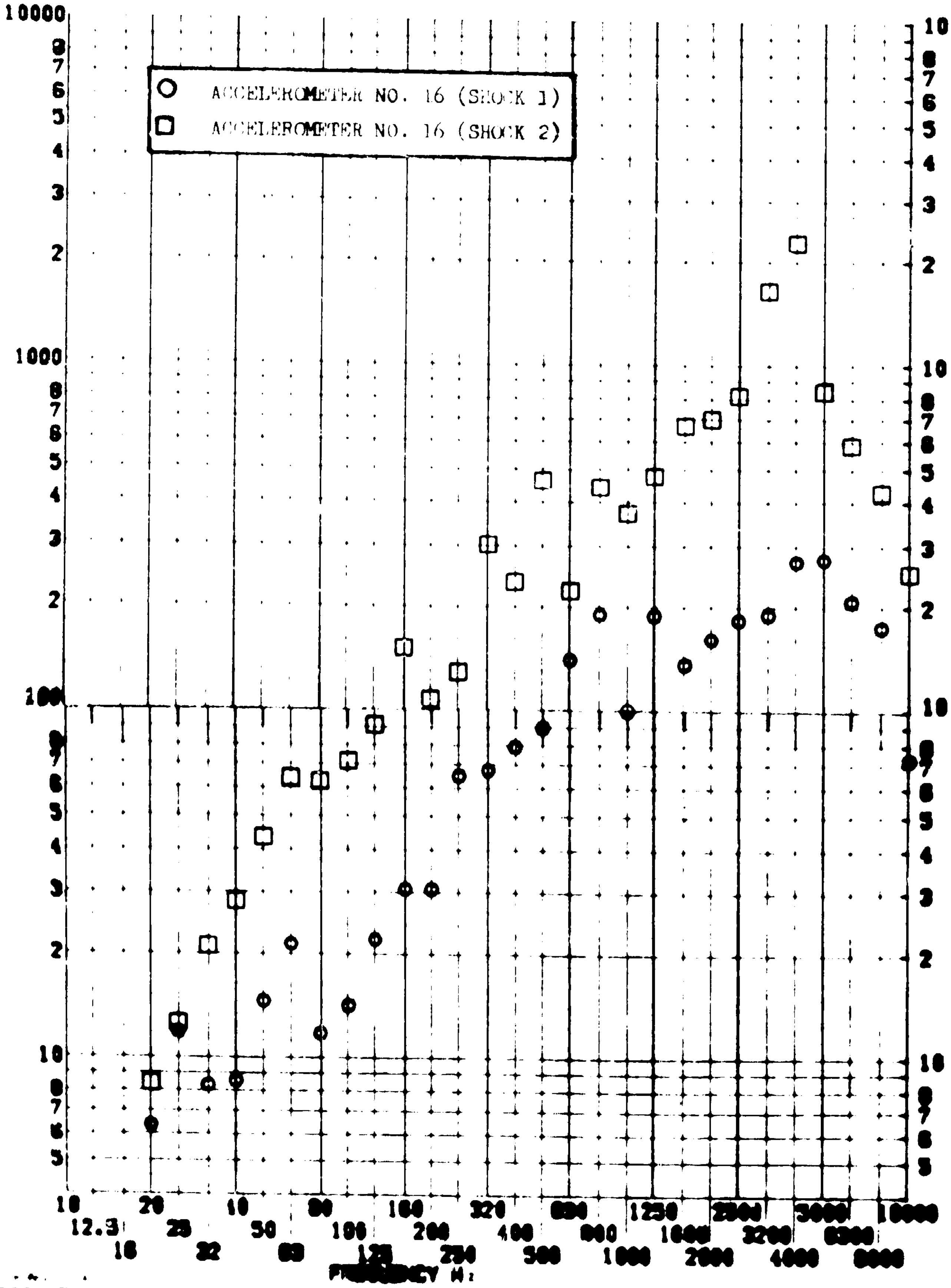


SHOCK TEST ANALYSIS DATA SHEET II.D.1.50

TEST ITEM 429-315,312
SERIAL NO. —
SHOCK AXIS RADIAL —

PART NO. STRUCTURE
TEST DATE MAR 1968
SHOCK NO. 1 & 2

RESPONSE G-S



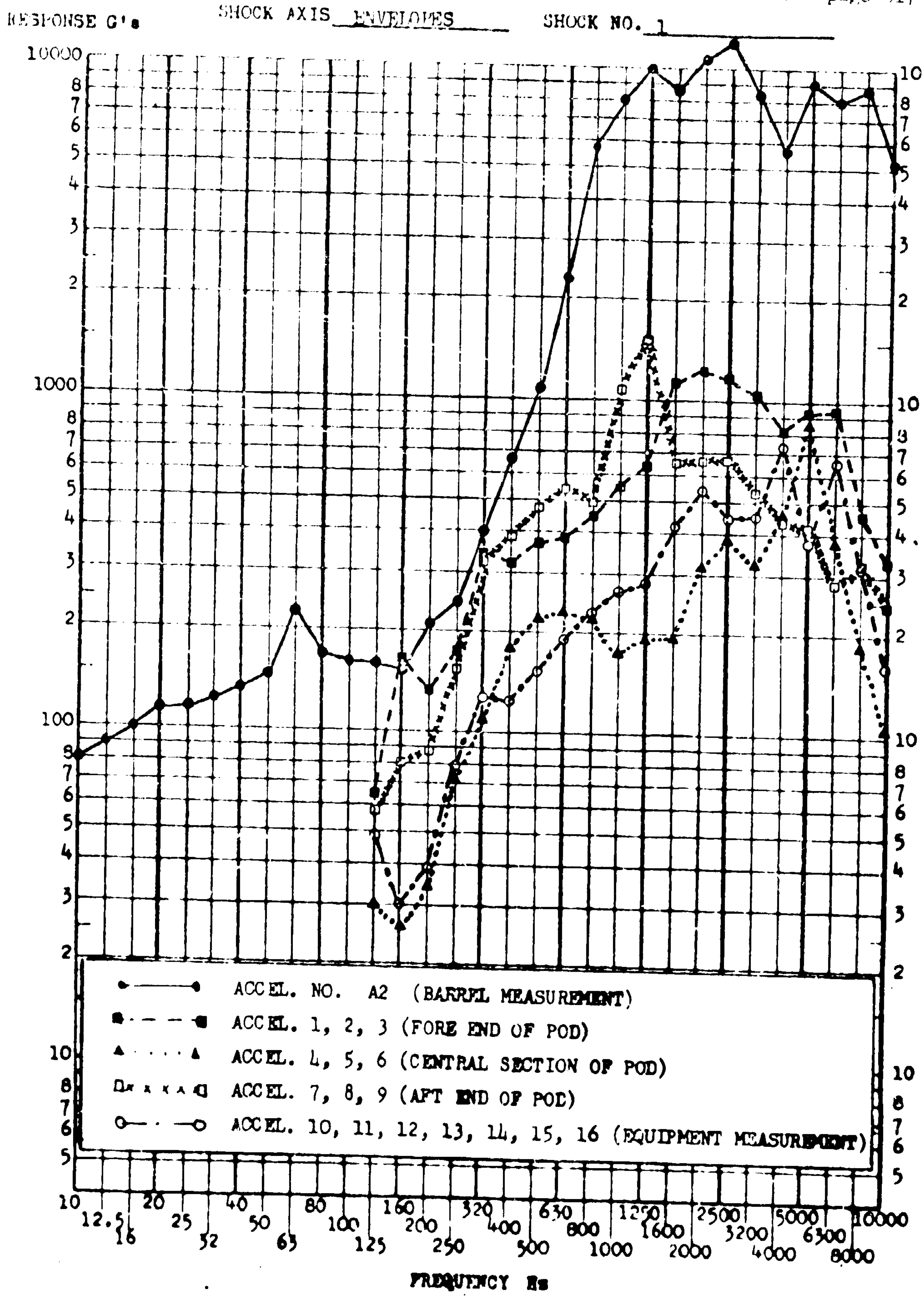


Figure II.D.1.51 COMPARISON OF BARREL MEASUREMENT A2 TO ENVELOPES OF EQUIPMENT MEASUREMENTS AND FORE, AFT AND CENTRAL STRUCTURAL MEAS. SHOCK 1

SECTION NO. II.D.2

REPORT NO. 447

SUBJECT:

QUALIFICATION OF EXTERNAL POD FOR

PYROSHOCK WITH BARREL TESTER, POD 2

SECTION II.D.2

SUMMARY

The purpose of this test was to qualify a pod for booster separation on the SCTB barrel tester. The pod contained functional equipment.

Qualification was successful. The pod and its equipment survived testing without failures.

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SECTION II.D.2

* L - Longitudinal, R - Radial, T - Tangential

LIST OF FIGURES (Cont.)

SECTION II.D.2

11.5.2.1 INTRODUCTION

When the booster adapter separates from the vehicle, high shocks are generated by the separation joint which transmit through the structure. These pyro-generated shocks can cause equipment and structural failures. It is thus necessary to subject vehicle equipment, or modules containing equipment (such as the pods), to shock levels above those which they would encounter in flight to establish their qualification.

II.D.2.2 DISCUSSION AND ANALYSIS

II.D.2.2.1 Test Configuration and Instrumentation

The barrel structure on which the pod was mounted is shown in Figures II.D.2.2 and II.D.2.3. The structure was made up of two five foot long, five foot diameter barrels which are normally used separately for performing pyroshock qualification tests at SCTB. For this test they were mated together and hung by bungee cords from one of the test stands. The barrels were modified to accept the pod in the same manner as it is fitted on a flight vehicle. The pod attaches by means of a sliding joint on the end near the booster separation joint and is fastened solidly at the opposite end of the pod as indicated in Figure II.D.2.2 The separation joint consisted of a 30 grain per foot primacord and a 0.190 inch magnesium thorium separation skin segment.

Seven accelerometers were located in the pod as indicated in Figure II.D.2.3 These locations are detailed in Figure II.D.2.4. A summary of the accelerometers, including distance from the shock source and the accelerometer type,is presented in Table II.D.2.1 . Accelerometers 1 and 2 were located on structure near the pod interface while the rest of the accelerometers were located at pod equipment interfaces.

II.D.2.2.2 Test Results and Analysis

Two shocks are required to qualify equipment for pyroshock. Shock spectra of the shock from the seven accelerometers are presented in Figures II.D.2.6 to II.D.2.19 for shocks 1 and 2. Shock spectra from shocks 1 and 2 are compared in Figures II.D.2.20 to II.D.2.26 for each accelerometer location to show the repeatability of the two shocks. Figure II.D.2.27 compares the shock spectrum levels from the two structure measurements (1 and 2) and the five equipment measurements to the barrel reference measurement. The reference measurement was used to confirm that the shock levels were sufficiently high to produce the overtest as required. The shock transmission path is through both the slip joint and the structure on which the pod is mounted.

The envelope of the equipment shock spectra are a maximum equipment environment and can be used as a basis for qualifying future pod equipment.

II.D.2.3 CONCLUSIONS

Testing was completed successfully. The pod was subjected to qualification shock levels. No structural or equipment failures were noted.

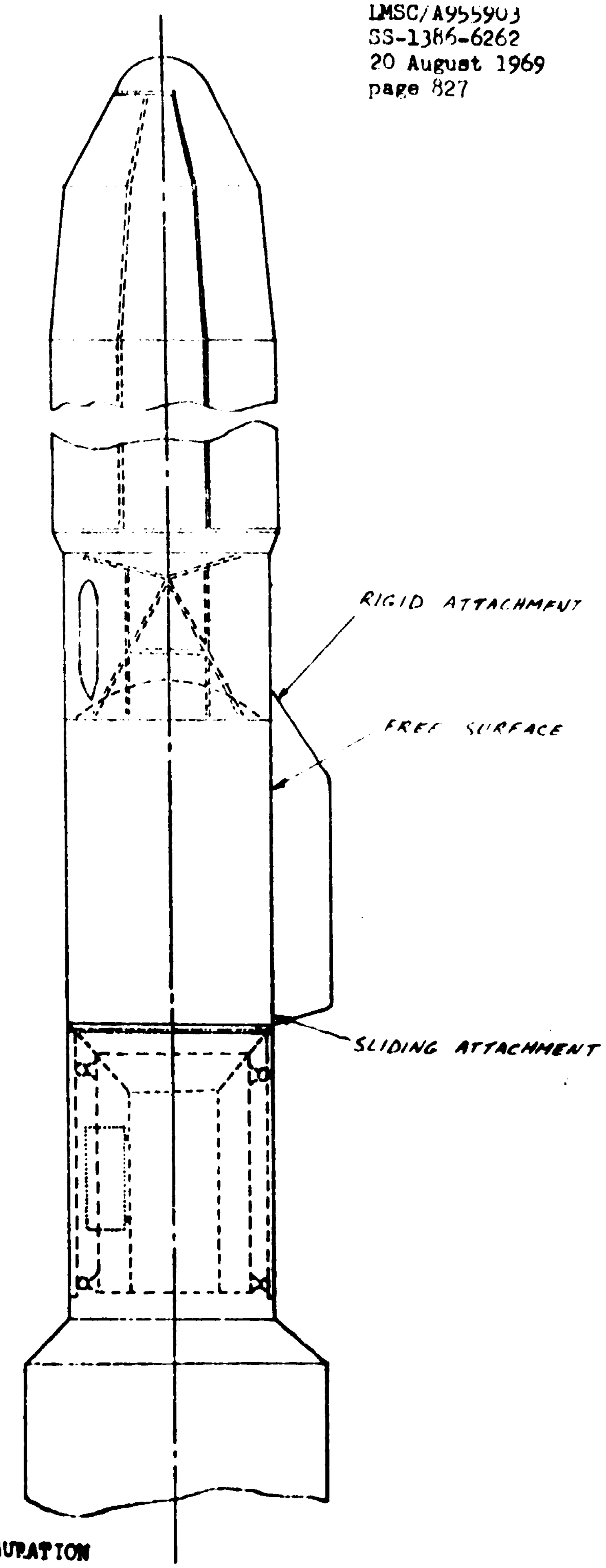
TABLE II.D.2.1

ACCELEROMETER INFORMATION AND LOCATIONS

ACCELEROMETER NO.	STATION	DIRECTION	DISTANCE TO SHOCK SOURCE (Inches)	ACCELEROMETER TYPE
1	384	L	9.9	ENDEVCO 2225
2	384	R	9.0	ENDEVCO 2225
3	383	T	10.0	ENDEVCO 2225
4	367	R	26.0	ENDEVCO 2225
5	355	R	38.0	ENDEVCO 2225
6	352	R	41.0	ENDEVCO 2225
7	345	R	48.0	ENDEVCO 2225

* Accelerometers 1 and 2 structure mountings, all other at equipment.

L - Longitudinal R - Radial T - Tangential



4 Figure II.D.2.1 FLIGHT CONFIGURATION

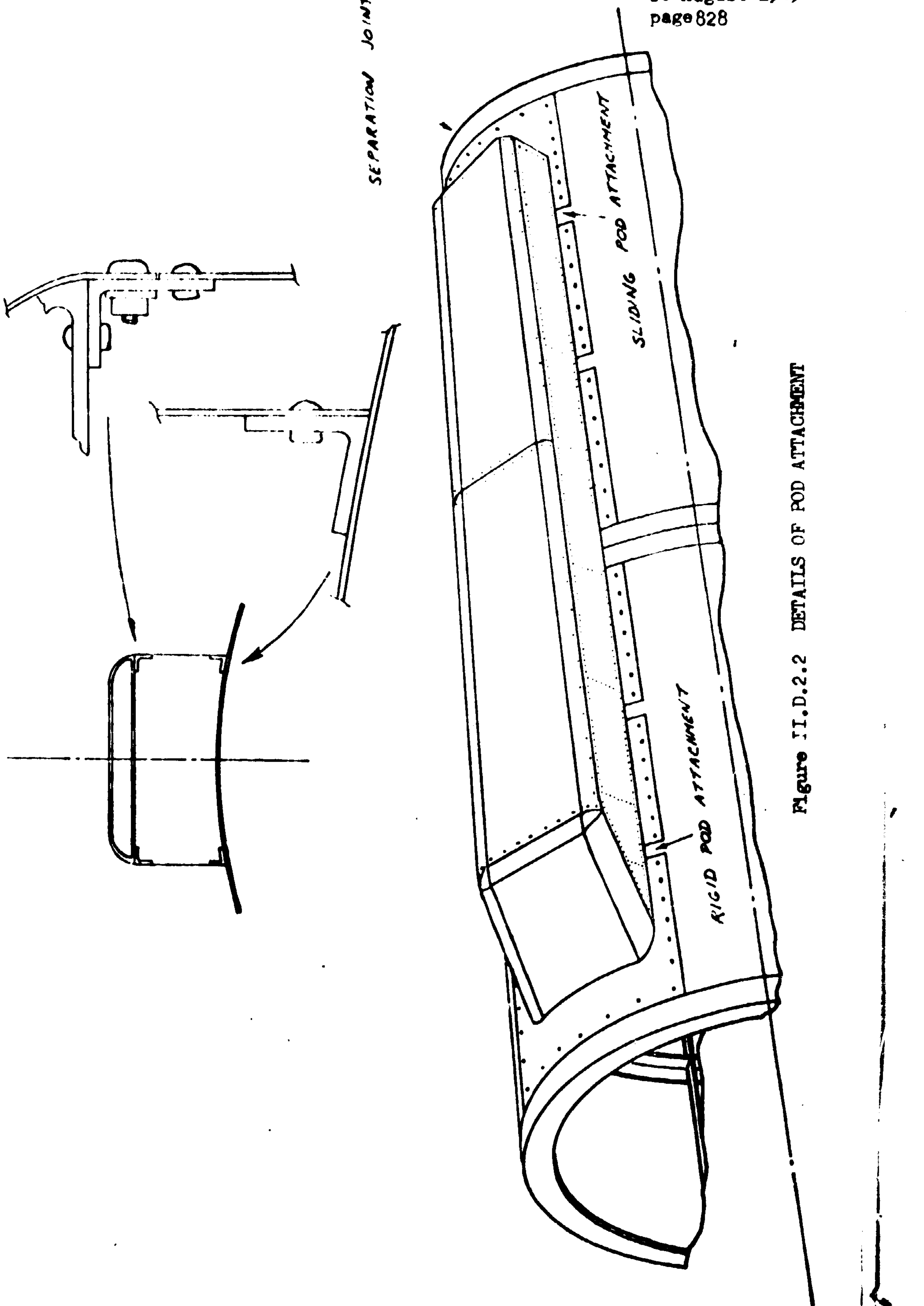


Figure II.D.2.2 DETAILS OF POD ATTACHMENT

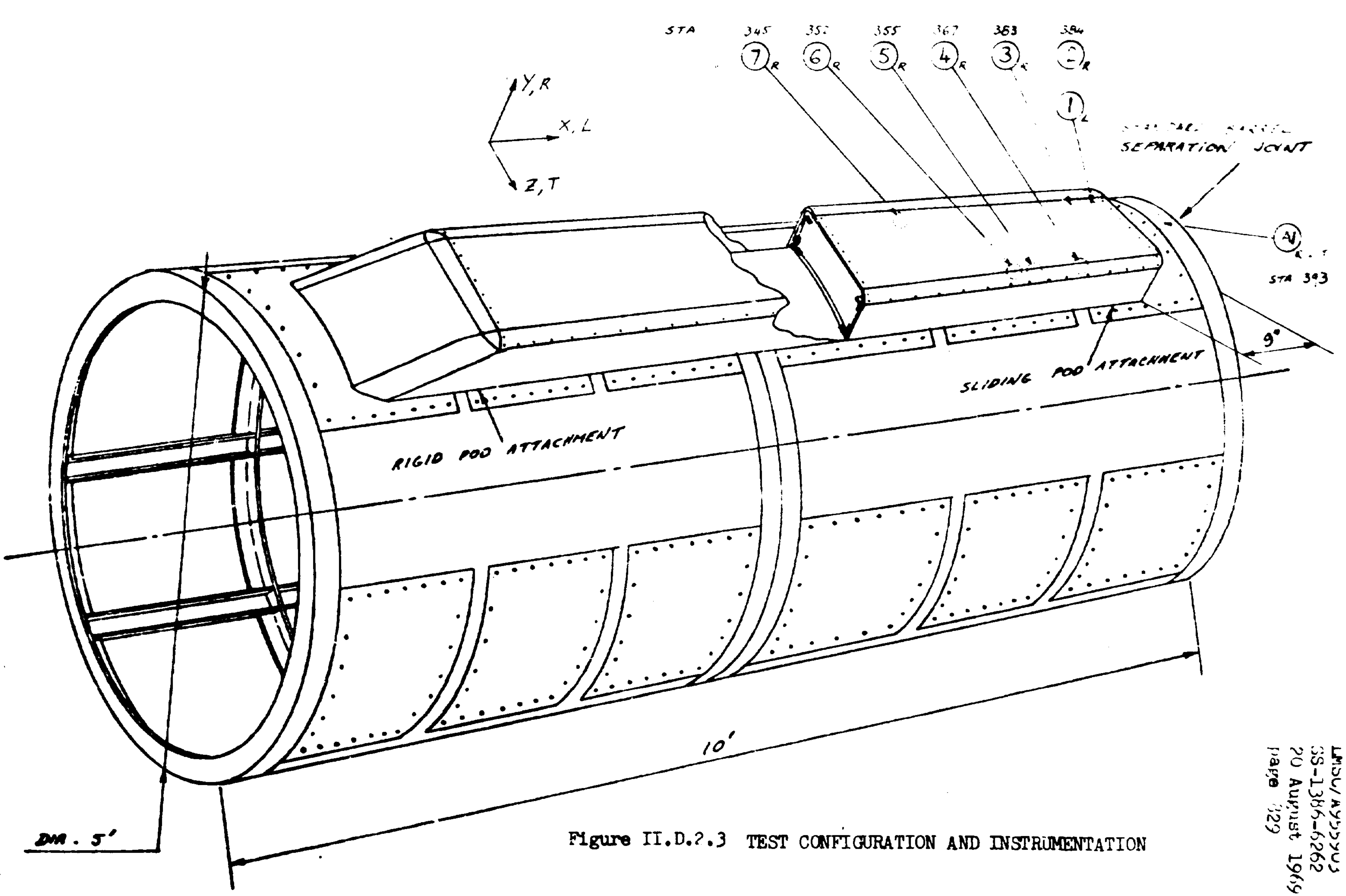


Figure II.D.2.3 TEST CONFIGURATION AND INSTRUMENTATION

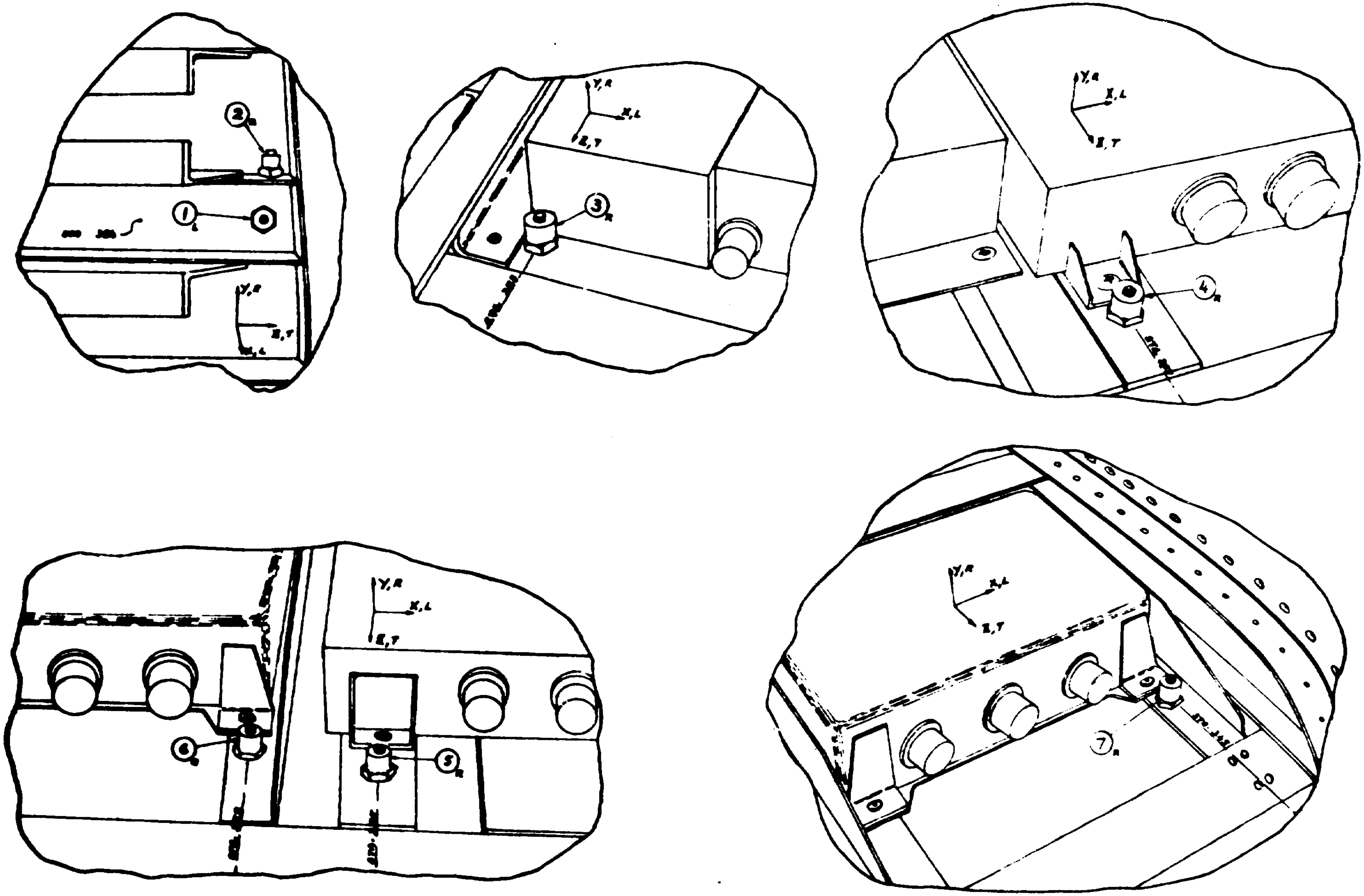


Figure II.D.2.4 DETAILS INSTRUMENTATION LOCATIONS

SHOCK TEST ANALYSIS DATA SHEET II.D.2.5

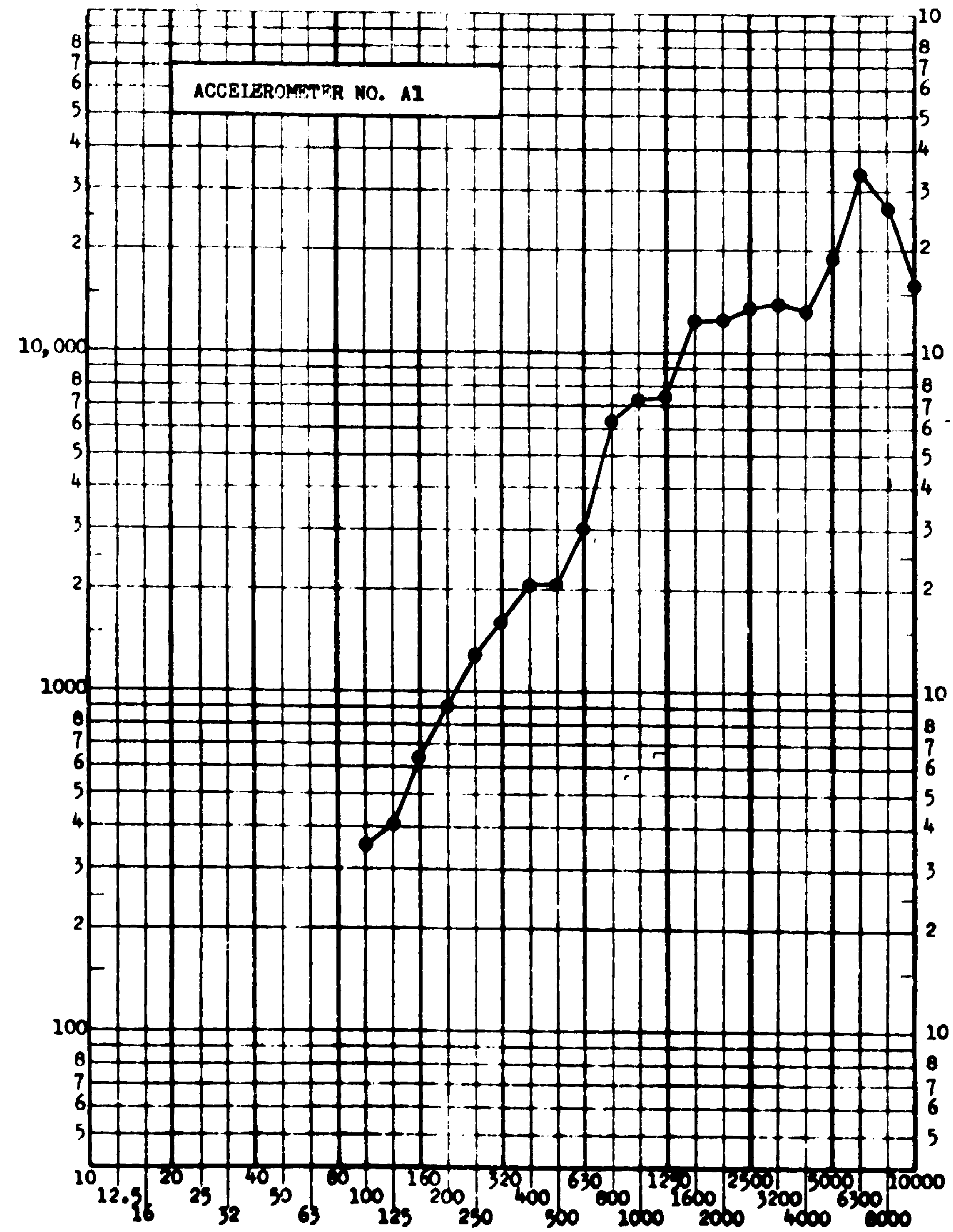
TEST ITEM 447 PART NO. STUCTURE

SERIAL NO. ______ TEST DATE 12 OCT 1967

SHOCK AXIS L, R, T SHOCK NO. 1

COMPOSITE

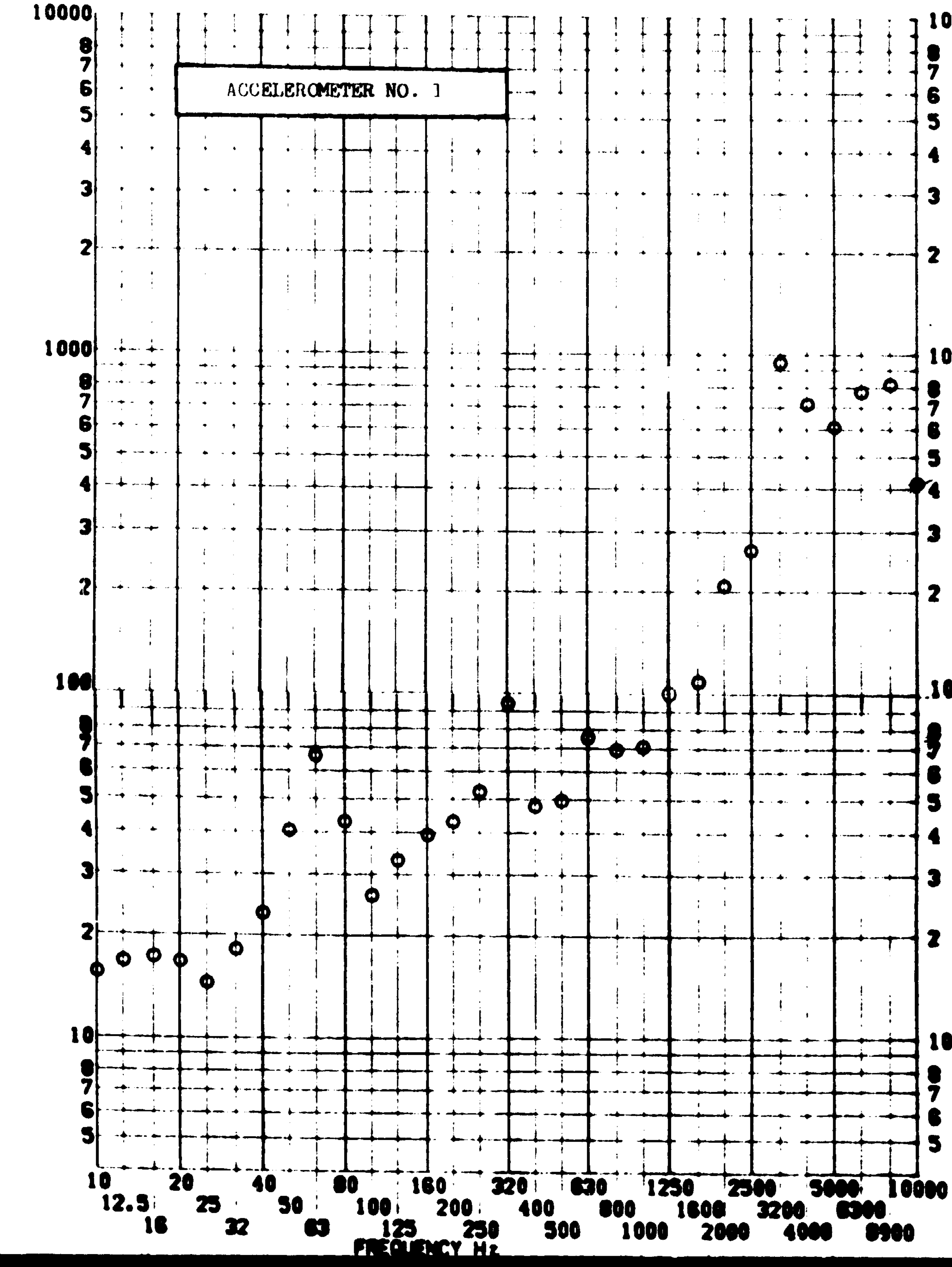
RESPONSE G's



SHOCK TEST ANALYSIS DATA SHEET II.D.2.6

TEST ITEM 447-116
SERIAL NO.
SHOCK AXIS LONGITUDINAL

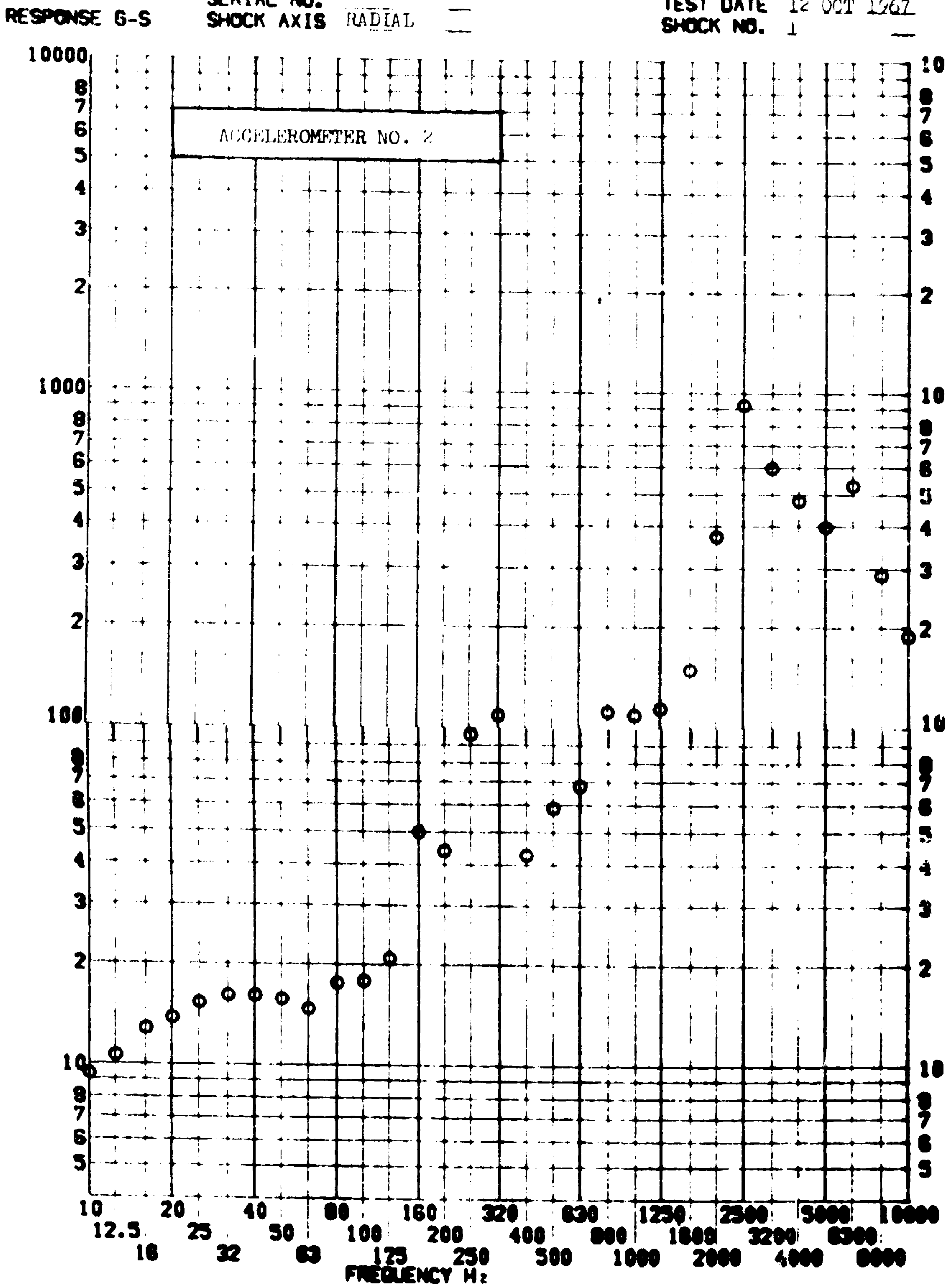
PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.D.2.7

TEST ITEM 447-117
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1

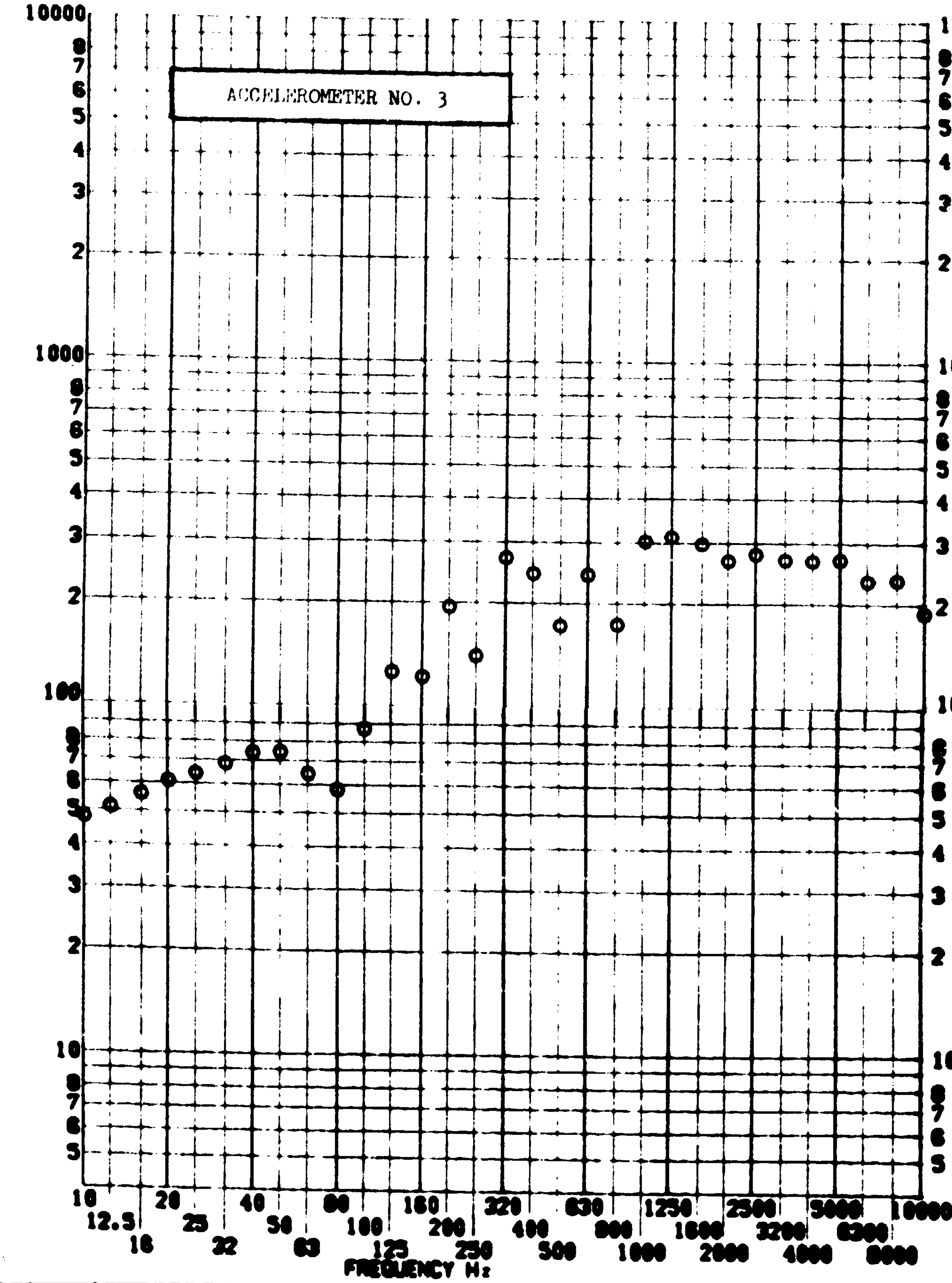


SHOCK TEST ANALYSIS DATA SHEET II.D.2.8

TEST ITEM 447-118
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1

RESPONSE G-S

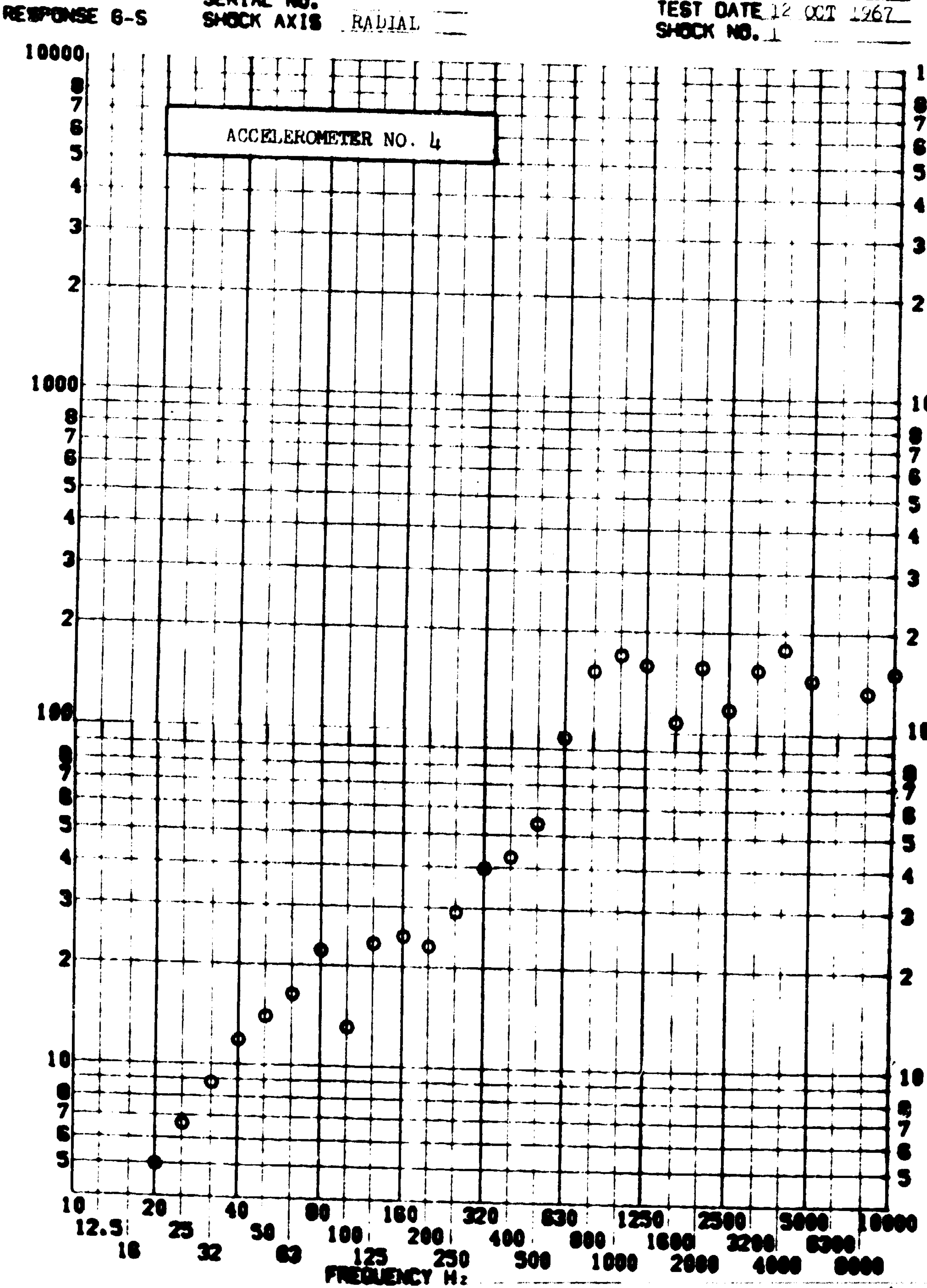


SHOCK TEST ANALYSIS DATA SHEET

II.D.2.9

TEST ITEM 447-119
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1

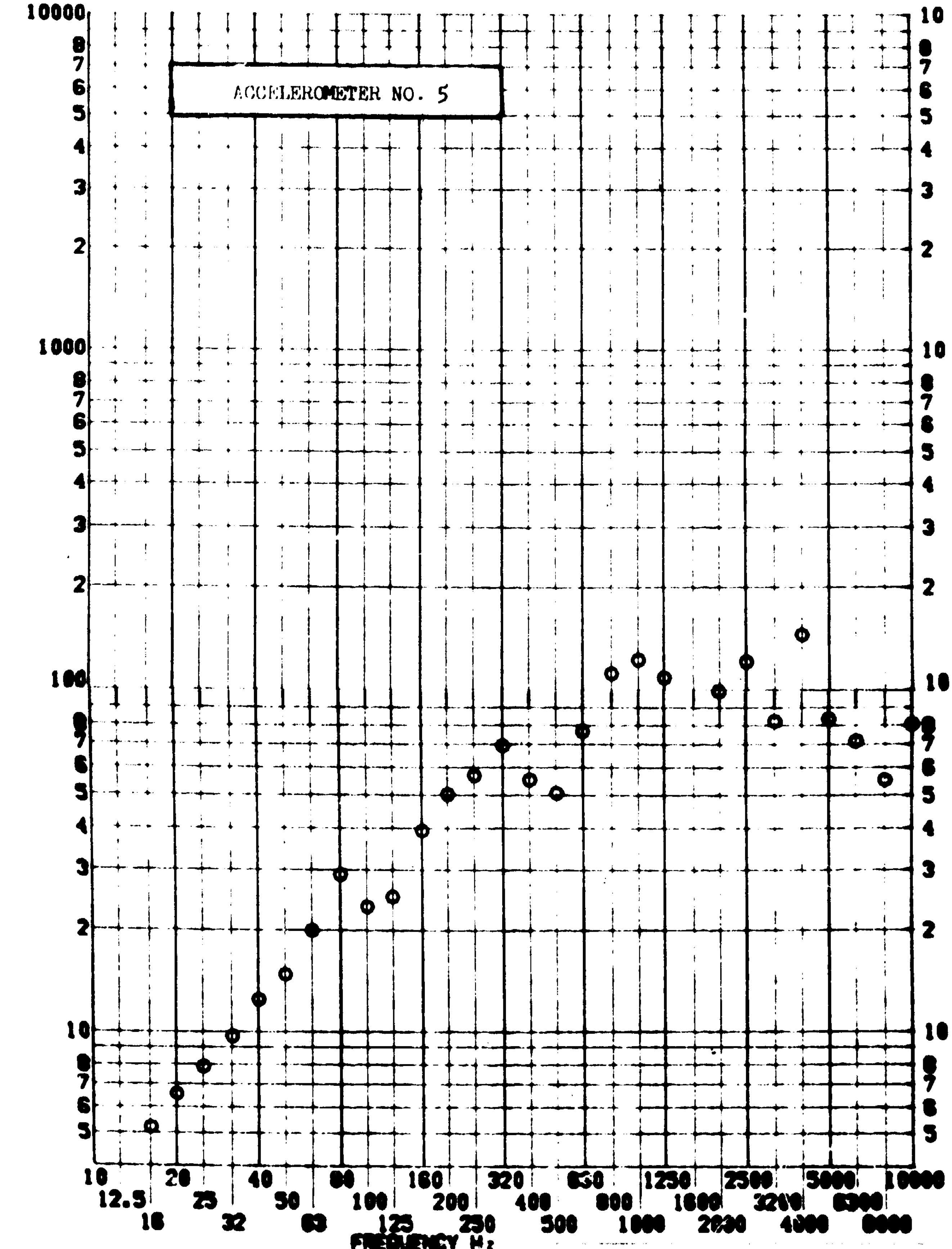


SHOCK TEST ANALYSIS DATA SHEET II.D.2.10

TEST ITEM ML7-120
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET

II.D.2.11

TEST ITEM 447-12

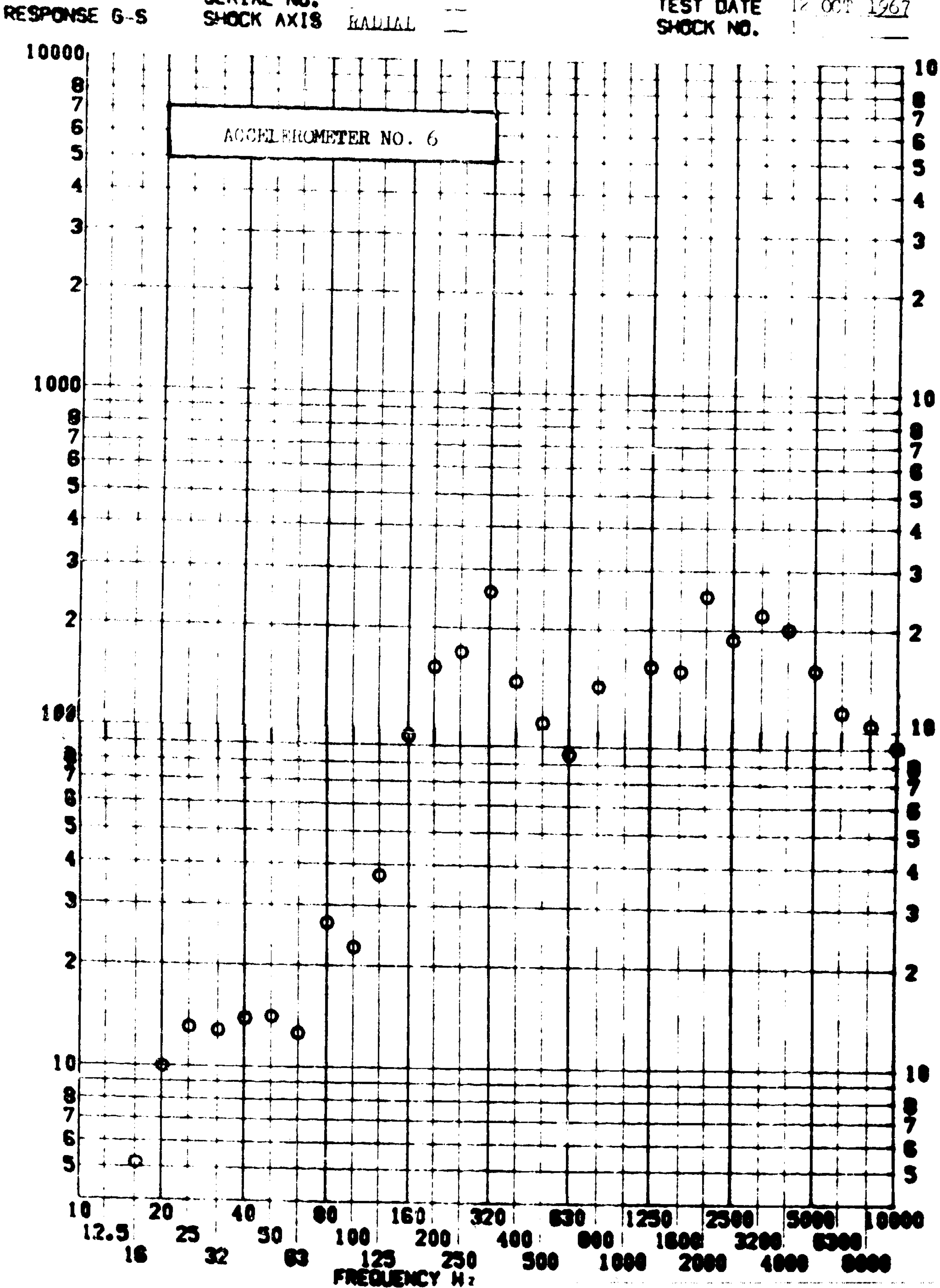
SERIAL NO.

SHOCK AXIS RADIAL

PART NO. STRUCTURE

TEST DATE 12 OCT 1967

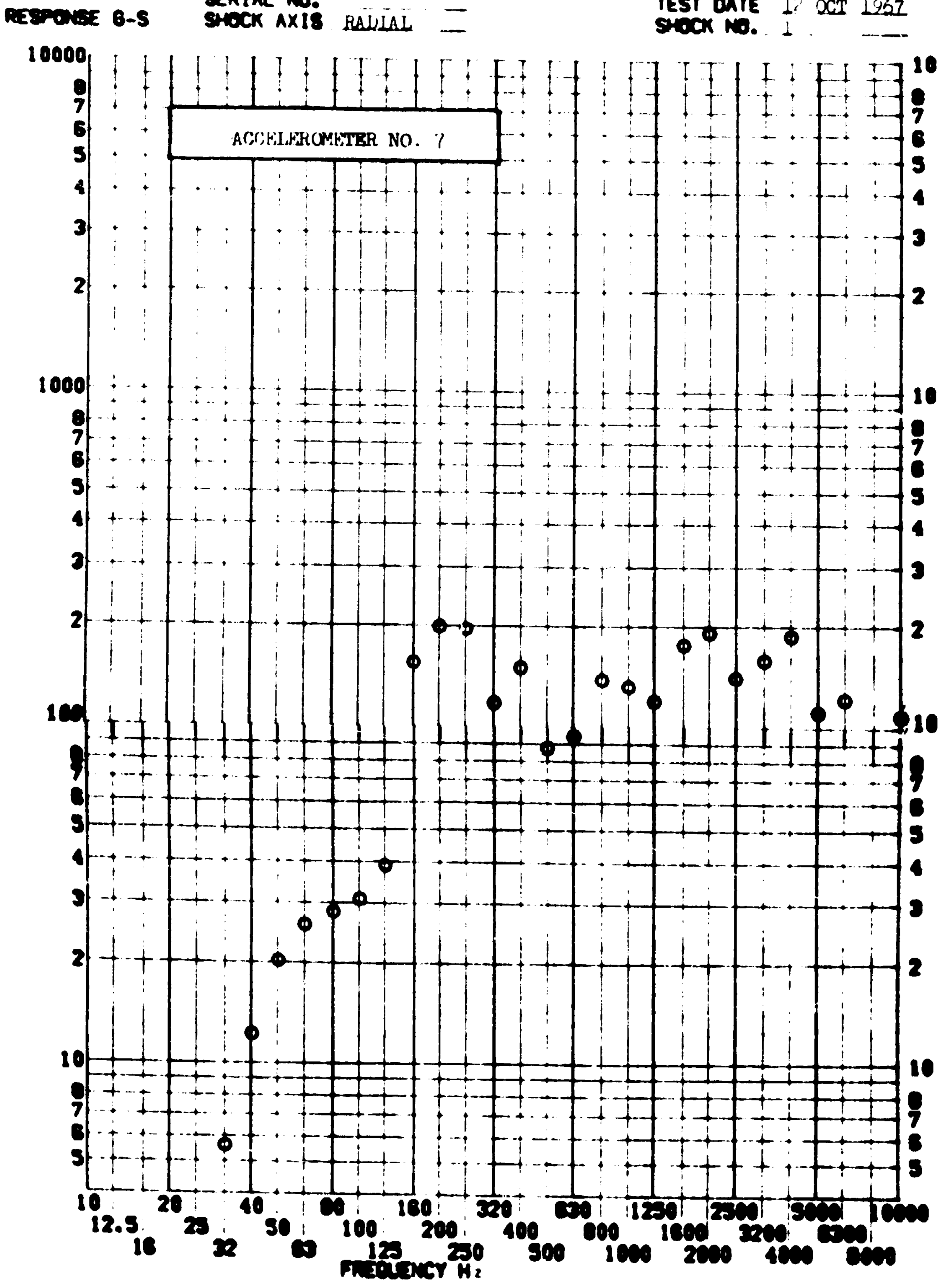
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.D.2.12

TEST ITEM 447-122
SERIAL NO.
SHOCK AXIS RADIAL

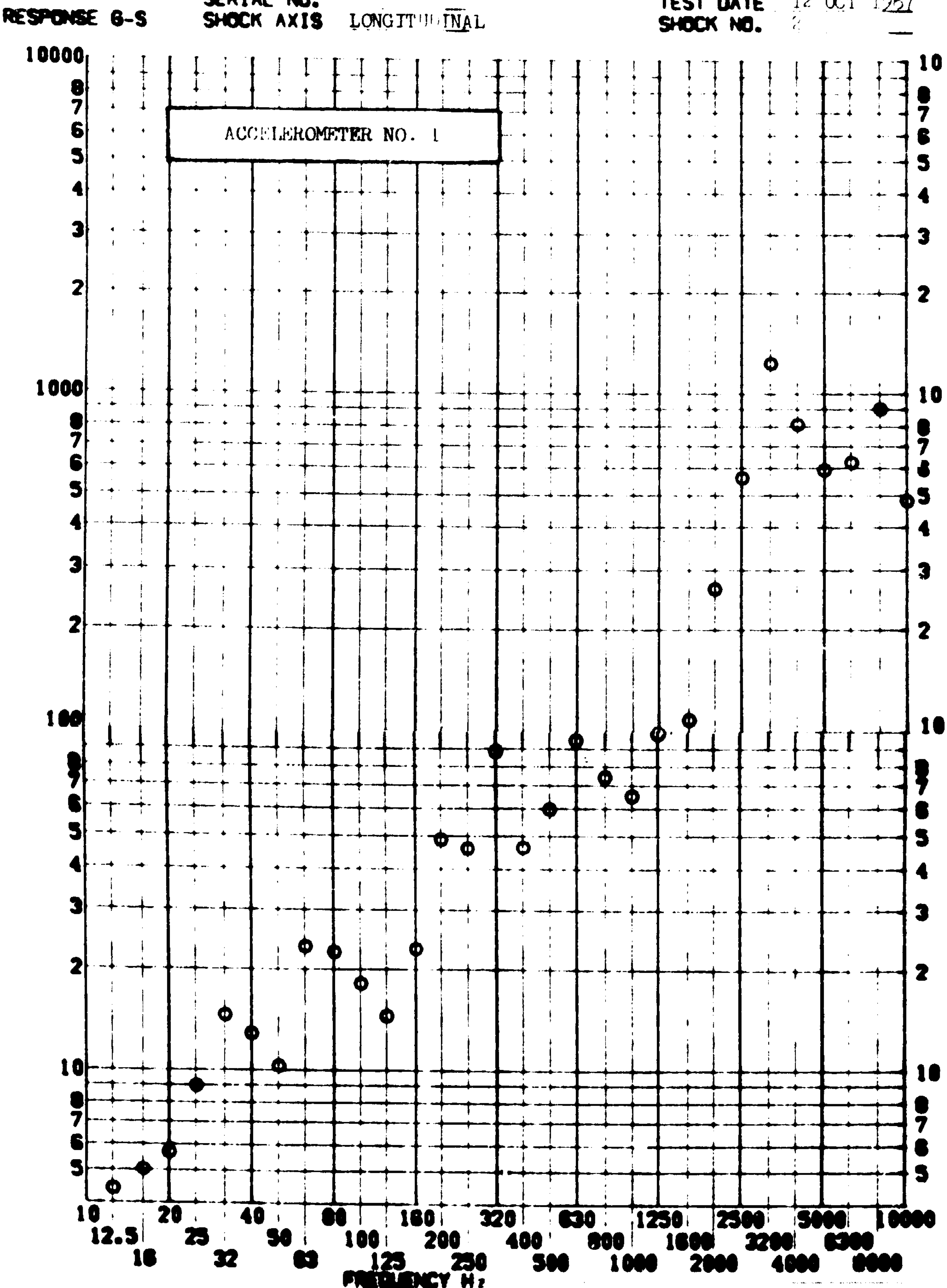
PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.D.2.13

TEST ITEM 447-12[illegible]
SERIAL NO.
SHOCK AXIS LONGIT[illegible]INAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 2

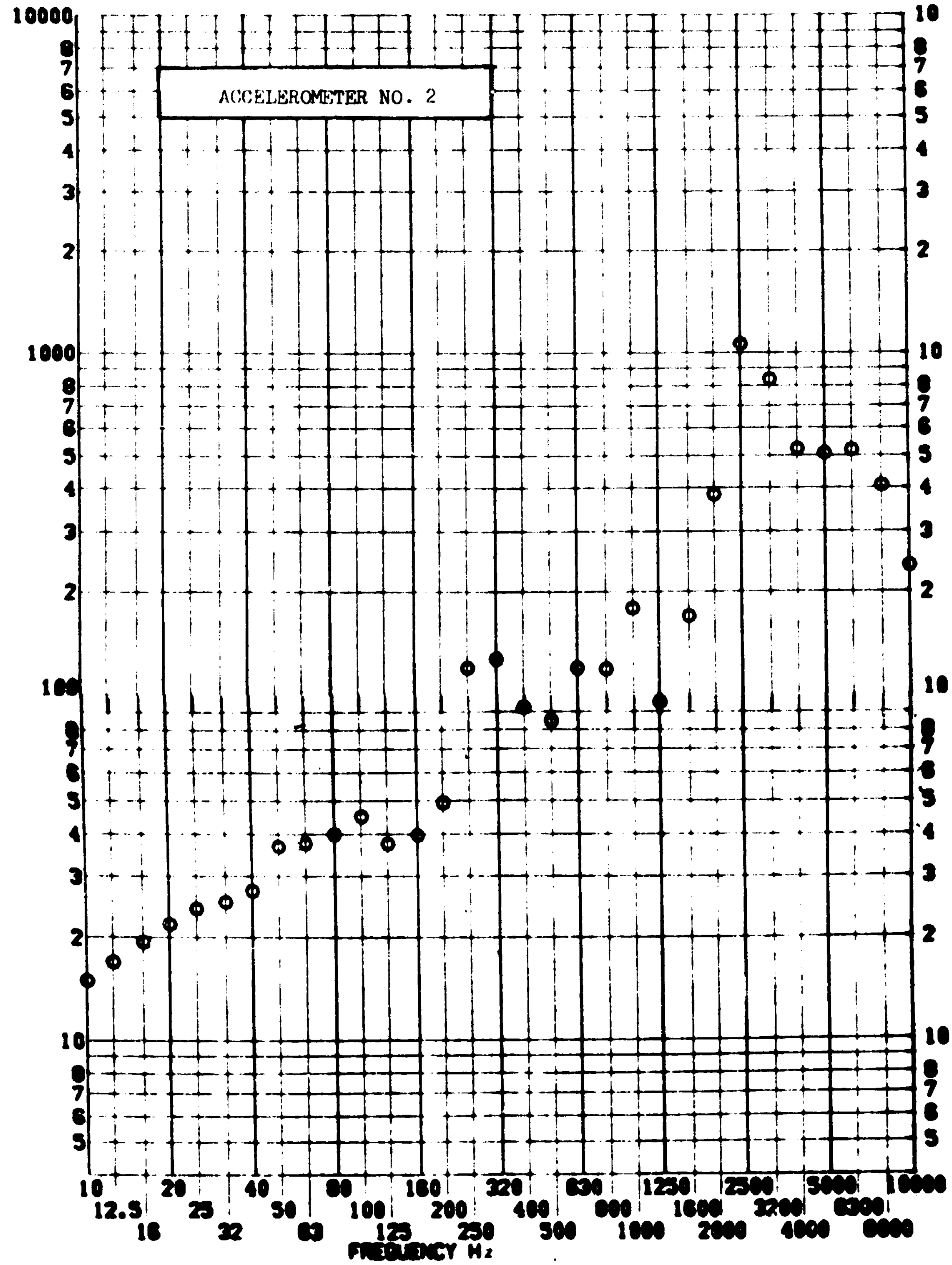


SHOCK TEST ANALYSIS DATA SHEET II.D.2.14

TEST ITEM 447-124
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET

II.D.2.15

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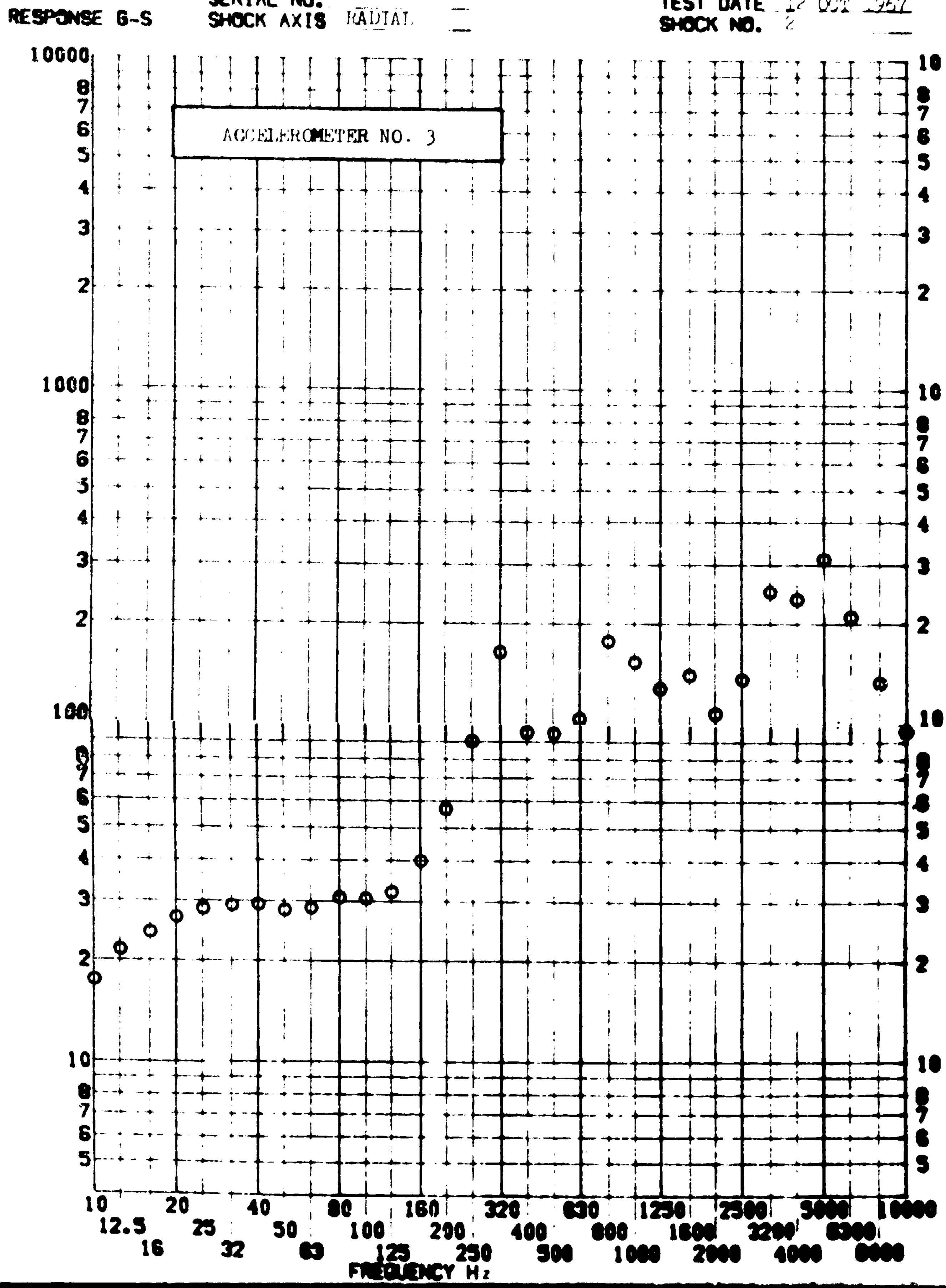
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.D.2.16

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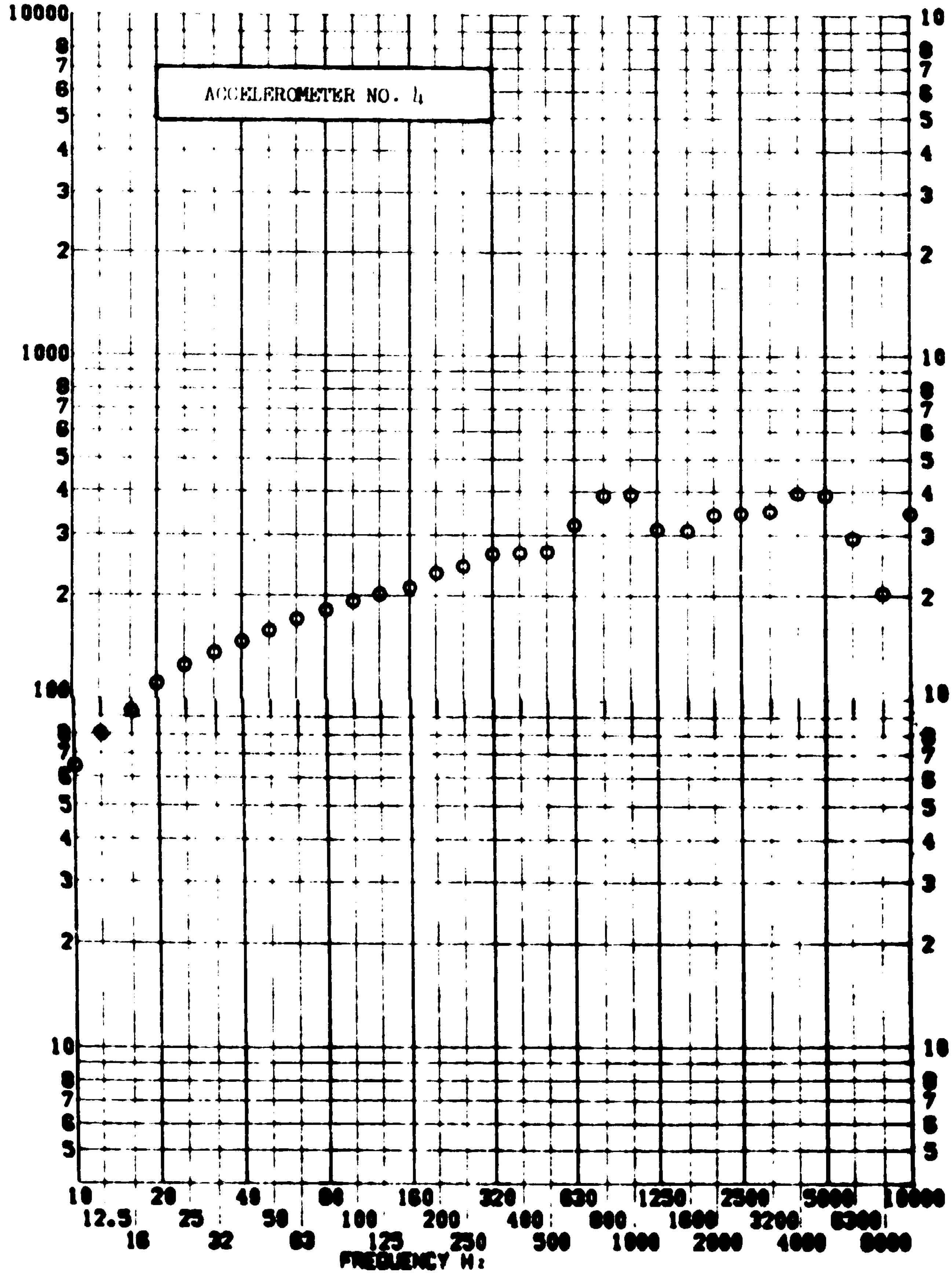
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.2.17

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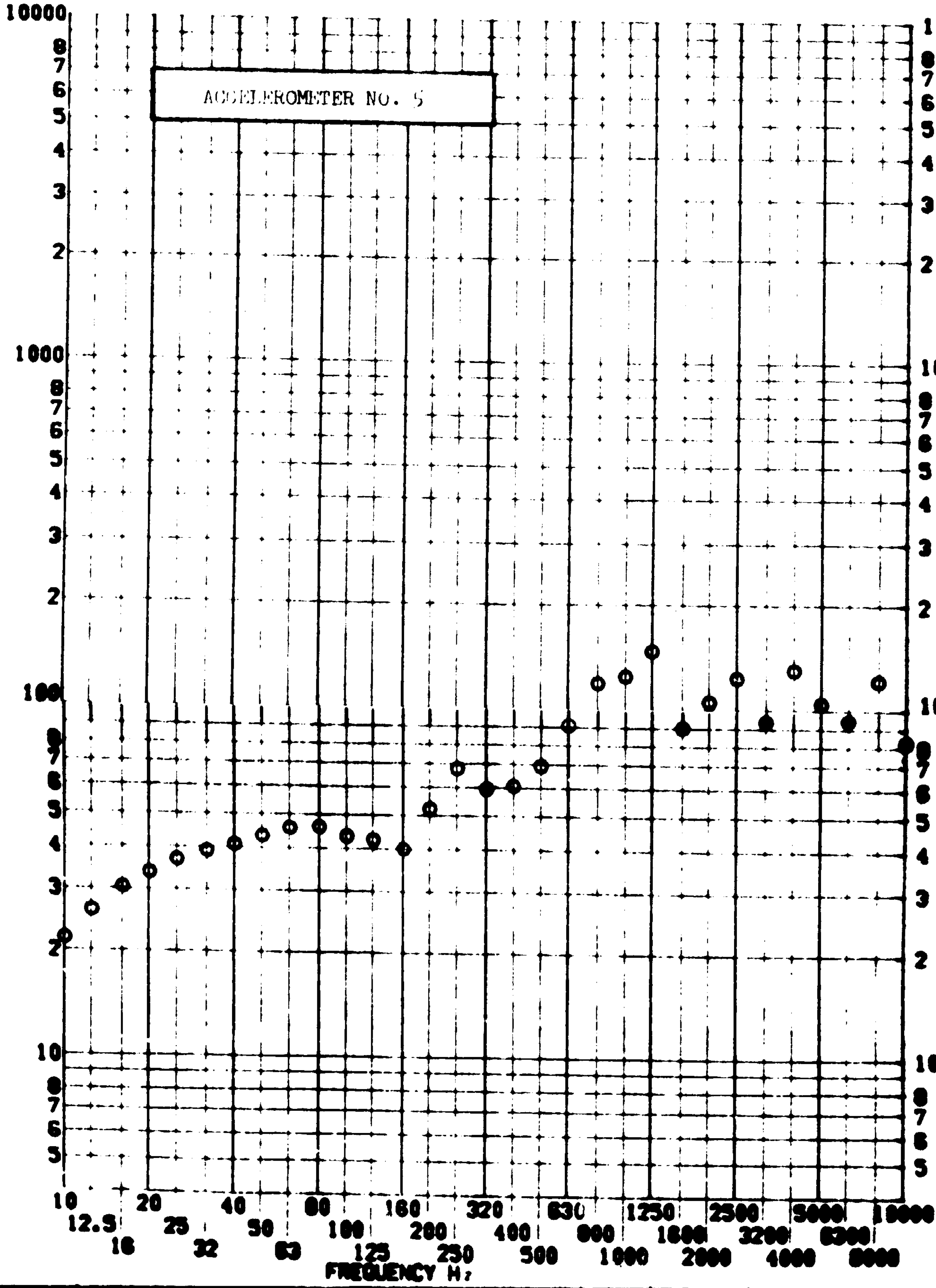
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 2

RESPONSE G-S

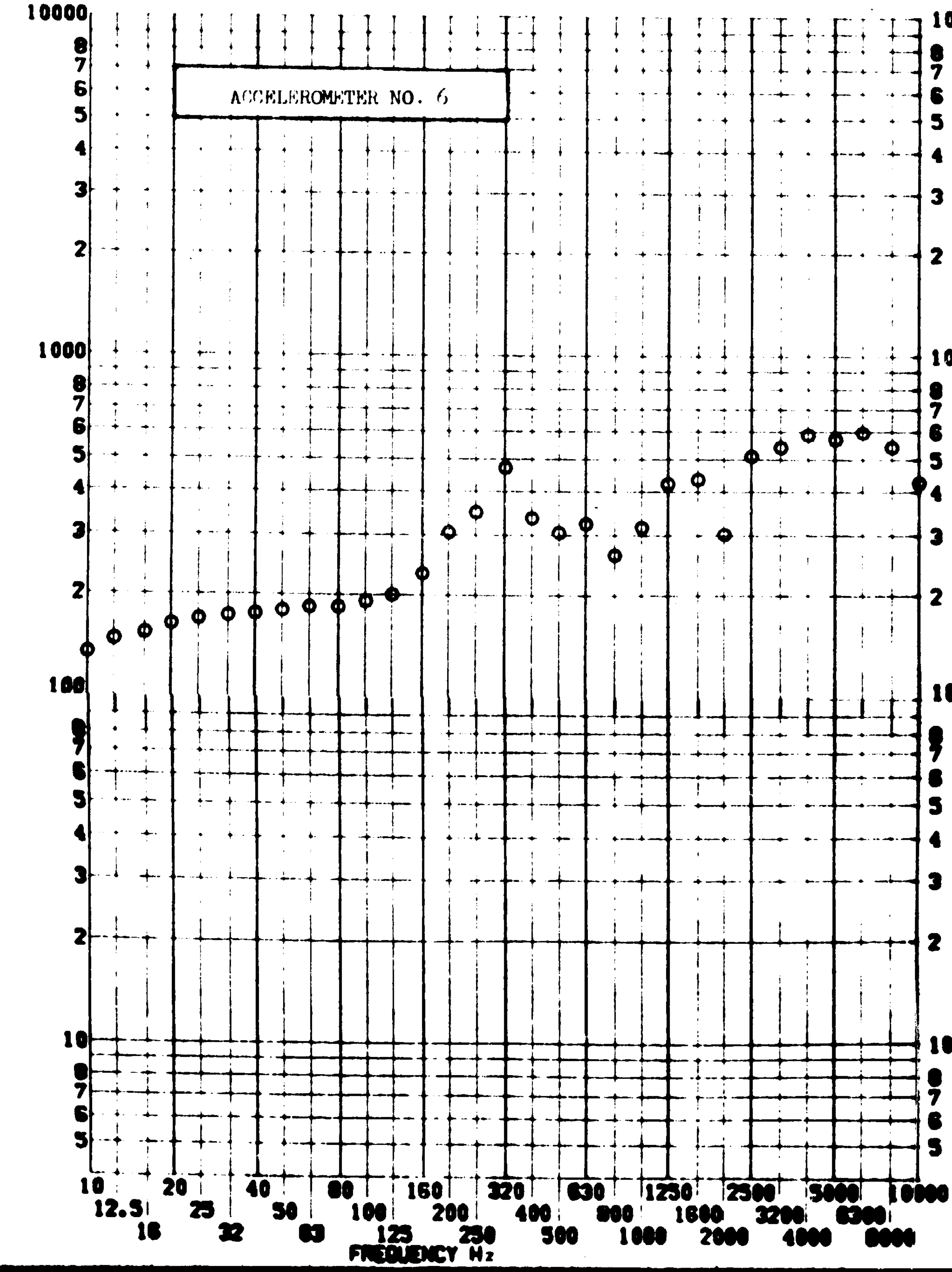


SHOCK TEST ANALYSIS DATA SHEET II.D.2.18

TEST ITEM 447-128
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 2

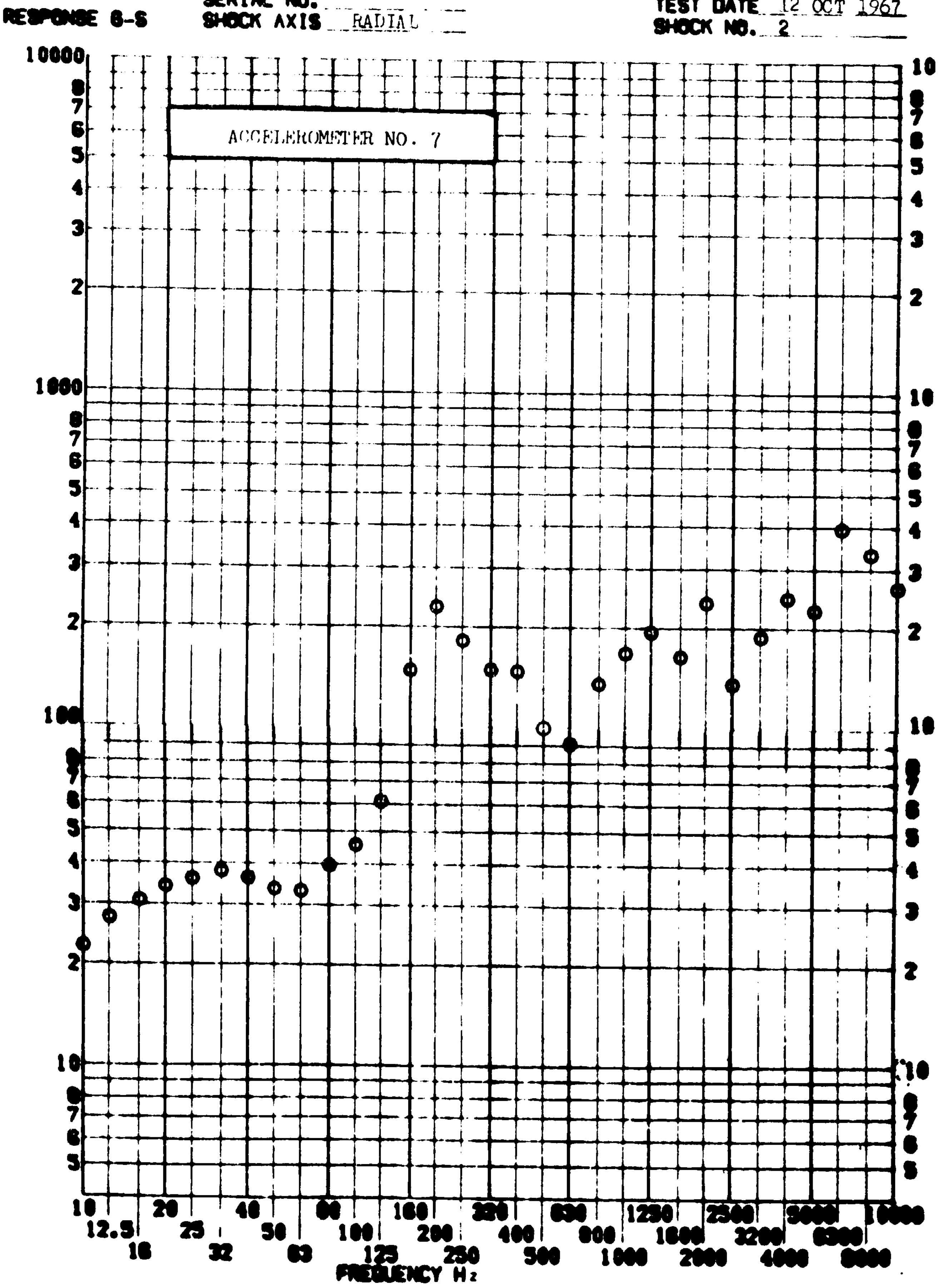
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.2.19

TEST ITEM 447-129
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 2

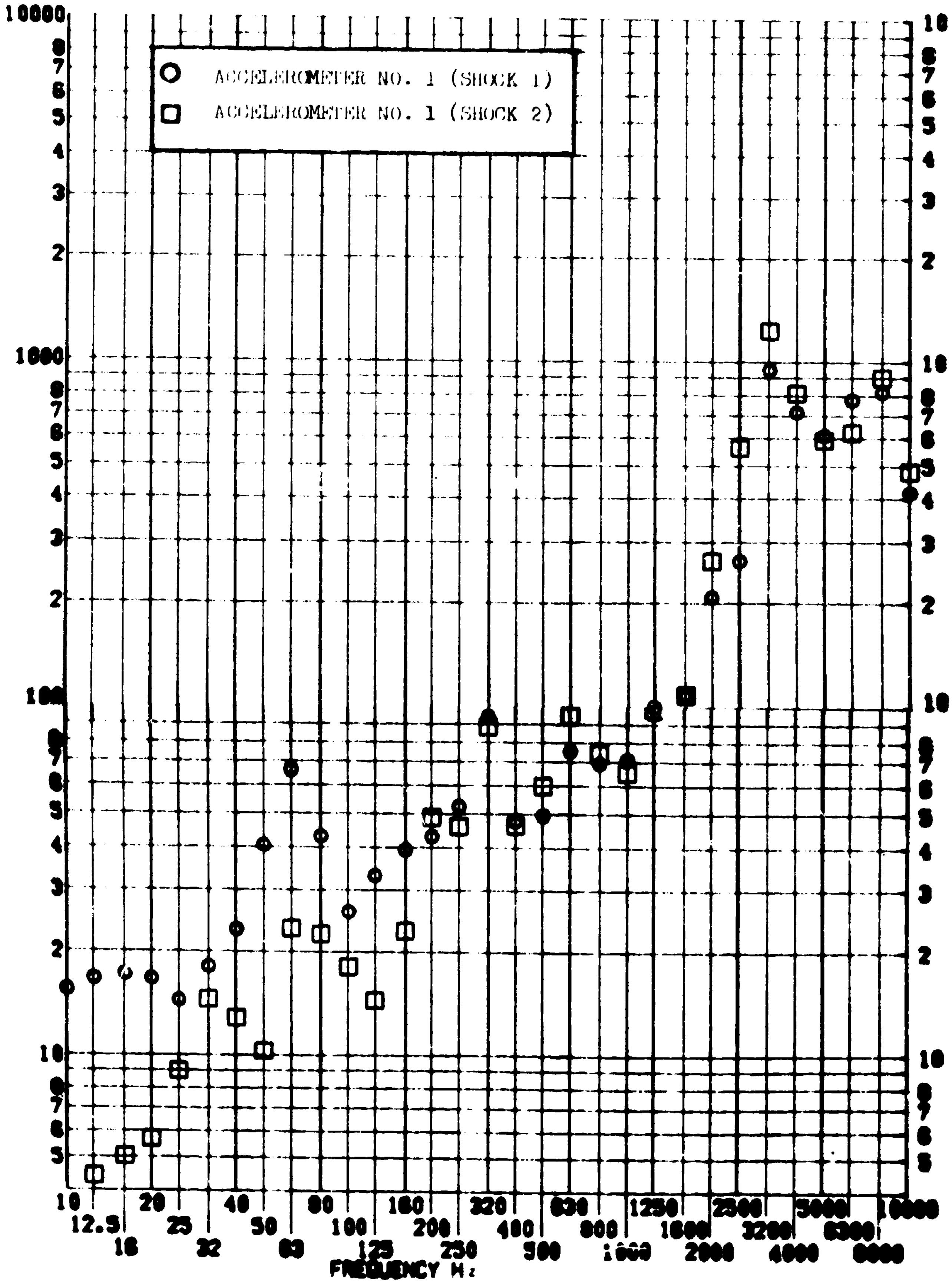


SHOCK TEST ANALYSIS DATA SHEET II.D.2.20

TEST ITEM 447-116,123
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1 & 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.2.21

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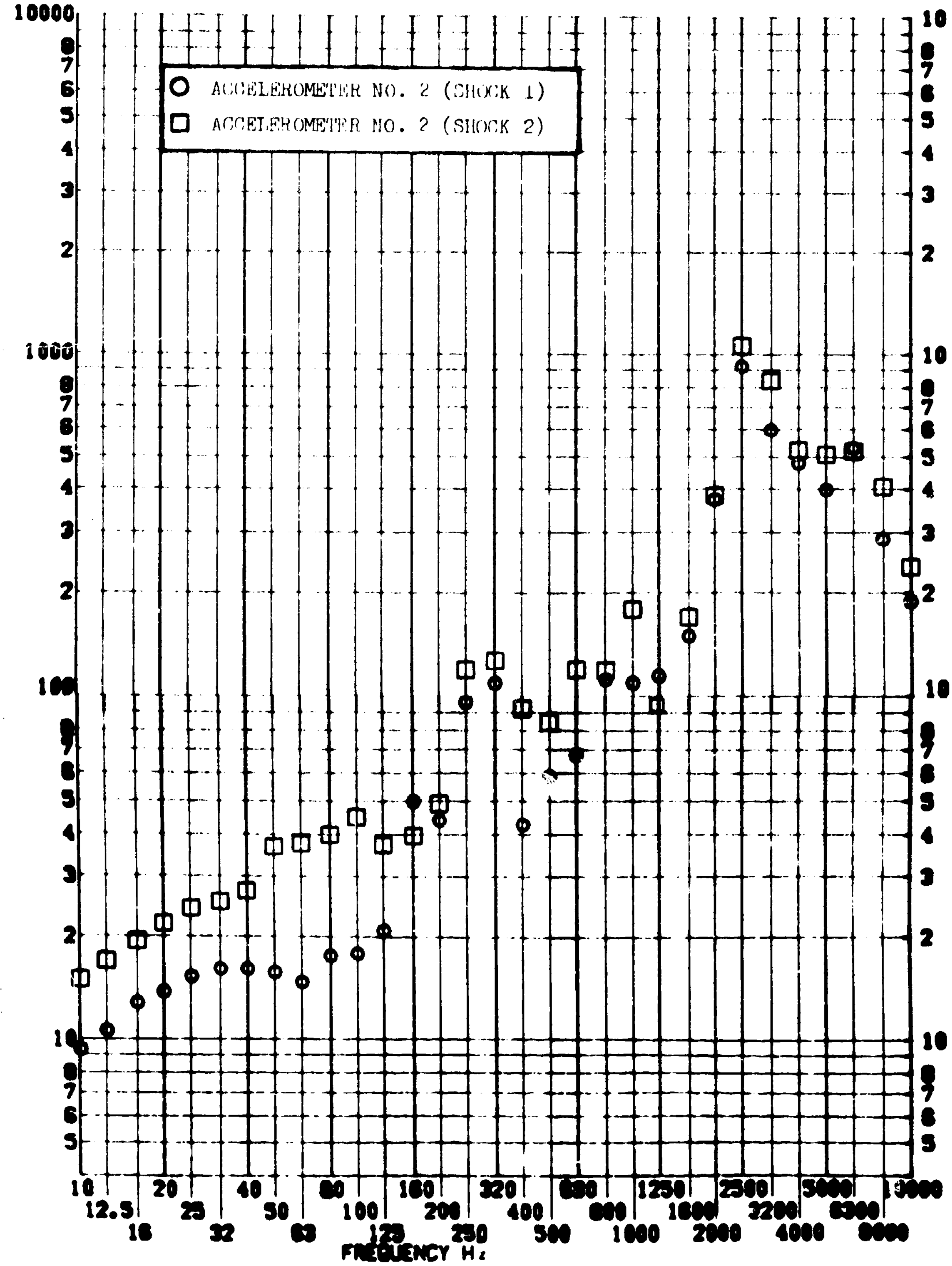
SERIAL NO. —
SHOCK AXIS RADIAL —

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1 & 2

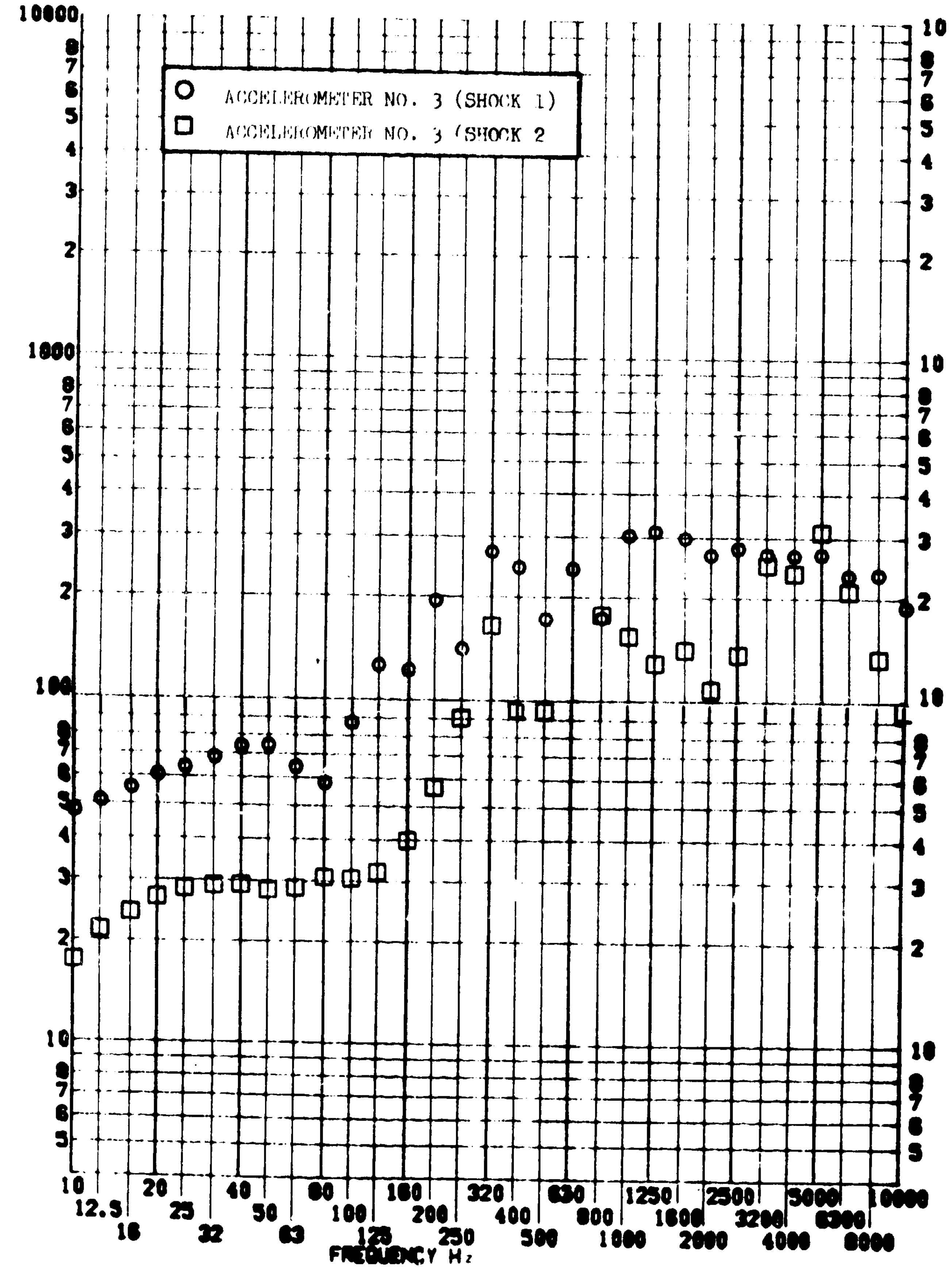


SHOCK TEST ANALYSIS DATA SHEET II.D.2.22

RESPONSE G-S

TEST ITEM 447-118,125
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.D.2.23

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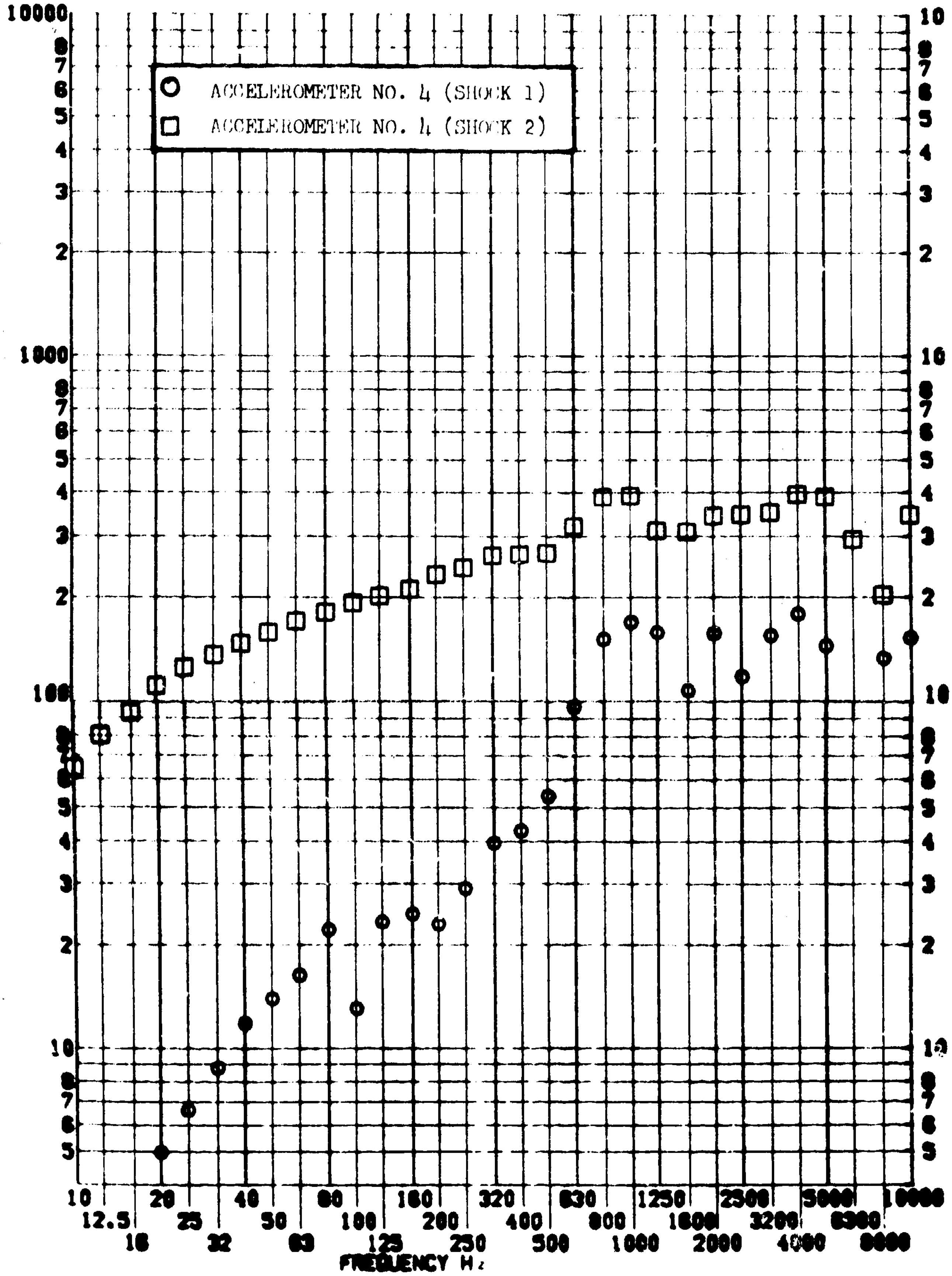
SHOCK AXIS RADIAL —

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1 & 2

SPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.D.2.24

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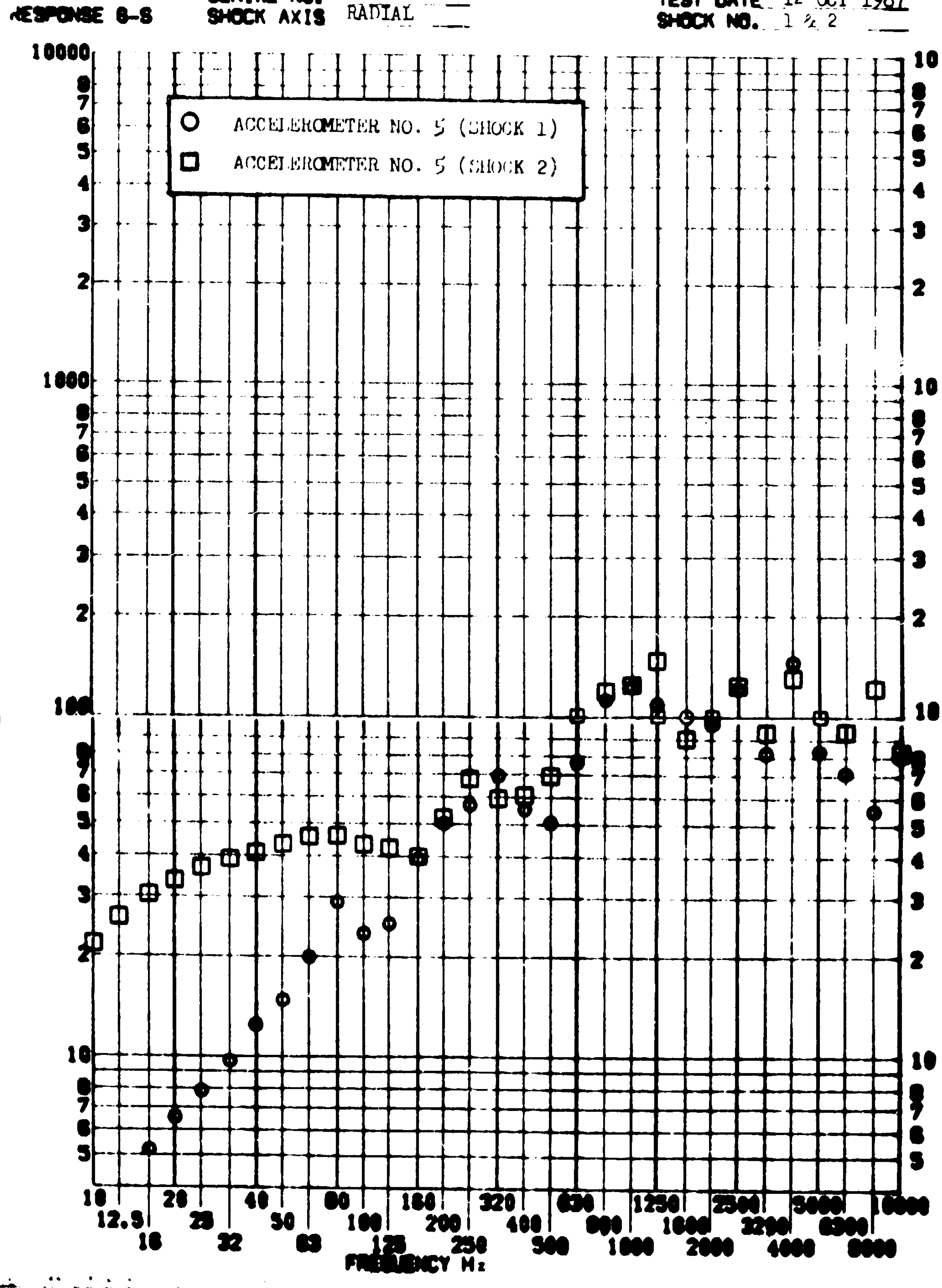
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1 & 2

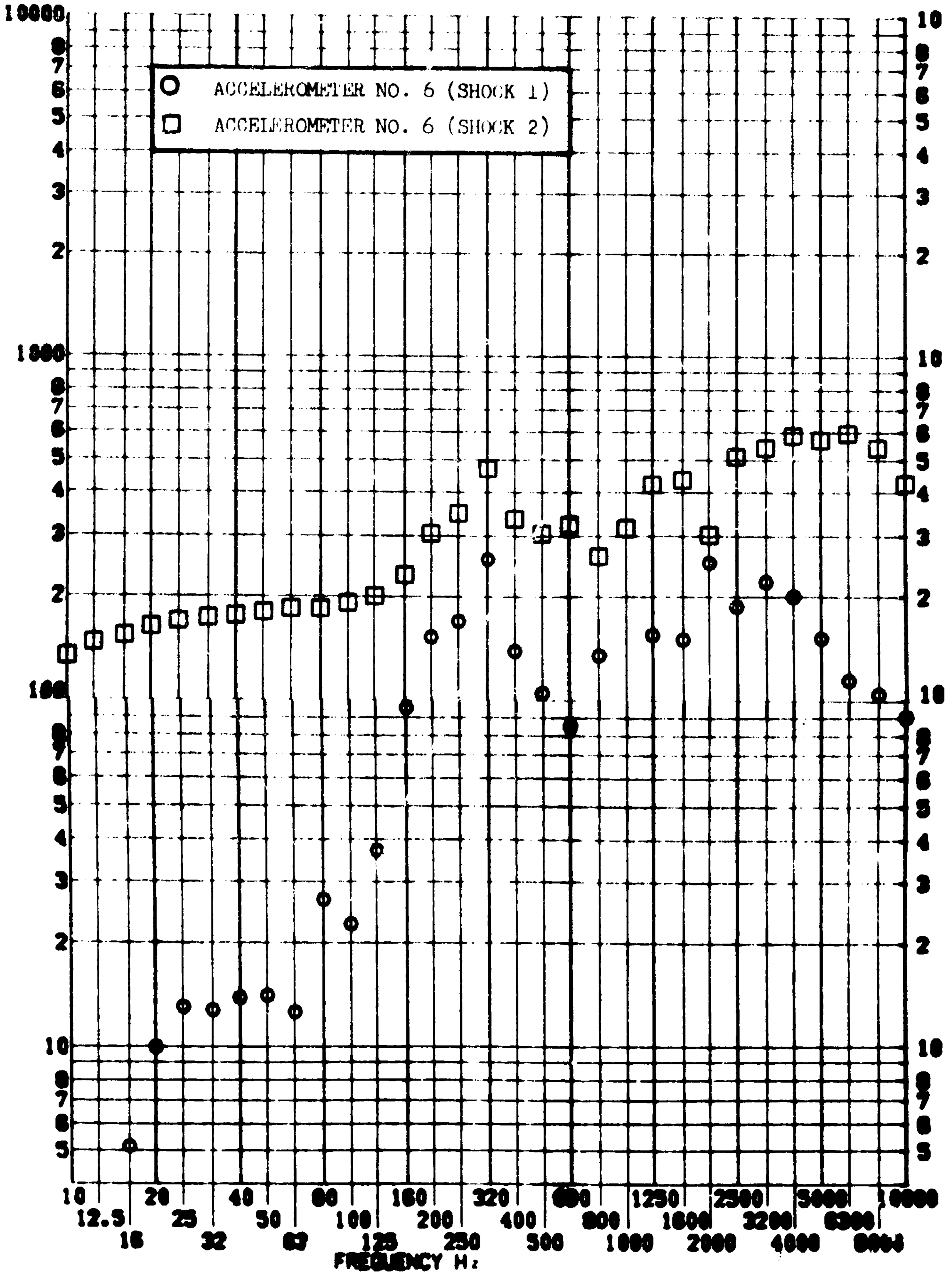


SHOCK TEST ANALYSIS DATA SHEET II.D.2.25

TEST ITEM 447-121,128
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1 & 2

SPONSE 6-S

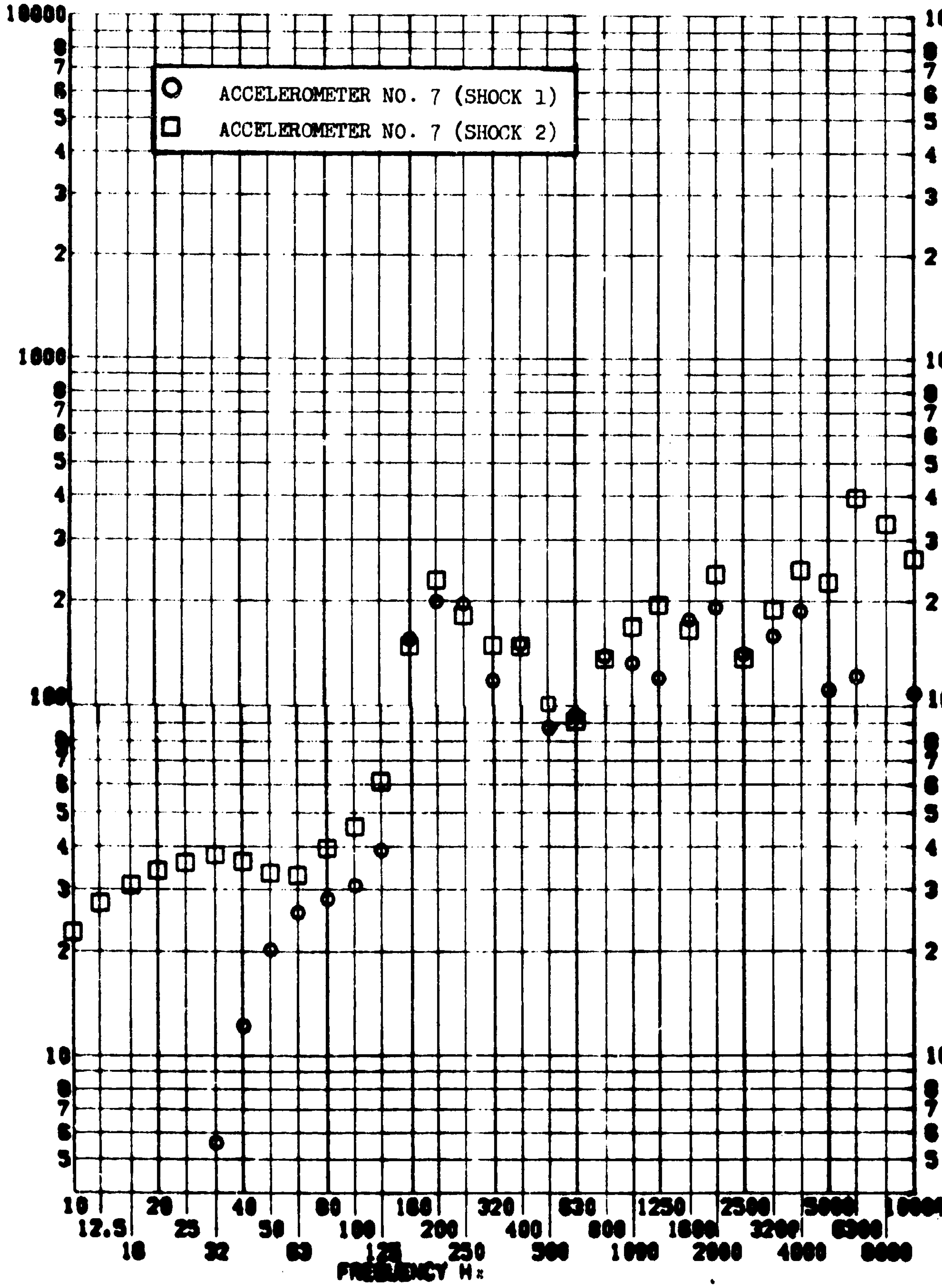


SHOCK TEST ANALYSIS DATA SHEET II.D.2.26

TEST ITEM 447-122,129
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 12 OCT 1967
SHOCK NO. 1 & 2

RESPONSE G-S



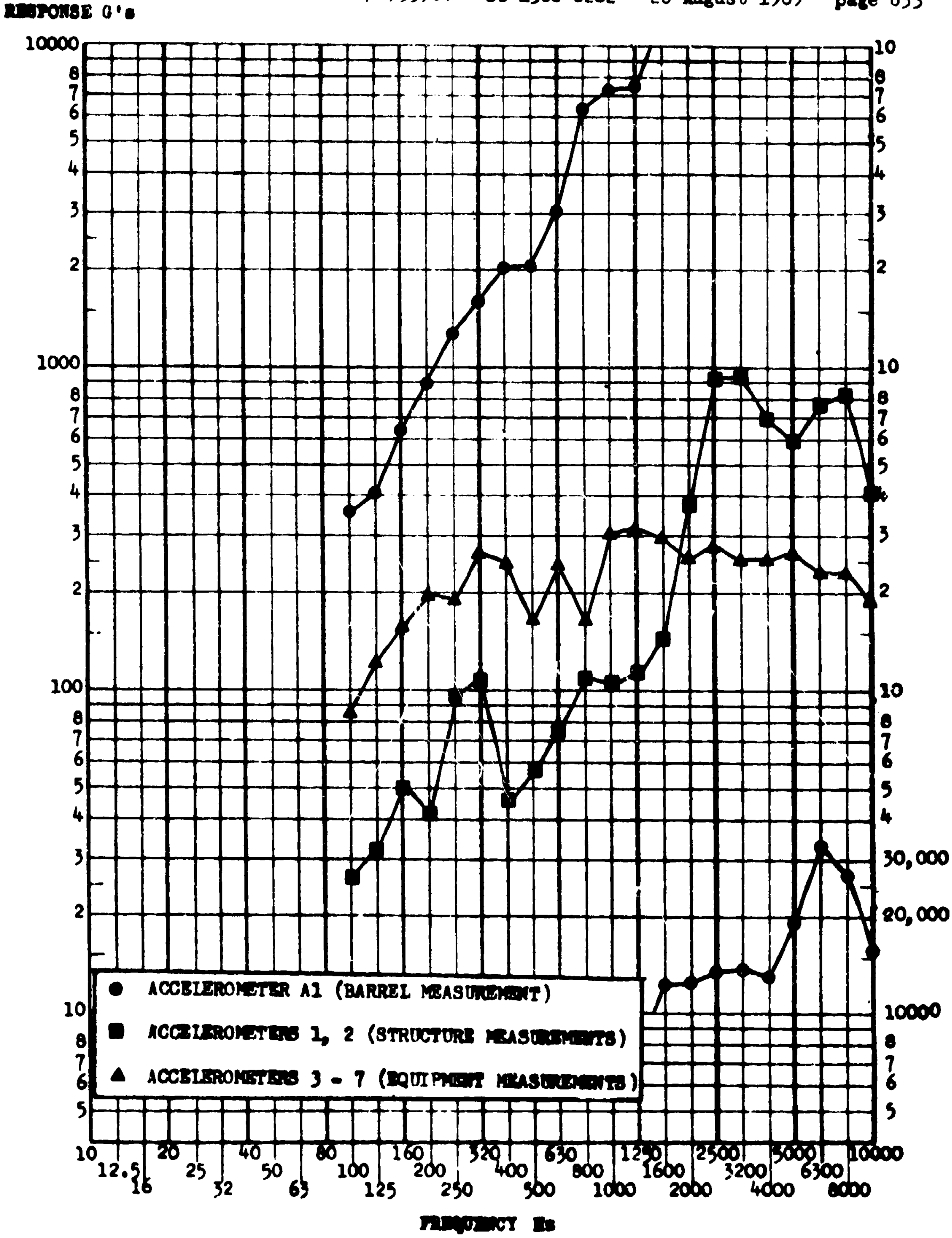


Figure II.D.2.27 COMPARISON OF BARREL MEASUREMENT A1 WITH STRUCTURAL AND EQUIPMENT MEASUREMENTS, SHOCK 1

II.D.3 DISCUSSION AND ANALYSIS

Structural measurements of the pod of Report 429 were made at both ends and the middle of the pod to determine its attenuation characteristics. Comparison of the shock spectra from these measurements (Figure II.D.1.51) showed the shock levels at the end of the pod furthest from the separation joint to be very much the same amplitude as the shock levels from measurements on the end of the pod nearest the separation joint. Measurements of the structural shock at the central section of the pod indicated that the shock was attenuated. Comparison of the structural measurements to the barrel reference measurement indicates a large reduction between that measurement and the structure measurements.

These observations indicated that the shock path was through both the slip joint and the structure on which the pod is mounted. The shock was significantly attenuated through the slip joint which would account for the similarity in shock amplitude at the two ends of the pod.

Because of the peculiar shock transmission path, attenuation/distance relationships as derived elsewhere in this report can not be applied in this case to determine shock levels at different equipment interfaces in the pod. Rather, the envelope of all equipment measurement shock spectrums for each of the pods should be used as a conservative estimate of the shock environment for any individual piece of equipment within the pods. Envelopes of the equipment measurements for the pods of Reports 429 and 447 are presented in Figure II.D.3.1 for this purpose.

II.D.4 CONCLUSIONS

The two tests which are documented in Reports 429 and 447 successfully established qualification of the two pods for pyroshock.

Comparison of the barrel reference measurement and the structural measurements on the pod indicates a large reduction in the shock. This is attributed to the transmission loss across the slip joint and the attenuation through the mounting structure to the far end of the pod.

The information of Reports 429 and 447 can be used for predicting the pyroshock environment on systems of this type.

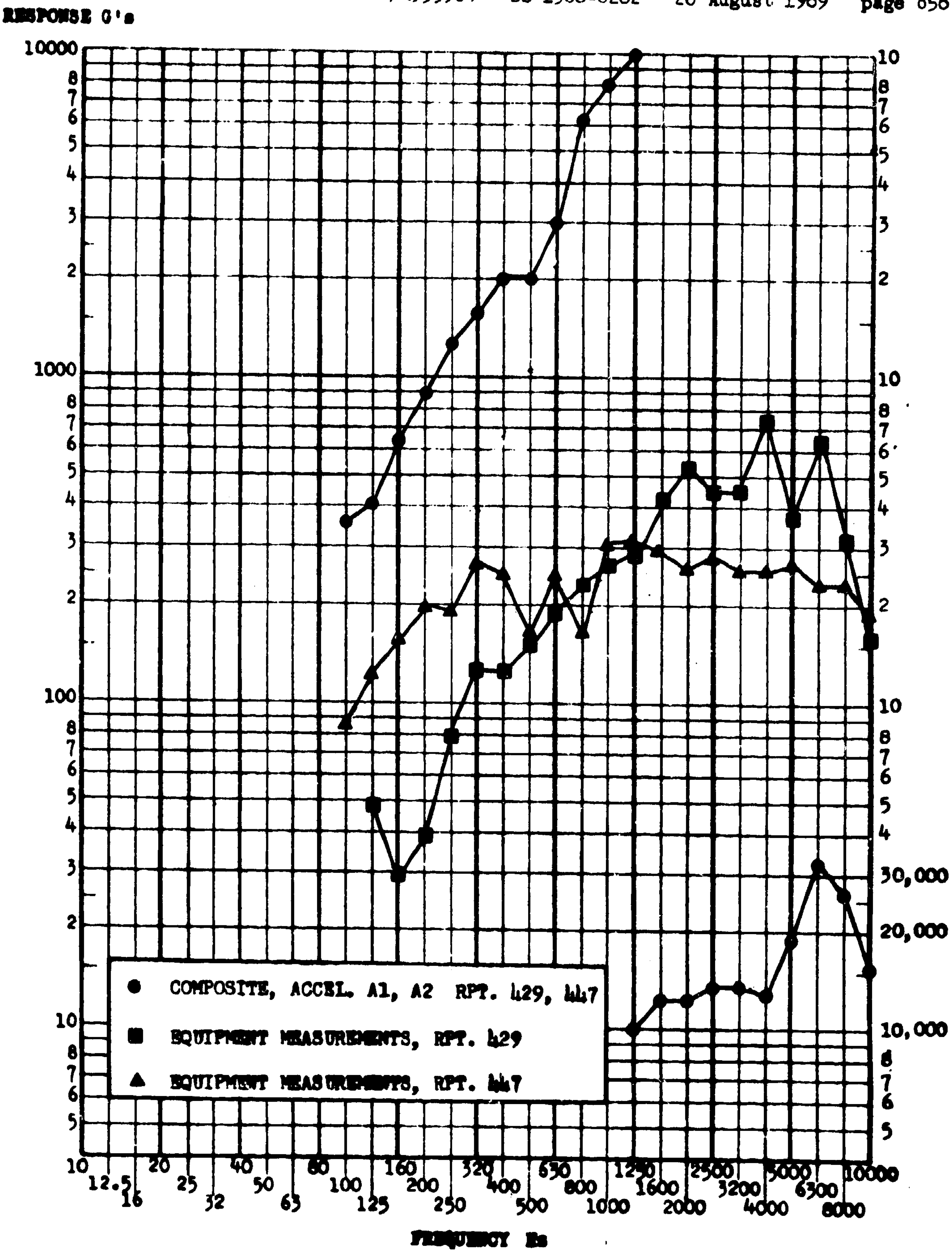


Figure II.D.1 COMPARISON OF EQUIPMENT MEASUREMENTS FOR PODS OF REPORTS 427 AND 447 TO COMPOSITE OF BARREL REFERENCE MEASUREMENTS

SECTION NO. II.E

REPORT NOS. 353, 456, 535, 543, 547, 562

SUBJECT:

EQUIPMENT TESTS PERFORMED ON BARREL TESTER

SECTION II.E

SUMMARY

This section contains six reports (No. 353, 456, 535, 543, 547 and 562) covering series of tests performed on the pyrotechnic barrel tester for either development or qualification of equipment.

The barrel tester philosophy and mode of operation are described in Section V of this report. Typical pyrotechnic environmental characteristics are presented in Section II.F.2

Except in special cases, it is standard practice to perform two successive shock tests with the specimen rotated by 180° for the second shock.

The subjects of each report contained in this section are briefly reviewed below:

Report No. 353 covers qualification testing of two boxes: one mounted directly onto a second bay removable panel; the other having vibration isolators. Both boxes survived the test.

Report No. 456 covers qualification testing of three boxes; one mounted directly onto a second bay removable panel, the two others having vibration isolators. All boxes survived the test. Some difficulties were experienced in the data recording and a few accelerometer results are questionable. However, the bulk of the data is reliable.

Report No. 535 describes tests performed to check the strength of structural epoxy bonds under pyrotechnic environment. The particular brand of epoxy under consideration was found inadequate for this purpose.

Report No. 543 covers simulation of actual flight conditions through use of a reduced explosive charge and thinner separation plate (barrel bay 2).

Report No. 547 covers qualification testing of a Reaction Module Engine to the environment of barrel bay 1.

Report No. 562 covers qualification testing of a vibration isolated Velocity Meter whose sensitivity along one axis was critical. The vibration isolators provided adequate attenuation to protect this delicate instrument.

The results of these tests show evidence of the excellent repeatability of the shock environments.

These reports were selected for this section because in addition to the standard barrel instrumentation, additional measurements were made on the equipment under test.

Further barrel testing for special cases is presented in Section II.D which makes use of double barrel arrangement.

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SECTION II.E

SECTION NO. II.E.1

REPORT NO. 353

SUBJECT:

ELECTRONIC BOX TESTS ON BARREL TESTER

SECTION II.E.1

SUMMARY

The barrel tester was used for the pyrotechnic qualification testing of a Transponder box weighing 5.5 pounds and a Telemetry box weighing 12 pounds.

In order to reproduce the environment to which these boxes would be subjected in flight, the two boxes were mounted externally to the barrel second bay, and a 30 Gr MDF explosive was used in combination with a .19 inch magnesium-thorium separation plate. Each box was mounted on a pair of Z brackets attached to the barrel removable panels. The Transponder attachment to the Z brackets included vibration isolators made from wire mesh material. The Telemetry box was simply bolted onto its Z brackets.

Two tests were carried out with the boxes rotated 180 degrees for the second tests. All accelerometers provide good data. One set of three accelerometers monitored the environment at the barrel removable panel while two other sets monitored the environment to which the boxes were subjected.

Both mounting brackets provided about 80 percent attenuation at high frequencies. The isolated Transponder installation provides substantial attenuation throughout the frequency range while the hard mounted Telemetry box shows amplification below about 300 cps.

Information provided by this type of test form a background of experimental data which is useful in predicting the attenuation which may be obtained with similar installation.

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SECTION II.E.1

II.E.1.1 INTRODUCTION

Two electronic boxes, a 5.5 pound Transponder and a 12 pound Telemetry box were subjected to pyrotechnic qualification tests on the barrel tester. These boxes were attached with Z brackets to the barrel second bay removable panels in order to simulate the appropriate flight environment. The Transponder box was mounted on vibration isolators made from wire mesh material while the Telemetry box was simply bolted onto the brackets.

The standard tests were performed with the boxes rotated 180 degrees for the second firing. The tests were carried out with 30 Gr MDF charges and .19 magnesium-thorium separation plates.

II.E.1.2 DISCUSSION AND ANALYSIS

II.E.1.2.1 Test Configuration and Instrumentation

A standard barrel tester as described in Section II.F.1 was used for this test. The general test arrangement is shown on Figure II.E.1.1. The box installation Z brackets were rivetted to the barrel second bay removable panels as shown on Figure II.E.1.2 and II.E.1.3.

The instrumentation included nine accelerometers in sets of three to read longitudinal, radial and tangential accelerations. One set (accelerometers No. 1, 2 and 3) was placed on the removable panel near the Transponder box Z bracket. Another set (accelerometers No. 4, 5 and 6) was placed on the Transponder box, just above the Z bracket. The third set (accelerometers No. 7, 8 and 9) was placed by the manufacturer inside the Telemetry box, thus the exact location and attachment structure is not known.

Accelerometer "B" was used for standard test monitoring (see Section II.F.1 for environment) but this data was not included in this section.

Accelerometer data is given on Table II.E.1.1 and a summary of the tests on Table II.E.1.2.

Shock spectra for each accelerometer and each test are presented on Figure II.E.1.5 to II.E.1.22. Repeatability is shown on Figure II.E.1.23 to II.E.1.31 which compare the readings of each accelerometer for shock 1 and 2.

II.E.1.2.2 Technical Discussion

Upon completion of the test, inspection of the specimen showed that no failure occurred. The accelerometer records were considered reliable.

Reduction of the test data was performed on the UNIVAC 1108 after digitizing the analog tape.

II.E.1.2.3 Analysis

Since the two test specimens survived the shocks without damage, two considerations are of interest:

a. Attenuation provided by the Z brackets and vibration isolators.
b. Repeatability of the environment provided by shocks 1 and 2.

The attenuation provided by the Z brackets is shown by comparing the environment at the removable panel (accelerometers No. 1, 2 and 3) with that measured on the boxes. Experience with the barrel tester has demonstrated that the environment at the removable panels for similar weights and types of installation is not significantly affected. Therefore, the readings of accelerometers 1, 2 and 3 can be used as a basis for comparing with both boxes. This comparison is presented on Figure II.E.1.4 which is plotted from the data presented on Table II.E.1.3. Both brackets provide attenuation at high frequencies and the effect of the vibration isolators on the Transponder provide attenuation over most of the range of interest. The Telemetry box data indicates that amplification occurs below about 500 cps. However, since the detail of these internal accelerometer installations is not known, it is not possible to determine whether the amplification is due to the box mount or to some local component inside the box.

Repeatability of the environment is shown to be good for all accelerometers on Figure II.E.1.23 to II.E.1.31. Turning the boxes around by 180 degrees has little effect on the shock level and the differences between data points may be attributed to normal scatter.

II.E.1.3 CONCLUSION

Both boxes withstood the environment provided by two shocks without failure of any kind.

The vibration isolators fitted to the Transponder attachment were effective in reducing, by a significant amount, the environment level to which this box was subjected.

The Telemetry box data indicates attenuation at high frequencies and amplification at low frequencies. Since the internal accelerometers were installed by the manufacturer, no details of their locations are available. Since the box withstood the environment without damage, it may be concluded that this amplification was not harmful.

Repeatability of the environment recorded by all accelerometers for both shocks was found to be satisfactory.

TABLE II.E.1.1

ACCELEROMETERS AND LOCATIONS

Accelerometer Number	Box	Direction	Location Bay	Distance to Shocksource	Accelerometer Type
1	Panel	L	II	30	Endevco 2225
2	Panel	R	II	30	Endevco 2225
3	Panel	T	II	30	Endevco 2225
4	Transponder	L	II	30	Endevco 2225
5	Transponder	R	II	30	Endevco 2225
6	Transponder	T	II	30	Endevco 2225
7	T/M Pack	L	II	30	Endevco 2220
8	T/M Pack	R	II	30	Endevco 2220
9	T/M Pack	T	II	30	Endevco 2220

TABLE II.E.1.2

SUMMARY OF TESTS

Test Number	Configuration	Explosive Size	Test Purpose	Shock Isolation
1	Shear Plate	30 Gr/ft MDF	Box Qual.	Yes *
2	Shear Plate	30 Gr/ft MDF	Box Qual.	Yes *

* Transponder box only

TABLE II.E.1.3

SHOCK LEVEL ENVELOPES AND RATIOS

Test 1	Envelope A	Envelope B	Envelope C	B/A	C/A
125	66	59	427	.89	15.5
160	96	79	400	.82	4.2
200	190	140	292	.74	1.5
250	403	140	320	.35	.79
320	557	262	614	.47	1.10
400	1787	1034	575	.58	.32
500	1669	675	1341	.41	.81
630	1319	447	1936	.34	1.46
800	3755	770	1264	.21	.34
1000	2270	617	1614	.27	.71
1250	2072	425	1980	.21	.96
1600	2312	542	957	.23	.42
2000	1961	932	843	.47	.43
2500	2395	1062	723	.44	.30
3200	3051	708	711	.23	.23
4000	9605	637	1006	.14	.25
5000	4488	899	630	.20	.14
6300	4529	768	614	.17	.14
8000	4941	683	849	.14	.17
10000	2558	443	507	.15	.20

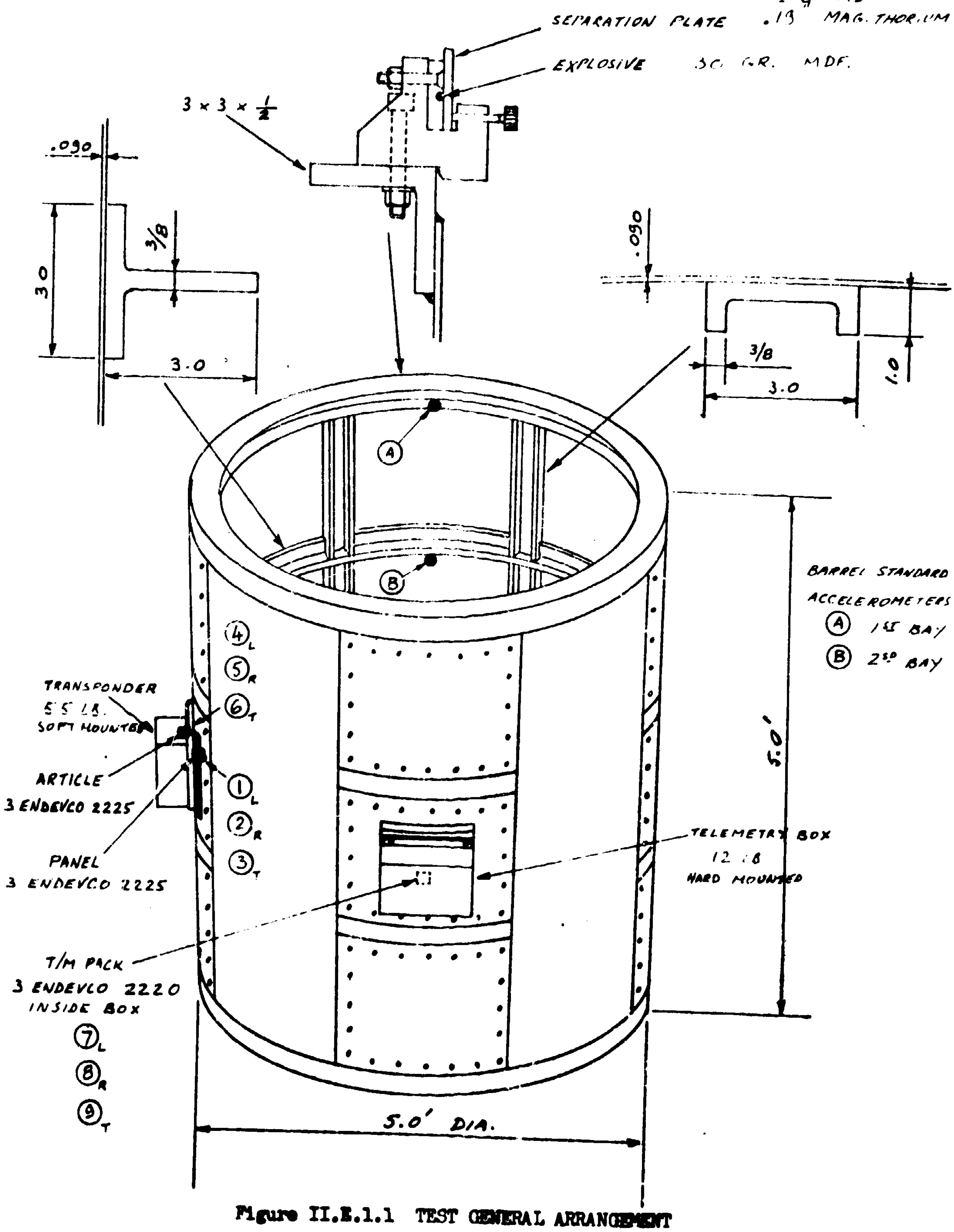


Figure II.E.1.1 TEST GENERAL ARRANGEMENT

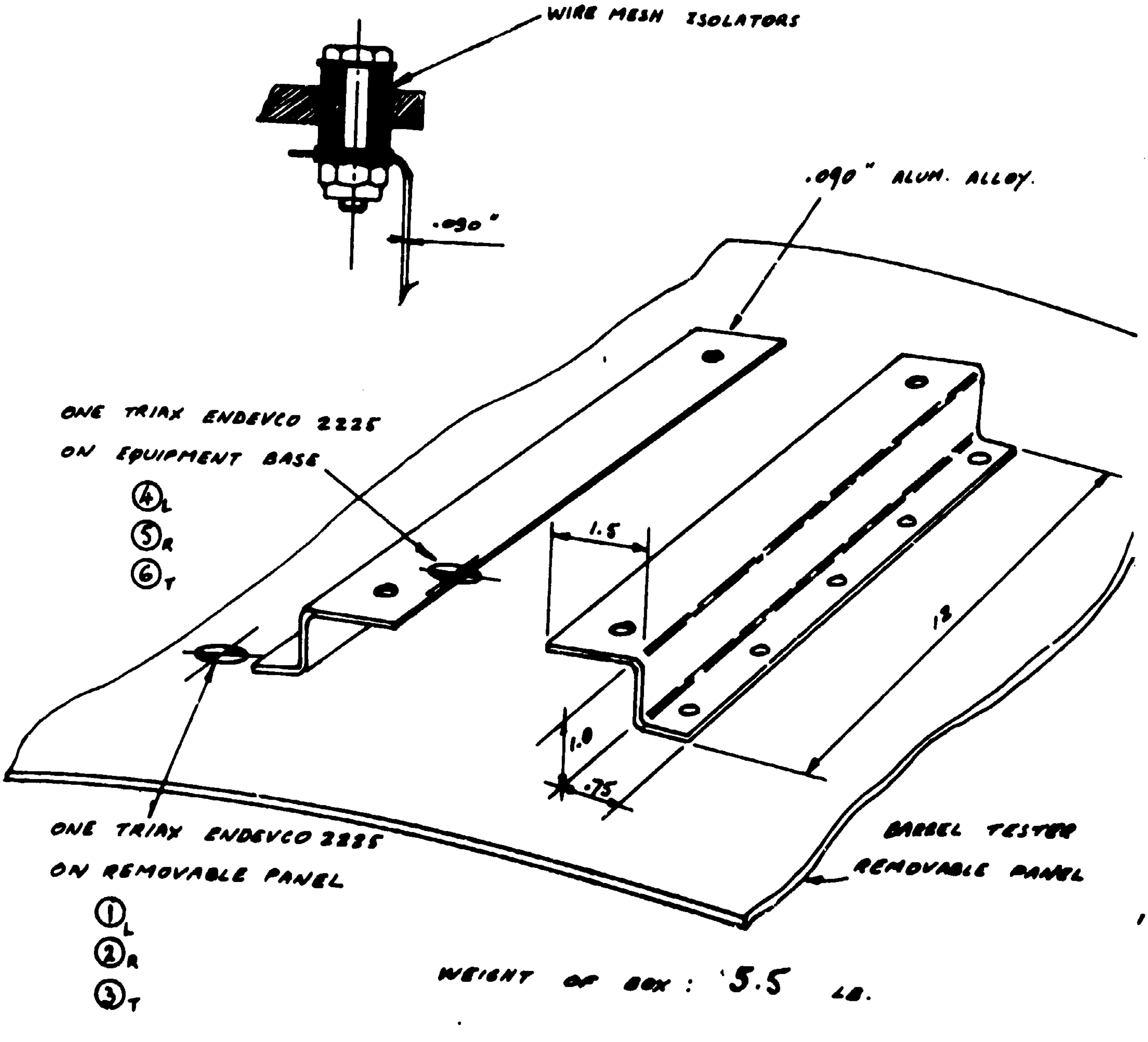
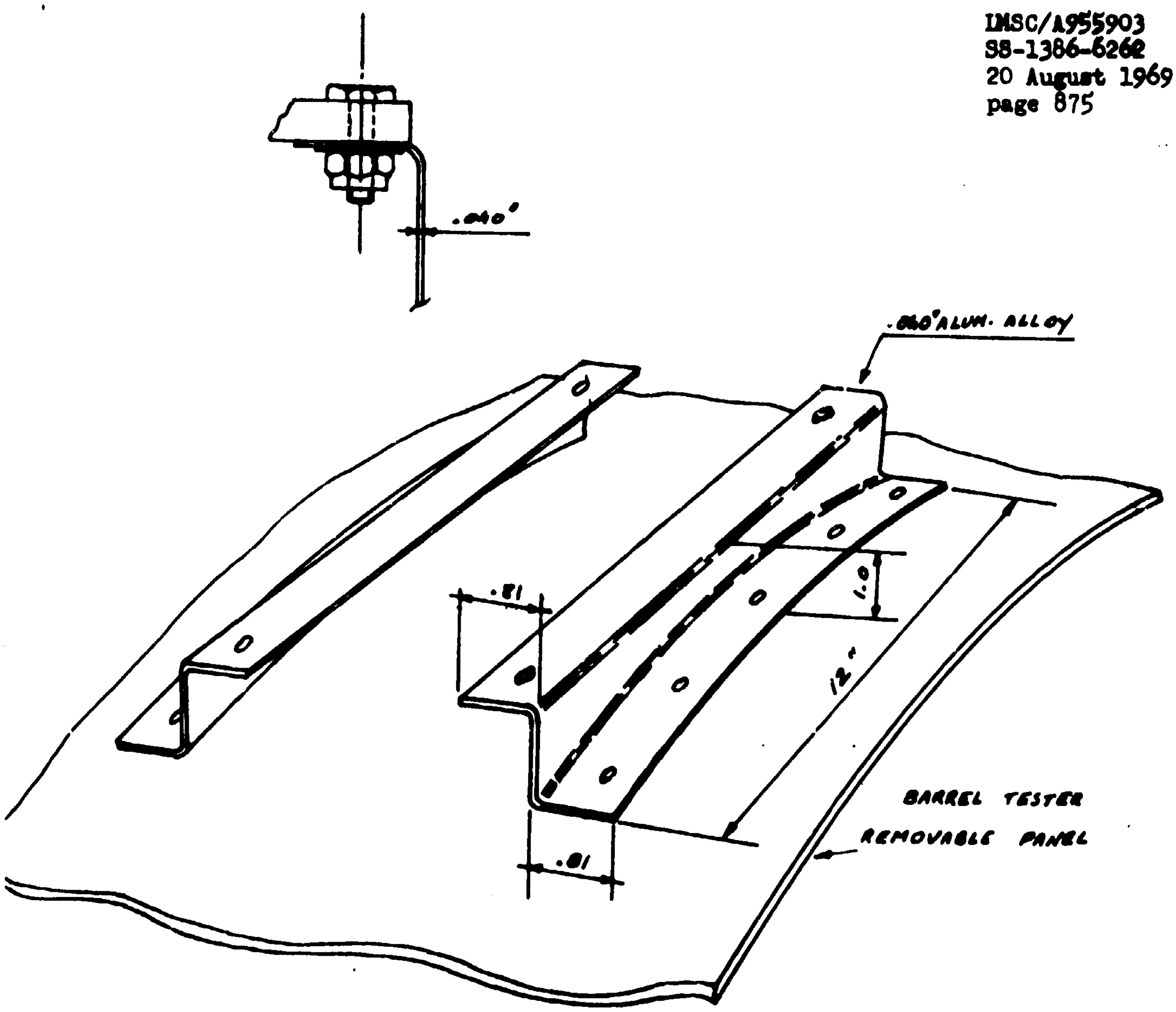


Figure II.E.1.2 TRANSPONDER INSTALLATION ON BARREL TESTER



WEIGHT OF BOX : 12. LB.

ONE SET OF 3 ENDEVCO 2220 ACCELEROMETERS INSTALLED INSIDE BOX - EXACT LOCATION UNKNOWN.

Figure II.2.1.3 TELEMETRY INSTALLATION ON BARREL TESTER

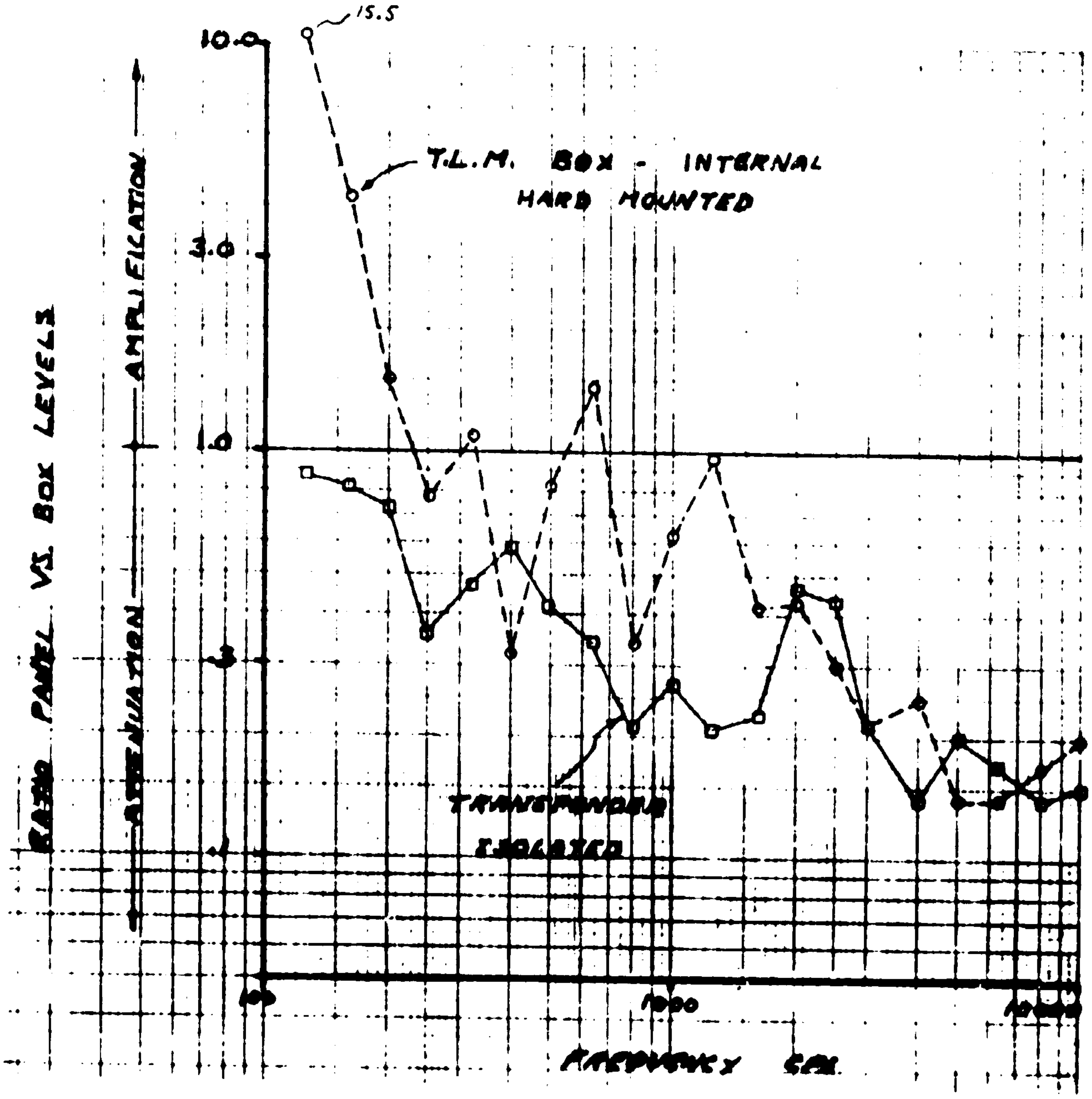


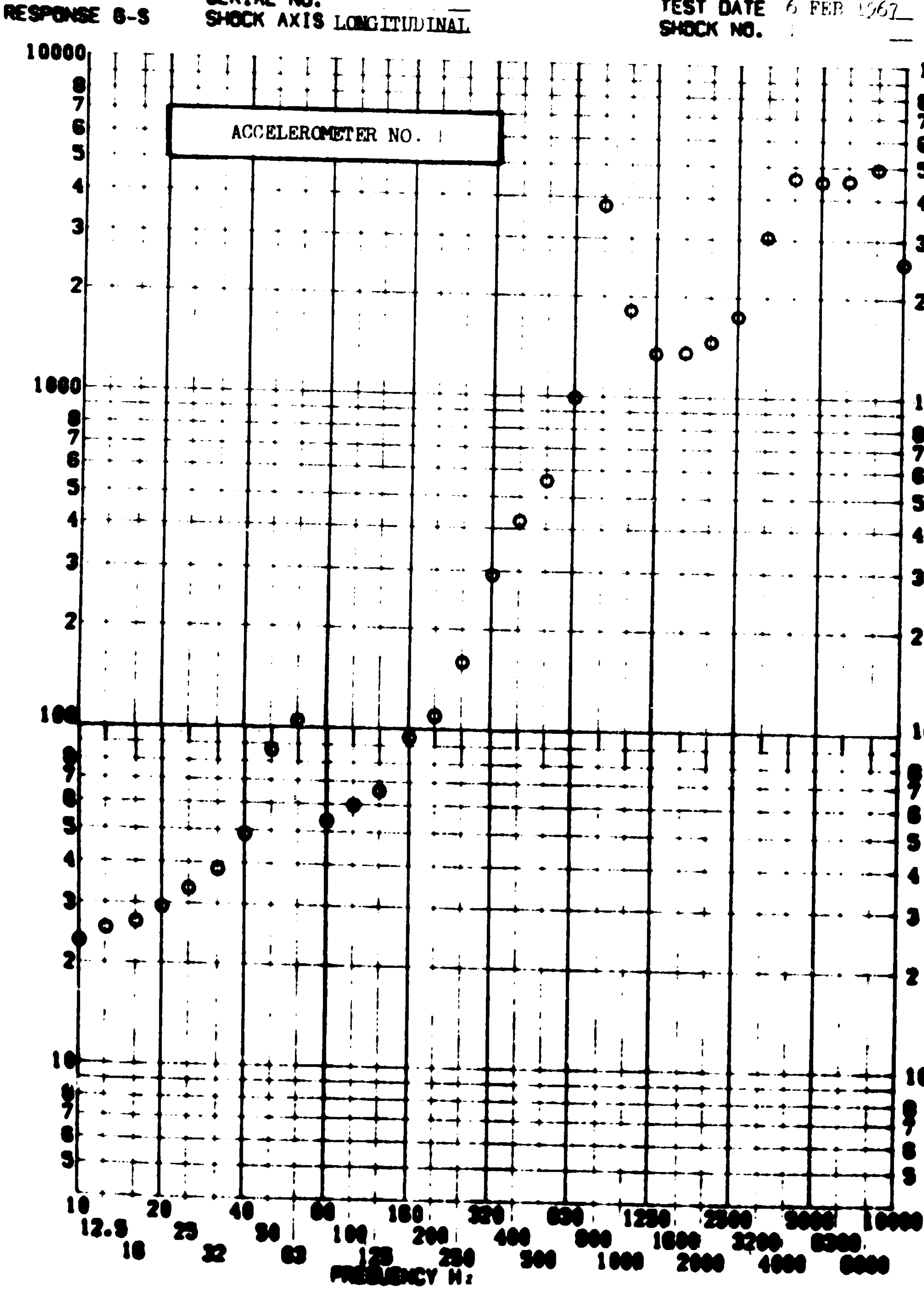
Figure II.E.1.4 SHOCK ATTENUATION PROVIDED BY MOUNTING BRACKETS

SHOCK TEST ANALYSIS DATA SHEET

II.E.1.5

TEST ITEM 353-279
SERIAL NO.
SHOCK AXIS LONGITUDINAL

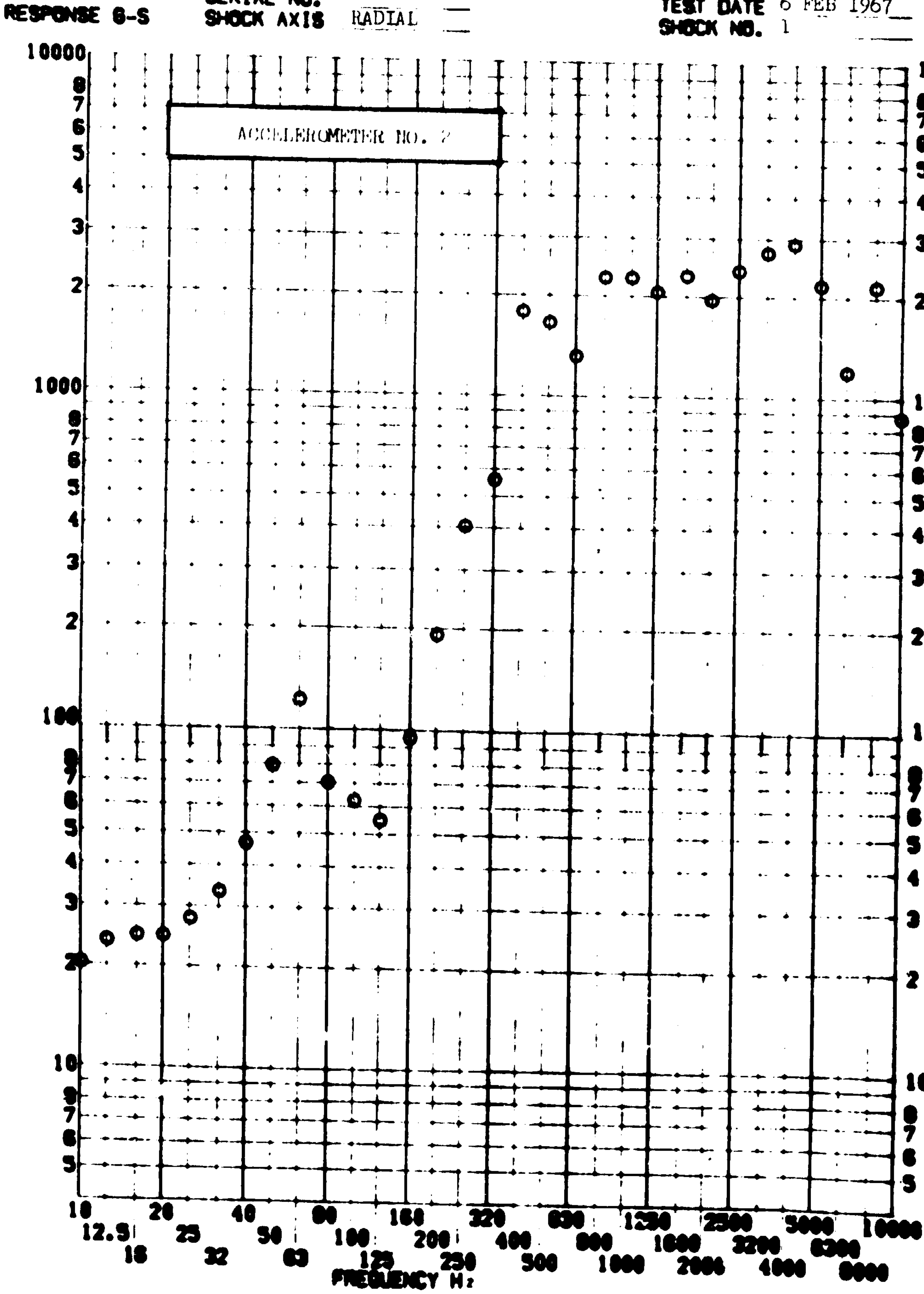
PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO.



SHOCK TEST ANALYSIS DATA SHEET II.E.1.6

TEST ITEM 353-280
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 1



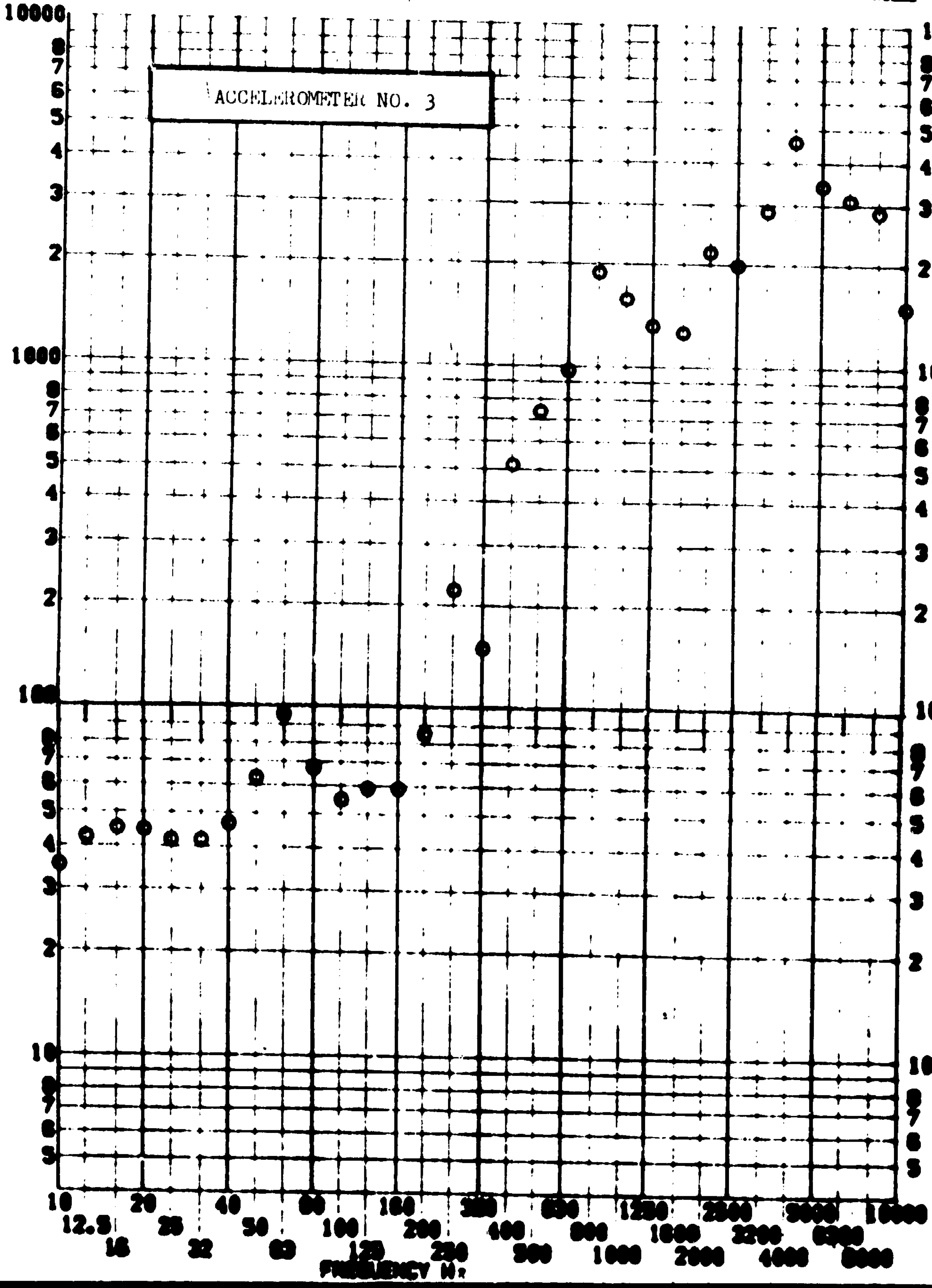
SHOCK TEST ANALYSIS DATA SHEET

II.E.1.7

TEST ITEM 353-281
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 1

RESPONSE G-S

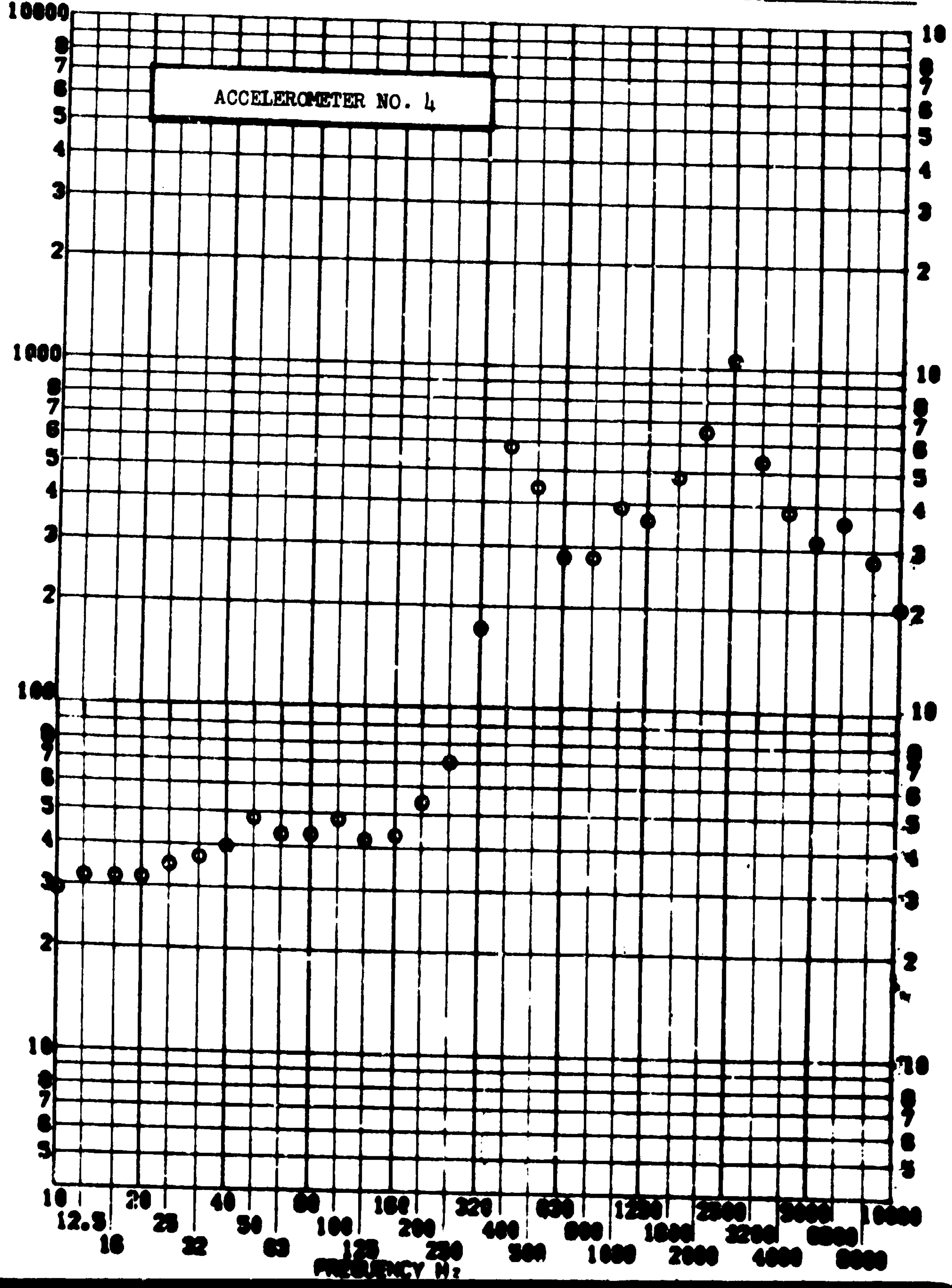


SHOCK TEST ANALYSIS DATA SHEET II.E.1.8

TEST ITEM 353-282
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1

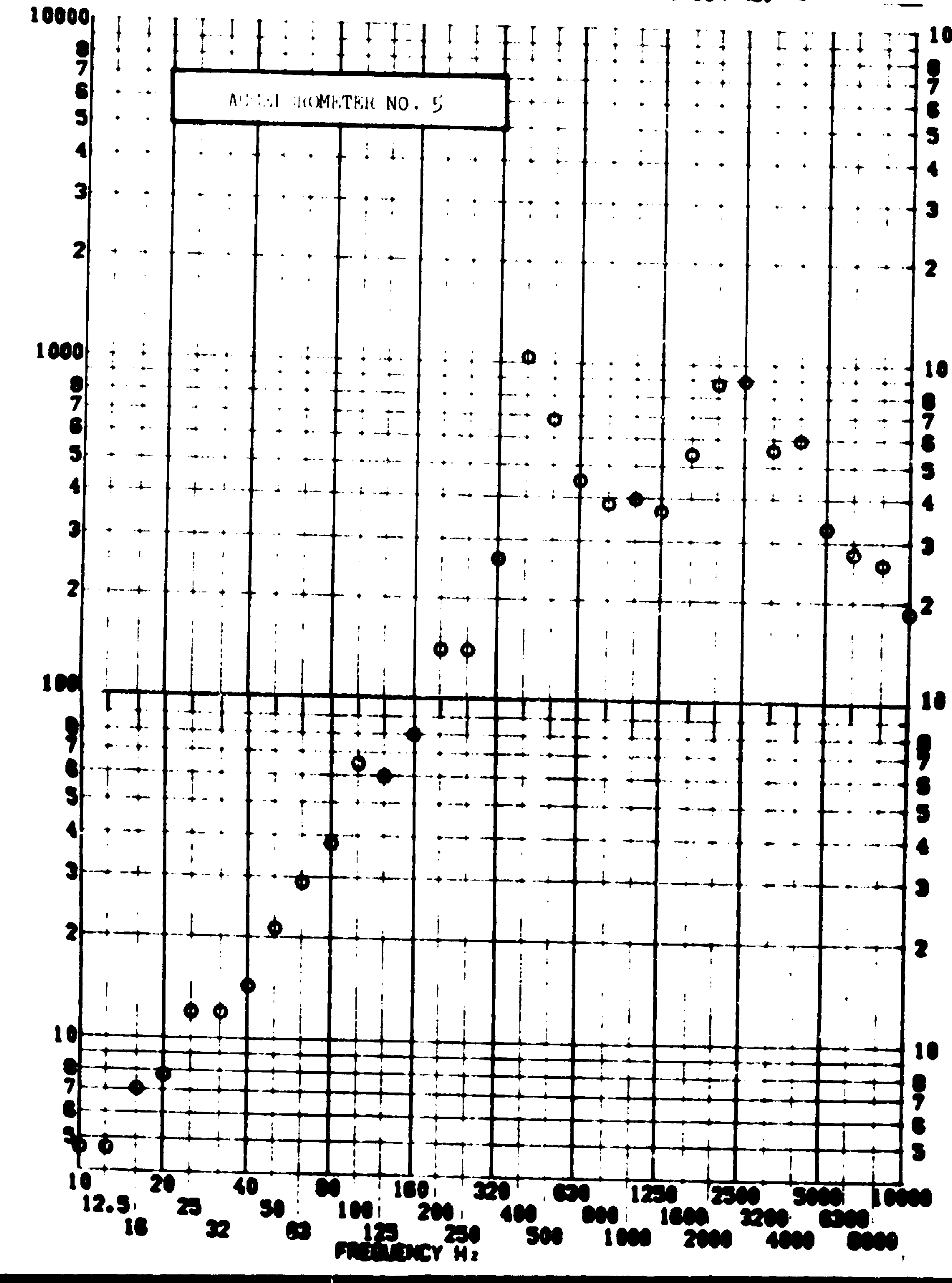
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.1.9

TEST ITEM 353-283
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1

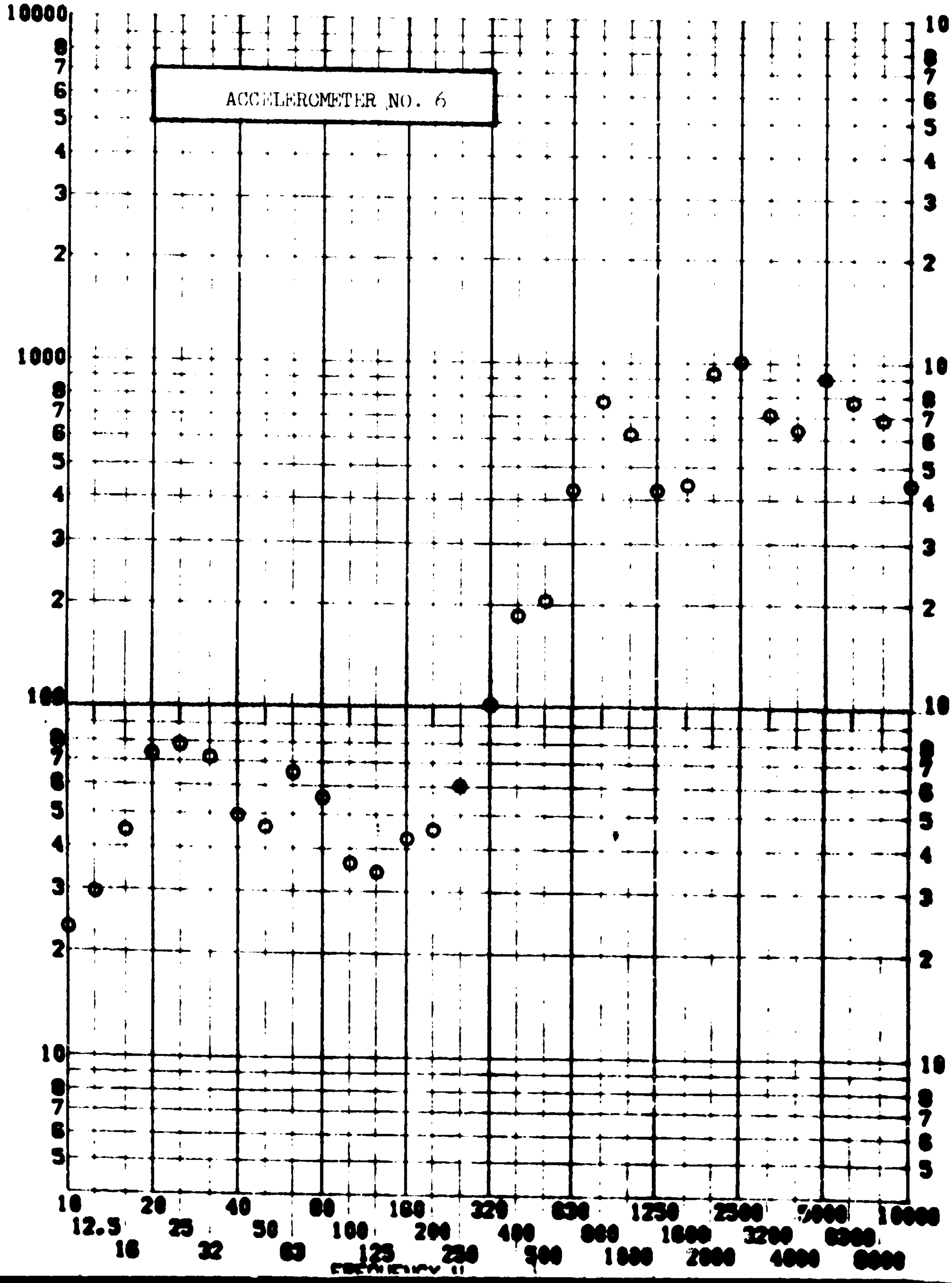


SHOCK TEST ANALYSIS DATA SHEET II.E.1.10

TEST ITEM 353-284
SERIAL NO.
SHOCK AXIS TANGENTIAL

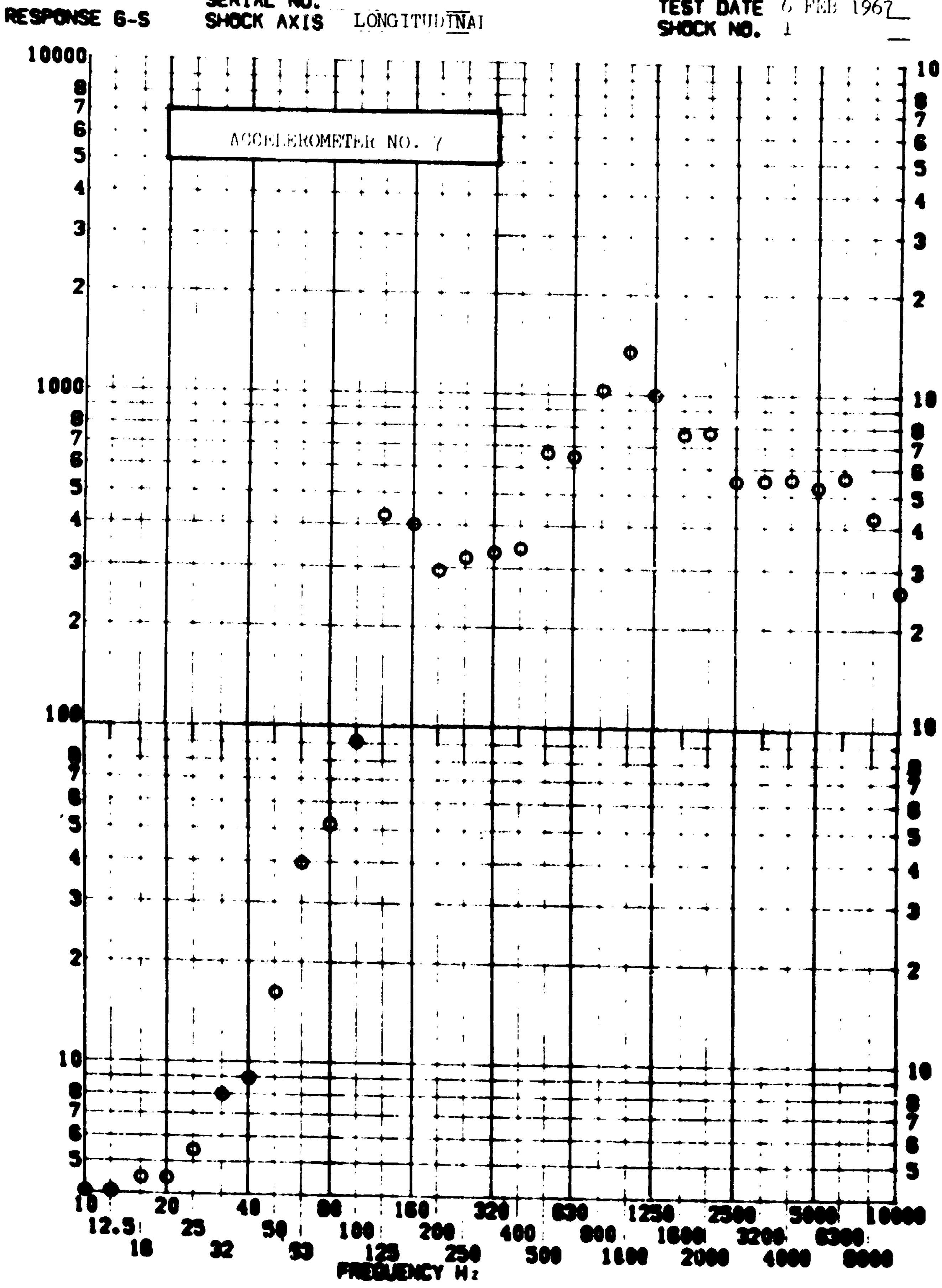
PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.1.11

TEST ITEM 353-285 PART NO. EQUIPMENT
SERIAL NO. TEST DATE 6 FEB 1967
SHOCK AXIS LONGITUDINAL SHOCK NO. 1

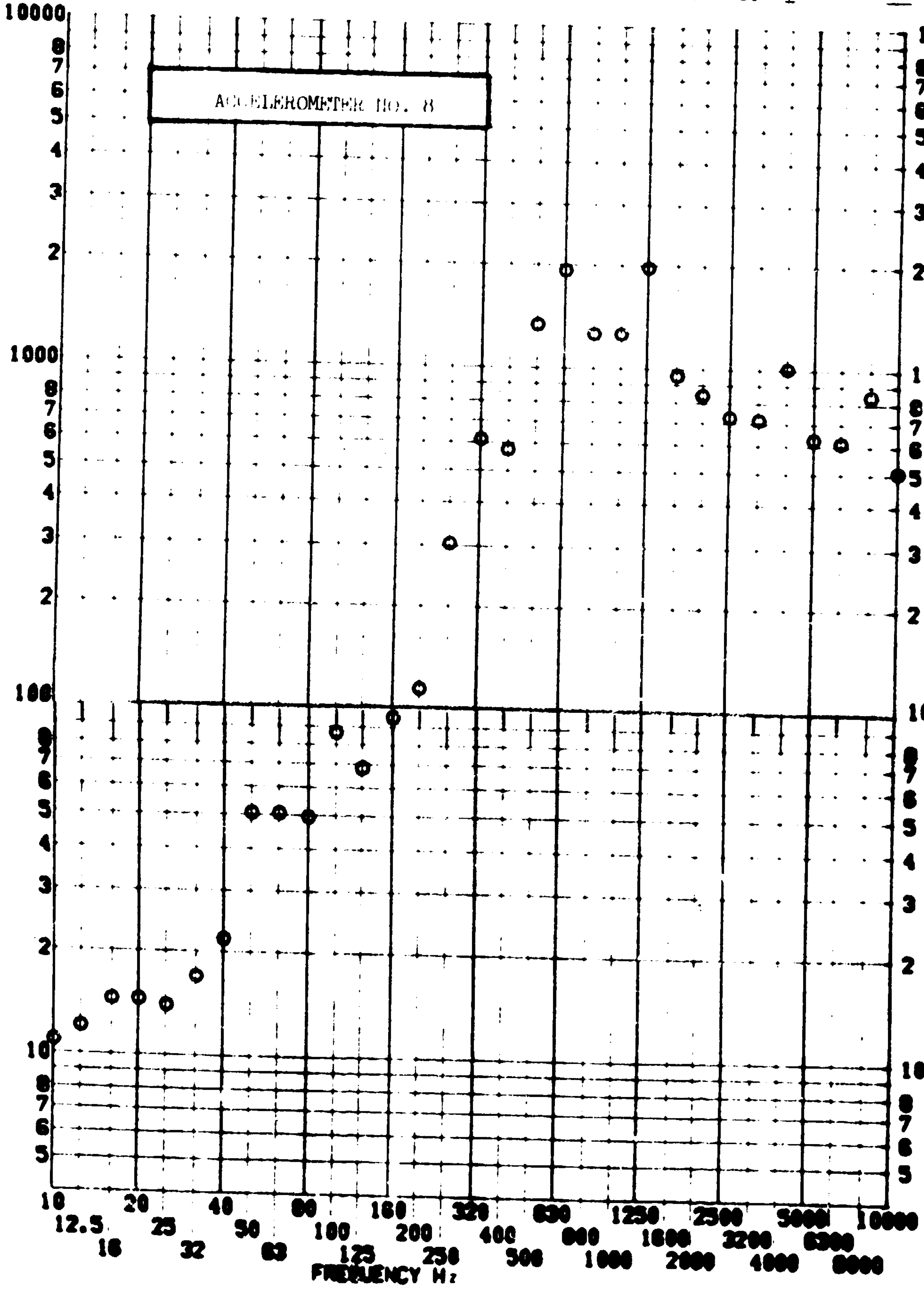


SHOCK TEST ANALYSIS DATA SHEET II.E.1.12

TEST ITEM 353-286
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1

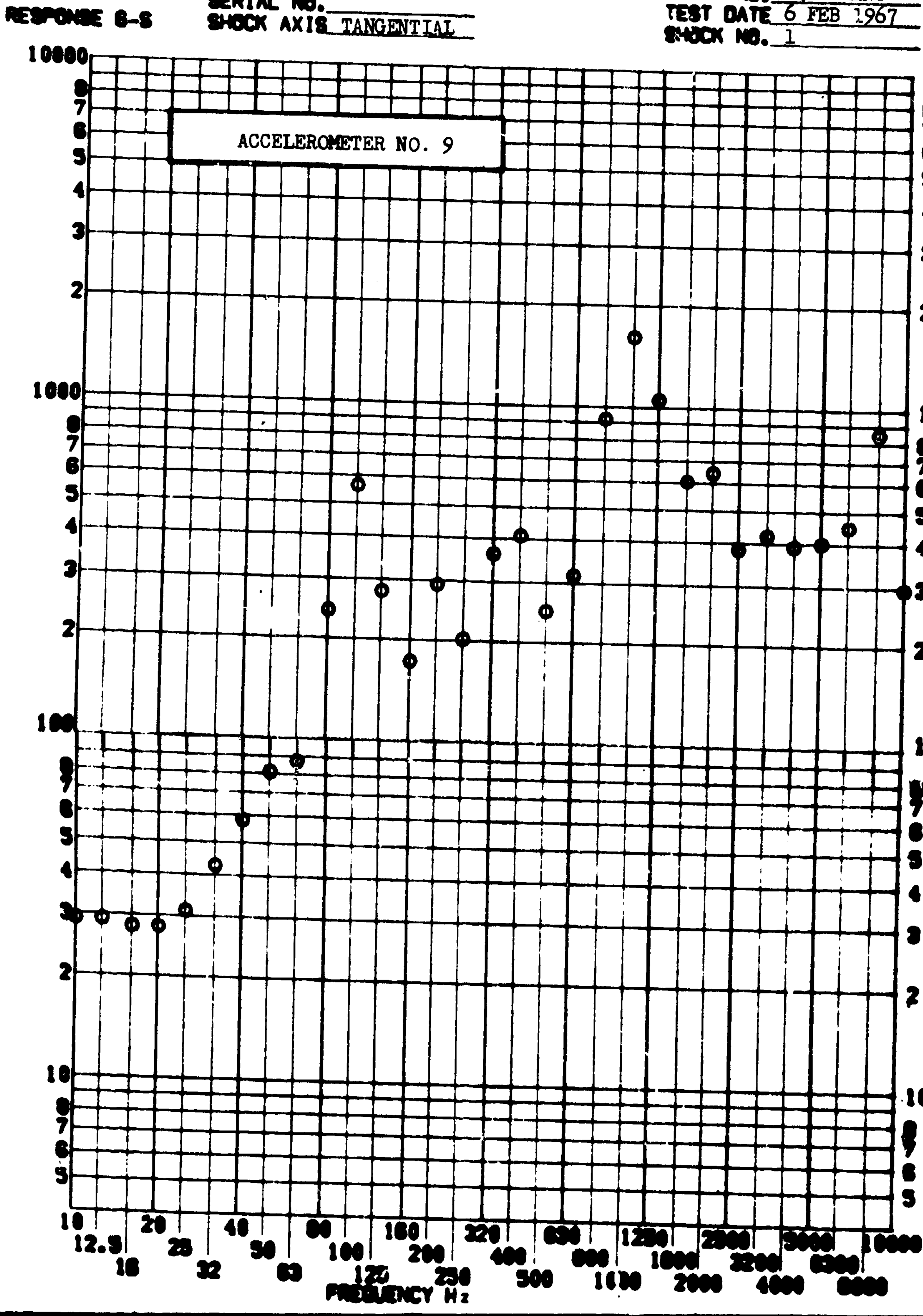
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.1.13

TEST ITEM 353-287
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1

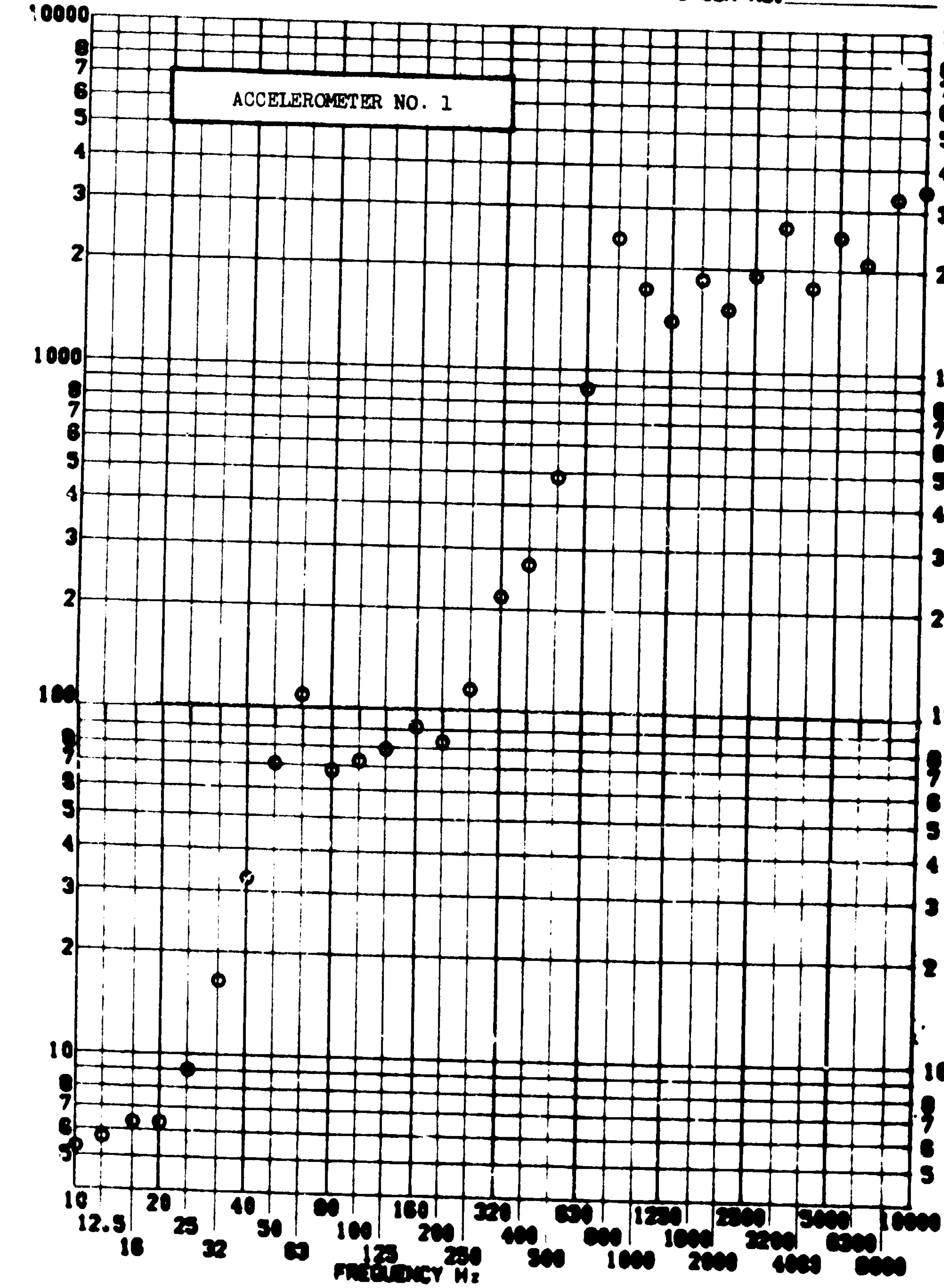


SHOCK TEST ANALYSIS DATA SHEET II.E.1.14

TEST ITEM 353-288
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 2

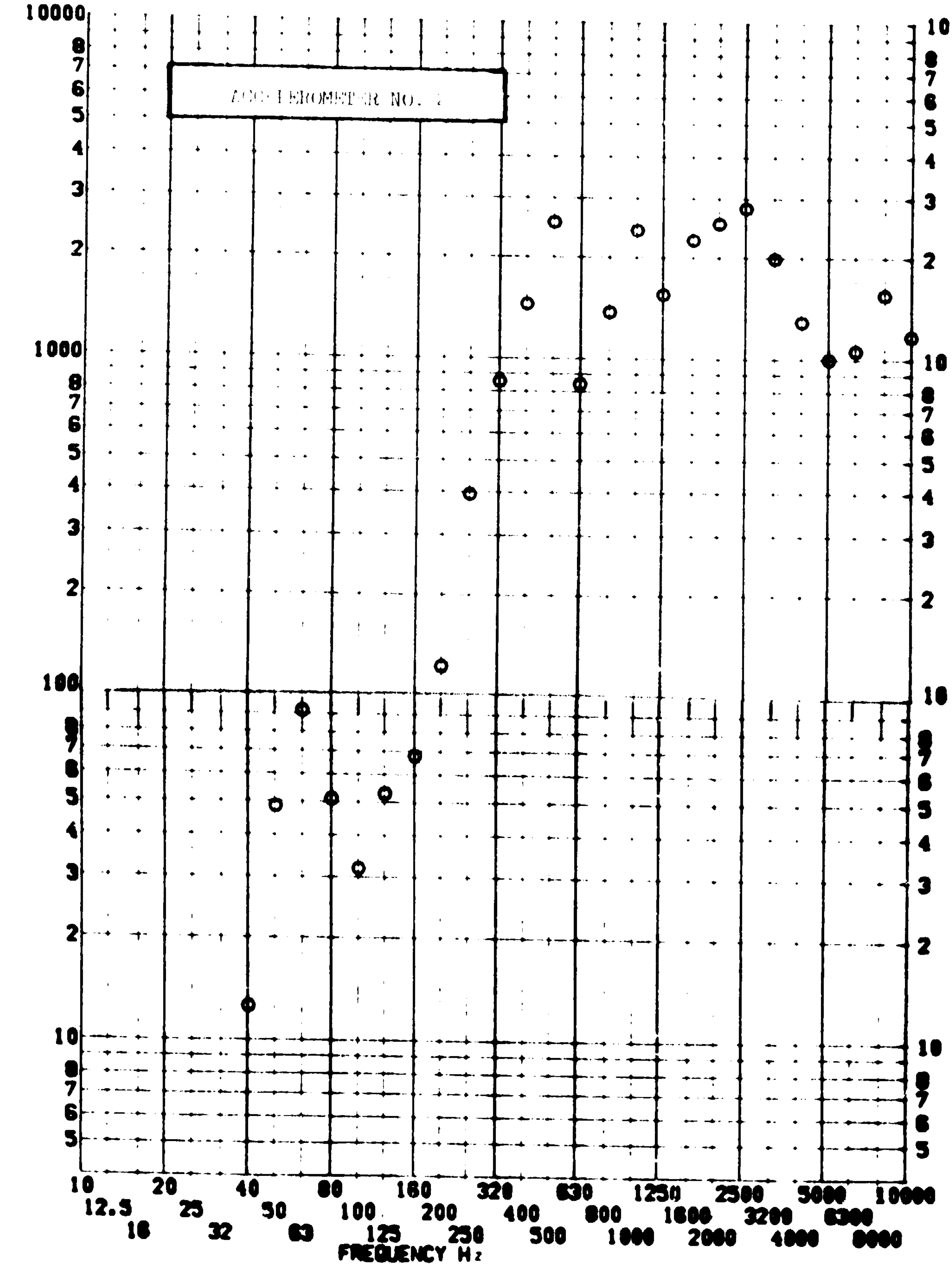
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM 353-287
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 2

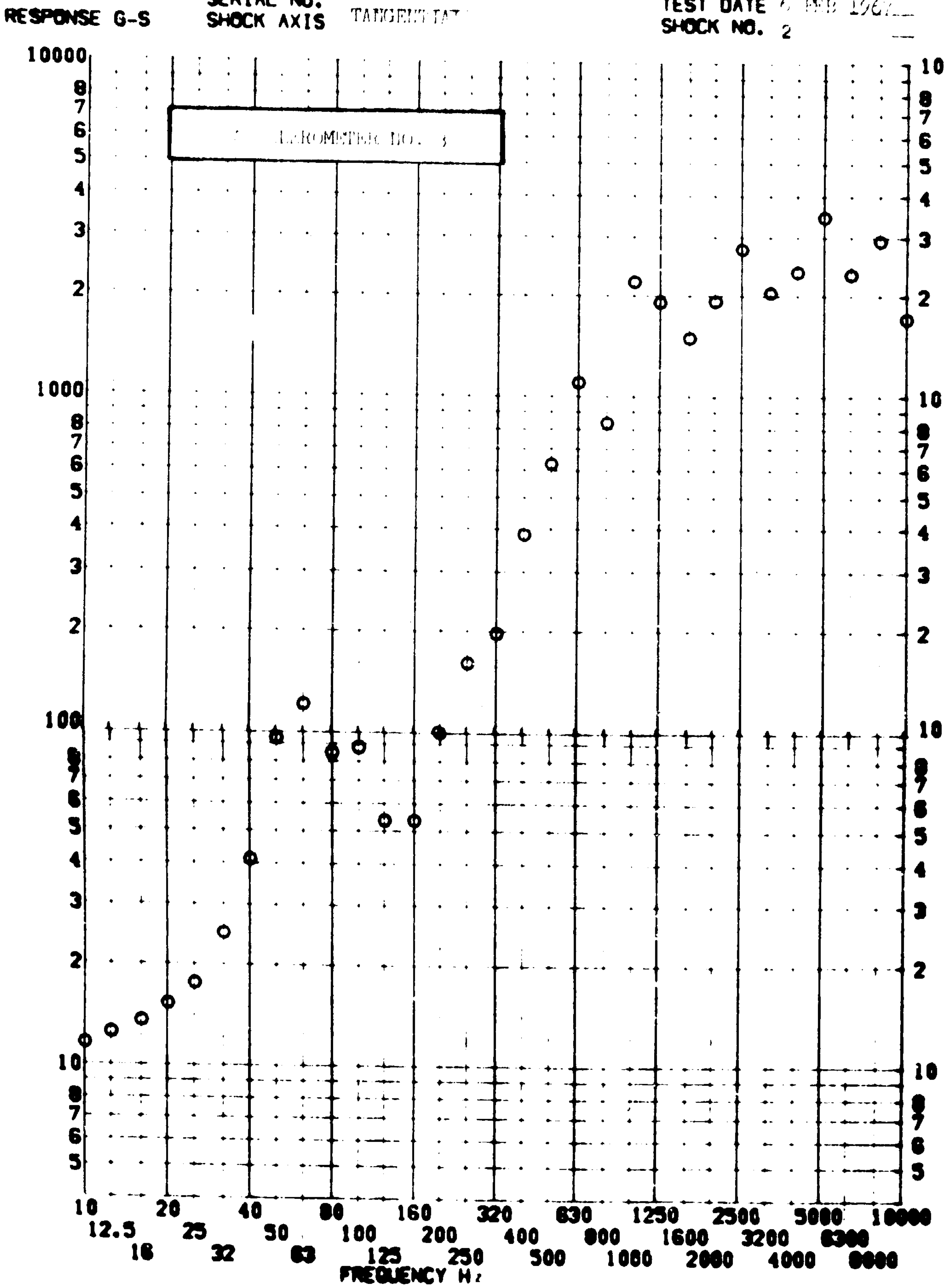


SHOCK TEST ANALYSIS DATA SHEET

II.E.1.16

TEST ITEM 353-2[illegible]
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 2

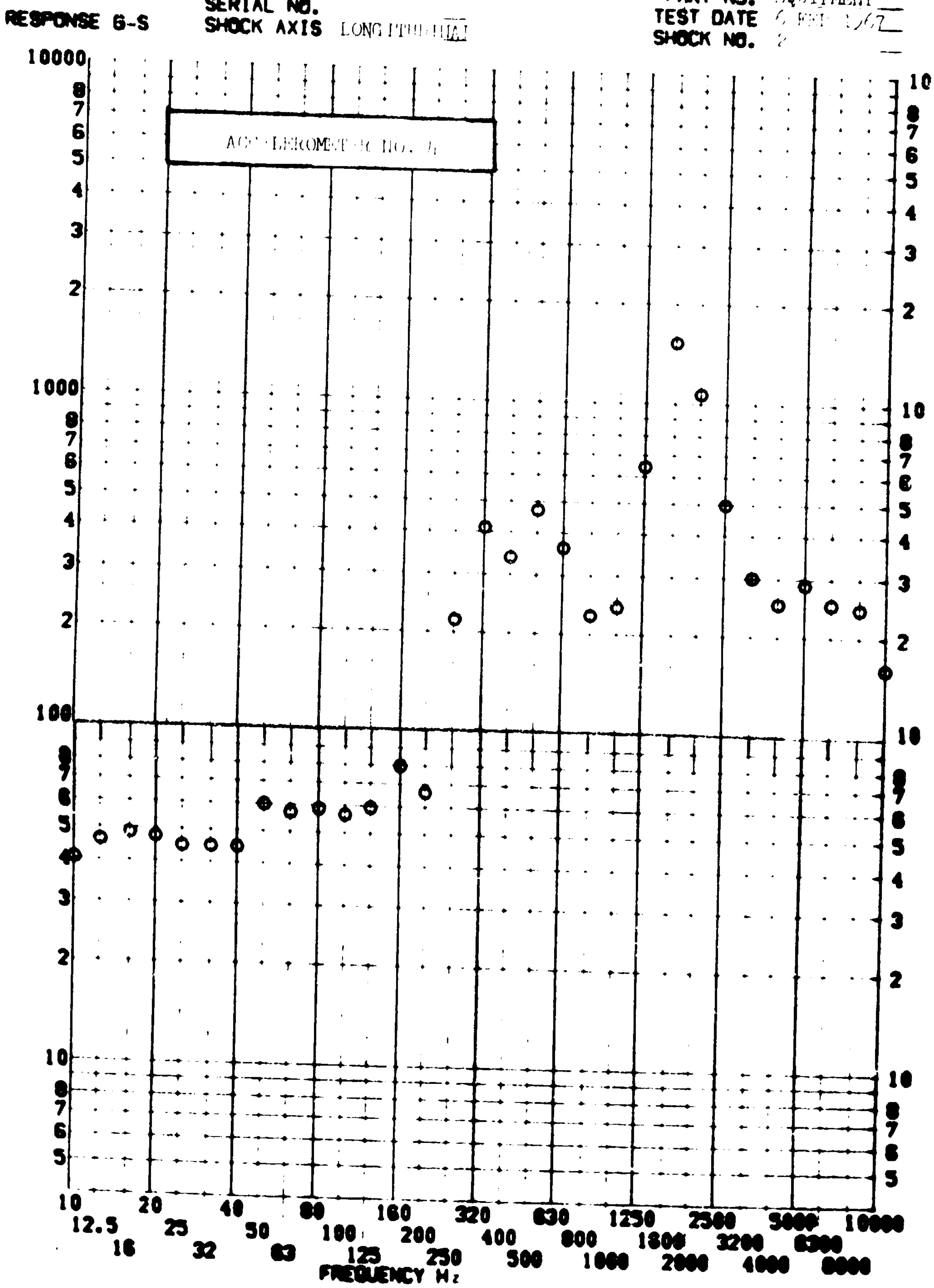


SHOCK TEST ANALYSIS DATA SHEET

II.E.1.17

TEST ITEM 353-221
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 2

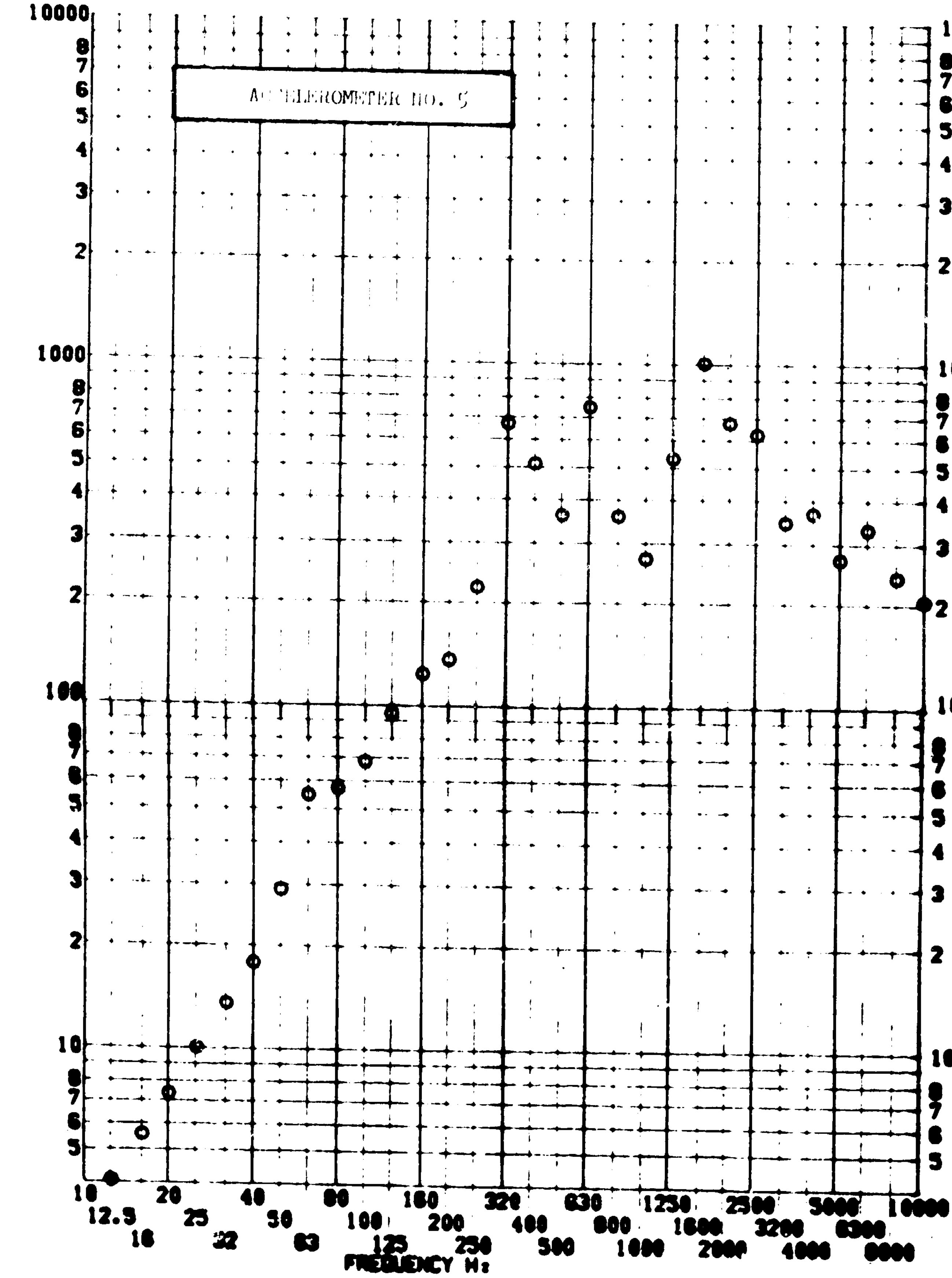


SHOCK TEST ANALYSIS DATA SHEET

II.E.1.18

TEST ITEM 353-292
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 2

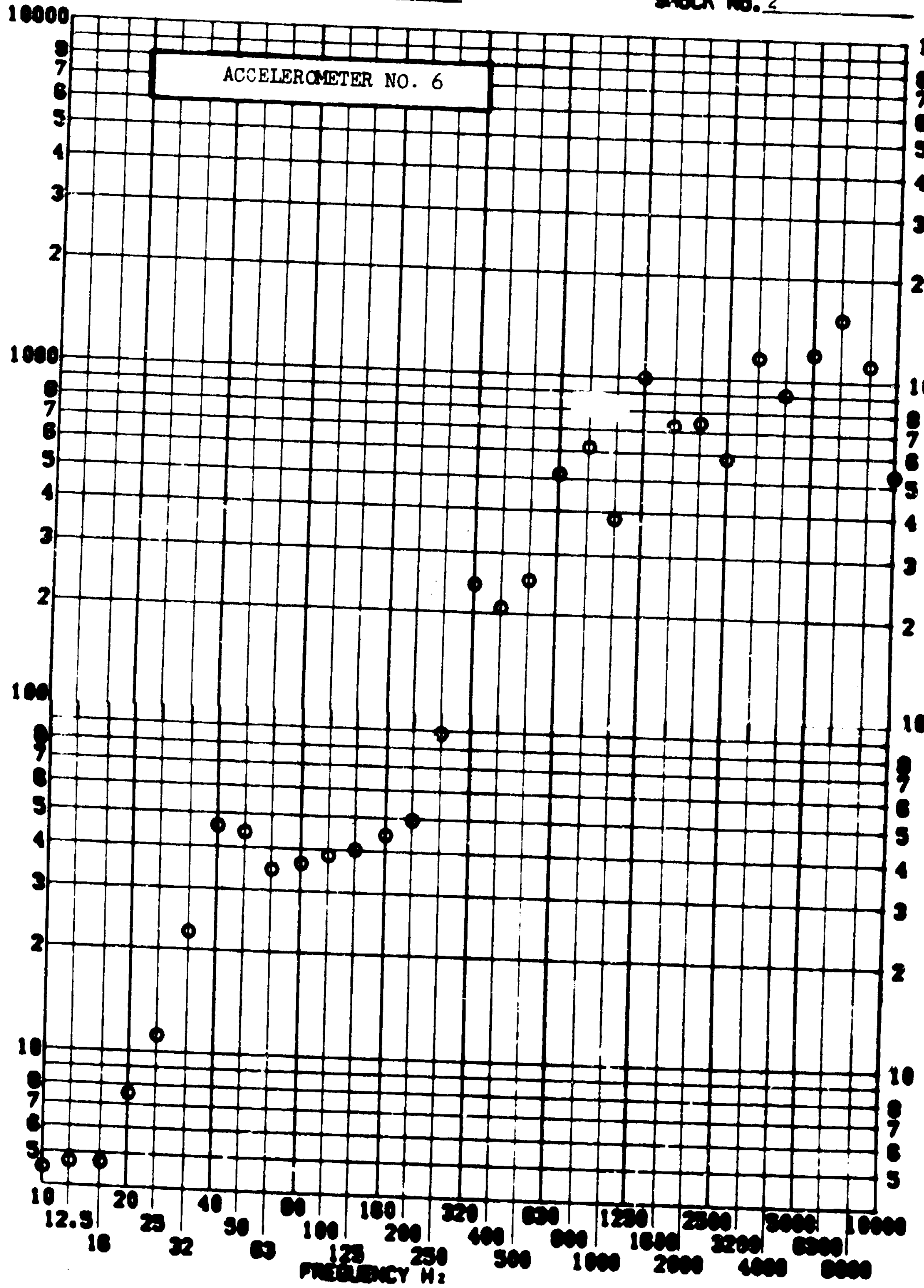


SHOCK TEST ANALYSIS DATA SHEET II.E.1.19

TEST ITEM 353- 293
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 2

RESPONSE G-S



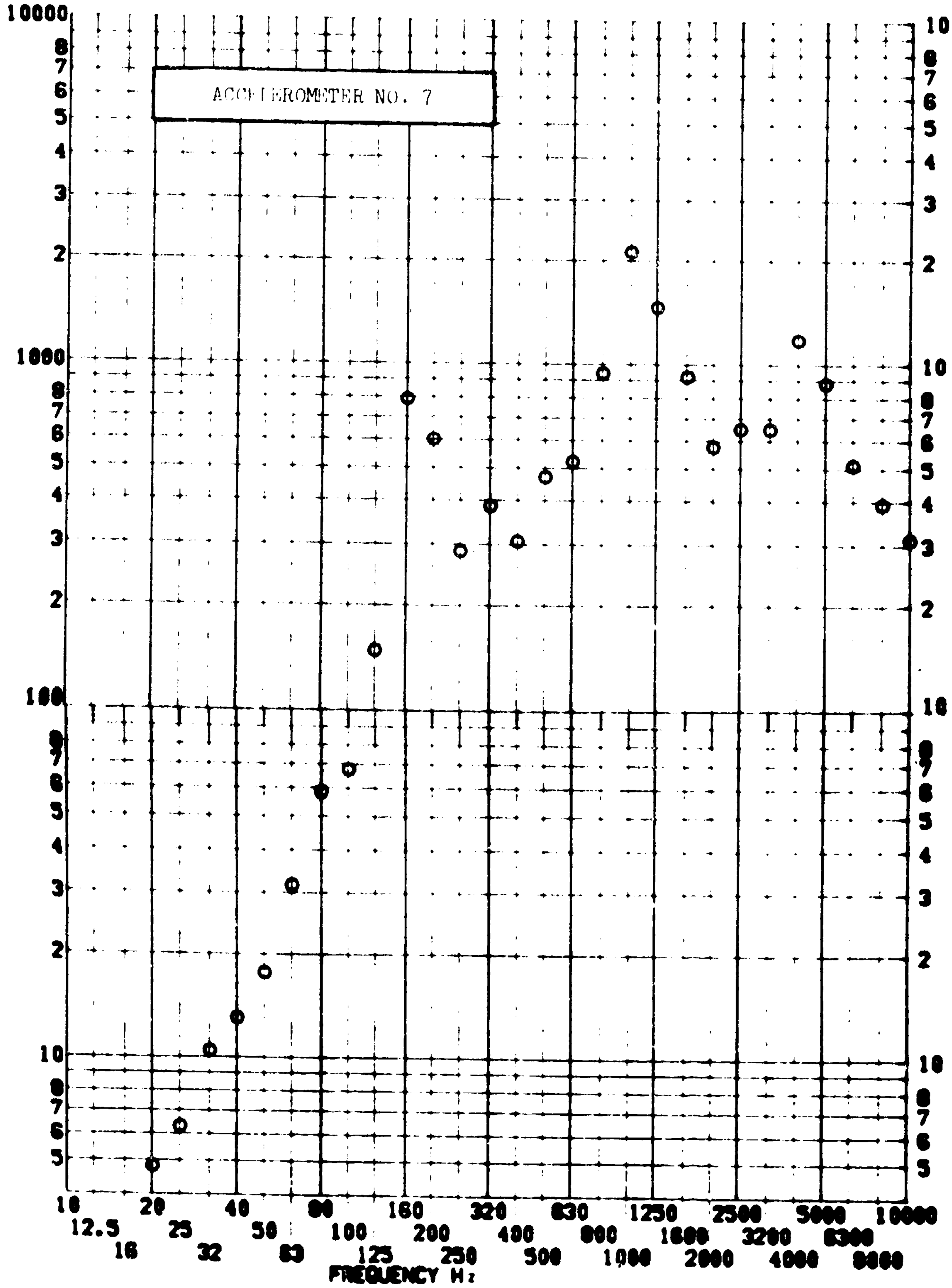
SHOCK TEST ANALYSIS DATA SHEET

II.E.1.20

TEST ITEM 353-29L
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 2

RESPONSE G-S

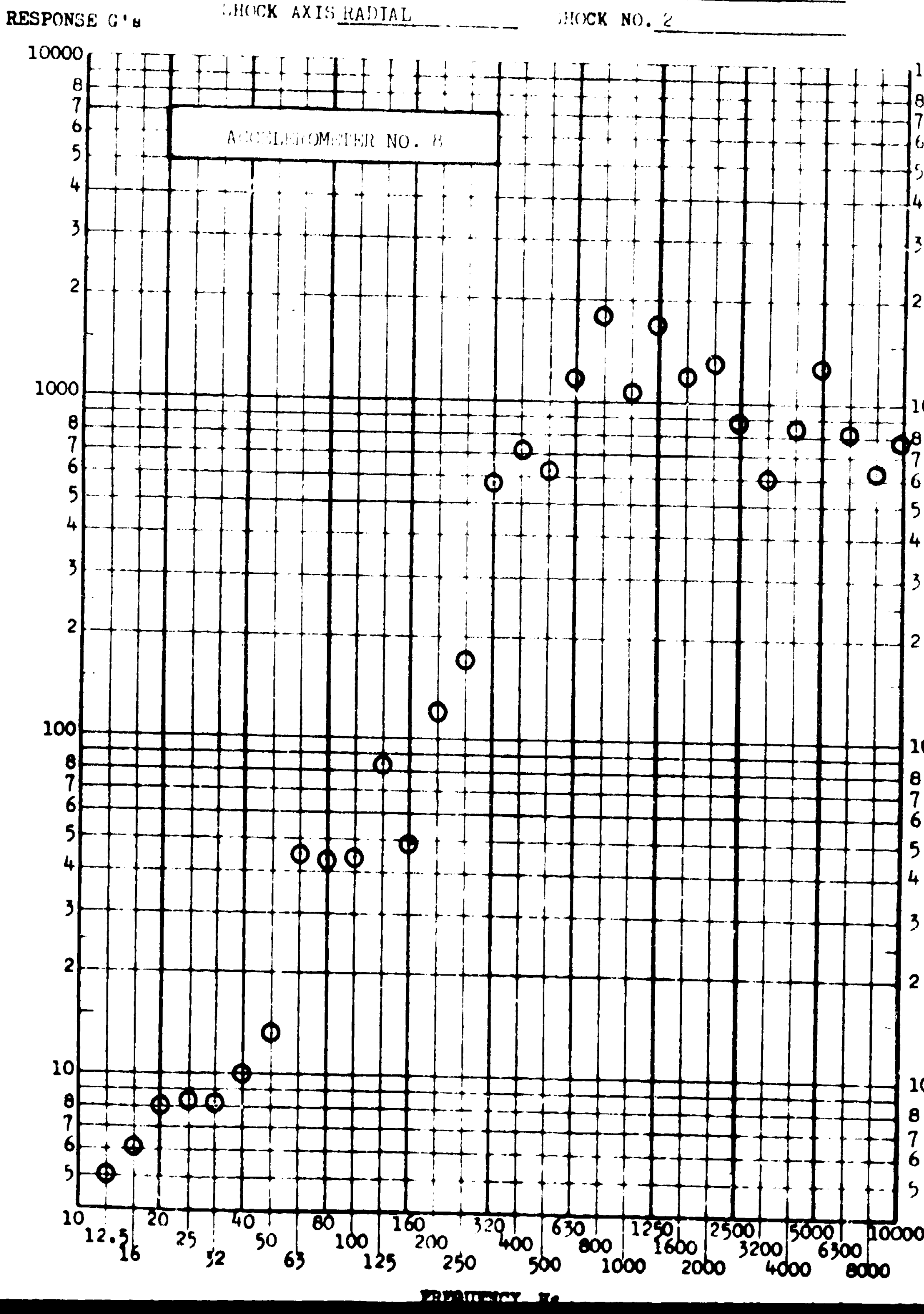


SHOCK TEST ANALYSIS DATA SHEET II.E.1.21

TEST ITEM 353-295 PART NO. EQUIPMENT

SERIAL NO. ________ TEST DATE 6 Feb 1967

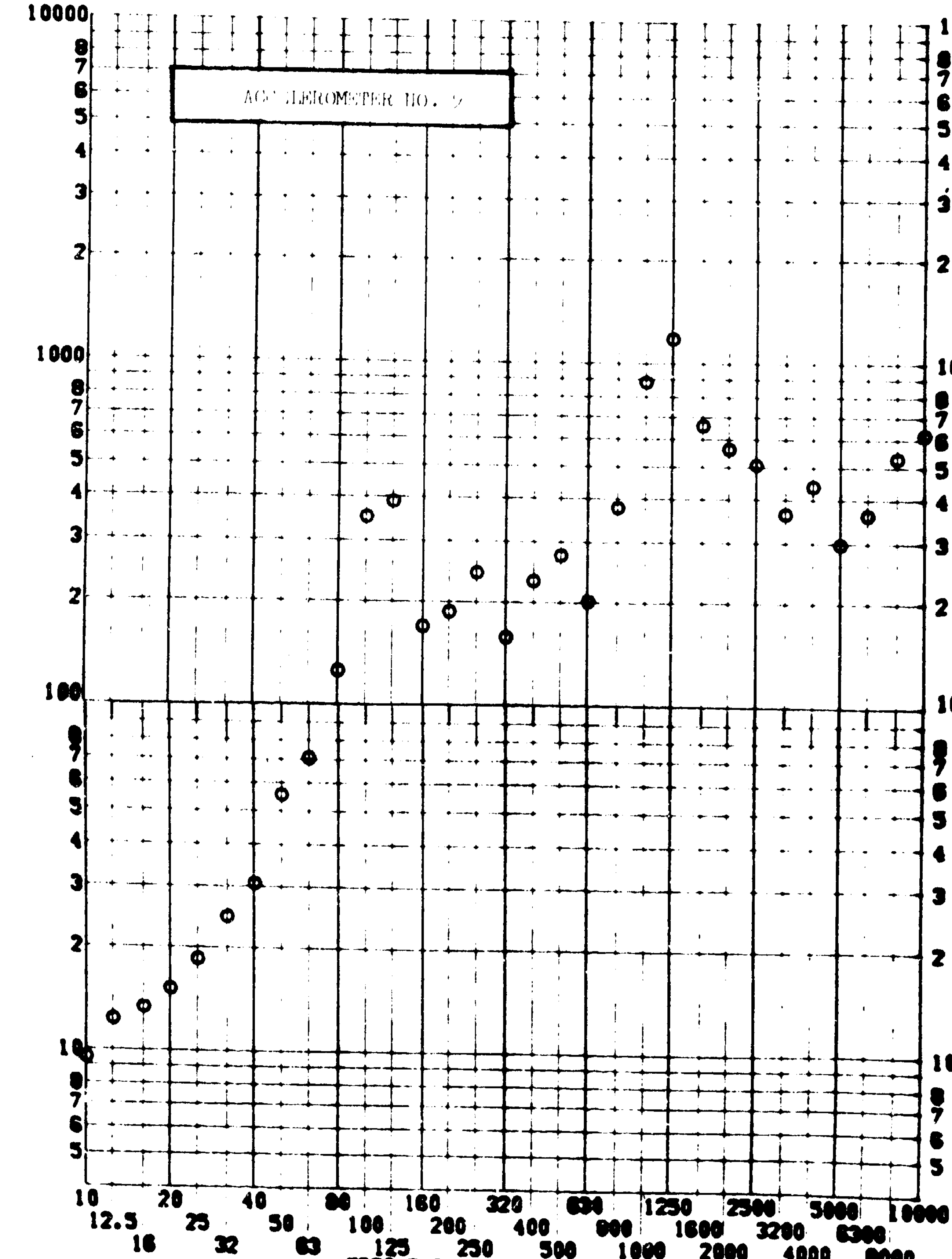
SHOCK AXIS RADIAL SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.1.22

TEST ITEM 353-296
SERIAL NO.
SHOCK AXIS TANGENTIAL

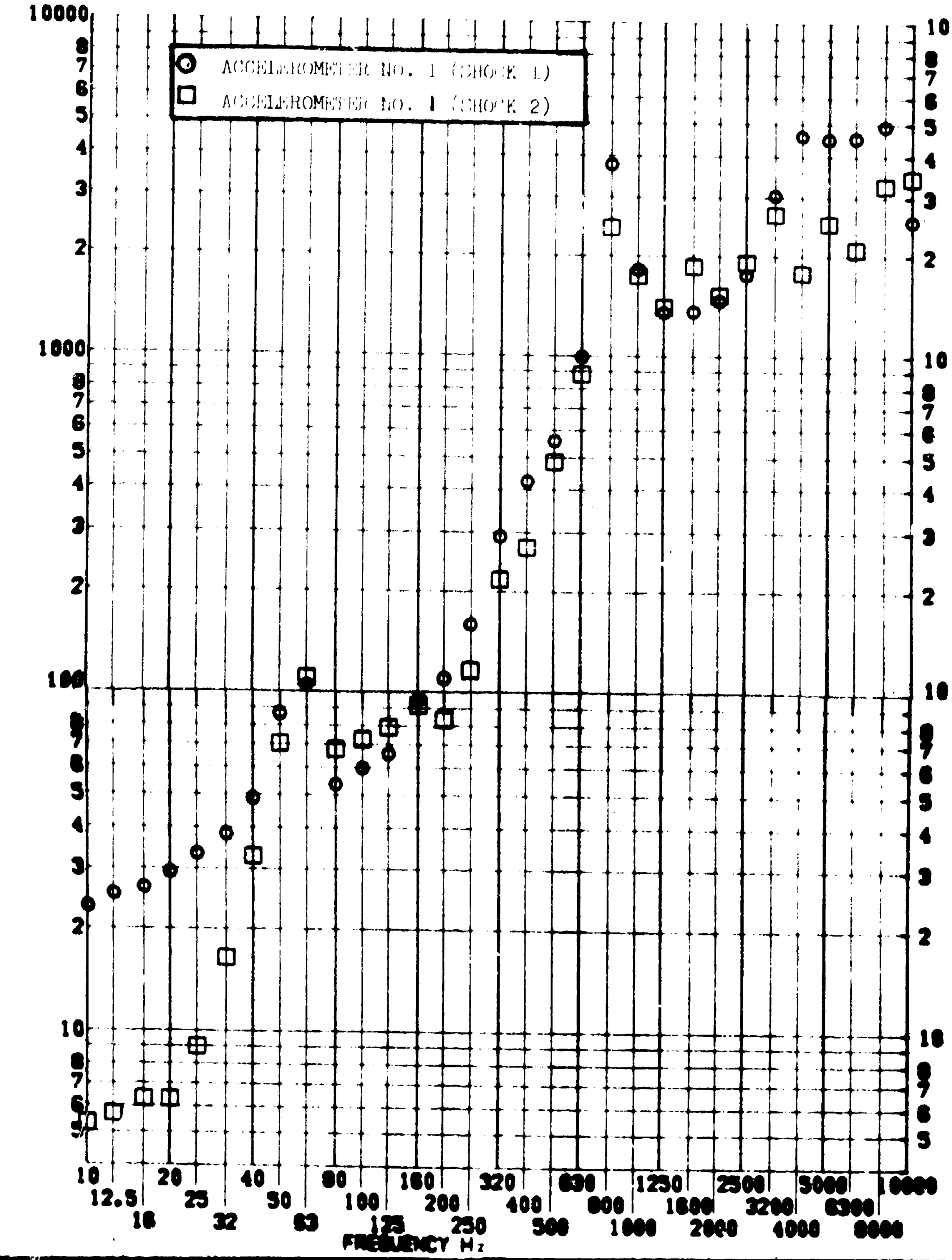
PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.1.23

TEST ITEM 353-279,280
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 1 & 2

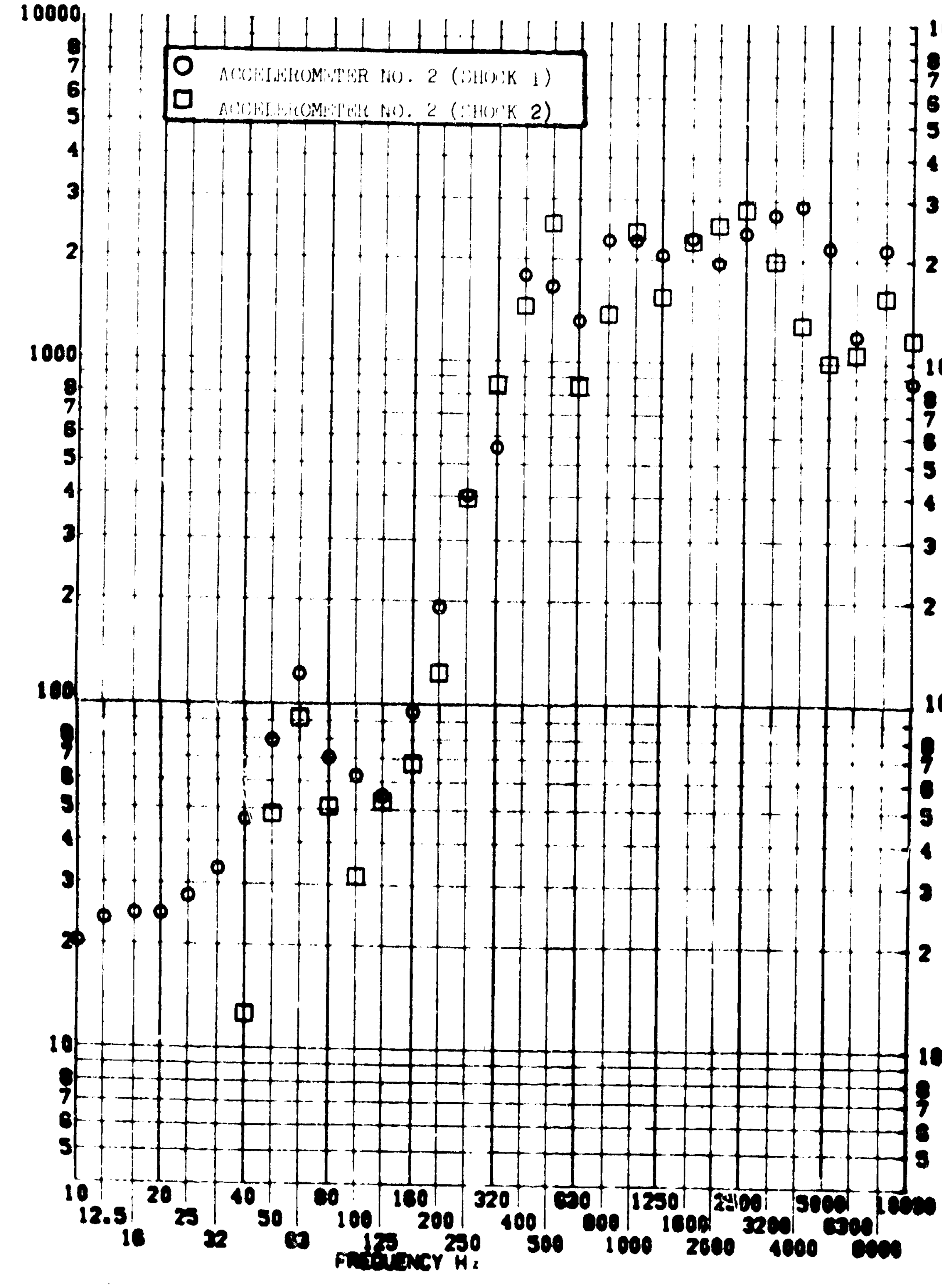


SHOCK TEST ANALYSIS DATA SHEET

II.E.1.24

TEST ITEM 353-280,289
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 1 & 2

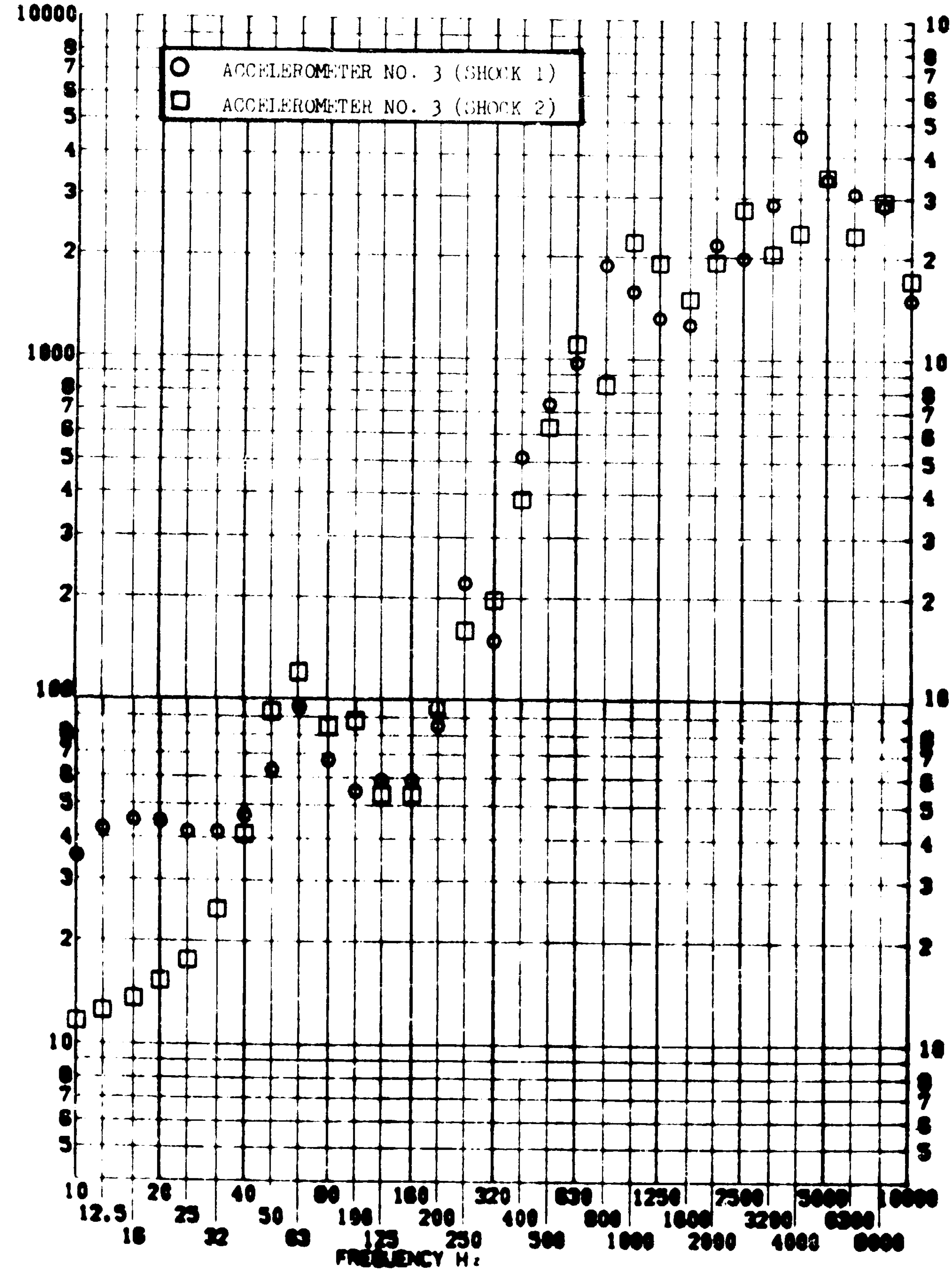


SHOCK TEST ANALYSIS DATA SHEET II.E.1.25

TEST ITEM 353-281,290
SERIAL NO.
SHOCK AXIS TANGENTIAL

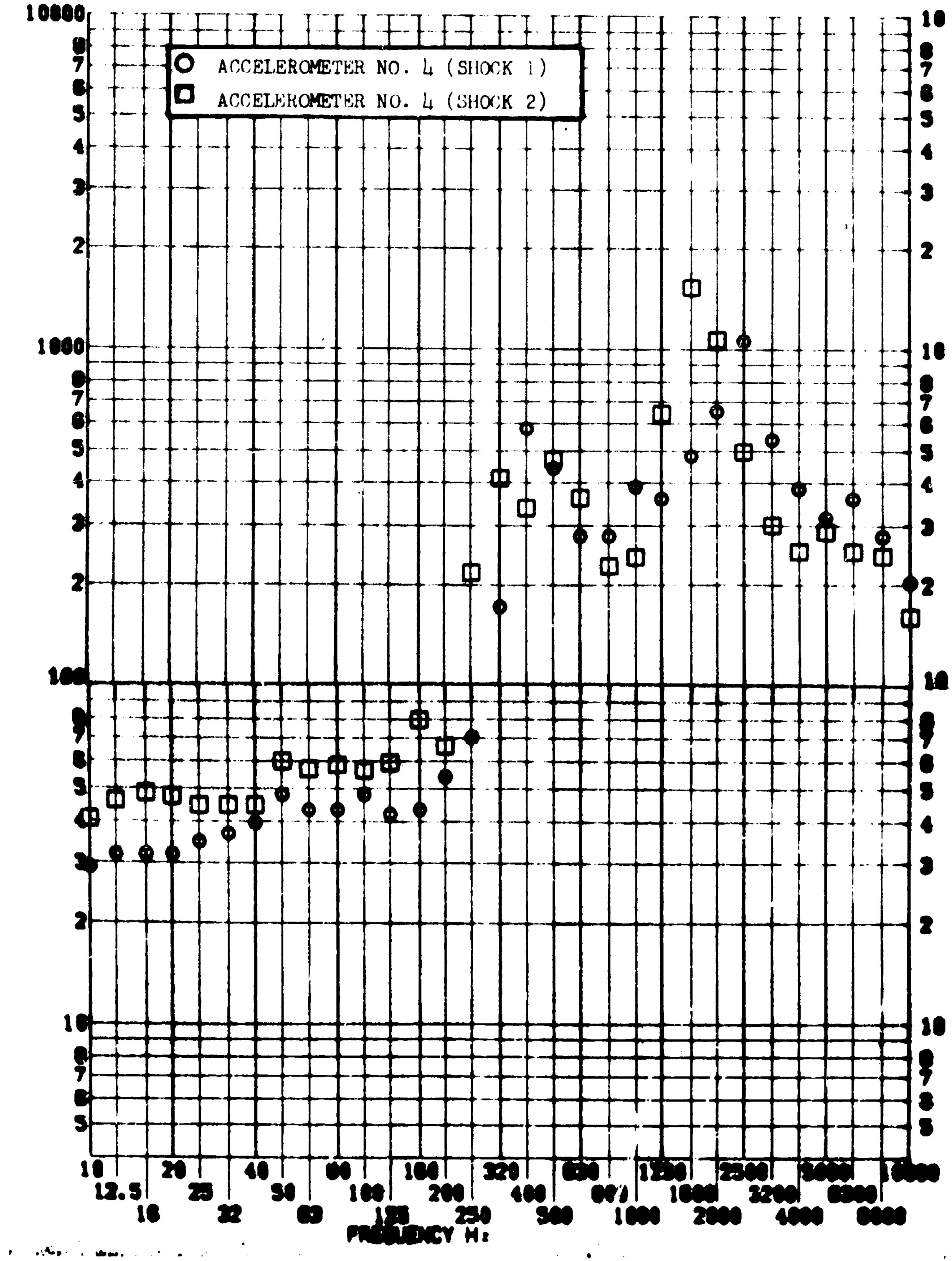
PART NO. STRUCTURE
TEST DATE 6 FEB 1967
SHOCK NO. 1 & 2

ESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.1.26

TEST ITEM 353-282,291 PART NO. EQUIPMENT
SERIAL NO. TEST DATE 6 FEB 1967
RESPONSE G-S SHOCK AXIS LONGITUDINAL SHOCK NO. 1 & 2

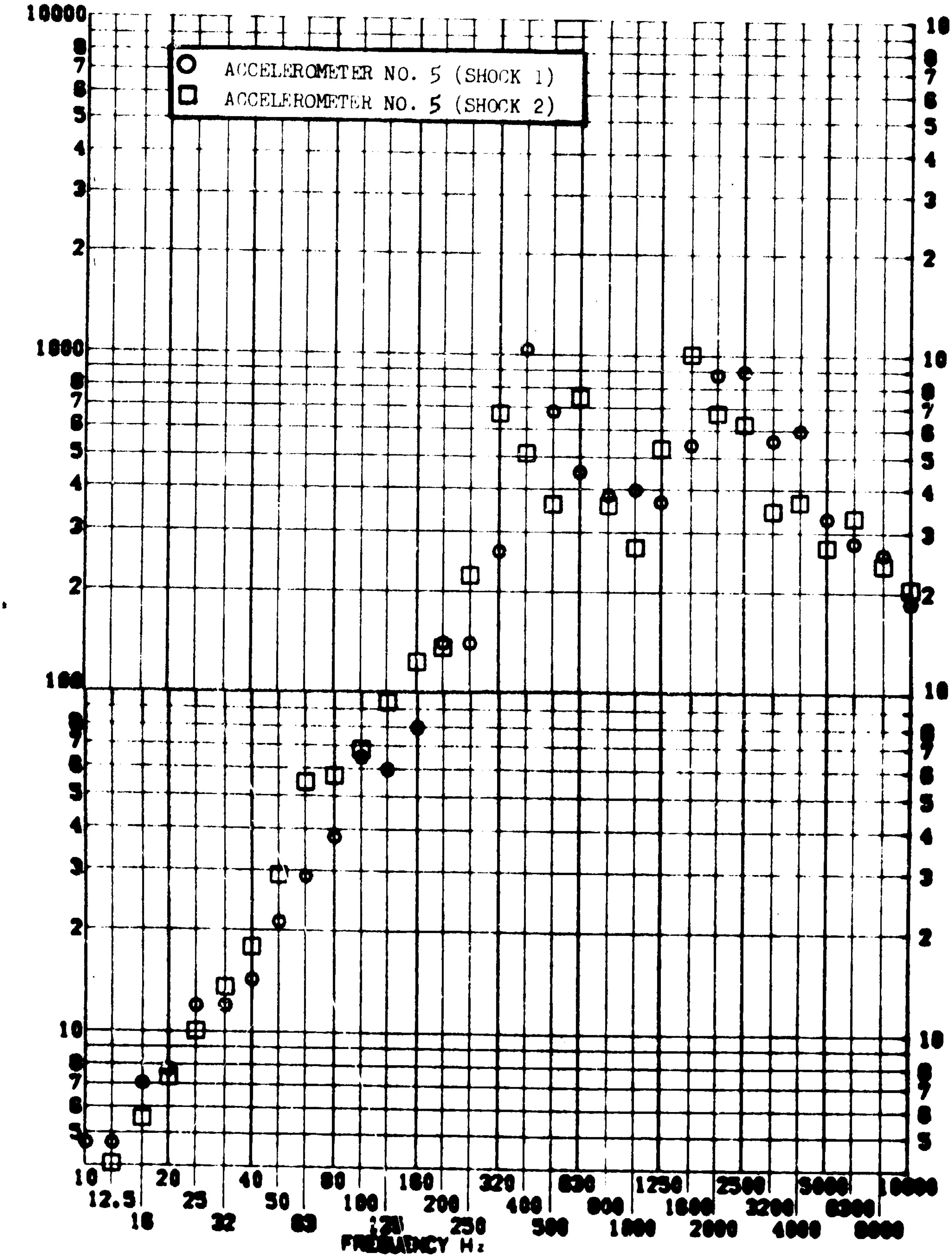


SHOCK TEST ANALYSIS DATA SHEET II.E.1.27

TEST ITEM 353-282,292
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1 & 2

RESPONSE G-S

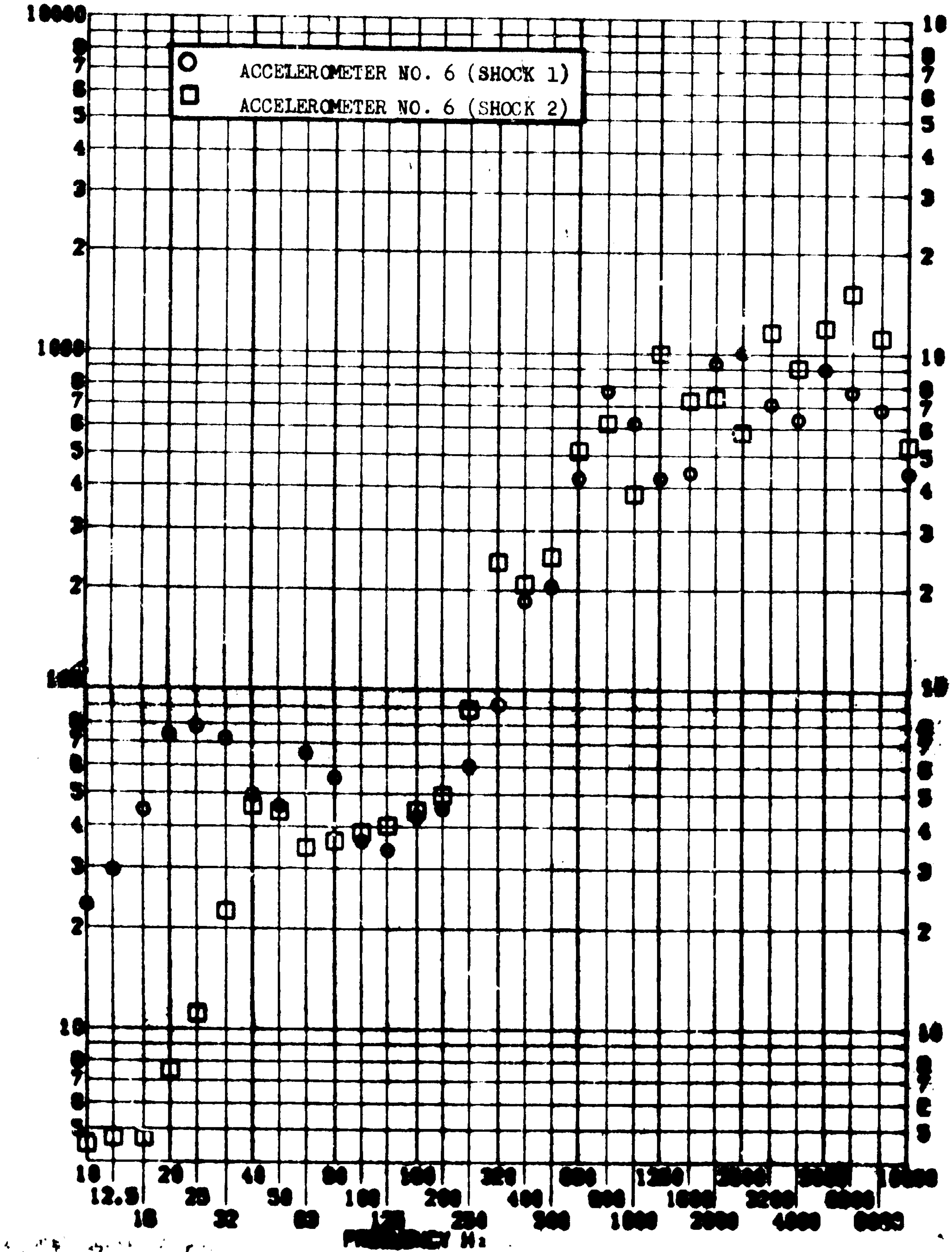


SHOCK TEST ANALYSIS DATA SHEET

II.E.1.28

TEST ITEM 353-284,293
SERIAL NO.
SHOCK AXIS TANGENTIAL

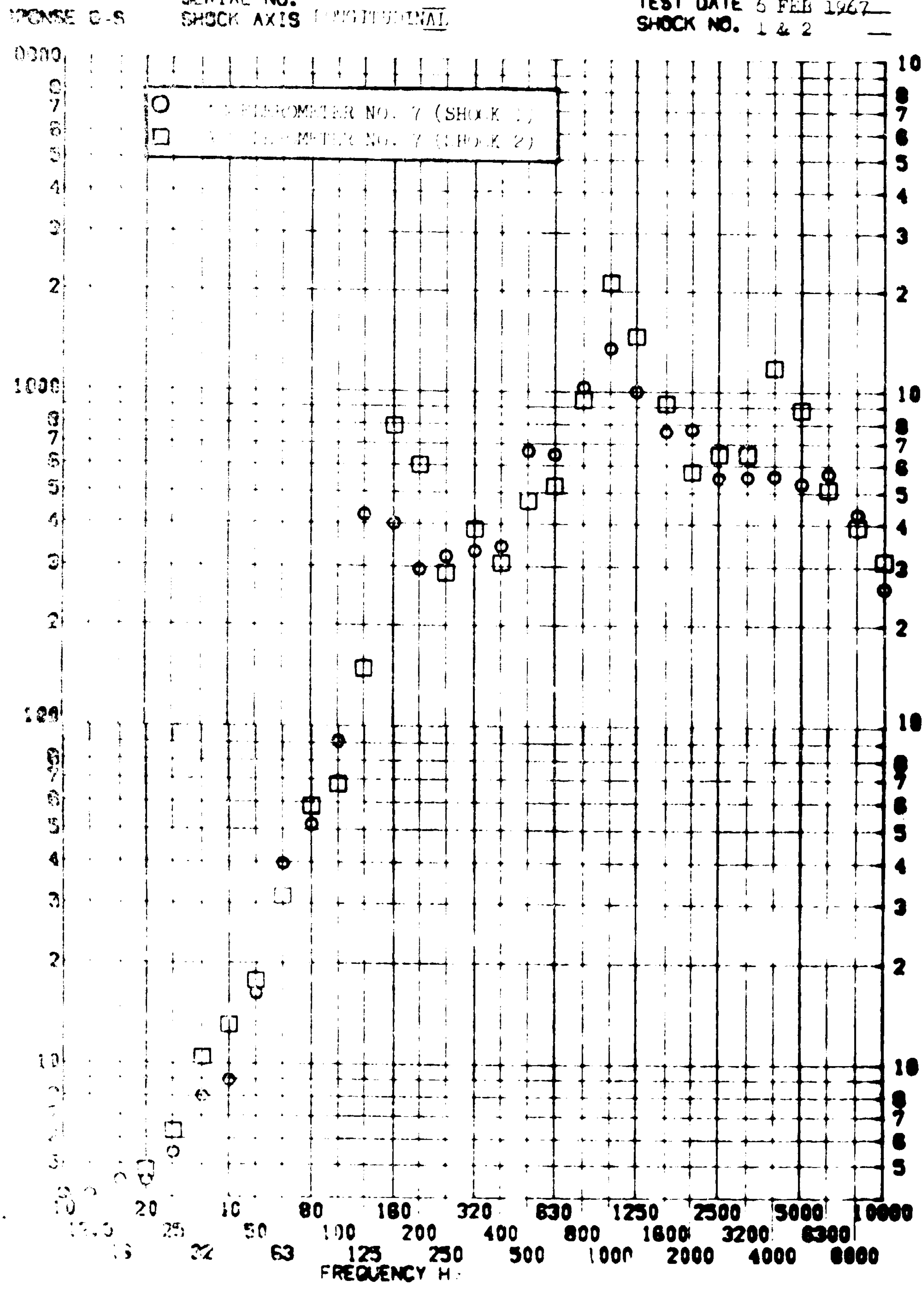
PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.1.29

TEST ITEM 353-285,294
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1 & 2

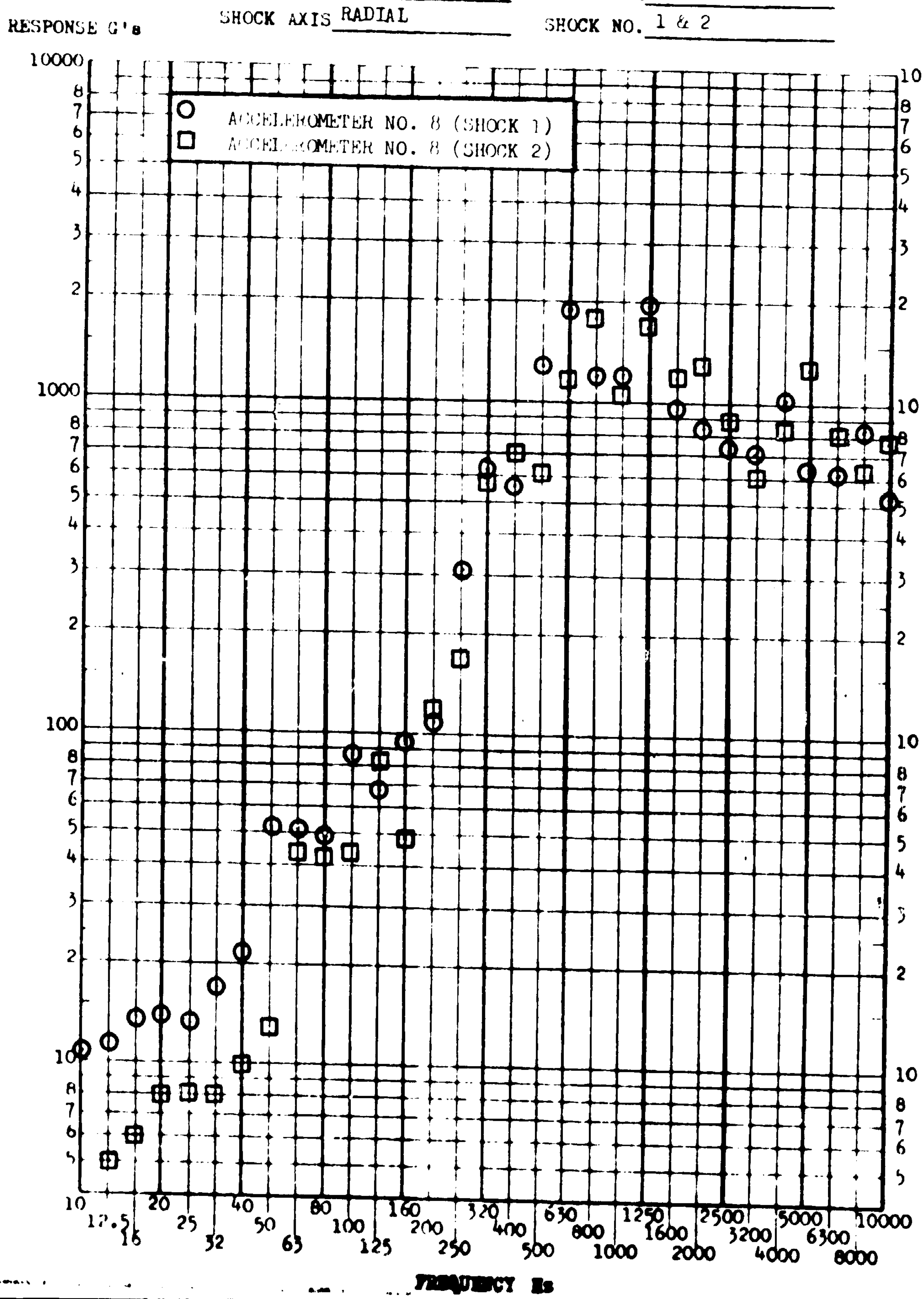


SHOCK TEST ANALYSIS DATA SHEET II.E.1.30

TEST ITEM 353-286.295 PART NO. EQUIPMENT

SERIAL NO. ____ TEST DATE 6 FEB 1967

SHOCK AXIS RADIAL SHOCK NO. 1 & 2

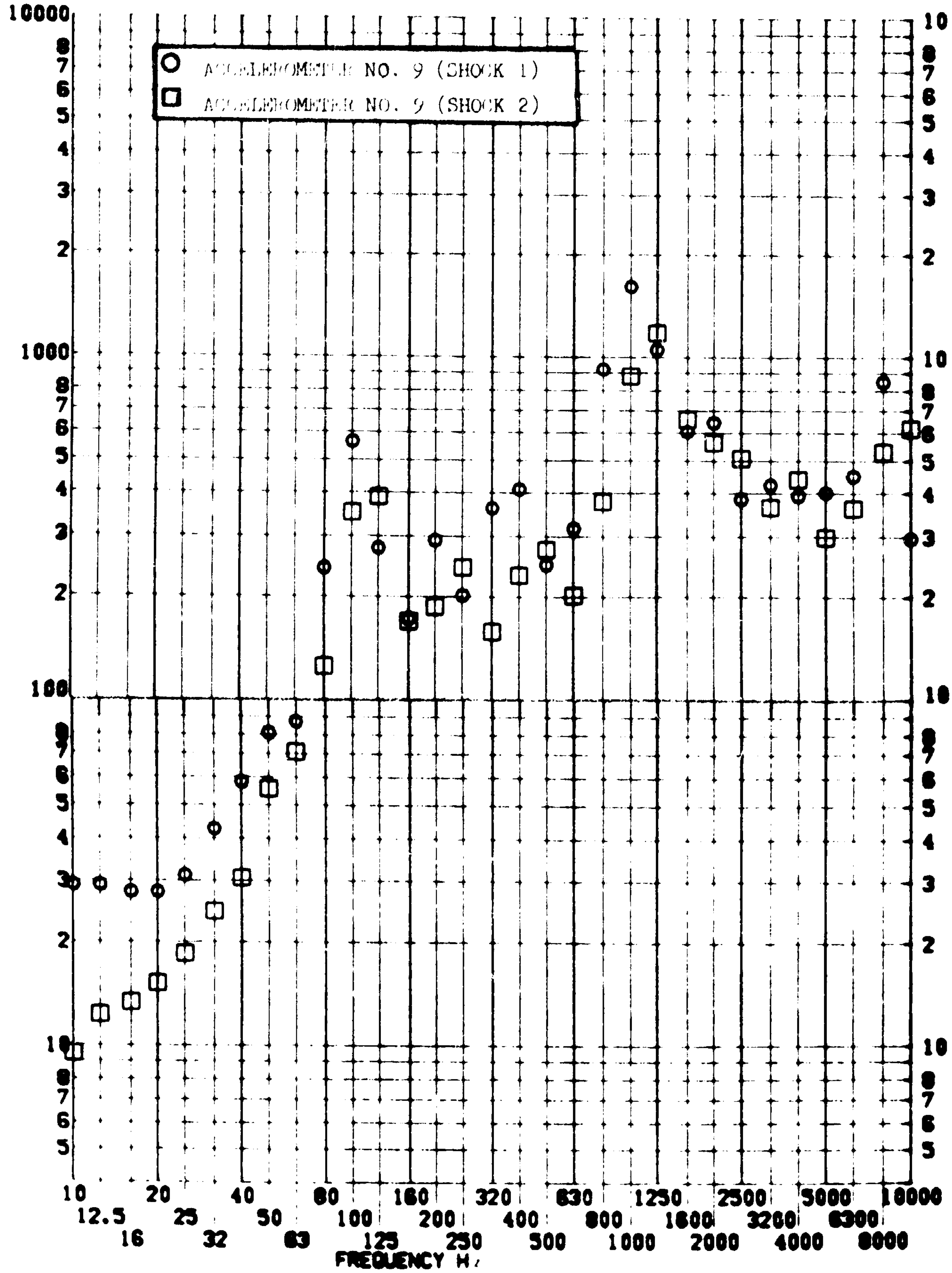


SHOCK TEST ANALYSIS DATA SHEET II.E.1.31

TEST ITEM 353-287,296
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. EQUIPMENT
TEST DATE 6 FEB 1967
SHOCK NO. 1 & 2

RESPONSE G-S



SECTION NO. II.E.2

REPORT NO. 456

SUBJECT:

ELECTRONIC BOX TESTS ON BARREL TESTER

SECTION II.E.2

SUMMARY

This report covers the simultaneous testing of three electronic boxes mounted on 3 supporting brackets on the barrel tester second bay removable panels. A fourth box was mounted on the remaining removable panel but its data was not recorded in this test.

One of the three boxes monitored in the test was hard mounted (18.5 pound box) and contained a set of three internal accelerometers located by the manufacturer.

The two other boxes were mounted on vibration isolators made from silicon elastomer. A 7.5 pound box had one external set of three accelerometers while a six pound box had three sets of three accelerometers: one on the removable barrel panel, one on the box and the third set internally located by the manufacturer.

Standard .19 inch magnesium-thorium separation plates and 30 Gr MDF explosive charges were used for the two tests performed. Some recording difficulties were experienced in this test and five accelerometers gave questionable data. The boxes were rotated by 180 degrees for the second test.

All boxes survived the tests without failures of any kind.

In order to determine the attenuation provided by each box mounting, the envelope of each set of accelerometers is compared to that of the removable panel set. Substantial attenuation is evident in all cases at high frequencies while at frequencies below 200 cps, some amplification may occur.

This test provides some insight about the transmission of pyrotechnic shock through box mounting brackets and vibration isolators. Results of this kind add to the background of experimental data which is useful in predicting the attenuation which may be obtained with similar installations.

The simultaneous testing of several boxes provided a substantial cost savings during this program without decreasing the quality of the test environment.

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SECTION II.E.2

LIST OF FIGURES (Cont.)

SECTION II.E.2

REPEATABILITY

II.E.2.1 INTRODUCTION

Three electronic boxes, weighing respectively 7.5 pounds, 18.9 pounds and 6 pounds, were subjected to pyrotechnic qualification tests on the barrel tester. The 18.9 pound box was hard mounted, the two others were mounted on silicone elastomer vibration isolators. These boxes were attached with Z brackets to the barrel second bay removable panels in order to simulate the appropriate flight environment.

Two standard tests were performed with the boxes rotated 180 degrees for the second firing. The tests were carried out with 30 Gr MDF charges and .19 inch magnesium-thorium separation plates.

II.E.2.2 DISCUSSION AND ANALYSIS

II.E.2.2.1 Test Configuration and Instrumentation

A standard barrel tester as described in Section II.F.2 was used for this test. The general test arrangement is shown on Figure II.E.2.1. The box installation Z brackets were rivetted to the barrel second bay removable panels as shown on Figure II.E.2.2 which also shows a typical silicone elastomer vibration isolator.

Accelerometer B was used for standard test monitoring but the data is not presented in this section of the report.

The instrumentation included a total of fifteen accelerometers as detailed on Table II.E.2.1 and located as shown on Figure II.E.2.1. It will be noted that the sets of accelerometers (No. 7, 8 and 9, and 10, 11 and 12) were placed inside the boxes by their manufacturers. There is no available information regarding their exact location and mounting structures.

A summary of the tests performed is given on Table II.E.2.2.

Shock spectra for each accelerometer and each test are presented on Figure II.E.2.7 to II.E.2.36. Repeatability is shown on Figures II.E.2.37 to II.E.2.51 which compare the readings of each accelerometer for shock 1 and 2.

II.E.2.2.2 Technical Discussion

Upon completion of the test, inspection of the specimen showed that no failure occurred.

The test results were generally good but several accelerometer readings suffered from disturbances such that this data is questionable. Disturbances occurred mostly during the first firing, affecting accelerometers No. 6, 11, 12, 14 and 15. During the second firing, only accelerometers No. 6 and 15 were affected. The origin of these disturbances could not be ascertained. The data is presented here for the sake of completeness.

Reduction of the test data was performed on the UNIVAC 1108 after digitizing the analog tape.

II.E.2.2.3 Analysis

Since the test specimen survived the shocks without damage, two considerations are of interest:

a. Attenuation provided by the box mounting.
b. Repeatability of the environment provided by shock 1 and 2.

The attenuation provided by the box mounting is shown by comparing the environment at the removable panels (accelerometers 1, 2 and 3) with that measured on the boxes. Experience with the barrel tester has demonstrated that the environment at the removable panels is not significantly affected by similar masses and installations. Therefore, the readings of accelerometers 1, 2 and 3 can be used as a basis for comparison. Figures II.E.2.3 to II.E.2.6 show the relationship between the various groups of accelerometers on the basis of shock environment envelopes for the more reliable data of shock 2.

Figure II.E.2.3 shows the shock level reduction provided by vibration isolators to the 6 pound box. It will be noted that accelerometer 5 data is questionable as well as accelerometers 4 and 6 below 200 cps. Nevertheless, a significant trend in environment level reduction is evident.

Figure II.E.2.4 shows similar data for the 18.5 pound box. Since the readings of accelerometers 7, 8 and 9 were not affected by disturbances, the attenuation shown in this plot is reliable. However, accelerometers 7, 8 and 9 are internal. Their installation is unknown so that pertinent conclusion cannot be drawn.

Figure II.E.2.5 shows data comparison for the internal accelerometers of the 6 pound box. Some similarity can be seen with Figure II.E.2.4. However, pertinent conclusion cannot be drawn for the reason cited above.

Figure II.E.2.6 presents the data comparison for the 6 pound box external accelerometers No. 13, 14 and 15. Due to disturbance in accelerometer 15 readings, the data is questionable below 250 cps. However, the vibration isolators provide a substantial reduction of the shock level through most of the frequency range.

Repeatability of the environment is shown to be good for all accelerometers which provided reliable data. Figures II.E.2.37 to II.E.2.51. Turning the boxes around by 180 degrees has little effect on the shock levels and the differences between data points may be attributed to normal data scatter.

II.E.2.3 CONCLUSION

The boxes withstood the environment provided by two shocks without failures of any kind.

The vibration isolators fitted to the 6 pound box and to the 7.5 pound box were effective in reducing, by a significant amount, the environment levels to which these boxes were subjected.

The internal accelerometers placed in the 6 pound and in the 18.5 pound boxes recorded significant attenuation of the shock levels. Although the lack of information about accelerometer installation prevents drawing pertinent conclusion, this data is important to the box manufacturers for design purpose.

Repeatability of the environment recorded by the reliable accelerometers for both shocks was found to be satisfactory.

The simultaneous testing of several boxes provided a substantial cost savings.

TABLE II.E.2.1

ACCELEROMETERS AND LOCATIONS

Accelerometer Number	Box	Direction	Location	Distance to Shocksource	Accelerometer Type
	6 lb. Box				
1	Soft Mounted	L	Barrel	30	Endevco 2225
2	Soft Mounted	R	Barrel	30	Endevco 2225
3	Soft Mounted	T	Barrel	30	Endevco 2225
	7.5 lb. Box				
4	Soft Mounted	L	Box	30	Endevco 2225
5	Soft Mounted	R	Box	30	Endevco 2225
6	Soft Mounted	T	Box	30	Endevco 2225
	18.5 lb. Box				
7	Hard Mounted	L	Box Internal	30	Endevco 2220
8	Hard Mounted	R	Box Internal	30	Endevco 2220
9	Hard Mounted	T	Box Internal	30	Endevco 2220
	6 lb. Box				
10	Soft Mounted	T*	Box Internal	30	Endevco 2220
11	Soft Mounted	T*	Box Internal	30	Endevco 2220
12	Soft Mounted	T*	Box Internal	30	Endevco 2220
13	Soft Mounted	L	Box	30	Endevco 2225
14	Soft Mounted	R	Box	30	Endevco 2225
15	Soft Mounted	T	Box	30	Endevco 2225

* Internal - Silicone Rubber Mounted

TABLE II.E.2.2

SUMMARY OF TESTS

Test Number	Configuration	Explosive Size	Test Purpose	Shock Isolation
1	1*	30 Gr/ft MDF	Box Qual.	2 Boxes
2	2	30 Gr/ft MDF	Box Qual.	2 Boxes

* Boxes rotated 180° for test 2.

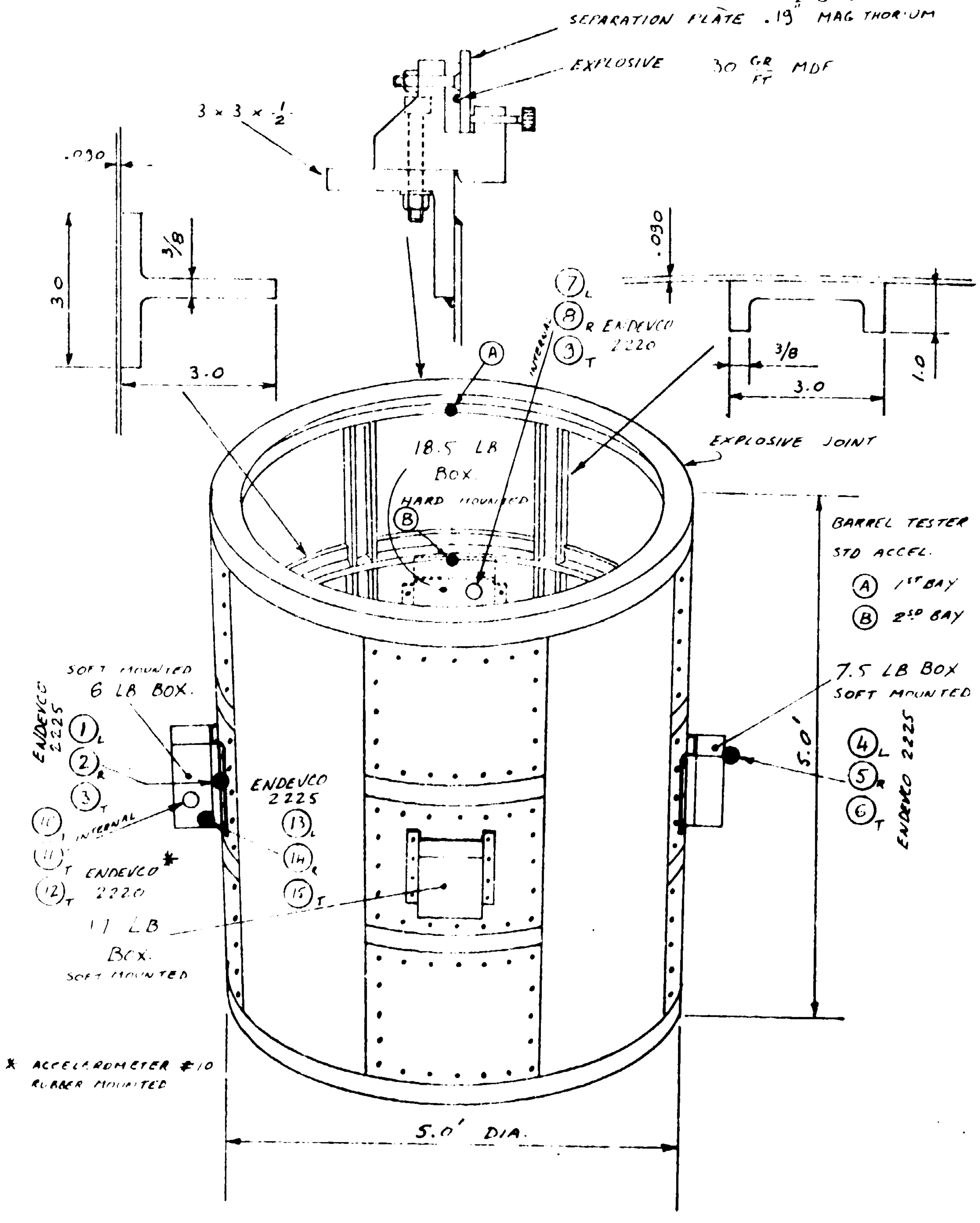


Figure II.E.2.1 TEST GENERAL ARRANGEMENT

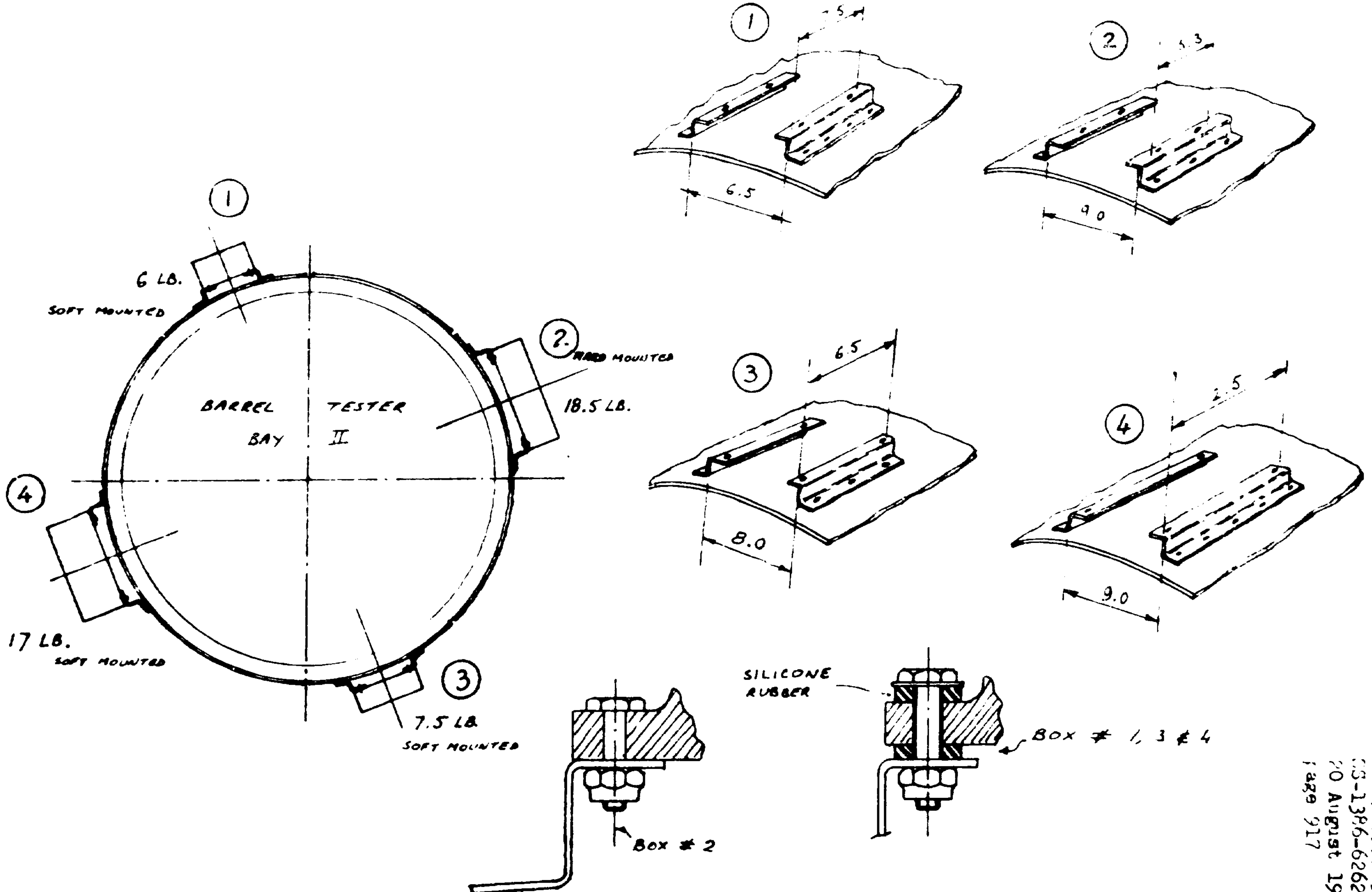


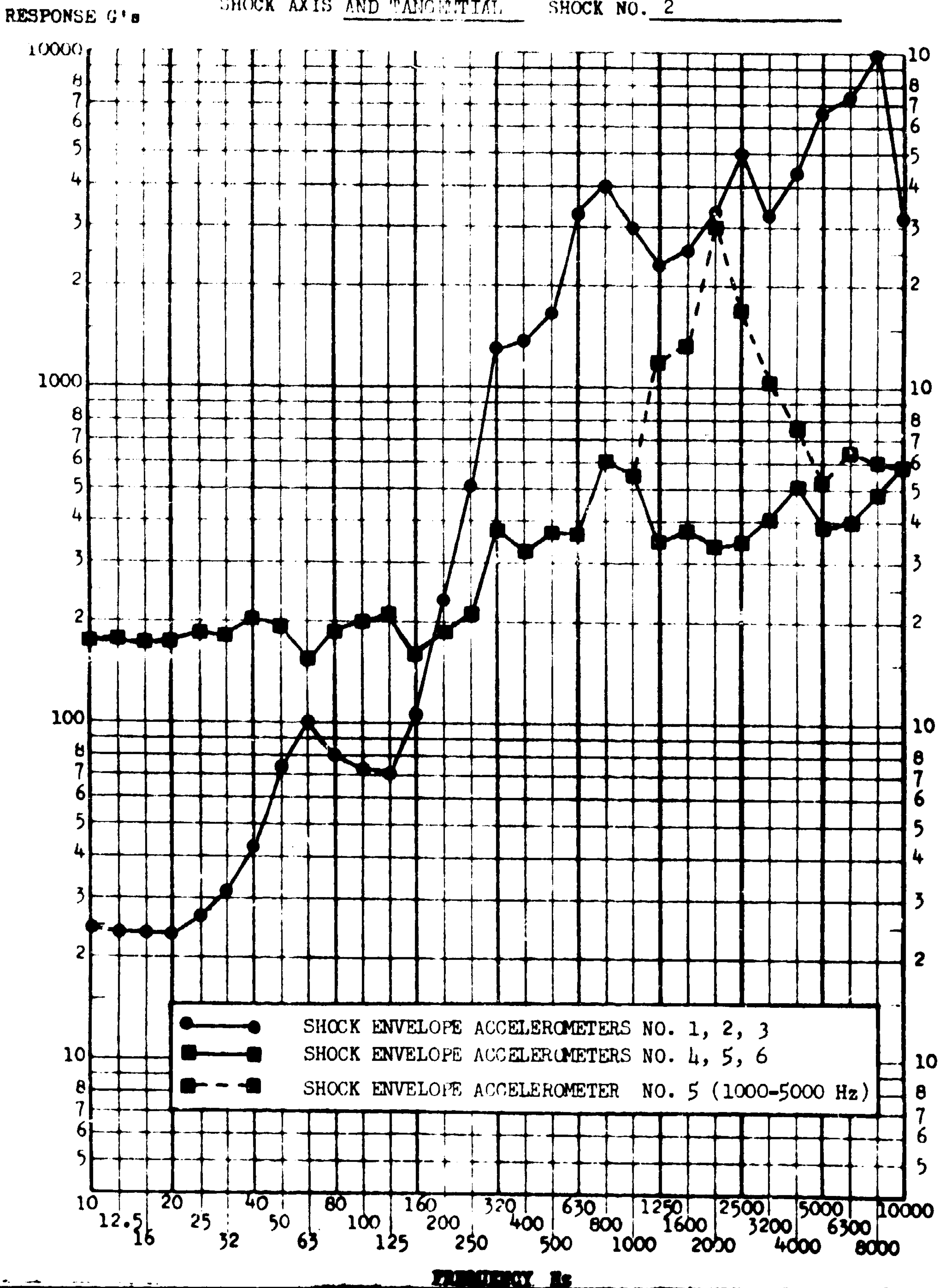
Figure II.E.2.2 MOUNTING BRACKETS

SHOCK TEST ANALYSIS DATA SHEET II.E.2.3

TEST ITEM 456- (345-347) (351-353) PART NO. STRUCTURE AND 7.5 LB BOX

SERIAL NO. ______ TEST DATE 20 OCT 1967

SHOCK AXIS LONGITUDINAL, RADIAL AND TANGENTIAL SHOCK NO. 2

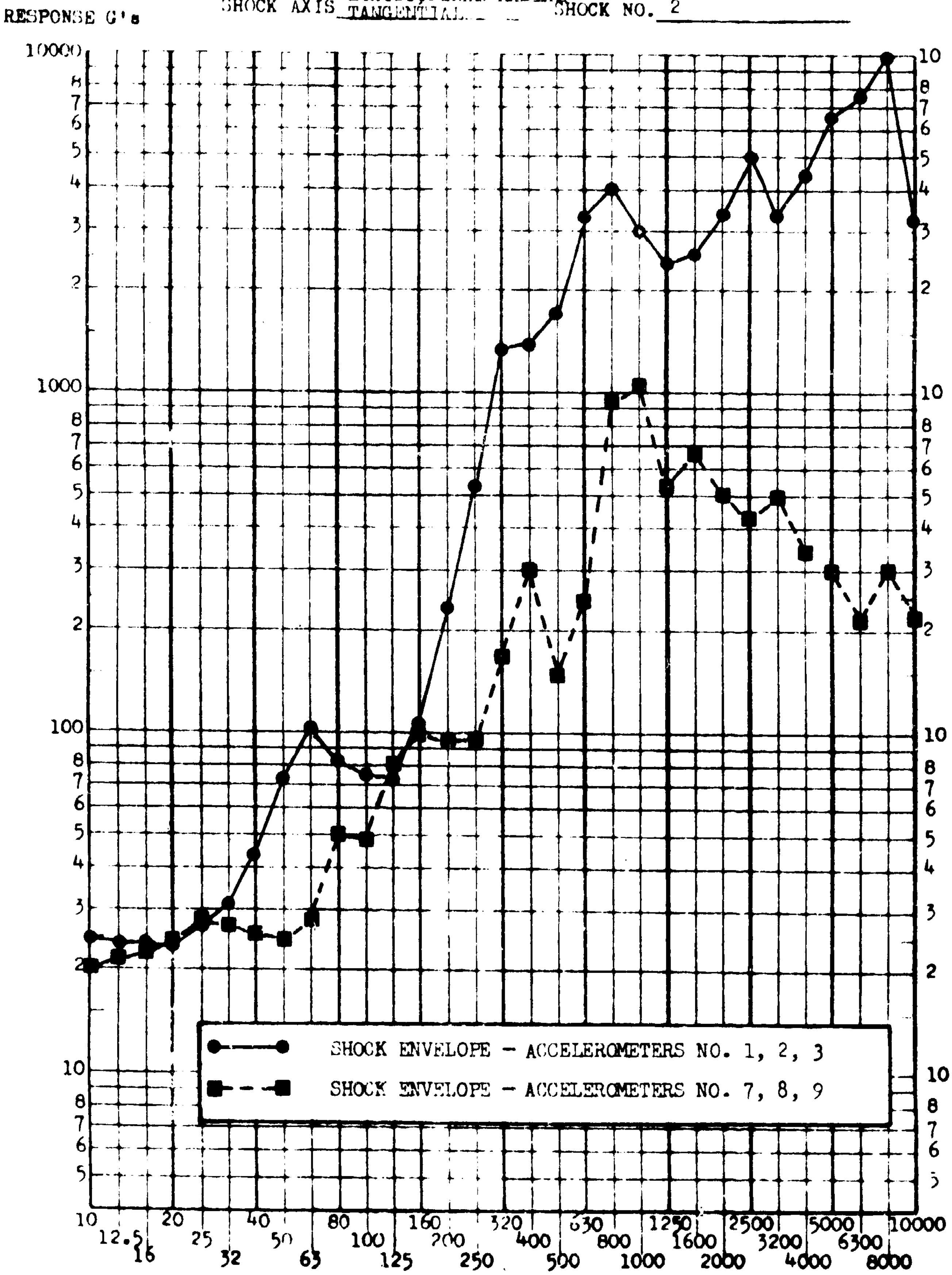


SHOCK TEST ANALYSIS DATA SHEET II.E.2.4

TEST ITEM 456 (345-347) (363-364) PART NO. STRUCTURE AND 18.5 LB BOX

SERIAL NO. ______ TEST DATE 20 OCT 1967

SHOCK AXIS LONGITUDINAL RADIAL TANGENTIAL SHOCK NO. 2

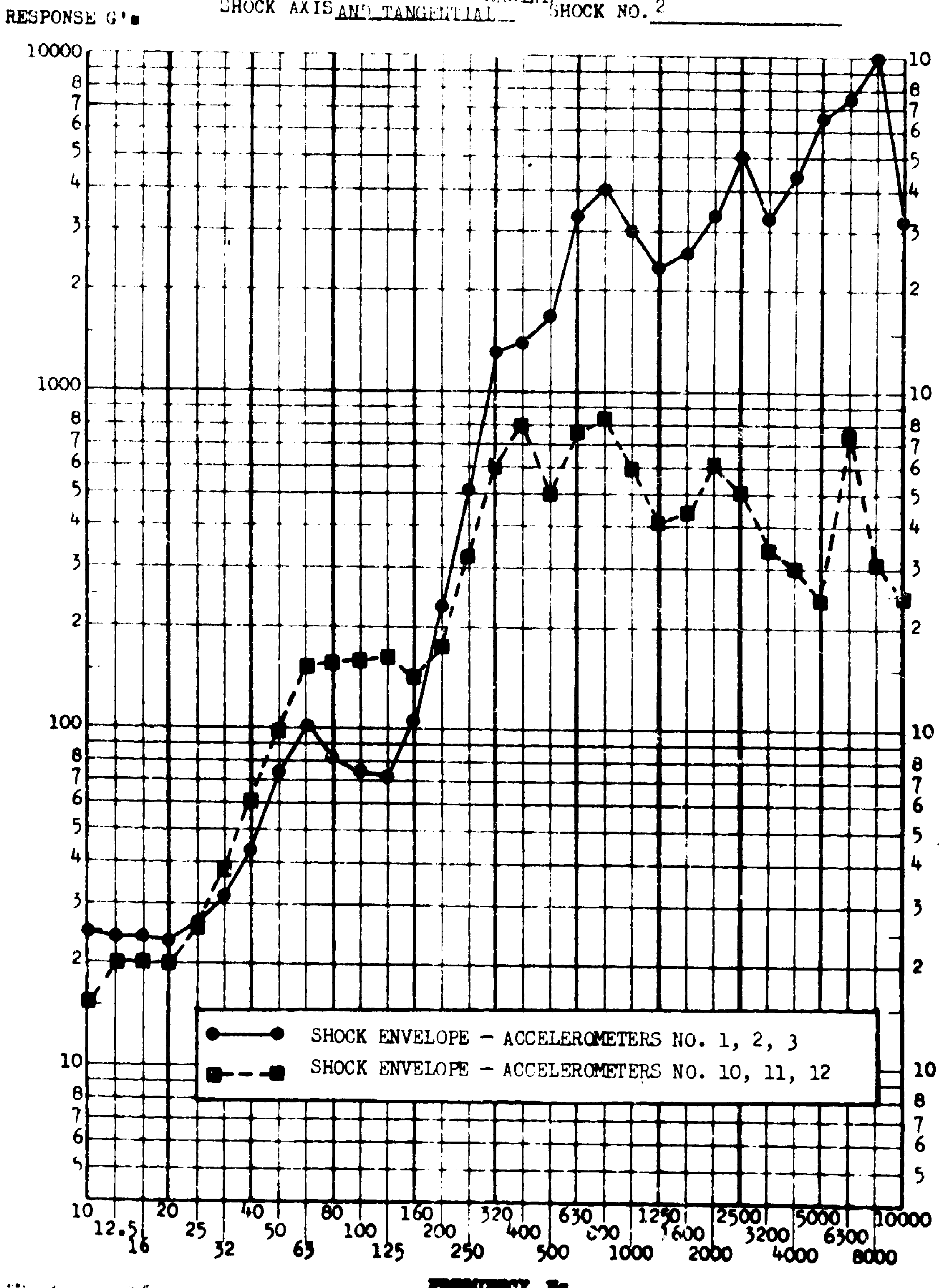


SHOCK TEST ANALYSIS DATA SHEET II.E.2.5

TEST ITEM 456-(349-347 / 357-359) PART NO. STRUCTURE AND 6 LB BOX (ISOLATED INTERIOR)

SERIAL NO. TEST DATE 20 OCT 1967

SHOCK AXIS LONGITUDINAL RADIAL AND TANGENTIAL SHOCK NO. 2

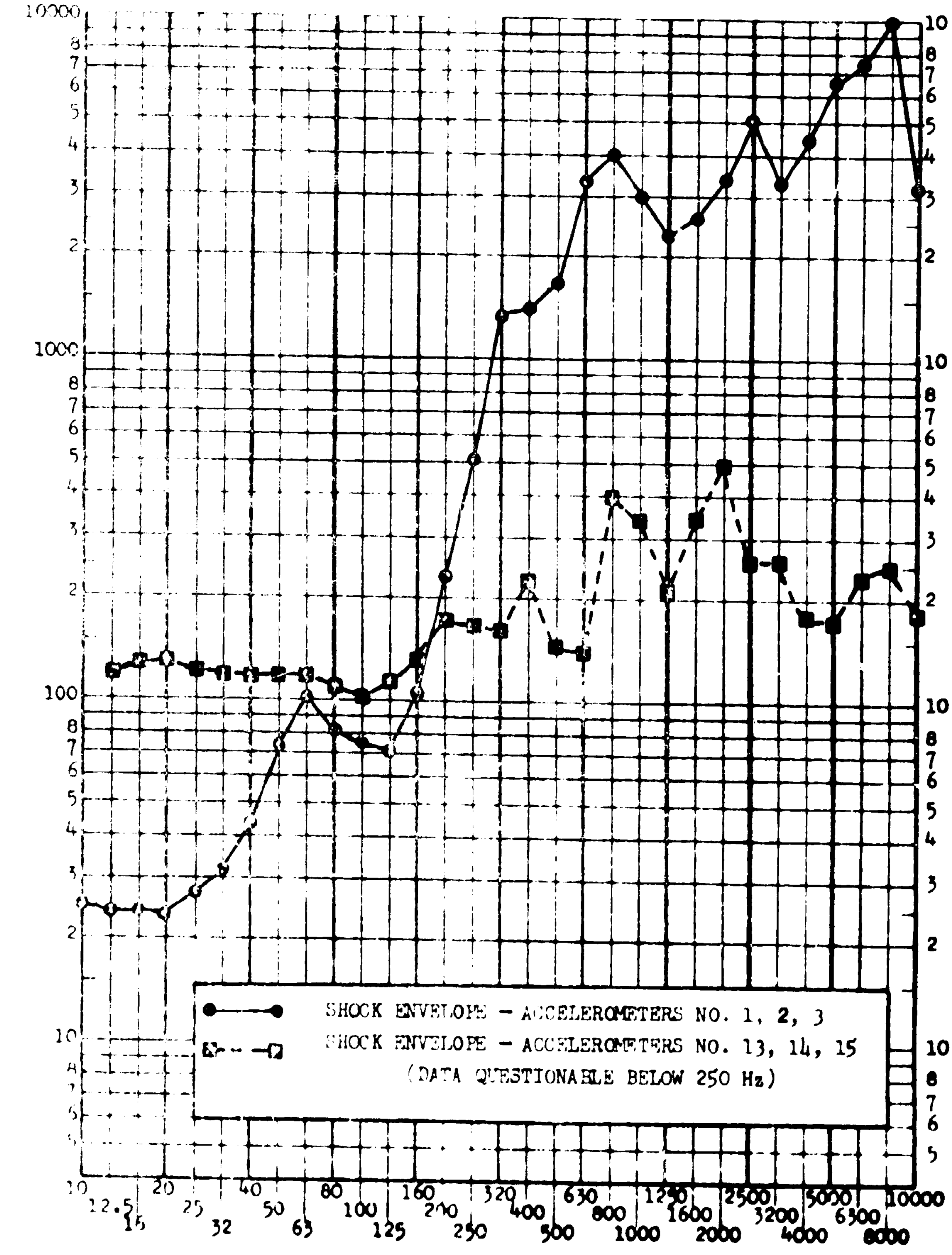


SHOCK TEST ANALYSIS DATA SHEET II.E.2.6

TEST ITEM 456-(345-347) (369-371) PART NO. STRUCTURE AND 6 LB BOX (ISOLATED)

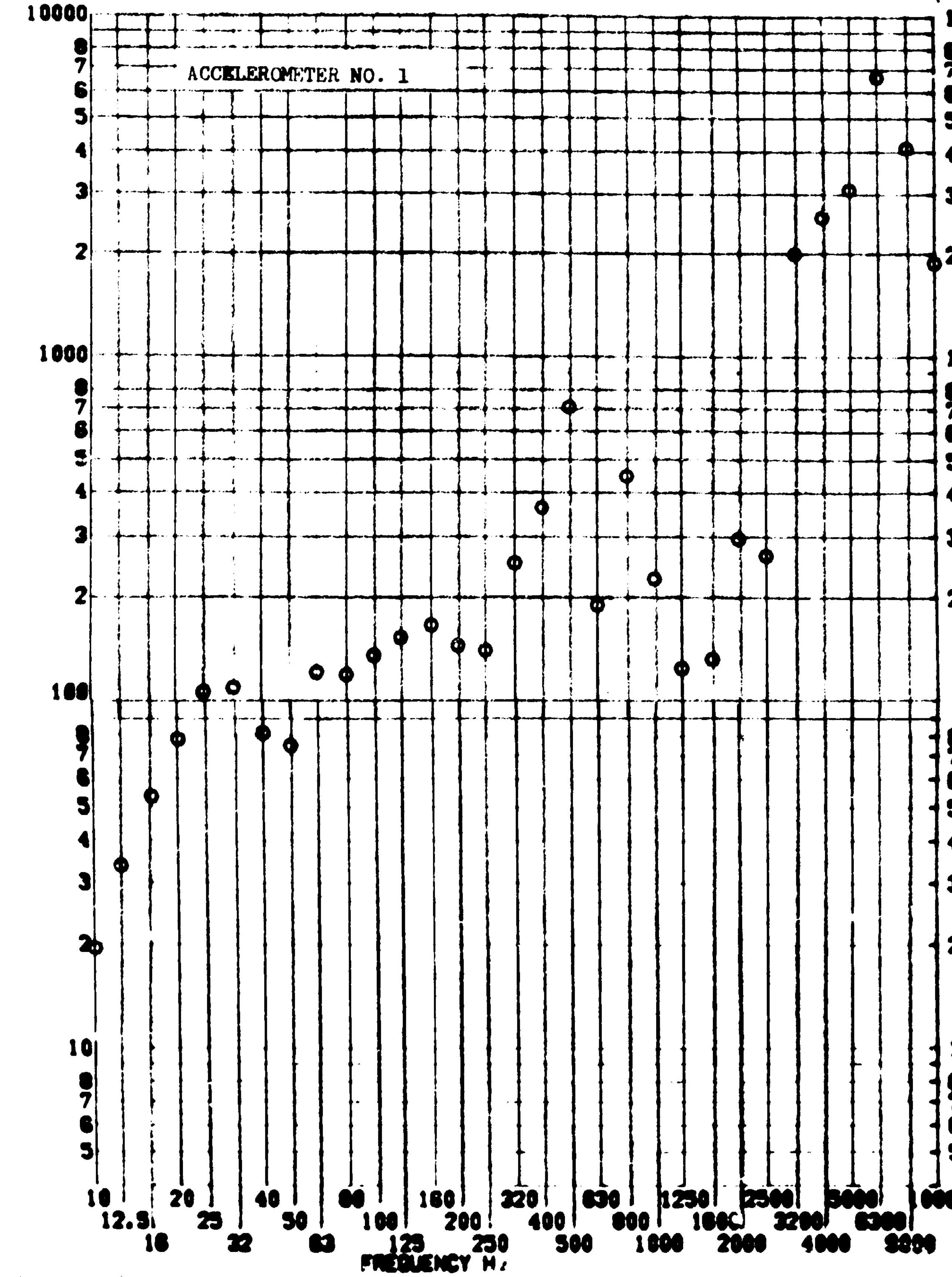
SERIAL NO. ________ TEST DATE 20 OCT 1967

SHOCK AXIS LONGITUDINAL RADIAL TANGENTIAL SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.7

TEST ITEM 456-342
SERIAL NO.
SHOCK AXIS LONGITUDINAL
PART NO. STRUCTURE
TEST DATE 20 OCT 1967
SHOCK NO. 1

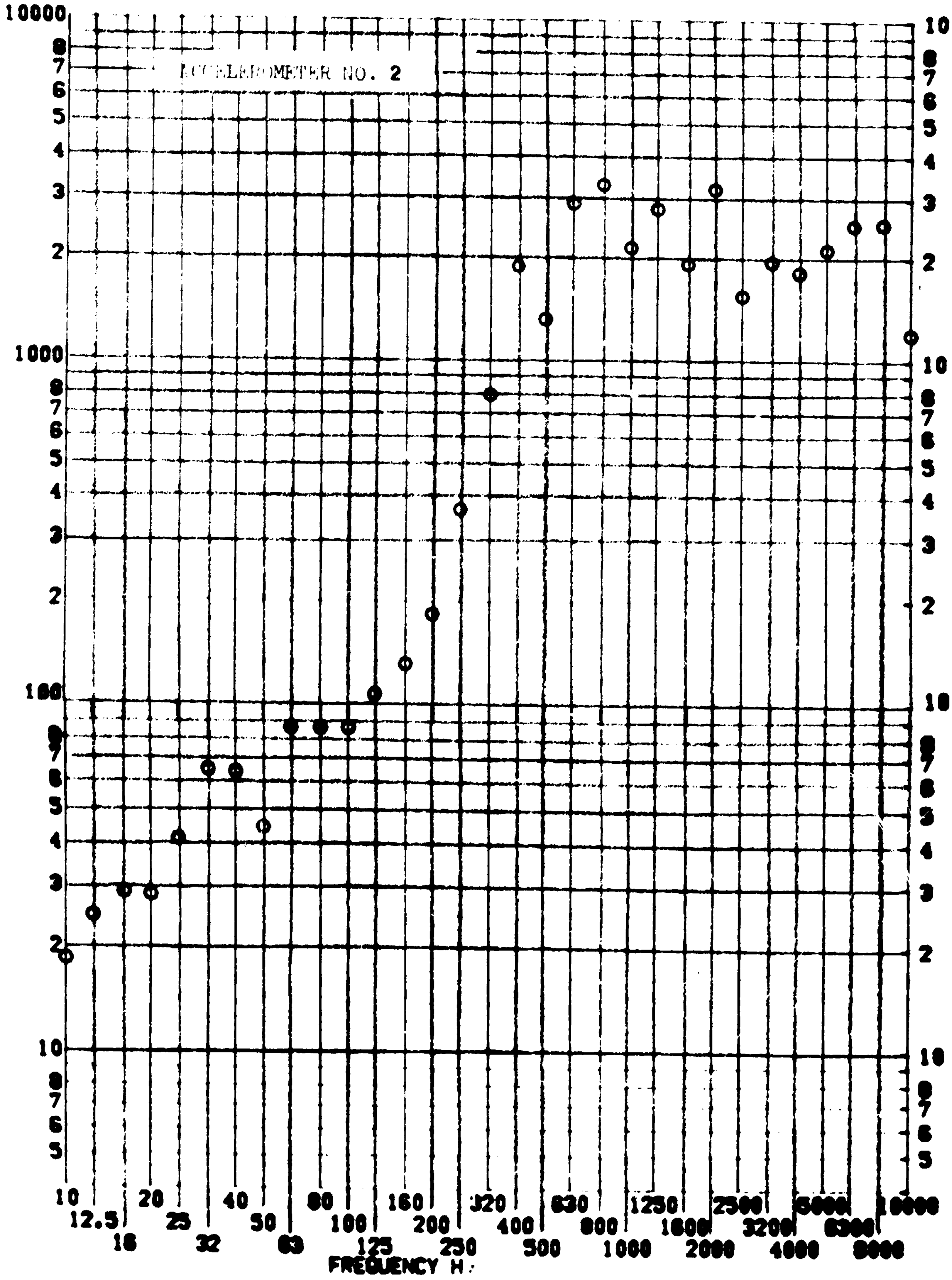


SHOCK TEST ANALYSIS DATA SHEET II.E.2.8

TEST ITEM 456-343
SERIAL NO.
SHOCK AXIS RADIAL

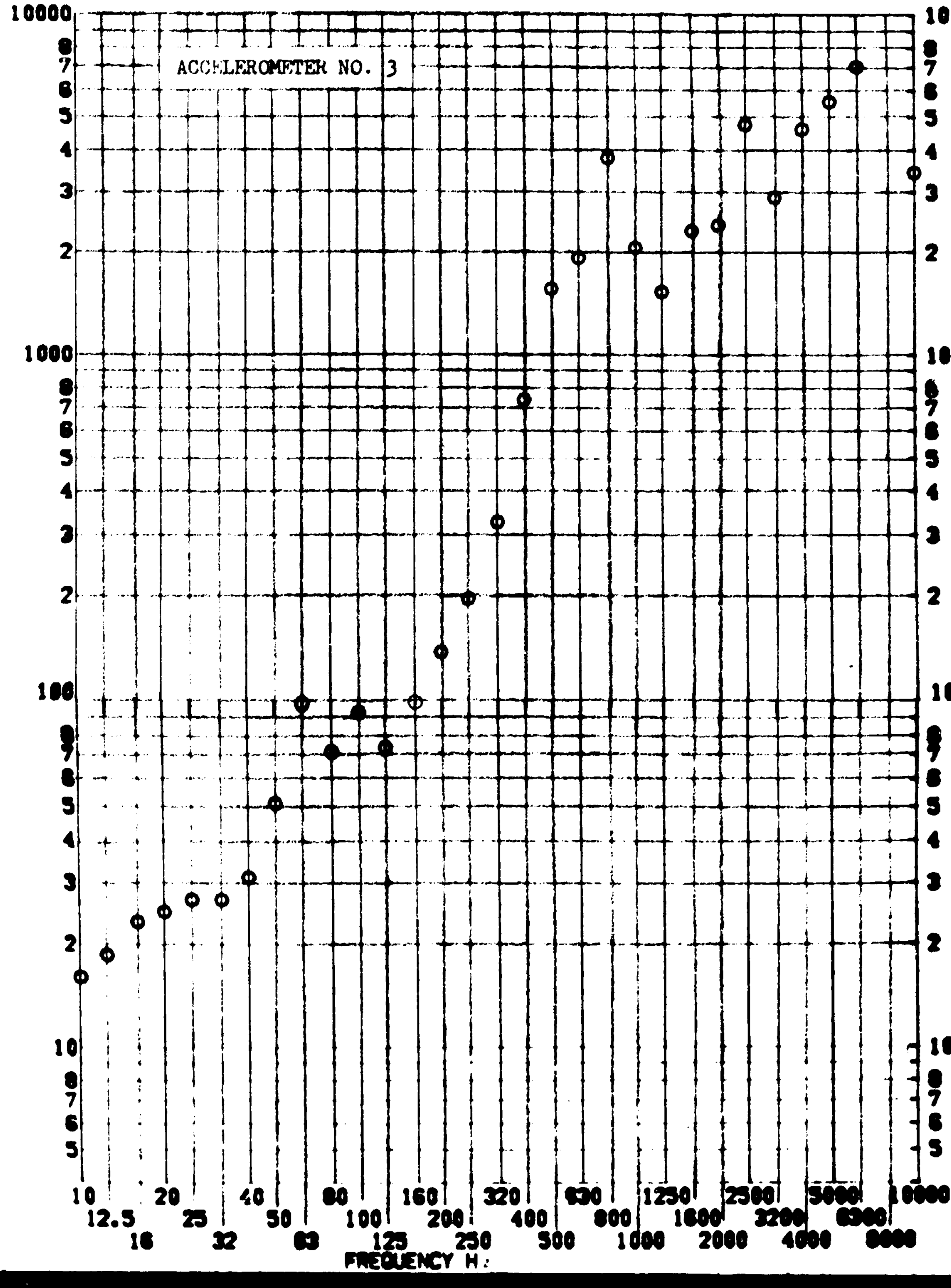
PART NO. STRUCTURE
TEST DATE 20 OCT 1967
SHOCK NO. 1

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.2.9

TEST ITEM 456-344 PART NO. STRUCTURE
SERIAL NO. TEST DATE 20 OCT 1967
RESPONSE G-S SHOCK AXIS LONGITUDINAL SHOCK NO. 1

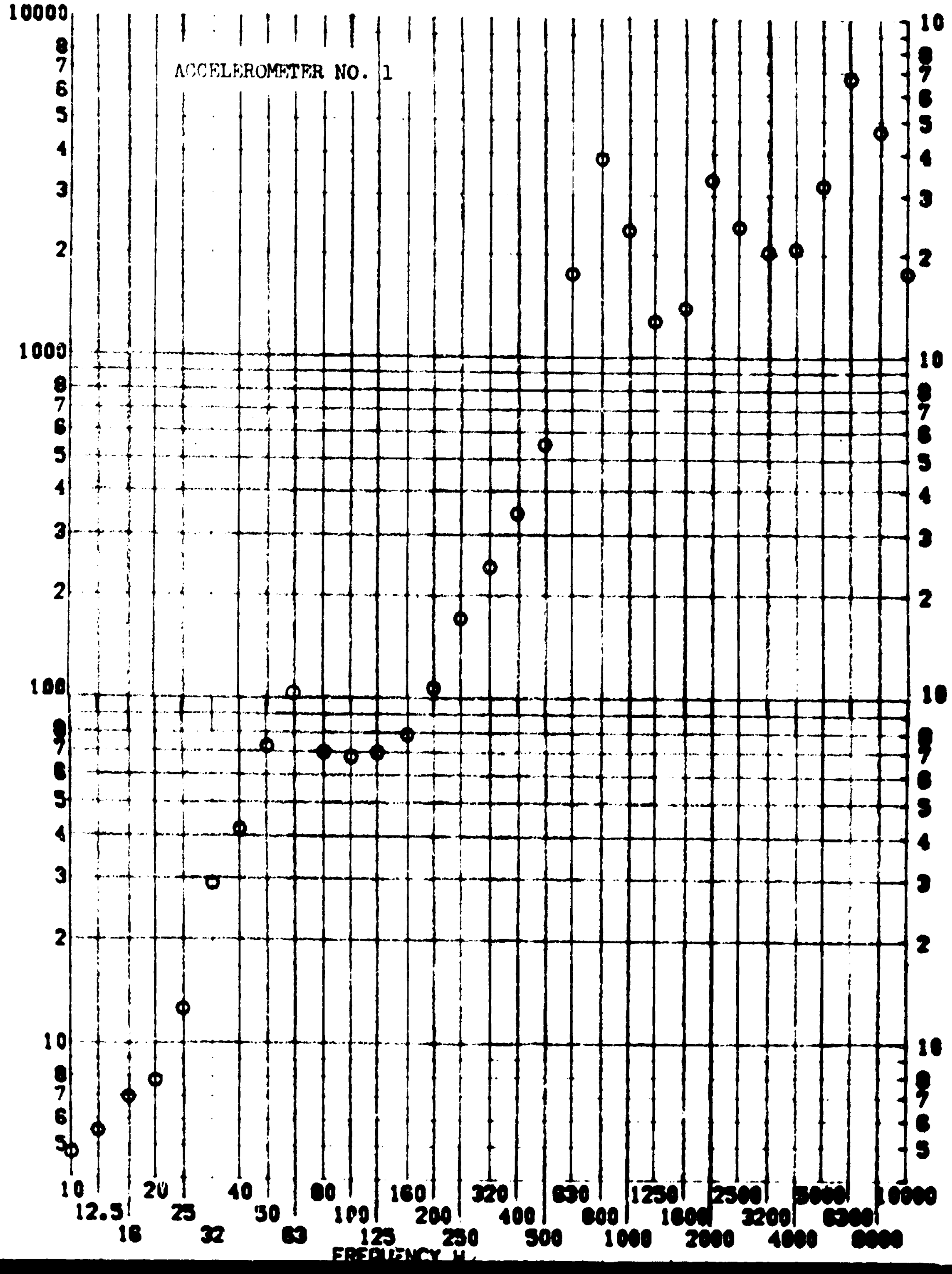


SHOCK TEST ANALYSIS DATA SHEET II.E.2.10

TEST ITEM 456-345
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. STRUCTURE
TEST DATE 20 OCT 1967
SHOCK NO. 2

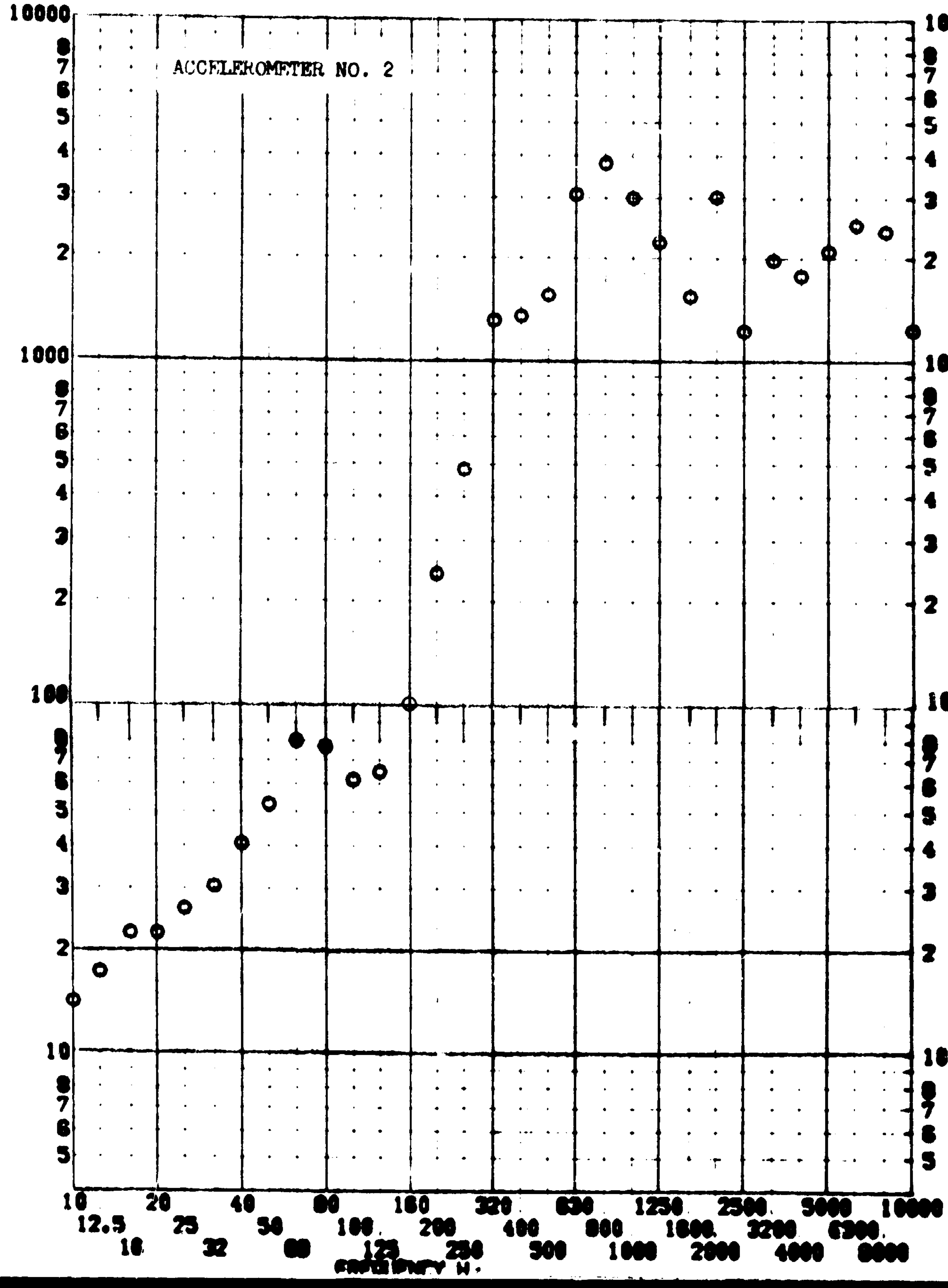
RESPONSE 6-S



SHOCK TEST ANALYSIS DATA SHEET II.E.2.11

TEST ITEM 456-346
SERIAL NO.
SHOCK AXIS RADIAL
PART NO. STRUCTURE
TEST DATE 20 OCT 1967
SHOCK NO. 2

RESPONSE G-S

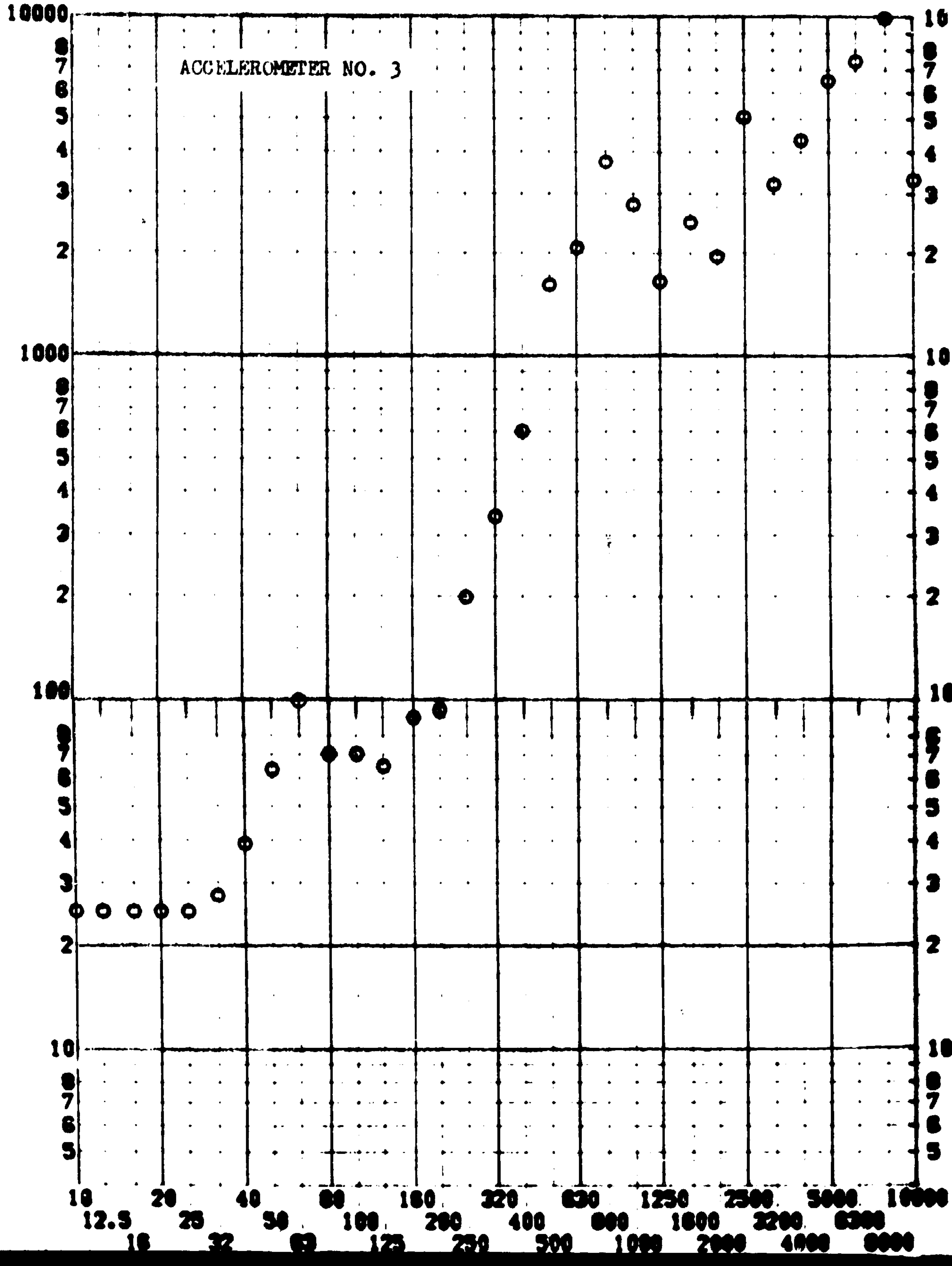


SHOCK TEST ANALYSIS DATA SHEET II.E.2.12

TEST ITEM 456-347
SERIAL NO.
SHOCK AXIS TANGENTIAL

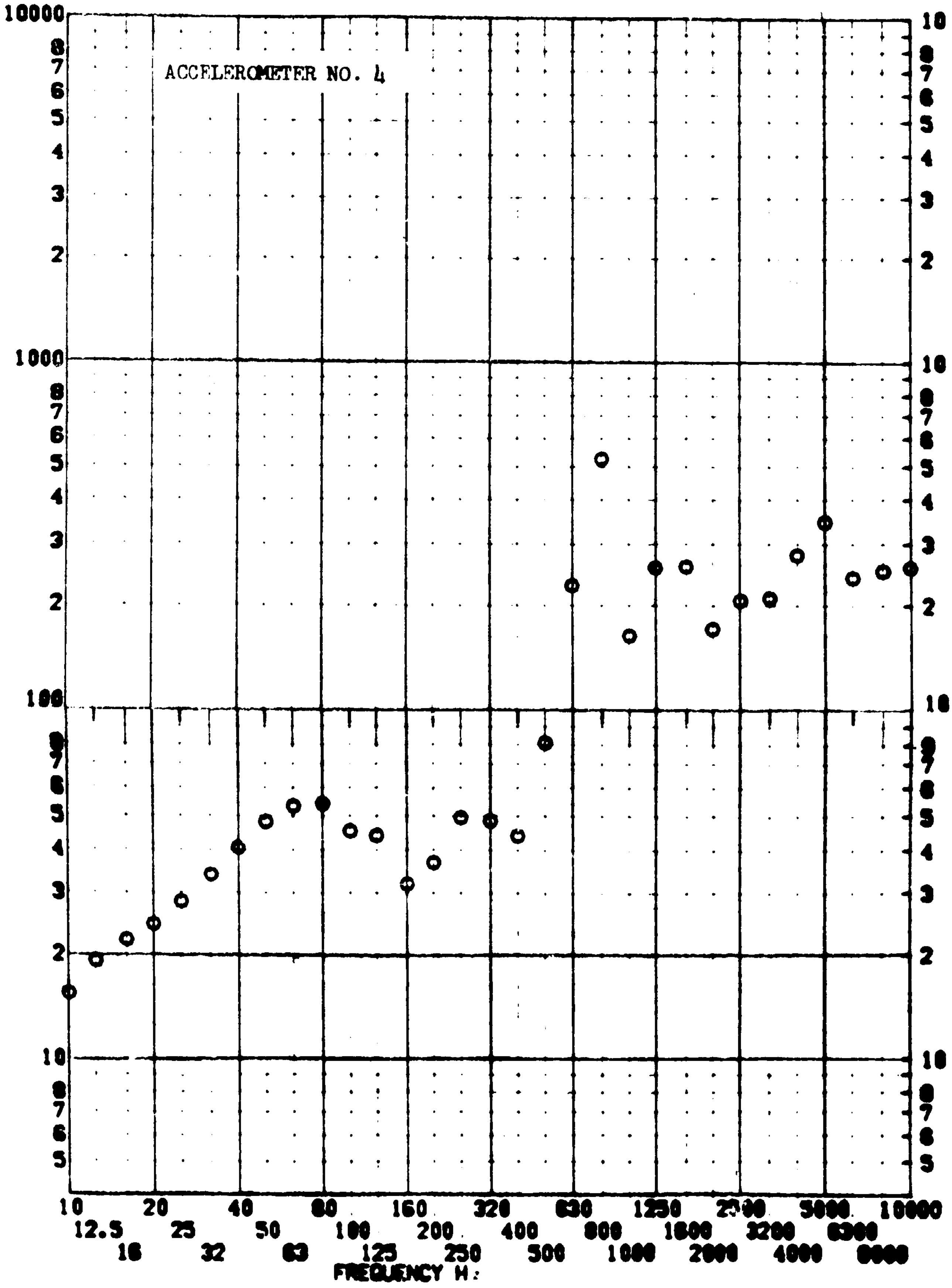
PART NO. STRUCTURE
TEST DATE 20 OCT 1967
SHOCK NO. 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.2.13

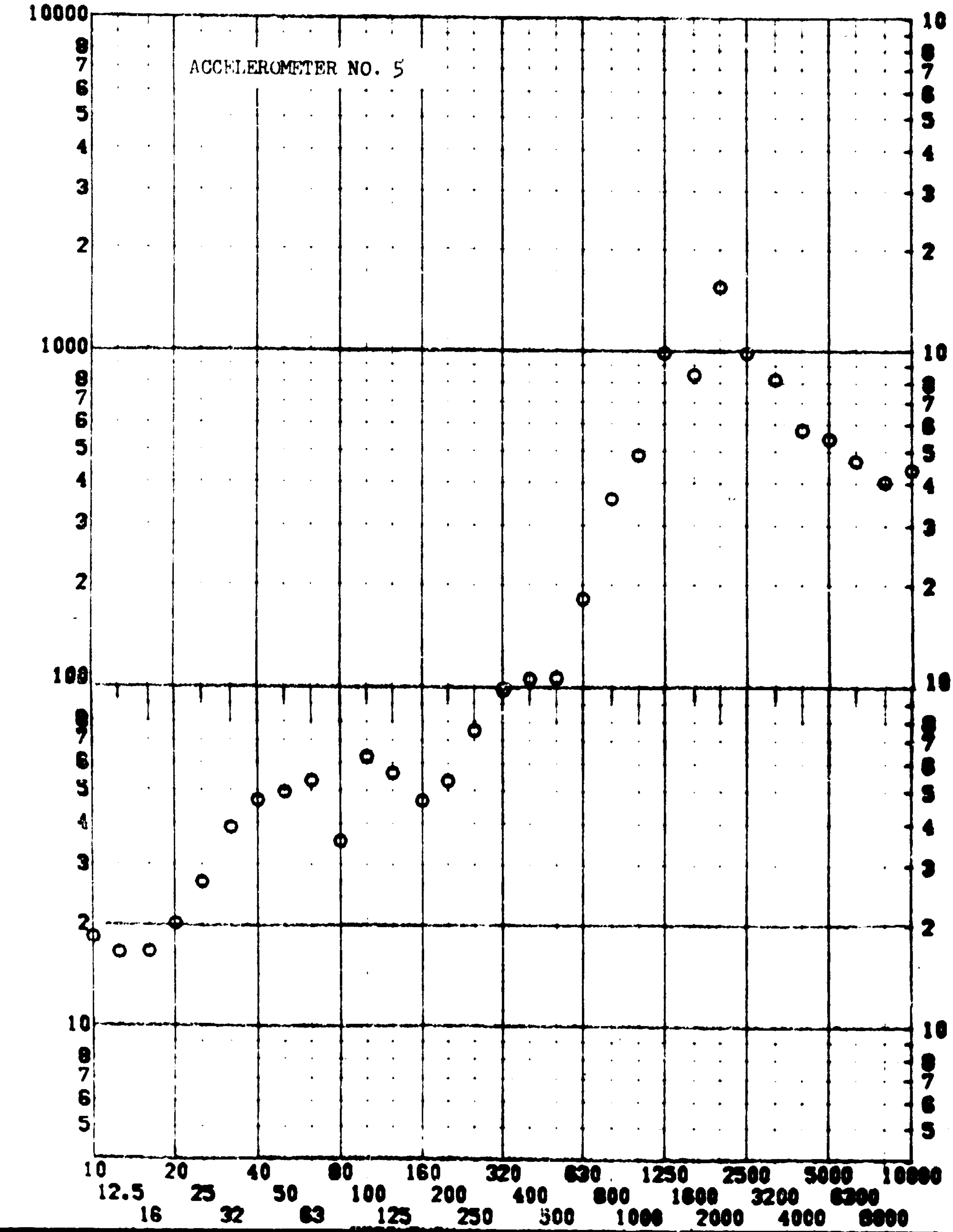
TEST ITEM 456-348 PART NO. 7.5 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
RESPONSE G-S SHOCK AXIS LONGITUDINAL SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.14

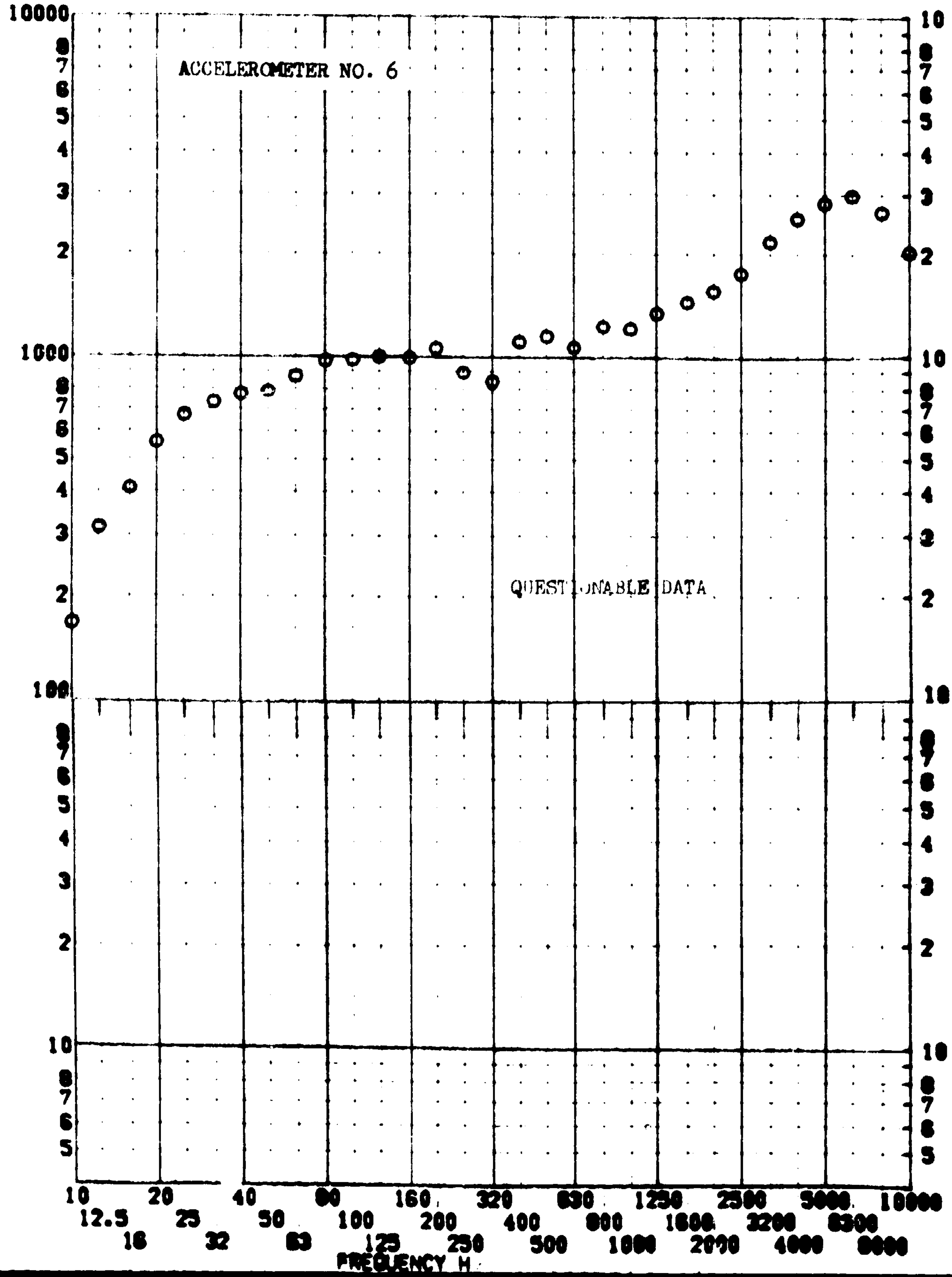
TEST ITEM 456-349
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. 7.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1



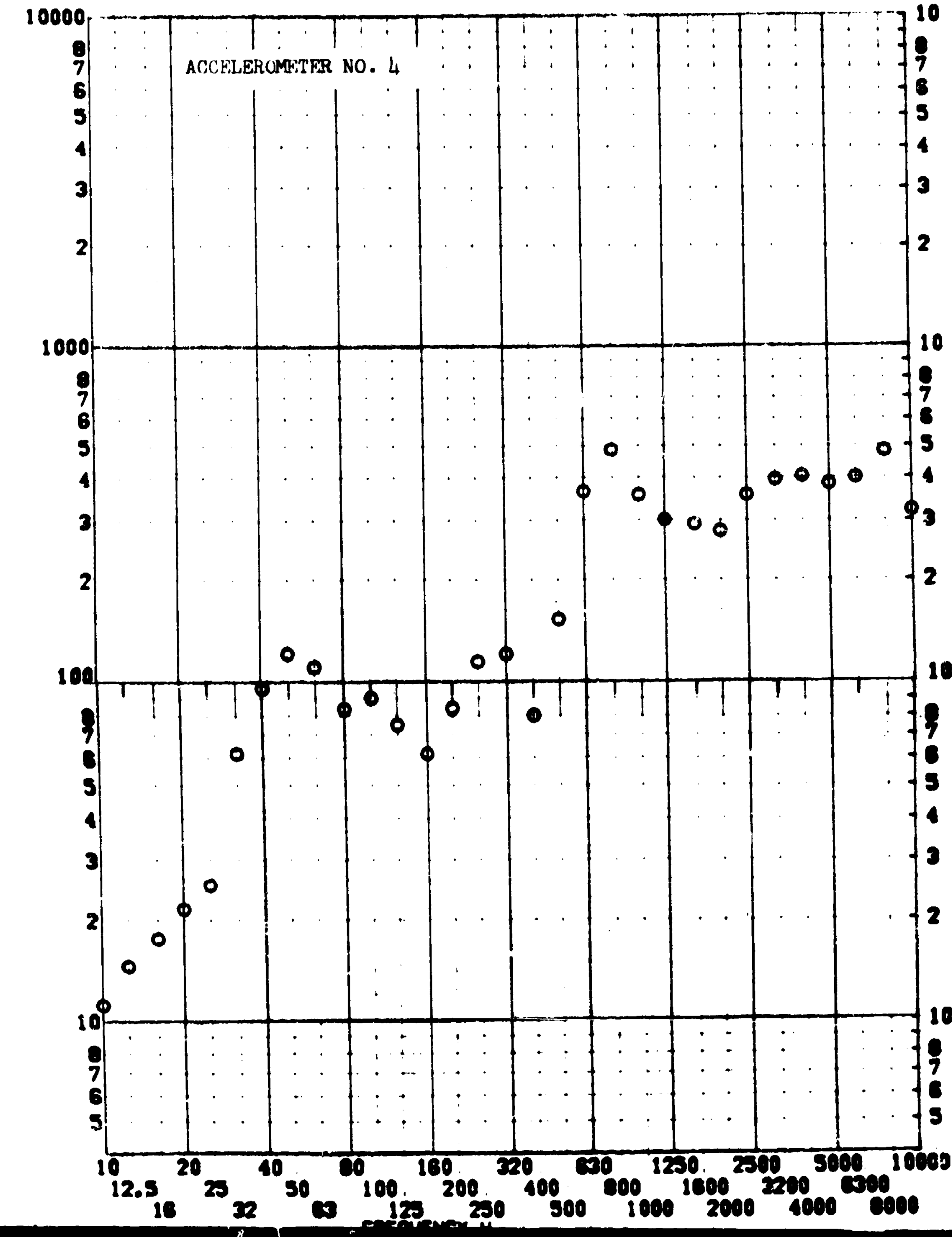
SHOCK TEST ANALYSIS DATA SHEET II.E.2.15

TEST ITEM 456-350 PART NO. 7.5 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
RESPONSE G-S SHOCK AXIS TANGENTIAL SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.16

TEST ITEM 456-351 PART NO. 7.5 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
RESPONSE G-S SHOCK AXIS LONGITUDINAL SHOCK NO. 2

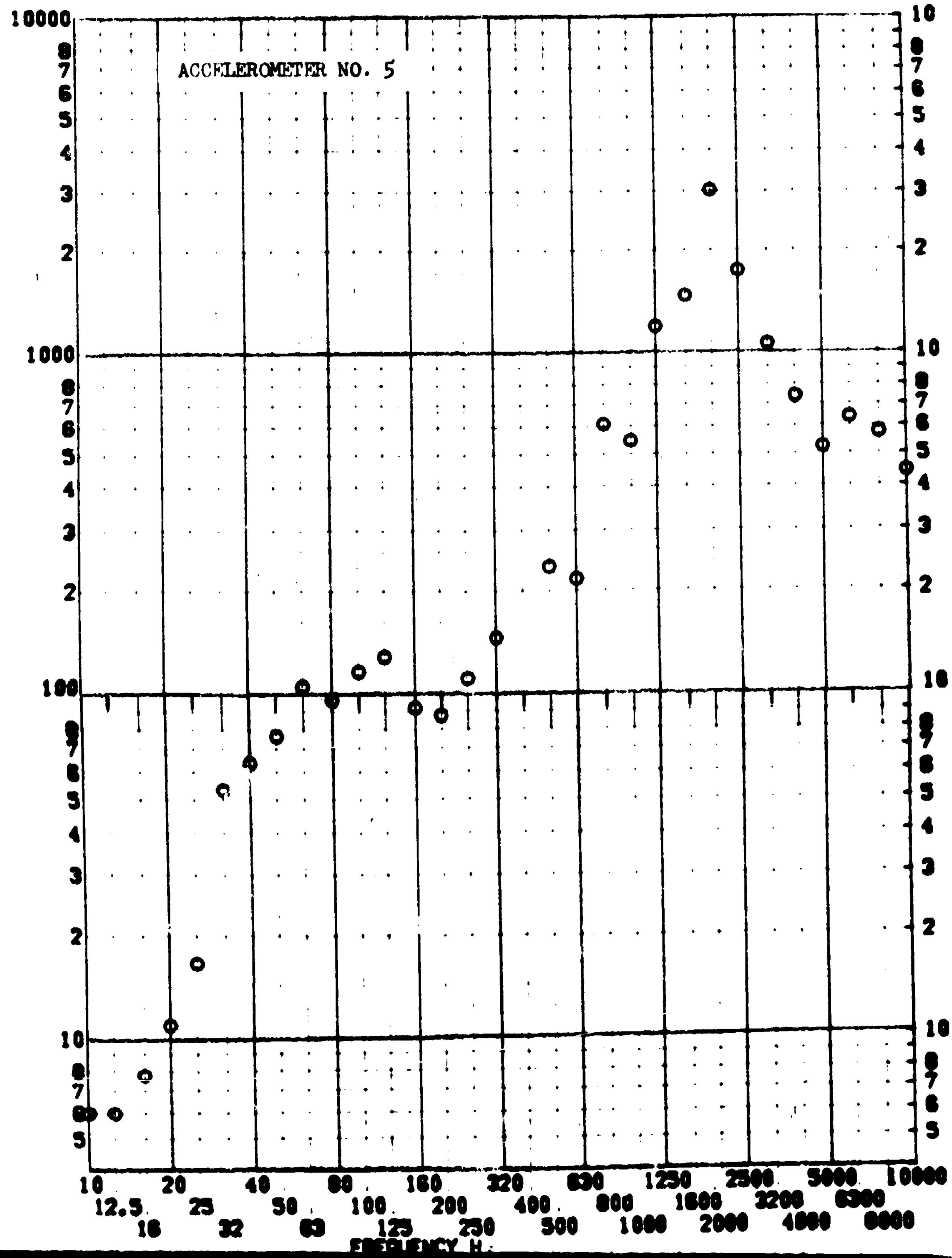


SHOCK TEST ANALYSIS DATA SHEET II.E.2.17

TEST ITEM 456-352
SERIAL NO.
SHOCK AXIS RADIAL

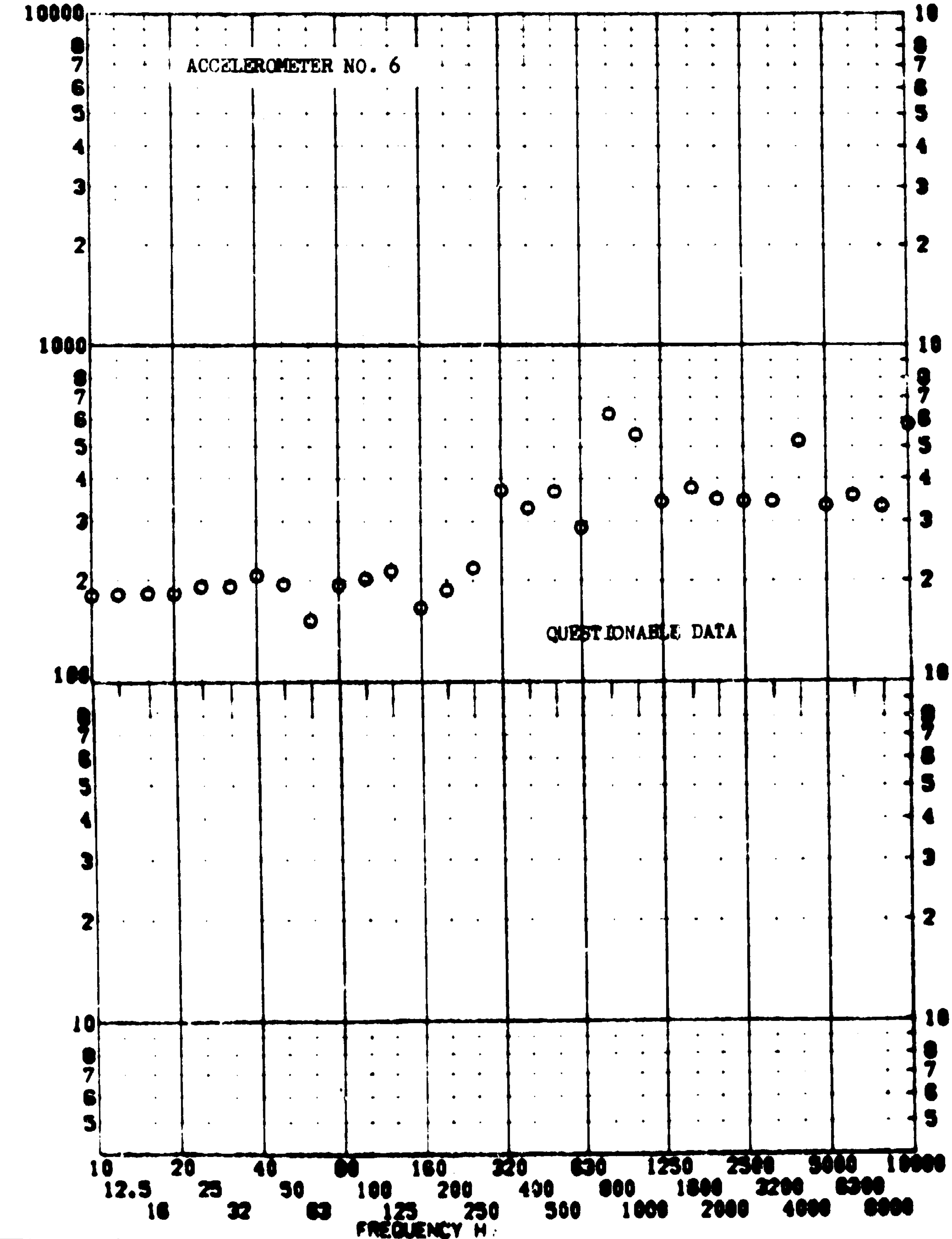
PART NO. 7.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 2

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.2.18

TEST ITEM 456-353 PART NO. 7.5 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
RESPONSE G-S SHOCK AXIS TANGENTIAL SHOCK NO. 2

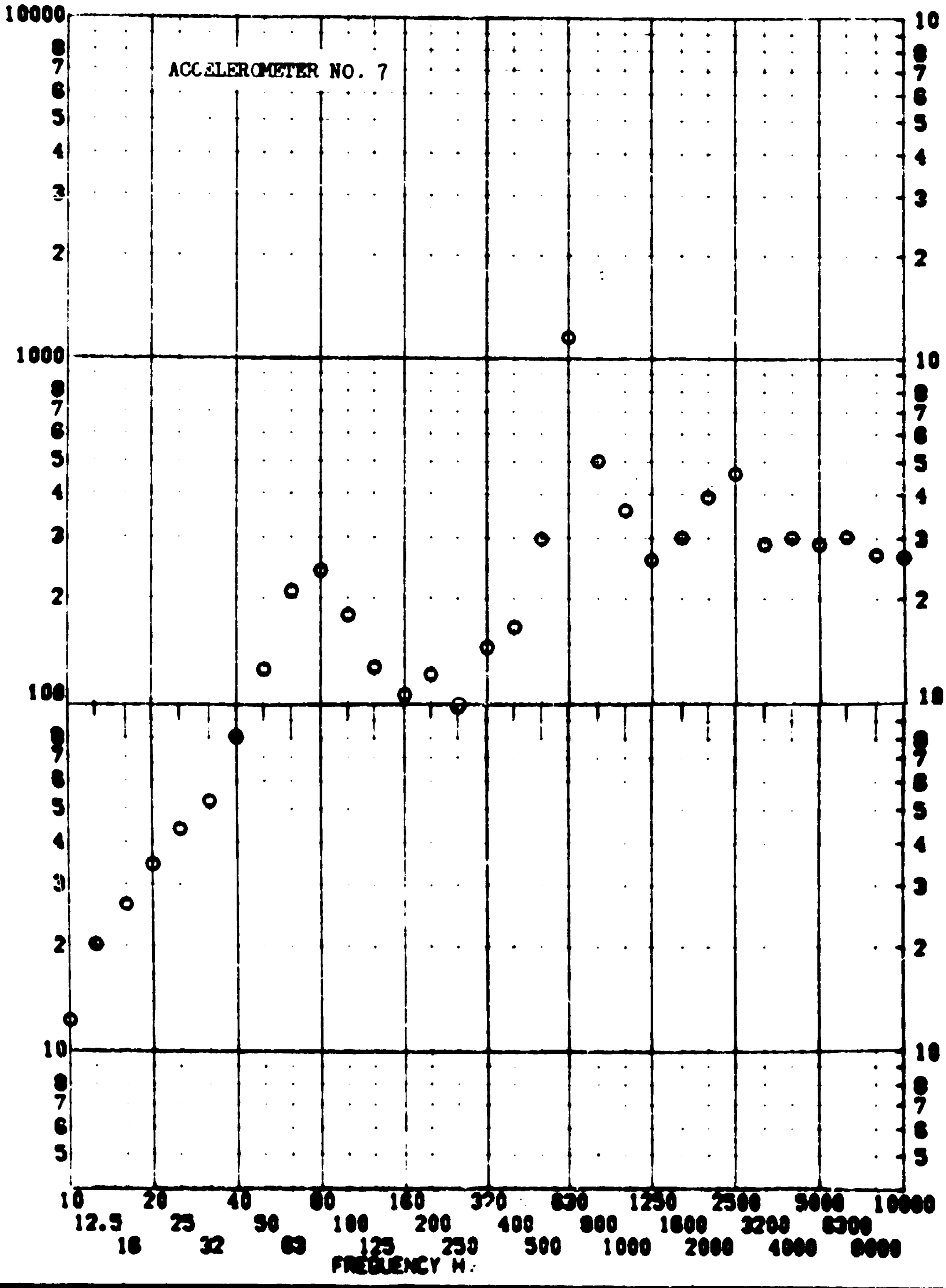


SHOCK TEST ANALYSIS DATA SHEET II.E.2.19

TEST ITEM 456-354
SERIAL NO.
SHOCK AXIS LONGITUDINAL

PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1

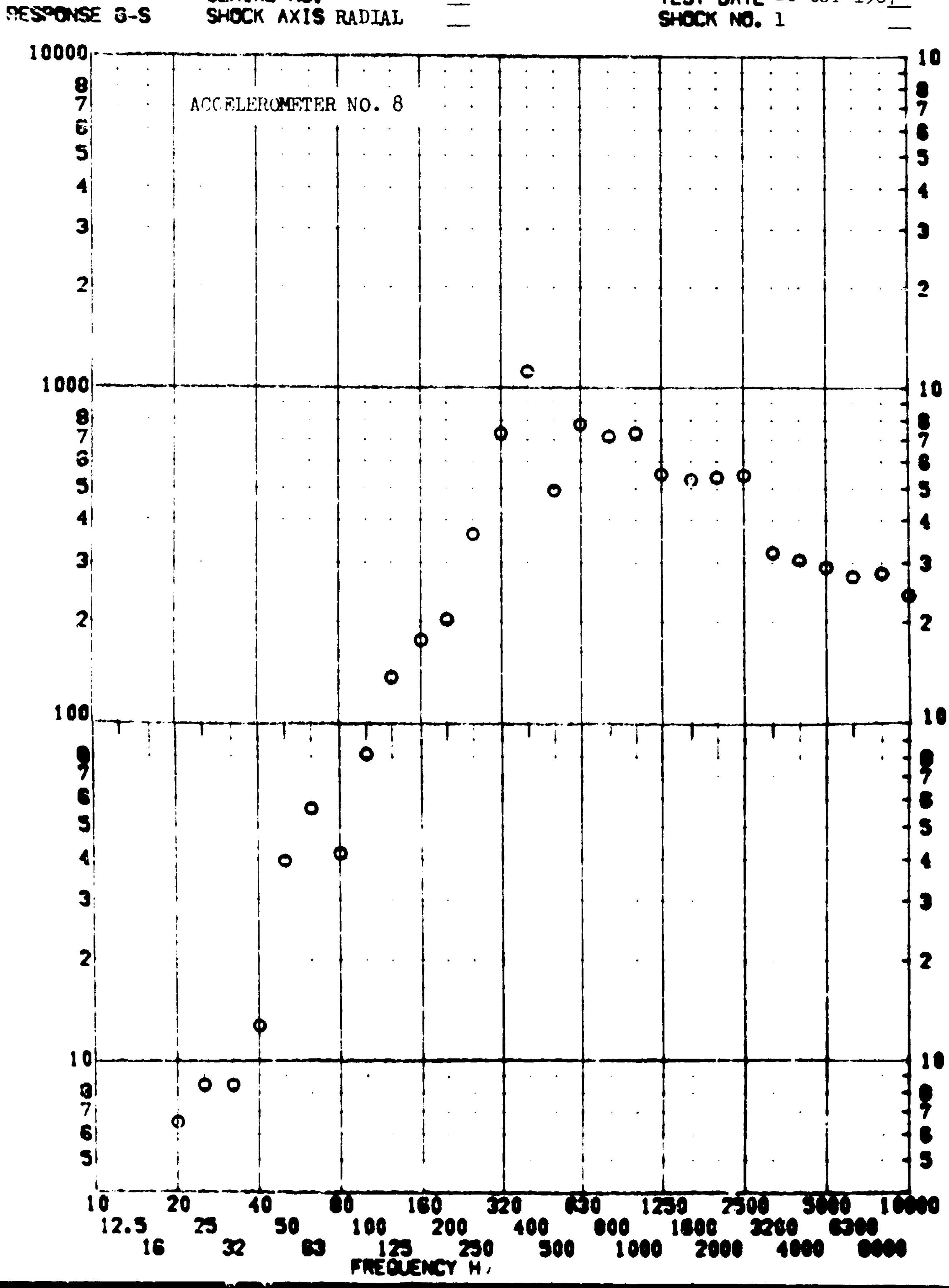
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.2.20

TEST ITEM 456-355
SERIAL NO.
SHOCK AXIS RADIAL

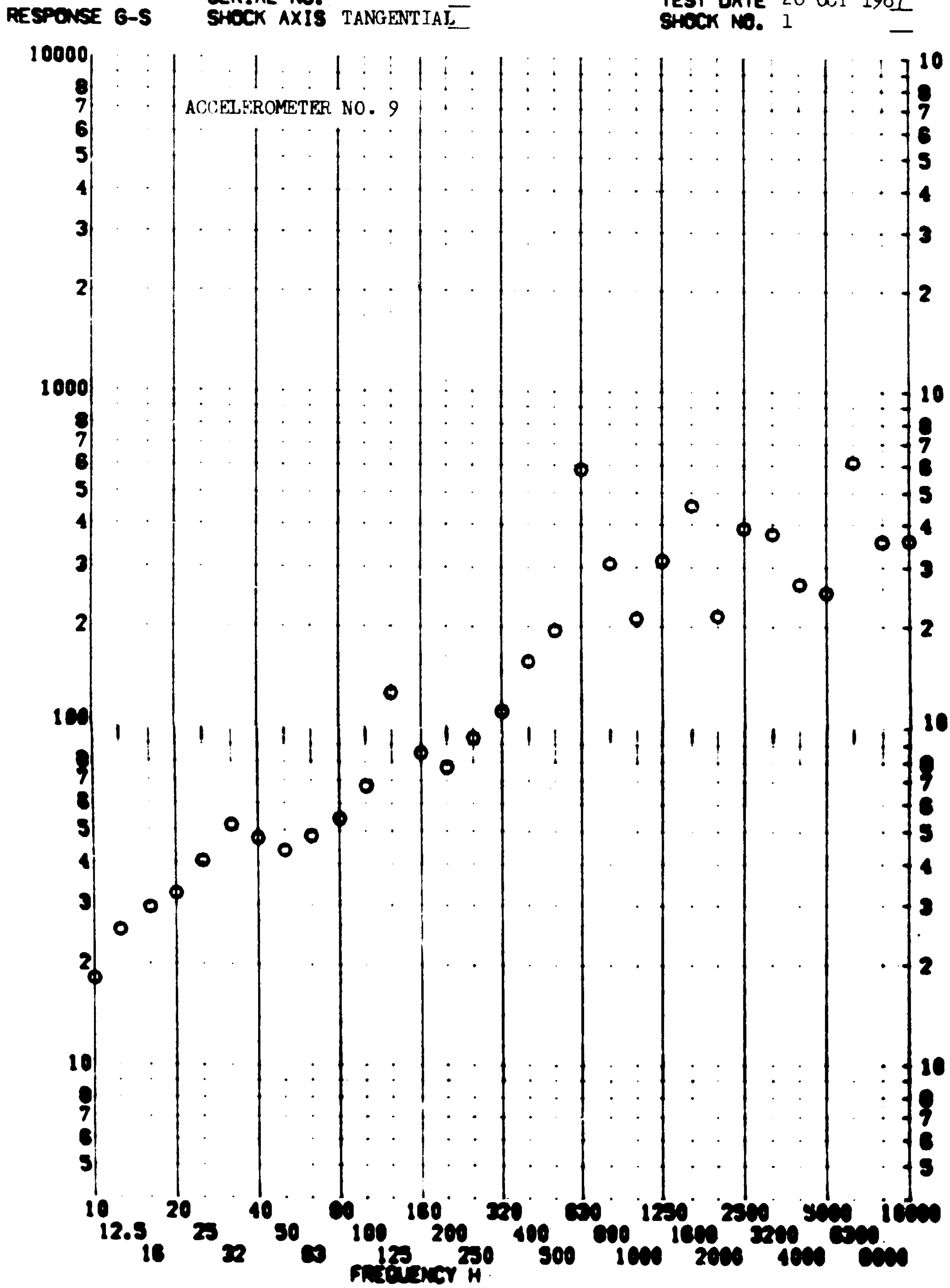
PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.21

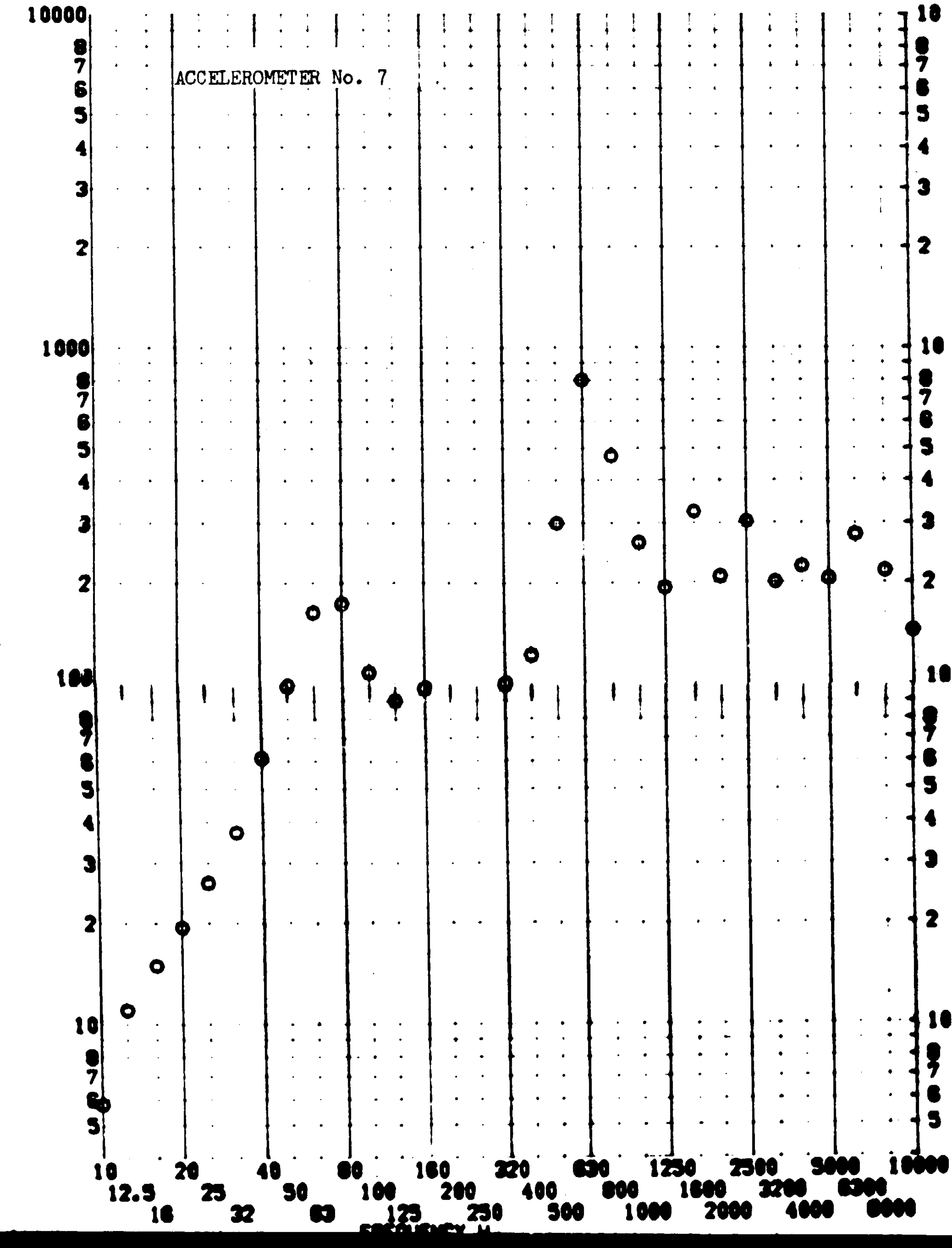
TEST ITEM 456-356
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.22

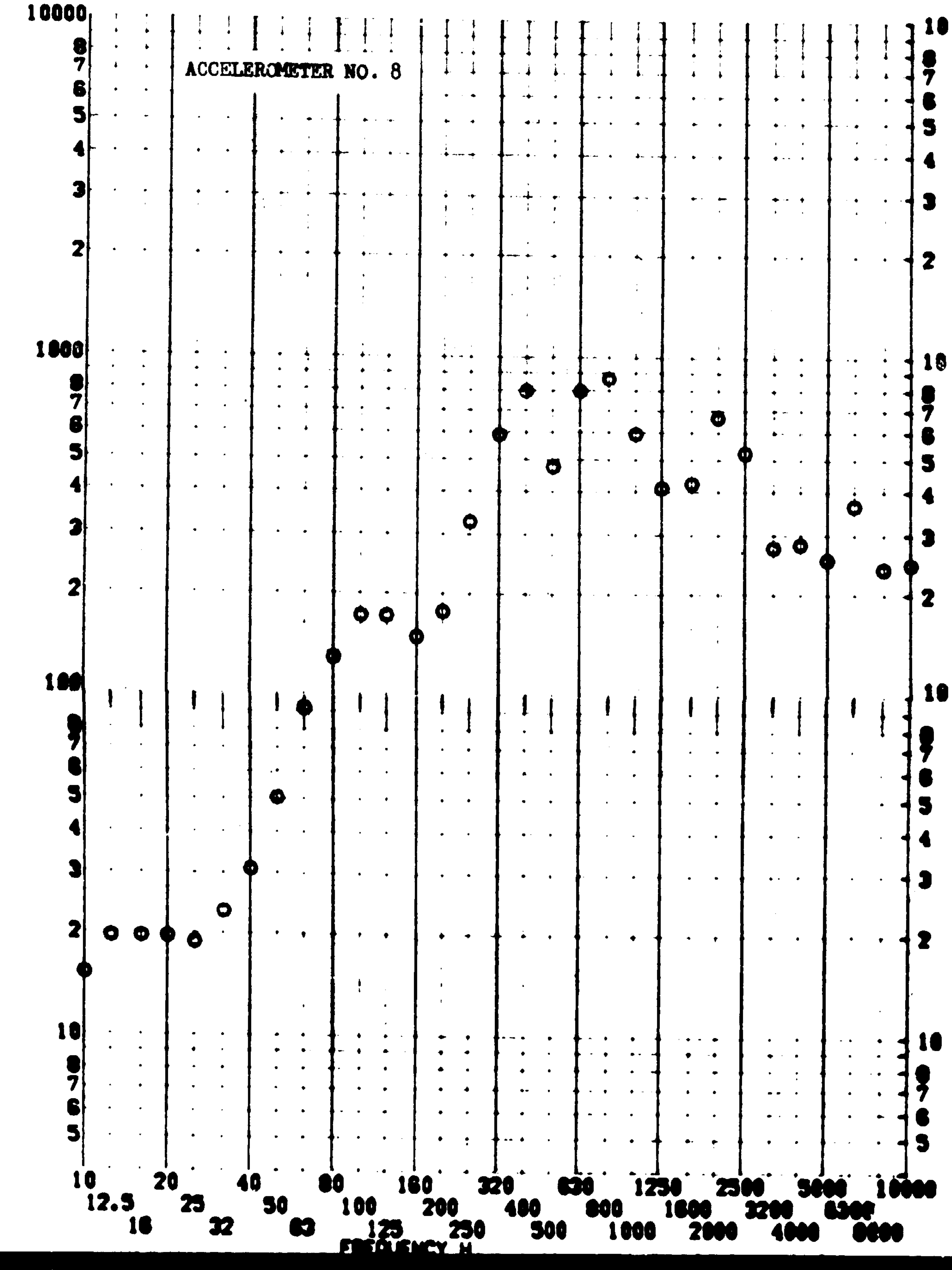
TEST ITEM 456-357 PART NO. 18.5 LB BOX
SERIAL NO. TEST DATE 20 Oct 1967
RESPONSE G-S SHOCK AXIS LONGITUDINAL SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.23

TEST ITEM 456-358
SERIAL NO.
SHOCK AXIS RADIAL

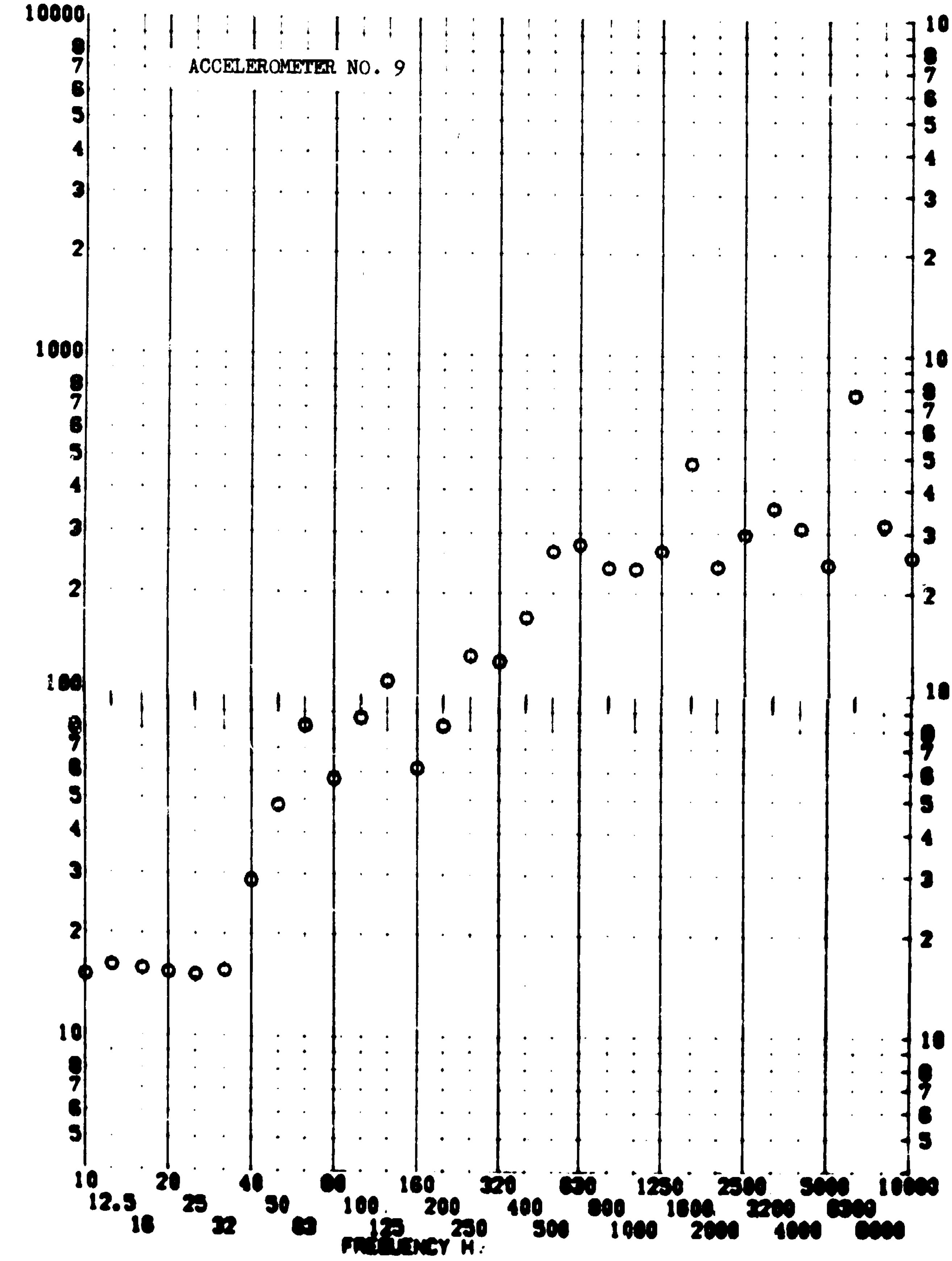
PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.24

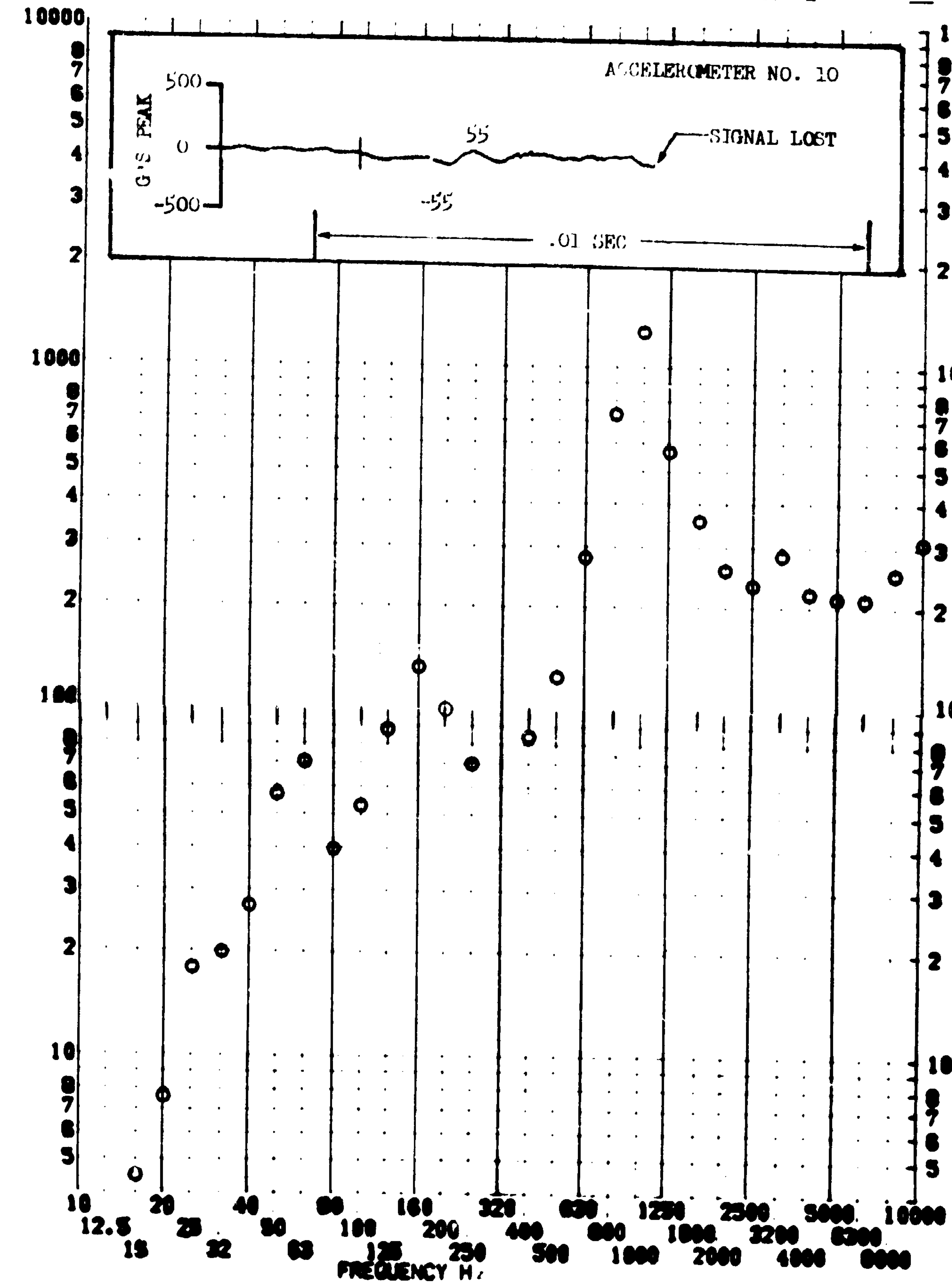
TEST ITEM 456-359
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.25

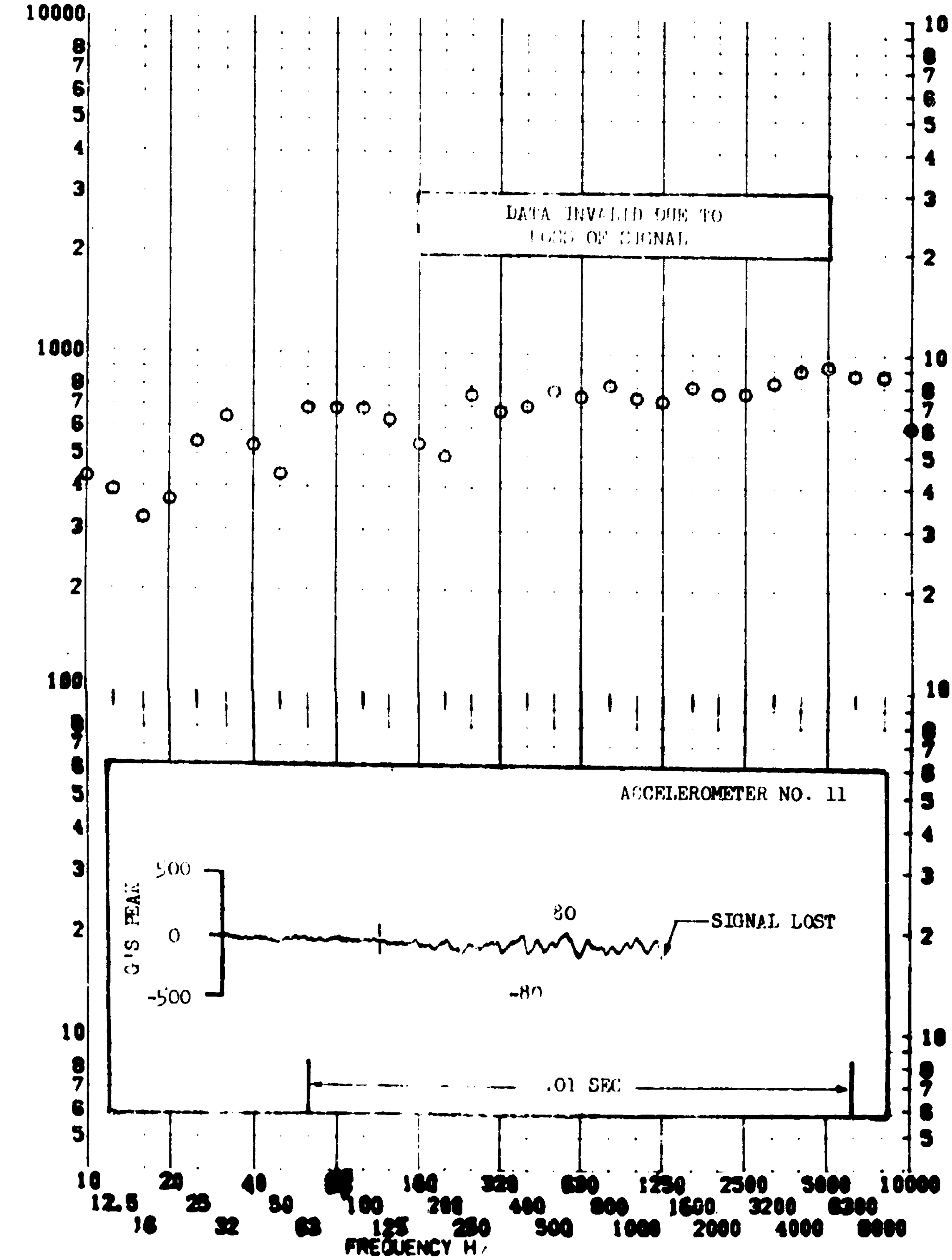
TEST ITEM 456-360 PART NO. 6 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
RESPONSE G-S SHOCK AXIS TANGENTIAL SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.26

TEST ITEM 456 361
SERIAL NO.
SHOCK AXIS TANGENTIAL

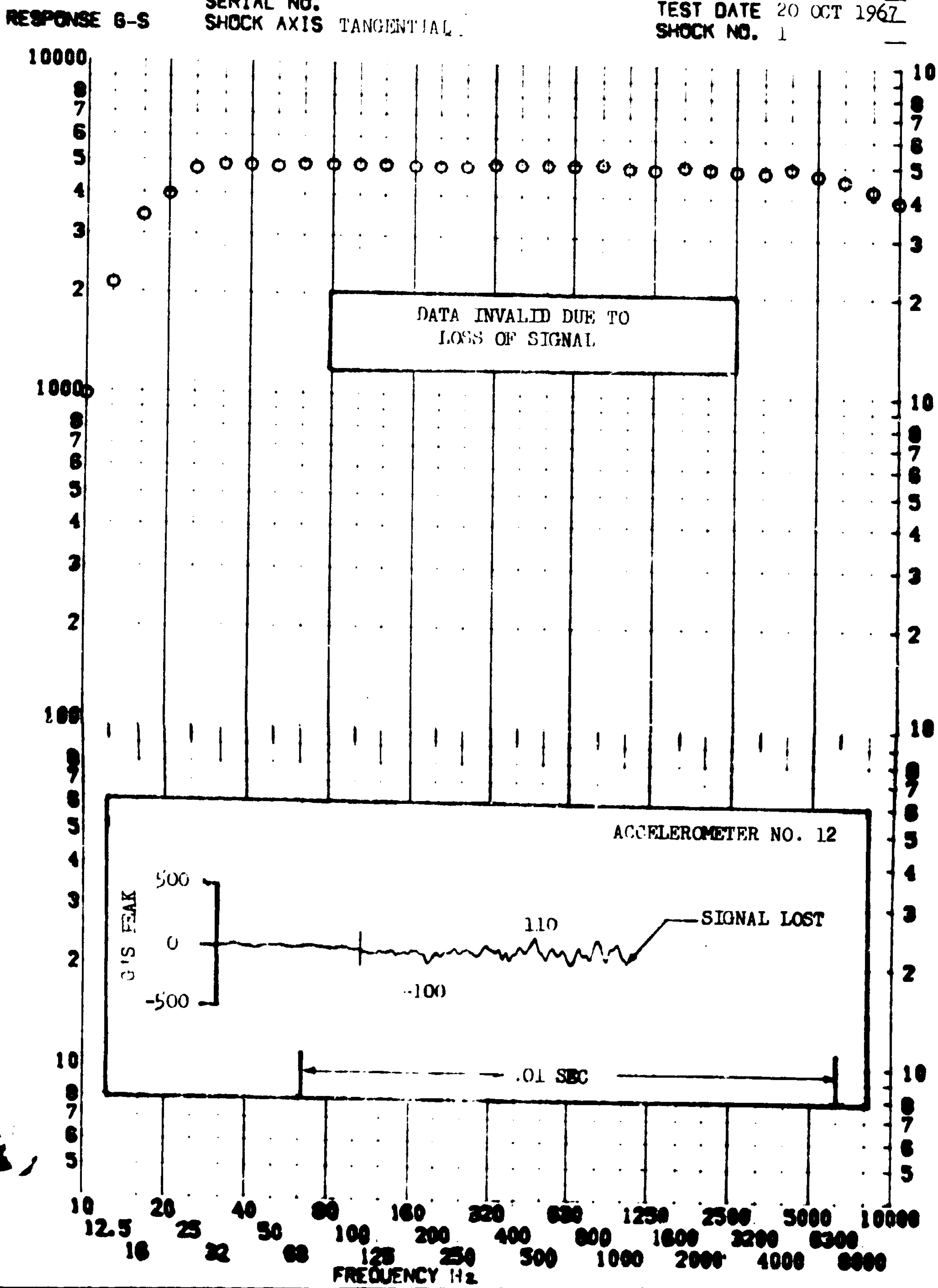
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.27

TEST ITEM 456-362
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1

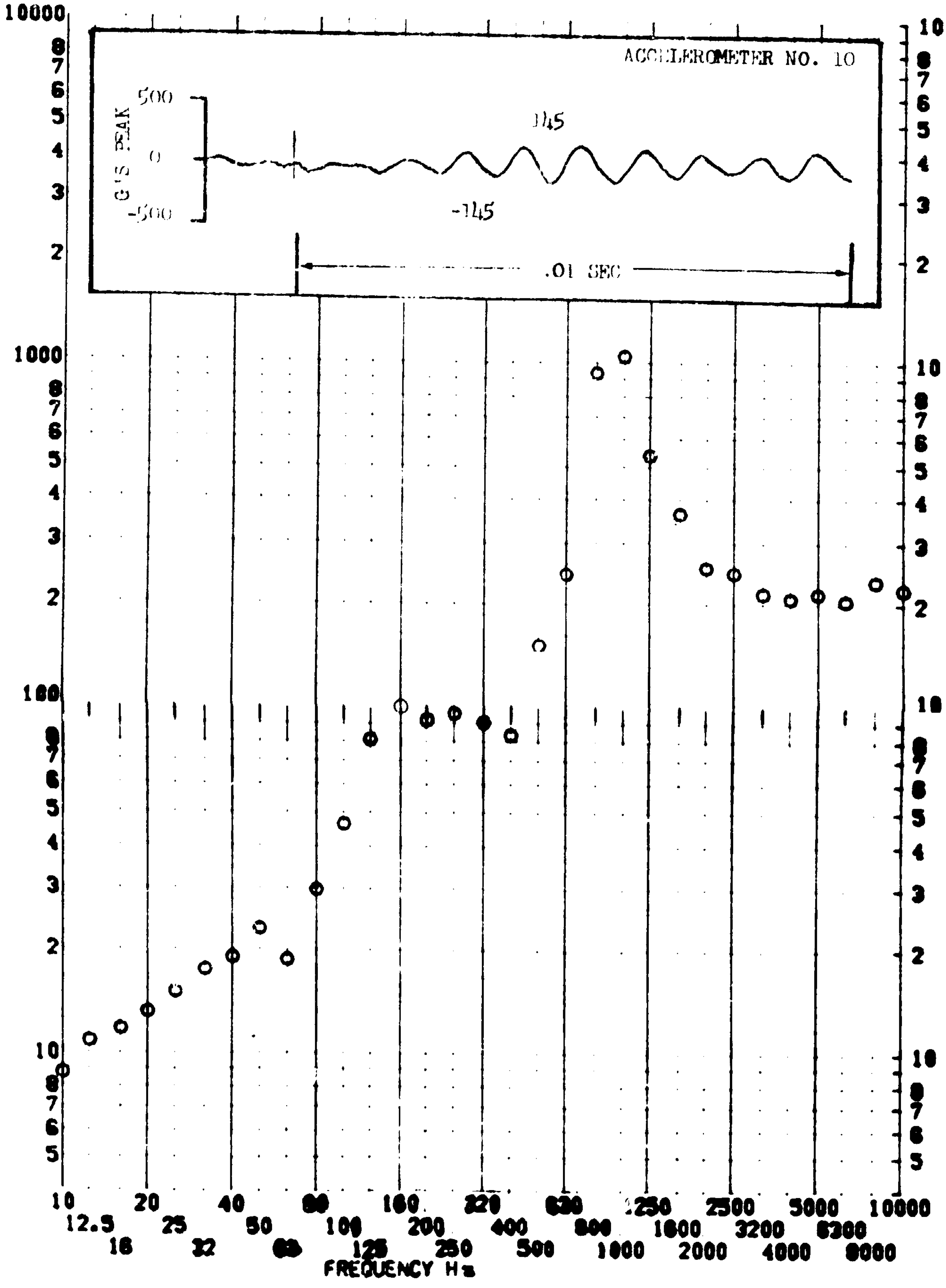


SHOCK TEST ANALYSIS DATA SHEET II.E.2.28

TEST ITEM 456-363
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 2

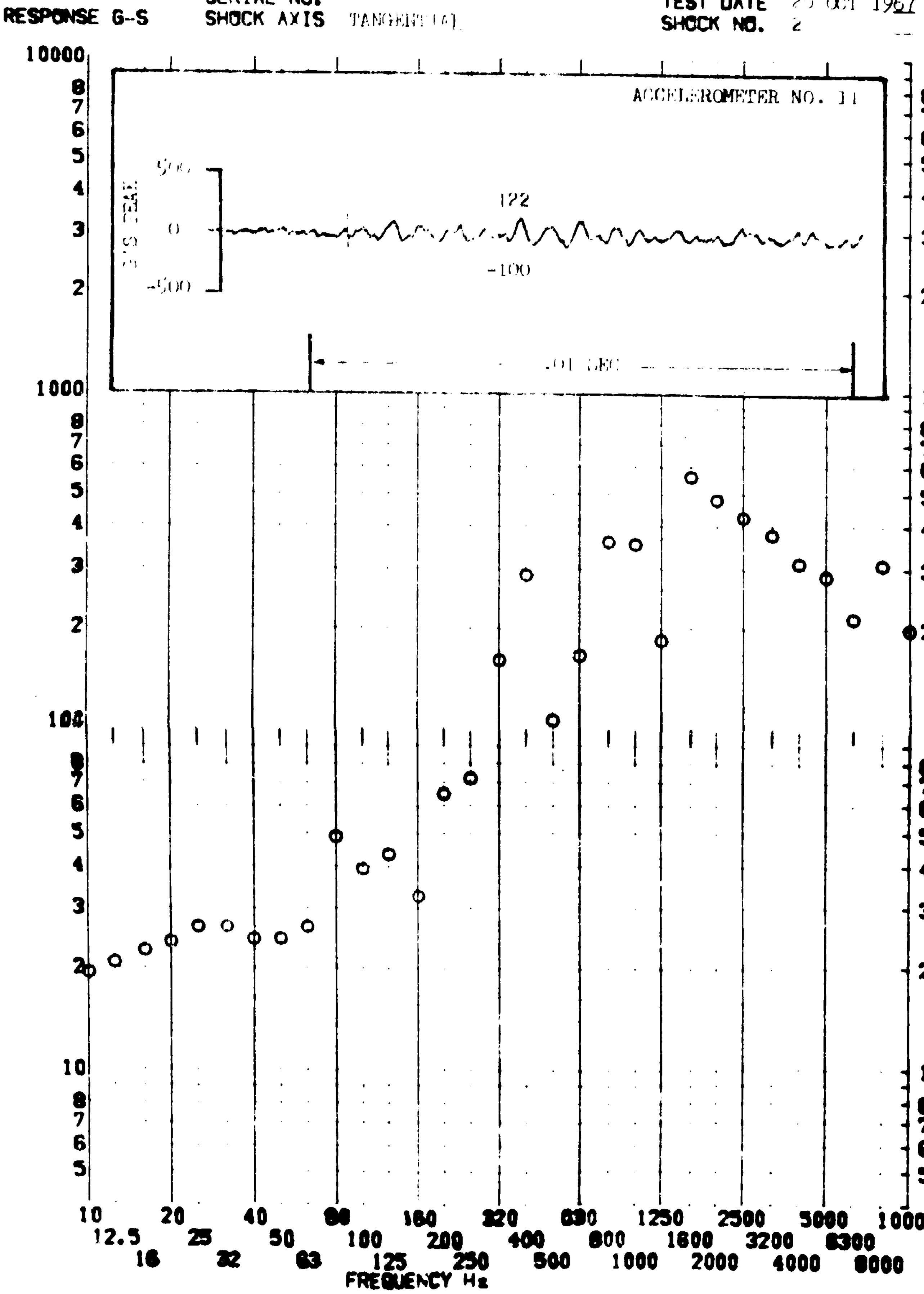
RESPONSE 6-S



SHOCK TEST ANALYSIS DATA SHEET II.E.2.29

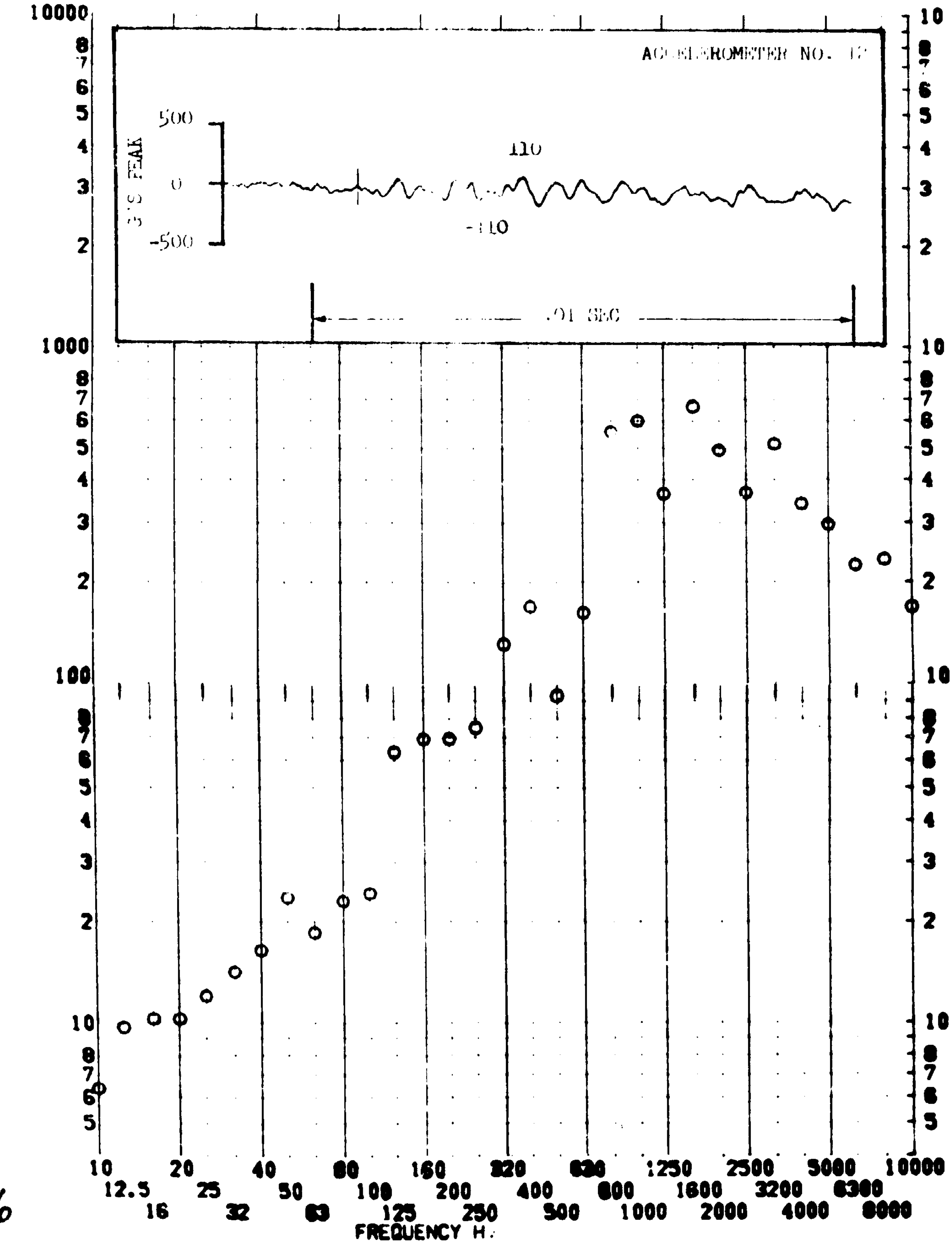
TEST ITEM 456-30[illegible]
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. 6 LB BOX
TEST DATE 2? OCT 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.30

TEST ITEM 456-365 PART NO. 6 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
SHOCK AXIS TANGENTIAL SHOCK NO. 2

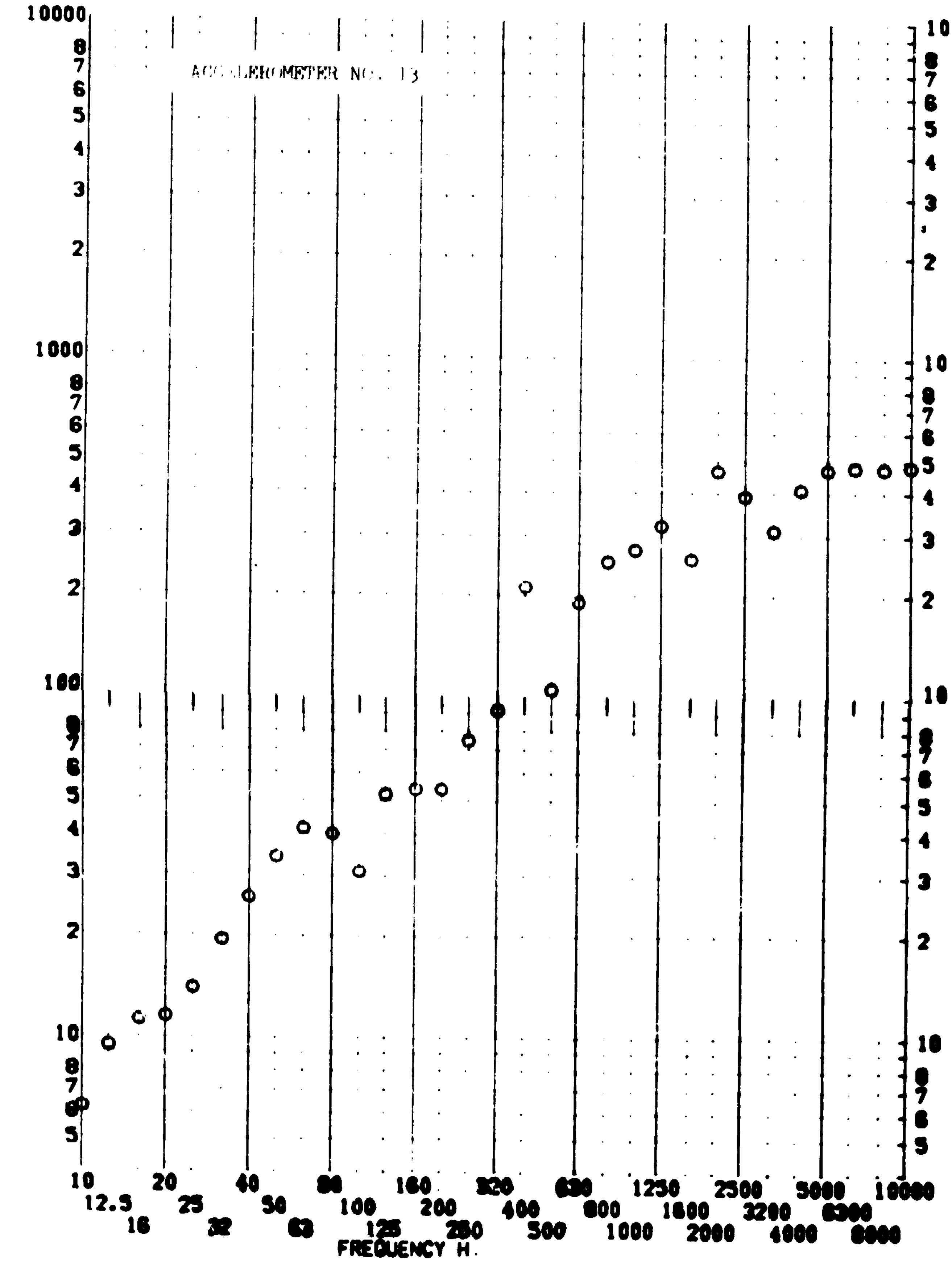


6

SHOCK TEST ANALYSIS DATA SHEET 11.E.2.31

TEST ITEM 456-366
SERIAL NO.
SHOCK AXIS LONGITUDINAL

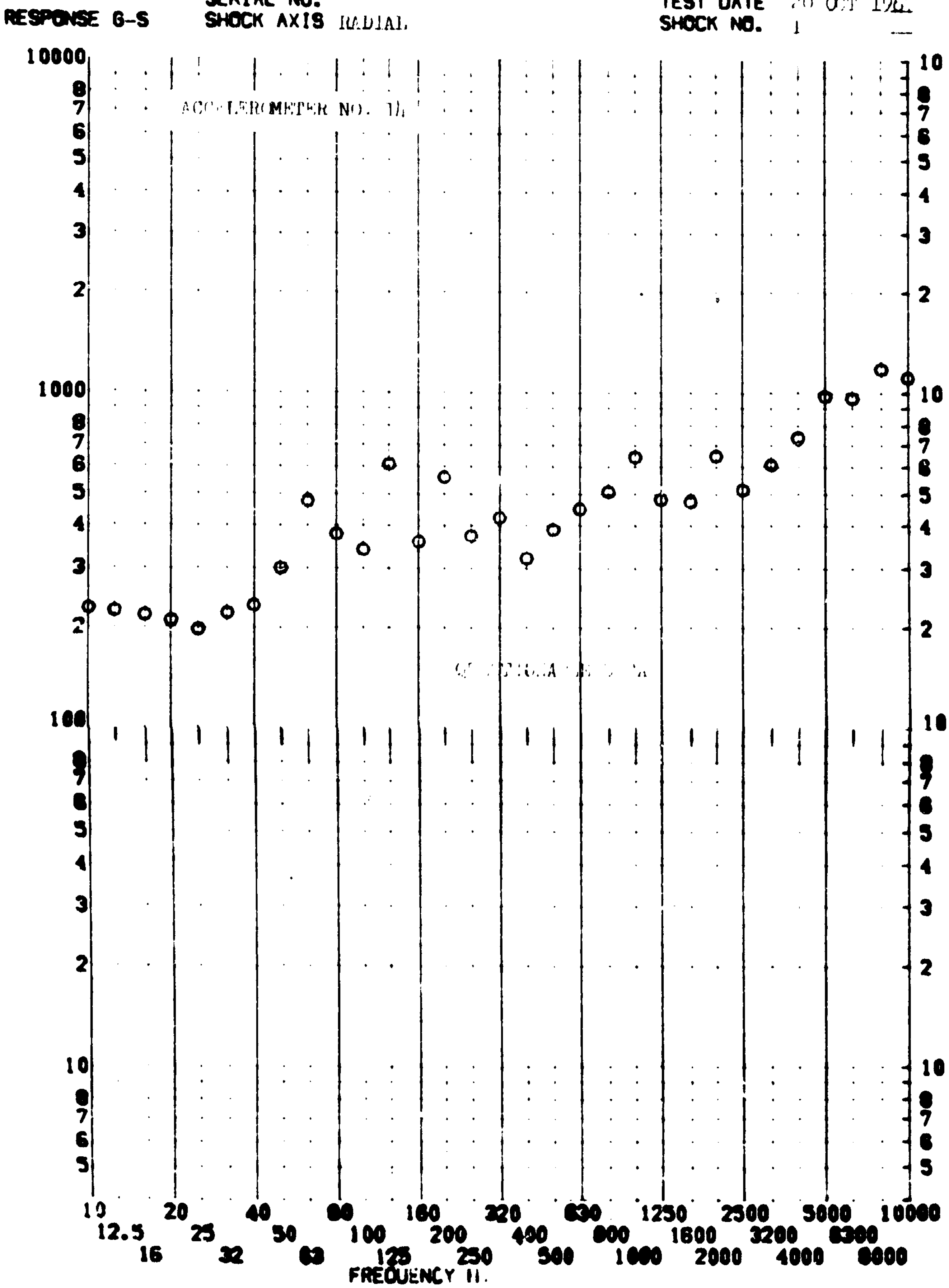
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.32

TEST ITEM 456-367
SERIAL NO.
SHOCK AXIS RADIAL

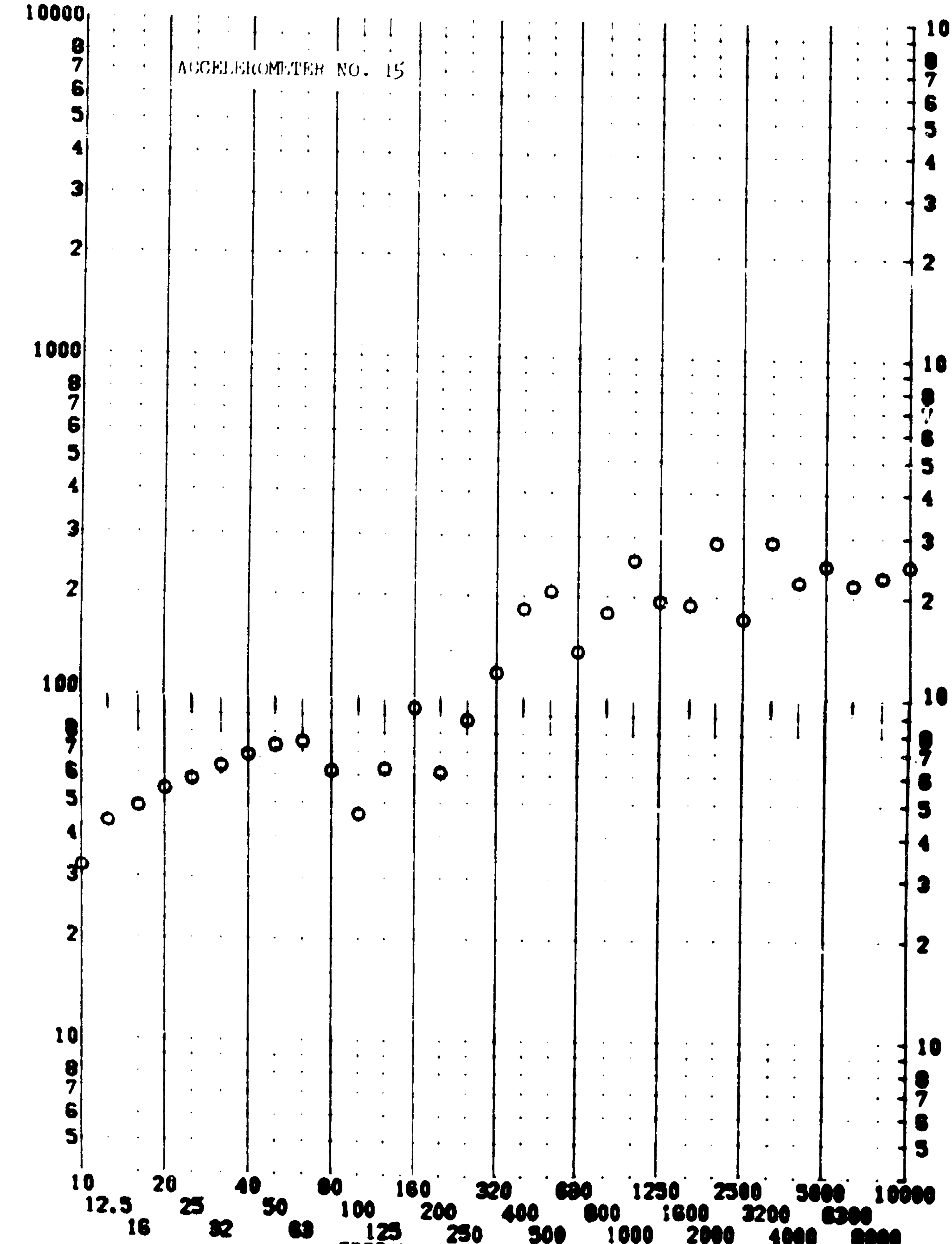
PART NO. 6 LB BOX
TEST DATE 20 OCT 196
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.33

TEST ITEM 456-368
SERIAL NO.
SHOCK AXIS TANGENTIAL

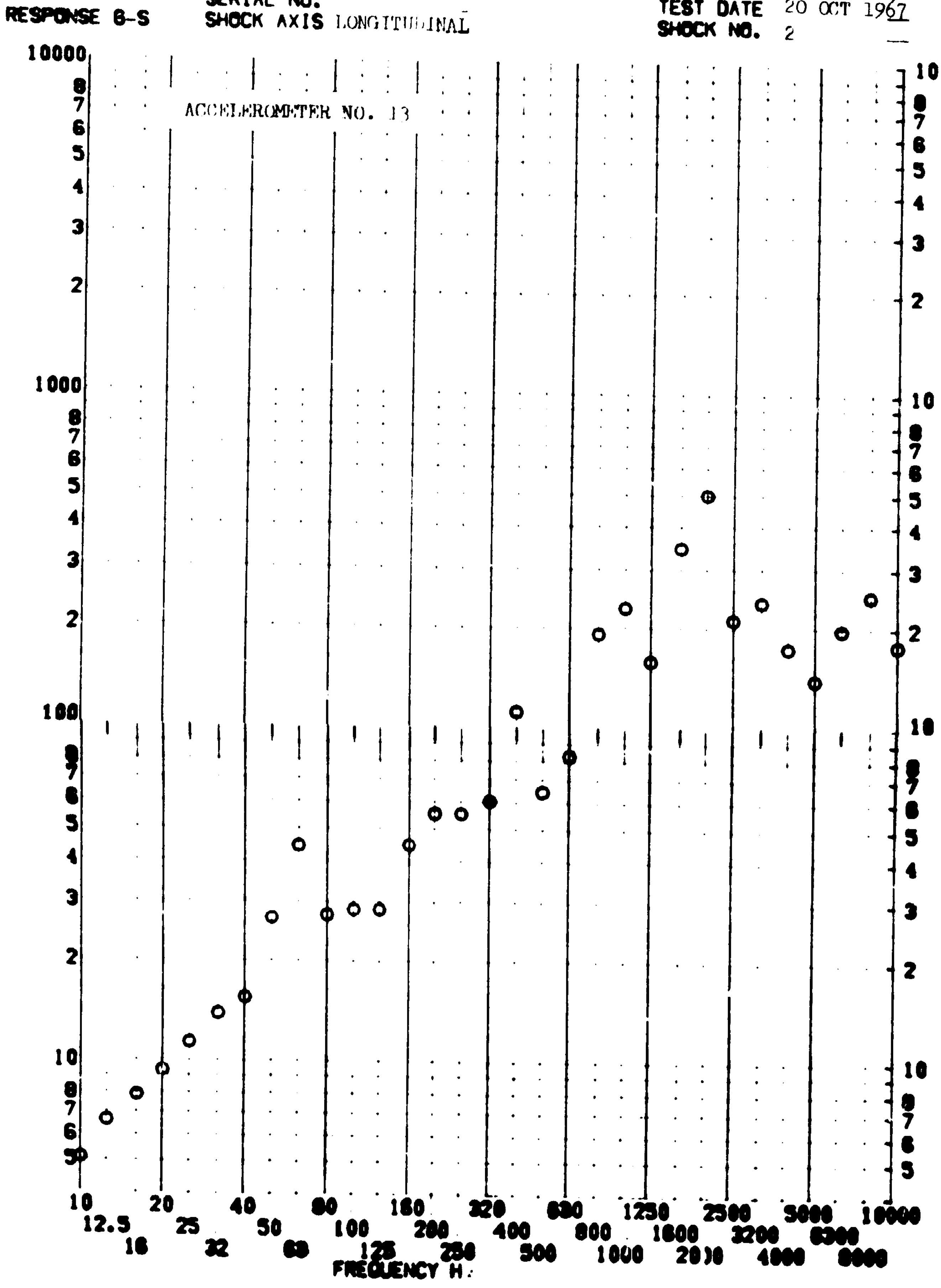
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.2.34

TEST ITEM 456-369
SERIAL NO.
SHOCK AXIS LONGITUDINAL

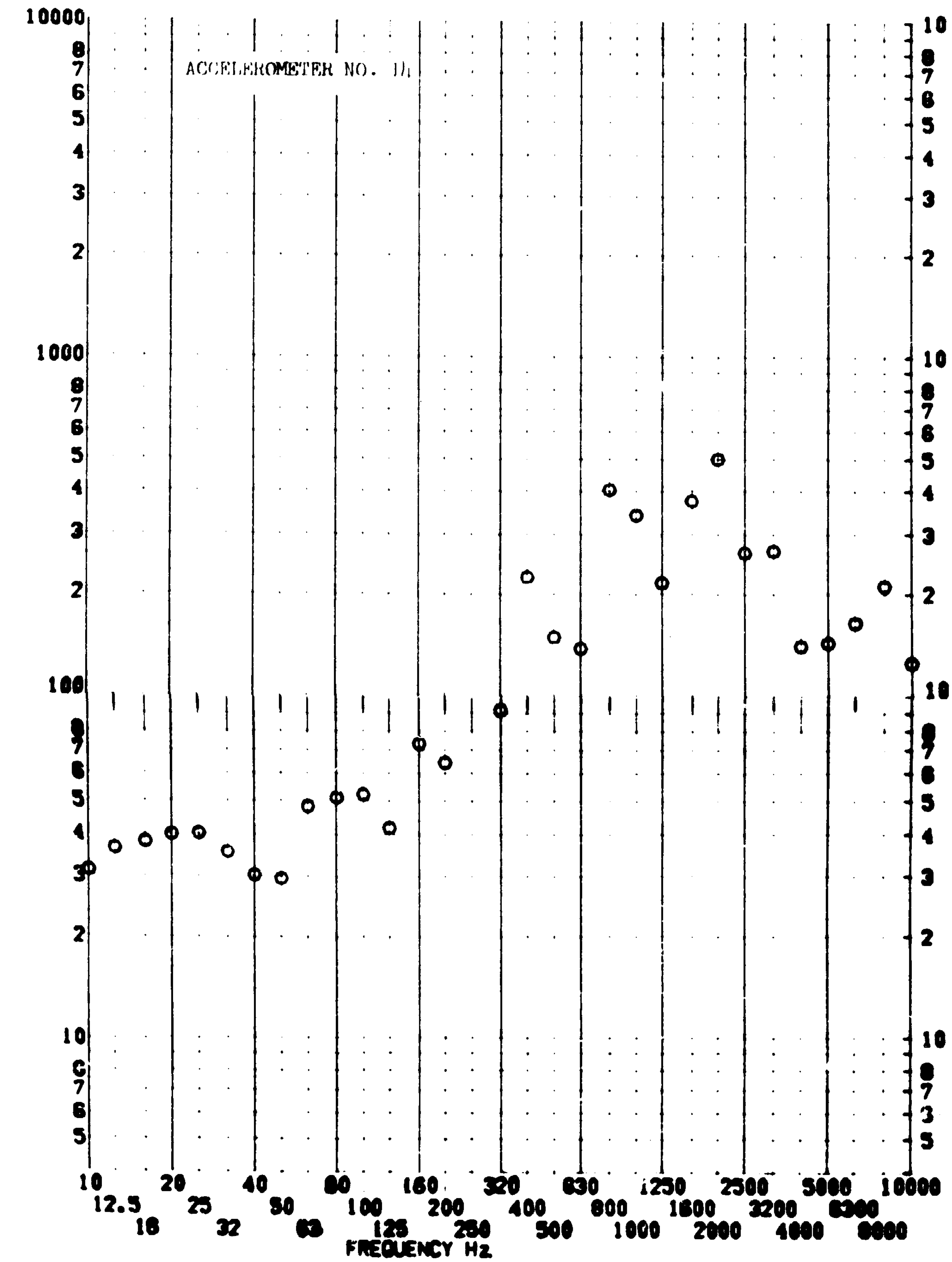
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.35

TEST ITEM 456-370
SERIAL NO.
SHOCK AXIS RADIAL

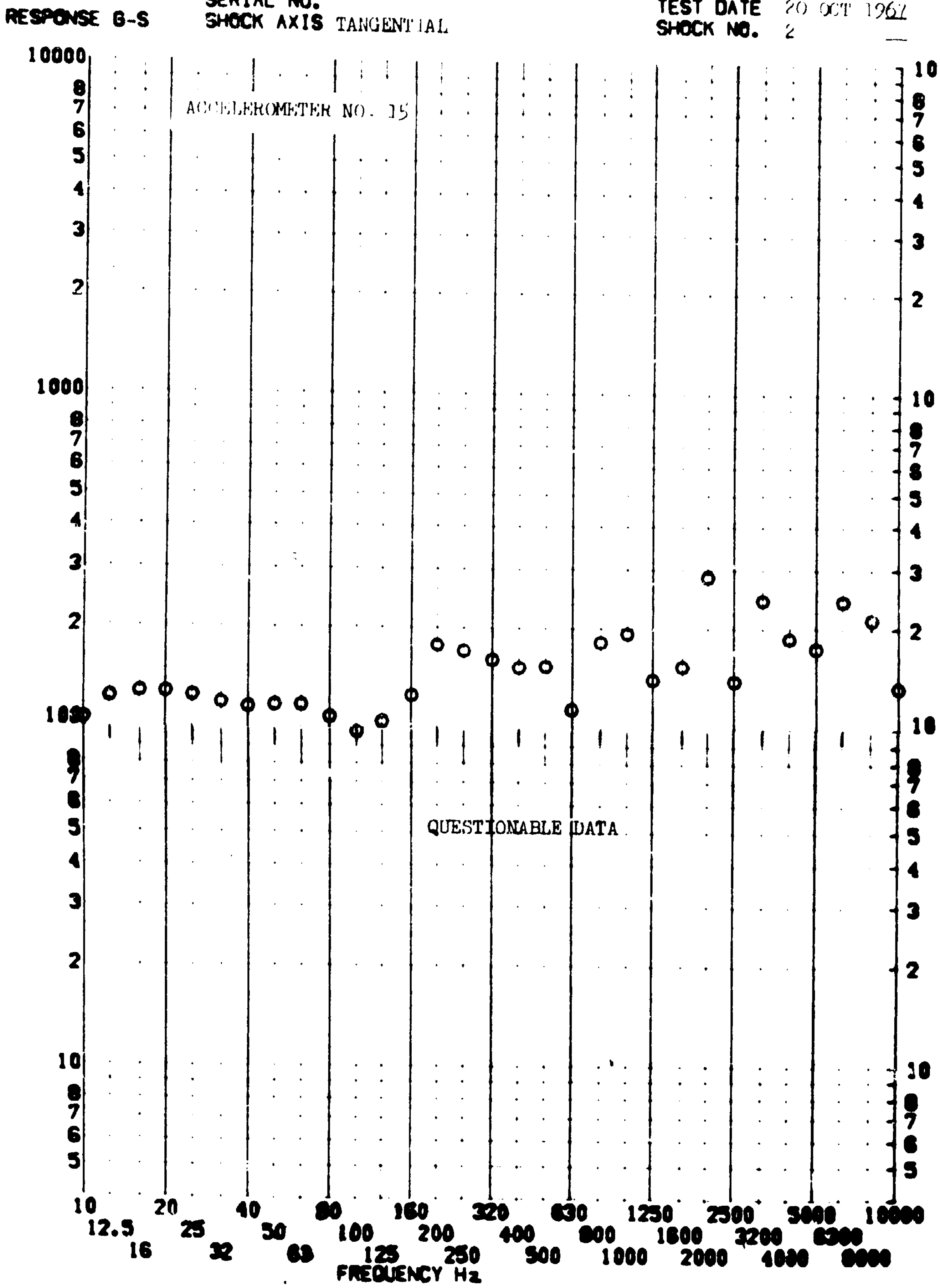
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.36

TEST ITEM 456-371
SERIAL NO.
SHOCK AXIS TANGENTIAL

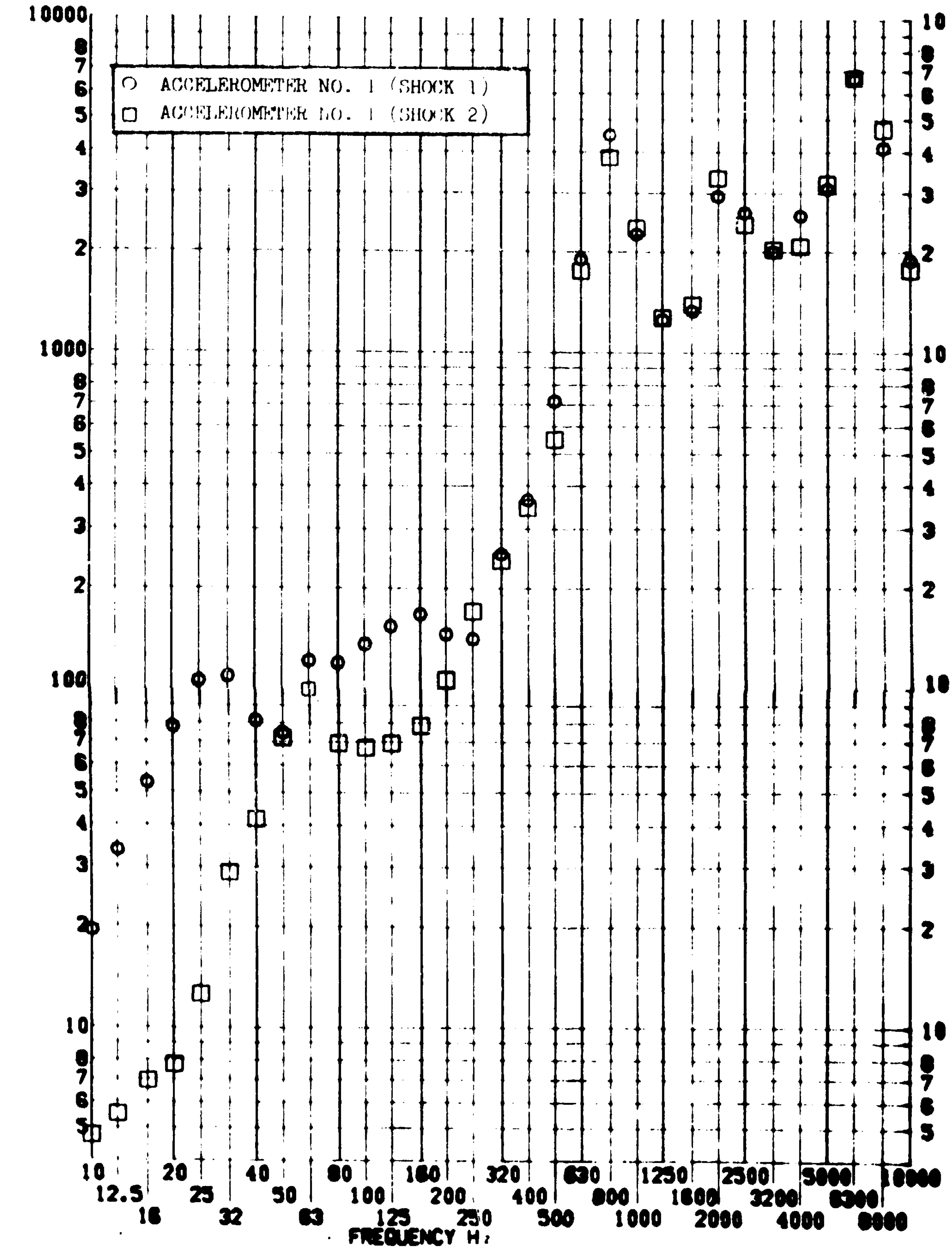
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.F.2.37

TEST ITEM 456-342,345
SERIAL NO.
SHOCK AXIS LONGITUDINAL

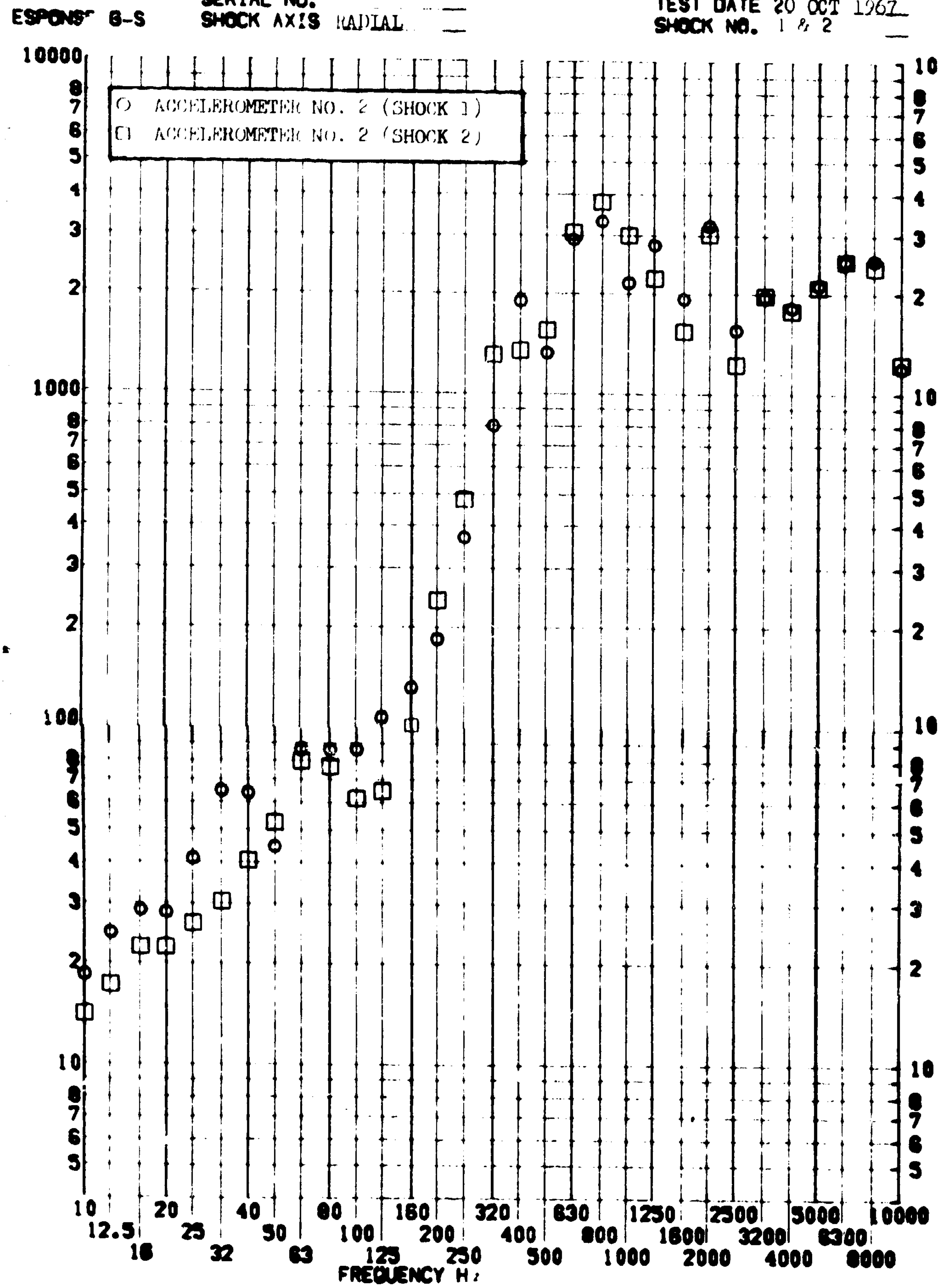
PART NO. STRUCTURE
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.38

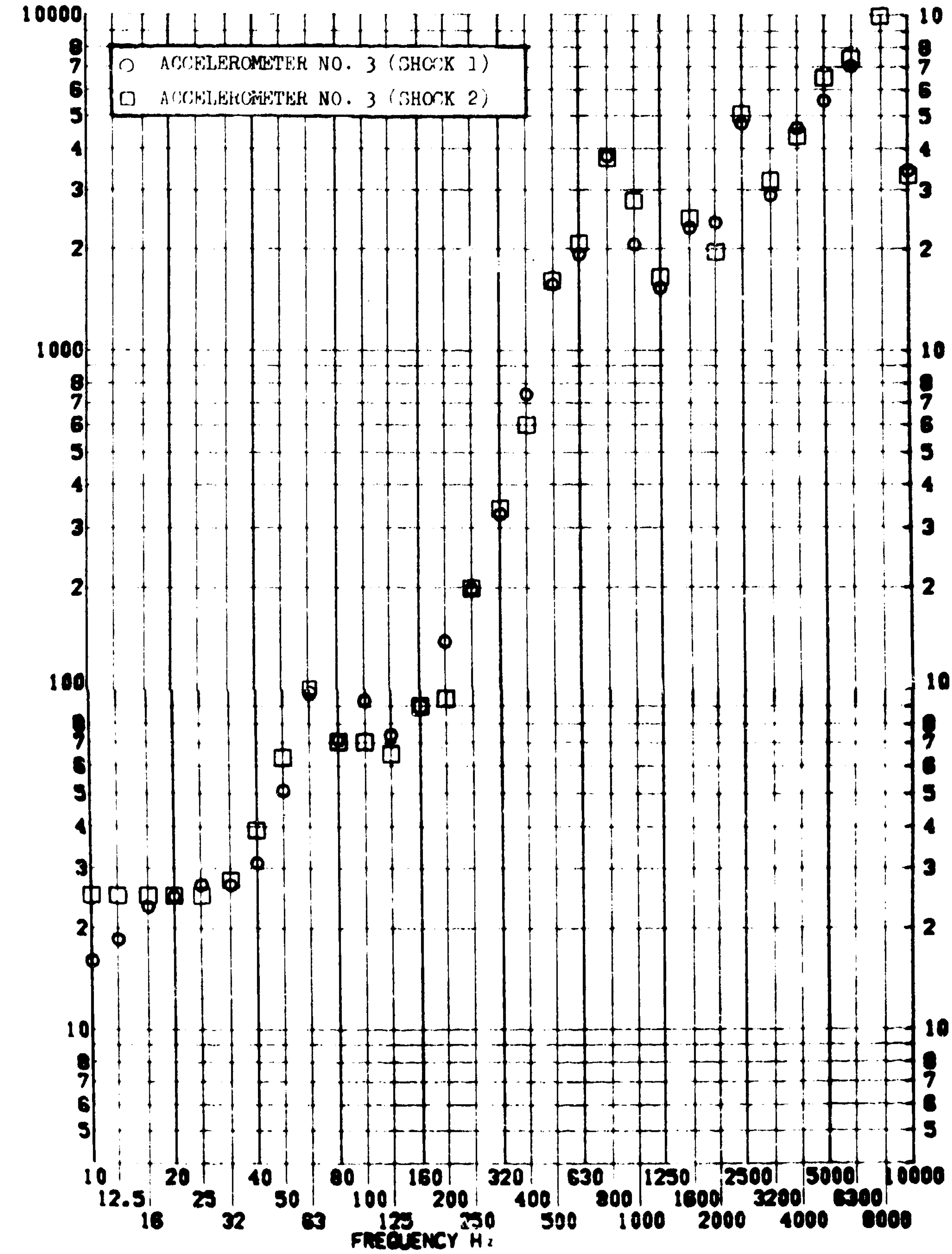
TEST ITEM 456-343,346
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. STRUCTURE
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



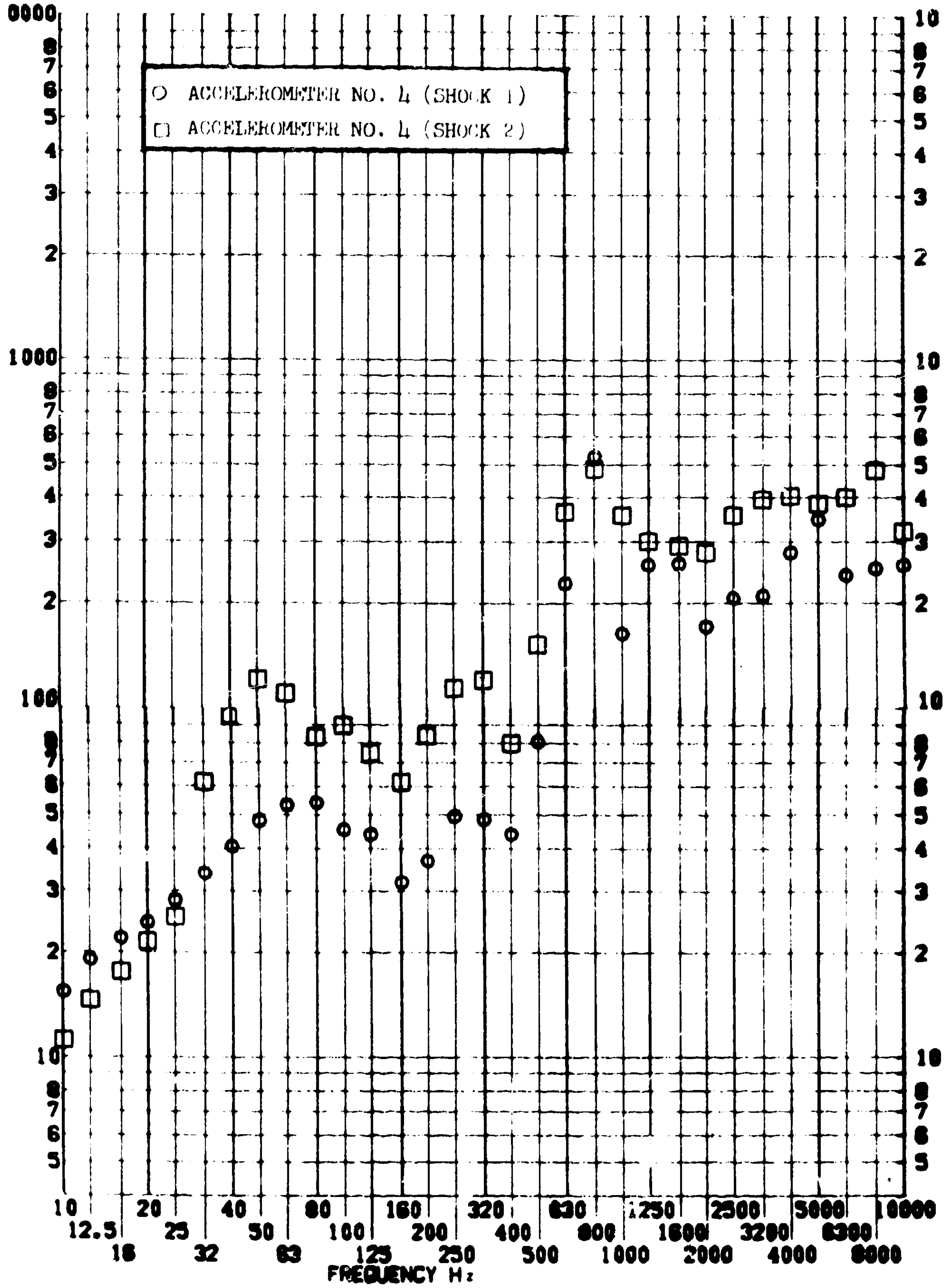
SHOCK TEST ANALYSIS DATA SHEET II.E.2.39

TEST ITEM 456-344,347 PART NO. STRUCTURE
SERIAL NO. TEST DATE 20 OCT 1967
RESPONSE G-S SHOCK AXIS TANGENTIAL SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.40

TEST ITEM 456-348,351 PART NO. 7.5 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
SHOCK AXIS LONGITUDINAL SHOCK NO. 1 & 2

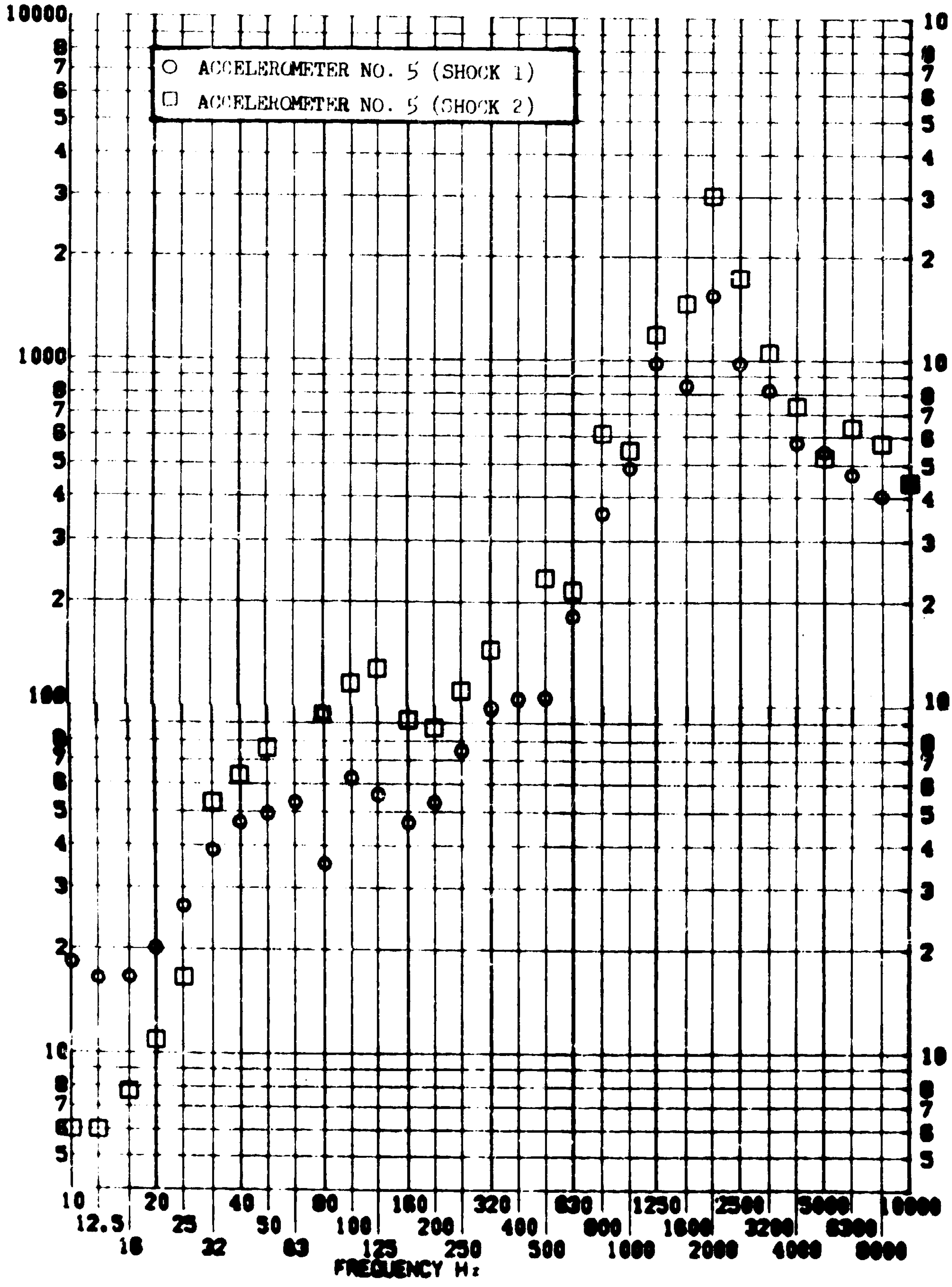


SHOCK TEST ANALYSIS DATA SHEET IT.E.2.41

TEST ITEM 456-349,352
SERIAL NO. —
SHOCK AXIS RADIAL —

PART NO. 7.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2

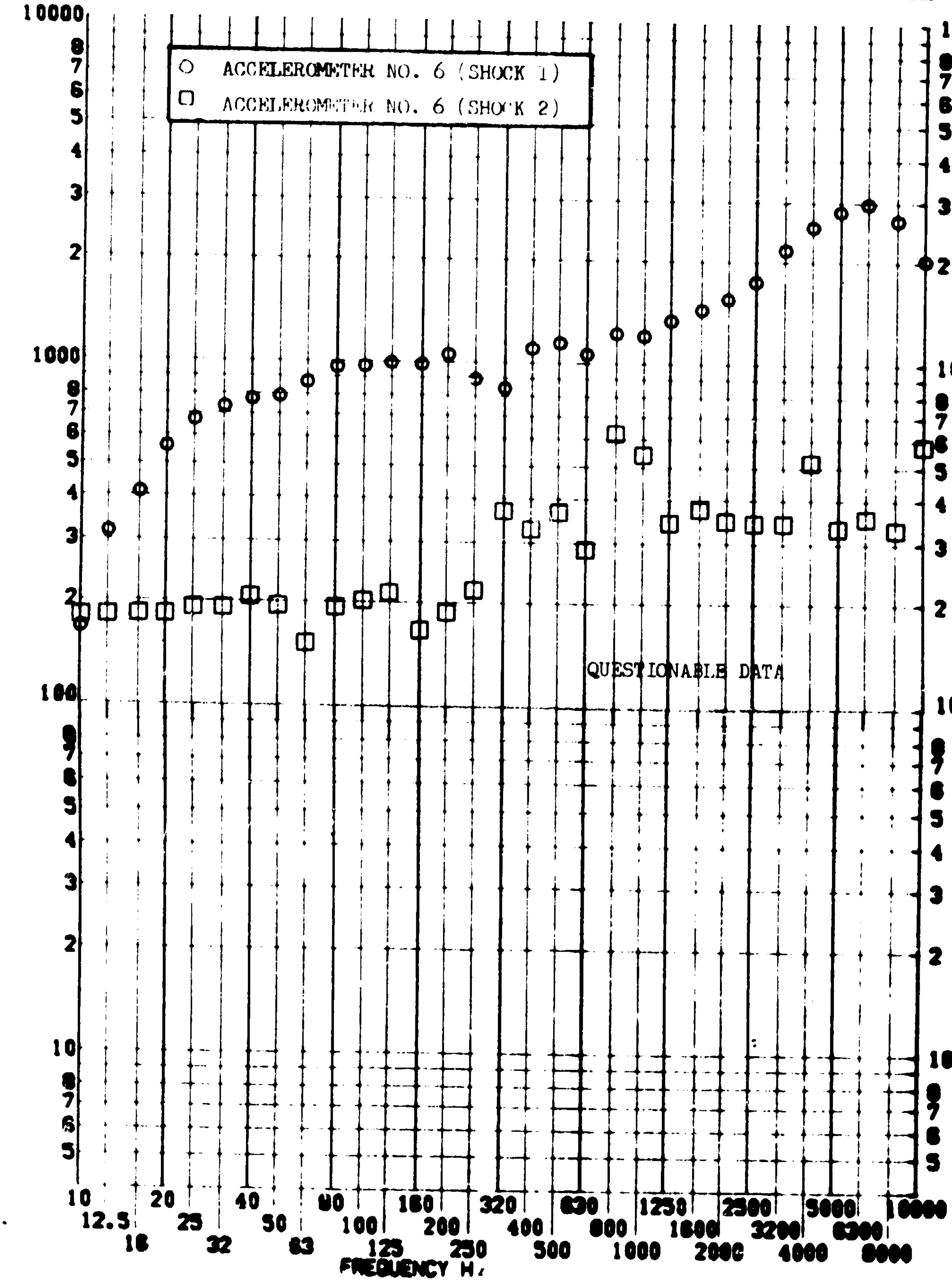
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.2.42

TEST ITEM 456-350,353
SERIAL NO.
SHOCK AXIS TANGENTIAL

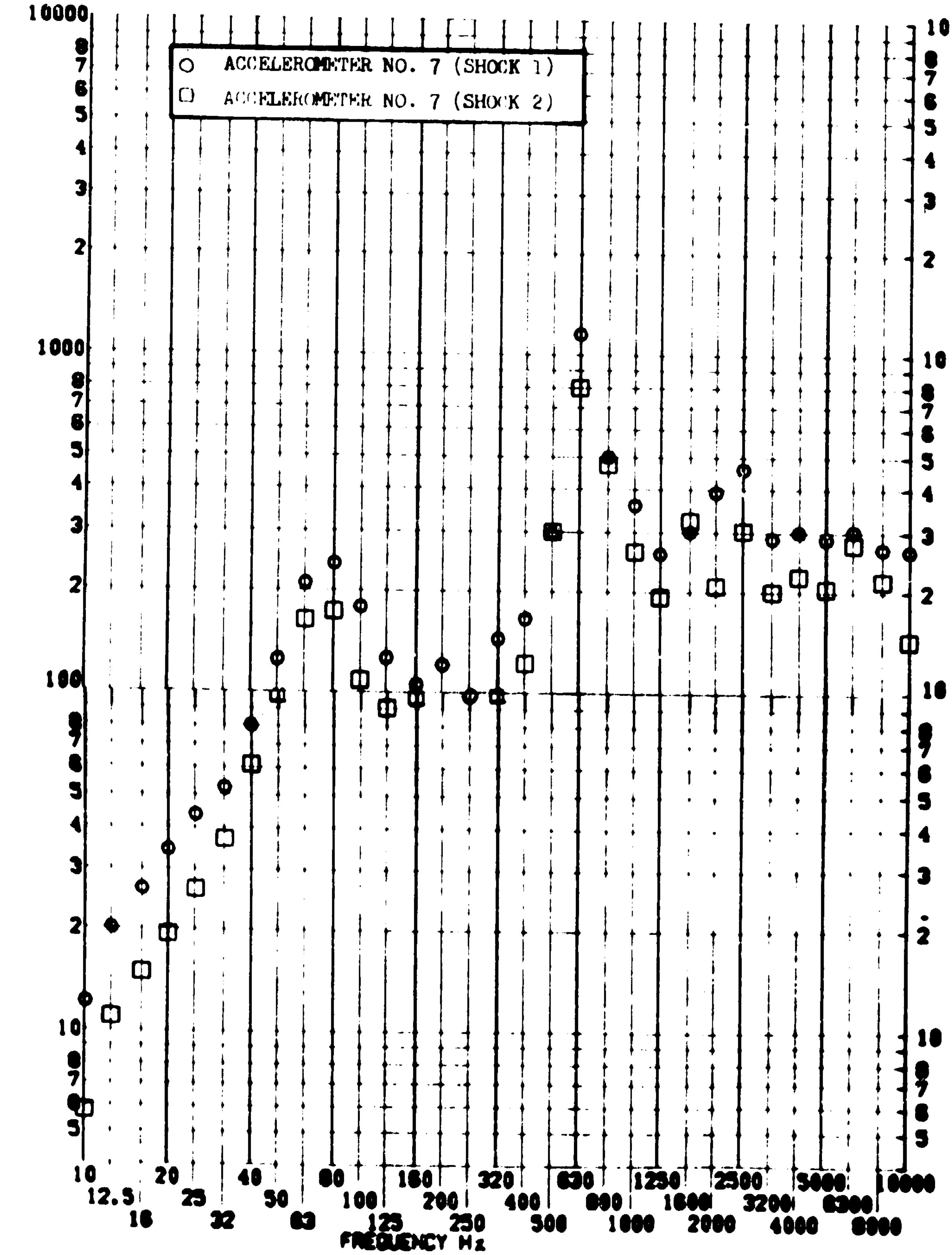
PART NO. 7.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.43

TEST ITEM 456-354,357
SERIAL NO.
SHOCK AXIS LONGITUDINAL

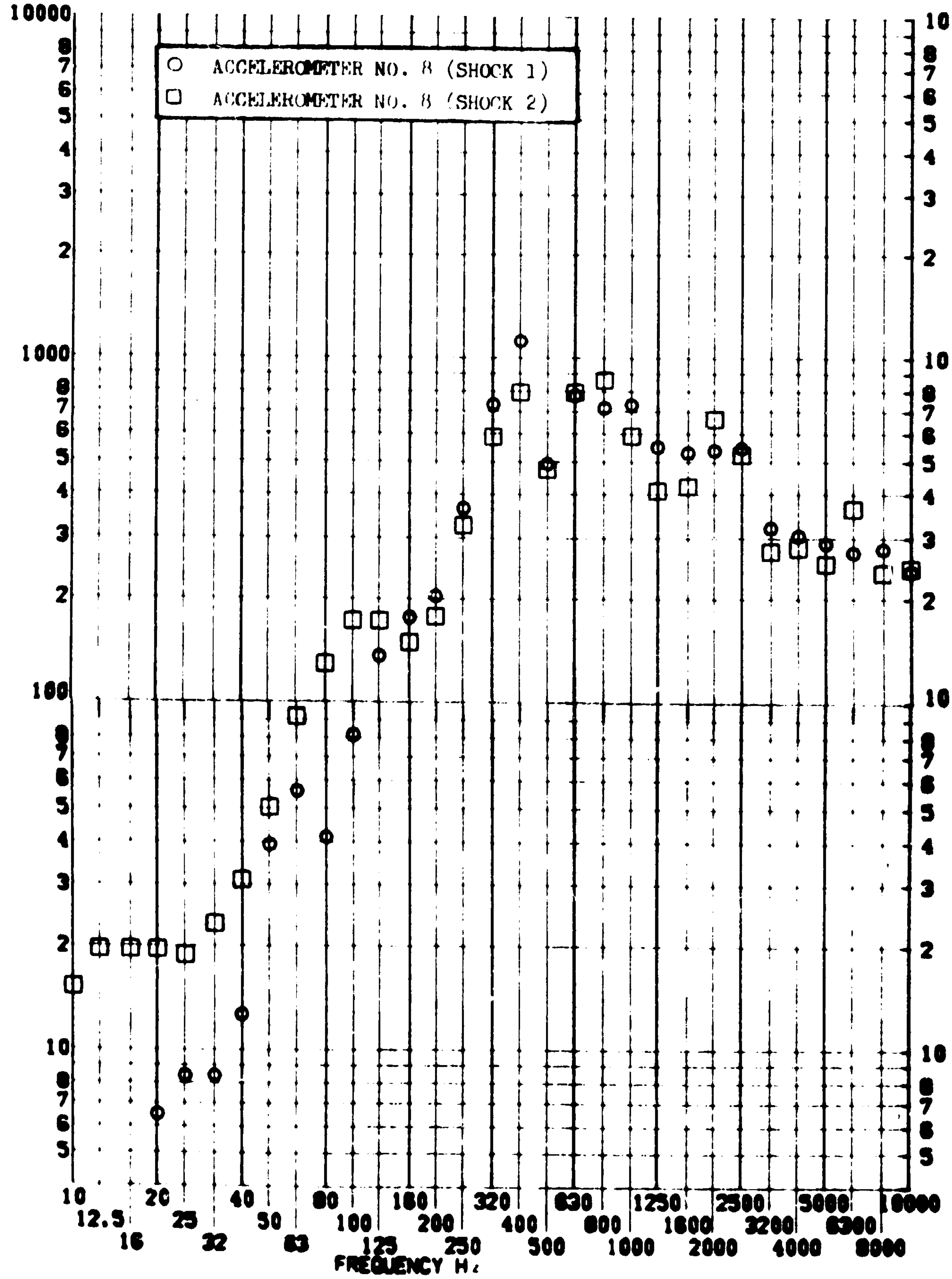
PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.44

TEST ITEM 456-355,358
SERIAL NO. —
SHOCK AXIS RADIAL —

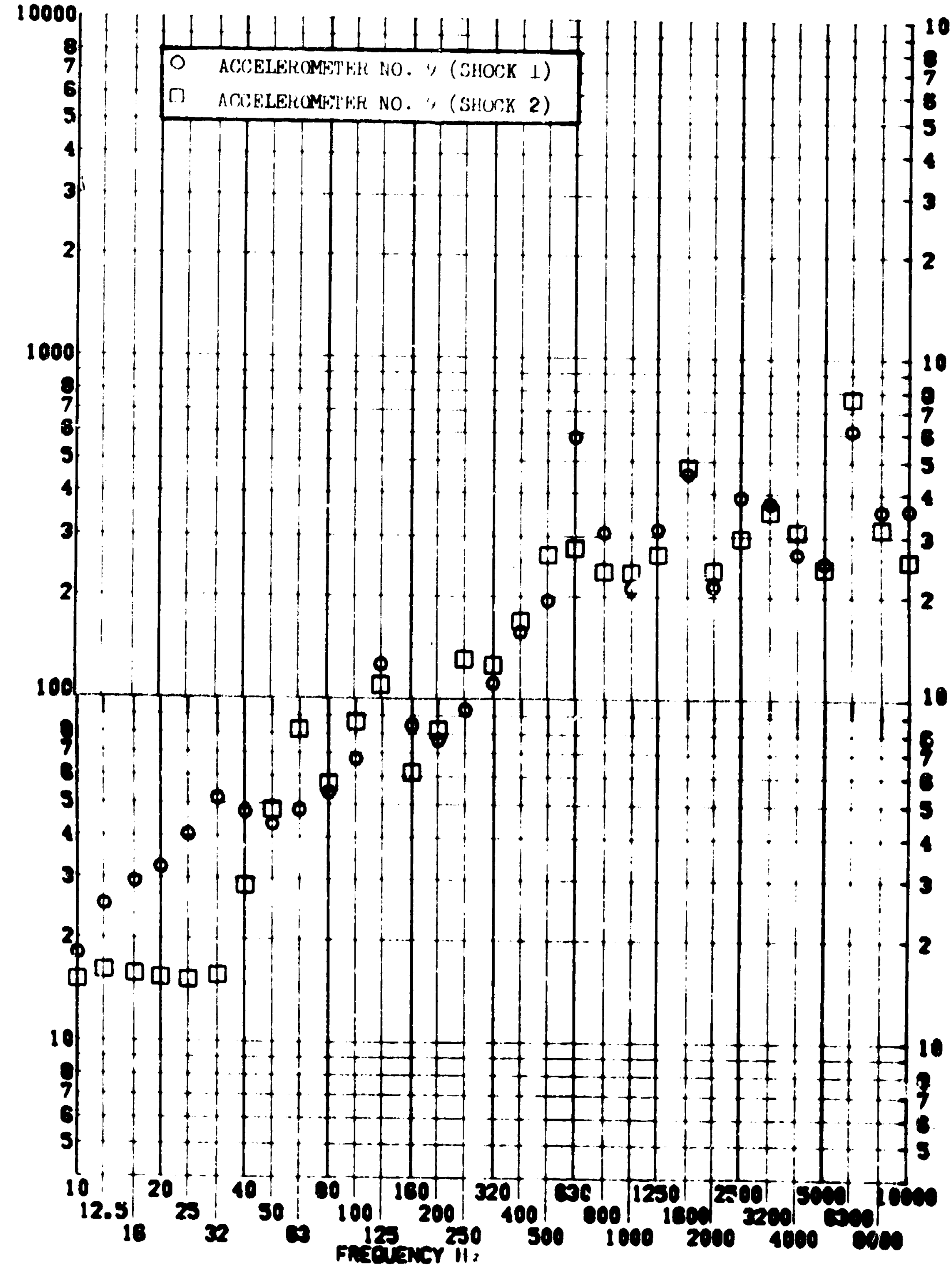
PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.45

TEST ITEM 456-356,352
SERIAL NO. —
SHOCK AXIS TANGENTIAL

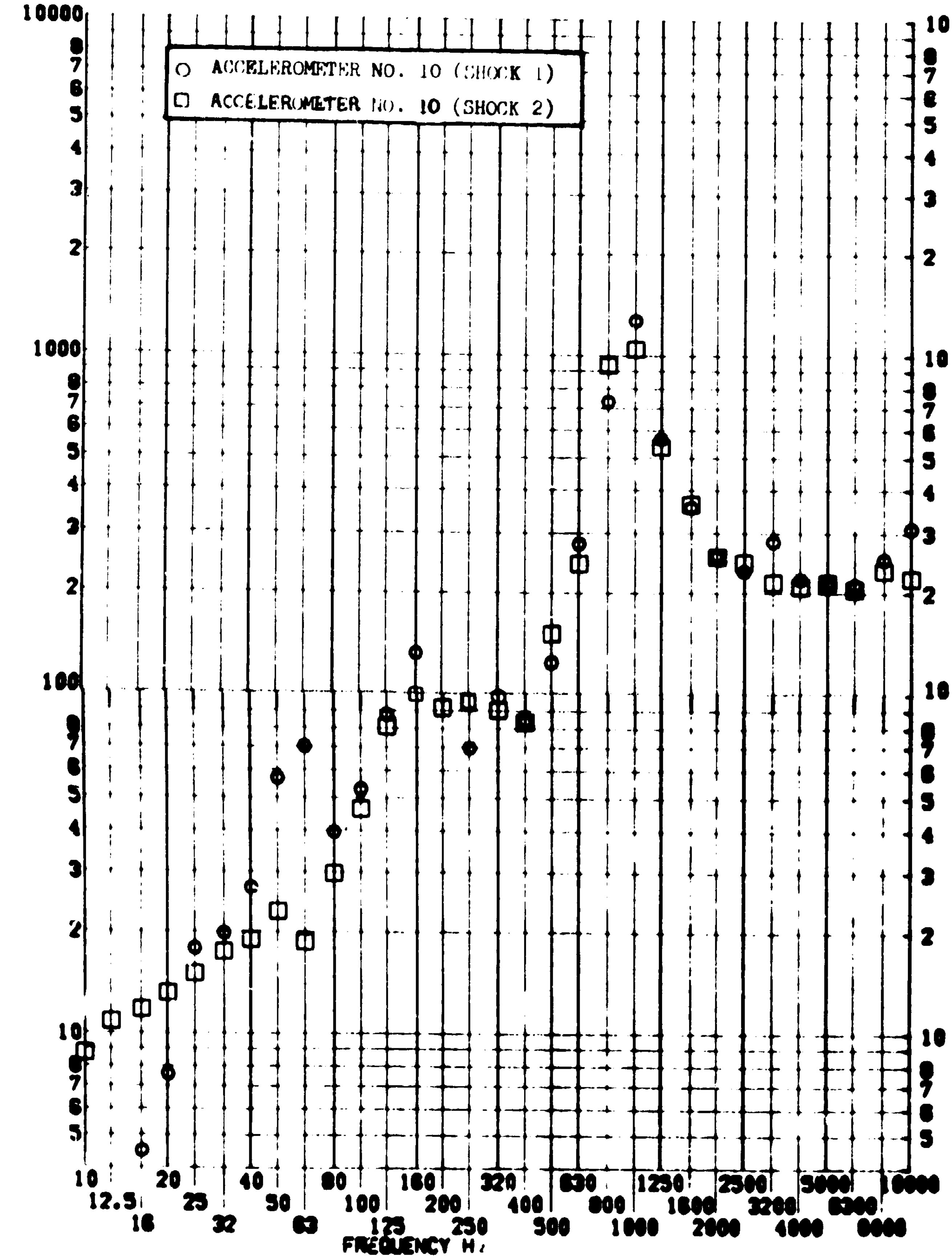
PART NO. 18.5 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.46

TEST ITEM 456-360,363
SERIAL NO.
SHOCK AXIS TANGENTIAL

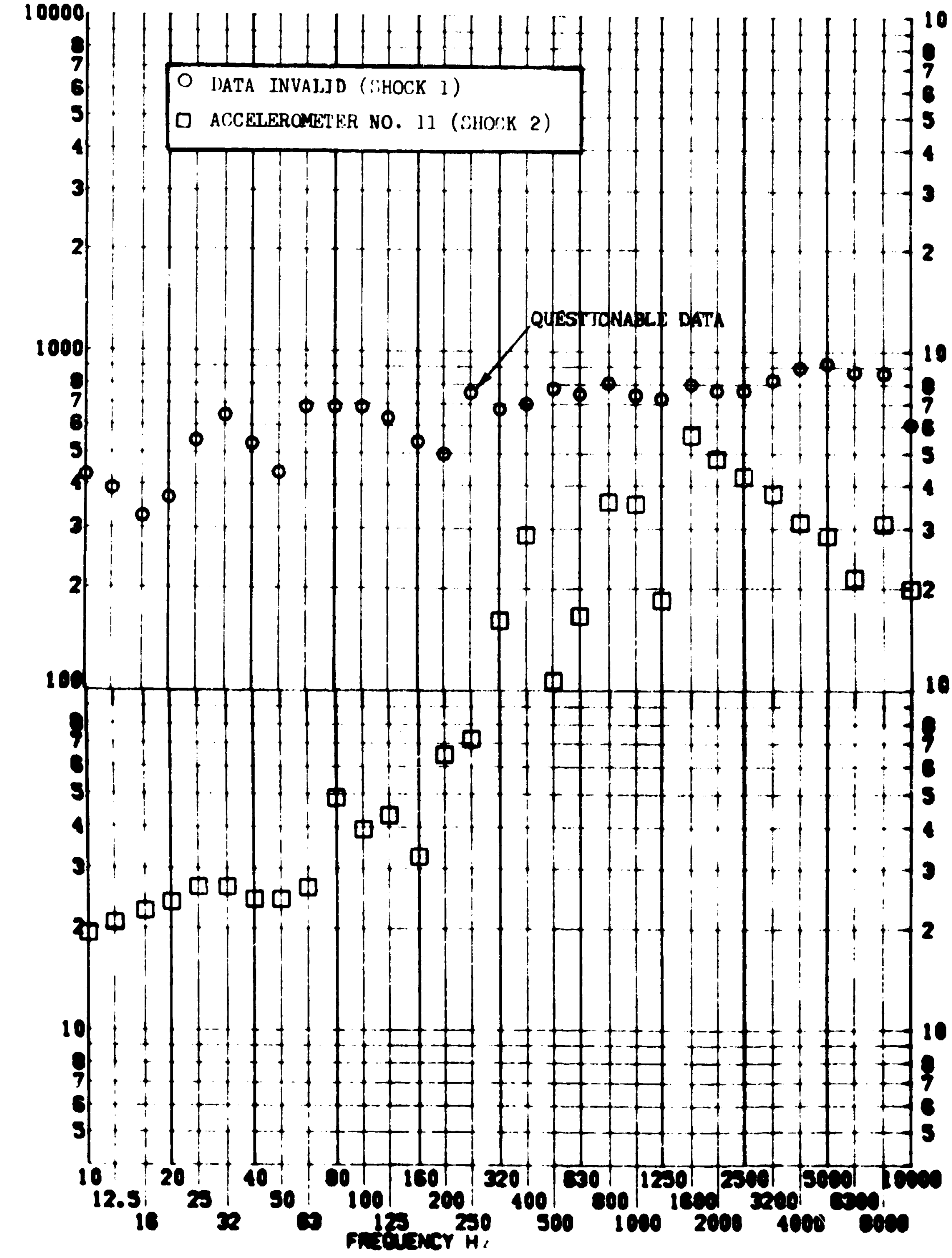
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.47

TEST ITEM 456-361,364
SERIAL NO.
SHOCK AXIS TANGENTIAL

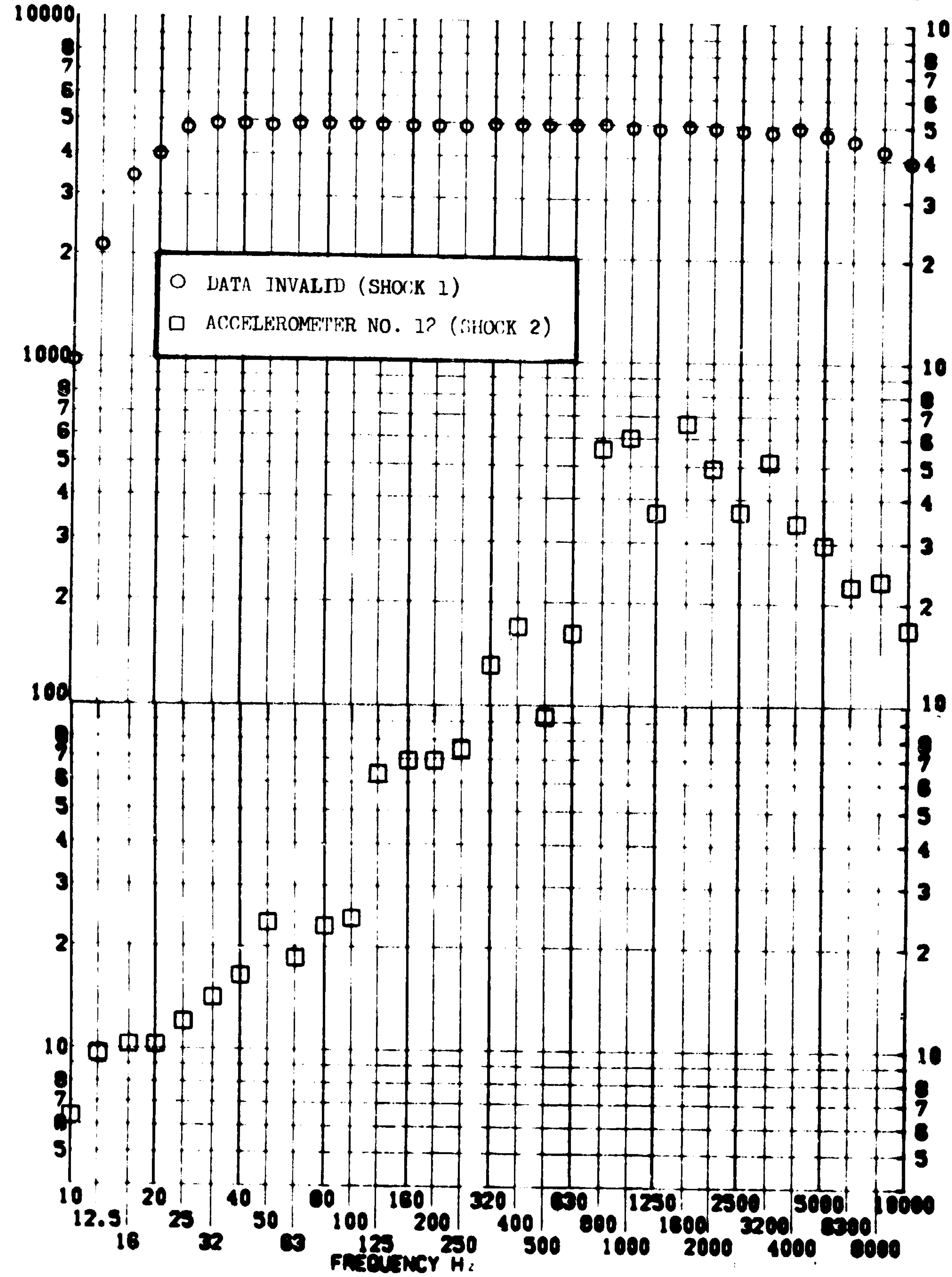
PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.48

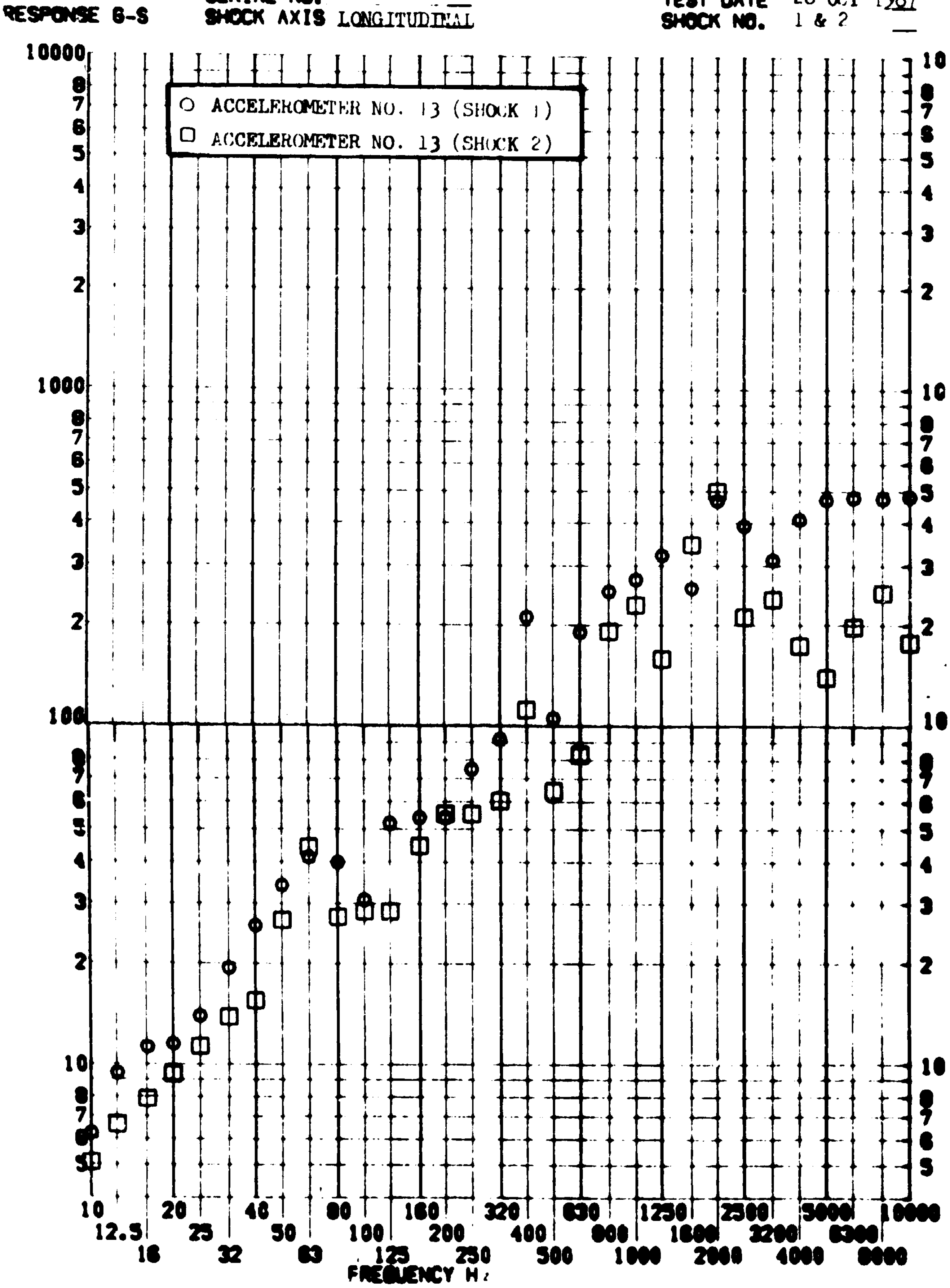
TEST ITEM 456-362,365
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. 6 LB BOX
TEST DATE 20 OCT 1967
SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.49

TEST ITEM	456-366,369	PART NO.	6 LB BOX
SERIAL NO.		TEST DATE	20 OCT 1967
SHOCK AXIS	LONGITUDINAL	SHOCK NO.	1 & 2

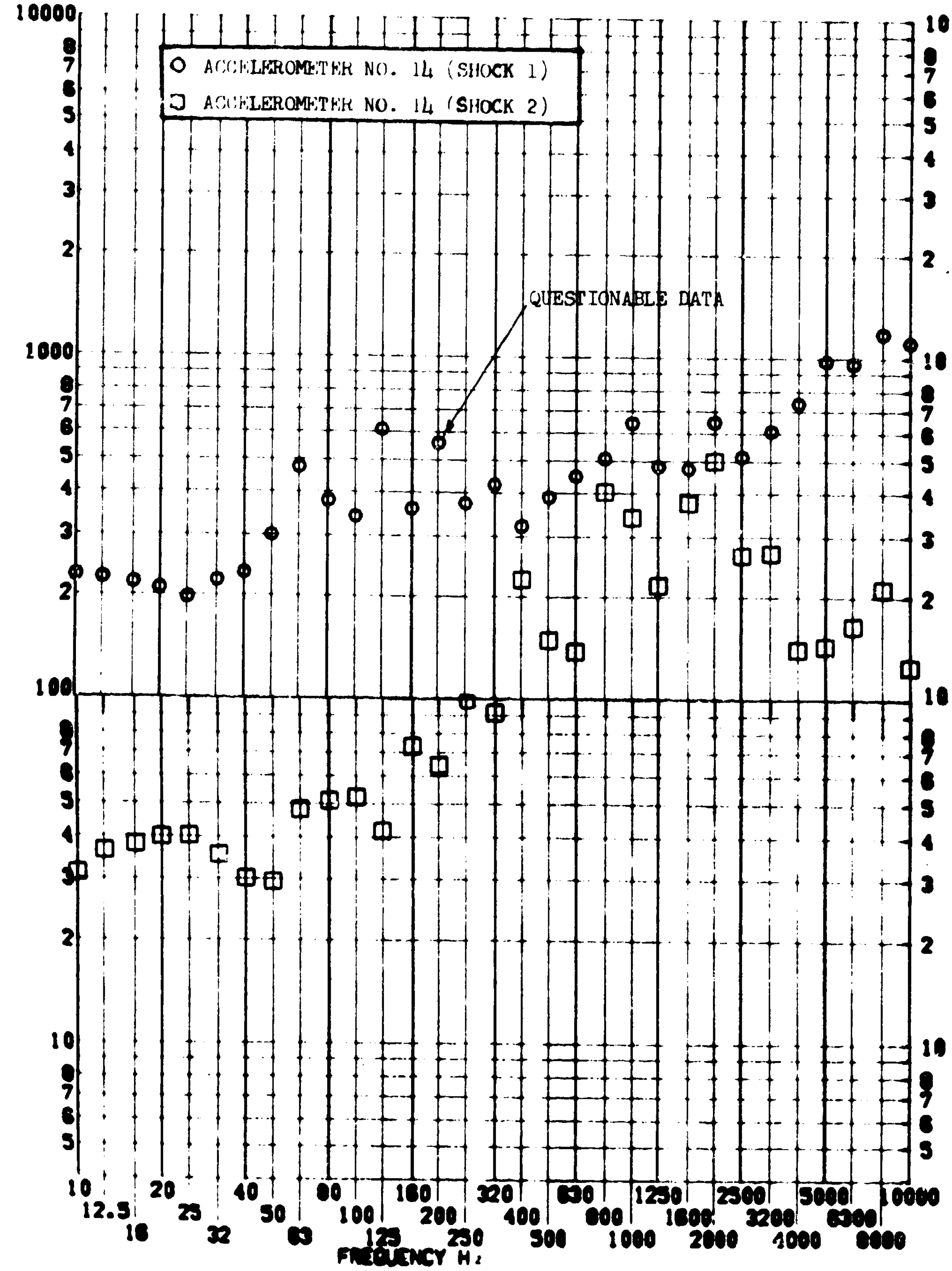


SHOCK TEST ANALYSIS DATA SHEET II.E.2.50

TEST ITEM 456-367,370 PART NO. 6 LB BOX

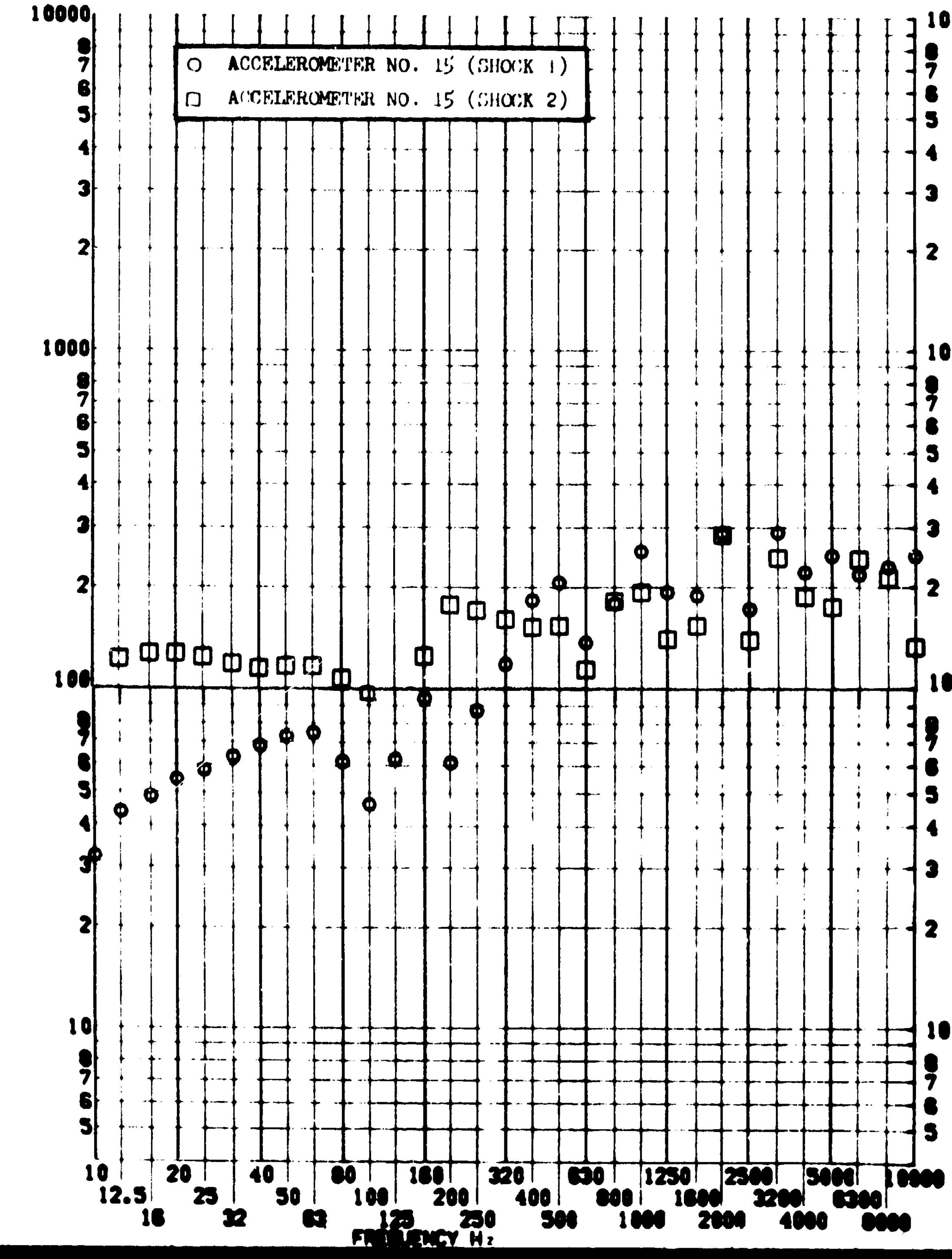
SERIAL NO. — TEST DATE 20 OCT 1967

ESPONSE G-S SHOCK AXIS RADIAL SHOCK NO. 1 & 2



SHOCK TEST ANALYSIS DATA SHEET II.E.2.51

TEST ITEM 456-368,371 PART NO. 6 LB BOX
SERIAL NO. TEST DATE 20 OCT 1967
SHOCK AXIS TANGENTIAL SHOCK NO. 1 & 2



SECTION NO. II.E.3

REPORT NO. 535

SUBJECT:

EFFECT OF PYROTECHNIC SHOCK ON BONDED JOINTS

BARREL TESTER

SECTION II.E.3

SUMMARY

In this series of pyrotechnic tests, an attempt is made to evaluate the strength of epoxy bond in a shock environment. The test was set up to simulate a proposed flight installation.

A barrel tester with a .19 inch magnesium-thorium separation plate and 30 Gr MDF explosive charge produced the shock on a honeycomb panel straddling first and second bay removable panels. Three small brackets supporting masses simulating boxes were bonded at selected locations on the honeycomb panel. A triax accelerometer was also bonded at the center of the panel.

All test data was found to be reliable for both shocks but the strength of the epoxy bond was not sufficient to resist the shock levels and failure occurred. Rigid fasteners were required for the vehicle design fix.

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SECTION II.E.3

II.E.3.1 INTRODUCTION

A set of three small brackets and masses simulating boxes were subjected to pyrotechnic shock tests in order to evaluate the practicality of epoxy bonding onto honeycomb material. A barrel tester was equipped with a honeycomb panel as shown in Figure II.E.3.1 supported by two Z brackets rivetted to removable panels of Bay I and II. The panel was held to the Z brackets by screws and the specimens were bonded to it with epoxy in a proposed flight configuration.

Two standard tests were performed with .19 inch magnesium thorium separation plates and 30 Gr MDF explosive charge.

The epoxy bonds were unable to withstand the shock.

II.E.3.2 DISCUSSION AND ANALYSIS

II.E.3.2.1 Test Configuration and Instrumentation

A standard barrel tester, as described in Section II.F.1, was used for this test. The general test arrangement is shown on Figure II.E.3.1. The honeycomb panel Z brackets were rivetted to bay 1 and bay 2 removable panels as shown on Figure II.E.3.2. The small test brackets and loading mass are also described on Figure II.E.3.2. These brackets were bonded to the honeycomb panel with Shell EPON 921 structural epoxy.

The instrumentation consisted of one set of three accelerometers, as described on Table II.E.3.1, mounted on a triax block bonded at the center of the honeycomb panel. A summary of the tests performed is given on Table II.E.3.2.

All data recorded was free from disturbance.

Prior to testing, the natural frequency of the test set-up was measured to be approximately 156 cps.

Shock spectra for each accelerometer and each test are presented on Figures II.E.3.4 to II.E.3.9. Repeatability is shown on Figures II.E.3.10 to II.E.3.12 which compare the readings of each accelerometer for shock 1 and 2. Data from accelerometer A was available but accelerometer B used for standard test monitoring was not recorded for the purpose of this test.

II.E.3.2.2 Technical Discussion

In both firings, the strength of the epoxy bond was found inadequate and one or more brackets separated from the honeycomb panel.

The test results recorded by the accelerometers were not affected by any kind of disturbance and the data is reliable. Reduction of the test data was performed on the UNIVAC 1108 after digitizing the analog tape.

II.E.3.2.3 Analysis

Since the test specimen did not survive the shocks, it is important to determine whether the honeycomb panel provided large amplification. The envelope of measurements from accelerometers 1, 2 and 3 is compared with the envelope of measurements from Triax A2 which provide bay 1 levels and the nominal environment of bay 2 taken from Section II.F.1. This data is presented on Figure II.E.3.3 which shows that significant amplification is present around 350 cps while some attenuation exists at high frequencies.

Repeatability of the environment was shown to be good for all accelerometers. On Figure II.E.3.10 to II.E.3.12, the differences between data points may be attributed to normal scatter.

II.E.3.3 CONCLUSION

Failure of the structural epoxy under pyrotechnic shock environment indicates that this hard bonding agent is inadequate for this purpose. The results of this test suggest that a more resilient type of bonding agent might be better able to resist the environment levels under consideration.

Repeatability of the environment for the two shocks was found to be satisfactory.

A design fix used fasteners to attach the bracket to the Honeycomb panel.

TABLE II.E.3.1

ACCELEROMETERS AND LOCATIONS

Accelerometer No.	Box	Direction	Location	Distance to Shocksource	Accelerometer Type
1	Test Brackets	L	Honeycomb Panel	30"	Endevco 2225
2	Test Brackets	R	Honeycomb Panel	30"	Endevco 2225
3	Test Brackets	T	Honeycomb Panel	30"	Endevco 2225

TABLE II.E.3.2

SUMMARY OF TESTS

Test Number	Configuration	Explosive Size	Test Purpose	Shock Isolation
1	1	30 Gr/ft MDF	Bonding	None
2	1	30 Gr/ft MDF	Evaluation	None

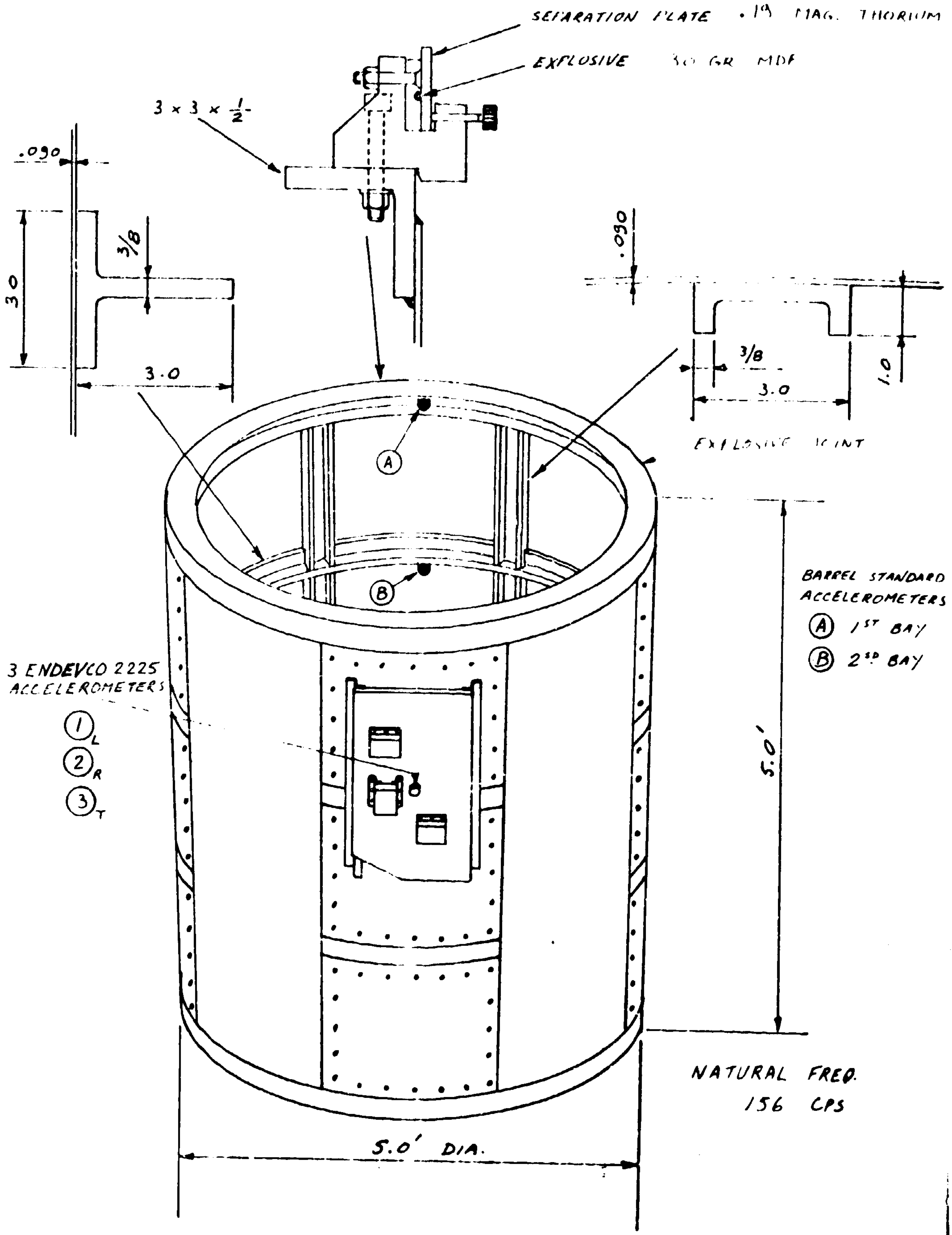


Figure II.E.3.1 TEST GENERAL ARRANGEMENT

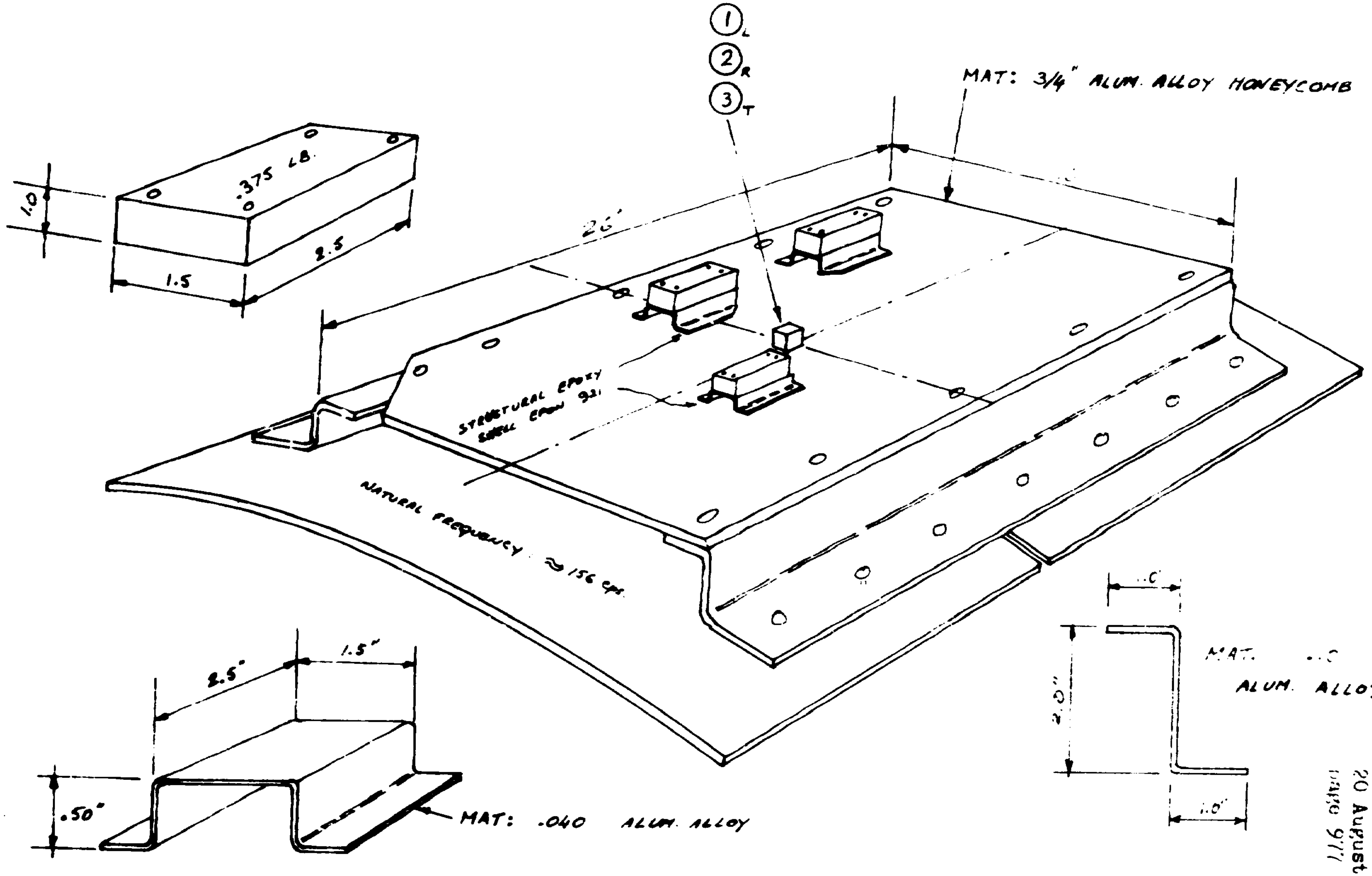


Figure II.E.3.2 TEST BRACKET BOND TESTS

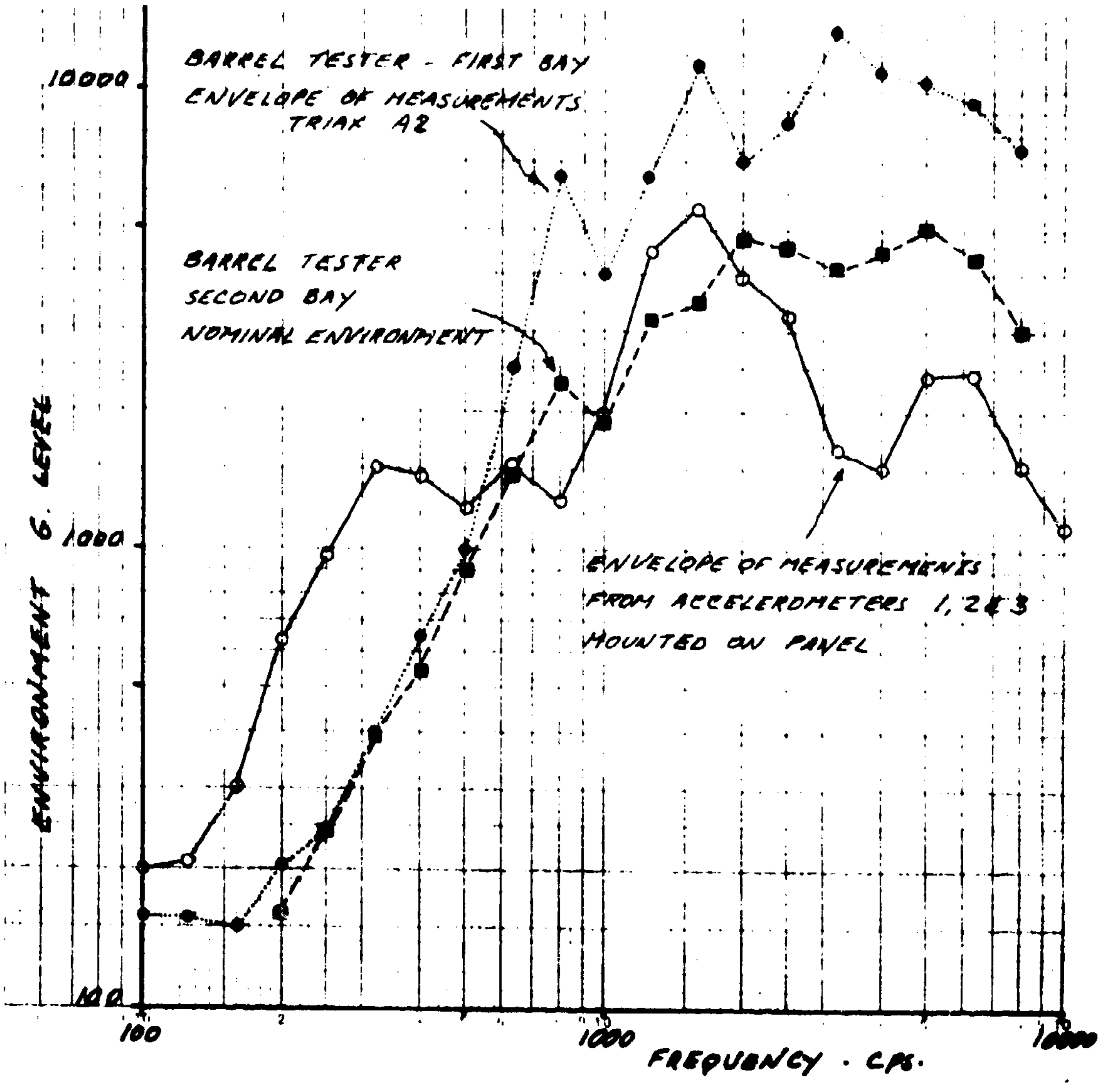
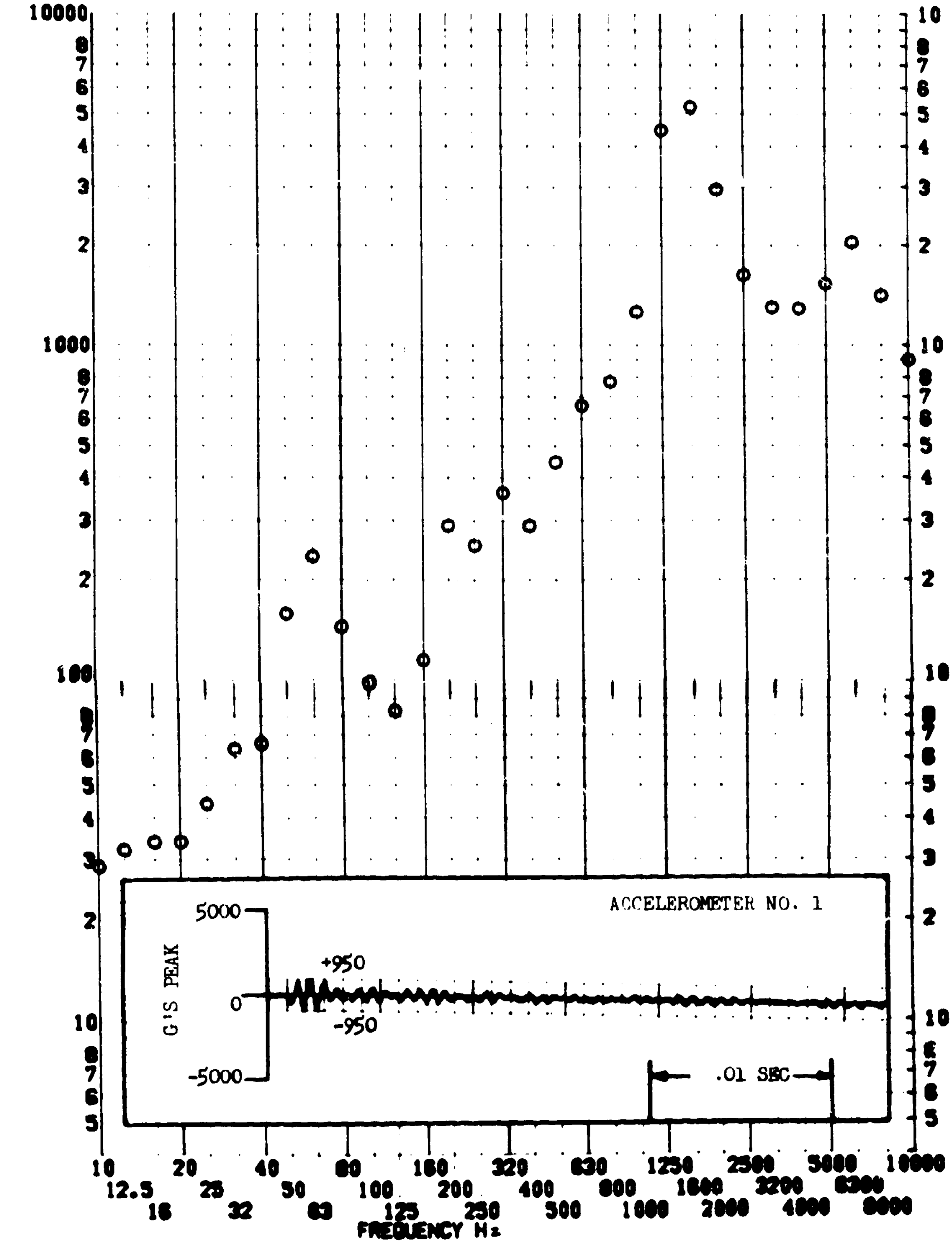


Figure II.E.3.3 COMPARISON OF PANEL SHOCK LEVEL ENVELOPE WITH BARREL TESTER FIRST AND SECOND BAY LEVELS

SHOCK TEST ANALYSIS DATA SHEET II.E.3.4

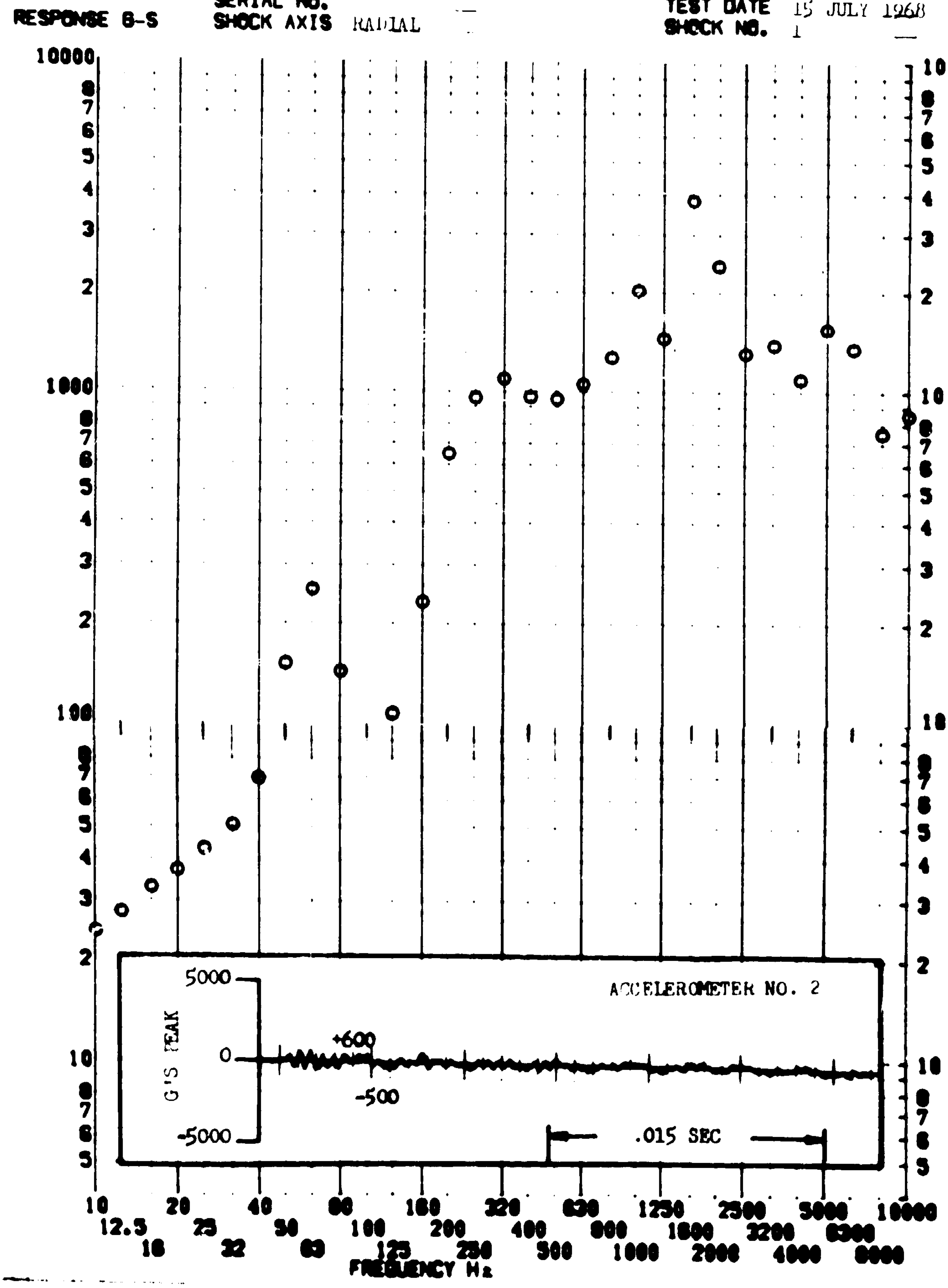
TEST ITEM 535-372 PART NO. STRUCTURE
SERIAL NO. TEST DATE 15 JULY 1968
SHOCK AXIS LONGITUDINAL SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET 11.E.3.5

TEST ITEM 535-373
SERIAL NO. —
SHOCK AXIS RADIAL

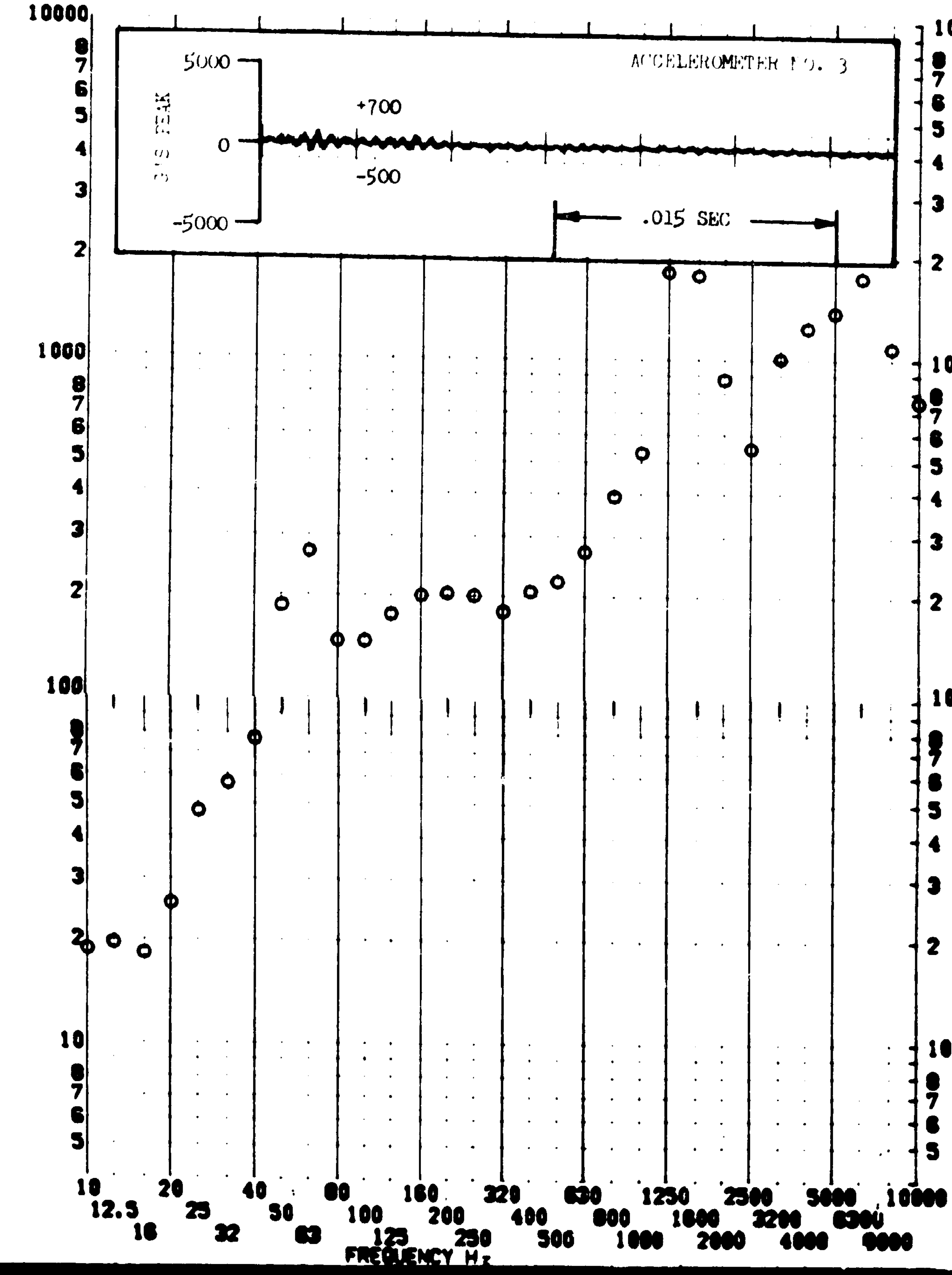
PART NO. STRUCTURE
TEST DATE 15 JULY 1968
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.3.6

TEST ITEM 535-374
SERIAL NO.
SHOCK AXIS TANGENTIAL

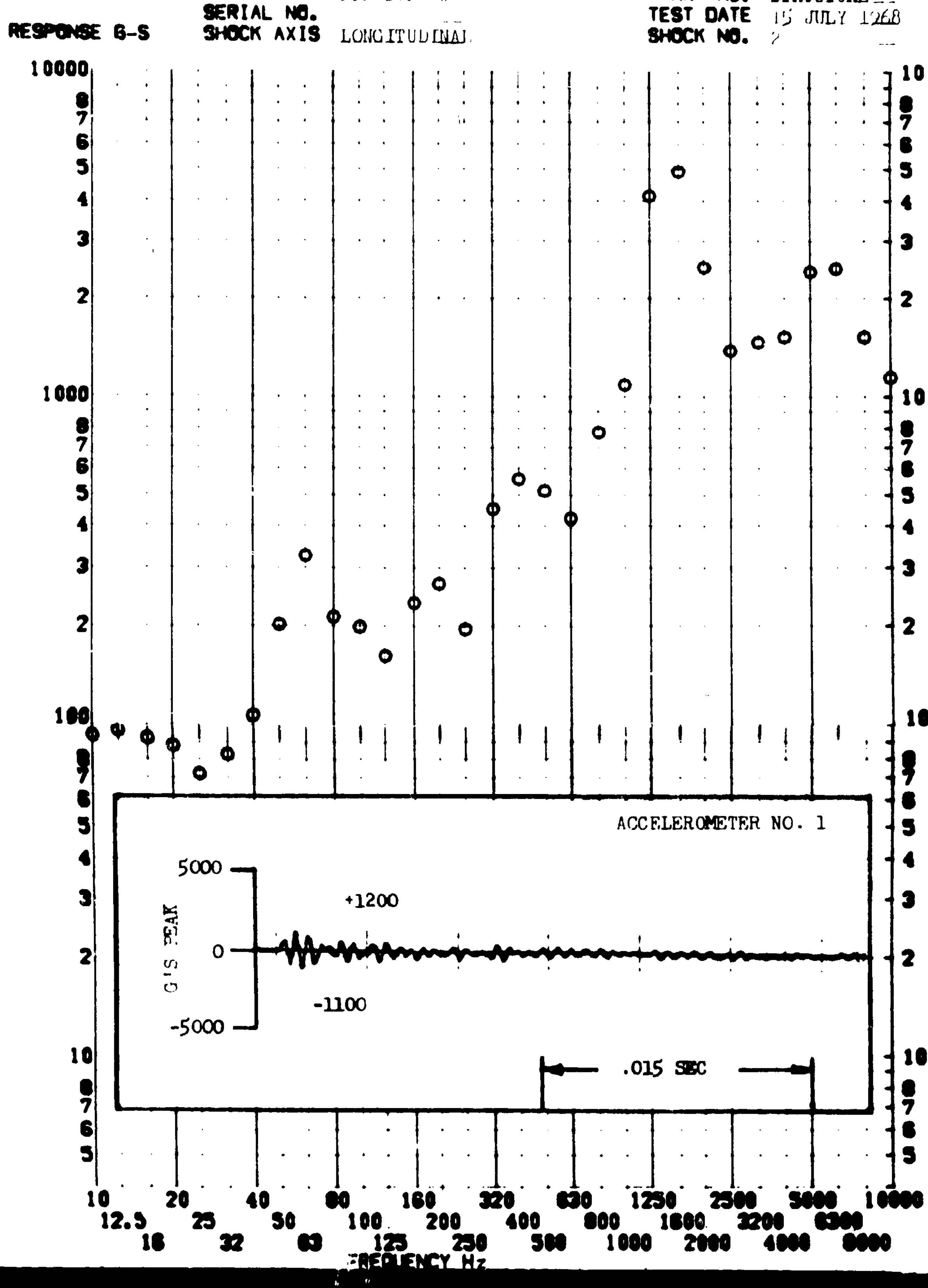
PART NO. STRUCTURE
TEST DATE 15 July 1967
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET 11.E.3.7

TEST ITEM 535-375
SERIAL NO.
SHOCK AXIS LONGITUDINAL

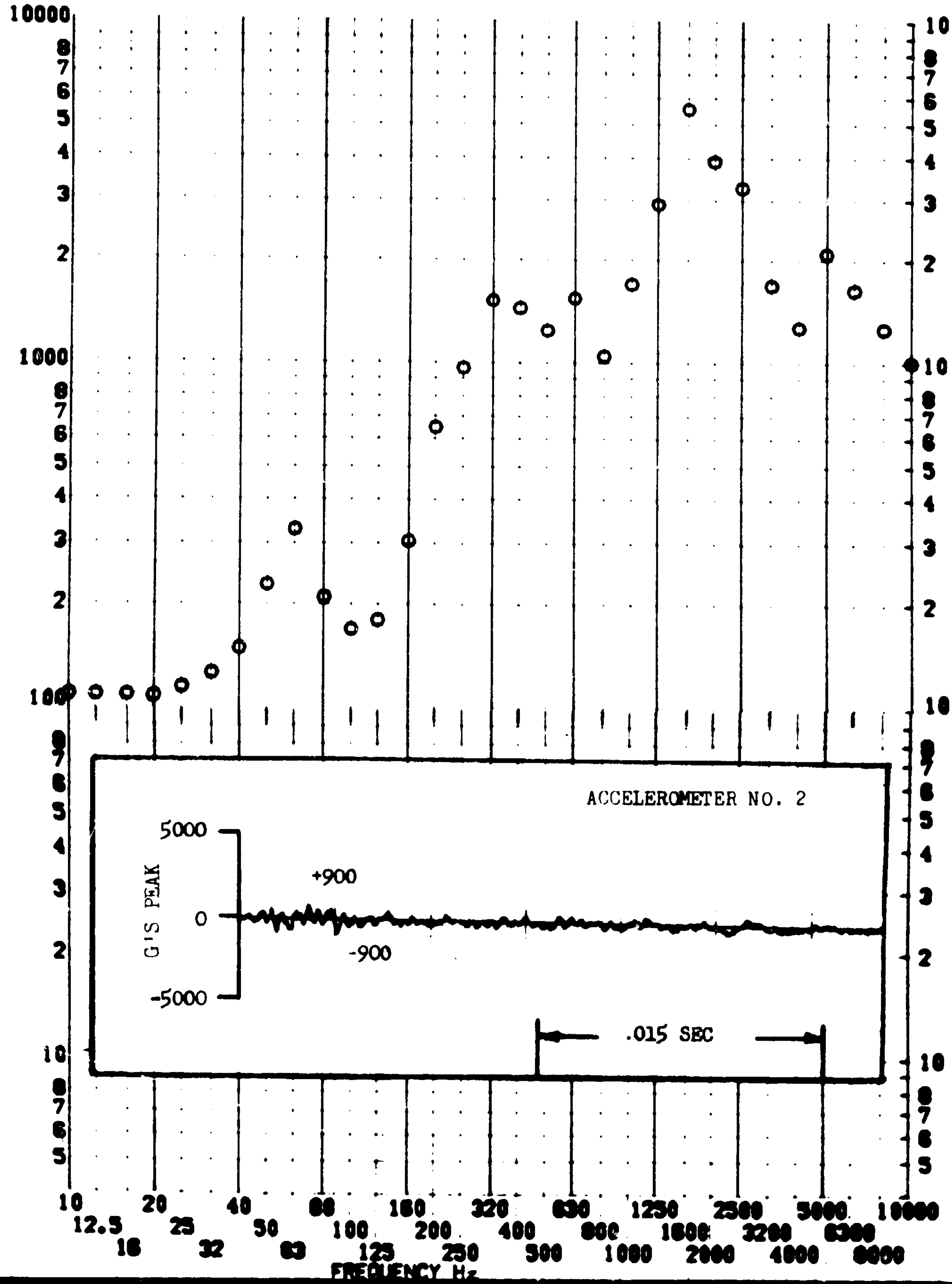
PART NO. STRUCTURE
TEST DATE 15 JULY 1968
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.3.8

TEST ITEM	535-376	PART NO.	STRUCTURE
SERIAL NO.	—	TEST DATE	15 JULY 1968
SHOCK AXIS	RADIAL	SHOCK NO.	2

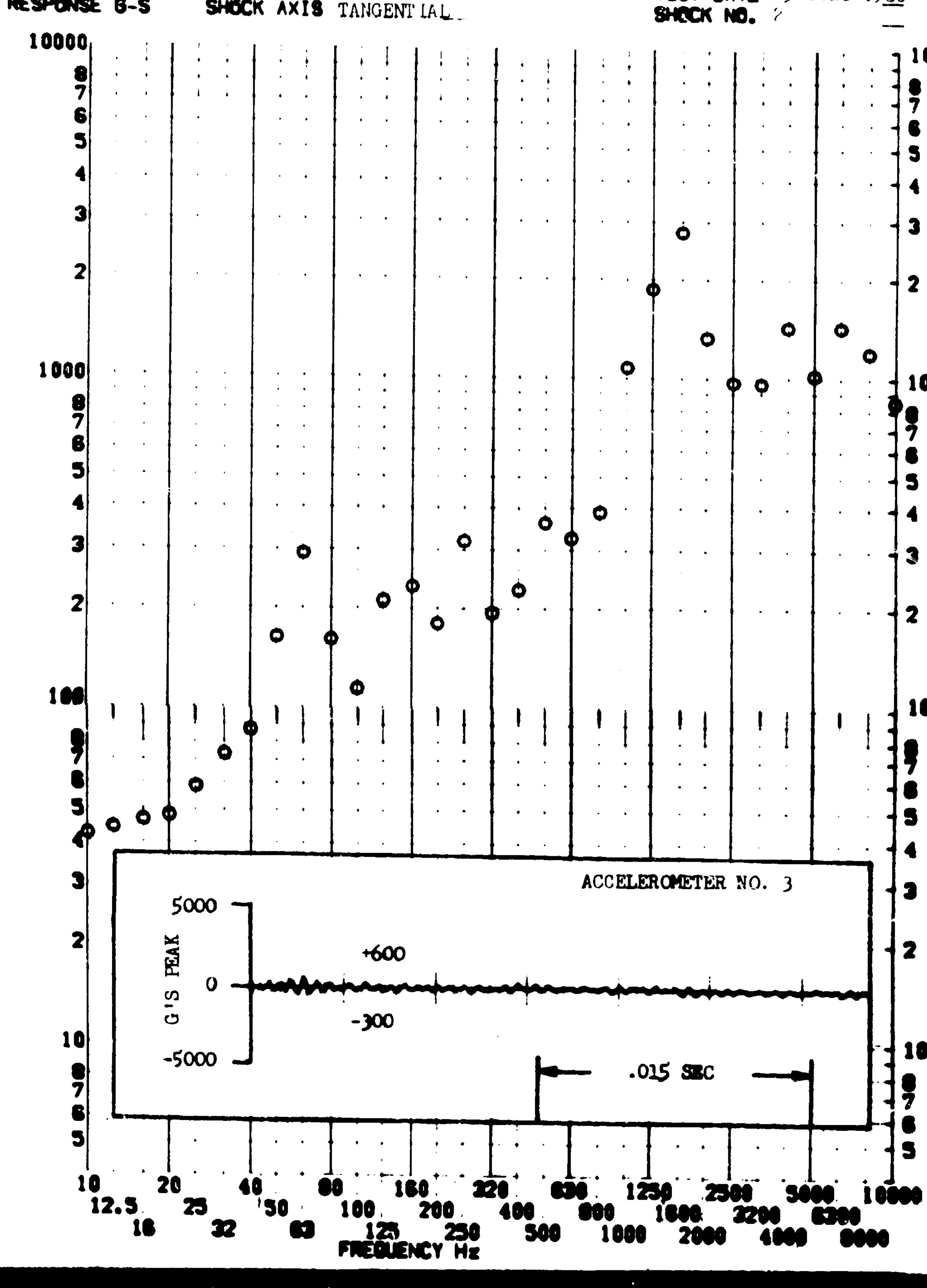
RESPONSE G-S

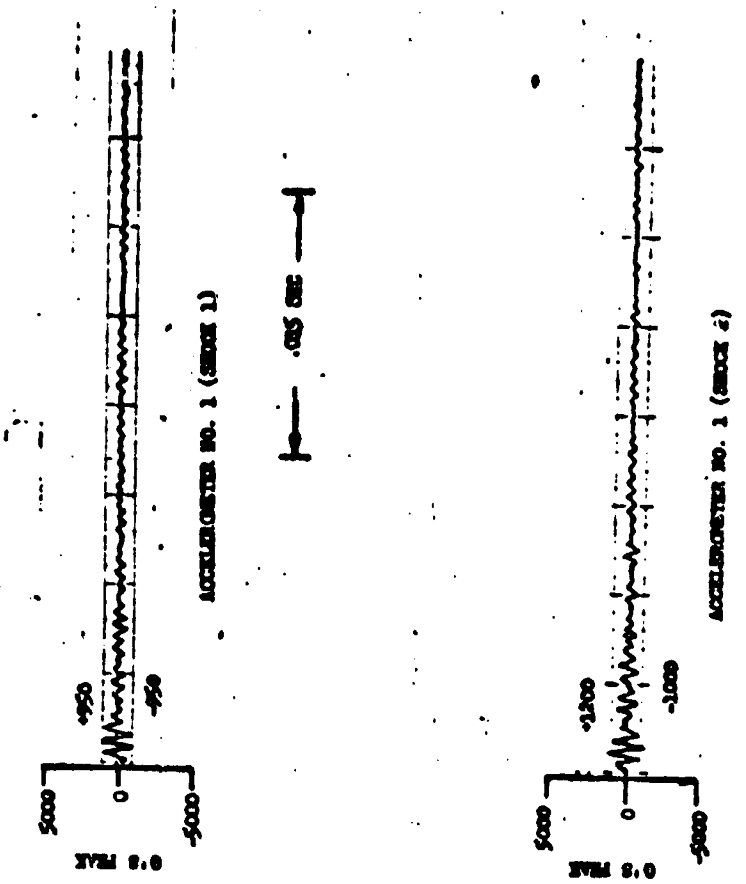


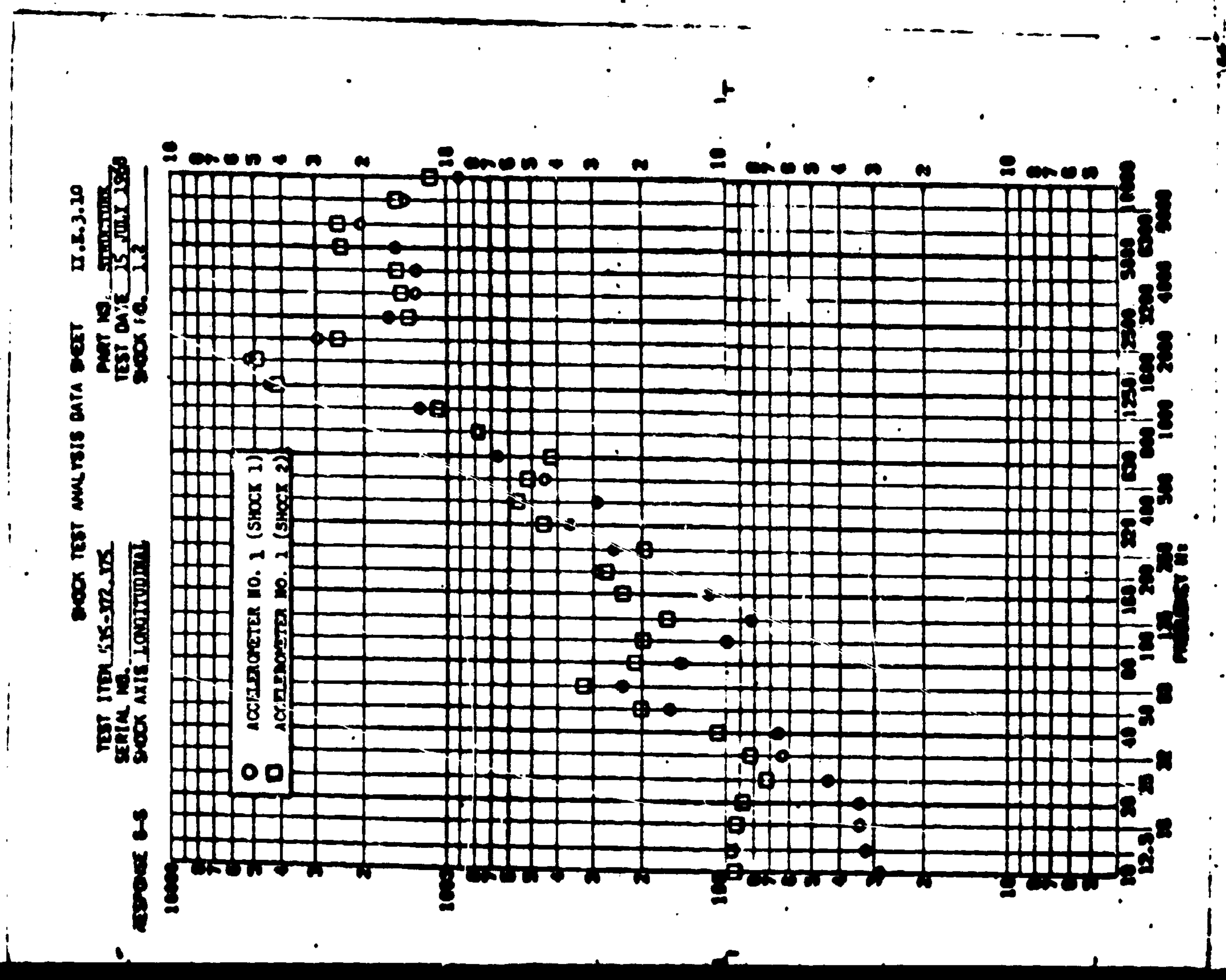
SHOCK TEST ANALYSIS DATA SHEET II.E.3.9

TEST ITEM 535-377
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. STRUCTURE
TEST DATE 15 JULY 1968
SHOCK NO. 2

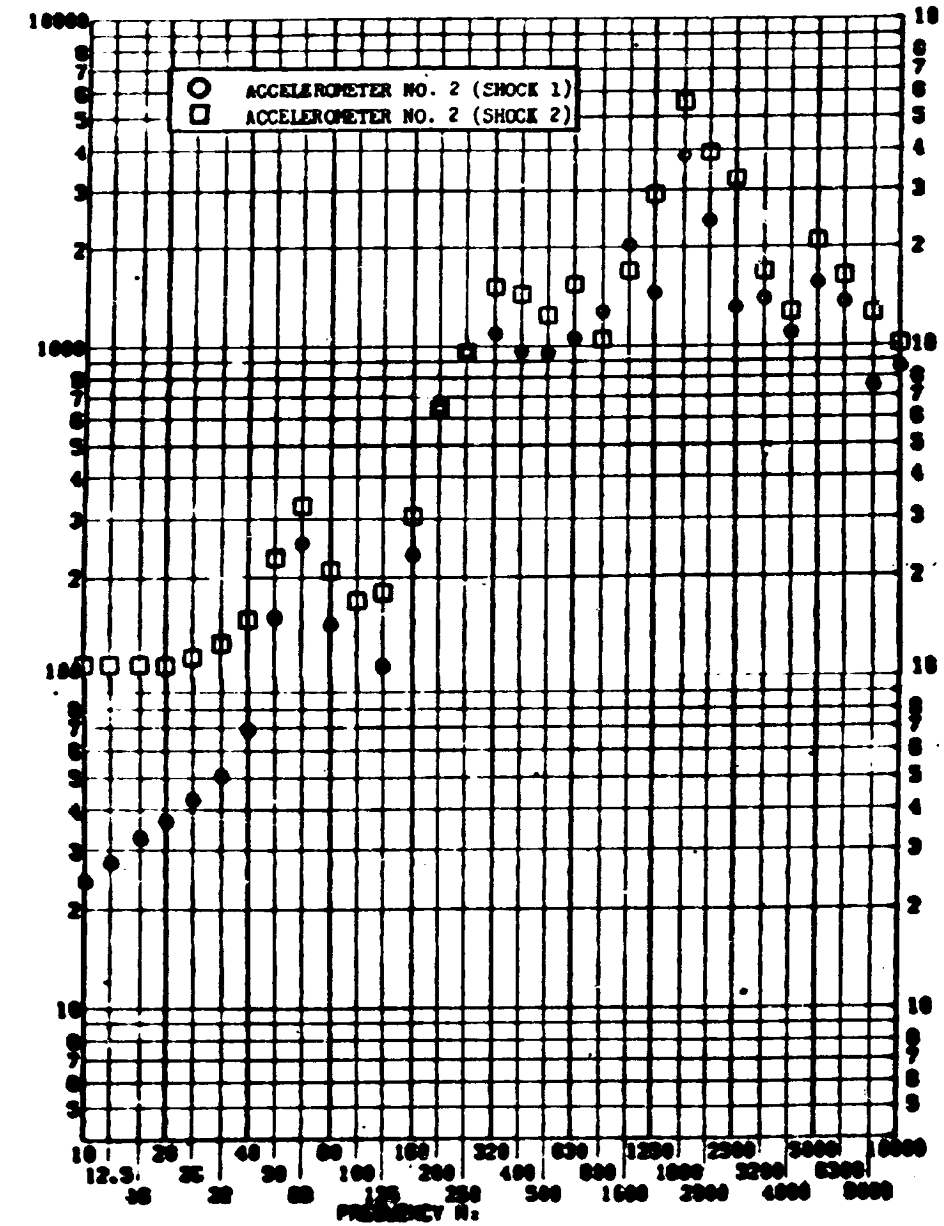


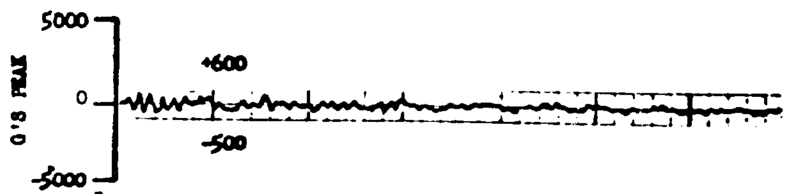

ACCELEROMETER NO. 1 (SHOCK 1)
.005 SEC
ACCELEROMETER NO. 1 (SHOCK 2)
G'S PEAK
G'S PEAK


SHOCK TEST ANALYSIS DATA SHEET
SHOCK AXIS LONGITUDINAL
ACCELEROMETER NO. 1 (SHOCK 1)
ACCELEROMETER NO. 1 (SHOCK 2)
RESPONSE G-S
FREQUENCY HZ

SHOCK TEST ANALYSIS DATA SHEET   TT.R.3.11

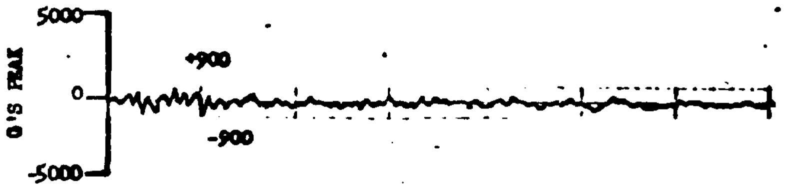
TEST ITEM 535-373,376   PART NO. STRUCTURE
SERIAL NO.   TEST DATE 15 JULY 1968
RESPONSE G-S   SHOCK AXIS RADIAL   SHOCK NO. 1,2



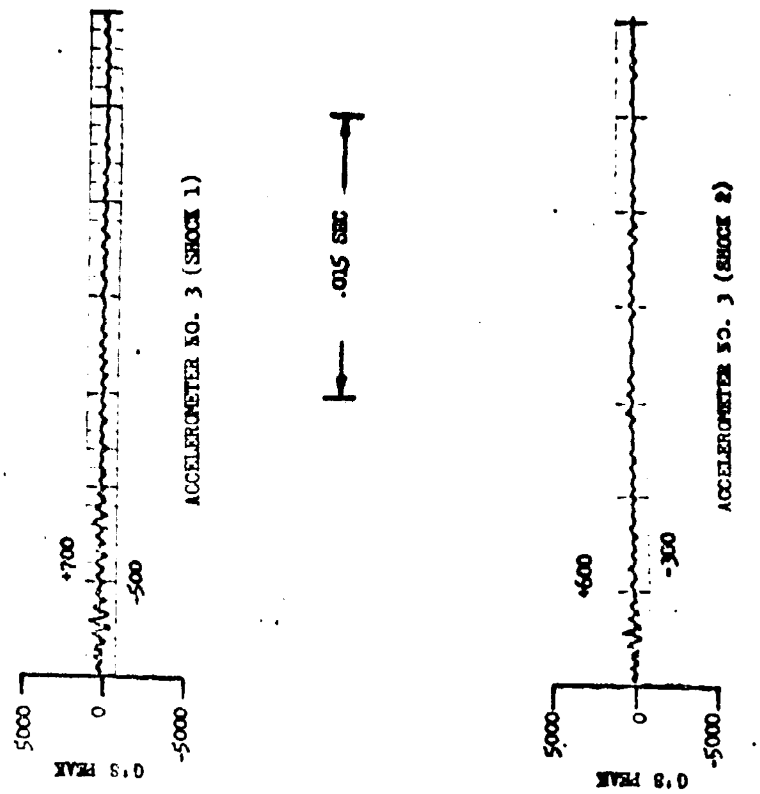


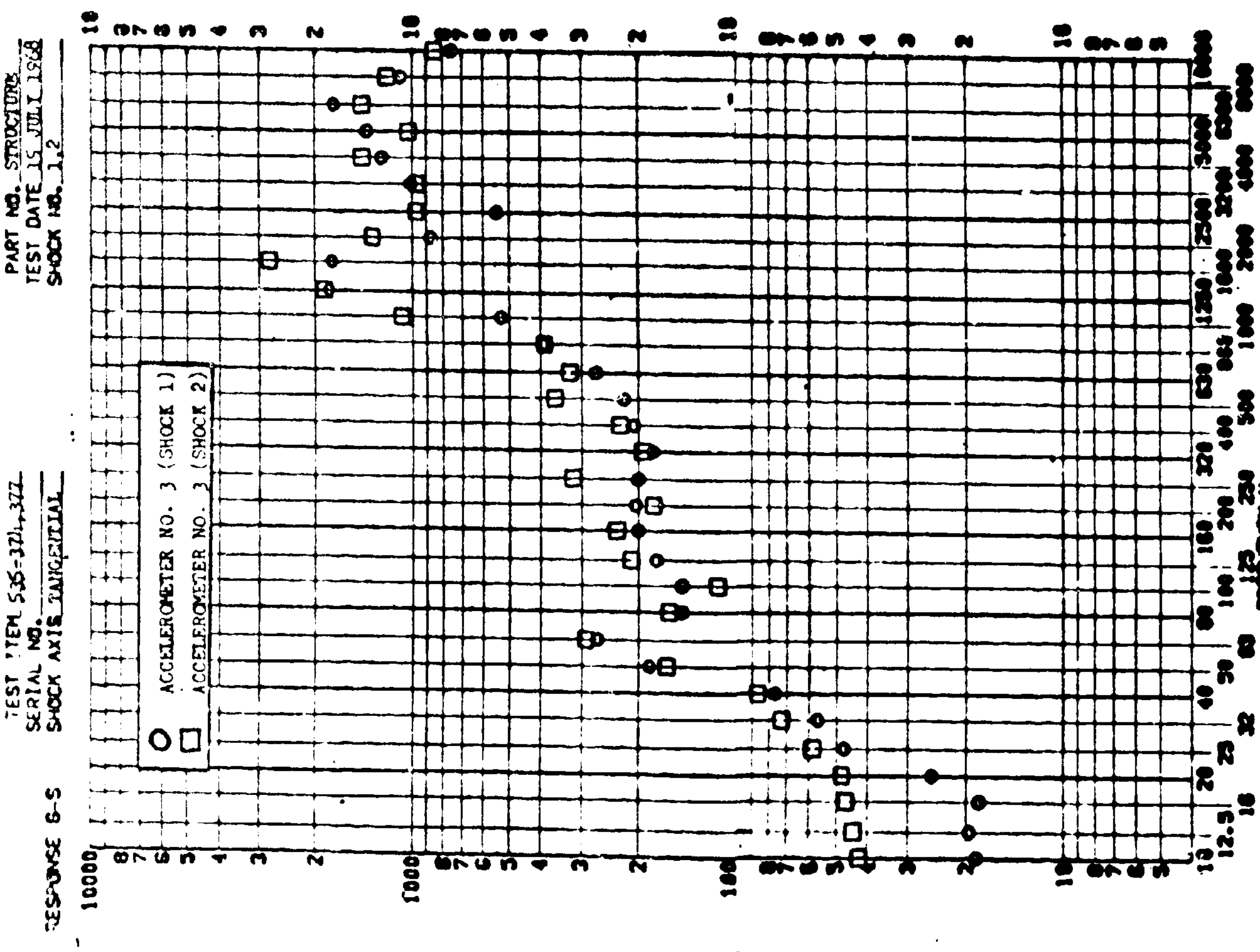
ACCELEROMETER NO. 2 (SHOCK 1)

.015 SEC



ACCELEROMETER NO. 2 (SHOCK 2)


ACCELEROMETER NO. 3 (SHOCK 1)
.015 SEC
ACCELEROMETER NO. 3 (SHOCK 2)
+700
-500
+600
-300
5000
0
-5000
G'S PEAK


TEST ITEM 535-324,327
SERIAL NO.
SHOCK AXIS TANGENTIAL
PART NO. STRUCTURE
TEST DATE 15 JULY 1968
SHOCK NO. 1,2
ACCELEROMETER NO. 3 (SHOCK 1)
ACCELEROMETER NO. 3 (SHOCK 2)
RESPONSE G-S
FREQUENCY Hz

SECTION NO. II.E.4

REPORT NO. 543

SUBJECT:

ELECTRONIC BOX TESTS ON BARREL TESTER

SECTION II.E.4

SUMMARY

A special test is the subject of this section where the standard barrel tester is used to simulate a predicted flight environment. This was achieved by using a thinner than usual separation plate and a smaller explosive.

A .050 inch separation plate was used instead of the usual .19 inch and the explosive charge was reduced from 30 Gr to 5 Gr. The resulting environment correlated well with the prediction.

The test specimen was subjected to only one shock and no failure occurred. All test data was found reliable for both shocks and repeatability was satisfactory.

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SECTION II.E.4

II.E.4.1 INTRODUCTION

One electronic box was subjected to a special test representative of flight conditions. The barrel was fitted with an available flight installation structure for the best test simulation. One set of three accelerometers was used to record the shock level at the box interface.

One single test was performed with a .050 inch magnesium-thorium separation plate and a 5 Gr MDF explosive charge. Prior to performing the test the environment was predicted based on data shown in Report 831 in Section II.F.2 of this report. See Figure II.E.4.4.

II.E.4.2 DISCUSSION AND ANALYSIS

II.E.4.2.1 Test Configuration and Instrumentation

The test configuration is shown on Figure II.E.4.1 and II.E.4.2. A standard barrel tester is used with a flight structure attached to two of its main longerons in such a manner that it be subjected to the environment of bay 2. The test specimen is attached to the flight structure as shown on Figure II.E.4.2.

The instrumentation included the standard B monitoring sets of accelerometers (Triax) and another set of three accelerometers mounted as shown on Figure II.E.4.3. Accelerometer characteristics are given on Table II.E.4.1 and a summary of the test performed on Table II.E.4.2.

Shock spectra were established for the specimen and for the B sets of accelerometers. They are presented on Figure II.E.4.5 to II.E.4.10.

II.E.4.2.2 Technical Discussion

Upon completion of the test, inspection of the test specimen showed that no failure occurred.

The test results were good with no disturbance except for accelerometer B3 (tangential) whose low frequency data appears somewhat questionable.

Reduction of the test data was performed on the UNIVAC 1108 after digitizing the analog tape.

II.E.4.2.3 Analysis

Since the transmissibility of the flight structure added to the barrel was important in this test, a comparison of the barrel second bay level with that experienced at the specimen interface is of interest.

The envelope of accelerometers 1, 2 and 3 measurements is compared on Figure II.E.4.4 with that derived from measurement of bay 2 environment from accelerometers B. It can be seen that within the expected data scatter, the two curves are almost coincident.

Another matter of interest concerns the shock level provided by the reduced explosive charge and thinner separation plate. The reduced environment can be estimated from Figure II.E.4.4 where the second bay nominal environment has been added for the standard case of 30 Gr MDF and .19 inch separation plate.

II.E.4.3 CONCLUSION

This test shows that the barrel tester is not limited to qualification testing of more or less standard items but can be adapted readily to simulate other environments.

The test reported here shows that a specified environment may be duplicated with reasonable accuracy.

This test improved our confidence in the reliability of this delicate piece of equipment.

TABLE II.E.4.1

ACCELEROMETERS AND LOCATIONS

Accelerometer Number	Box	Direction	Location	Distance to Shocksource	Accelerometer Type
1	VCA	L	Bay 2	30"	Endevco 2225
2	VCA	R	Bay 2	30"	Endevco 2225
3	VCA	T	Bay 2	30"	Endevco 2225

TABLE II.E.4.2

SUMMARY OF TESTS

Test Number	Configuration	Explosive Size	Test Purpose	Shock Isolation
1	1	5 Gr/ft MDF	Box Qual.	None

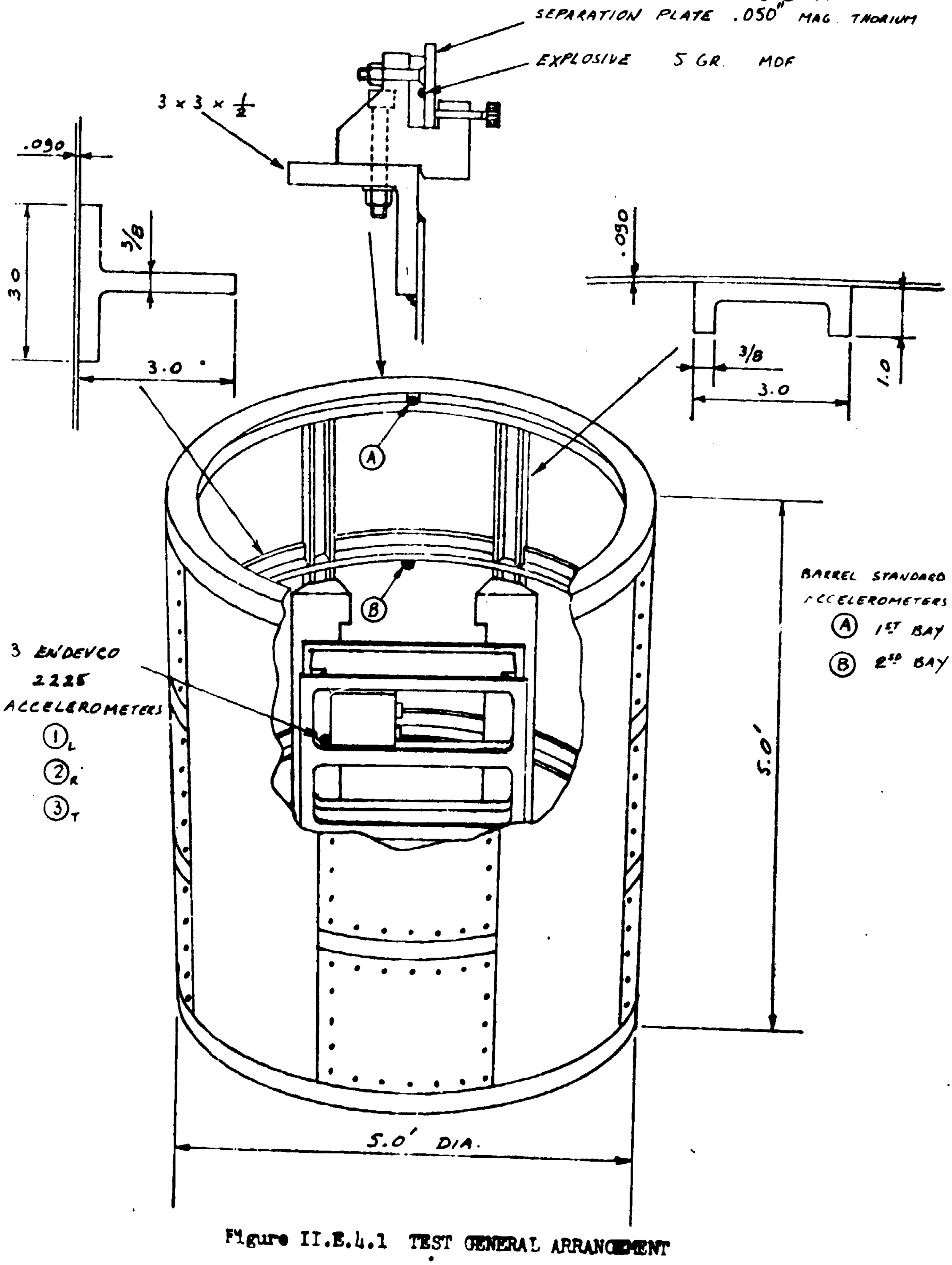


Figure II.E.4.1 TEST GENERAL ARRANGEMENT

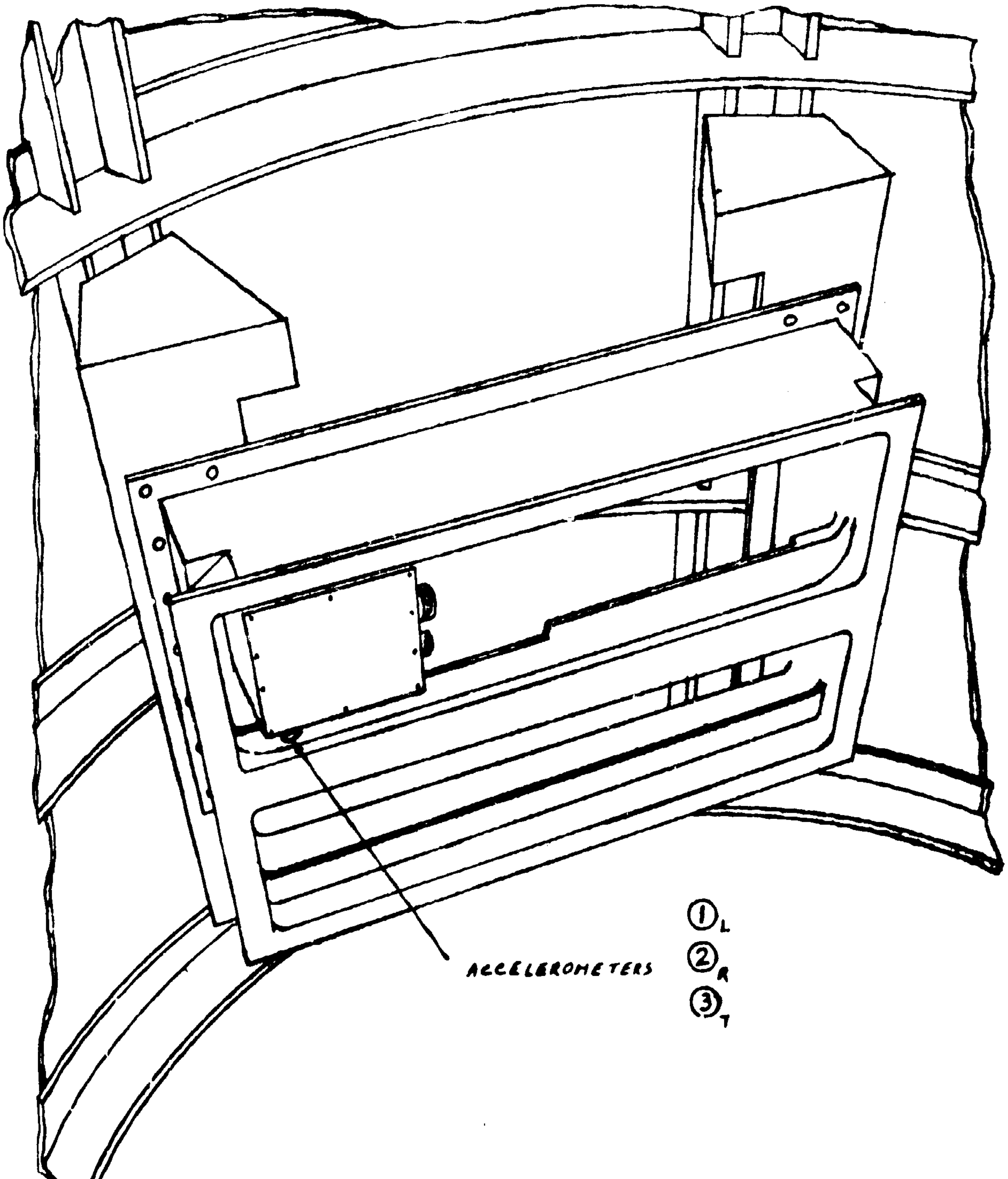


Figure II.E.4.2 EQUIPMENT INSTALLATION
VIEW LOOKING DOWN INTO BARREL TESTER

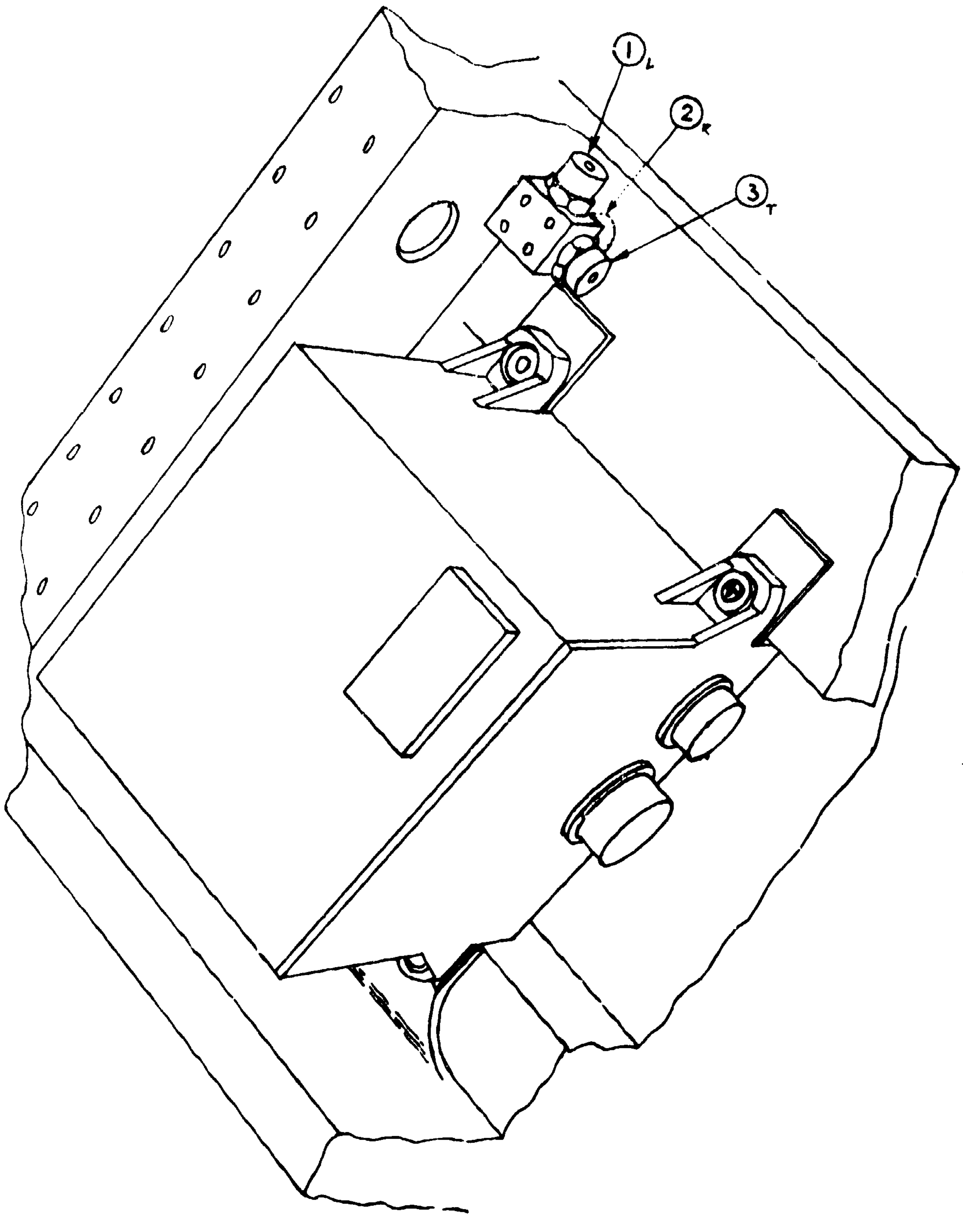


Figure II.E.4.3 ACCELEROMETER LOCATIONS

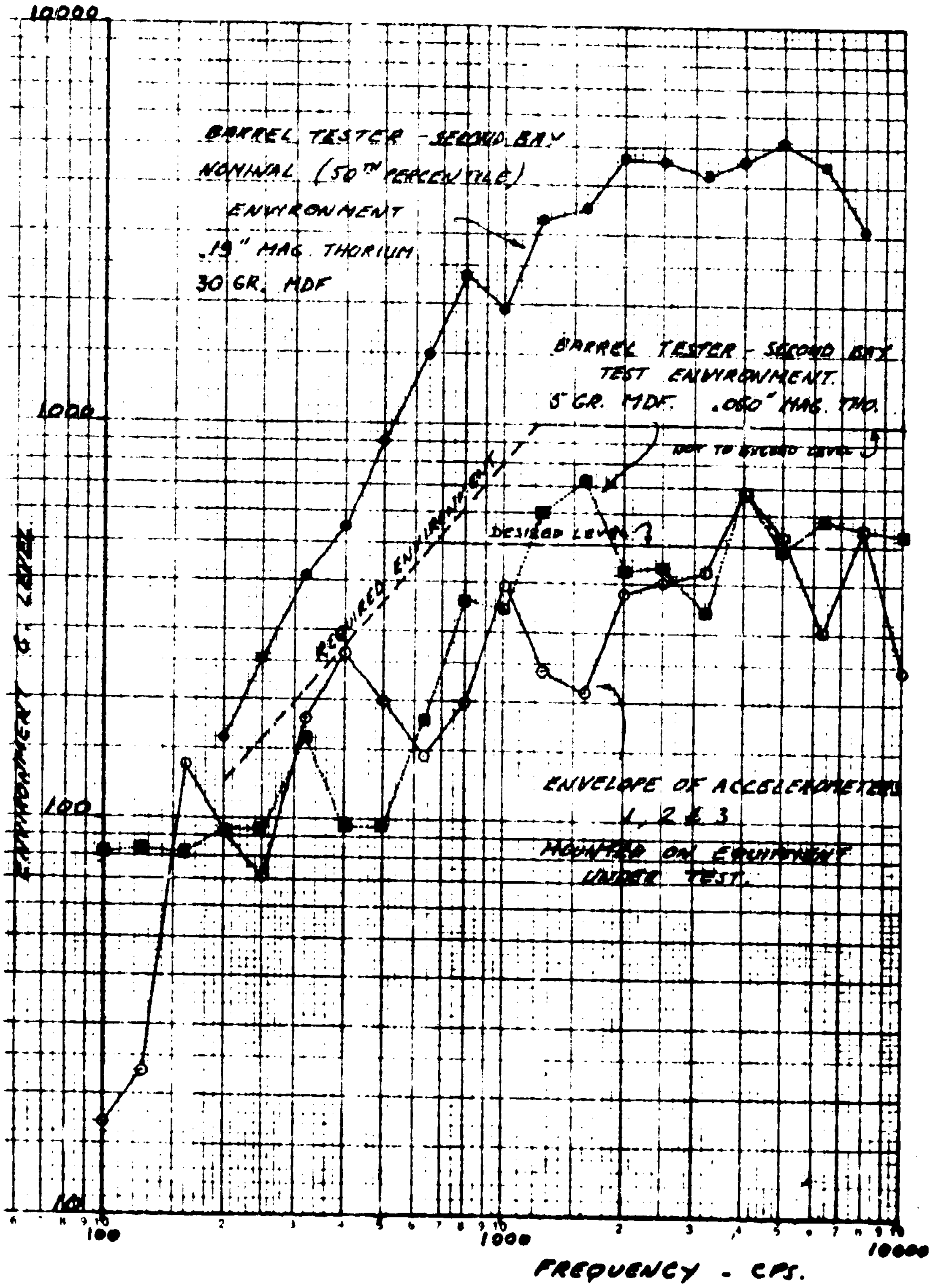


Figure II.E.4.4 COMPARISON OF G LEVEL ENVELOPE MEASURED ON EQUIPMENT WITH BARREL SECOND BAY LEVEL

SHOCK TEST ANALYSIS DATA SHEET II.E.4.5

TEST ITEM 543-378

SERIAL NO.

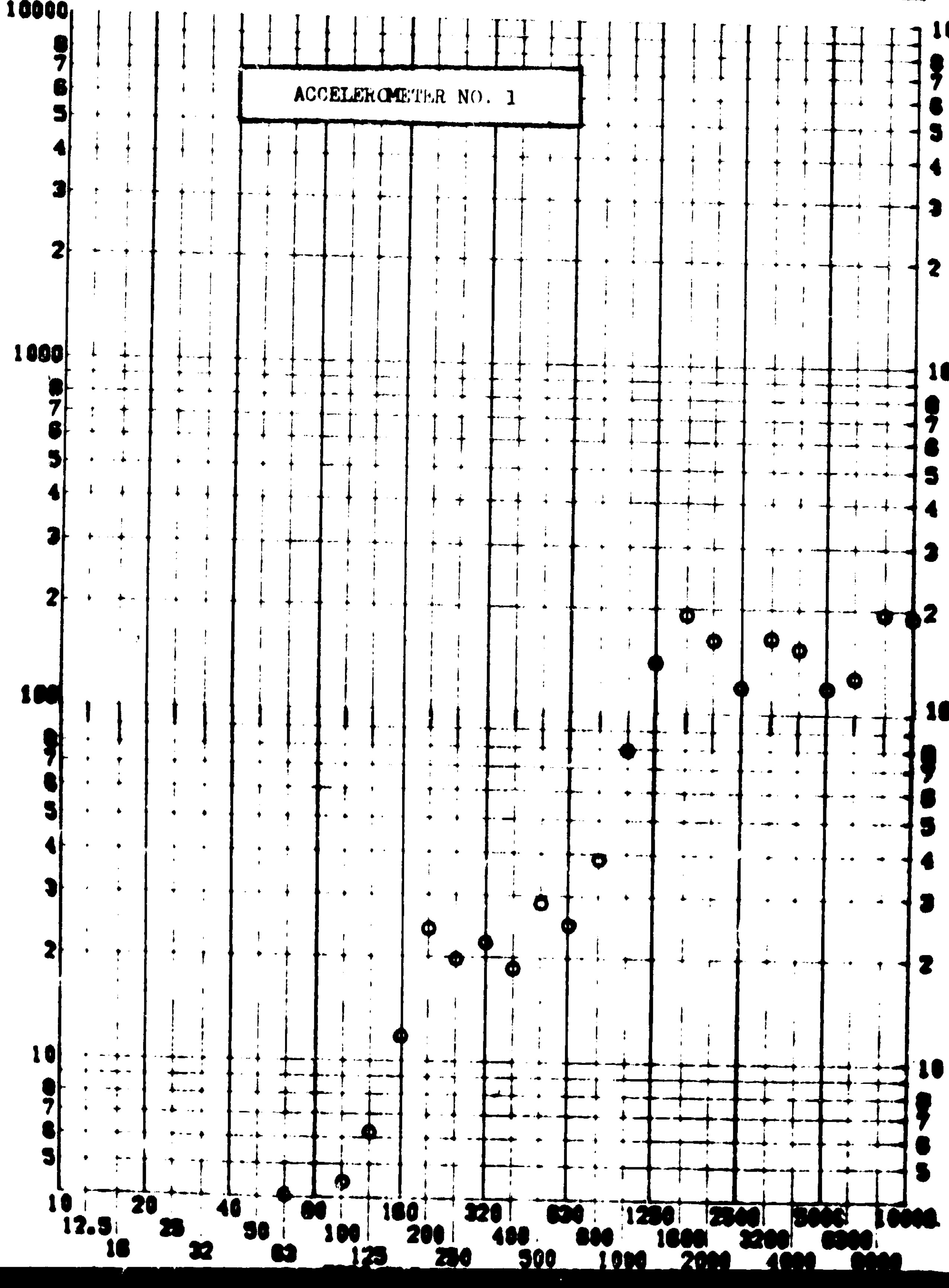
SHOCK AXIS LONGITUDINAL

PART NO. EQUIPMENT

TEST DATE 28 AUG 1969

SHOCK NO. 1

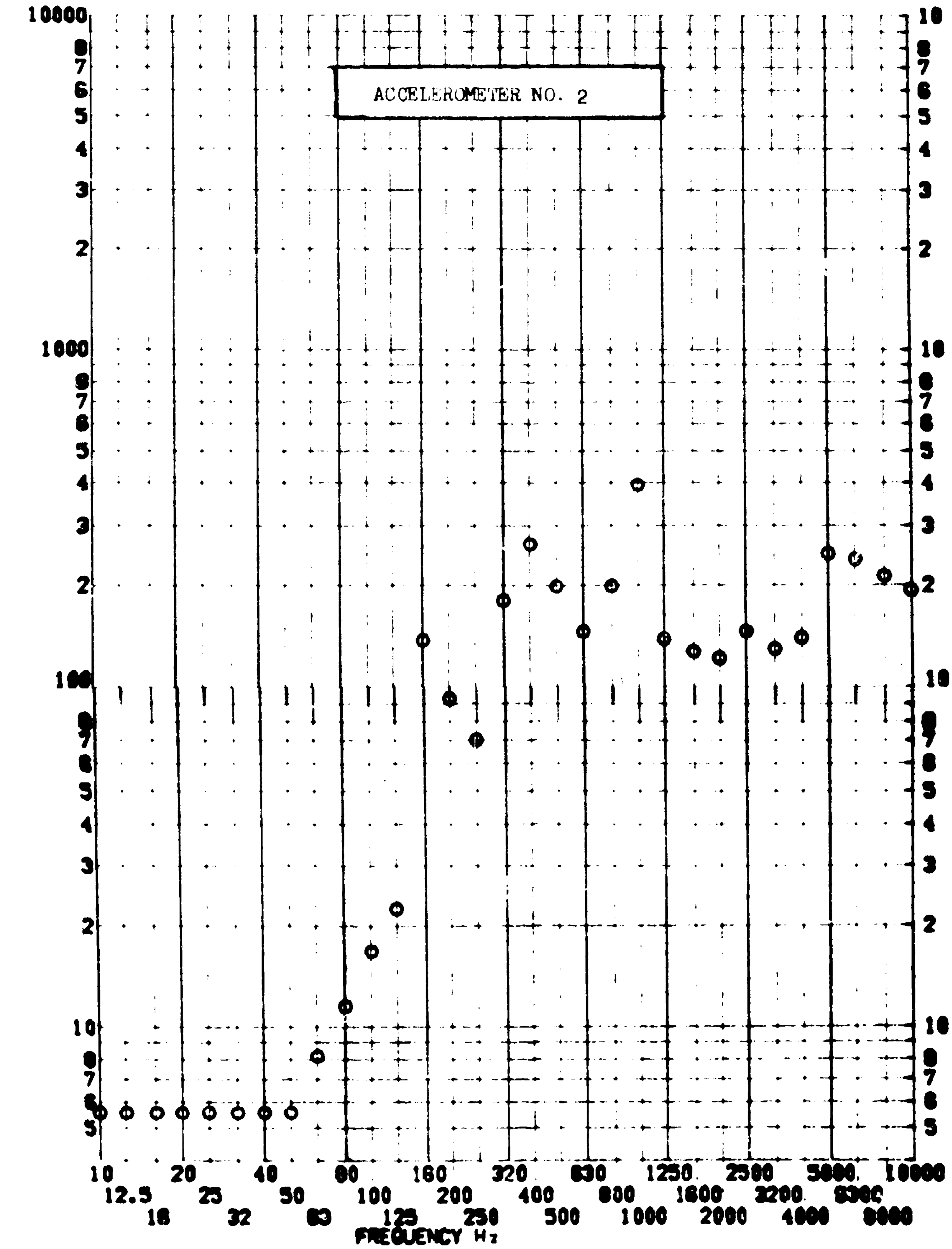
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.4.6

TEST ITEM 543-379
SERIAL NO.
SHOCK AXIS RADIAL

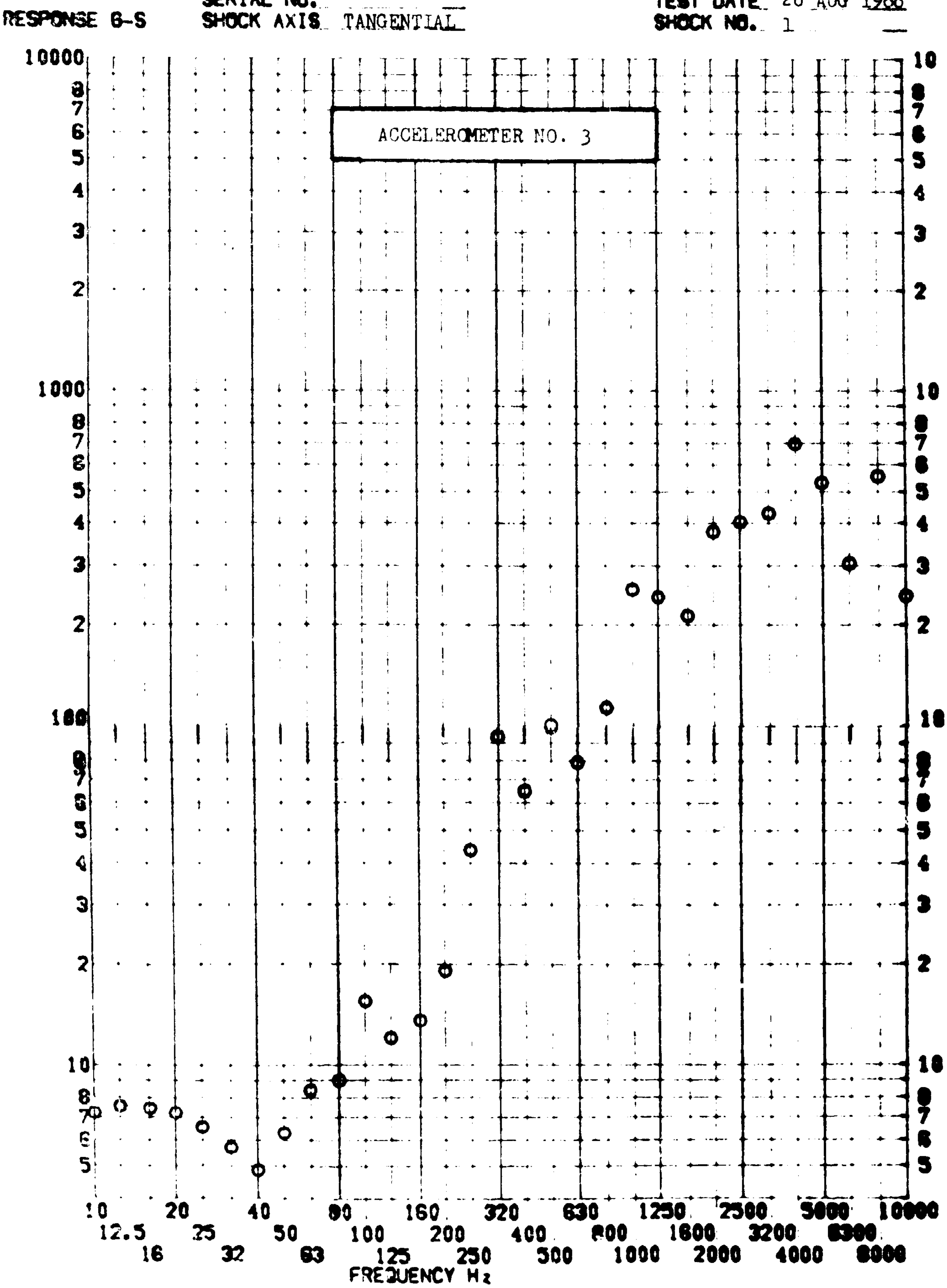
PART NO. EQUIPMENT
TEST DATE 28 AUG 1968
SHOCK NO. 1



SHOCK TEST ANALYSIS DATA SHEET II.E.4.7

TEST ITEM 543-380
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. EQUIPMENT
TEST DATE 28 AUG 1968
SHOCK NO. 1

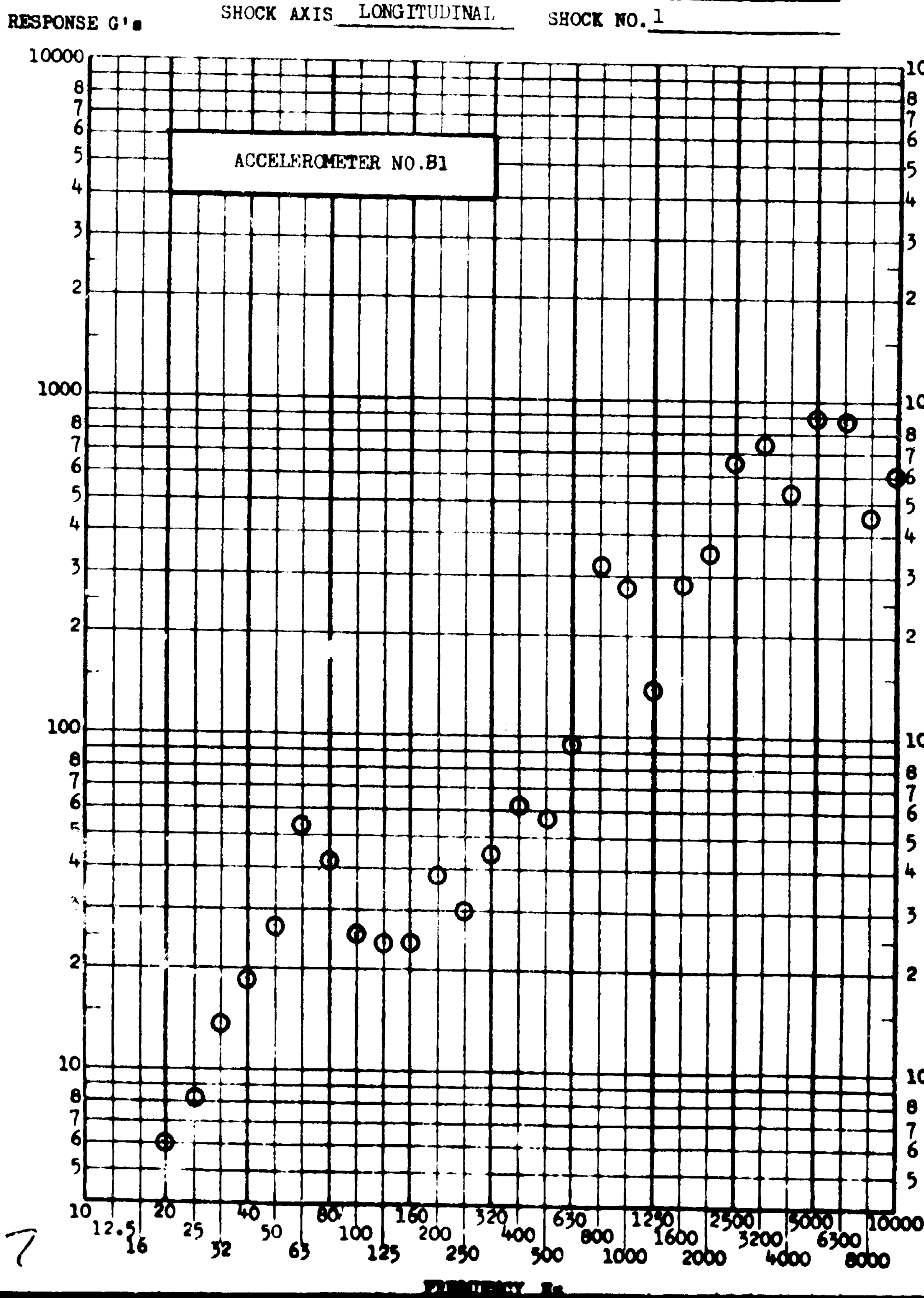


SHOCK TEST ANALYSIS DATA SHEET II.E.4.8

TEST ITEM 543-378A PART NO. STRUCTURE

SERIAL NO. ______ TEST DATE 28 AUG 1969

SHOCK AXIS LONGITUDINAL SHOCK NO. 1



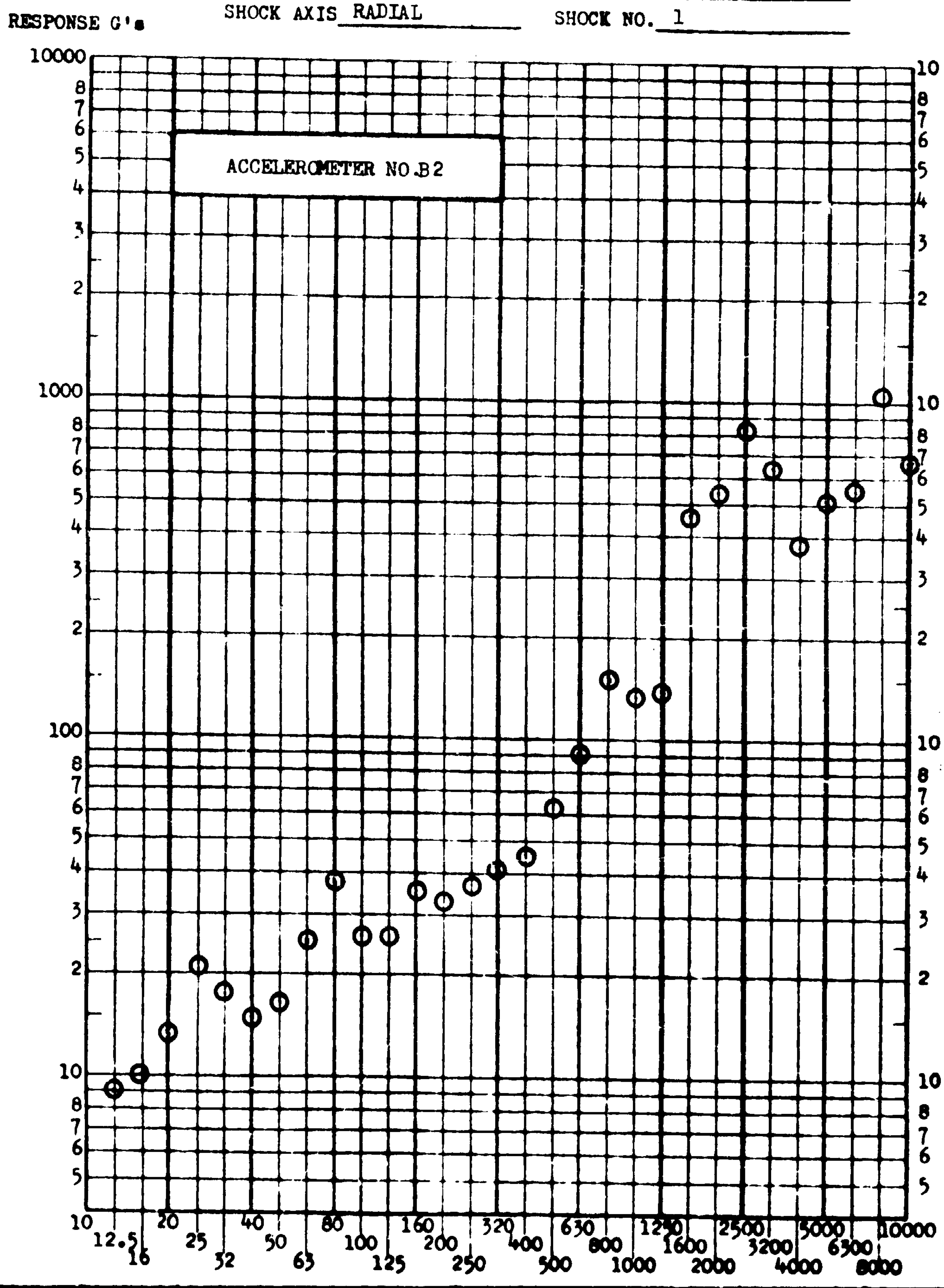
7

SHOCK TEST ANALYSIS DATA SHEET II.E.4.9

TEST ITEM 543-379A PART NO. STRUCTURE

SERIAL NO. TEST DATE 28 AUG 1969

SHOCK AXIS RADIAL SHOCK NO. 1

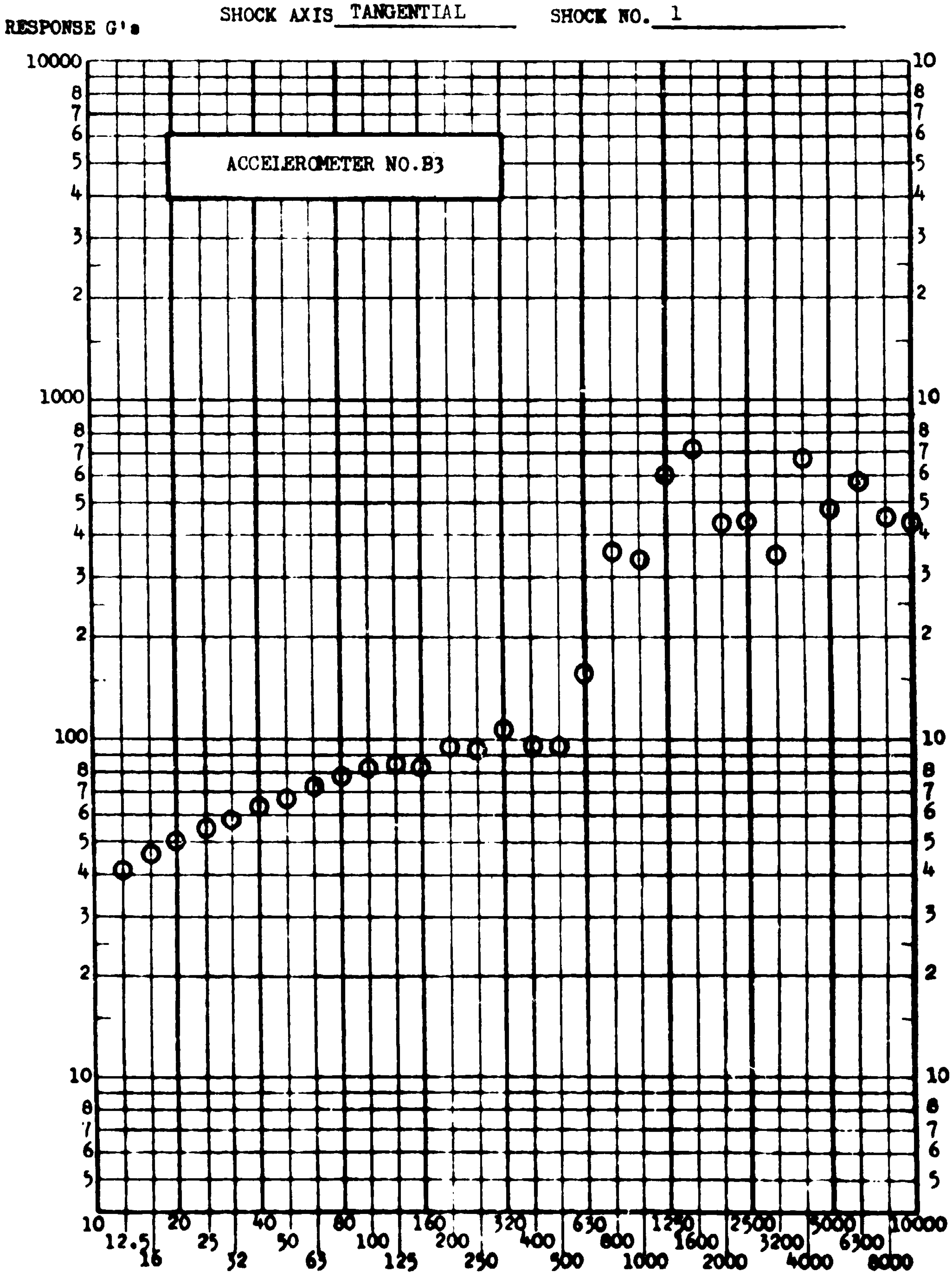


SHOCK TEST ANALYSIS DATA SHEET II.E.4.10

TEST ITEM 543-380A PART NO. STRUCTURE

SERIAL NO. TEST DATE 28 AUG 1969

SHOCK AXIS TANGENTIAL SHOCK NO. 1



SECTION NO. II.E.5

REPORT NO. 547

SUBJECT:

EQUIPMENT TESTS ON BARREL TESTER

SECTION II.E.5

SUMMARY

This report covers the pyrotechnic testing of a specimen representative of a Reaction Engine Module performed on the barrel tester.

The specimen was mounted through a special removable panel in bay 1 of the barrel in order to be subjected to the appropriate environment level. Two accelerometers were mounted on the specimen to record radial and tangential acceleration.

The data reduction included the "A" barrel monitoring accelerometers. No data recording difficulties occurred.

Standard .19 inch magnesium-thorium separation plates and 30 Gr MDF explosive charges were used for the two tests performed.

The specimen survived the tests without damage of any kind.

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II.E.5.1 INTRODUCTION

A Reaction Engine Module weighing about 9 pounds including its fiberglass flight jacket and mounting angles was installed through a special barrel tester removable panel. The whole unit was placed in bay 1 of a standard barrel tester.

Two firings were carried out with a .19 inch magnesium-thorium separation plate and 30 Gr MDF explosive charge.

The specimen withstood the test without failure of any kind.

II.E.5.2 DISCUSSION AND ANALYSIS

II.E.5.2.1 Test Configuration and Instrumentation

A standard barrel tester, as described in Section II.F.2, was used for this test. The general test arrangement is shown on Figure II.E.5.1. The REM specimen is mounted through a cut out in a bay 1 removable panel together with its fiberglass flight shield. The two aluminum angles normally used for flight installation were rivetted onto the inner face of the removable panel duplicating closely the flight installation.

The instrumentation consisted of one set of two accelerometers, as described on Table II.E.5.1, reading radial and tangential accelerations. In addition, the standard A triax accelerometers were recorded to provide barrel tester bay 1 environment. Accelerometer readings were free from disturbance.

Shock spectra for each accelerometer and each test are presented on Figure II.E.5.4 to II.E.5.7. Repeatability is shown on Figure II.E.5.8 and II.E.5.9 which compare the readings of each accelerometer for tests 1 and 2.

II.E.5.2.2 Technical Discussion

Upon completion of the test, inspection of the specimen showed that no failure occurred.

The test results were good with no disturbance affecting any of the accelerometer readings.

Reduction of the test data was performed on the UNIVAC 1108 after digitizing the analog tape.

II.E.5.2.3 Analysis

Since the test specimen survived the shocks without damage, two considerations are of interest.

a. Attenuation provided by the specimen mounting.
b. Repeatability of the environment provided by shocks 1 and 2.

The attenuation provided by the REM mounting is shown by comparing the environment read by accelerometers No. 1 and 2 with the barrel bay 1 environment from the set of accelerometers A. The envelope of these two measurements are presented on Figure II.E.5.3 which shows a very substantial attenuation over the whole frequency range.

Repeatability of the environment between test 1 and 2 is presented on Figure II.E.5.8 and II.E.5.9 which show excellent correlation. Differences between data points may be attributed to normal data scatter.

II.E.5.3 CONCLUSION

The REM specimen withstood the environment provided by two shocks without failure of any kind.

The installation provided a substantial shock attenuation, although no vibration isolators were fitted.

Repeatability of the environment recorded by all accelerometers for both shocks was satisfactory.

Information provided by this test adds to the background of experimental data which is useful in predicting the attenuation which may be obtained with similar installation.

TABLE II.E.5.1

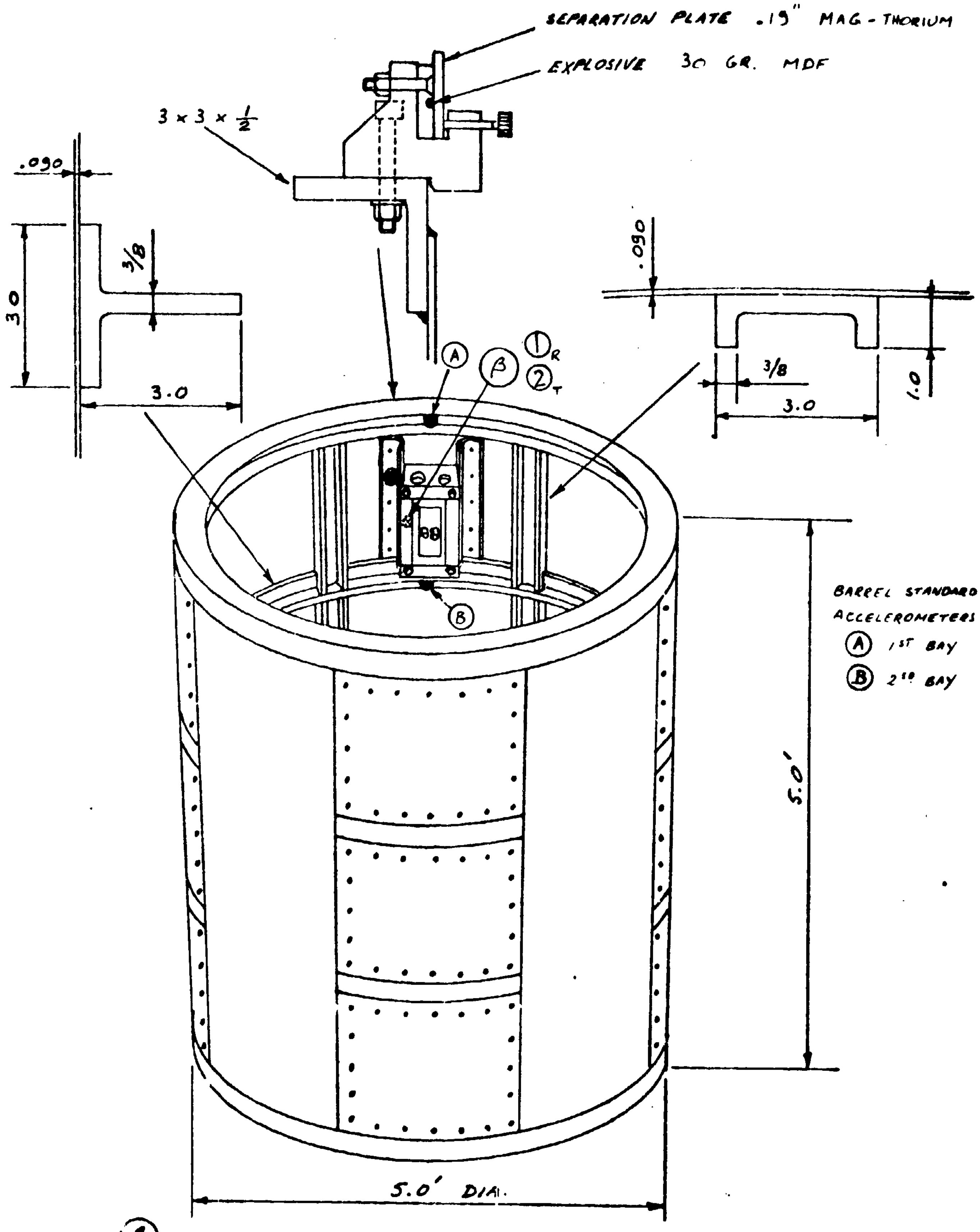
ACCELEROMETERS AND LOCATIONS

Accelerometer Number	Box	Direction	Location	Distance to Shocksource	Accelerometer Type
1	Specimen	R	Bay 1	15"	Columbia 2231
2	Specimen	T	Bay 1	15"	Columbia 2231

TABLE II.E.5.2

SUMMARY OF TESTS

Test Number	Configuration	Explosive Size	Test Purpose	Shock Isolation
1	1	30 Gr/ft MDF	Qual.	None
2	2	30 Gr/ft MDF	Qual.	None



β TWO COLUMBIA 2231 ACCELEROMETERS ON REM CHASSIS.

Figure II.E.5.1 TEST GENERAL ARRANGEMENT

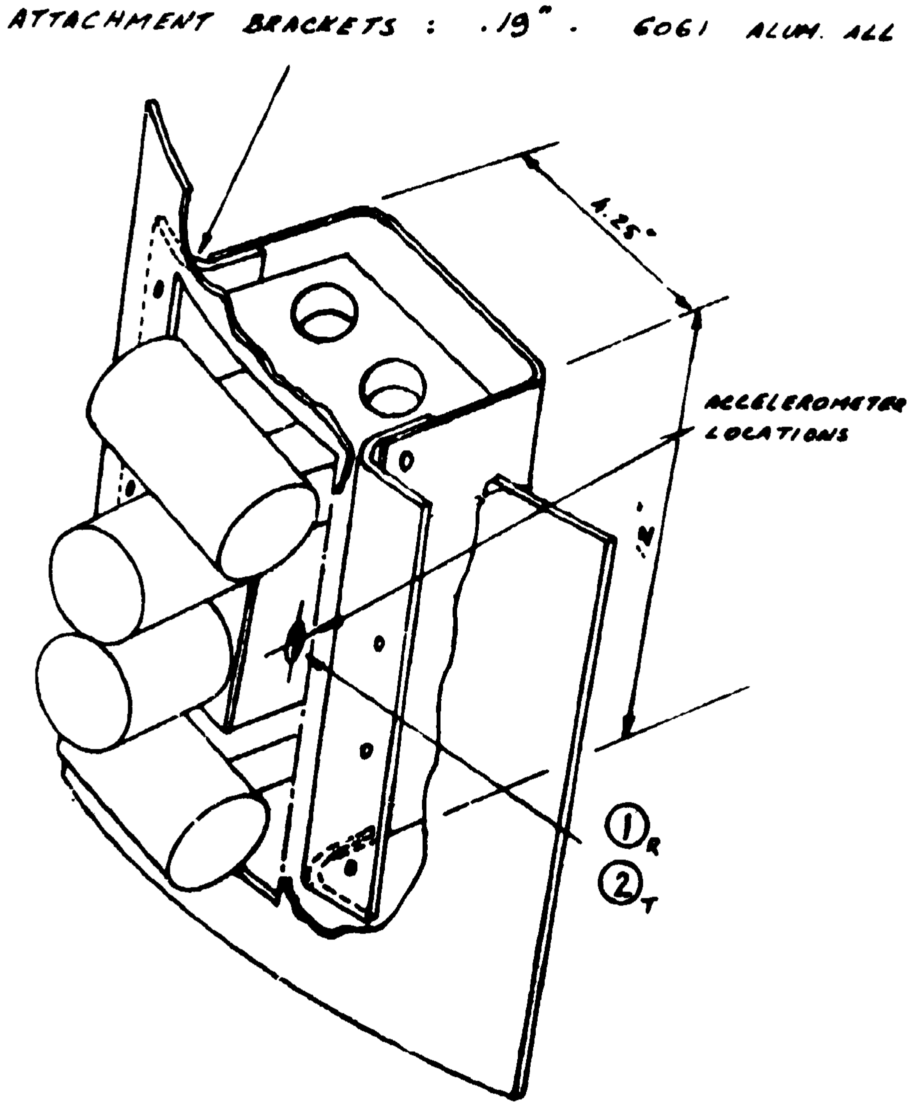


Figure II.2.5.2. SPECIMEN ATTACHMENT BRACKETS

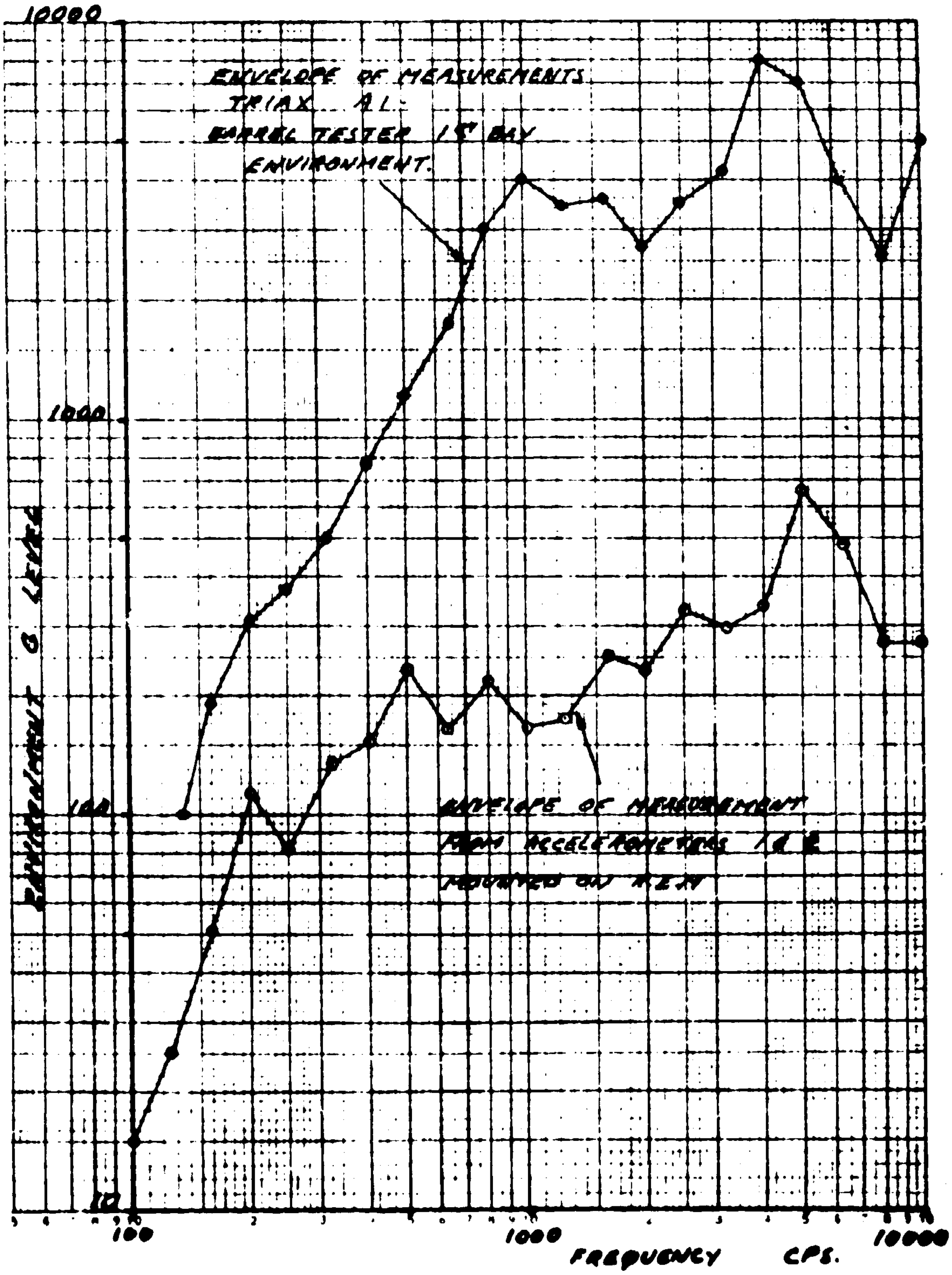
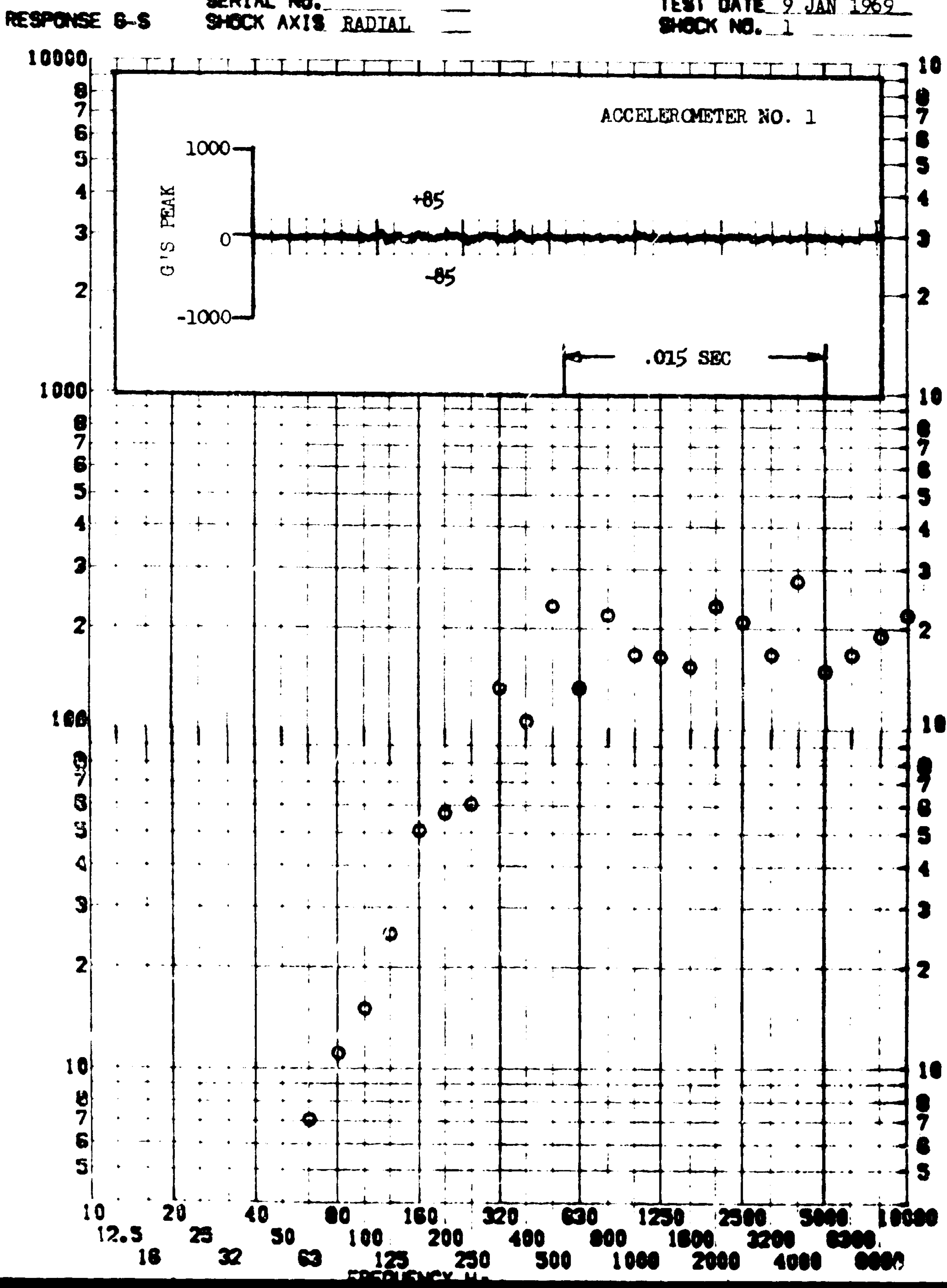


Figure II.E.5.3 COMPARISON OF ENVIRONMENT G LEVEL MEASURED ON EQUIPMENT WITH BARREL TESTER FIRST AND SECOND BAY LEVELS

SHOCK TEST ANALYSIS DATA SHEET II.E.5.4

TEST ITEM	547-381	PART NO.	EQUIPMENT
SERIAL NO.		TEST DATE	9 JAN 1969
SHOCK AXIS	RADIAL	SHOCK NO.	1

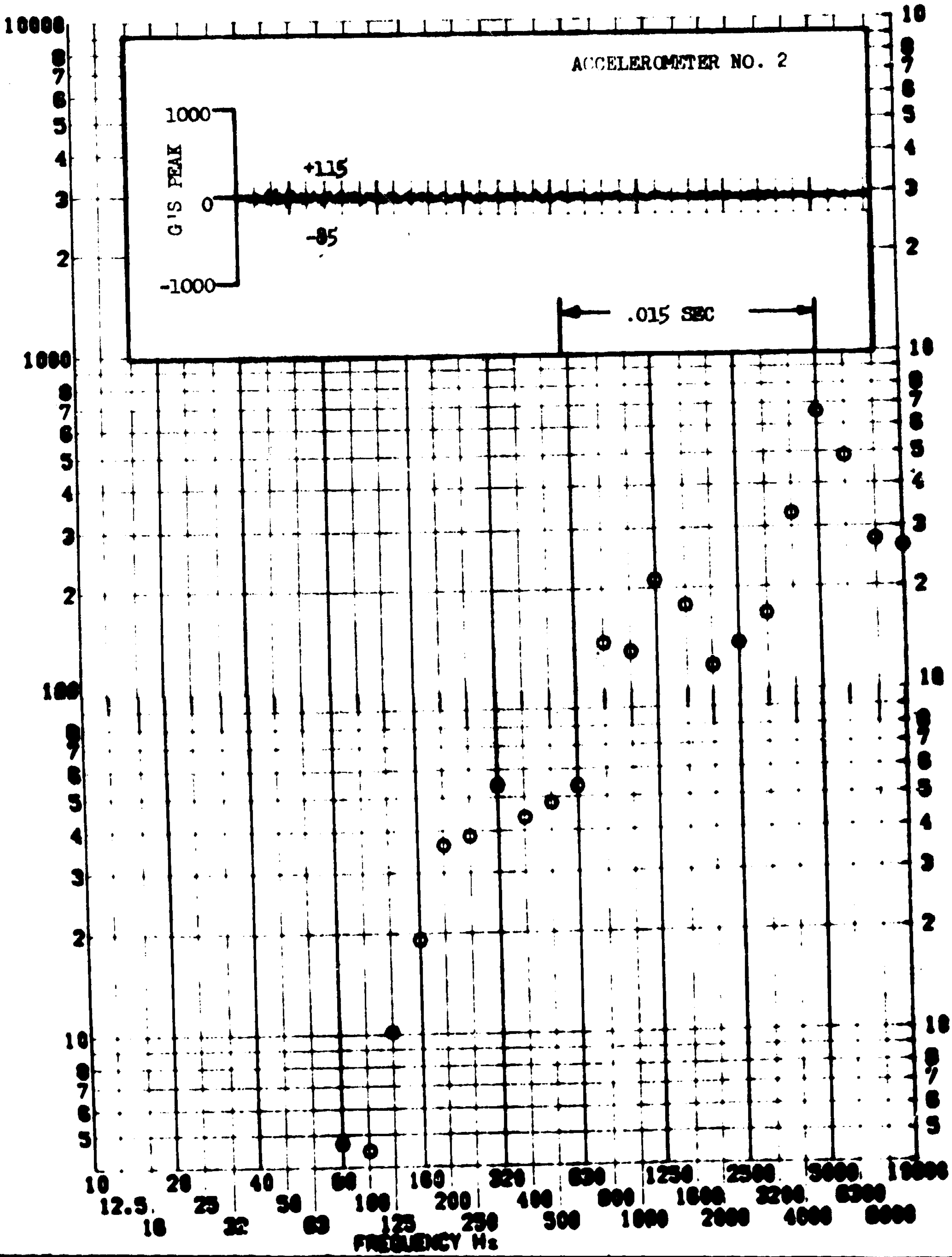


SHOCK TEST ANALYSIS DATA SHEET II.E.5.5

TEST ITEM 547-383
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. EQUIPMENT
TEST DATE 9 JAN 1969
SHOCK NO. 1

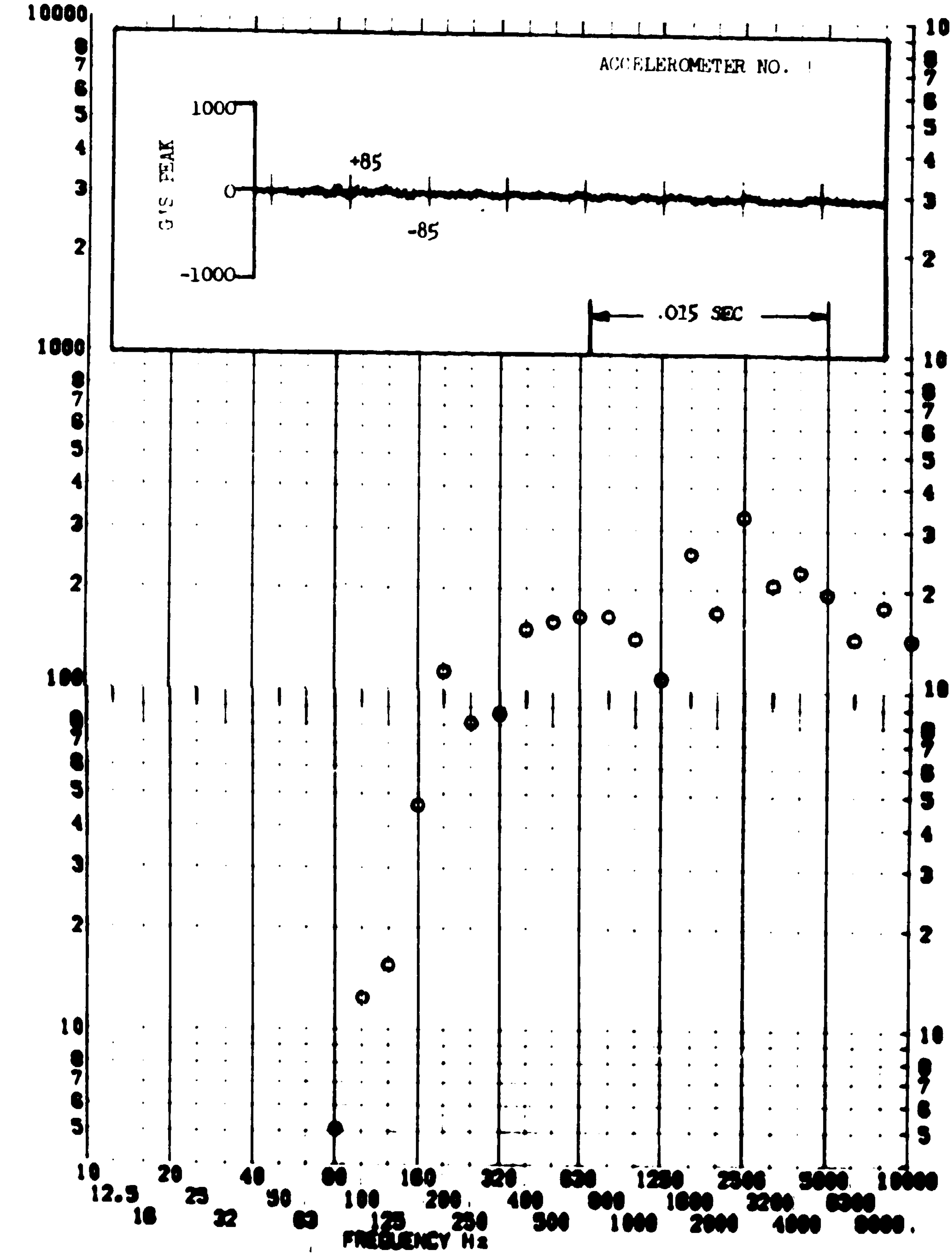
RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.5.6

TEST ITEM 547-382 —
SERIAL NO. —
SHOCK AXIS RADIAL —

PART NO. EQUIPMENT
TEST DATE 9 JAN 1969
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET 11.E.5.7

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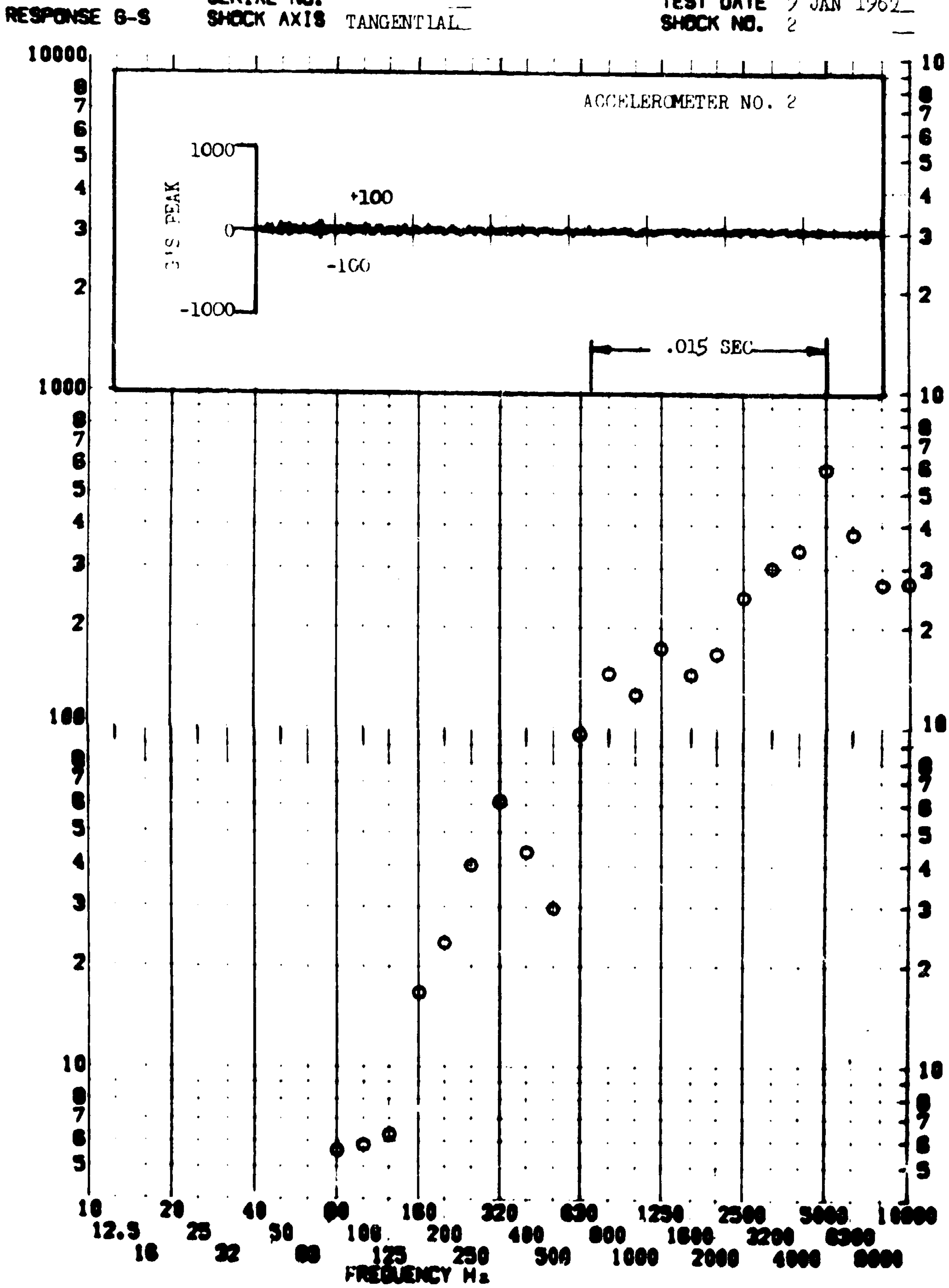
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. EQUIPMENT
TEST DATE 9 JAN 1962
SHOCK NO. 2



SHOCK TEST ANALYSIS DATA SHEET II.E.5.8

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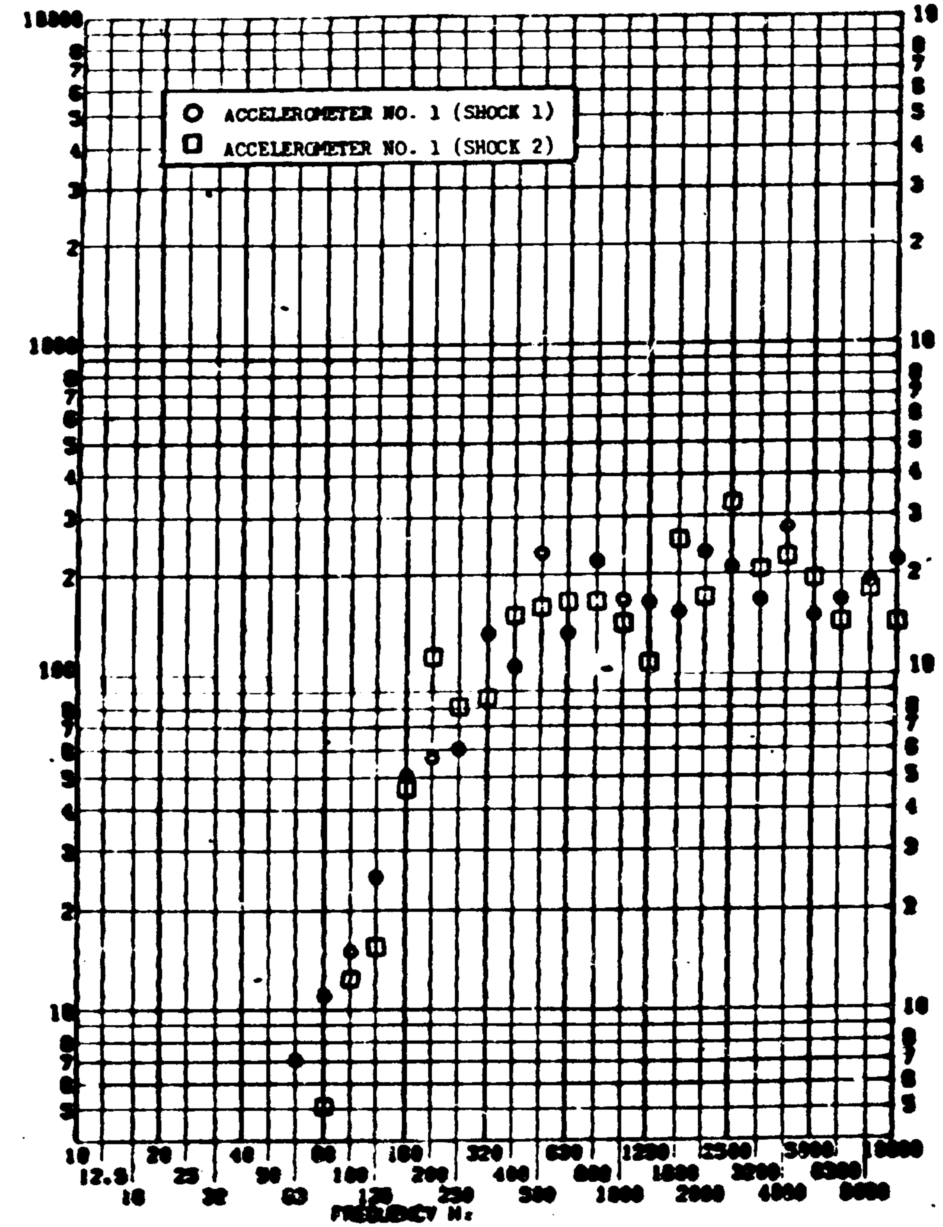
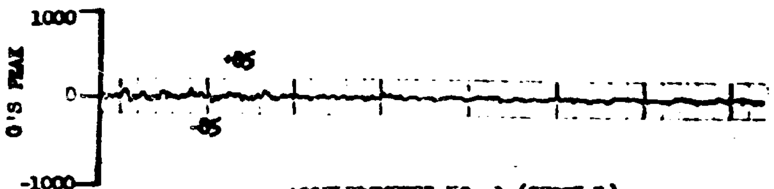
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. EQUIPMENT
TEST DATE 9 JAN 1969
SHOCK NO. 2

RESPONSE G-S





ACCELEROMETER NO. 1 (SHOCK 1)

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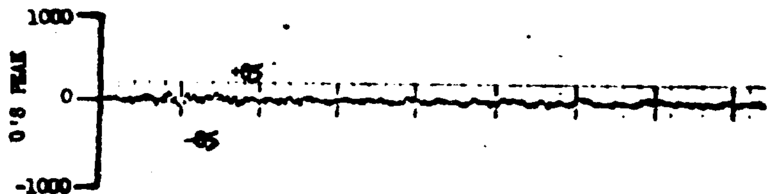

ACCELEROMETER NO. 1 (SHOCK 2)

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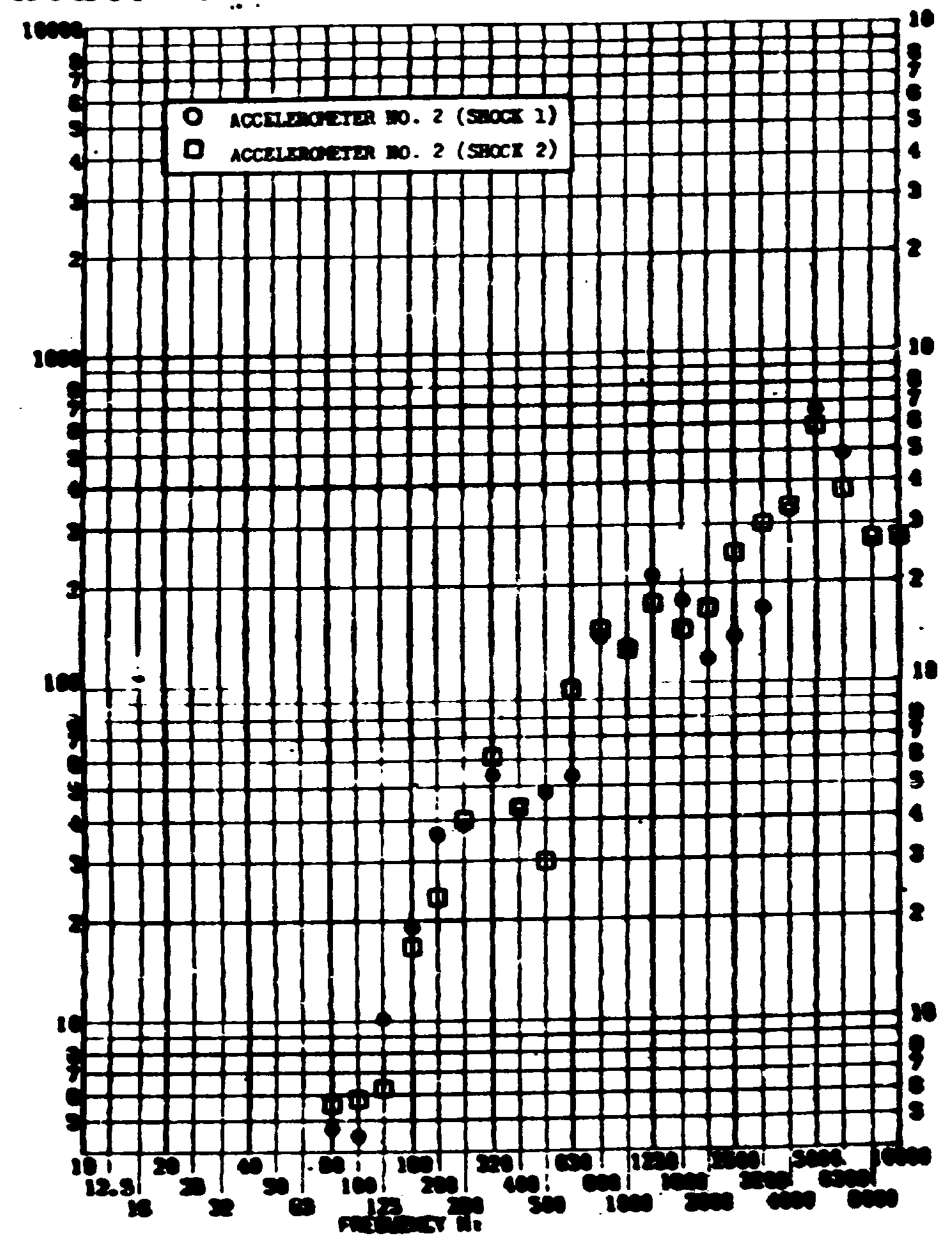
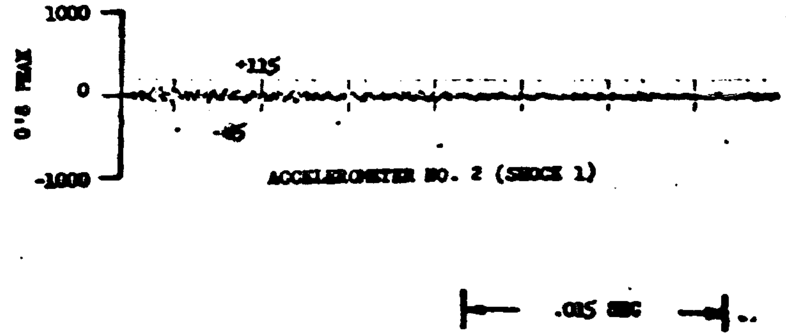
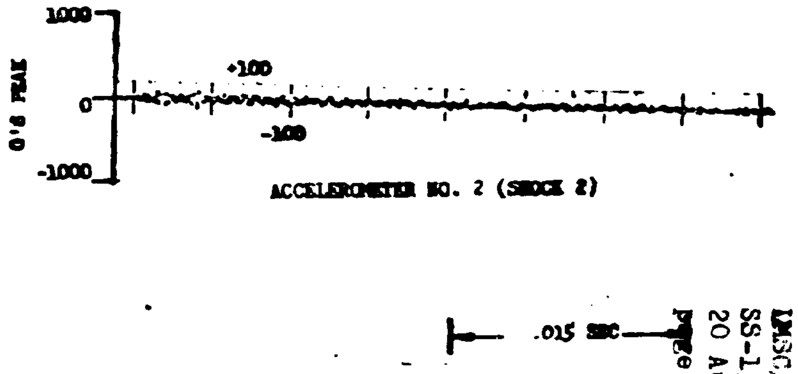
SHOCK TEST ANALYSIS DATA SHEET II.B.5.9

TEST ITEM 517-383,384
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO. EQUIPMENT
TEST DATE 9 JAN 1969
SHOCK NO. 2







SECTION NO. II.E.6

REPORT NO. 562

SUBJECT:

ELECTRONIC BOX TESTS ON BARREL TESTER

SECTION II.E.6

SUMMARY

This report covers the qualification testing of a Velocity Meter box installed on the barrel tester by means of a structure simulating actual flight hardware.

The Velocity Meter box was mounted with silicone elastomer vibration isolators. Instrumentation consisted of two sets of three accelerometers mounted one on the Guidance Module near the box/module interface and the other on the box itself.

Standard .19 inch magnesium-thorium separation plates and 30 Gr MDF explosive charges were used for each of the two shocks performed.

No data recording difficulties were encountered. The Velocity Meter box survived the tests without failure of any kind and repeatability of the environment between shock 1 and 2 was good.

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LIST OF FIGURES (Cont.)

SECTION II.E.6

II.E.6.1 INTRODUCTION

An 8 pound Velocity Meter box mounted on the side of a Guidance Module base was subjected to pyrotechnic shock qualification testing. This box was attached in three points fitted with silicone elastomer vibration isolators. The test arrangement was a close duplicate of the flight hardware.

Two shock tests were performed with the box being subjected to a functional checkout after each shock. The tests were carried out with .19 inch magnesium-thorium separation plates and 30 Gr MDF explosive charges.

II.E.6.2 DISCUSSION AND ANALYSIS

II.E.6.2.1 Test Configuration and Instrumentation

A standard barrel tester as described in Section II.F.2 was used for this test. The Guidance Module base was attached to two of the barrel longerons as shown on Figure II.E.6.1. The Velocity Meter was installed on the side of the Guidance Module base by three machined brackets containing the vibration isolators as shown on Figure II.E.6.2. The vibration isolators are commercial type made from silicone rubber by Marshall Research and Development Company as indicated on Figure II.E.6.2.

The instrumentation included a total of six accelerometers in two triax located as shown on Figure II.E.6.1 and II.E.6.2. Standard barrel triax A and B were used for test monitoring but their data was not recorded for the purpose of this test. Characteristics of the instrumentation are given on Table II.E.6.1 and a summary of the tests performed is given on Table II.E.6.2.

Shock spectra for each accelerometer and each shock are presented on Figure II.E.6.4 to II.E.6.15. Repeatability is shown on Figure II.E.6.16 to II.E.6.21 which compare the readings of each accelerometer for shock 1 and 2.

The recorded data was found to be free of disturbance hence its reliability is good.

II.E.6.2.2 Technical Discussion

Upon completion of each shock test, the Velocity Meter was subjected to complete functional tests which showed no detrimental effect of any kind.

The test results were good and all accelerometer readings were reliable.

Reduction of the test data was performed on the UNIVAC 1108 after digitizing the analog tape.

II.E.6.2.3 Analysis

Since the test specimen survived the shock without damage, two considerations are of interest.

a. Attenuation provided by the box mounting.

b. Repeatability of the environment provided by shock 1 and 2.

The attenuation provided by the box mounting is shown by comparing the environment recorded by the two sets of accelerometers (1, 2, 3) and (4, 5, 6). Since this box was very critical along the longitudinal axis, the attenuation is computed separately for each axis taking ratios of accelerometer readings paired as follows: (1, 4), (2, 5), (3, 6) then considering the average value of the two shocks (Table II.E.6.3). These results are presented on Figure II.E.6.3 which shows good attenuation provided for the longitudinal axis (accelerometer No. 1/No. 4). The other axes show amplification for a small frequency range above 100 cps which is attributed to a normal mode of about 120 cps (tangential).

Repeatability of the environment was good for all accelerometers. It is presented on Figure II.E.6.16 to II.E.6.21. Differences between data points may be attributed to normal data scatter.

II.E.6.3 CONCLUSION

The Velocity Meter withstood the environment provided by two shocks without failure of any kind.

The vibration isolators provided substantial attenuation especially along the critical longitudinal axis.

Repeatability of the environment recorded by all accelerometers for both shocks was satisfactory.

Information provided by this test add to the background of experimental data which is useful in predicting the attenuation which may be obtained with similar installation.

TABLE II.E.6.1

ACCELEROMETERS AND LOCATIONS

Accelerometer Number	Box	Direction	Location	Distance to Shocksource	Accelerometer Type
1	VM.	L	Box 2	15"	Endevco 2211
2	VM.	R	Box 2	15"	Endevco 2211
3	VM.	T	Box 2	15"	Endevco 2211
4	Guidance module base	L	Box 1	15"	Endevco 2223
5	Guidance module base	R	Box 1	15"	Endevco 2223
6	Guidance module base	T	Box 1	15"	Endevco 2223

TABLE II.E.6.2

SUMMARY OF TESTS

Test Number	Configuration	Explosive Size	Test Purpose	Shock Isolation
1	1	30 Gr/ft MDF	Box Qual.	Yes
2	2	30 Gr/ft MDF	Box Qual.	Yes

TABLE II.E.6.3

AVERAGE LEVELS BETWEEN SHOCK 1 AND SHOCK 2

Frequency cps	Test 1 1/4	Test 2 1/4	Average	Test 1 2/5	Test 2 2/5	Average	Test 1 3/6	Test 2 3/6	Average
125		.44	.44		2.20	2.20			
160	.42	.43	.42	1.95	2.64	2.29			
200	.45	.58	.51	.82	.90	.86	3.40	3.20	3.30
250	.39	.47	.43	1.00	.80	.90	1.70	1.63	1.66
320	.33	.41	.37	.85	1.15	1.00	1.23	1.65	1.44
400	.27	.19	.23	.55	.65	.60	.95	.80	.87
500	.23	.15	.19	.47	.37	.42	.65	.54	.59
630	.09	.16	.12	.25	.38	.31	.40	.46	.43
800	.21	.10	.15	.35	.42	.38	.47	.32	.39
1000	.16	.17	.16	.34	.32	.33	.71	.42	.56
1250	.23	.16	.19	.31	.47	.39	.44	.55	.50
1600	.86	.52	.69	.46	.52	.49	.38	.24	.31
2000	.30	.23	.26	.30	.58	.44	.08	.14	.11
2500	.25	.19	.22	.46	.39	.42	.17	.29	.23
3200	.15	.08	.11	.54	.69	.61	.17	.17	.17
4000	.08	.08	.08	.29	.49	.39	.21	.38	.29
5000	.06	.07	.06	.18	.36	.27	.17	.33	.25
6300	.13	.14	.13	.21	.22	.21	.26	.39	.32
8000	.10	.08	.09	.47	.50	.48	.17	.32	.25
10000	.19	.15	.17	.57	.53	.55	.29	.65	.47

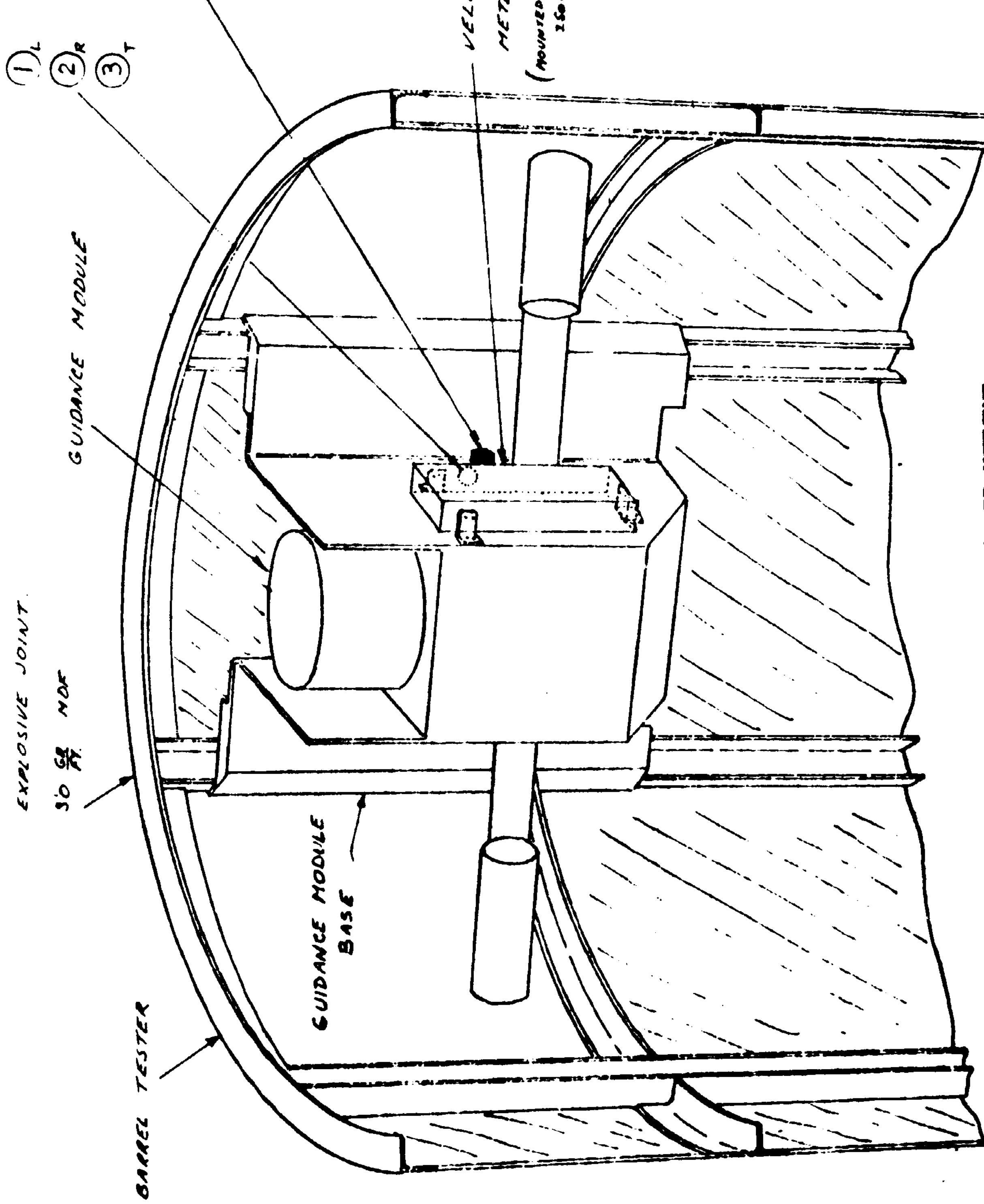
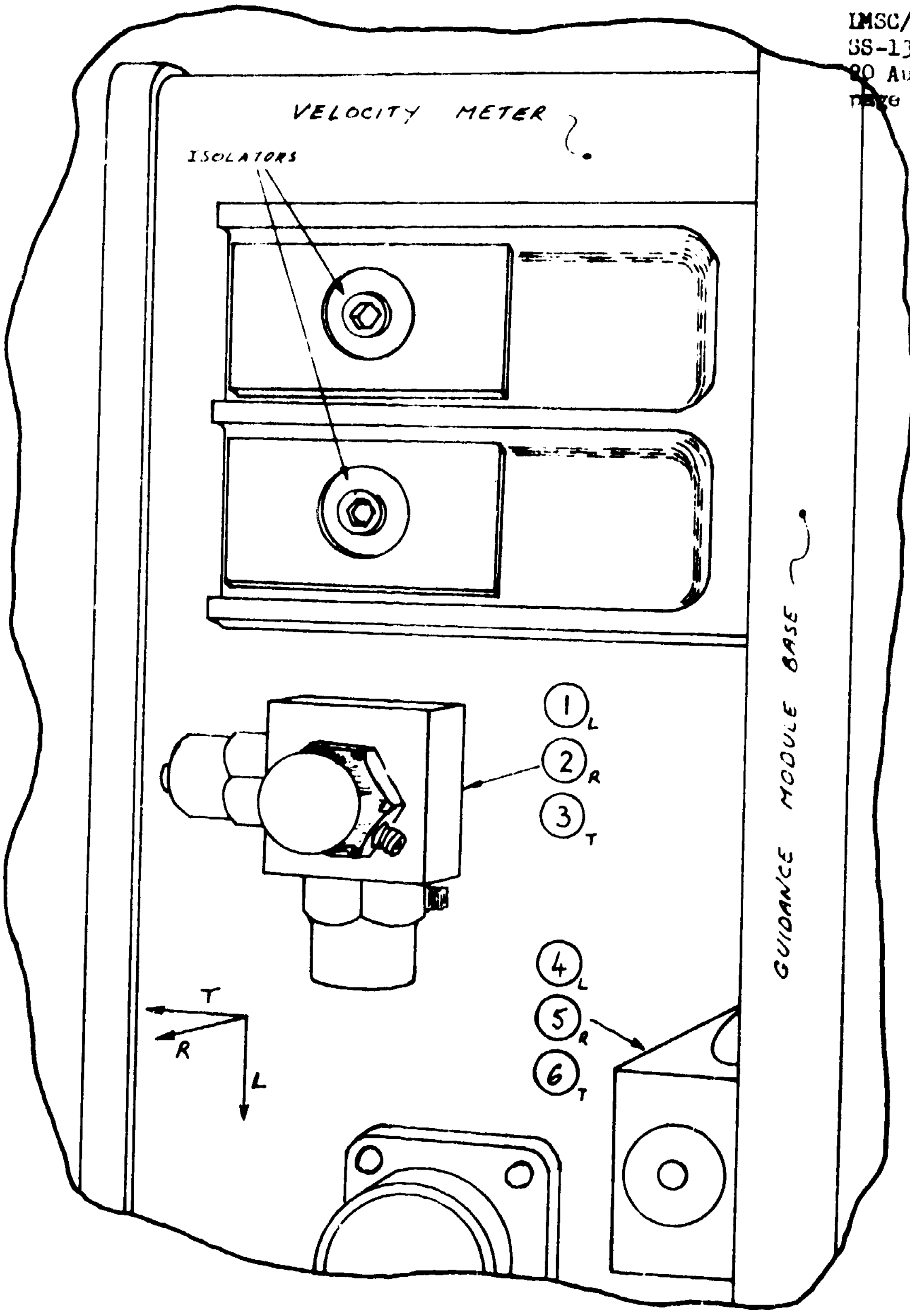


Figure II.E.6.1 TEST GENERAL ARRANGEMENT



MARSHALL RESEARCH & DEVELOPMENT COMPANY
BURLINGTON, MASS.
MODEL: B-10734-2 - 2 OFF - ON LOWER BRACKET
MODEL: B-10732-1 - 4 OFF - ON SIDE BRACKETS

Figure II.E.6.2 VELOCITY METER ISOLATORS AND SHOCK ACCELEROMETERS

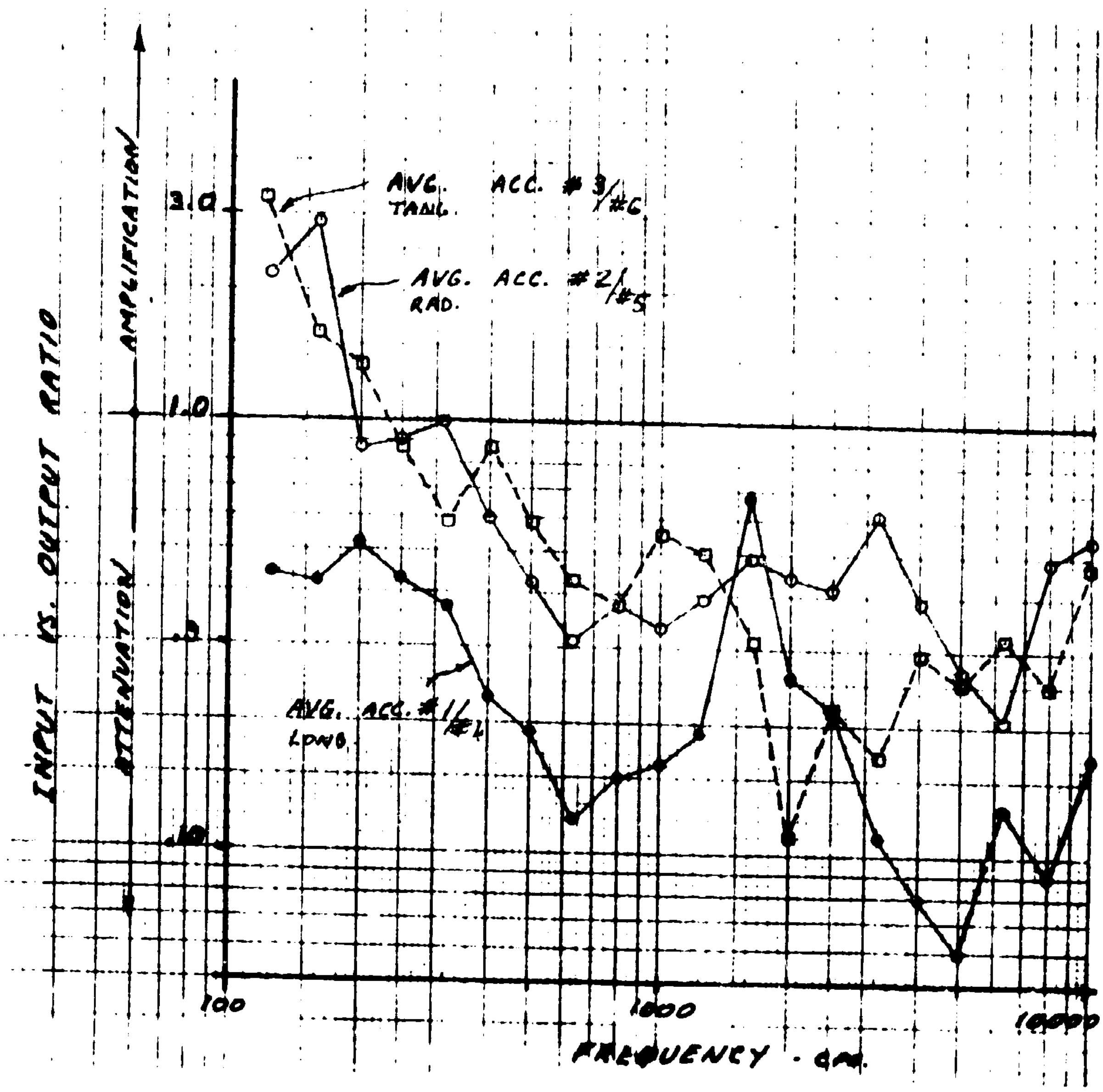


Figure II.E.6.3 ATTENUATION PROVIDED BY BRACKET AND ISOLATORS

SHOCK TEST ANALYSIS DATA SHEET

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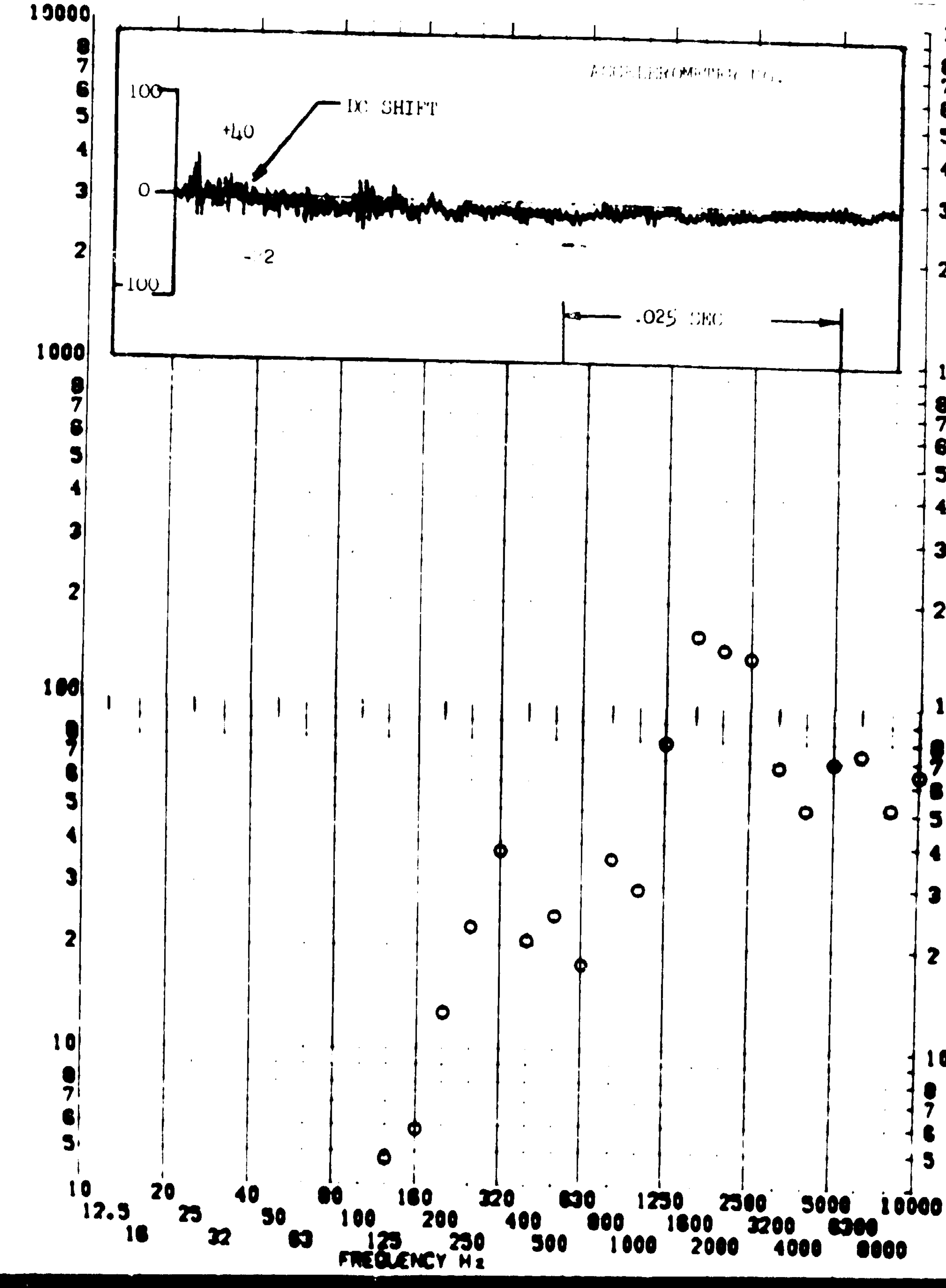
SERIAL NO.	TEST DATE
SHOCK AXIS LONGITUDINAL	SHOCK NO.



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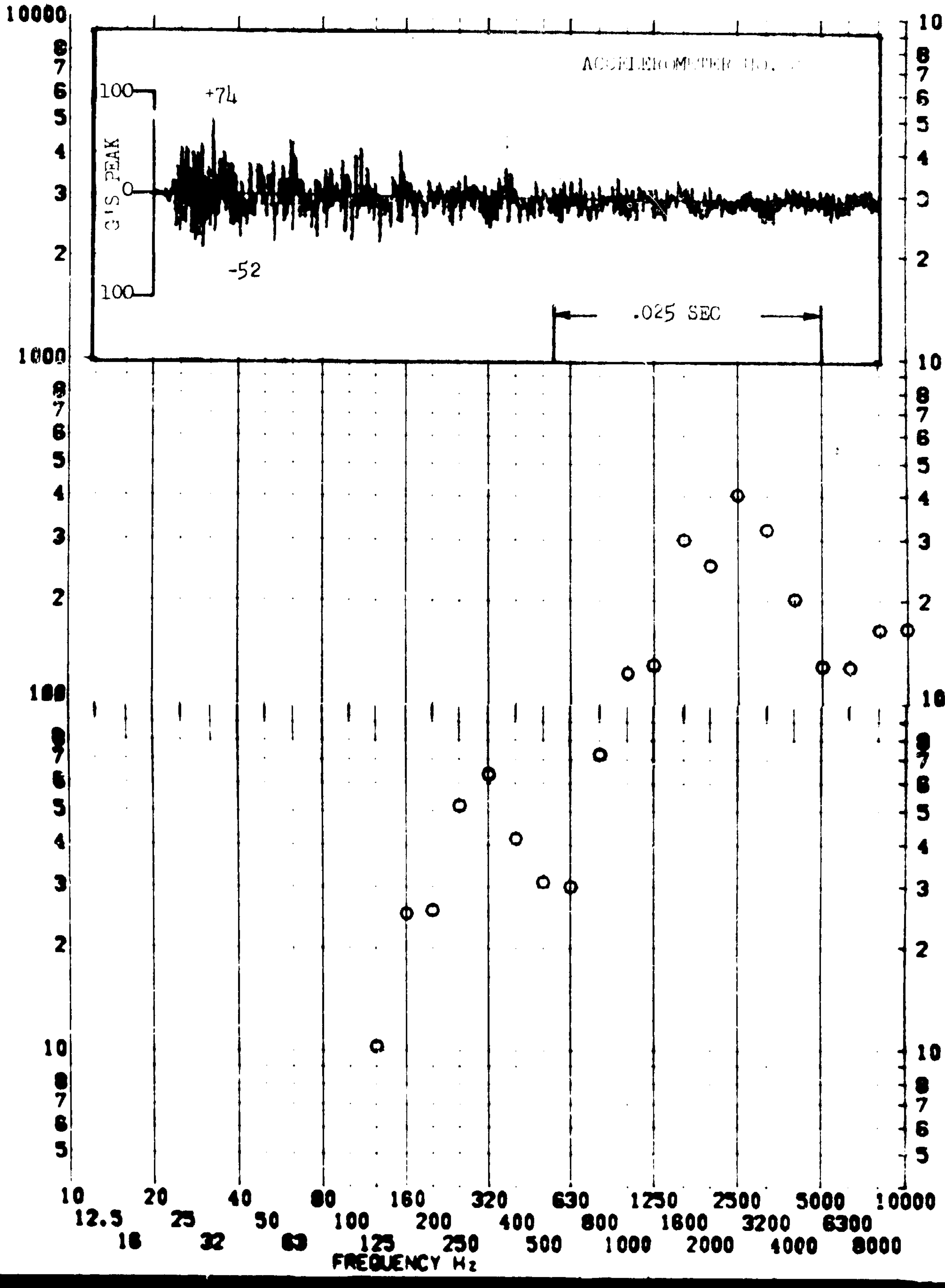
SHOCK AXIS RADIAL

PART NO. [illegible]
TEST DATE [illegible] 1968
SHOCK NO.

RESPONSE G-S



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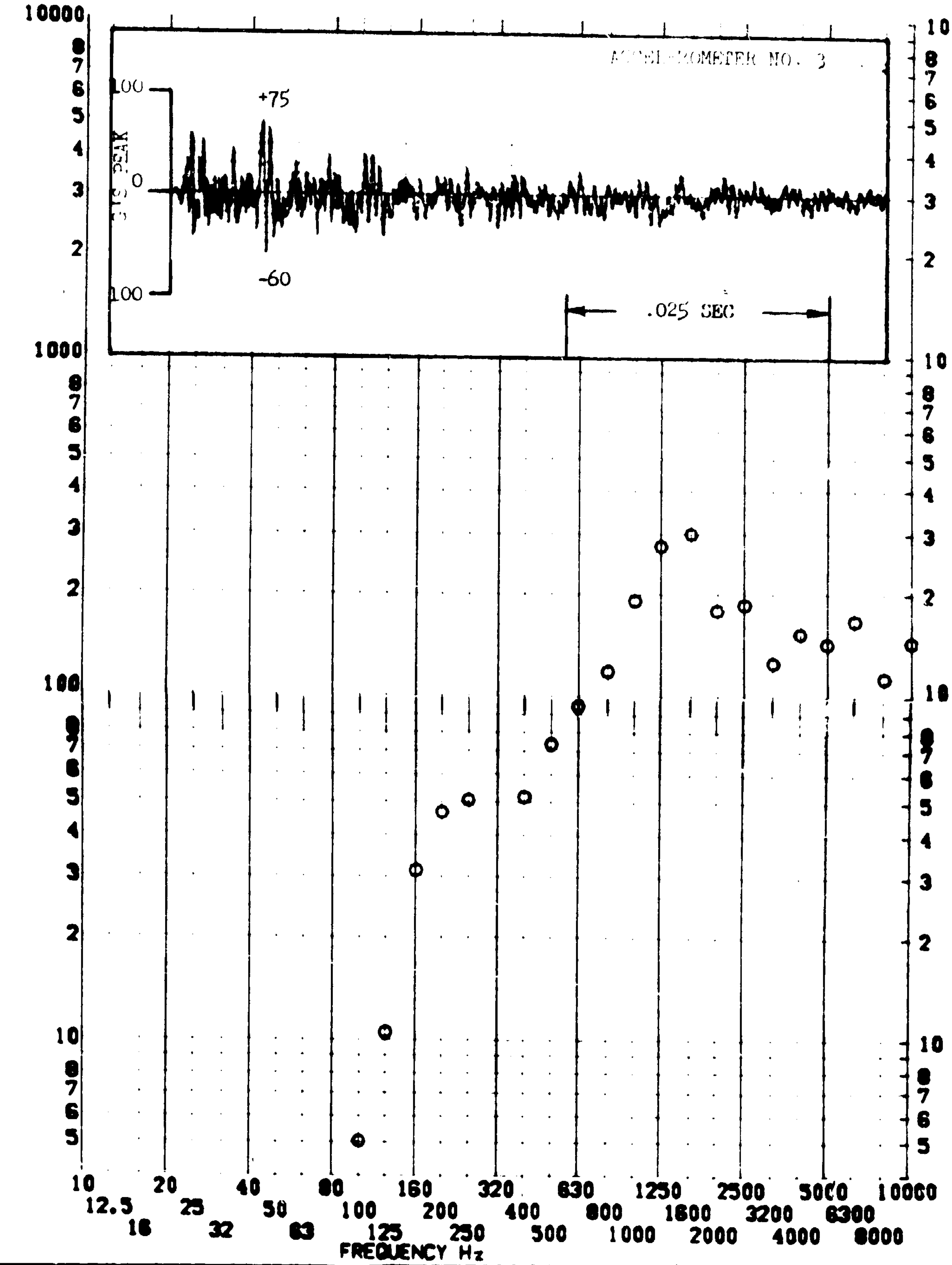
SERIAL NO.
SHOCK AXIS TANGENTIAL

PART NO.
TEST DATE
SHOCK NO.

RESPONSE G-S



SHOCK TEST ANALYSIS DATA SHEET II.E.6.7

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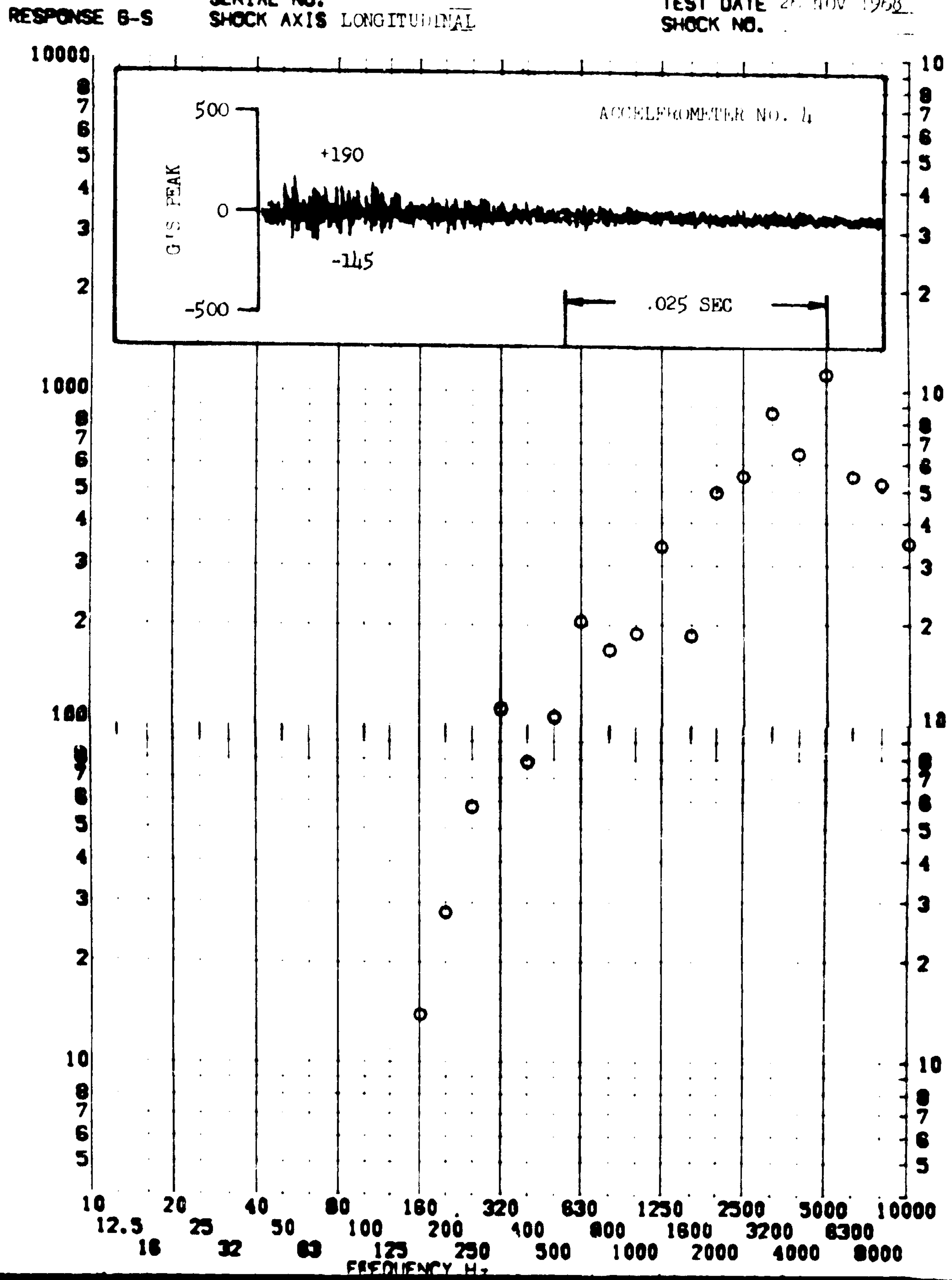
PART NO. EQUIPMENT BASE
TEST DATE 26 NOV 1968
SHOCK NO.



SHOCK TEST ANALYSIS DATA SHEET II.E.6.3

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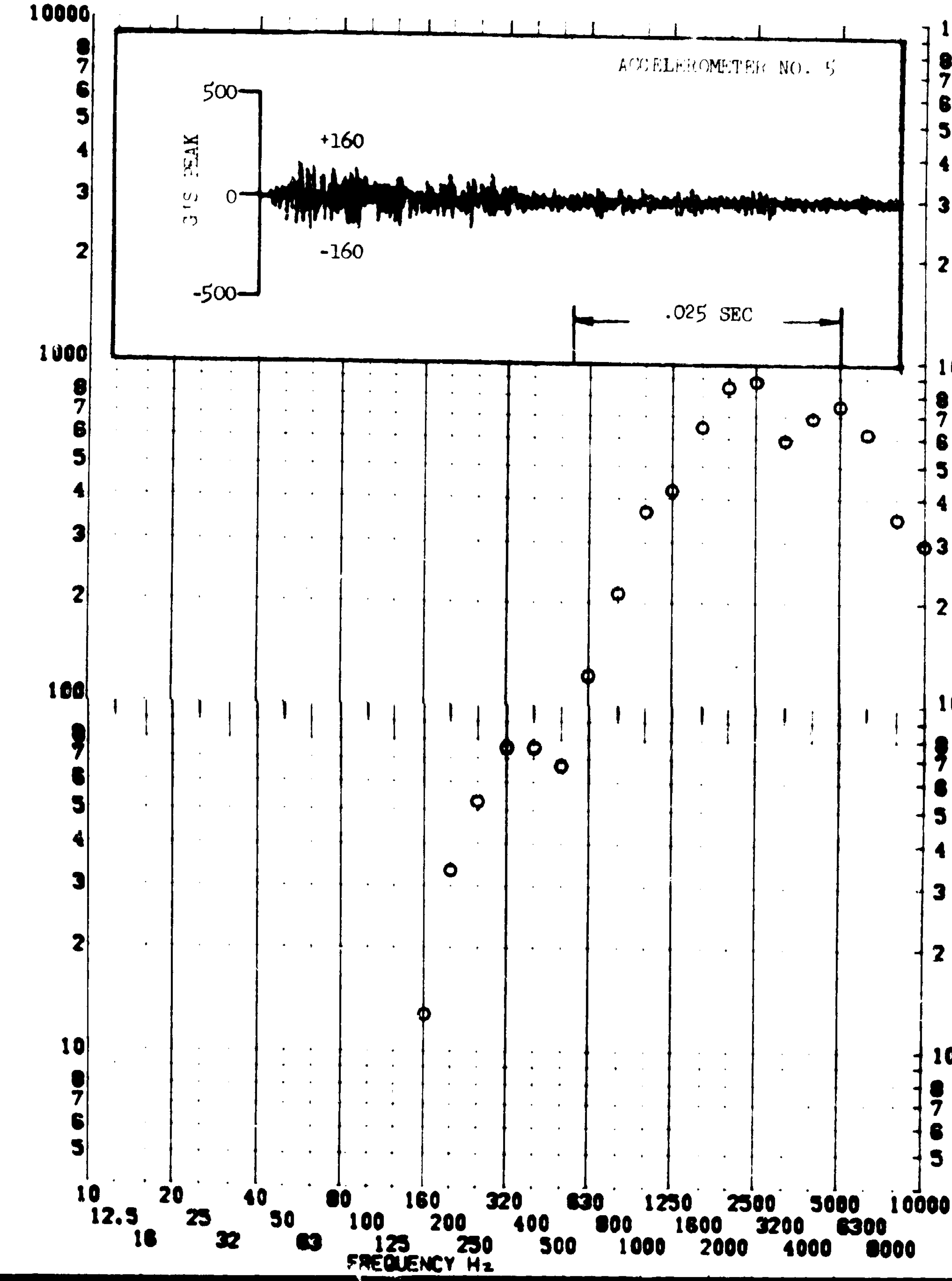
SERIAL NO.
SHOCK AXIS RADIAL

PART NO. EQUIPMENT BASE
TEST DATE 26 NOV 1968
SHOCK NO. 1

RESPONSE G-S



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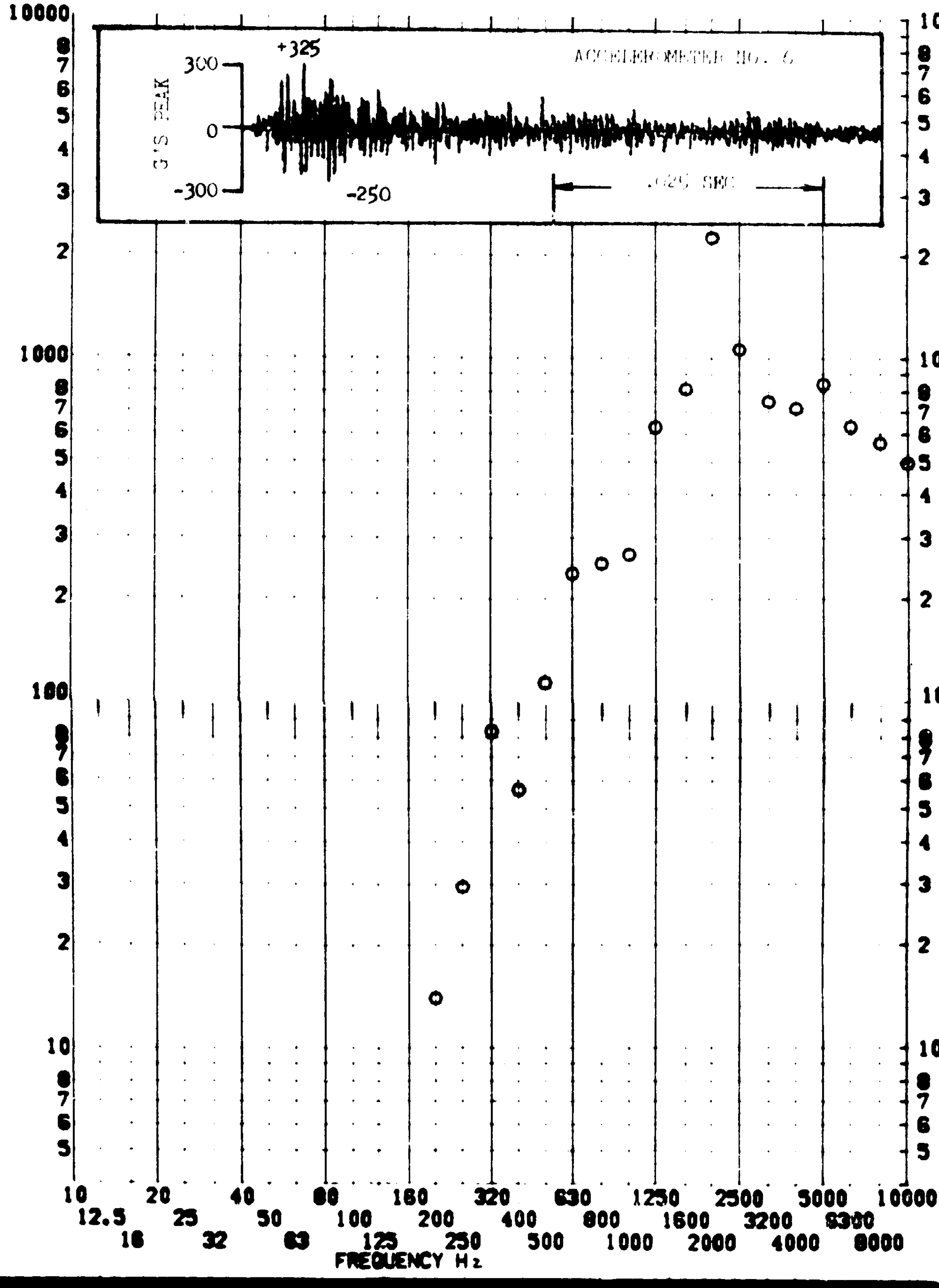
SERIAL NO. —
SHOCK AXIS TANGENTIAL
PART NO. EQUIPMENT BASE
TEST DATE 26 NOV 1968
SHOCK NO. —

RESPONSE G-S



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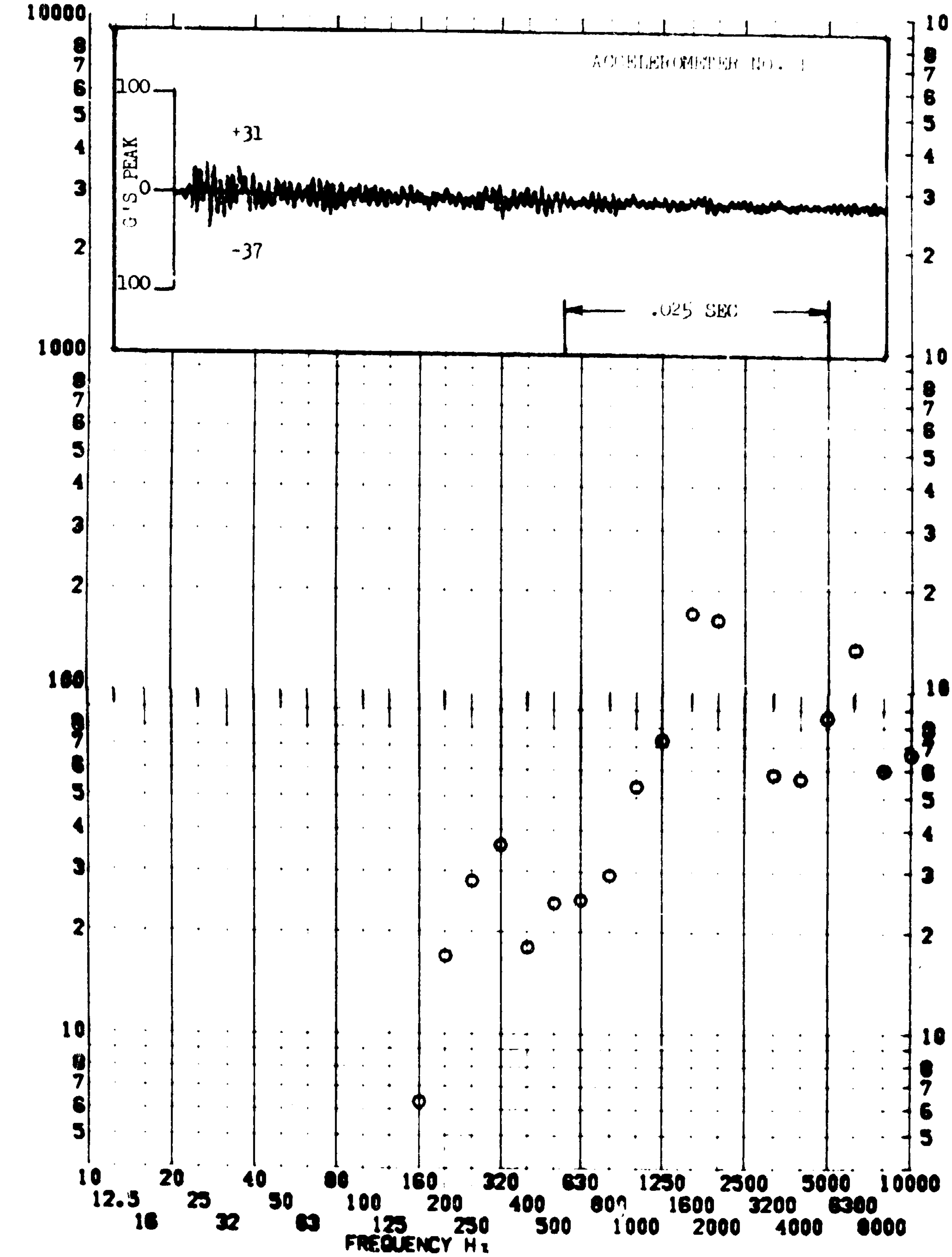
SHOCK AXIS LONGITUDINAL

PART NO. EQUIPMENT
TEST DATE 27 NOV 1968
SHOCK NO. 2



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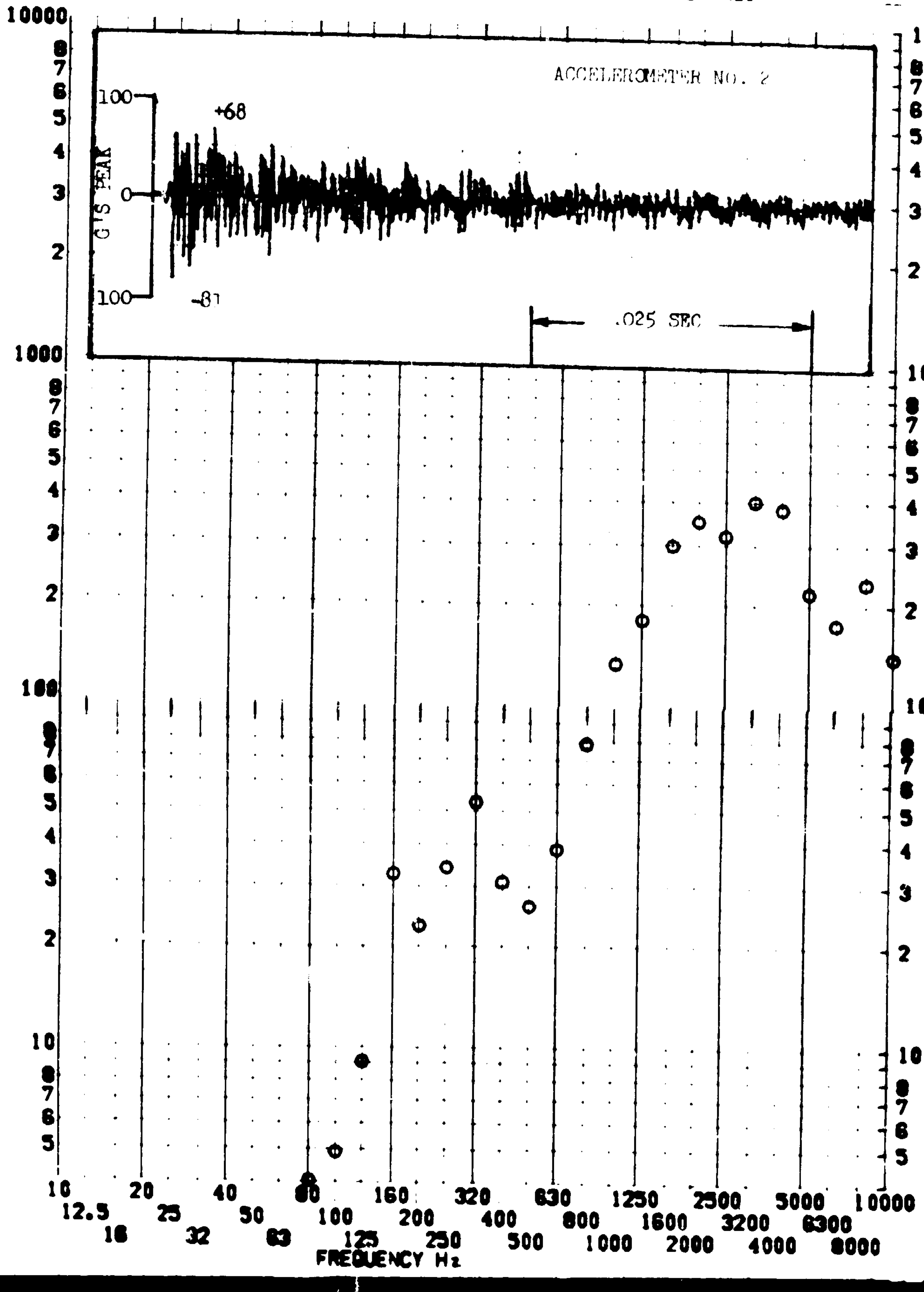

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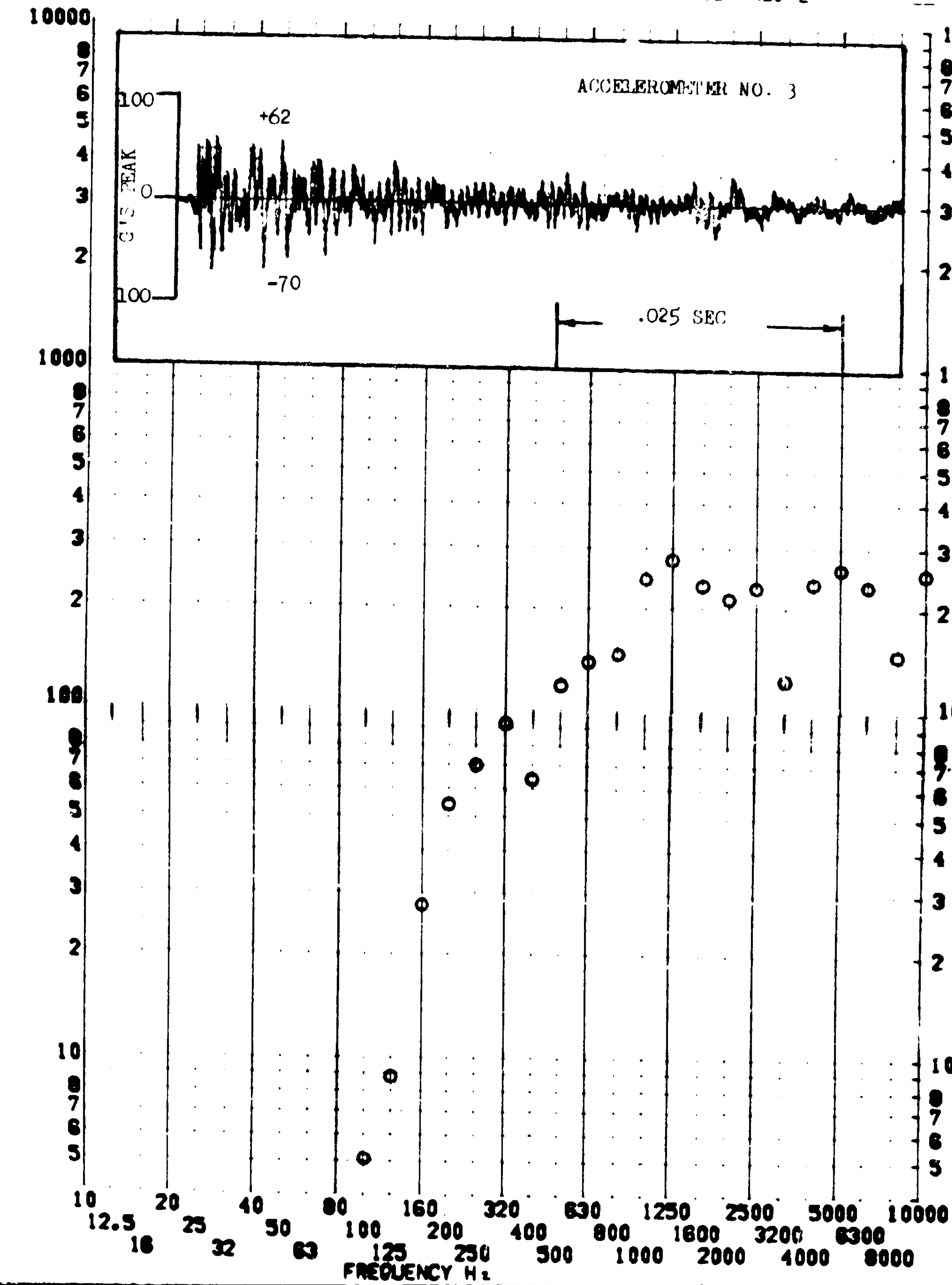
SHOCK AXIS	TANGENTIAL	SHOCK NO.	2

RESPONSE G-S



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PART NO. EQUIPMENT BASE
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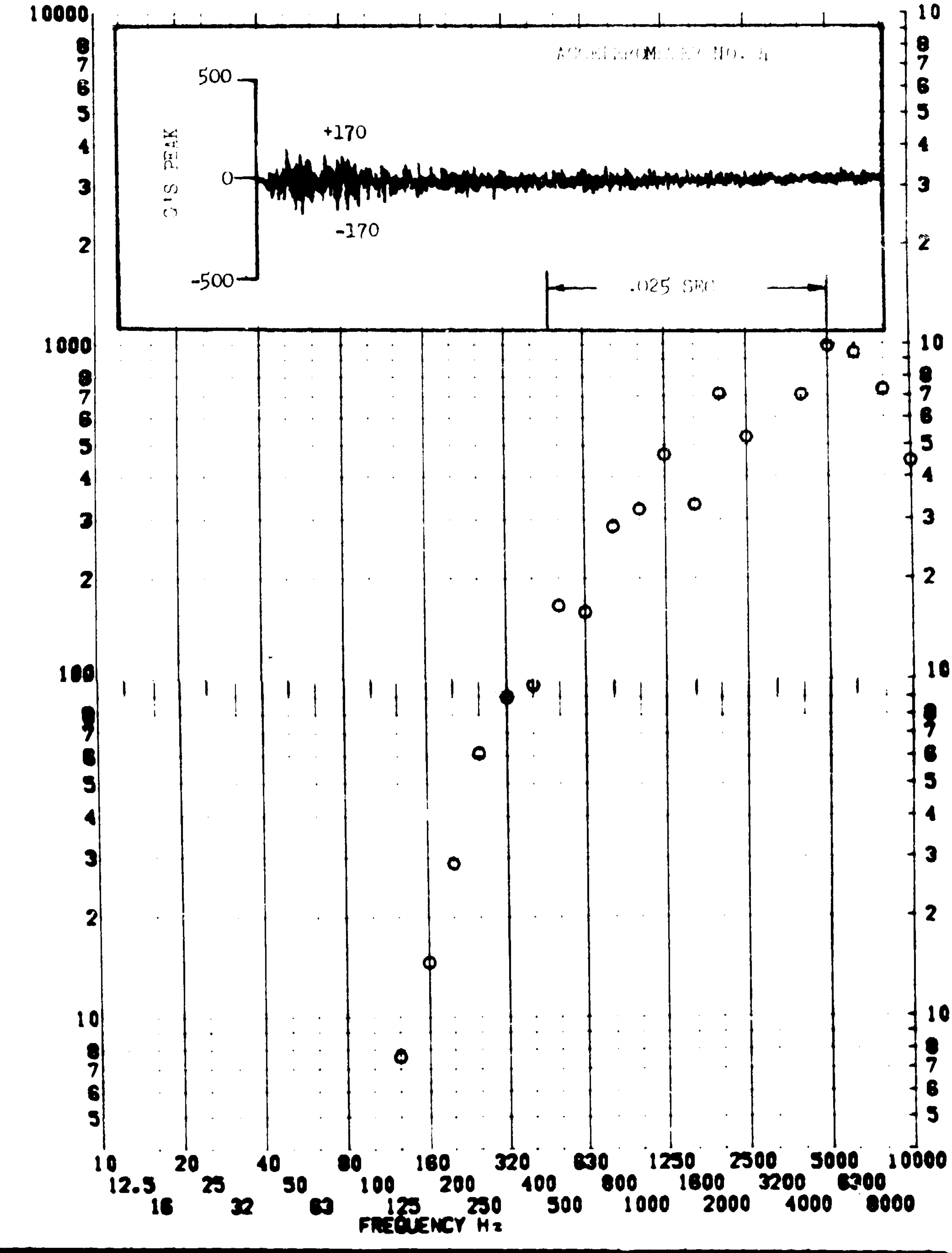
RESPONSE G-S



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PART NO. [illegible]
TEST DATE [illegible]
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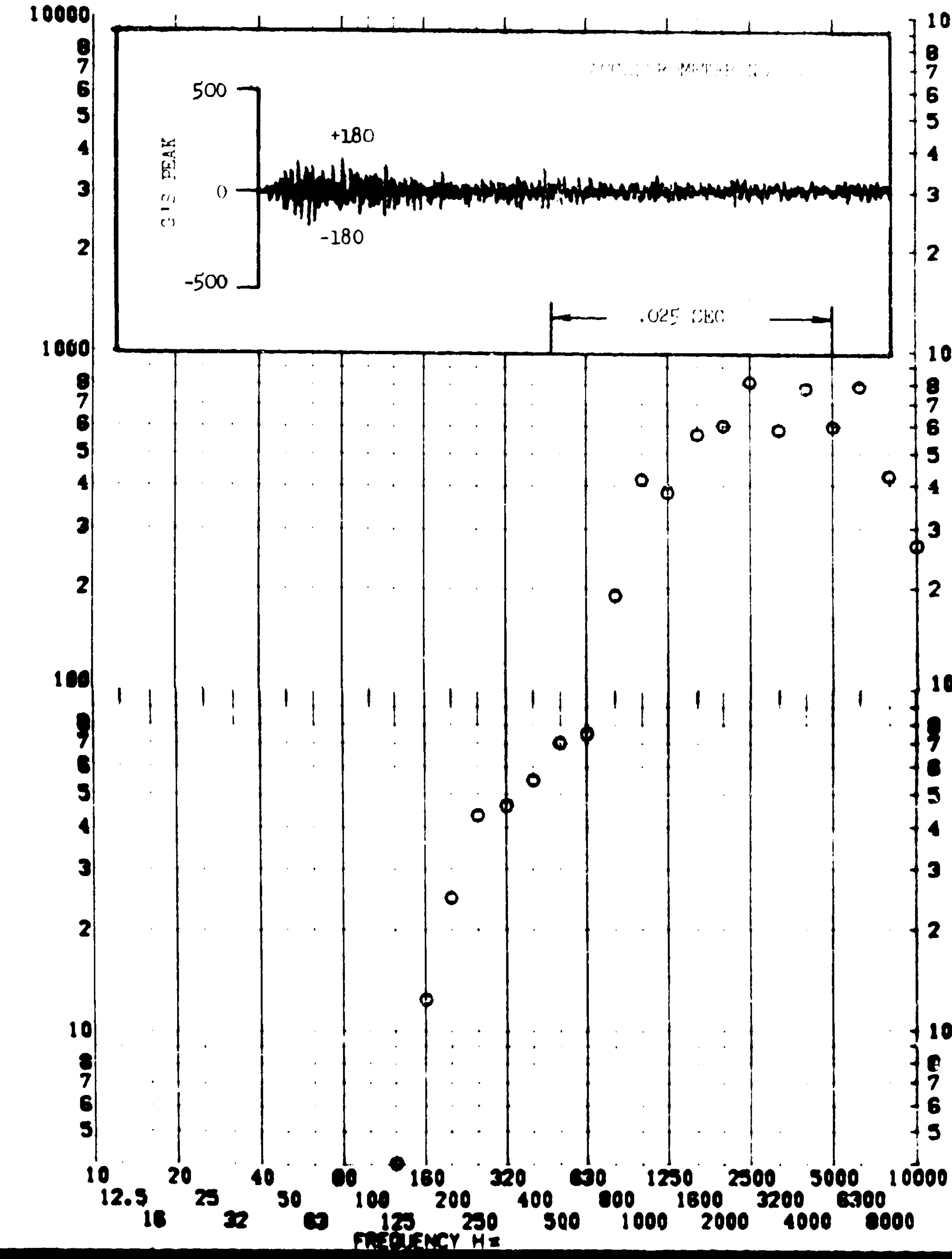

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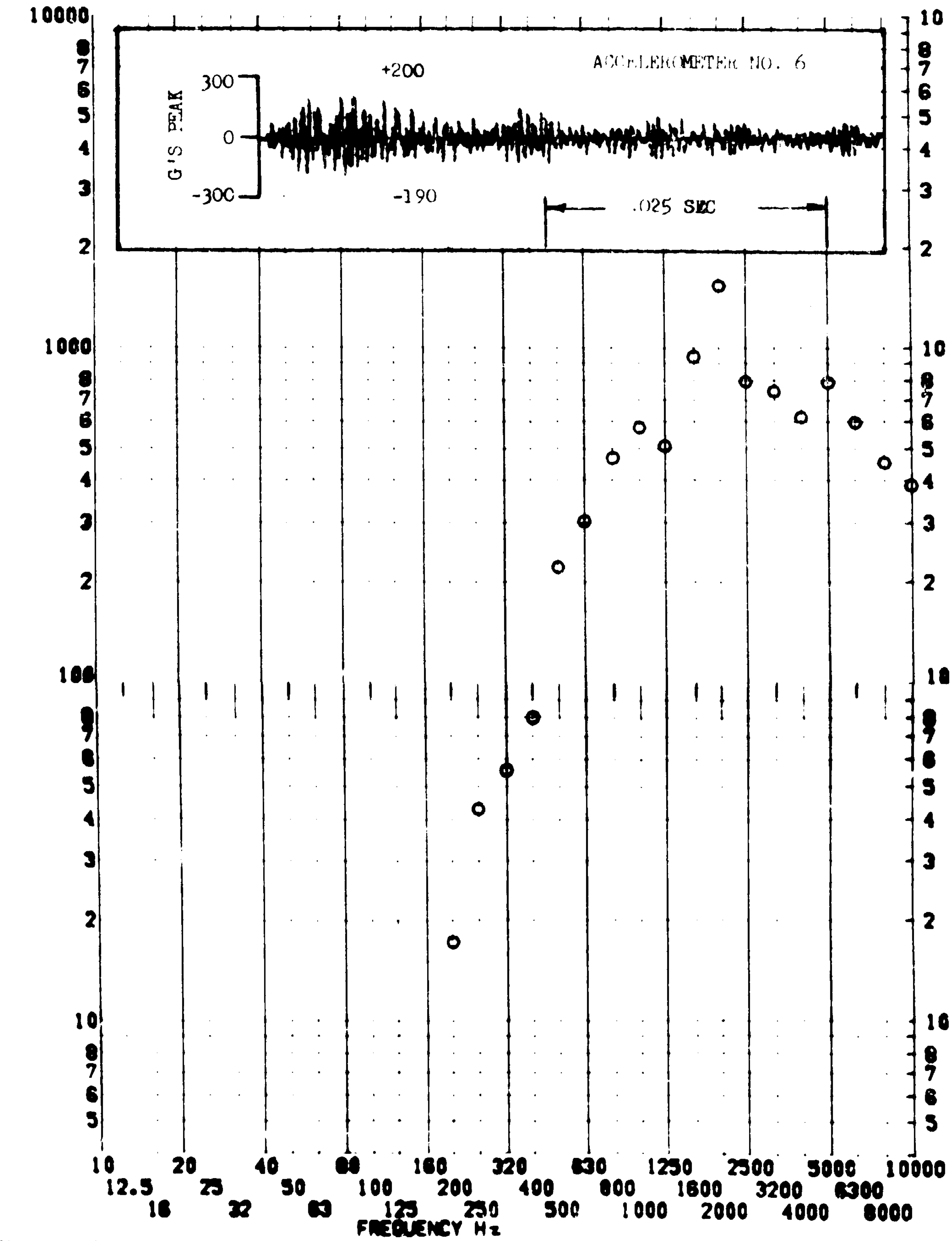
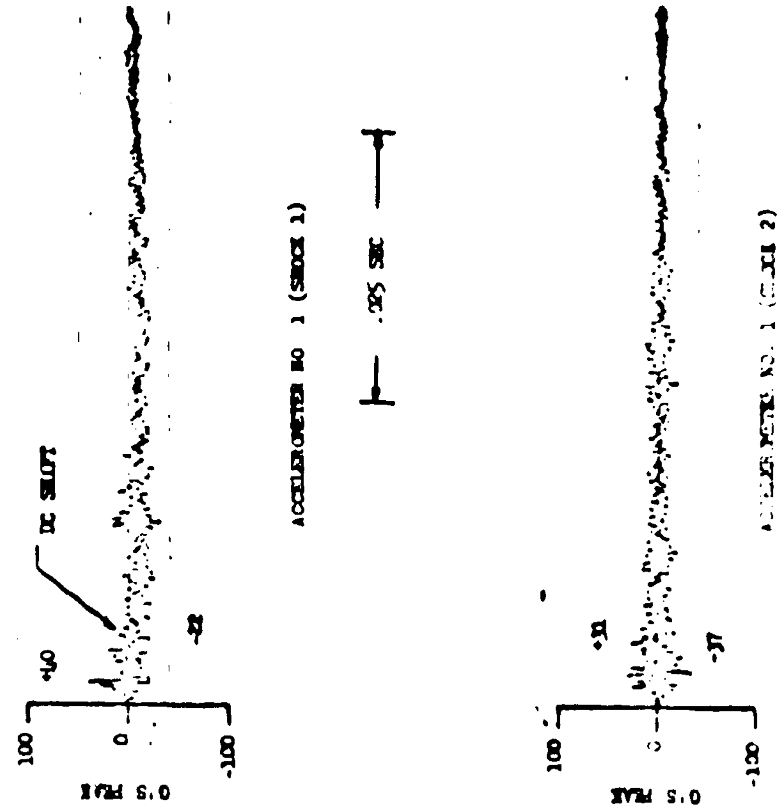
PART NO. EQUIPMENT BASE
TEST DATE 2? NOV 1968
SHOCK NO.

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+31
-37
ACCELEROMETER NO. 1 (SHOCK 2)
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-100
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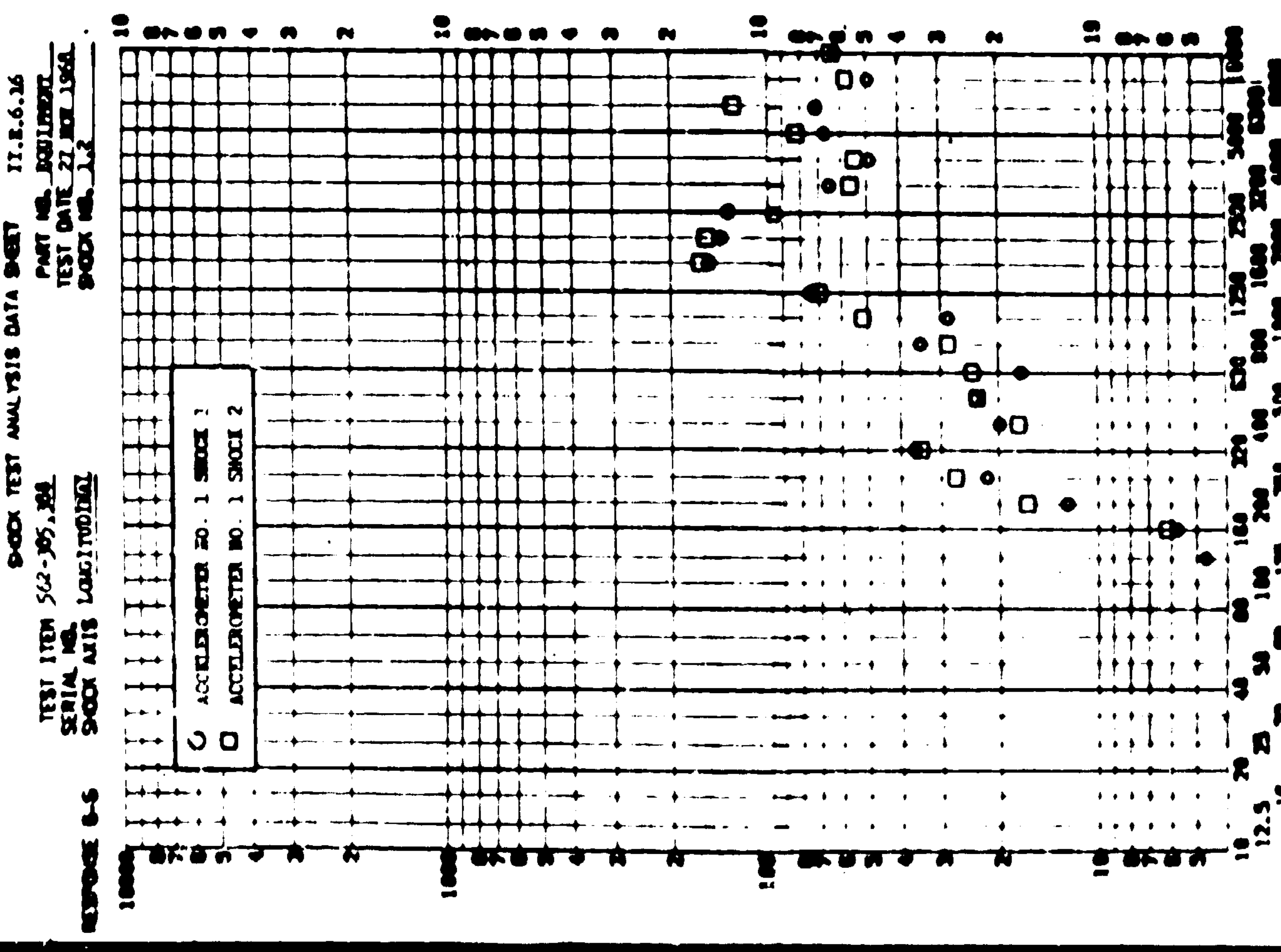
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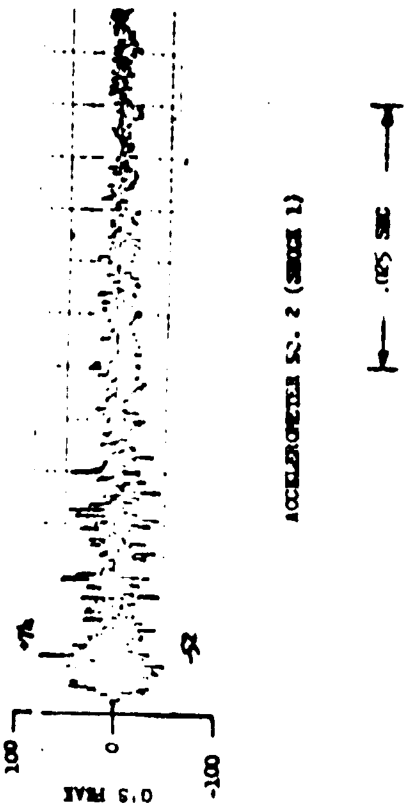
SHOCK AXIS LONGITUDINAL
PART NO. EQUIPMENT
TEST DATE 22 NOV 1968
SHOCK NO. 1,2
RESPONSE G-S
ACCELEROMETER NO. 1 SHOCK 1
ACCELEROMETER NO. 1 SHOCK 2
FREQUENCY HZ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G'S PEAK
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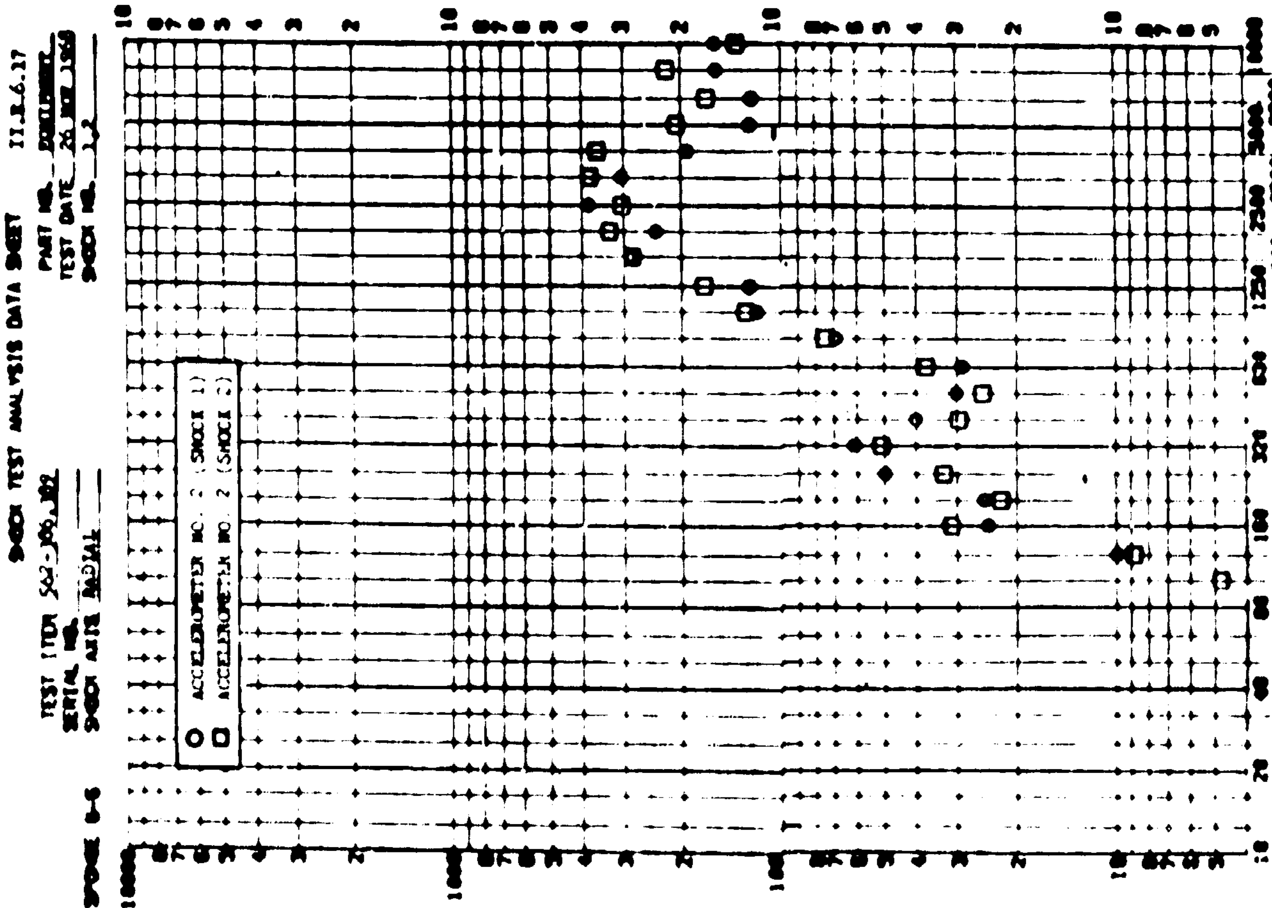
0
-100
G'S PEAK
ACCELEROMETER NO. 2 (SHOCK 2)
.025 SEC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II.B.6.17
TEST ITEM 562-106,102
SERIAL NO.
SHOCK AXIS RADIAL
PART NO.
TEST DATE 26 NOV 1968
SHOCK NO. 1,2
ACCELEROMETER NO. 2 (SHOCK 1)
ACCELEROMETER NO. 2 (SHOCK 2)
RESPONSE G-S
FREQUENCY Hz

SHOCK TEST ANALYSIS DATA SHEET II.B.6.18

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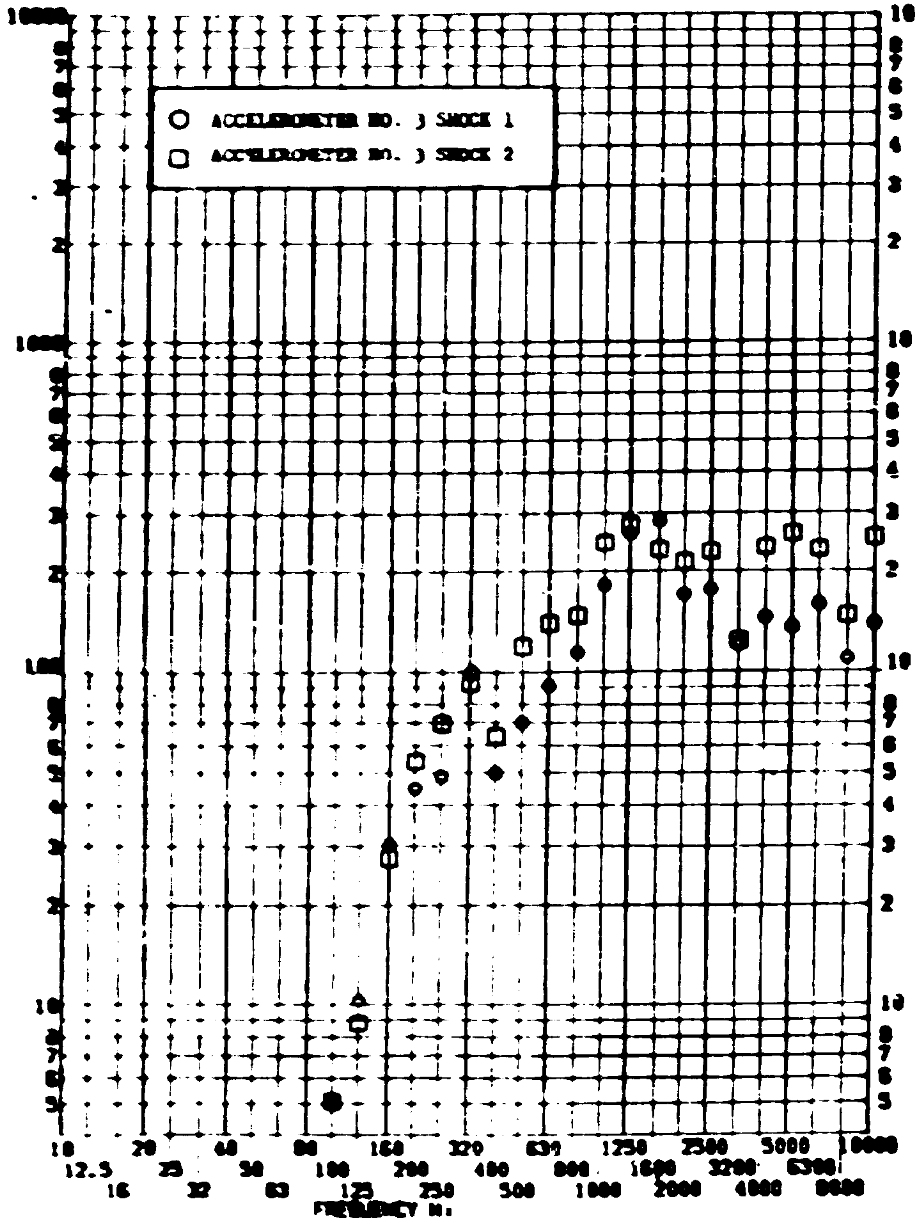
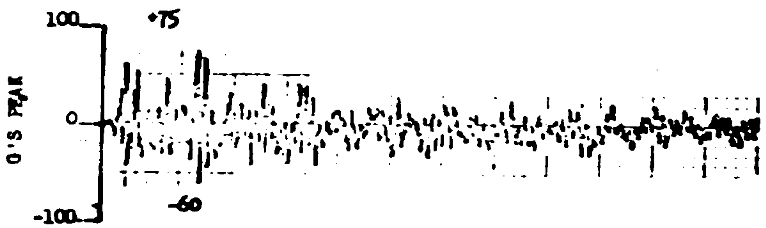
SERIAL NO. TEST DATE 26 NOV 1968
SHOCK AXIS TANGENTIAL SHOCK NO. 1,2





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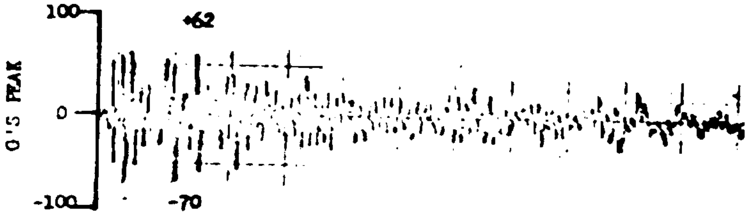

ACCELEROMETER NO. 3 (SHOCK 2)

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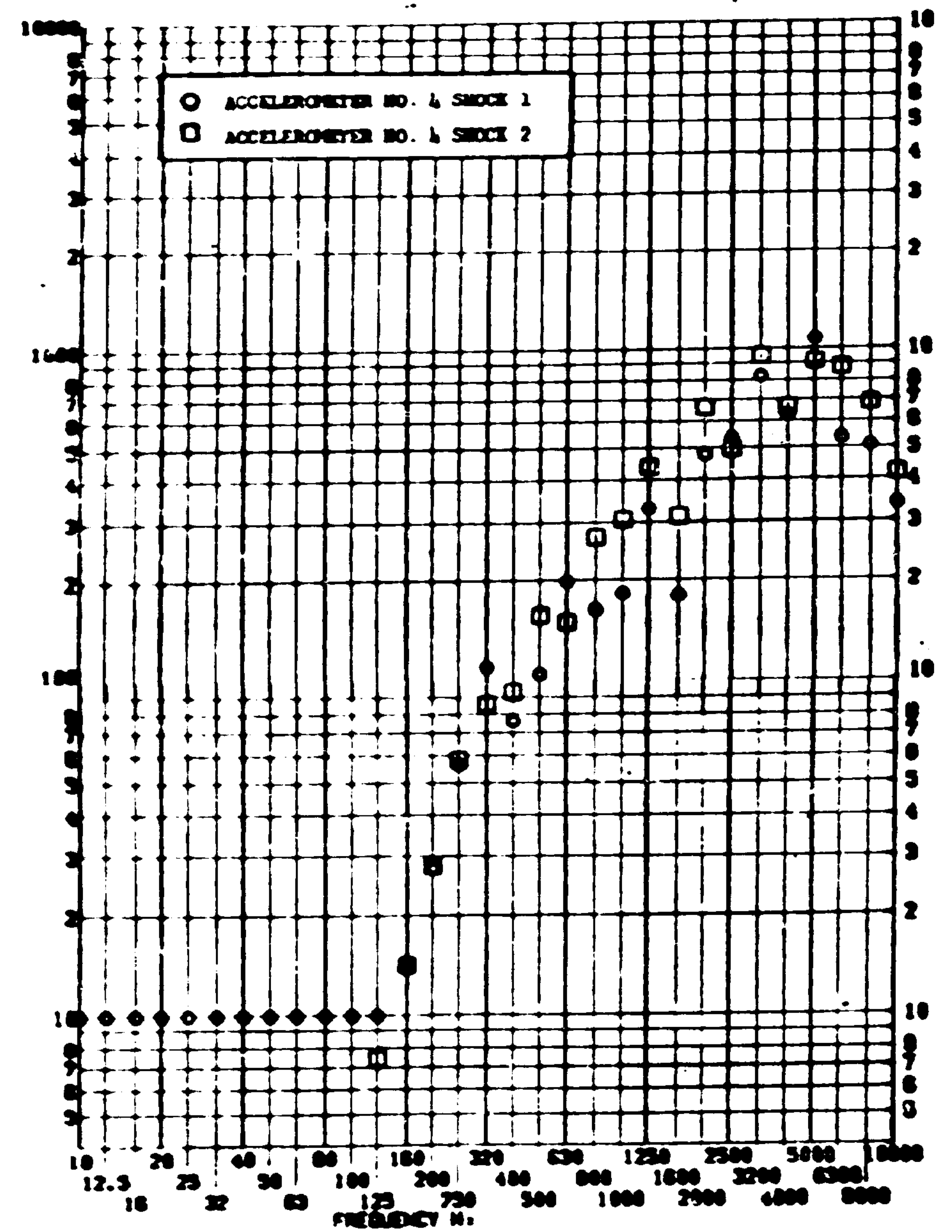
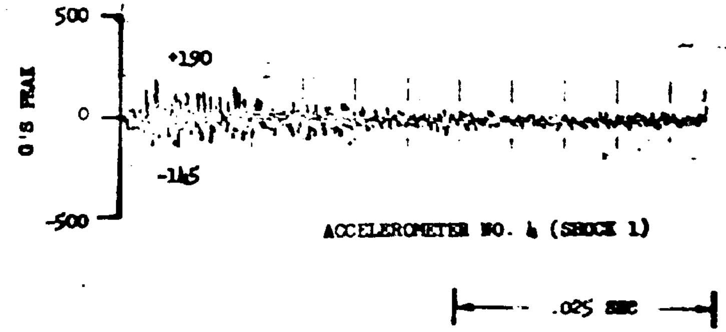
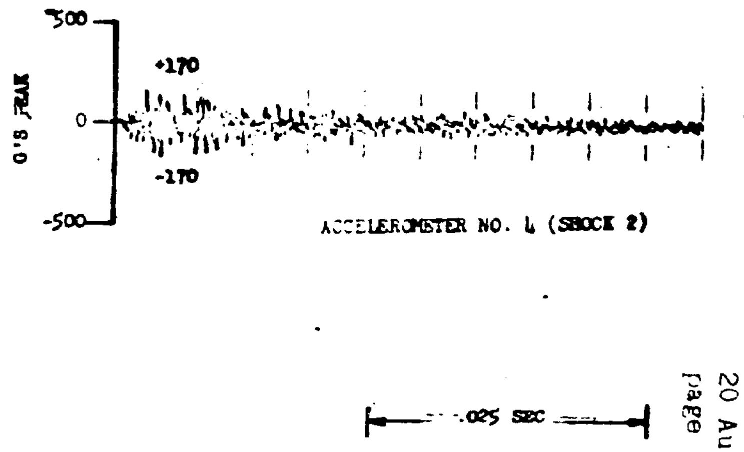
SHOCK TEST ANALYSIS DATA SHEET   II.B.6.19

TEST ITEM 562-391.384   PART NO. EQUIPMENT BASE
SERIAL NO.   TEST DATE 26 NOV 1968
SHOCK AXIS LONGITUDINAL   SHOCK NO. 1,2







SHOCK TEST ANALYSIS DATA SHEET II.E.6.20

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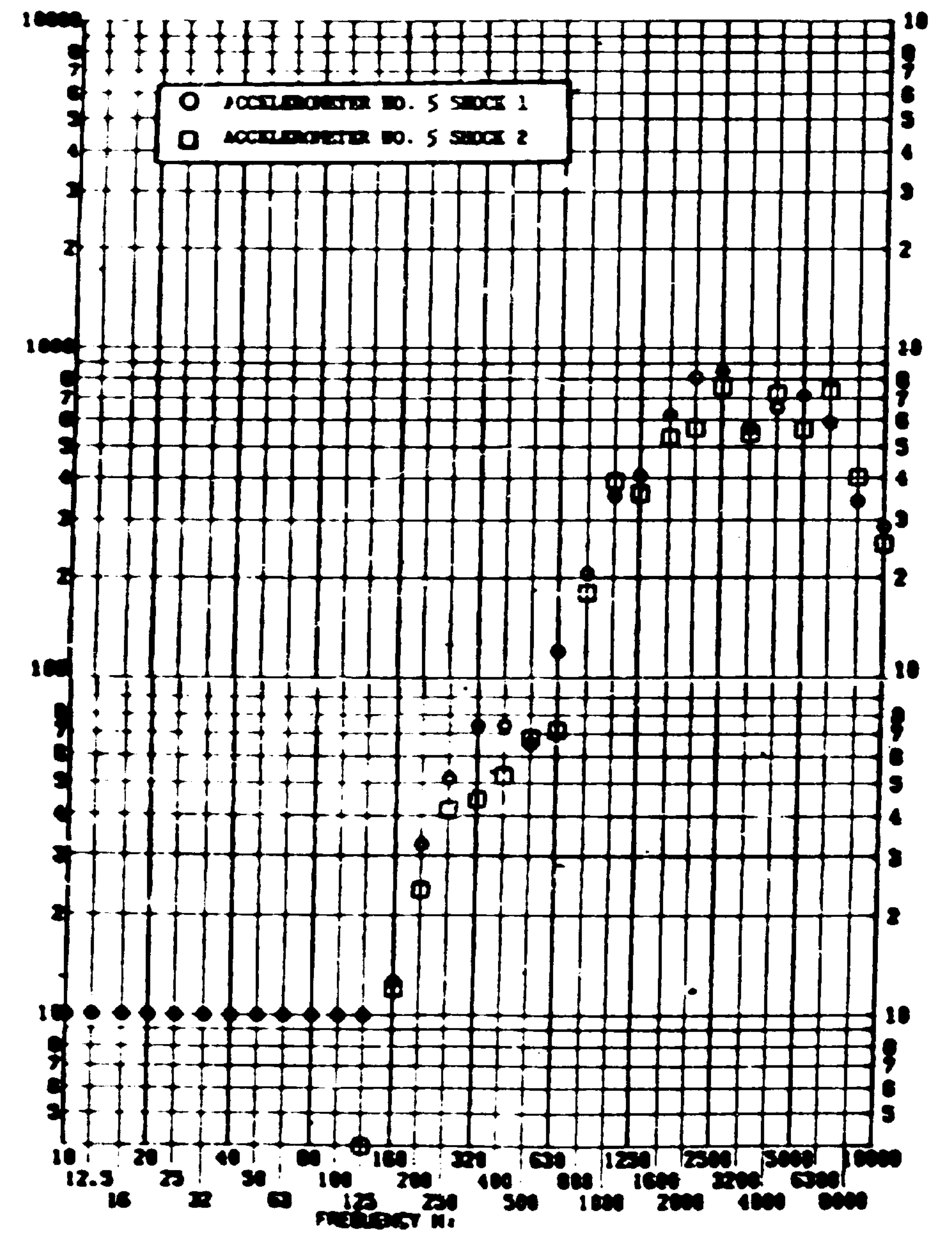
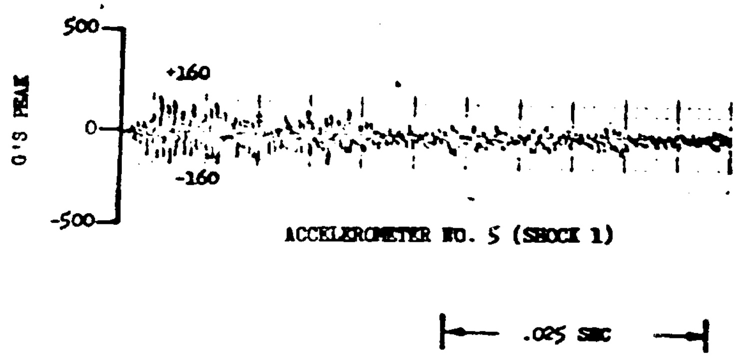
PART NO. EQUIPMENT
TEST DATE 27 NOV 1968
SHOCK NO. 1,2

RESPONSE G-S





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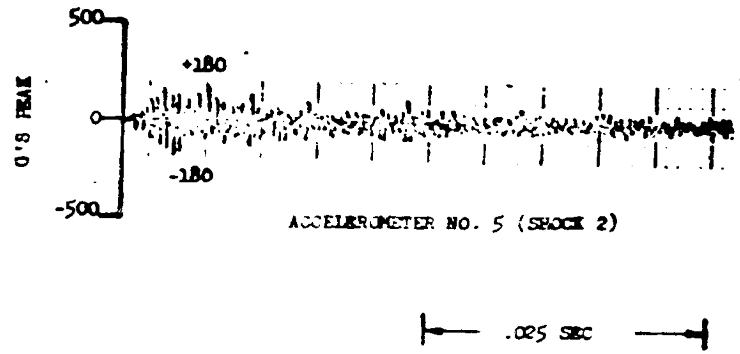
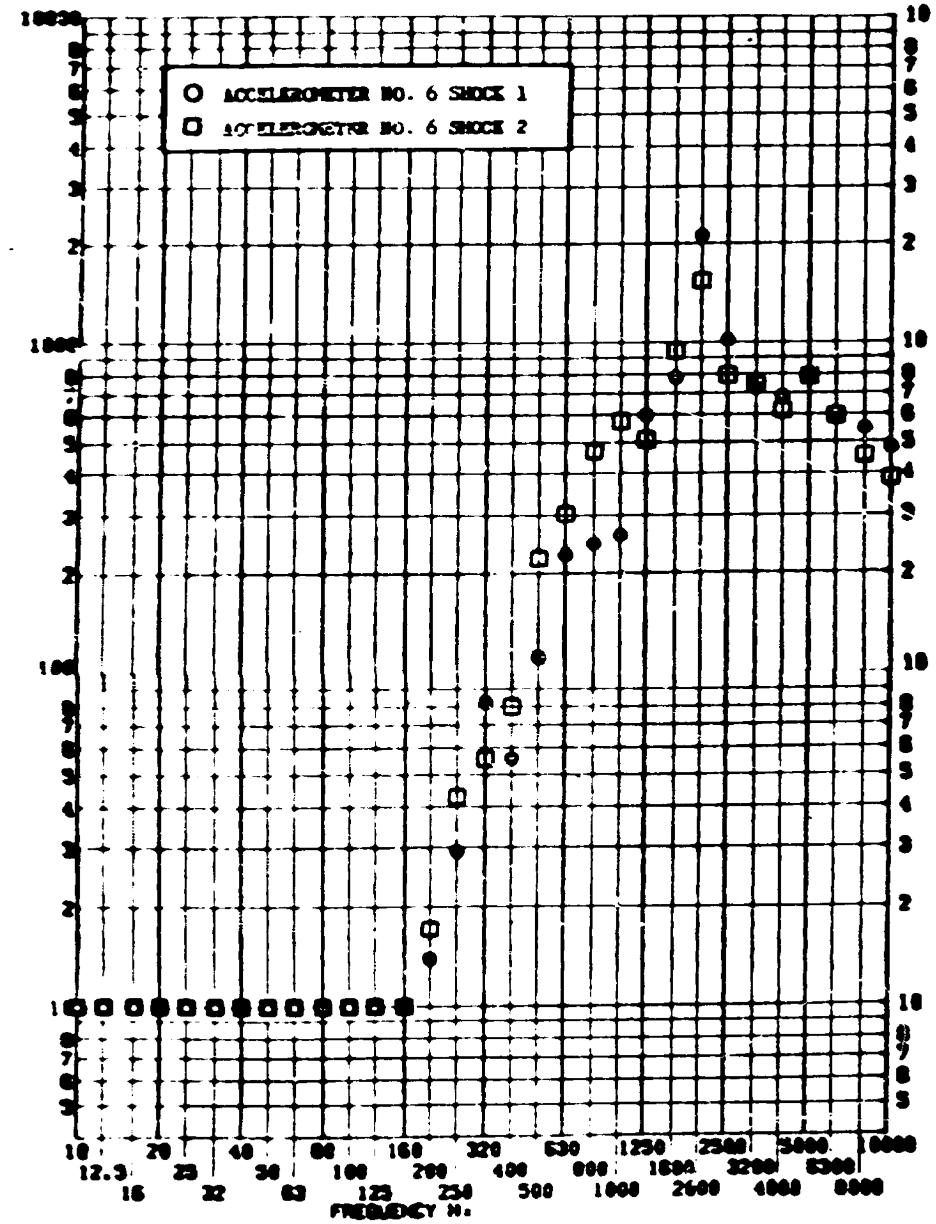


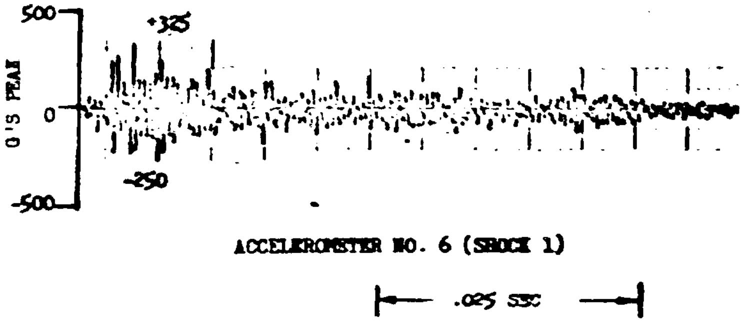
ACCELEROMETER NO. 5 (SHOCK 2)

SHOCK TEST ANALYSIS DATA SHEET II.B.6.21

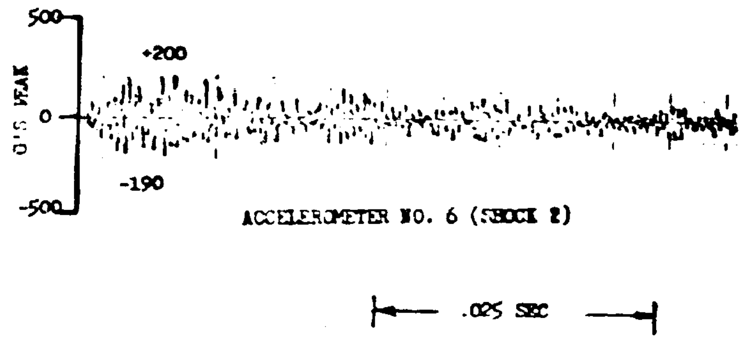
TEST ITEM 562-387,380 PART NO. EQUIPMENT
SERIAL NO. TEST DATE 27 NOV 1968
SHOCK AXIS TANGENTIAL SHOCK NO. 1,2

RESPONSE G-S





ACCELEROMETER NO. 6 (SHOCK 1)



ACCELEROMETER NO. 6 (SHOCK 2)

II.E.7 DISCUSSION

The sets of six series of test presented in this section give a good survey of the barrel tester practical usage.

Although there is little basis of comparison among these test, the excellent repeatability, from shock to shock, of the environments must be noted. This repeatability is such that the environmental data remained within normal scatter range in all tests reported here. Thus, once a specified environment has been set up using simulated hardware, the actual equipment can be tested with complete confidence that it will be subjected to the appropriate shock levels.

II.E.8 CONCLUSION

The Pyrotechnic Barrel Tester has proven to be a reliable and versatile instrument for the development and qualification testing of spacecraft equipment and structural components. The excellent repeatability of its shock environment is of considerable importance in the establishment of specified environment levels.

SECTION NO. II.F

REPORT NOS. 831, 832

SUBJECT:

DEVELOPMENT OF PYRO SHOCK TEST FACILITIES

SECTION II.F

SUMMARY

Report No. 832 documents a series of tests which were conducted to determine the feasibility of simulating pyro shock to qualify equipment by means of a commercially available drop tester and an LMSC developed transfer table. Although the Transfer Table produced more satisfactory results than other mechanical testers because it was able to produce complex vibrations without excessive low frequency amplitude, it had a number of disadvantages which made it undesirable for use as a pyro shock qualification test facility. Chief among these were: the inability to produce a sufficient overtest, the limitation of the size of the specimen which could be tested, the influence of the Transfer Table mode shape on the shock response spectrum, and unknown factors in the actual pyro shock event which made it undesirable to simulate pyro shock by artificial means. On this basis, the Transfer Table was not given further consideration as a pyro shock qualification test facility.

Report No. 831 presents the results of a program to develop the barrel test facility to qualify equipment for pyrotechnic shock. The Barrel Tester is of basically the same construction as the vehicle with a shock generating joint at one end which simulates the vehicle booster separation joint. A total of 32 tests were conducted to develop the Barrel Tester in which the shock amplitude was controlled with various explosive sizes and separation joint thicknesses and the shock spectrum shape was obtained by changing the joint configuration.

The barrel was able to produce a shock environment very similar to that produced by the actual vehicle booster separation joint. A sufficient overtest was achieved to establish the Barrel Tester as a qualification test facility. The Barrel Tester has the capability of qualifying vehicle equipment with almost no size limitation. Since the barrel simulates the vehicle, the mode shapes associated with the barrel create the desired response at the equipment. Barrel test repeatability was found to be satisfactory for equipment qualification. A statistical analysis performed on 22 of the latest barrel shocks indicated that the shocks were repeatable to within a factor of 1.? at Bay ? and to within a factor of 1.55 at Bay II based on the 25th and 75th percentile values of a statistical analysis of the tests.

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SECTION II.F

SECTION NO. II.F.1

REPORT NO. 832

SUBJECT:

TRANSFER TABLE SHOCK TESTING MACHINE

SECTION II.F.1

SUMMARY

Experiments were carried out with a modified commercially available tester which simulates pyrotechnic shocks by means of a mass which drops from specified heights onto a Transfer Table. This device produces complex vibrations without excessive low frequency amplitude and thereby lessens the risks of damage to equipment.

Although some specified flight environments could be reasonably simulated, the device suffers from several limitations as follows:

1. Although the Transfer Table could reproduce some parts of the flight environment, it was unable to produce adequate overtests because the degree of control over the amplitude of the shock environment is limited.
2. The size of the test specimen is restricted to the volume of a 10 inch cube. This limits the testing to small components, excluding structures.
3. The excitation to which the specimen is subjected is dependent on the mode shapes of the Transfer Table which may tend to obliterate the desired response.
4. The differences between the shock effects produced by a drop table and that produced by a pyrotechnic device as unknown. The validity of the simulation is therefore questionable.

This meth d of testing has been superseded by testers using pyrotechnic shock devices.

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SECTION II.F.1

SHOCK SPECTRA AND OSCILLOGRAMS

II.F.1.1 INTRODUCTION

Simulation of pyrotechnic shock by purely mechanical means appears to be an attractive proposition since it would eliminate handling of dangerous explosives and also utilize standard available equipment. A commercially available shock tester was modified by adding a transfer table setup in order to reduce the low frequency overtest which normally results from the drop mass velocity change. A series of development tests was carried out with this device which is shown in Figure II.F.1.1. The transfer table was designed to absorb the low frequency shock and provide a reasonable duplication of the flight pyrotechnic shock spectrum.

II.F.1.2 DISCUSSION AND ANALYSIS

II.F.1.2.1 Test Configuration and Instrumentation

The standard commercial drop tester was modified by the installation of a transfer table as shown on Figure II.F.1.1. The Transfer Table consists essentially of a heavy aluminum plate mounted on solid supports bolted onto the drop tester seismic mass. Intermediate supports (T fixtures) are added between the table and the seismic mass to further modify the shock response by reducing cross-couplings. The specimen to be tested is attached to these fixtures.

Instrumentation consists of a set of three accelerometers reading X, Y and Z axis accelerations. (Table II.F.1.1). They are placed on the T fixture near the specimen interface.

For all tests, the shock duration programmer of the drop tester was set for a .12 millisecond shock. For each configuration, several shocks were performed in order to check the installation; the last shock accelerometer data was recorded on magnetic tape. Data reduction was performed on the UNIVAC 1108 after digitizing the tape. Shock spectra and oscillograms are shown in Figure II.F.1.2 to II.F.1.5 for various combinations of fixtures, drop heights and specimen weights.

II.F.1.2.2 Technical Discussion

By careful design of the transfer table modal frequencies, it was found possible to reproduce in a satisfactory manner the shape of a pyrotechnic shock spectrum curve. The data under consideration was obtained from a test of Transfer Table No. 4 - Figure II.F.1.1. Shock spectra and oscillograms are shown on Figure II.F.1.2 to II.F.1.5. (Table II.F.1.2)

Figure II.F.1.2 presents the results of a test carried out with a 5.5 pound specimen, a drop height of 8 inches and a T fixture installed.

Figure II.F.1.3 presents data similar to that of Figure II.F.1.2 with the T fixture removed.

Figure II.F.1.4 shows the effect of specimen weight and Figure II.F.1.5 the effect of drop height.

II.F.1.2.3 Analysis

From an examination of Figure II.F.1.2 and II.F.1.3, it can be seen that the shock response is strongly directional. The vertical X axis response is signficantly higher than that of the two other axes.

On Figure II.F.1.4, the effect of varying specimen weight shows relatively small effect on the response levels. It will be noted also that the shock level increases with the mass of the specimen. This is in contradiction with what was expected since for a fixed force level, a higher mass would correspond to a lower acceleration.

Figure II.F.1.5 shows that the drop height has little effect on the response of the system. For drop heights varying by a factor of 2:1, the shock levels remain virtually within the expected normal data scatter.

II.F.1.3 CONCLUSION

The transfer table method of simulating pyrotechnic shock appears to be so limited in scope that it is not acceptable for acceptance and qualification testing of components. Although it may be useful for diagnostic and comparative testing, it is not suitable as substitute to purely pyrotechnic testing for the following reasons:

1. The shape of the response curve is dependent on the geometry of the Transfer Table. Modifications, therefore, would require redesign of table and fixtures.

2. The maximum shock level attainable was unable to provide for over-test requirements.

3. The size and weight of specimen is very limited.

4. The mode shapes of the Transfer Table assembly have considerable influence on the test results.

5. Significant differences may exist between the effects of the shock transients produced by a drop table as compared to that of a pyrotechnic shock. The validity of the simulation is therefore questionable.

The Transfer Table Shock Tester cannot seriously be considered for the simulation of pyrotechnic shocks.

TABLE II.F.1.1

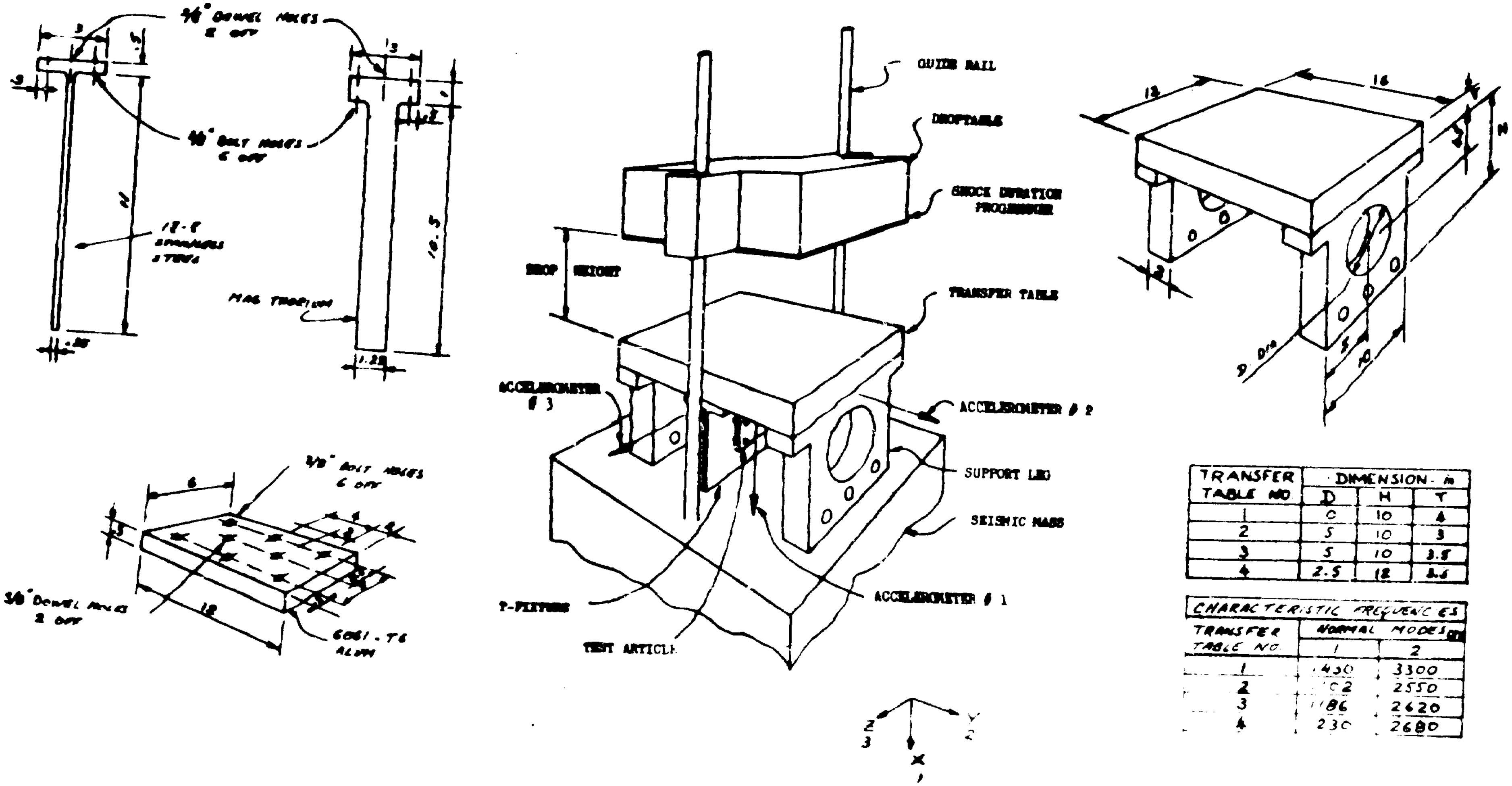
ACCELEROMETERS AND LOCATIONS

Accelerometer Number	Direction	Accelerometer Type
1	X	Endevco 2225
2	Y	Endevco 2225
3	Z	Endevco 2225

TABLE II.F.1.2

SUMMARY OF TESTS

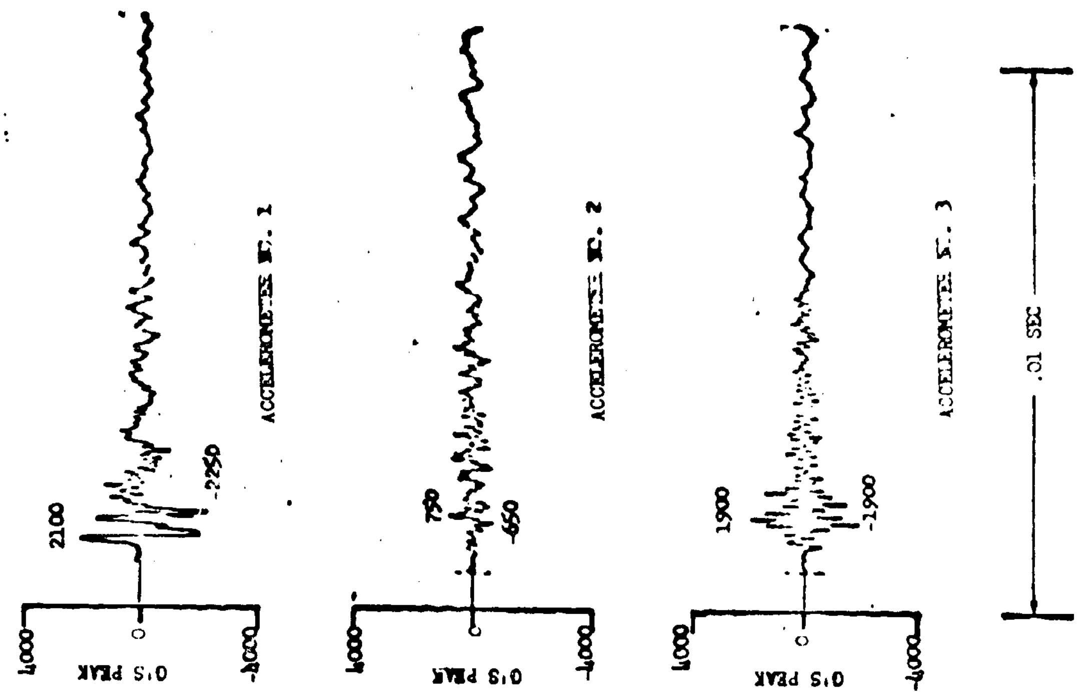
Test Number	Specimen Weight LB	Drop Height IN	Accelerometer 1 X	Accelerometer 2 Y	Accelerometer 3 Z	Fixture
1	5.5	8	*	*	*	T
2	5.5	8	*	*	*	Flat Plate
3	0	8	*			T
4	5.5	8	*			T
5	11	8	*			T
6	5.5	6	*			T
7	5.5	8	*			T
8	5.5	12	*			T

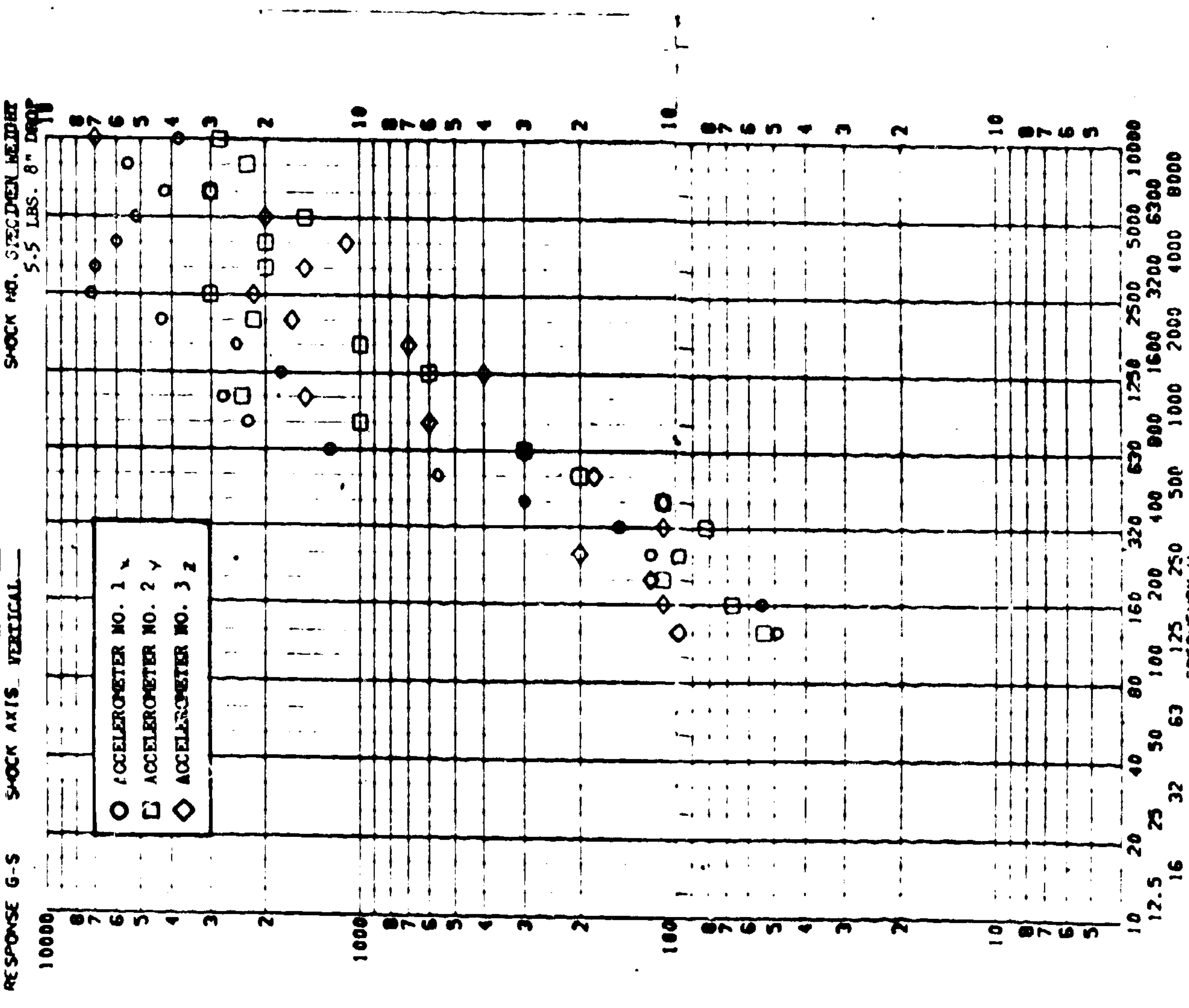


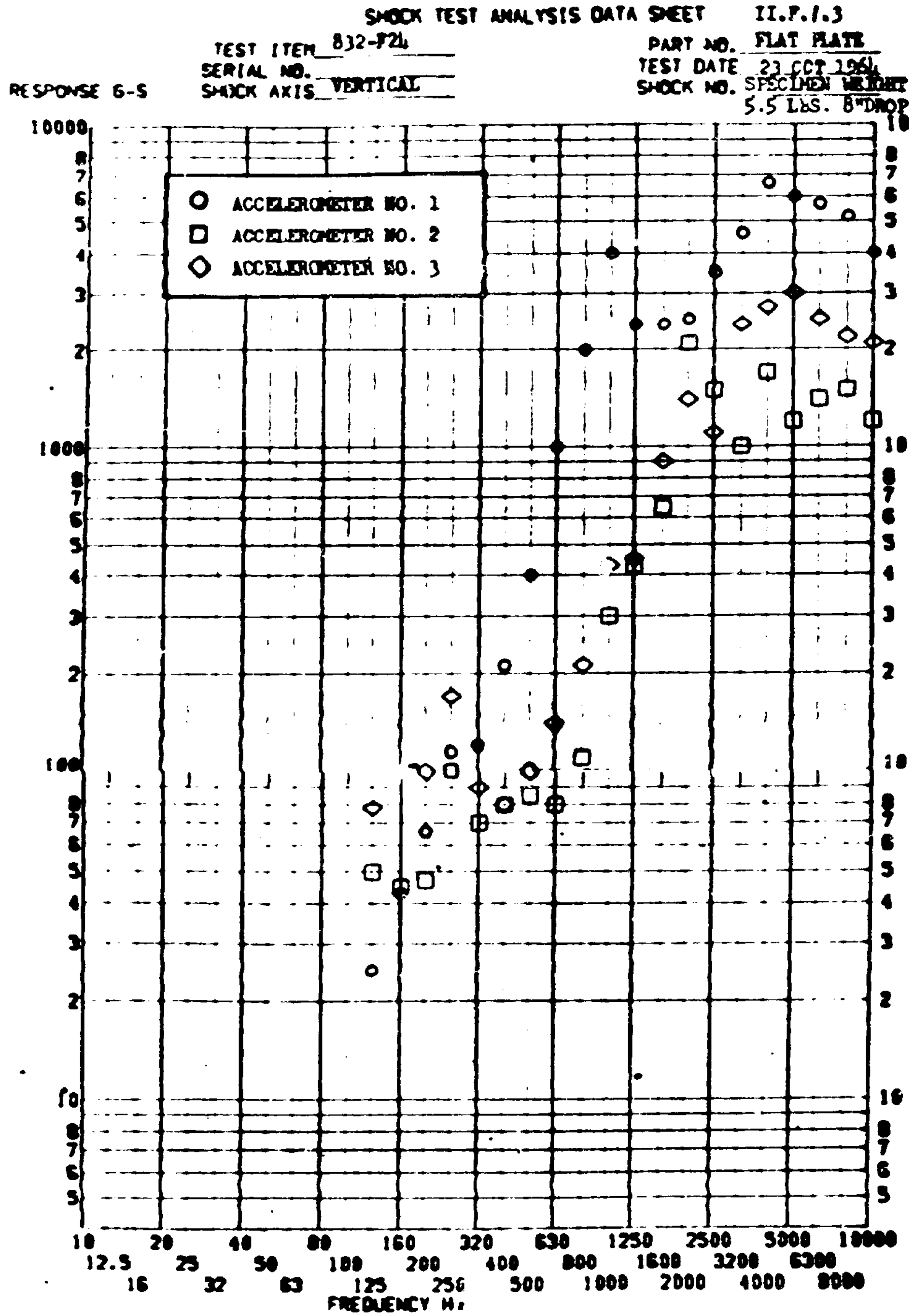
TRANSFER TABLE NO	DIMENSION - in D	H	T
1	0	10	4
2	5	10	3
3	5	10	3.5
4	2.5	12	3.5

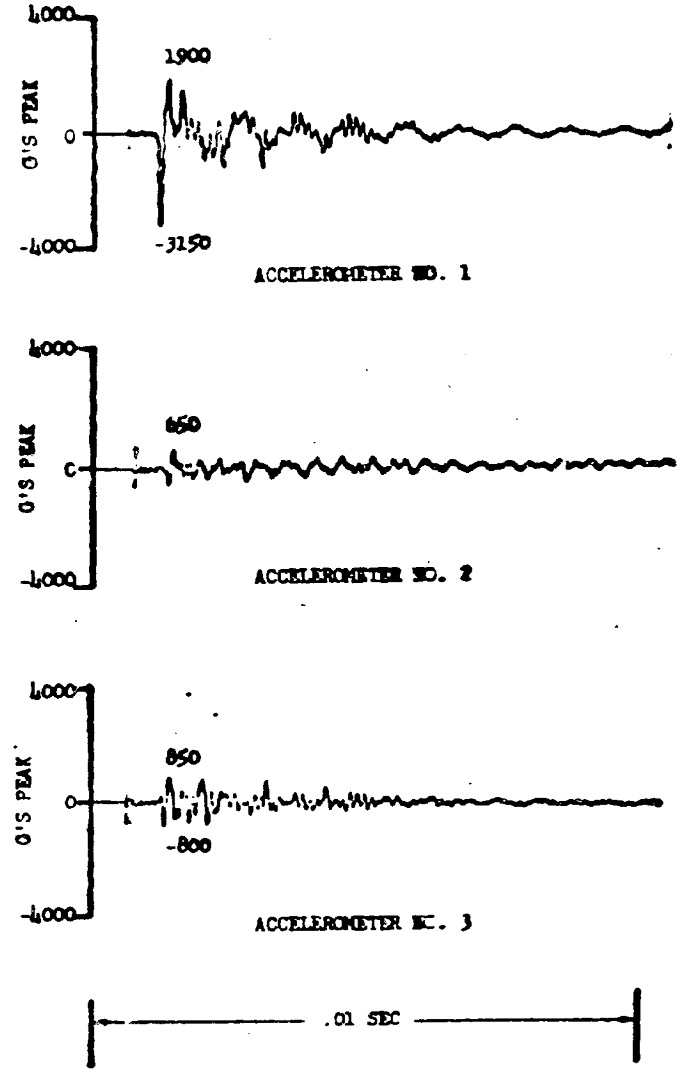
CHARACTERISTIC FREQUENCIES		
TRANSFER TABLE NO.	NORMAL MODES 1	2
1	1430	3300
2	[illegible]	2550
3	1186	2620
4	230	2680

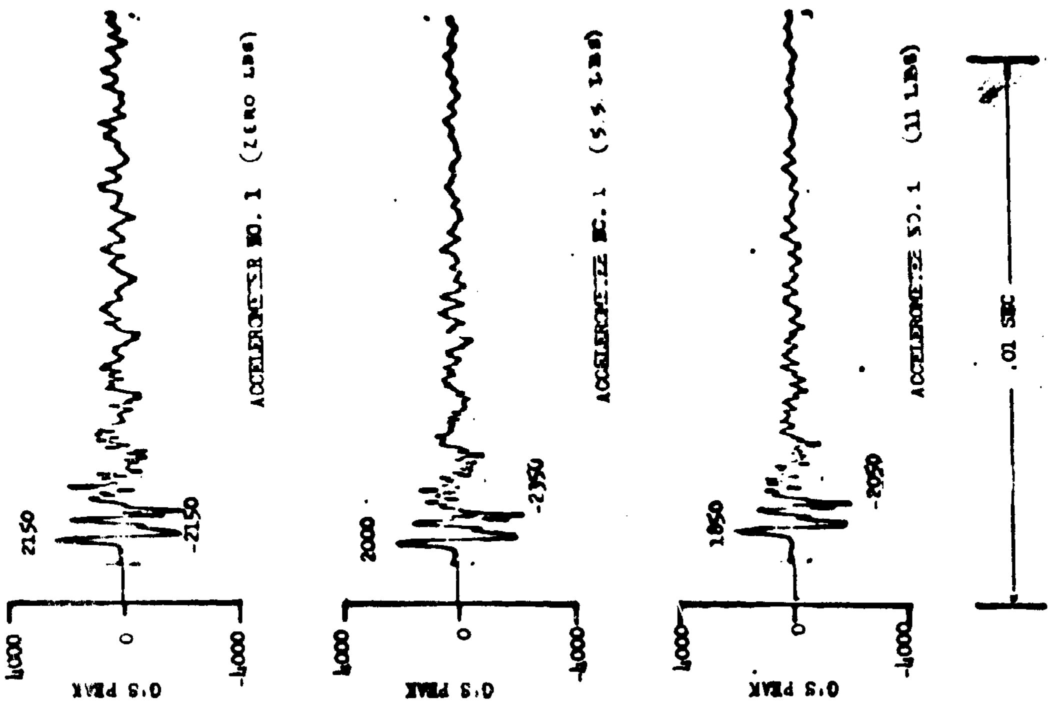
Figure .1.1 TRANSFER TABLE SHOCK TESTER - GENERAL ARRANGEMENT

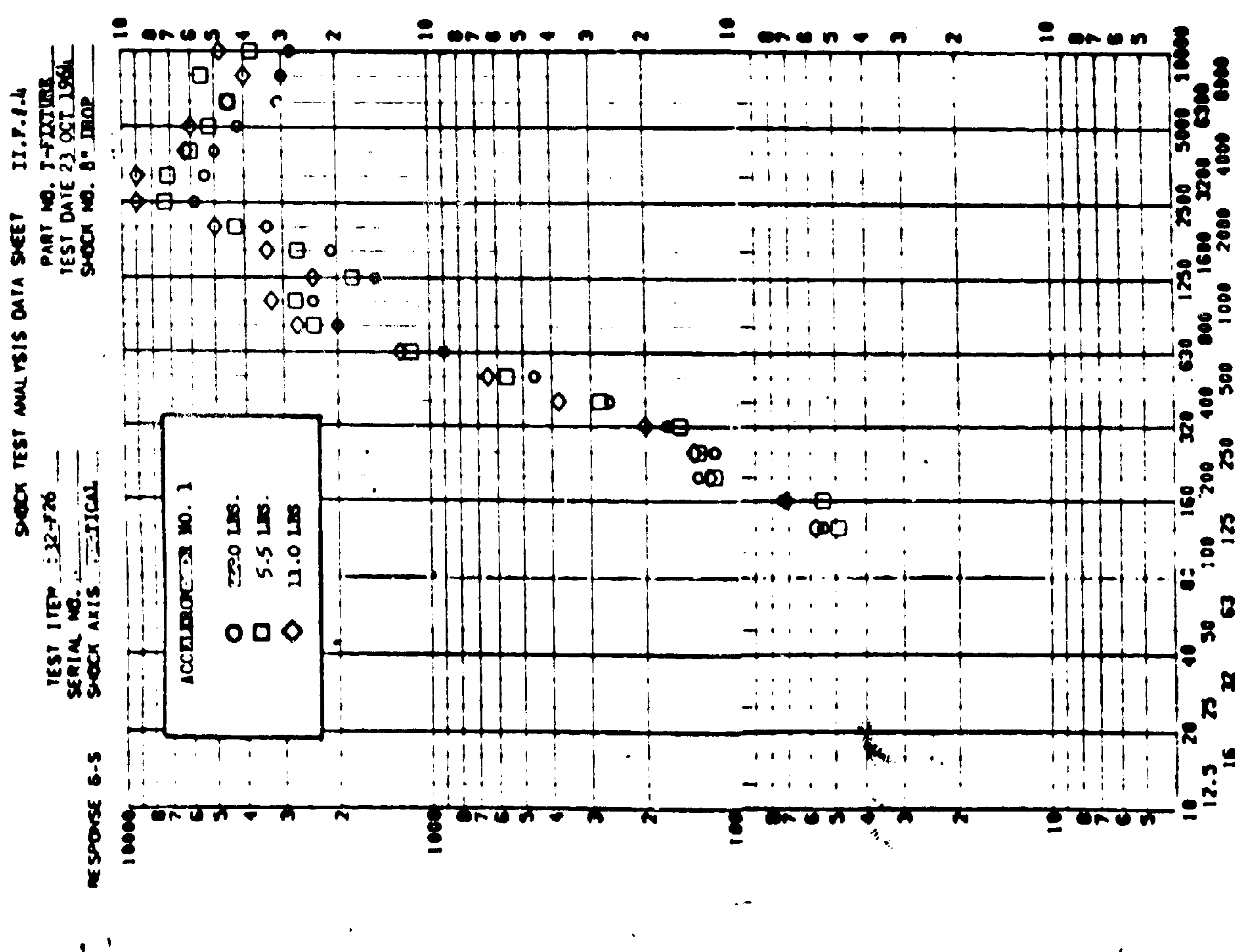

ACCELEROMETER NO. 1
ACCELEROMETER NO. 2
ACCELEROMETER NO. 3
2100
-2250
750
-650
1900
-1900
4000
0
-4000
O.S PEAK
.01 SEC

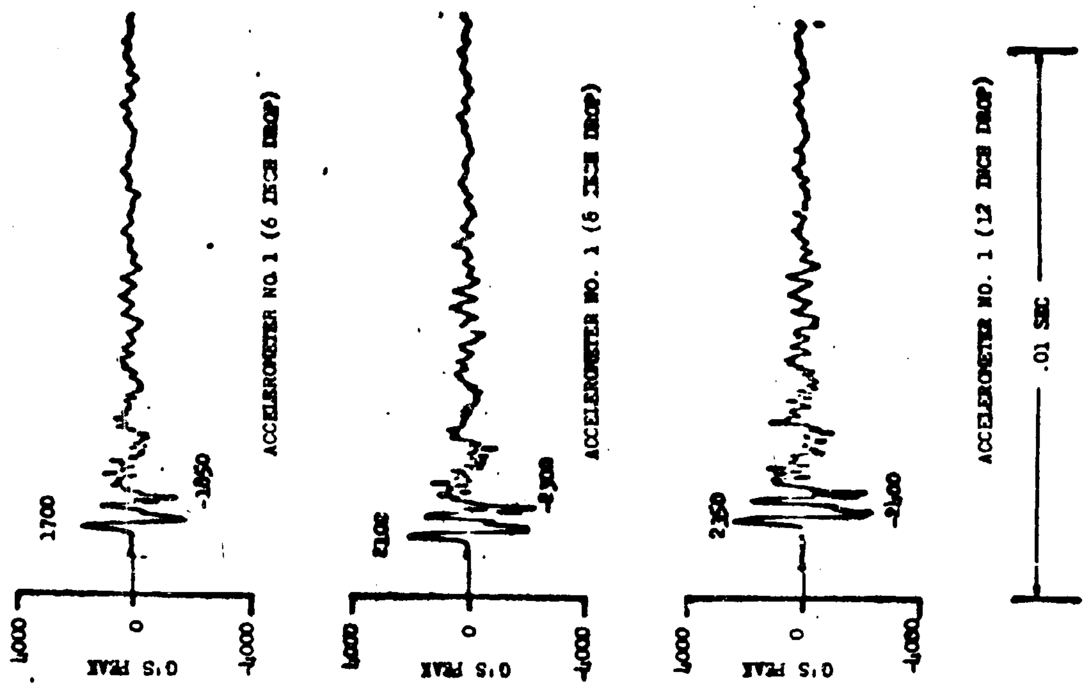

SHOCK TEST ANALYSIS DATA SHEET
TEST ITEM 832-F17
SERIAL NO.
SHOCK AXIS VERTICAL
PART NO. II.F.1.2 T-FIXTURE
TEST DATE 23 OCT 1964
SHOCK NO. SPECIMEN WEIGHT 5.5 LBS. 8" DROP
RESPONSE G-S
FREQUENCY Hz
ACCELEROMETER NO. 1 x
ACCELEROMETER NO. 2 y
ACCELEROMETER NO. 3 z

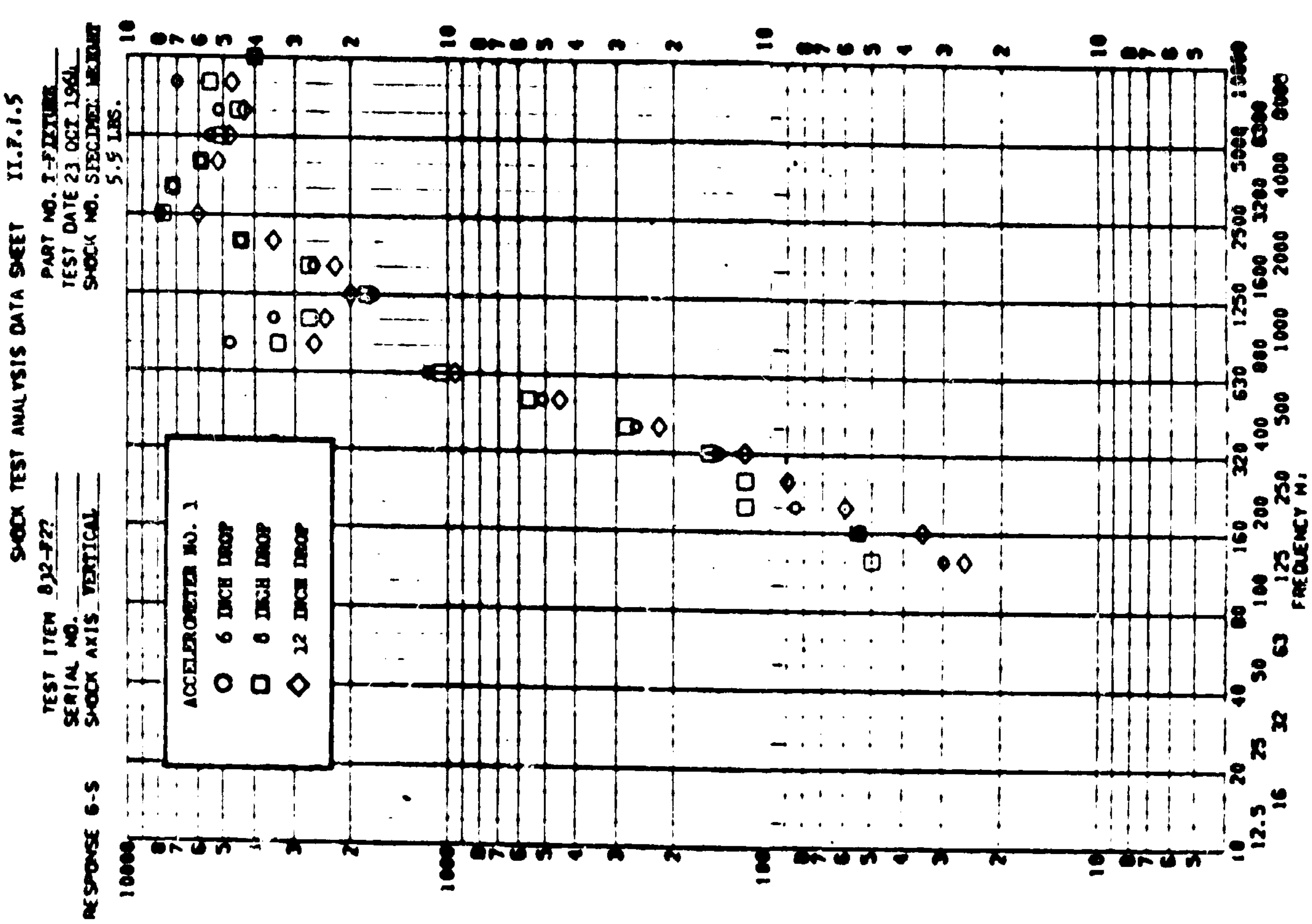

SHOCK TEST ANALYSIS DATA SHEET
II.F.4.3
TEST ITEM 832-F24
SERIAL NO.
SHOCK AXIS VERTICAL
PART NO. FLAT PLATE
TEST DATE 23 OCT 1964
SHOCK NO. SPECIMEN WEIGHT 5.5 LBS. 8"DROP
RESPONSE G-S
ACCELEROMETER NO. 1
ACCELEROMETER NO. 2
ACCELEROMETER NO. 3
FREQUENCY Hz


G'S PEAK
1900
-3150
ACCELEROMETER NO. 1
850
ACCELEROMETER NO. 2
850
-800
ACCELEROMETER NO. 3
.01 SEC


ACCELEROMETER NO. 1 (ZERO LBS)
ACCELEROMETER NO. 1 (5.5 LBS)
ACCELEROMETER NO. 1 (11 LBS)
.01 SEC
2150
-2150
2000
-2350
1850
-2050
G'S PEAK
4000
0
-4000


SHOCK TEST ANALYSIS DATA SHEET
II.F.4.4
TEST ITEM 32-F26
SERIAL NO.
SHOCK AXIS VERTICAL
PART NO. T-FIXTURE
TEST DATE 23 OCT 1964
SHOCK NO. 8" DROP
RESPONSE G-S
ACCELEROMETER NO. 1
ZERO LBS.
5.5 LBS.
11.0 LBS
FREQUENCY Hz


ACCELEROMETER NO 1 (6 INCH DROP)
1700
-1850
ACCELEROMETER NO. 1 (8 INCH DROP)
2100
-2300
ACCELEROMETER NO. 1 (12 INCH DROP)
2350
-2400
G'S PEAK
4000
0
-4000
.01 SEC


SHOCK TEST ANALYSIS DATA SHEET II.F.1.5
TEST ITEM 832-P27
SERIAL NO.
SHOCK AXIS VERTICAL
PART NO. F-FIXTURE
TEST DATE 23 OCT 1964
SHOCK NO. SPECIMEN WEIGHT 5.5 LBS.
ACCELEROMETER NO. 1
6 INCH DROP
8 INCH DROP
12 INCH DROP
RESPONSE G-S
FREQUENCY Hz

SECTION NO. II.F.2

REPORT NO. 831

SUBJECT:

BARREL TESTER DEVELOPMENT

SECTION II.F.2

SUMMARY

This report presents the results of a development program which was performed to produce a test facility which would be capable of qualifying equipment for pyrotechnic shock environments.

The test facility, or Barrel Tester, which resulted from the investigation is a barrel type structure five feet in diameter and five feet in length. Located at one end of the barrel is the shock generating joint which contains an explosive and a metallic separation plate. Detonation of the explosive fractures the metallic plate and the combined fracture and explosive detonation produces the desired pyrotechnic shock environment.

A total of 32 tests were conducted to develop the Barrel Tester with various explosive sizes and separation joint thickness. Control of the environment was accomplished through the proper selection of explosive and separation joint thickness. A 30 grain/foot MDF in combination with a .190 inch thick separation joint provided the needed shock levels for equipment qualification. The test program indicated that the shock spectrum shape, once established by the geometry of the separation joint and barrel structure, cannot be significantly altered without an extensive development program. The shock amplitudes can, however, be easily modified by changing the explosive quantity and separation joint thickness.

The life of the explosive cavity was satisfactory for 20 to 30 shock tests using 30 grain explosives with a .190 inch separation joint. The life of the ring, with the addition of a hardened steel cutting edge is good for over 200 firings.

A statistical analysis which was performed on the most recent 22 barrel tests shows that the test levels are repeatable within a factor of 1.7 for Bay I and a factor of 1.55 for Bay II based on the 25th and 75th percentile deviation. Thus, the objectives originally set forth in the development program were achieved.

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II.F.2.1 INTRODUCTION

Pyro shock devices use explosives which have rapid burning rates and produce high shock input to the vehicle structure. The most practical method to date of dealing with pyro shock is by a test which simulates the actual event. A very realistic test method which has been developed here at LMSC is the Barrel Tester which is used to qualify equipment for all pyro shock events.

The test environment that was to govern the development of the Barrel Tester was obtained from flight vehicles by measurements taken at strategic locations on vehicle structure during the nose fairing, vehicle/booster separation, and horizon sensor fairing jettison events. The transient structure response was then converted to equipment qualification test criteria by use of shock spectrum analysis.

Tentative criteria were then established which could be used to determine equipment qualification for pyro shock. These criteria are outlined in Section IV.3.4.3.

The Barrel Tester duplicates the environment by virtue of similarity to the flight vehicle in diameter, skin thicknesses (although the barrel structure was a compromise between a substantial structure required for a test facility and a structure that approximated the flight vehicle) and excitation mechanism. The similarity of the flexibility between the barrel and the vehicle structure provided for essentially the same path for the pyrotechnic shocks to travel to component packages. The mechanism of excitation is similar to that in the vehicle system in that both use explosives and both fracture a metallic separation joint.

Experience gained with explosives on previous programs had shown that the shock event was very repeatable. The problem was, therefore, to devise a test system that could control the shock amplitude. The development program which this report documents was undertaken to investigate three variables which were known to provide for a limited degree of control over the shock environment. The three variables were:

1. Distance from shock source.
2. Quantity of explosive used (5, 10, 15, 30 grains/foot).
3. Separation joint thickness (0.05, 0.092, 0.125, 0.190 inches).

II.F.2.2 DISCUSSION AND ANALYSIS

II.F.2.2.1 Test Configuration and Instrumentation

Barrel Design

The Barrel Tester is basically an aluminum cylinder five feet in diameter and five feet in length (see Figure II.F.2.1).The substructure consists of eight symmetrically located 3 x 1 x 3/8 inch aluminum channel longerons which terminate at either end of the structure in 3 x 3 x 1/2 inch aluminum angle rings. Equally located between the two angle rings are two additional 3 x 3 x 3/8 inch aluminum T section rings. The angle and T-ring sections then separate the barrel in the longitudinal axis into three symmetrical equipment mounting bays. The barrel substructure is then circumferentially symmetrical in eight quadrants and three bays. By alternately installing 0.090 inch welded and bolted panel sections in the eight symmetrical quadrants, the barrel was divided into four sections containing removable equipment mounting panels. In each equipment bay there are four panels available for equipment qualification test. The entire barrel structure is a continuous weldment with the exception of the twelve bolted panel sections. Since all panels in a particular equipment bay are identical, the environment exposures for panels in that bay are also very similar. The requirement was, therefore, to calibrate the barrel in terms of explosive content and separation joint thickness so that the shock environment at various vehicle locations could be duplicated in a particular equipment bay on the barrel tester.

Shock Generating Joint

The use of an explosive joint as the shock generator was the basic requirement for the Barrel Tester approach. It was also a requirement that the joint structure be useful over a long period without degradation of performance. The two requirements were achieved successfully in the design shown in Figure II.F.2.1.

The joint construction consisted of three parts. The first and most difficult part was the explosive cavity. The explosive cavity was constructed from a 3/8 x 1 1/4 inch strip of 4130 steel that was heat treated to 190,000 psi. A 0.125-inch groove was machined into the steel to retain the explosive cord. The second part of the joint assembly is the separation plate which covers the steel insert and explosive cord. The third part of the shock generating joint is the basic structure which supports the steel insert and the separation plate. The basic joint structure also couples the shock to the barrel structure.

The operation procedure consists of inserting the explosive cord into the joint cavity and securing the separation plate in the basic joint structure with 32 5/16-inch machine bolts. The ignition of a detonator at one end of the explosive cord starts the explosive propagating (at a speed of approximately 20,000 fps) in the separation joint around the circumference of the barrel. The detonation then fractures the separation plate and thereby produces both an acoustic shock wave and a bending wave in the barrel structure.

Barrel Development Test Instrumentation

The response of the barrel structure was then measured with the same type instrumentation as was used during flight tests. A summary of the instrumentation and locations is given in Table II.F.2.2. A sketch of the expanded Barrel Tester is shown in Figure II.F.2.2. The equipment mounting bays and measuring locations are indicated on the sketch.

II.F.2.2.2 Development Tests

Tests 1 through 15

The first fifteen tests of the full ring joint assembly and barrel were performed to evaluate joint configuration B which is illustrated in Figure II.F.2.3. Tests 1 through 6 were conducted with no equipment mounted to the barrel and with a range of explosive sizes of from 5 to 15 grains/foot and a range of skin thicknesses of from .033 to .125 of an inch as illustrated in Table II.F2.1. Tests 7 through 15 were conducted with equipment mounted on the barrel in Bays I and II to determine the effect of the addition of equipment on the shock levels. As for tests 1 through 6, tests 7 through 15 were conducted with a range of explosive sizes and skin thicknesses as illustrated in Table II.F.2.1.

The results of tests 1 through 15 are presented in Table II.F.2.3 and Figure II.F.2.9. These are the peak g readings from the oscillograms. A comparison of the tests of equal grain size and skin thickness with and without equipment indicated very little difference in shock levels. Photographs which were taken of the joint after the 15 tests showed that joint design B had sustained onsiderable damage during the program. In addition to joint back-up structure damage, the bolts which held the clamp ring (Figure II.F.2.3) were severely damaged during the tests.

After reviewing the results of the 15 test series it was evident that the shock environment would have to be increased before the barrel could be used as a test facility. Extrapolation of the joint thickness and grain size corresponding to their respective shock environments indicated that a 30 grain/foot MDF explosive in combination with a .190-inch joint material would be needed to produce a suitable qualification shock level. Rather than attempt to modify the joint B configuration, it was decided to design a stronger separation joint before continuing with the testing program to accommodate the larger explosive.

Tests 29 through 35

These tests were performed to evaluate joint configuration D illustrated in Figure II.F.2.3. The tests were conducted with a range of explosive size and skin thickness as indicated in Table II.F.2.1.

The joint configuration was not used as a part of the barrel development program, however the three tests that were conducted with this joint provided useful information about the structural strength and shock environment created by the modified back-up structure which was used to develop joint configuration D.

Although joint C provided a sufficient overtest in the higher frequencies the spectrum shape below 3000 Hz was considerably lower than the flight data.

The explosive chamber and back-up structure of configuration C were not affected by the 30 grain explosive, however the clamp ring bolts were damaged and required torquing after each test. A greater skin thickness was needed for optimum utilization of the 30 grain/foot MDF. Also, the clamp ring structure needed to be eliminated to prevent the explosive gas from driving between the joint back-up structure and clamp ring and stretching the clamp bolts.

The peak g readings from the oscillograms for configuration D, tests 29 through 35, are presented in Table II.F.2.3.

The data from location A1, A2 on the barrel was compared with the maximum vehicle environment by means of shock spectrums. The comparison showed that the barrel spectrum exceeded the maximum vehicle spectrum except in the 350 to 2500 Hz range.

The spectrum closely resembled the joint C spectrum with the exception of the amplitude. It thus remained to reshape the shock spectrum.

Tests 36 through 40 and Test 47

A study of the shock spectrum curves of joint C which had the clamp ring and joint D which had no clamp ring showed that the shock environment was changed only in amplitude and not shaped by the modification to the clamp ring assembly. The only remaining difference between joint B and joint that could cause the severe change in the shock spectrum shape was either the construction of the explosive back-up structure or the addition of the brace shown in Figure II.F.2.3. A study of the design consideration of joints B and D indicated that although the local strength of joint D is greater, the bending stiffness is probably similar to that of joint B and that, therefore, the brace must be responsible for the shock spectrum difference and not the back-up structure design change. The theory was that the brace distributed the local bending (which resulted from the detonation) over a large area and this reduced the amplitude of the low frequency bending wave shock. It was decided to remove the braces which had been added to the upper ring during the joint C tests.

Peak g levels from the real time oscillograms for tests 36 through 40 and test 47 are presented in Table II.F.2.3 and Figure II.F.2.9.

All of tests 36 through 40 and test 47 were conducted with a .190-inch skin thickness and a 30 grain/foot MDF. No equipment was mounted on the barrel during these tests.

Comparison of the joint D shock spectrum to the modified joint D shock spectrum shows more excitation for the modified joint in the 100 to 1200 Hz region while the spectrum was reduced in the 1200 to 7500 Hz region.

The shock environments which were produced by the modified D joint were considered satisfactory for equipment testing.

The modified D joint deteriorated after about 20 tests and both the explosive cavity and the ring had to be replaced. Although the explosive cavity was relatively easy to replace at small cost, the ring required extensive time to replace at a much greater cost.

A hardened steel cutting edge was added to the ring (Figure II.F.2.3). The cutting edge extended the life of the ring from about 20 to well over 200 firings. This addition was accomplished without affecting the barrel performance.

II.F.2.2.3 Analysis

A statistical analysis of the most recent 22 barrel tests was performed for the purpose of the shock study. One of the results of this study is presented in Figure II.F.2.4. The 50th percentile and ± 1 sigma values were computed for the longitudinal, radial and tangential shock spectrums of measurement B in Bay II of the barrel to show the repeatability of the barrel in each axis. These spectrums show that the repeatability is very much the same for all axes and that the spectrums are very similar.

Thus the environment at a particular location on the barrel is best defined by a composite spectrum of all axes at that location. The 50th percentile composite spectrum, also illustrated in Figure II.F.2.4, is not a composite of the 50th percentile in each axes, but rather a 50th percentile composite based on a statistical analysis on all 22 measurements of all three axes taken collectively.

The statistical analysis was completed only for measurement location A for the composite spectrum on the assumption that the repeatability for each axis at location A was similar to the repeatability for each axis at location B. The composite spectrums for locations A and B are presented in Figure II.F.2.5. The 50th percentile composite spectra for measurements A and B are also compared in Figure II.F.2.5. The comparison spectrum is a good indication of the average environment in each location and of the attenuation from location A in Bay I to location B in Bay II as a function of frequency.

The repeatability of the barrel tester at locations A and B based on the composite spectrums (composite of all axes) of the 25th and 95th percentile spectrums is shown in Table II.F.2.5 and in Figure II.F.2.6. The figure indicates that the maximum deviation is ± a factor of 1.7 for the 25th and 75th percentile and a factor of 3.5 for the 95th percentile for location A, Bay I, and ± a factor of 1.55 for the 25th and 75th percentile and a factor of 2.9 for the 95th percentile for location B, Bay II.

Figures II.F.2.7 and II.F.2.8 compare the maximum vehicle engine cone and aft rack environment with the barrel test environments in Bays I and II. The maximum vehicle environments are based on measurements taken during ground and flight tests of fully equipped vehicles (Sections II.A.1, II.A.2 and II.A.6 of this study).

The barrel test environment is based on the same statistical analysis of barrel measurements from 22 of the latest tests as referred to above. The shaded area lies between the 25th and 75th percentile values of the composite spectrum for measurements A and B. The percentiles refer to the probability of obtaining a shock spectrum g level lower than some value (at any particular frequency) in one test. For example, Figure II.-2.7 indicates that there is a 25 percent chance that the shock spectrum level at 200 Hz will be below 370 g's and a 75 percent chance that the level will be below 950 g's in any one test. It should be noted that the two tests increase the probability of reaching a desired shock spectrum g level. This factor has not been evaluated in this analysis. Thus, one of the reasons for conducting two tests to qualify a piece of equipment for pyro shock on the barrel tester is to give added confidence that an overtest will be achieved.

238 tests, which have qualified some 119 items of equipment, have proven the test environments satisfactory for all of the vehicle equipment which was tested. Section VI deals with these tests and with equipment/component failures that have occurred during pyroshock qualification testing. In addition, a number of tests have been conducted for outside vendors.

II.F.2.3 CONCLUSIONS

The barrel tests achieved all the objectives originally required by the test program.

The shock environment created by the Barrel Tester is very similar to th vehicle data. This was observable in the shock spectra as well as the acceleration-time history.

The Barrel Tester provides a sufficient overtest in every octave band to qualify equipment.

Significant changes in joint thickness and grain size result in only relatively small changes in shock amplitude (see analysis, Section III.B

The installation of flight equipment packages on the Barrel Tester does not significantly change the barrel environment.

An analysis of the last 22 barrel tests shows that the test levels are repeatable within a factor of $\pm$ 1.7 at location A and within a factor of $\pm$ 1.55 at location B based on the 25th and 75th percentile composite shock spectra (composite of radial, tangential and longitudinal axis). This repeatability is adequate for an environmental test facility.

The present useful life of the explosive cavity insert (Figure II.F.2.1 is about 30 tests. A hardened steel cutting edge has increased the life of the separation ring such that over 200 tests have been conducted without a ring failure.

The barrel test environment has proven satisfactory for qualifying 119 separate items of vehicle equipment. In addition, a number of tests have been conducted for outside vendors.

TABLE II.F.2.1

TEST CONFIGURATION AND TESTING SEQUENCE

Test Number	JOINT CONDITION Explosive Gr./ft.	Thickness In.	Joint Configuration
1	5	.033	Joint B
2	5	.050	↓
3	10	.050	
4	10	.092	
5	15	.092	
6	15	.125	
7	5	.033	
8	5	.050	
9	10	.050	
10	10	.092	
11	15	.092	
12	15	.125	
13	5	.050	
14	10	.092	
15	15	.125	
29	10	.092	Joint D
30	15	.125	↓
31	15	.156	
33	30	.156	
34	30	.190	
35	30	.190	
36	30	.190	Joint D Modified Structure
37	30	.190	
38	30	.190	
39	30	.190	
47	30	.190	

TABLE II.F.2.2

ACCELEROMETERS AND LOCATIONS

Accelerometer Number	Quad	Bay	Direction	Distance to Shocksource (inches)	Accelerometer Type
A1	II	I	L	3	Endevco 2225
A1	II	I	R	3	Endevco 2225
A1	II	I	T	3	Endevco 2225
A2	II	I	L	3	Endevco 2225
A2	II	I	R	3	Endevco 2225
A2	II	I	T	3	Endevco 2225
B1	II	II	L	23	Endevco 2225
B1	II	II	R	23	Endevco 2225
B1	II	II	T	23	Endevco 2225
B2	II	II	L	23	Endevco 2225
B2	II	II	R	23	Endevco 2225
B2	II	II	T	23	Endevco 2225
1	II	I	L	11.5	Endevco 2225
2	II	I	T	11.5	Endevco 2225
3	II	I	R	11.5	Endevco 2225
5	III	II	R	23	Endevco 2225
6	II	II	L	31.5	Endevco 2225
7	II	II	T	31.5	Endevco 2225
8	II	II	R	31.5	Endevco 2225
9	I	II	R	31.5	Endevco 2225
10	III	II	R	31.5	Endevco 2225
11	IV	II	R	31.5	Endevco 2225
12	II	III	R	41.5	Endevco 2225
13	II	III	L	51.5	Endevco 2225
14	II	III	T	51.5	Endevco 2225
15	II	III	R	51.5	Endevco 2225
16	III	III	R	51.5	Endevco 2225

TABLE II.F.2.3

OSCILLOGRAM PEAK G LEVELS

LOCATION	TEST NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	376	450	565	830	850	1430	810	850	700	1050	785	1070	614	1190	1575
2	605	680	830	870	860	1370	900	698	1160	915	715	1070	420	726	994
3	755	1110	955	1350	1430	1990	1610	860	1060	1360	1500	2630	653	1270	1380
4	570	665	570	712	785	1300	430	550	594	750	800	1400	594	674	1310
5	430	625	740	623	623	1000	506	565	684	570	760	1060	427	563	1200
6	280	260	330	540	440	810	384	384	630	435	465	720	294	494	816
7	290	290	270	251	1000	475	416	350	485	470	450	470	297	444	473
8	386	540	500	675	596	790	424	465	667	530	550	805	331	615	722
9	212	310	348	540	770	830	308	348	440	575	605	1230	375	506	900
10	309	348	425	580	570	720	292	390	490	470	624	663	434	690	945
11	386	405	540	540	887	750	276	296	396	614	636	775	315	650	906
12	290	425	388	560	376	950	317	337	436	445	419	597	256	650	780
13	199	300	270	310	360	440	266	358	342	316	367	405	220	426	574
14	139	162	191	209	300	282	190	150	338	358	248	340	237	283	283
15	133	157	186	244	299	318	165	220	208	295	324	332	251	336	404
16	179	191	277	333	374	697	270	234	299	364	338	468	226	426	575

LOCATION	29	30	31	33	34	36	37	38	39	40	47
1	1640	—	1880	4520	5200	—	—	--	--	4800	4400
2	1160	1440	1000	2000	1640	—	--	--	—	5300	3020
3	520	1360	1000	1540	3280	2100	2200	2100	2200	2470	2170
4	520	720	520	2400	1400	1770	1890	2040	1990	1990	2980
5	—	—	—	--	--	--	--	--	--	—	—
6	380	800	880	1430	1150	2430	2270	2480	2330	2110	2070
7	360	410	450	880	1320	1150	1010	1150	865	2230	1680
8	280	380	460	730	600	1550	1400	1440	1530	1420	1650
9	—	—	—	—	—	—	--	--	—	—	--
10	300	340	330	960	940	--	—	—	—	--	—
11	270	520	450	660	700	1930	1760	2080	2080	2190	1880
12	320	480	380	640	630	1350	1350	1230	1250	1110	1580
13	207	253	1866	577	590	1700	1590	1440	1540	1480	1410
14	294	360	443	714	536	1300	1130	1470	1240	970	970
15	280	333	293	567	527	1080	965	935	1060	840	974

TABLE II.F.2.[illegible]

STATISTICAL RESPONSE DATA FROM LOCATIONS A AND B, BAY I AND BAY II

1/3 OCTAVE FREQUENCY	LOCATION B 25%	LOCATION B 50%	LOCATION B 75%	LOCATION B 95%	LOCATION A 25%	LOCATION A 50%	LOCATION A 75%	LOCATION A 95%
200	105	161	248	460	340	562	930	1921
250	176	256	372	637	464	771	1280	2657
320	317	414	540	792	680	1061	1655	3137
400	420	550	721	1065	1072	1487	2063	3305
500	757	902	1074	1381	1554	2024	2636	3855
630	1110	1491	2003	3063	3006	3906	5074	7396
800	1769	2373	3183	4858	6910	8515	10491	14168
1000	1523	1939	2469	3495	6640	7866	9318	11891
1250	2726	3280	3947	5152	7413	8566	9885	12159
1600	2781	3514	4441	6219	8795	10424	12355	15776
2000	3878	4844	6050	8332	10204	12920	16359	22975
2500	3639	4669	5992	8579	13293	17720	23622	35728
3200	3366	4289	5465	7747	14268	19288	26075	40240
4000	3796	4633	5655	7534	13847	19298	26895	43367
5000	4213	5255	6556	9012	13725	17626	22636	32445
6300	3603	4538	5717	7971	12372	16466	21915	33068
8000	2478	3119	3925	5463	10336	13550	17763	26225

TABLE II.F.2.5

TEST DEVIATION EXPRESSED AS A RATIO FOR LOCATIONS A AND B, BAY I AND BAY II

1/3 OCTAVE FREQUENCY	LOCATION B		LOCATION A	
	Ratio 50/25, 75/50	Ratio 95/50	Ratio 50/25, 75/50	Ratio 95/50
200	1.53	2.86	1.62	3.42
250	1.45	2.48	1.66	3.45
320	1.30	1.91	1.56	2.96
400	1.31	1.94	1.38	2.22
500	1.19	1.53	1.3	1.91
630	1.34	2.05	1.3	1.89
800	1.35	2.05	1.23	1.66
1000	1.27	1.8	1.18	1.51
1250	1.21	1.57	1.15	1.42
1600	1.26	1.77	1.18	1.51
2000	1.25	1.72	1.27	1.78
2500	1.28	1.84	1.33	2.02
3200	1.27	1.80	1.35	2.09
4000	1.22	1.62	1.39	2.25
5000	1.25	1.71	1.28	1.84
6300	1.26	1.76	1.33	2.01
8000	1.26	1.75	1.31	1.94

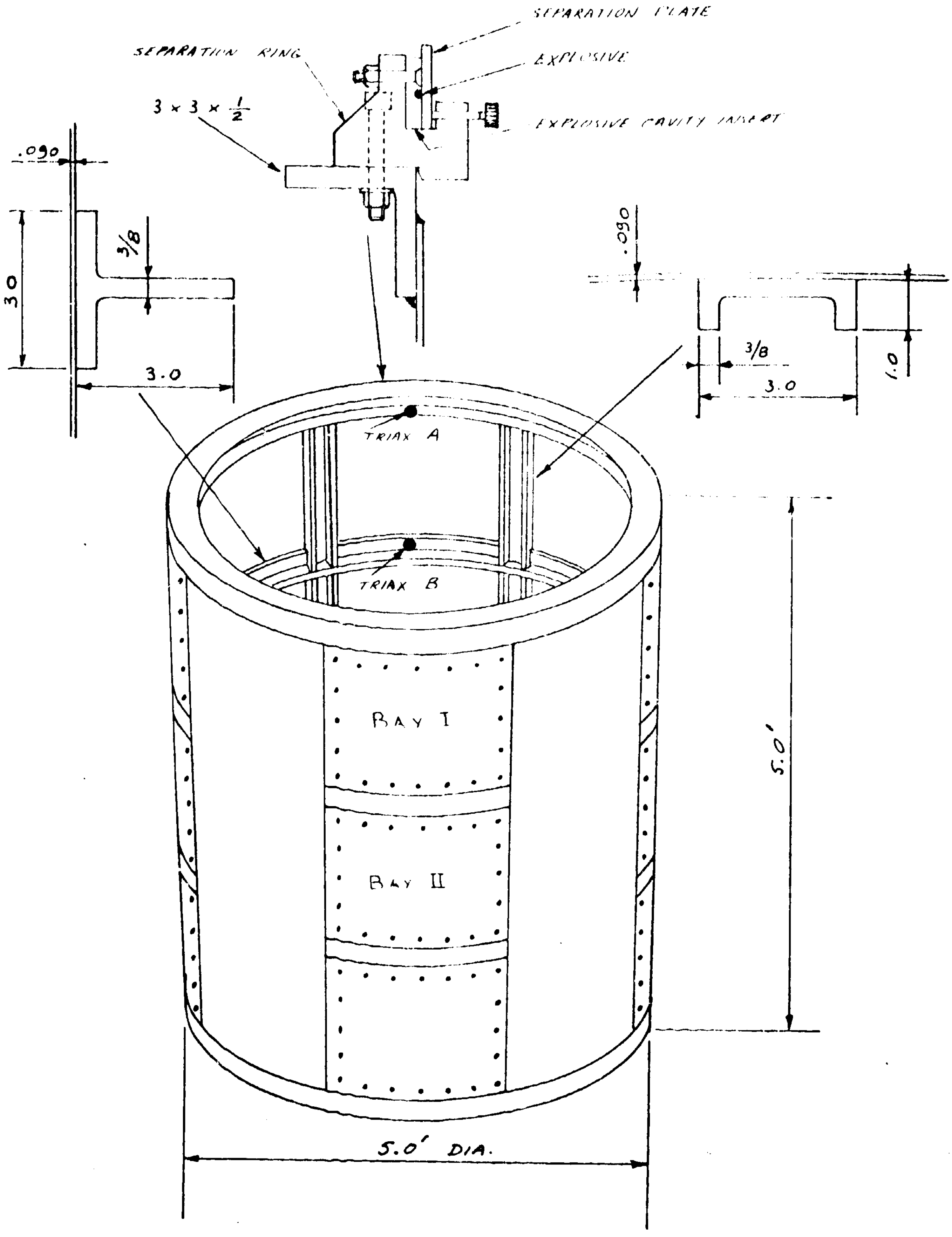


Figure II.F.2.1 BARREL AND SEPARATION JOINT DESIGN

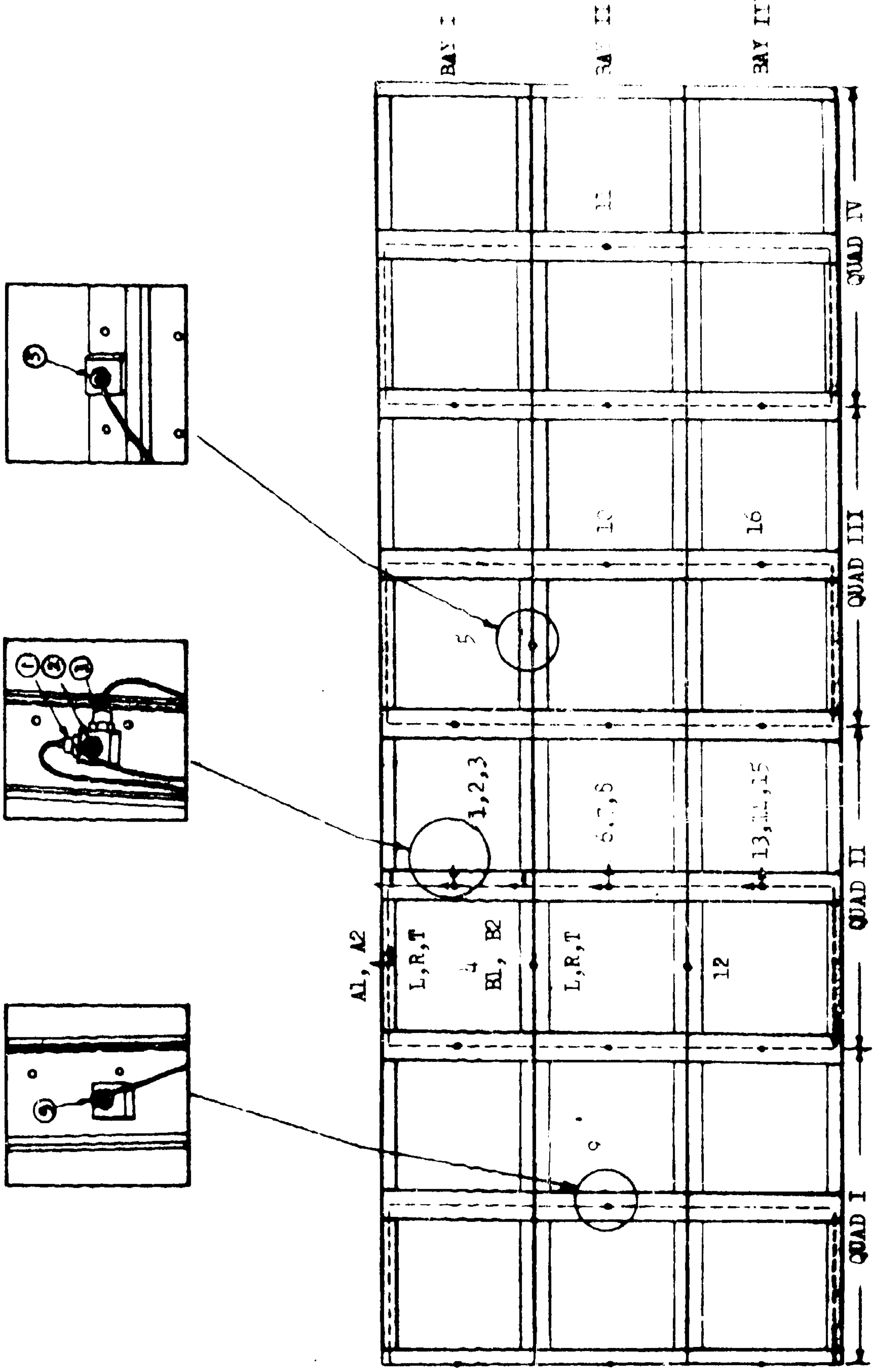
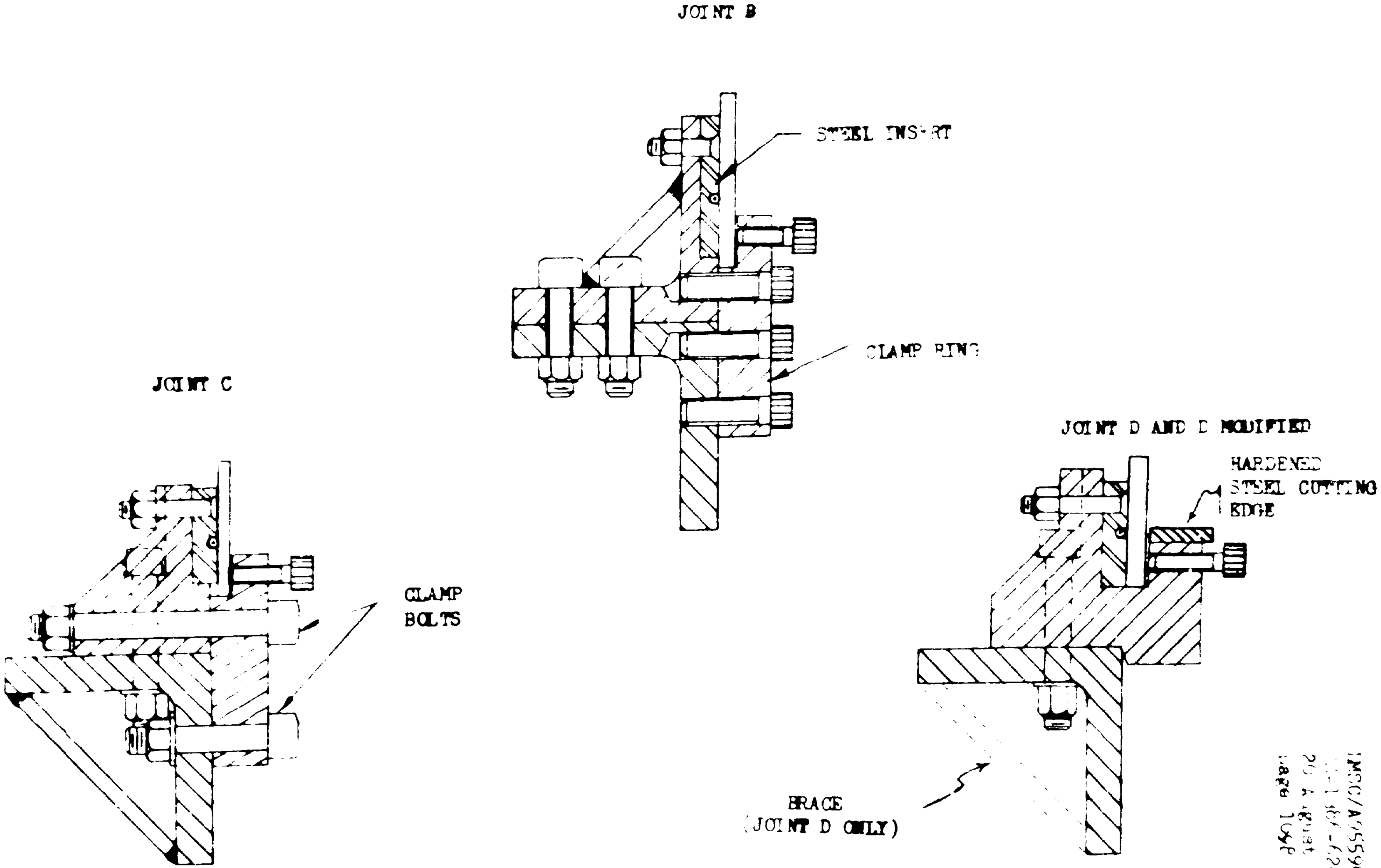


Figure II.F.2.2 INSTRUMENTATION LOCATIONS


JOINT B
STEEL INSERT
CLAMP RING
JOINT C
CLAMP
BOLTS
JOINT D AND D MODIFIED
HARDENED
STEEL CUTTING
EDGE
BRACE
(JOINT D ONLY)

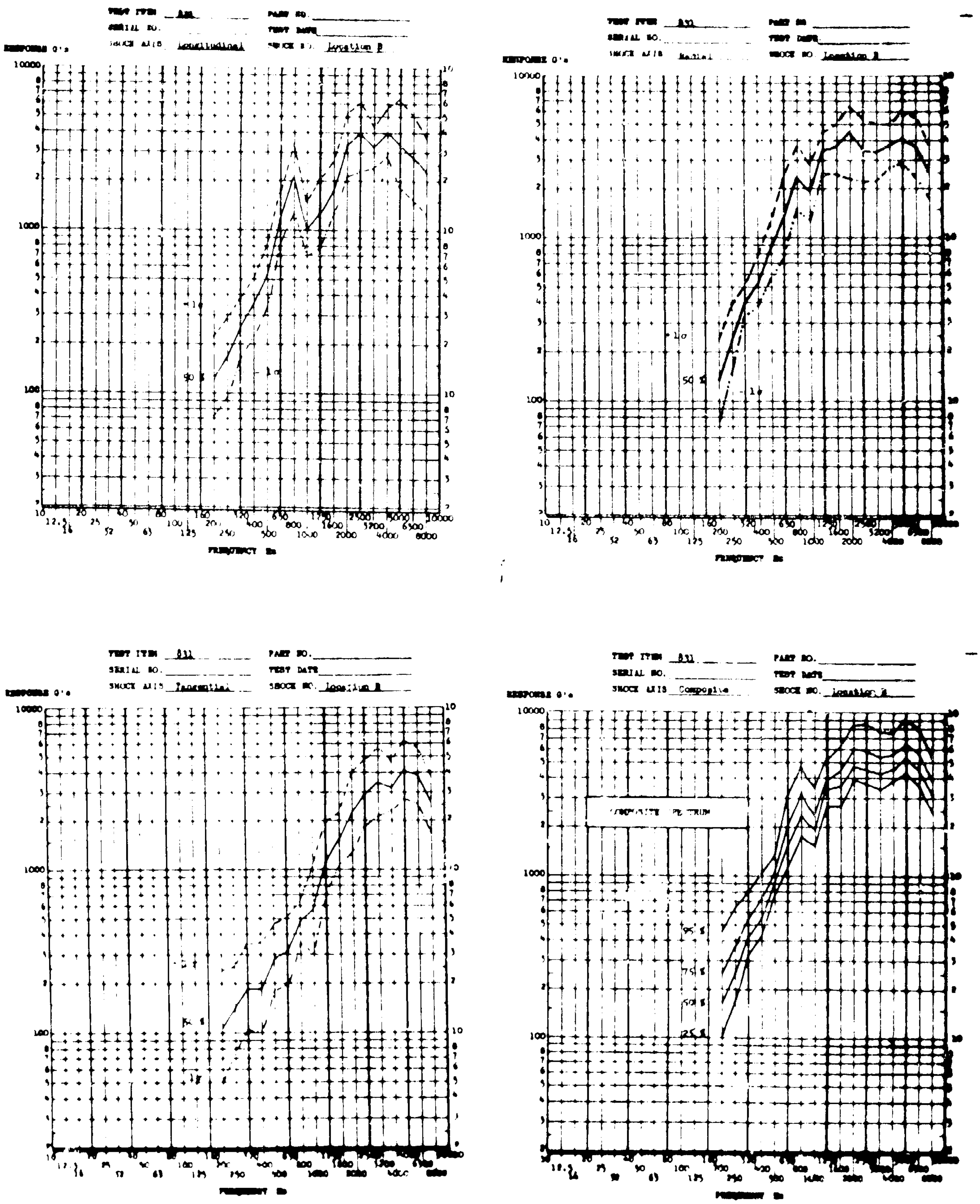
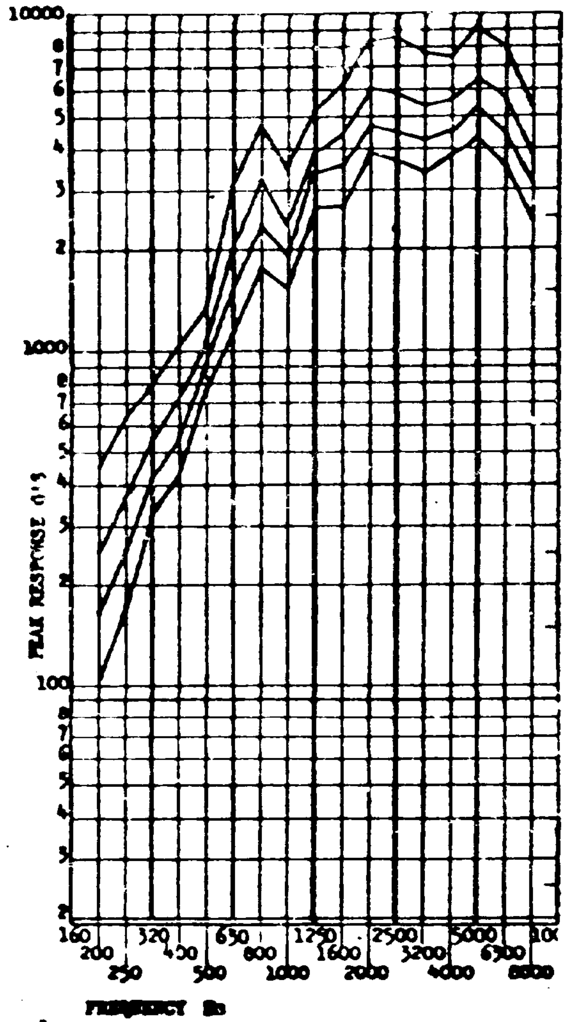
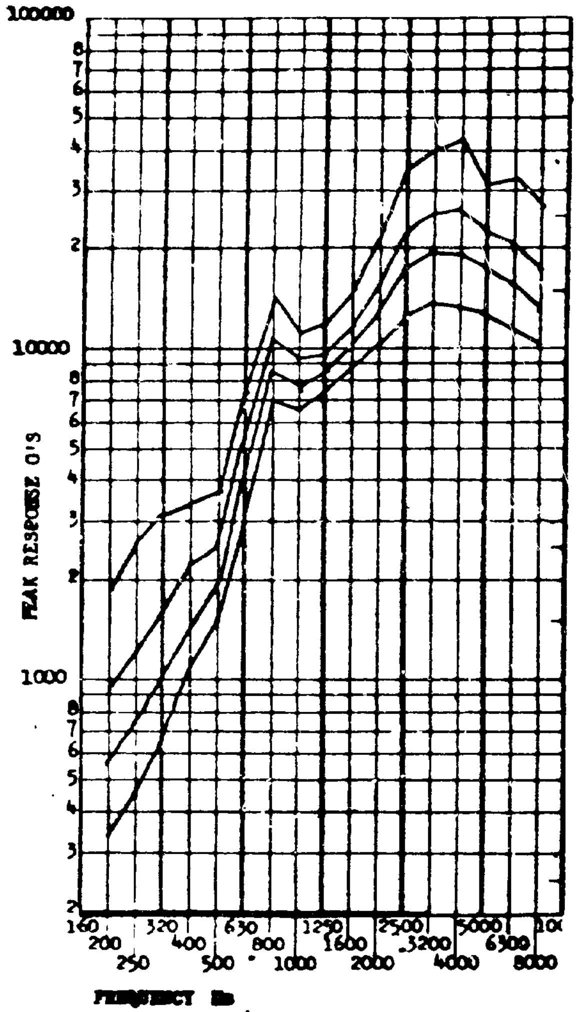


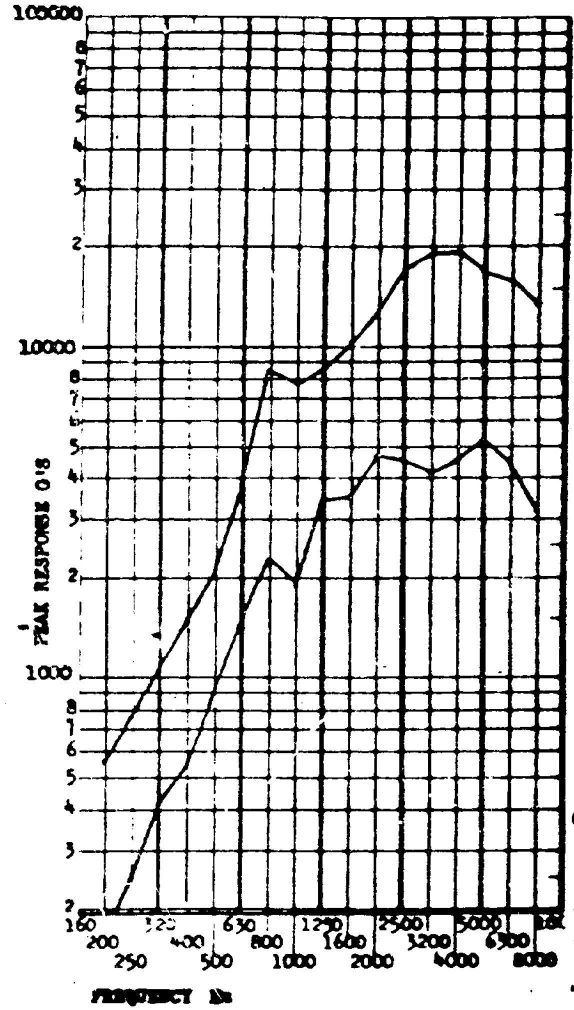
Figure II.F.2.4 SHOCK SPECTRUMS FROM THE BARREL TESTER
(LOCATION B, LONGITUDINAL, RADIAL, TANGENTIAL AND COMPOSITE)



25, 50, 75 and 95 PERCENTILE LEVELS LOCATION B



25, 50, 75, and 95 PERCENTILE LEVELS LOCATION A



50 PERCENTILE LEVELS LOCATION A AND B

Figure II.F.2.5 Statistical Response Data From Location A and B (Composite Spectrum Q = [illegible])

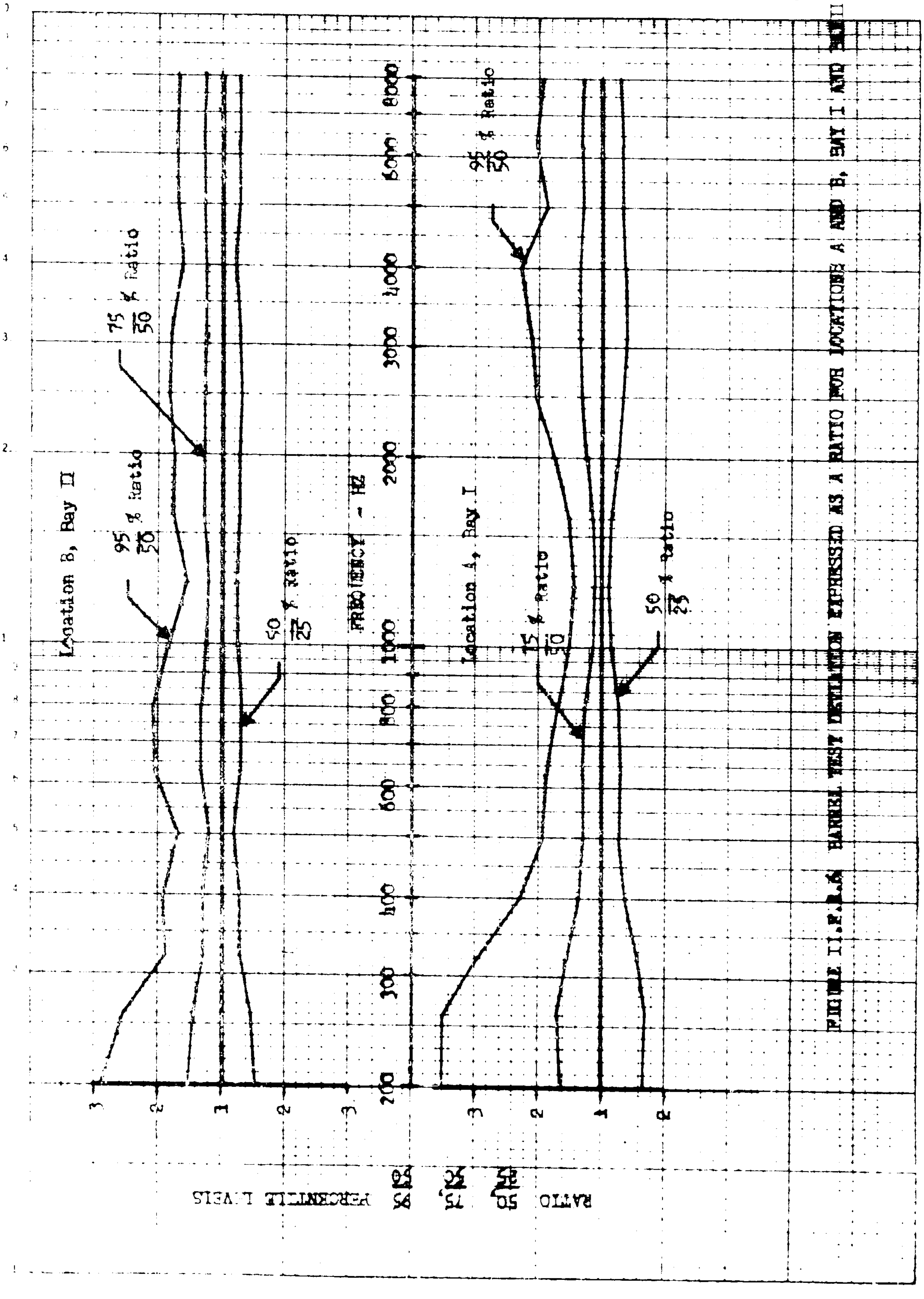


FIGURE II.F.2.6 BARREL TEST DEVIATION EXPRESSED AS A RATIO FOR LOCATIONS A AND B, BAY I AND BAY II

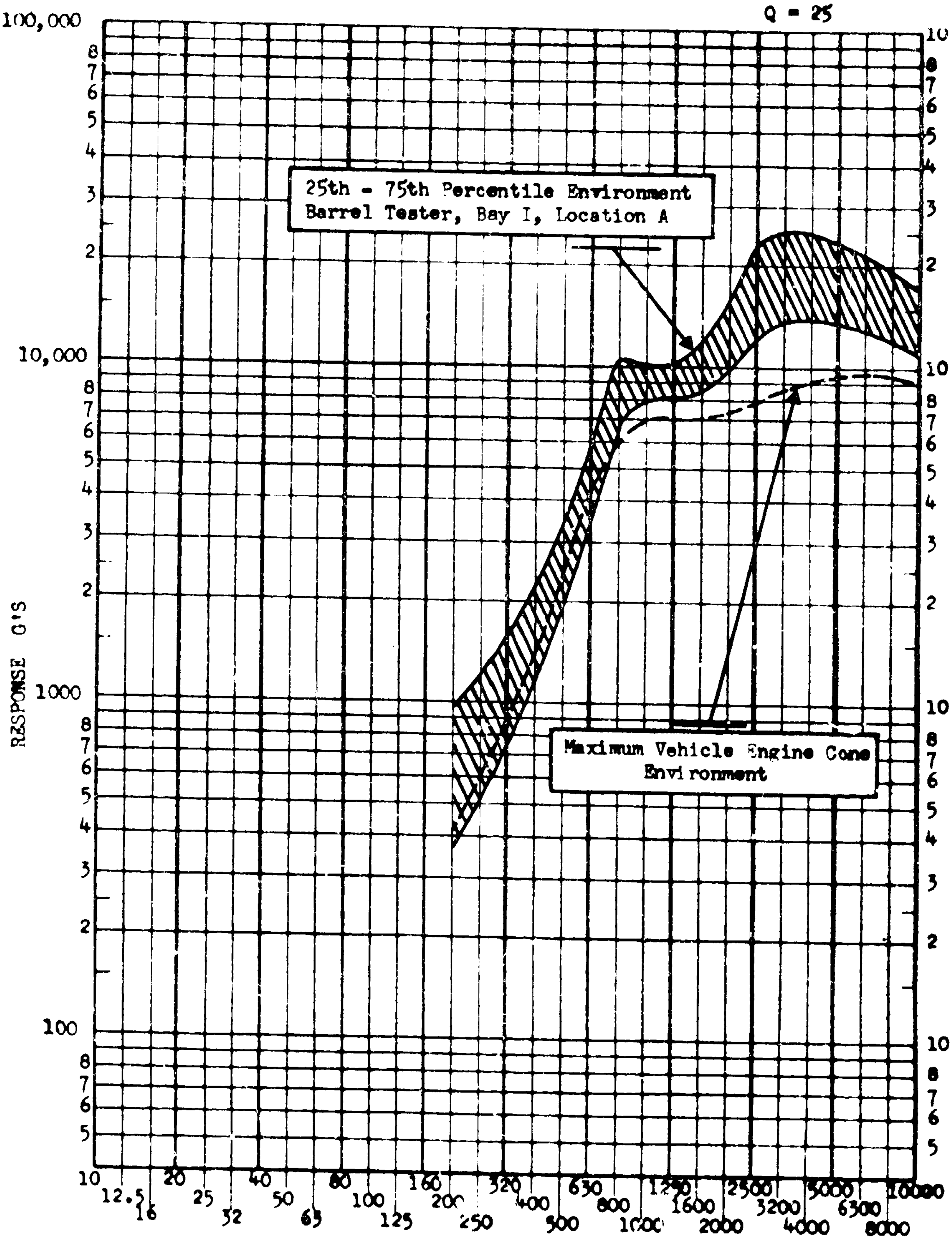


Figure II.F.2.7 COMPARISON OF BAY I, LOCATION A BARREL ENVIRONMENT AND MAXIMUM VEHICLE ENGINE CONE ENVIRONMENT

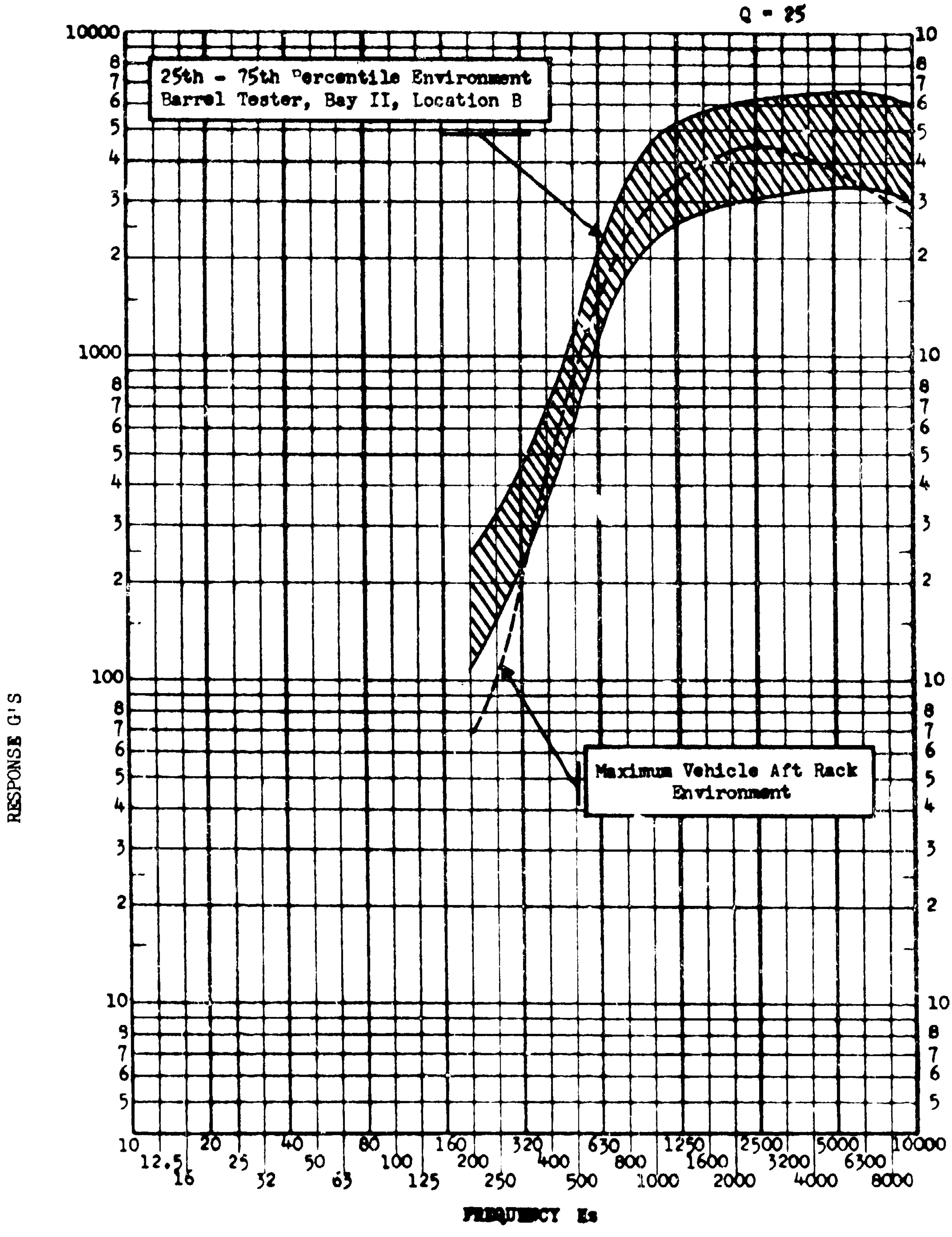


Figure II.F.2.8 COMPARISON OF BAY II, LOCATION B BARREL ENVIRONMENT AND MAXIMUM VEHICLE AFT RACK ENVIRONMENT

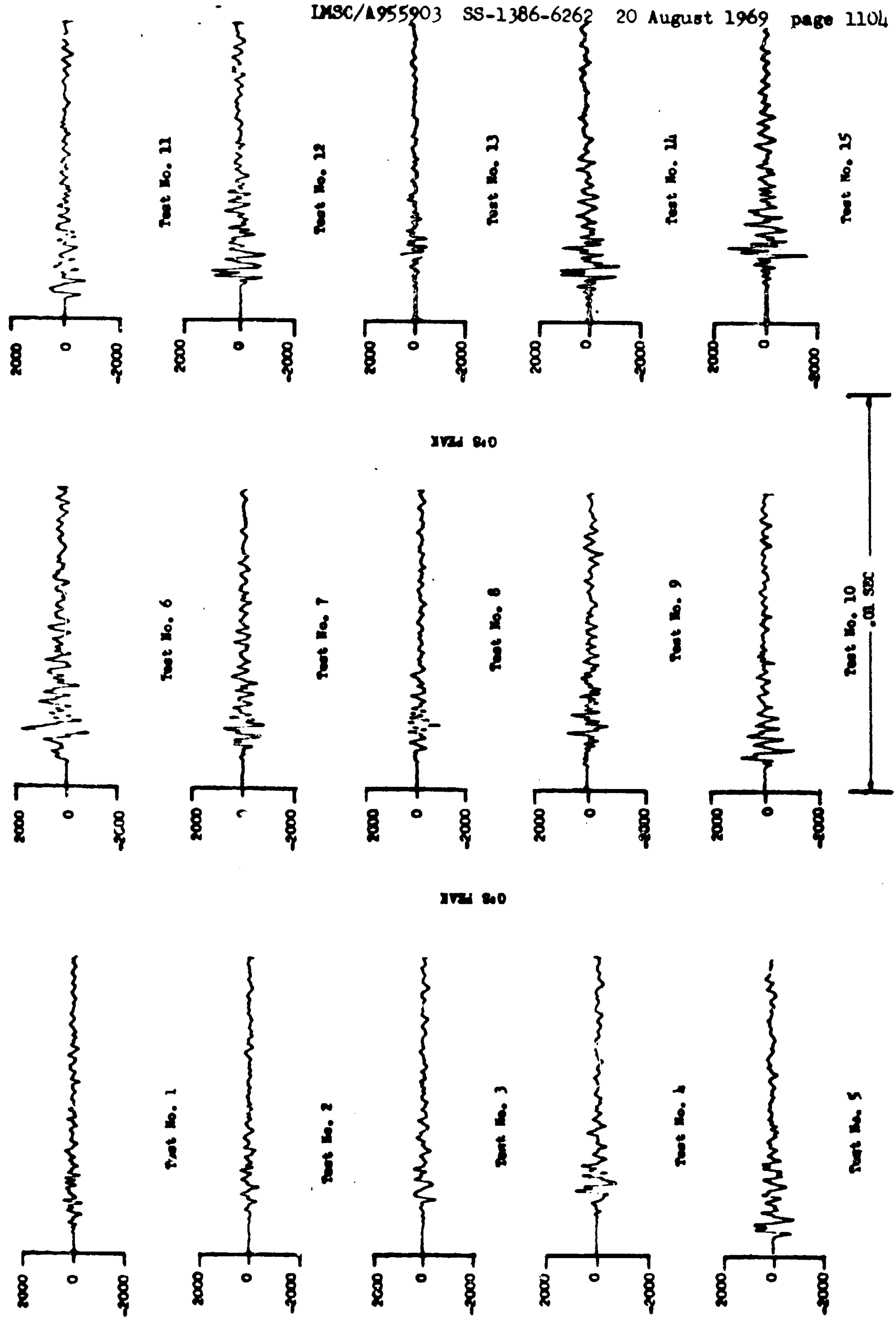
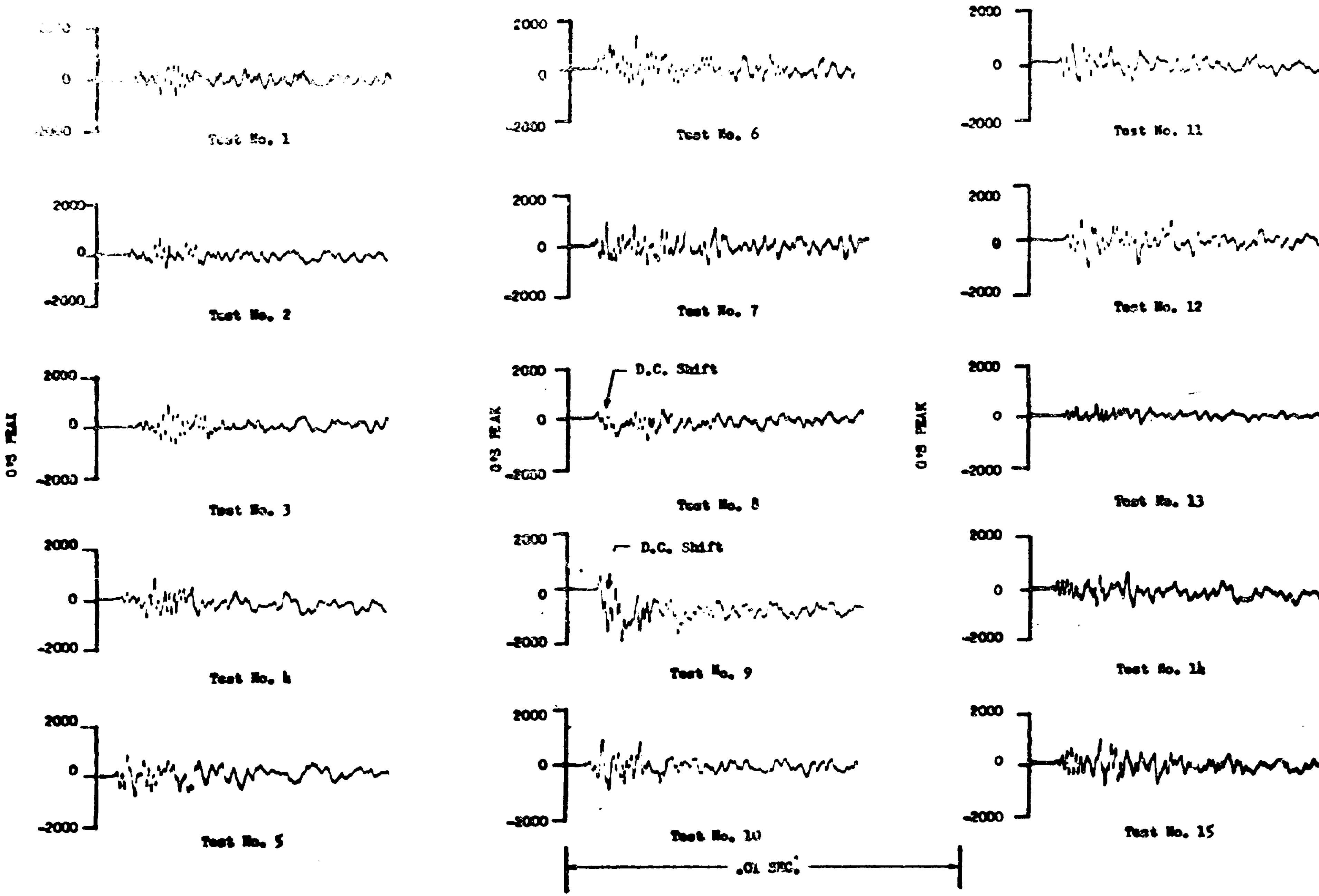


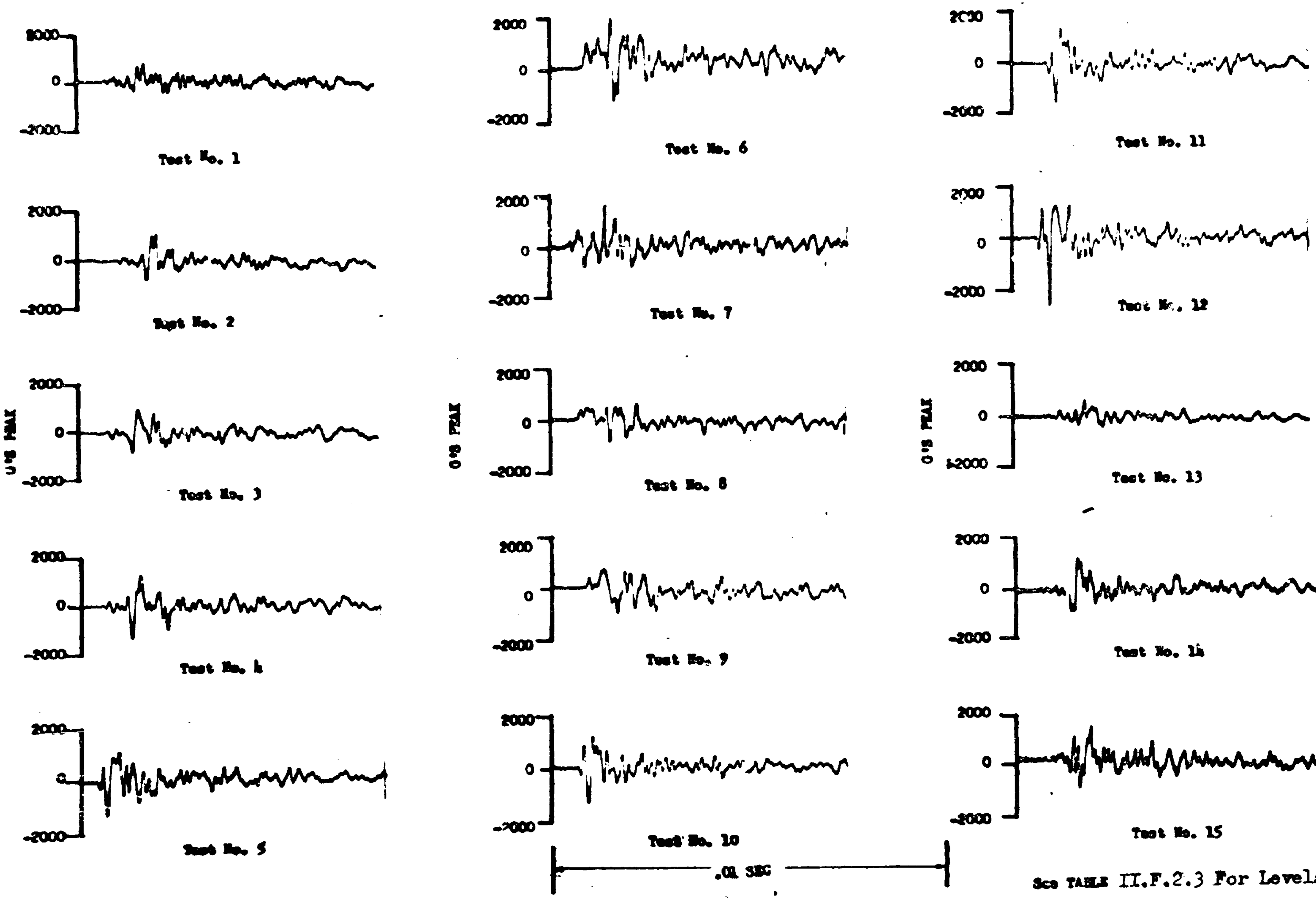
Figure II.F.2-9₁ Oscillograms Items 531 - Accelerometer No. 1 (Tests 1 to 15)

See TABLE II.F.2.3 For Levels



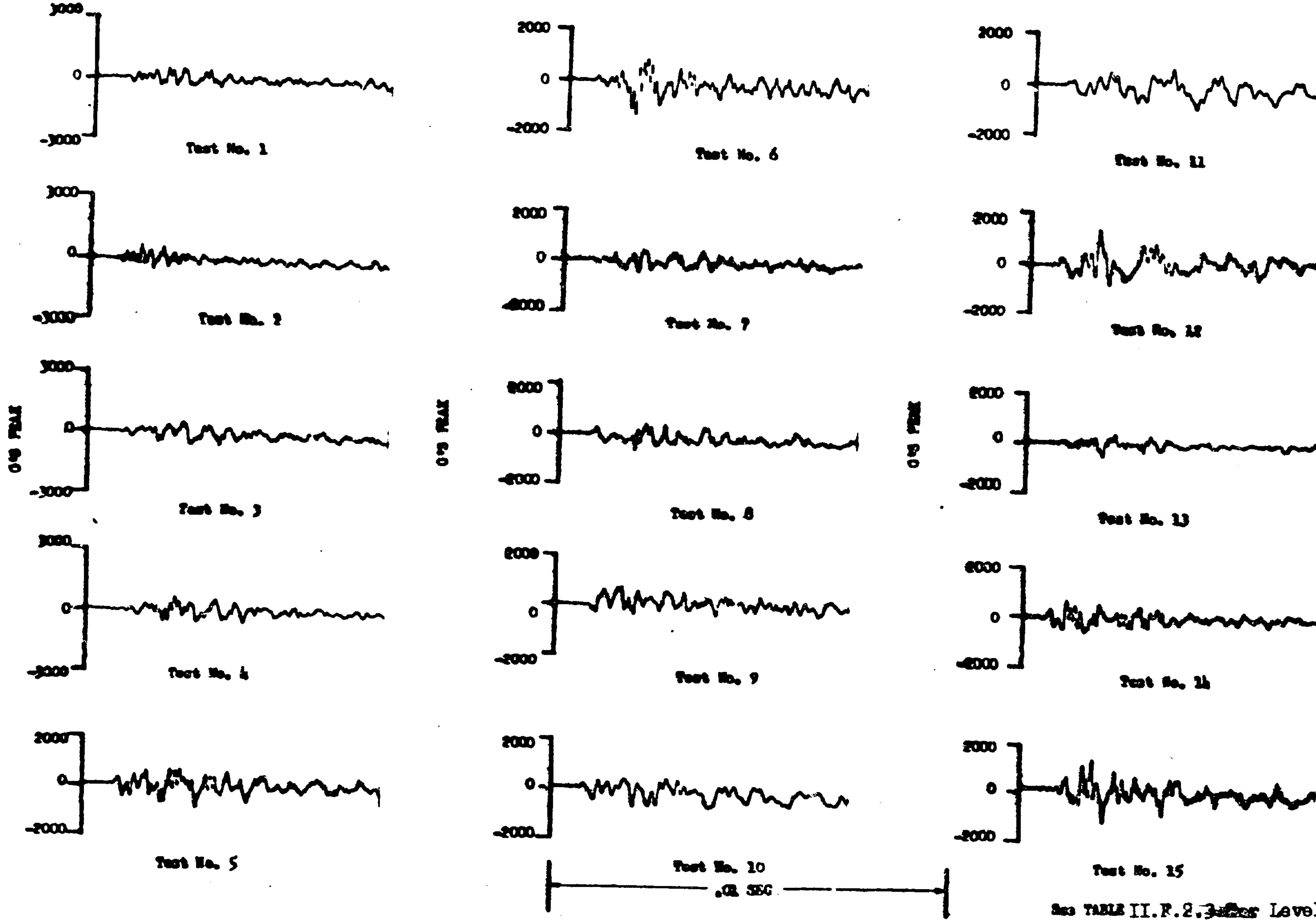
See TABLE II.F.2.3 For Levels

Figure II.F.2.9$_2$ Oscillograms Item 831 - Accelerometer No. 2 (Test 1 to 15)



See TABLE II.F.2.3 For Levels

Figure II.F.2.9$_3$ Oscillograms Item [illegible] - Accelerometer No. 3 (Test 1 to 15)



See TABLE II.F.2.3 for Levels

Figure II.F.2.9$_4$ Oscillograms Item 801 - Accelerometer No. 4 (Test 1 to 15)

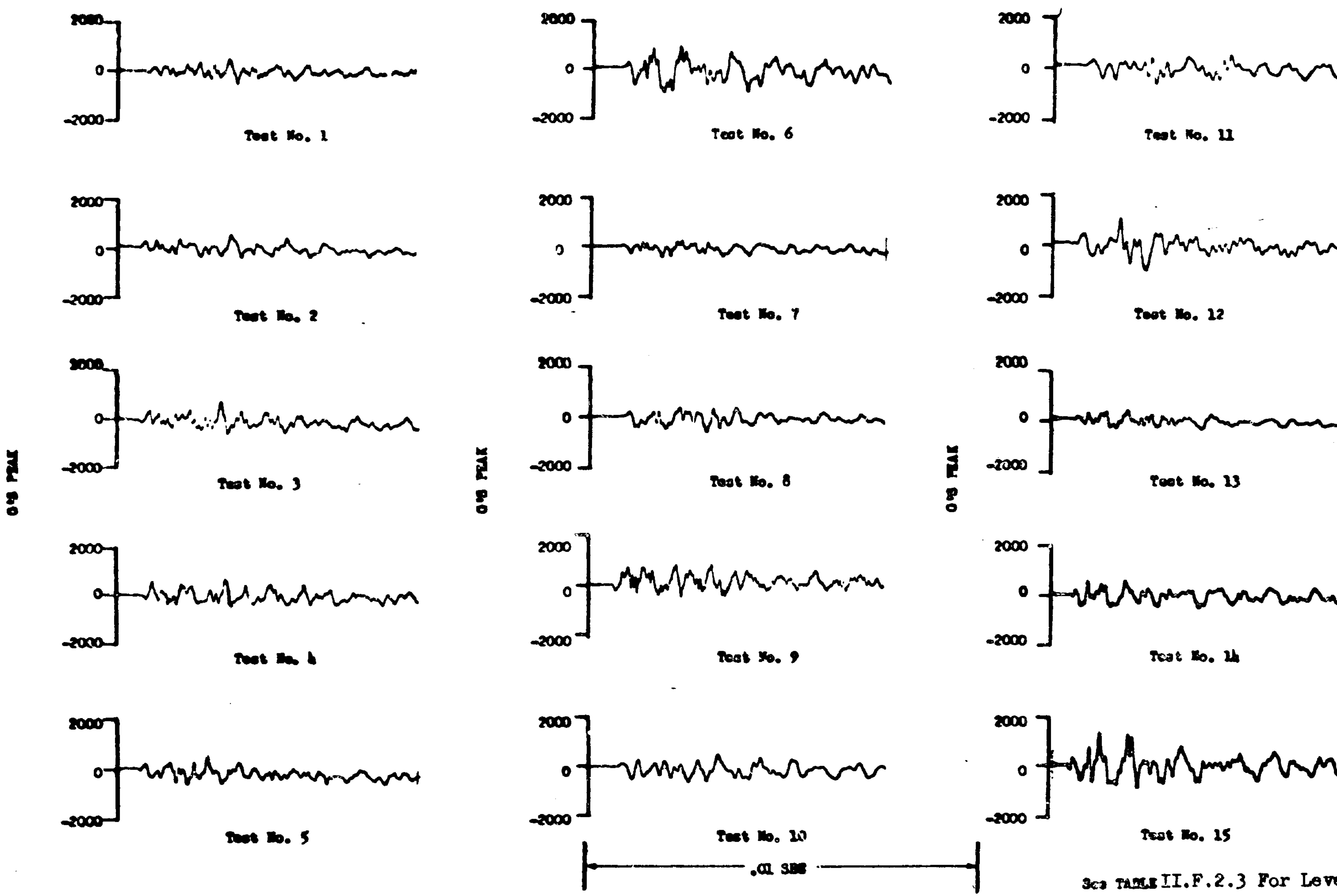
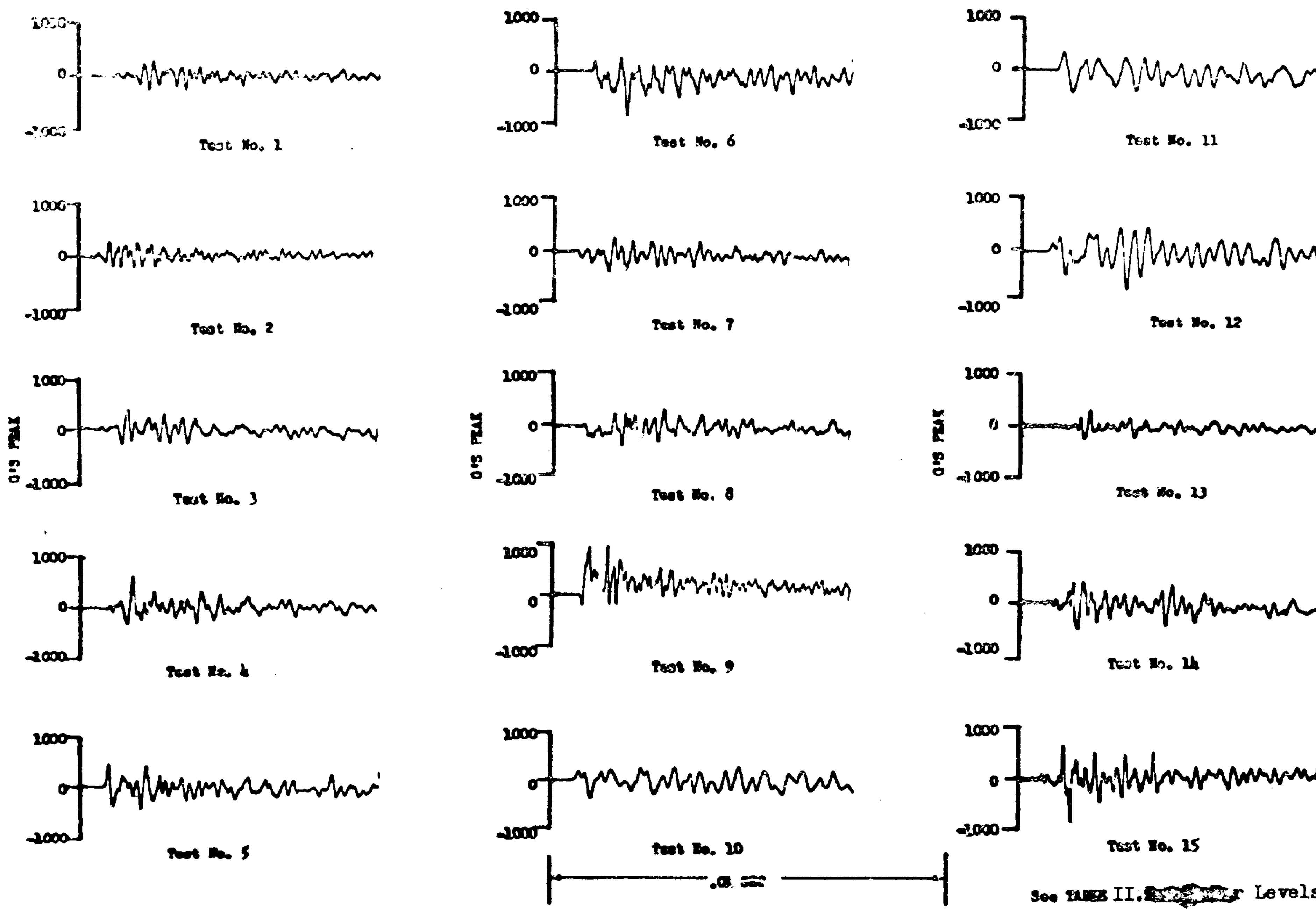


Figure II.F.2.95 Oscillograms Item 831 - Accelerometer No. 5 (Test 1 to 15)



See TABLE II. [illegible] Levels

Figure II.F.2.96 Oscillograms Item 631 - Accelerometer No. 6 (Test 1 to 15)

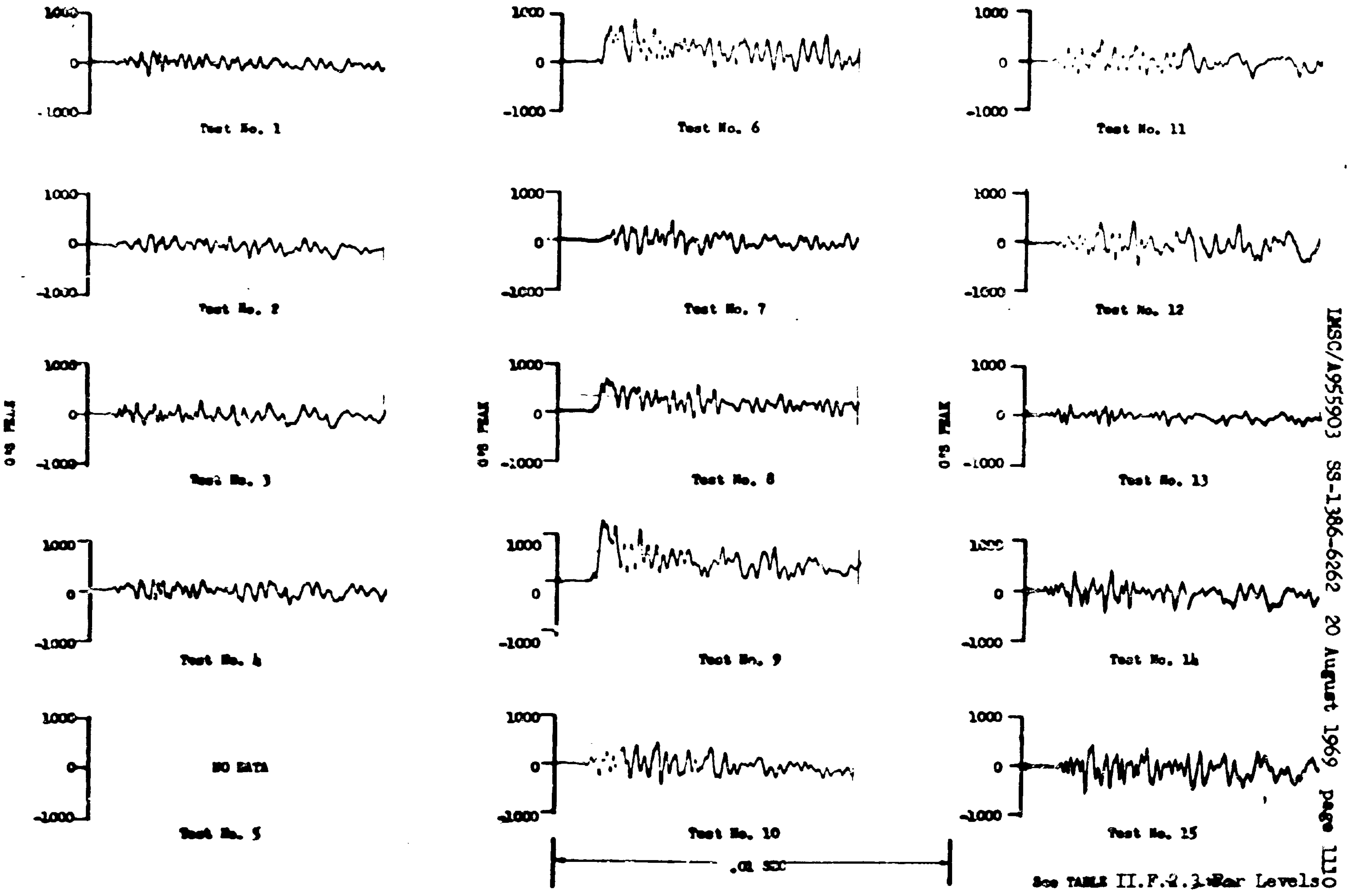
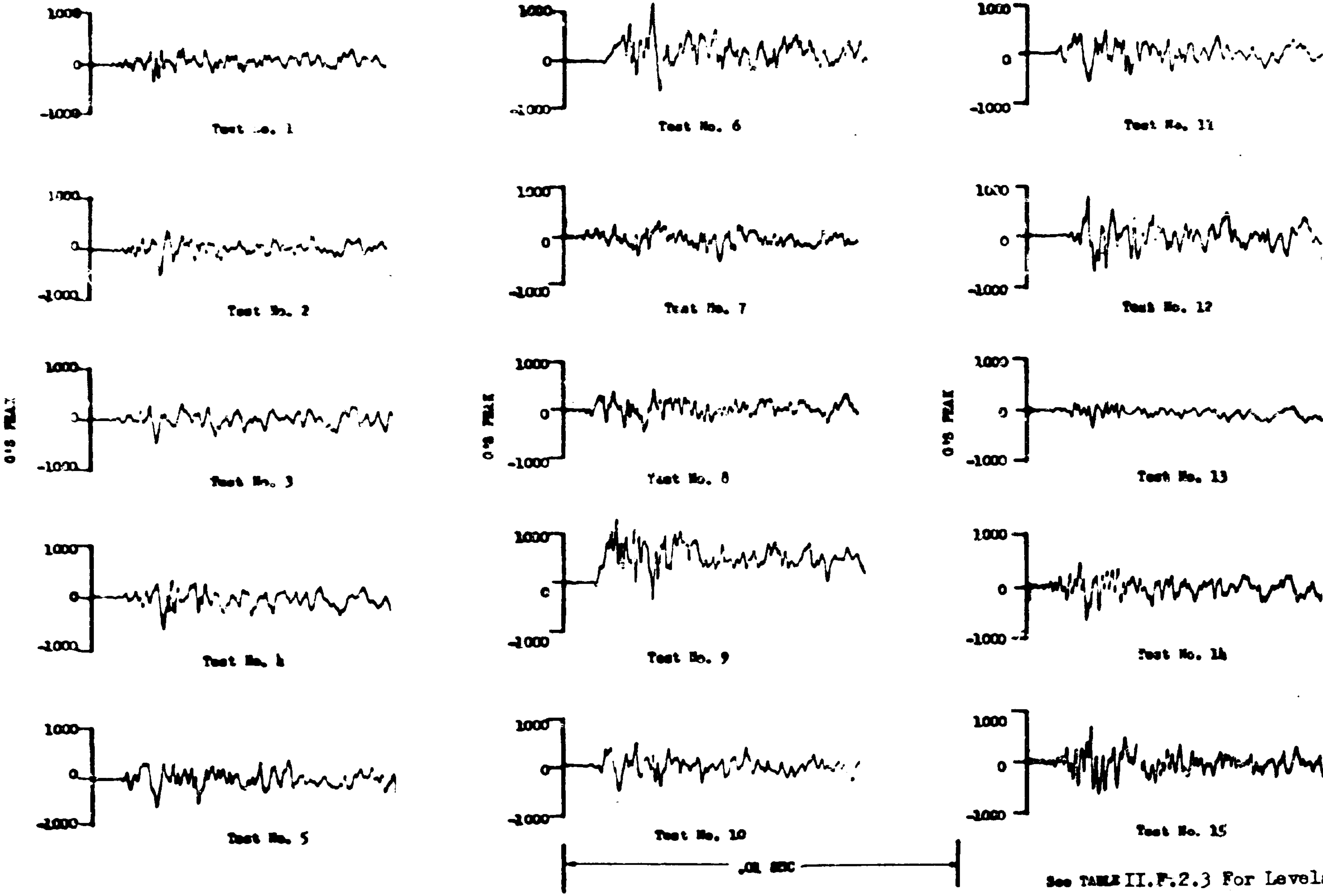
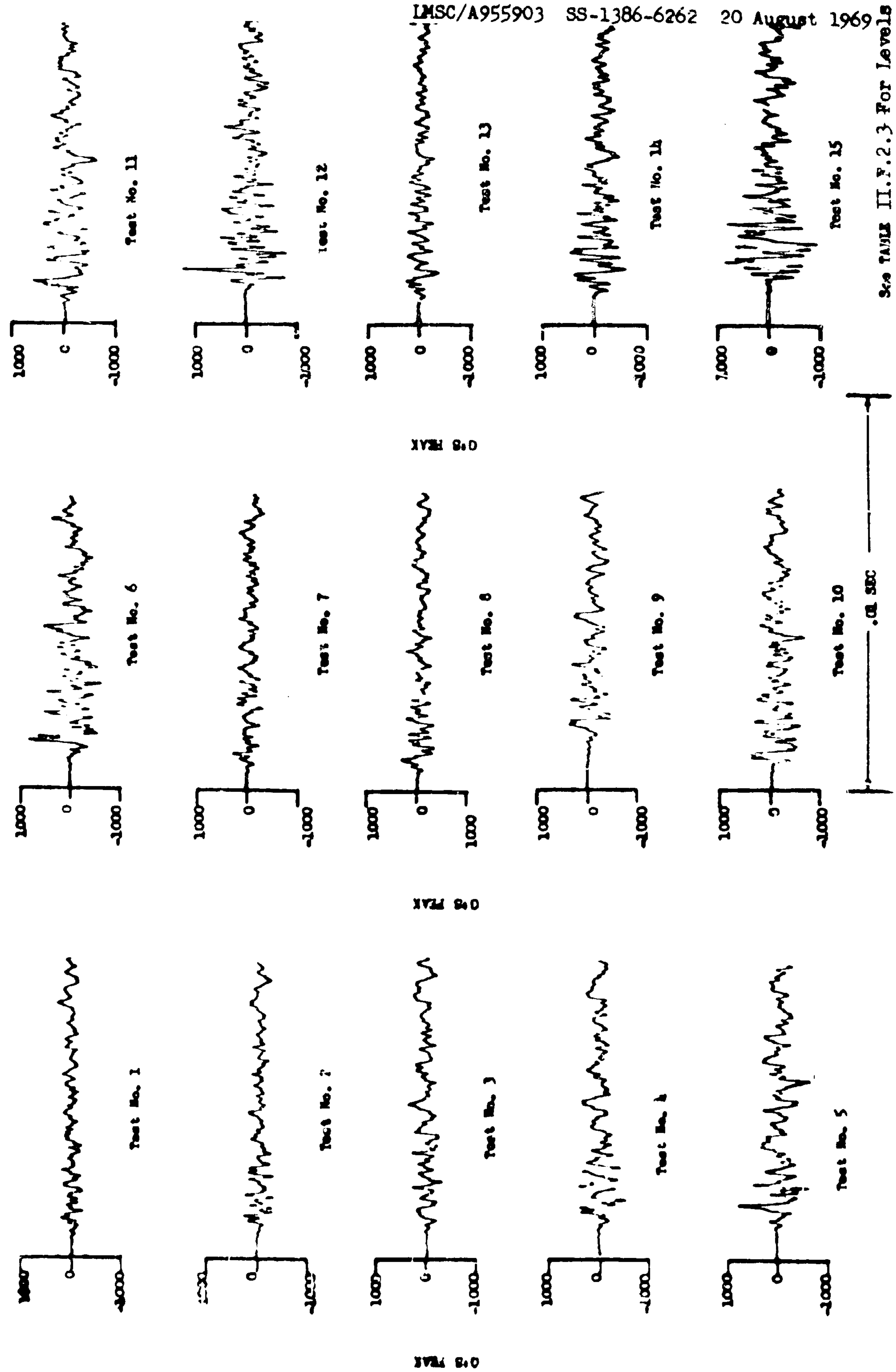


Figure II.F.2.9 Oscillograms Item 831 - Accelerometer No. 7 (Test 1 to 15)



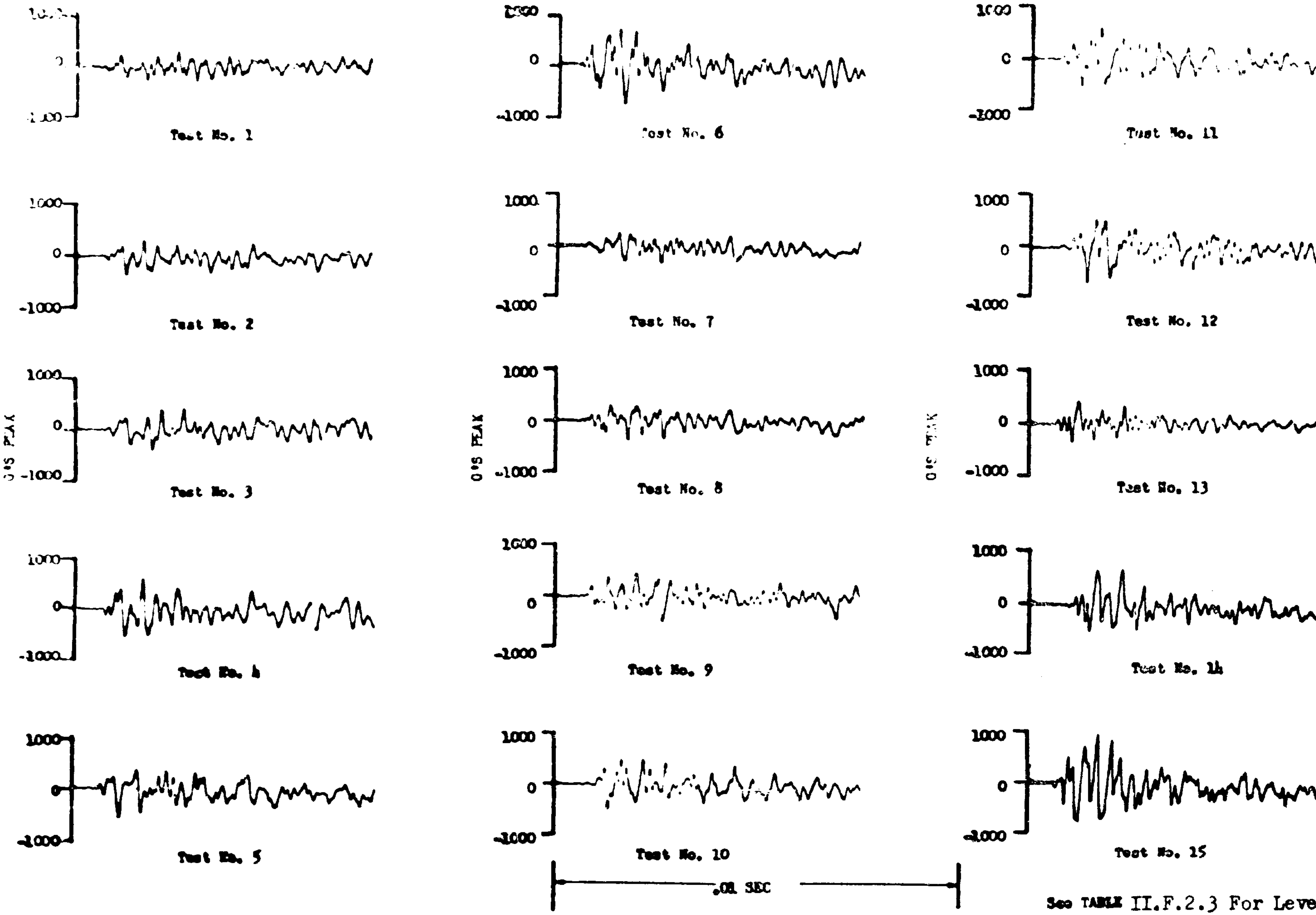
See TABLE II.F.2.3 For Levels

Figure II.F.2.9$_8$ Oscillograms Item 831 - Accelerometer No. 8 (Test 1 to 15)



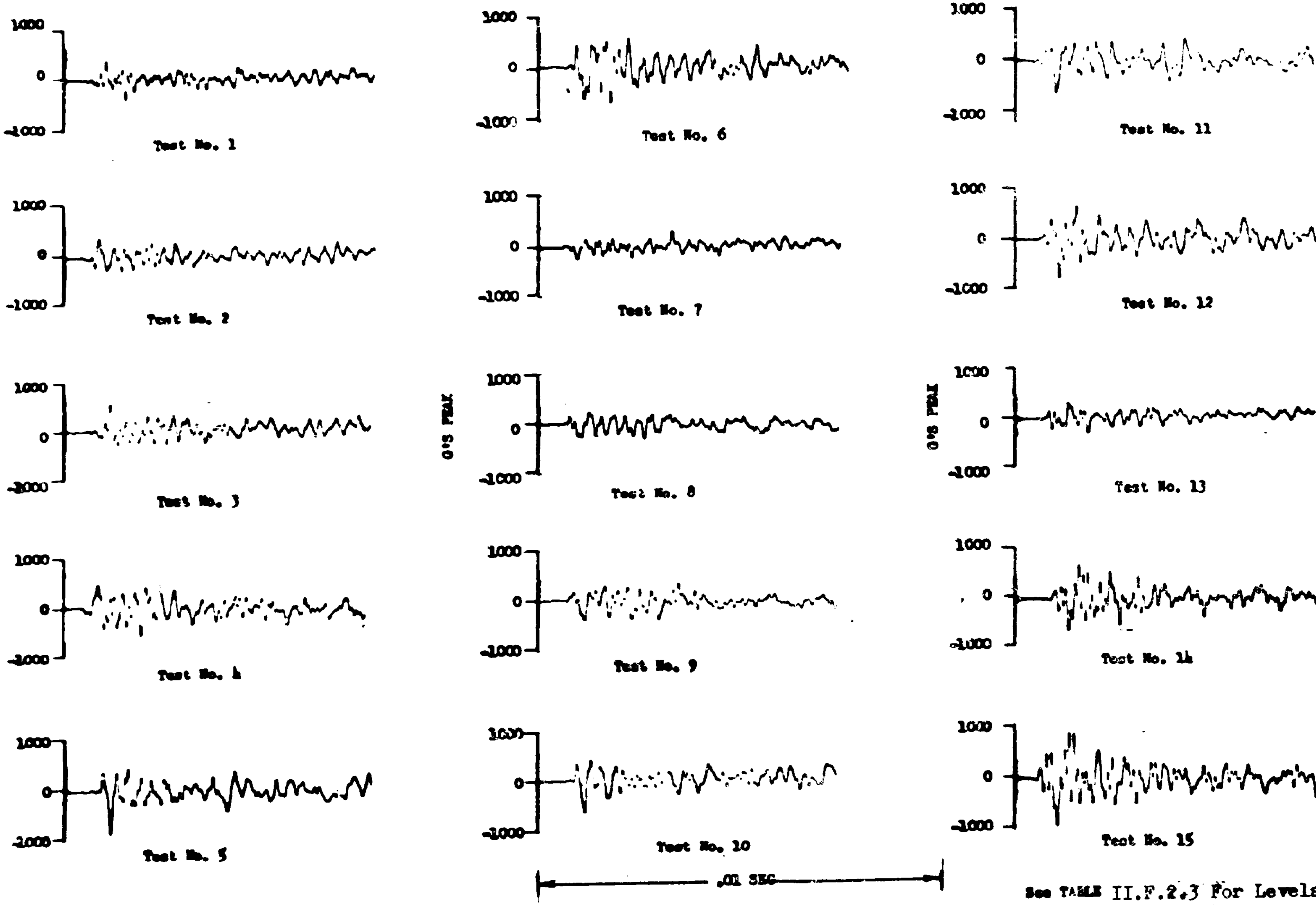
See TABLE II.F.2.3 For Levels

Figure II.F.2.9$_8$ Oscillograms Items 531 - Accelerometer No. 9 (Test 1 to 15)



See TABLE II.F.2.3 For Levels

Figure II.F.2.9$_9$ Oscillograms Item 831 - Accelerometer No. 10 (Test 1 to 15)



See TABLE II.F.2.3 For Levels

Figure II.F.2.9$_{10}$ Oscillograms Item 831 - Accelerometer No. 11 (Test 1 to 15)

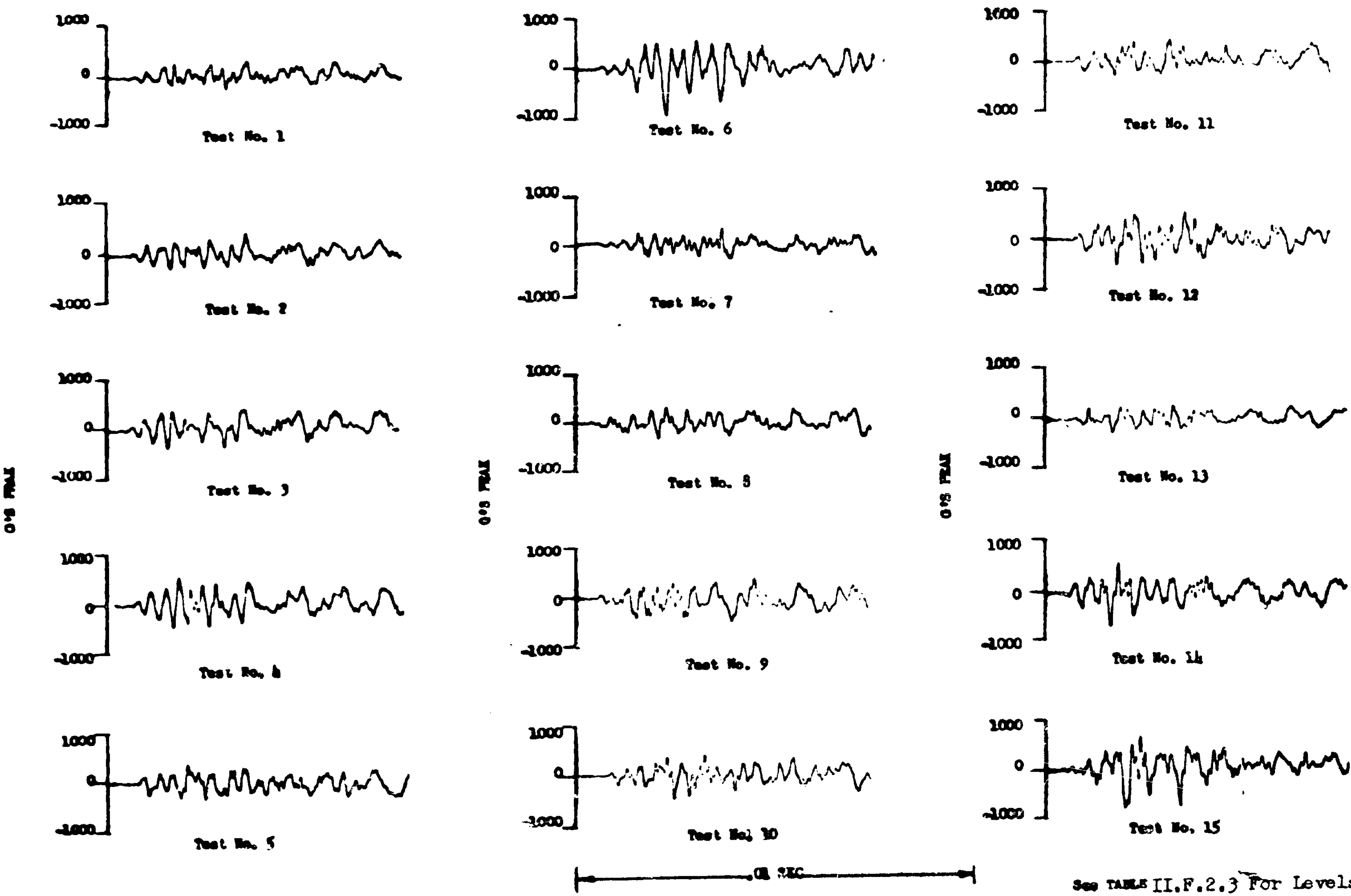
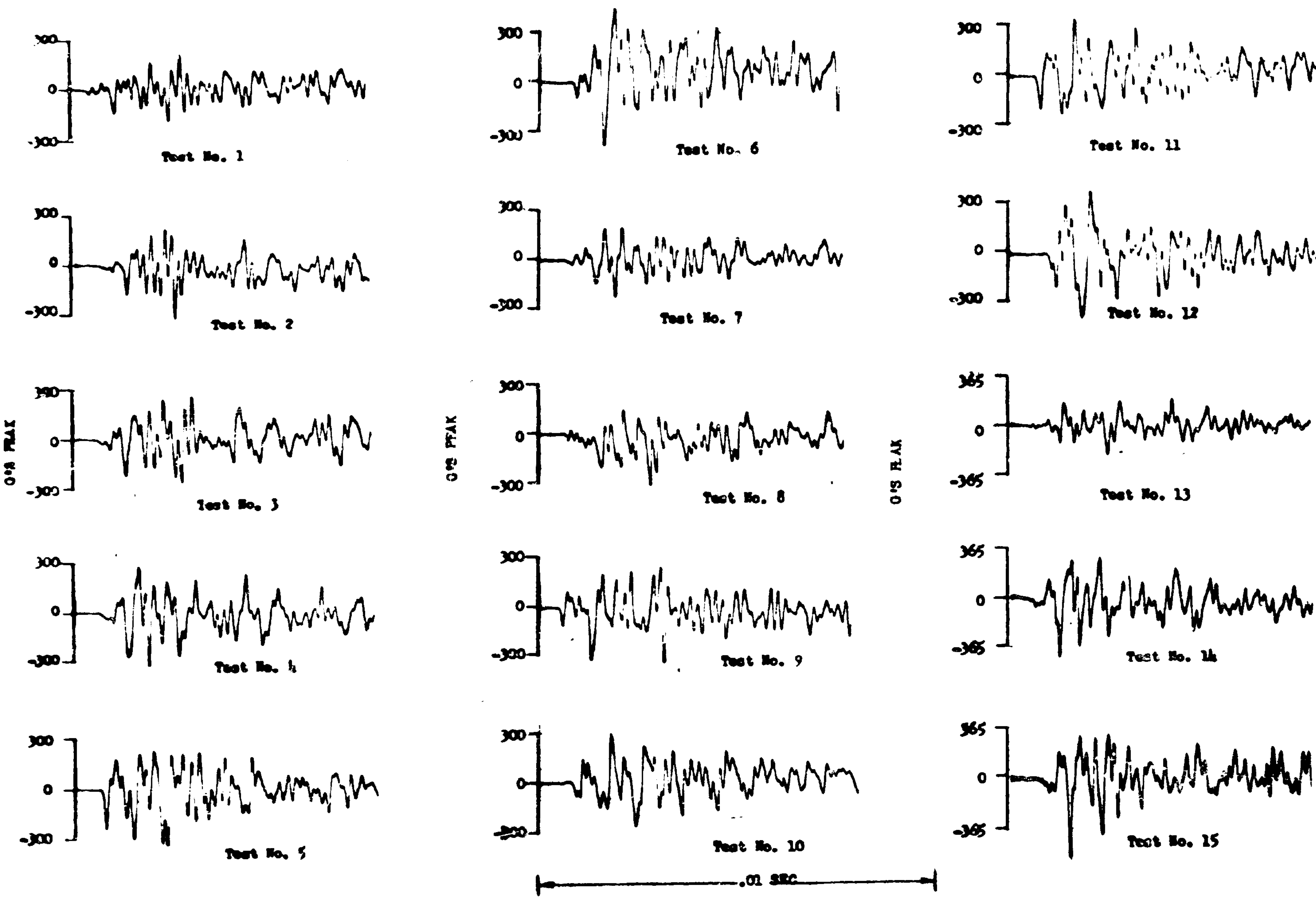
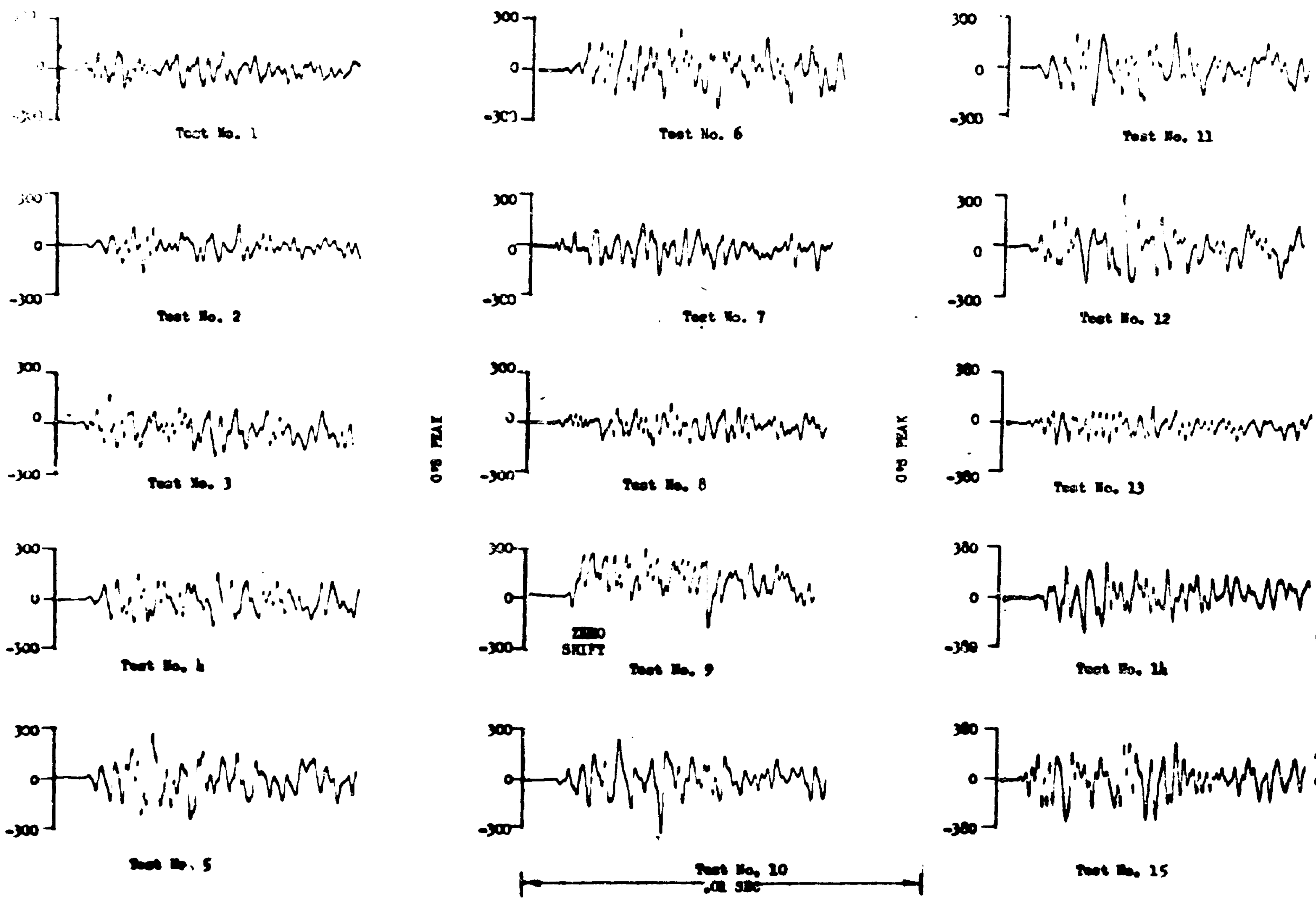


Figure II F.2.9₁₁ Oscillograms Item 831 - Accelerometer No. 12 (Test 1 to 15)



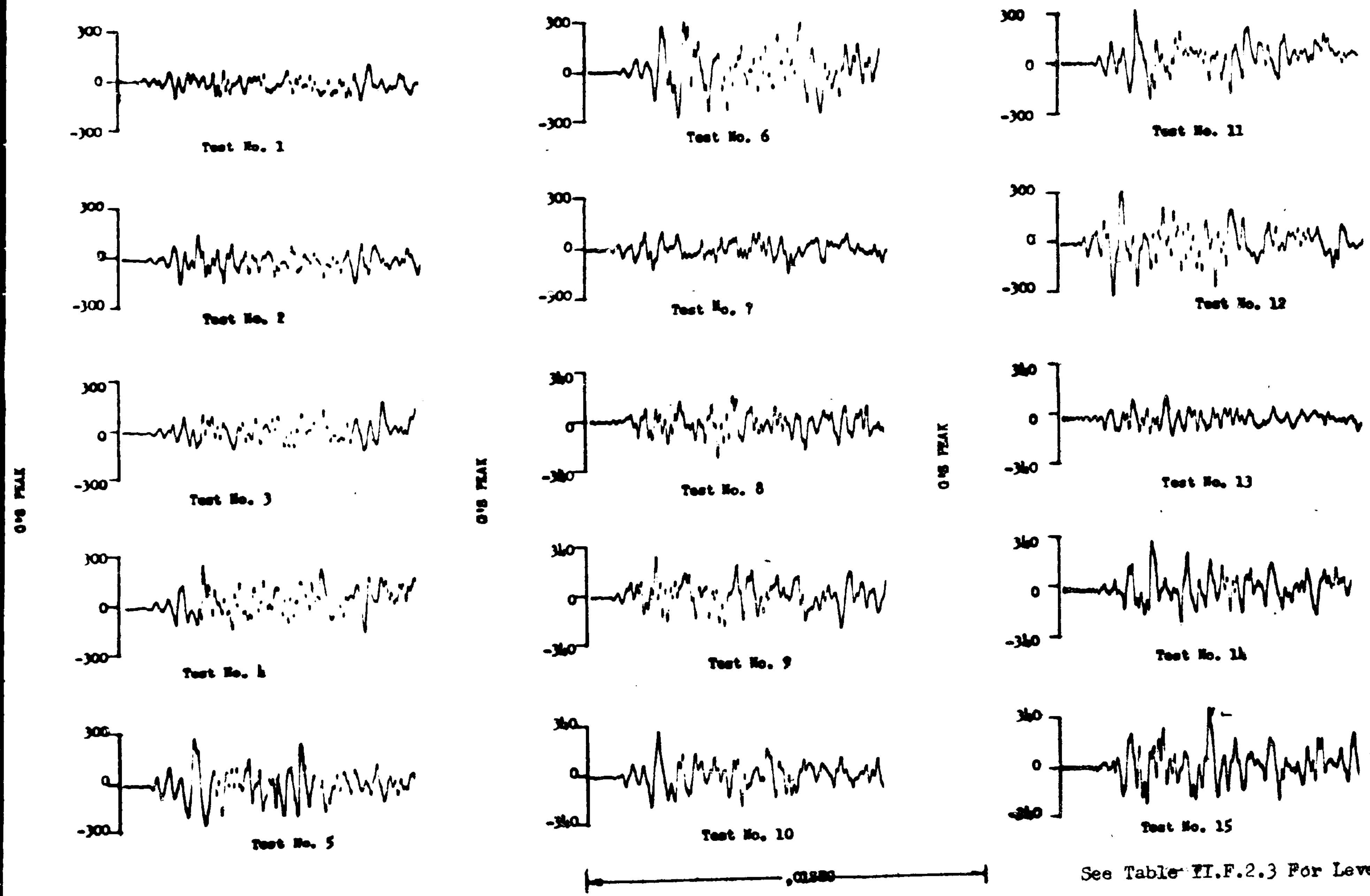
See Table II.F.2.3 For Levels

Figure II.F.2.9$_{12}$ Oscillograms Item 831 - Accelerometer No. 13 (Test 1 to 15)



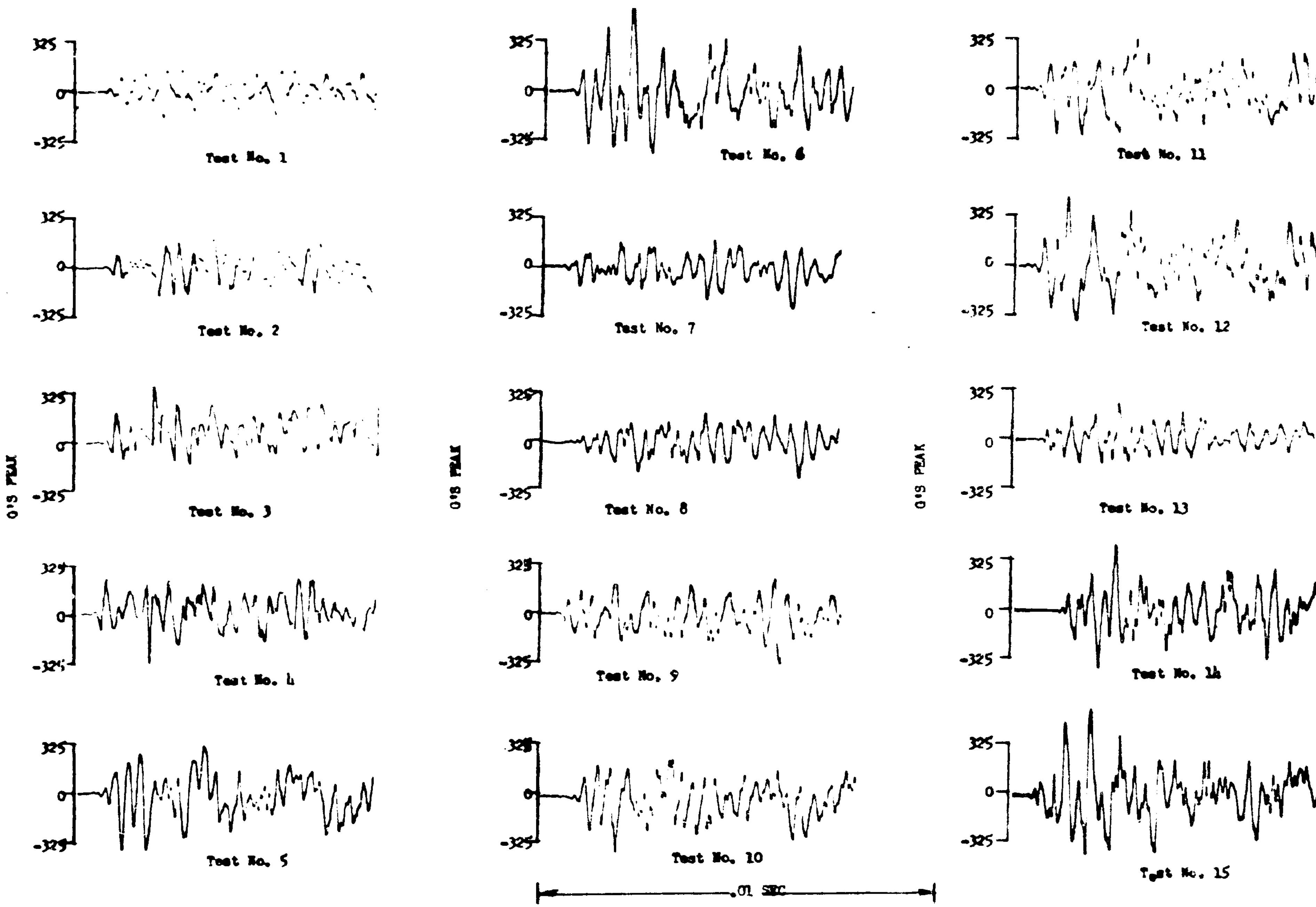
See TABLES II.F.2.3 For Levels

Figure II.F.2.9[13] Oscillograms Item 831 - Accelerometer No. 14 (Test 1 to 15)



See Table II.F.2.3 For Levels

Figure II.F.2.9$_{14}$ Oscillograms Item 831 - Accelerometer No. 15 (Test 1 to 15)



See TABLE II.F.2.3 For Levels

Figure- II.F .2.[illegible] Oscillograms Item 831- Accelerometer No. 16 (Test 1 to 15)

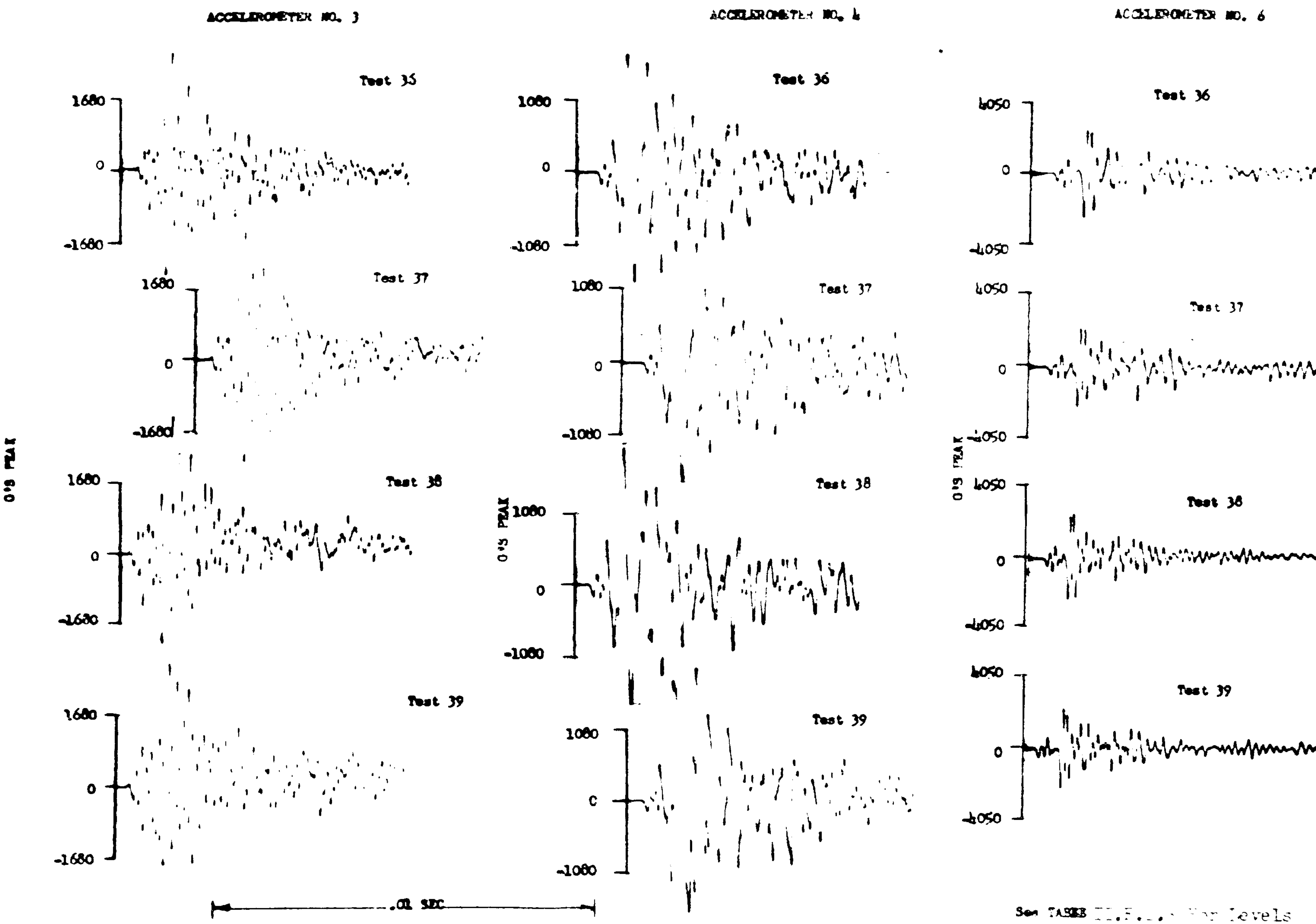


Figure II.F... Oscillograms Accelerometers 3, 4 and 6 Tests 36, 37, 38, and 39

See TABLE II.F... for levels

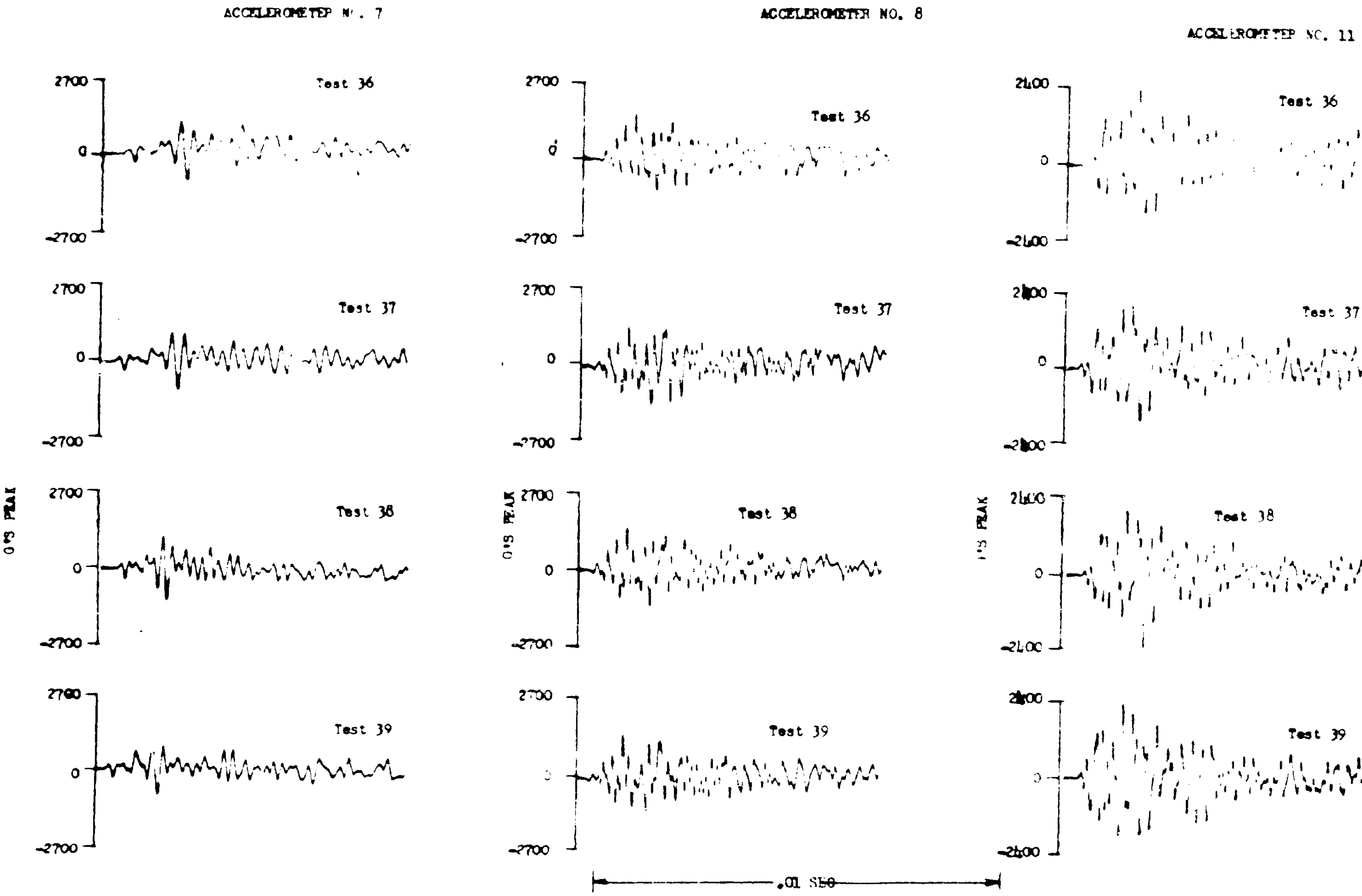


Figure II.F.2. Oscillograms Accelerometers 7, 8 and 11 Tests 36, 37, 38 and 39 See TABLE II.F.2. For Levels

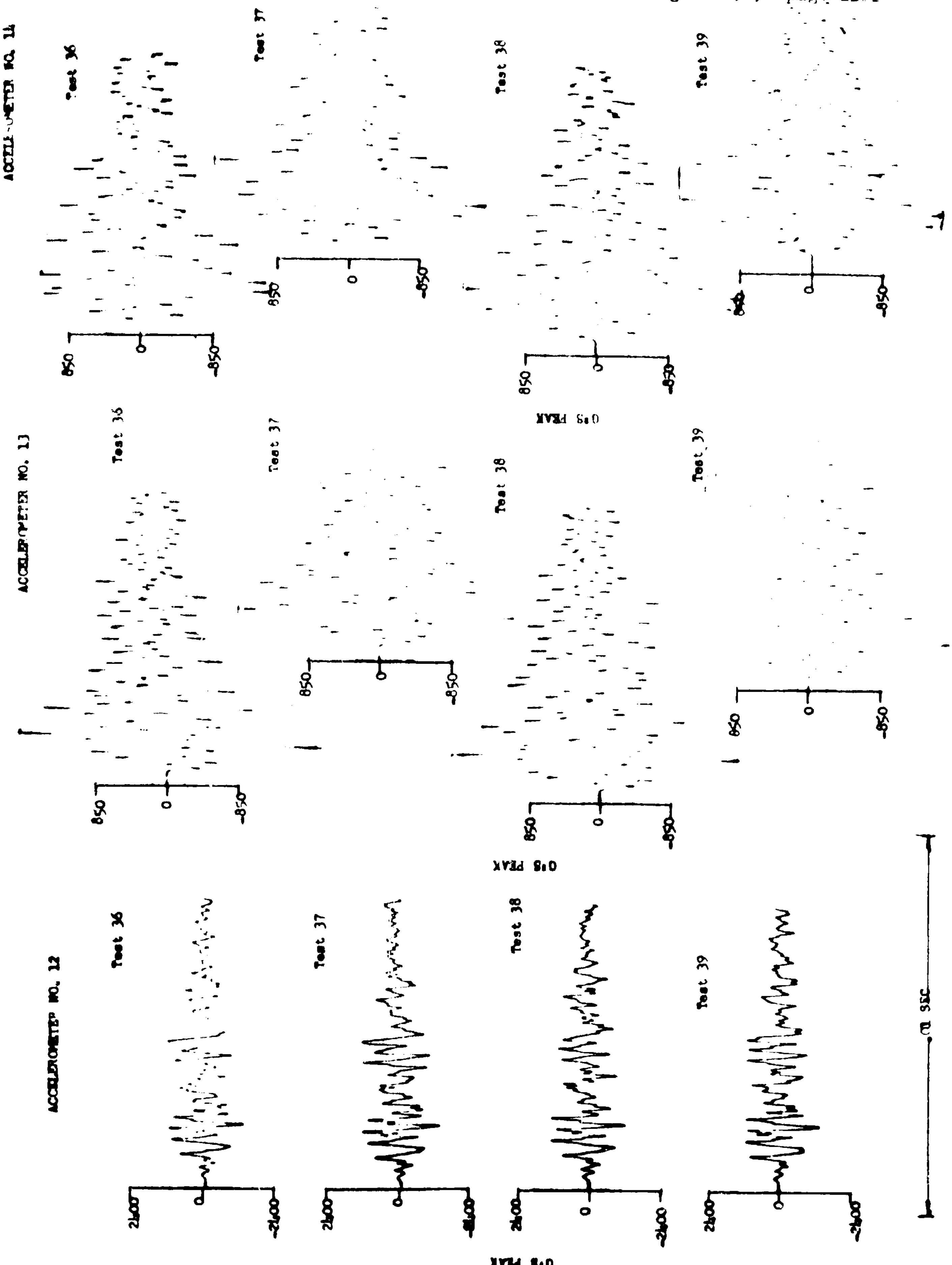


Figure III.?.?.? Oscillograms Accelerometers 12, 13 and 14 (Tests 36, 37, 38 and 39) See TABLE [illegible] For Levels

9

ACCELEROMETER NO. 15

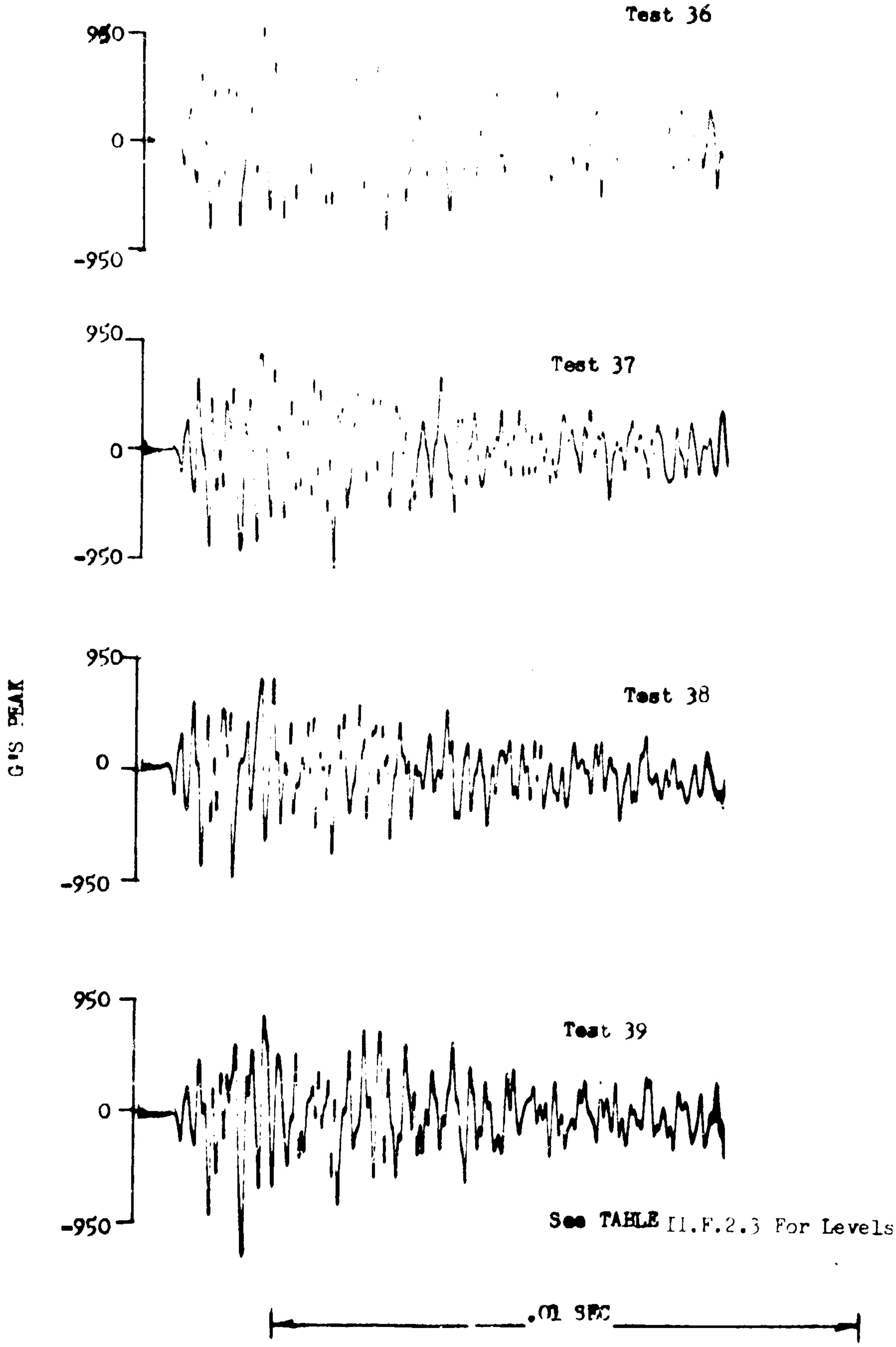


Figure II.F.2.9$_{19}$ Oscillograms Accelerometer No. 15 (Test 36,37,38, and 39)

II.F.3 CONCLUSIONS

The Transfer Table has a number of limitations which make it undesirable to use as a pyro shock test facility. These are: the Transfer Table response is dependent on the geometry of the table, the maximum attainable shock does not produce a sufficient overtest to qualify equipment for all events, the size of equipment which may be tested on the Transfer Table is limited to a 10-inch cube, and since many unknowns still exist as to the exact nature of pyro shock, it is undesirable to try to simulate the shock event by artificial means. The Transfer Table has some limited use in development testing of small equipment when the shock severity is within the range of the Transfer Table capability.

Since the Barrel Tester duplicates the actual vehicle structure and the booster separation joint to a considerable detail, the shock response bears close resemblance to the actual vehicle response to booster separation. As such, the barrel is especially adaptable to qualifying equipment for the booster separation, shroud separation, and horizon sensor fairing events. The Barrel Tester has also been used successfully to qualify equipment for other events such as pin puller actuation. A study which was conducted to determine the repeatability of the barrel tests indicates that the Barrel Test levels are repeatable within a factor of 1.7 in Bay I and within a factor of 1.55 in Bay II based on the 25th and 75th percentile shock spectrums. The Barrel Tester is capable of qualifying vehicle equipment regardless of size as well as many substructures such as pods, guidance modules, and subsatellites. The Barrel Tester has been used continuously over a period of five years since its development to successfully qualify over 119 separate items of equipment.

S E C T I O N III

SUBJECT:

GENERAL ANALYSIS

SECTION III

SUMMARY

This section is subdivided into two subsections A and B. Subsection A is a review of the analysis performed in Section II. It is intended to provide a general view of these analyses and point out some areas of interest.

Subsection B presents a statistical analysis performed on pyrotechnic shock test data to estimate repeatability and confidence level attainable for full scale vehicle testing.

The subjects treated by the analysis performed in Section II are:

a. Shock attenuation versus distance from the shock source.

b. Shock reduction as a function of the shock source configuration.

c. Repeatability of the shock environment from several tests.

d. Effect of the amplification factor "Q."

e. Comparison of 1/3 octave and narrow band shock spectrums.

f. Prediction of shock levels based on experimentally determined attenuation curves. (Comparison with actual levels).

g. Attenuation provided by specimen mounting brackets and isolators.

It will be noted that the above analysis are only intended to define trends and point out areas of interest. The purpose of this compilation was to collect, organize and present pyrotechnic shock data, thus the major effort was devoted to this end.

An effort has been made to define areas where more investigations appears to be needed in order to advance the State of the Art so that better shock load prediction and improved design of structures and equipment may be achieved.

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SECTION III

SECTION III-A

GENERAL ANALYSIS

SUBJECT:

INDEX SUMMARY OF ANALYSIS PERFORMED

IN SECTION II

SECTION III-A - Summary - Index of Analyses Performed in Section II

SECTION III-A.1 - GENERAL

In view of the bulk of this report, an index of analysis was found necessary to provide easier cross reference. The following list follows the general organization of the report and indicates the type of analysis performed in each section.

SECTION III-A.2 - List of Types of Analysis Performed in Each Section

SECTION II-A - Separation Joints

Report No. 606A - Section II-A.1

Analysis Performed:

a) Error introduced by reading narrow band data in 1/3 octave bands.
b) Correlation between flight and ground tests.
c) Need for reviewing component susceptibility to pyro shock.

Report No. 674 - Section II-A.2

Analysis Performed:

a) Shock attenuation versus distance from shock source.
b) Improve confidence in flight vehicle through full scale testing.
c) Environment severity for both fairing jettison and booster separation systems.

Report No. 768 - Section II-A.3

Analysis Performed:

a) Shock reduction versus small changes to standard joint configuration.
b) Effect of isolators on shock reduction.
c) Effect of brackets on shock reduction.

Report No. 790 - Section II-A.4

Analysis Performed:

a) Shock reduction versus joint configuration for redesigned booster separation systems.

Report No. 1080 - Section II-A.5

Analysis Performed:

a) Shock reduction through use of a strap cutter system.

b) Shock attenuation versus distance from source.

Report No. 1340 - Section II-A.6

Analysis Performed:

a) Repeatability of shock environment.

b) Comparison of 1/3 octave with narrow band shock spectra

c) Improve confidence in flight vehicle through full scale testing.

Report No. 1377 - Section II-A.7

Analysis Performed:

a) Shock attenuation versus distance from shock source.

b) Shock attenuation as a function of frequency.

c) Effect of the amplification factor "Q."

d) Repeatability of the shock environment.

e) Accumulate data for mapping the shock environment of a new vehicle system.

SECTION II-A.8 - General Analysis of Section II-A

Analysis Performed:

Section II-A.8.2 - Shock reduction versus separation joint configuration.

Section II-A.8.3 - Attenuation versus distance from oscillogram data.

Attenuation versus distance from shock spectrum data.

Application of shock attenuation data.

Section II-A.8.4 - Repeatability of the shock environment.

SECTION II-B - Fairing Jettison

Report No. 794 - Subsection II.B.1

Analysis Performed:

a) Repeatability of the shock environment.

b) Attenuation versus joint configuration.

Report No. 867 - Subsection II.B.2

Analysis Performed:

a) Improved results based on modified jettison mechanism development program (Pin puller operated).

Report No. 1353 - Subsection II.B.3

Analysis Performed:

a) Final flight fairing configuration(explosive nut operated).

b) Attenuation versus distance from shock source.

SECTION II.B.4 - General Analysis of Section II.B

Analysis Performed:

a) Attenuation versus joint configuration - Standard Configuration from Section II.B.1 - Pin Puller-Spring Release System II.B.2 - Explosive Nut Spring Release System II.B.3.

SECTION II.C - Pin Actuators

Report No. 1315 - Section II.C.1

Analysis Performed:

a) Proof of satisfactory overtest for flight qualification.

Report No. 1336 - Section II.C.2

Analysis Performed:

a) Force limiters, energy absorbers, elastomer isolators for pin actuators shock level reduction.

b) Repeatability of the shock environment.

c) Pin puller analytical model.

d) Shock levels produced from two different types of squibs.

SECTION II.C.3 - General Analysis of Section II.C

Analysis Performed:

a) Vibration isolators applied to pin pullers.
Payload qualification.

SECTION II.D - Qualification of External Pod for Pyro Shock with Barrel Tester

Report No. 429 - Section II.D.1

Analysis Performed:

a) Shock level mapping survey.

Report No. 447 - Section II.D.2

Analysis Performed:

a) Repeatability of the shock environment.

b) Shock level mapping survey.

SECTION II.D.3 - General Analysis of Section II.D

Discussion regarding shock transmission path through the structure.

SECTION II.E - Equipment Tests Performed on Barrel Tester

Report No. 353 - Section II.E.1

Analysis Performed:

a) Attenuation provided by brackets and isolators.

b) Repeatability of the shock environment.

Report No. 456 - Section II.E.2

Analysis Performed:

a) Attenuation provided by box mounting brackets.

b) Repeatability of the shock environment.

Report No. 535 - Section II.E.3

Analysis Performed:

a) Shock amplification produced by a honeycomb panel

b) Repeatability of the shock environment.

Report No. 543 - Section II.E.4

Analysis Performed:

a) Effect of transmissibility through secondary structure.

b) Effect of reduced explosive charge and joint thickness.

Report No. 547 - Section II.E.5

Analysis Performed:

a) Attenuation provided by specimen mounting bracket.

b) Repeatability of the shock environment.

Report No. 562 - Section II.E.6

Analysis Performed:

a) Attenuation provided by box mounting bracket.

b) Repeatability of the shock environment.

SECTION II.E - General Analysis - Discussion Only

SECTION II.F - Development of Pyro Shock Test Facilities

Report No. 832 - Section II.F.1

Analysis Performed:

a) Variation of environment with tester mechanical parameter.

Report 831 - Section II.F.2

Analysis Performed:

a) Barrel environment compared to the vehicle environment.

b) Effect of joint characteristics and explosive content on shock levels.

c) Repeatability of the shock environment.

SECTION NO. III.B

GENERAL ANALYSIS

SUBJECT:

TEST DEVIATION, CONFIDENCE LEVELS, AND PREDICTION OF SHOCK LEVELS FOR FULL SCALE VEHICLE FULL RING SEPARATION TESTS

SECTION III.B

SUMMARY

This section presents the results of a statistical analysis performed on pyrotechnic shock data. An estimate for test repeatability is obtained and used to analyze the confidence level attainable for full scale vehicle testing. In addition, a method for predicting shock levels for similar joints is derived.

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SECTION III.B

III.B.1 INTRODUCTION

Presented in this section are the results of a statistical analysis performed on pyrotechnic shock test data. An estimate for test repeatability is obtained, and is used to analyze the confidence level attainable for full scale vehicle testing. In addition a method for predicting shock levels for similar joints is derived.

III.B.2 DISCUSSION

III.B.2.1 Full Ring Separation Joint Pyrotechnic Shock Test Deviation

The variation of pyrotechnic shock data at any given point in the structure was examined by performing a statistical analysis of shock spectra derived from test data. The conclusions of this analysis are based on the assumption that all variation was due to differences in the excitation event and not in subsequent data analysis, etc. This excitation can vary in frequency content between tests, so that even for the same apparent peak amplitude input (i.e. peak g's), the structure may be excitated differently, resulting in different shock spectra for the same location. This fact is used to derive two estimates of the expected deviation. The first estimate is obtained by examining the variance of the shock spectra response at one point on a structure for 22 tests, and the second estimate is obtained by analyzing the response at 22 locations on one structure for two tests.

Presented in Table III.B.1 is the basic shock spectra data for one accelerometer location on the LMSC barrel tester which was monitored during 22 pyrotechnic qualification shock tests. Using this data, a log-normal distribution was fitted to the 22 points for each 1/3 octave frequency band, and the corresponding logarithmic-means and deviations were obtained. Table III.B.2 lists the results of this analysis. The results are also plotted in Figures III.B.1 to III.B.3. The actual distributions for the 500, 1000 and 5000 Hz 1/3 octave bands are plotted in Figure III.B.4 for the axial direction and are typical of the kind of fit that can be expected.

Since a log-normal distribution is assumed, the deviation can best be expressed as a ± db deviation about the nominal value. This is tabulated in Table III.B.2 and presented graphically in Figure III.B.5 as a function of frequency for each of the axes.

Data from 22 measurements monitored during two pyrotechnic tests of a vehicle was used to derive the second estimate of the variance. The ratio of test 1 to test 2 shock spectra levels for each accelerometer location was obtained and a log-normal distribution fitted to these ratios for each 1/3 octave band. Table III.B.3 presents the basic data and Table III.B.4 tabulates the results. Figure III.B.6 is a plot of the 16, 50 and 84th percentile levels (log-mean and $\pm$ one sigma levels) of the ratio as a function of frequency.

As before, the deviation is expressed as $\pm$ db, and is plotted in Figure III.B.5. This second estimate shows close agreement with the previous estimate. Examination of Figure III.B.5 indicates that the deviation is independent of frequency except at the lower frequencies in which the deviation is higher than for the rest of the spectrum. The majority of the points lie between 2.5 and 5 db.

Figures III.B.1, III.B.2 and III.B.3, which are plots of the 50th percentile and $\pm$ 1 sigma shock spectrums, show that the radial spectrum would comprise most of the envelope spectrum. The deviation for the radial spectrum from Figure III.B.5 is mostly less than 4 db. It is therefore concluded that a deviation of $\pm$ 4 db (1.59 factor) is a conservative estimate of the distribution that can be expected from pyrotechnic shock data.

III.B.2.2 Confidence Levels for Full Scale Vehicle Separation Joint Pyrotechnic Shock Tests

The results from the preceeding section were used to establish the test requirements and confidence levels for pyrotechnic shock qualification testing.

In the ensuing analysis it is assumed that nominal flight levels can be derived, and that overtesting is to be performed by detonating the pyrotechnic device on an actual flight-type structure.

Four parameters may then be used to determine test requirements:

1. Overtest factor - that factor by which the overall shock amplitude is increased by varying the shock test parameters.

2. Qualification level - that level, relative to the nominal shock amplitude, which is considered adequate for qualifying equipment for flight. (SEE PARAGRAPH III.B.2.4)

3. Confidence level - the degree of confidence, expressed as a probability, that qualification levels have been exceeded at least once.

4. Number of tests - the number of detonations of the pyrotechnic event on the structure.

Overtest levels may be established by adding a constant factor to the nominal level, or by relating it to the amplitude distribution expected for flight. For the present analysis two overtest levels are assumed; 6 db above nominal (factor of 2 on g's 0 - P) and 95th percentile. It is assumed that the response has a log-normal distribution with a deviation of $\pm$ 4 db as derived in Section III.B.2.1. Therefore, if the normalized nominal value is 1.00, the corresponding overtest levels are:

Percentile	db	Factor
93.2	6.0	2.00
95	6.6	2.15

The confidence level for a single test, or, equivalently, the probability of exceeding qualification, is function of the overtest factor used in test.

Assuming a log-normal distribution, i.e., a normal distribution of logarithms

where: α = log-mean

β = log-deviation

z = standard normal distribution

P = P (exceeding qual level)

a = overtest factor - additive constant (ln a) for log-normal distribution

x = random variable, shock level

X = specific value of random variable

i = subscript for the i^{th} percentile

q = subscript for qual level

t = subscript for test level

n = subscript for nominal level

then $$P = P\left[x_t \geq X_q\right] \quad (1)$$

$$P = P\left[\ln x_t \geq \ln X_q\right] \quad (2)$$

where $f(\ln x_t) = N(\alpha_t, \beta_t)$

An overtest factor (a) for testing can be expressed as

$$\alpha_t = \alpha_n + \ln a \quad (3)$$

$$\beta_t = \beta_n \quad (4)$$

Expressing the overtest level as a percentile value - i - of the nominal level

$$\ln Xq = Z_i \beta_n + \alpha_n \qquad 5$$

and re-arranging the test parameter into a standard normal random variable

$$P = P\left[\ln x_t \geq Z_i \beta_n + \alpha_n\right] \qquad 6$$

$$P = P\left[\frac{\ln x_t - \alpha_t}{\beta_t} \geq \frac{Z_i \beta_n + \alpha_n - \alpha_t}{\beta_t}\right] \qquad 7$$

substituting 3 and 4 into 7 leads to

$$P = P\left[\frac{\ln x_t - (\alpha_n + \ln a)}{\beta_n} \geq \frac{Z_i \beta_n - \ln a}{\beta_n}\right]$$

where $\frac{\ln x_t - (\alpha_n + \ln a)}{\beta_n}$ is N (0,1)

Using the fact that the deviation is 4 db (1.59 factor or $\beta_n = \ln 1.59 = 0.464$), and

$$Z_{93.2} = 1.492$$

$$Z_{95} = 1.645$$

P is derived as a function of -a- from tables of the standard normal distribution, and is plotted in Figure II.B.7 for the two overtest levels.

As can be seen in Figure III.B.7 the confidence level for one test is low unless a large overtest can be achieved. Since it is impractical to achieve overtest values greater than two (see Section III.B.3), a multiple firing test program must be considered.

The confidence level for multiple tests was derived from the binomial distribution and yields the relation:

$$P_J = 1 - (1 - P_1)^J$$

where

j = number of tests

P_1 = confidence level for one test

P_j = confidence level for j tests

Figure III.B.8 plots the number of tests required as a function of the overtest factor, to achieve a confidence level of 95 percent for both of the overtest levels. A large number of tests, however, is not considered desirable, and based on engineering judgment, a maximum of three tests on one structure is established as a limit. The confidence level for two and three tests is shown in Figure III.B.9 and indicates the low level associated with reasonable overtest factors.

As previously mentioned the above analysis was performed using two fixed values for overtest levels. These overtest levels may be reduced to obtain higher confidence levels. Figures III.B.10 and III.B.11 cross plot the confidence level as a function of overtest levels for various overtest factors for two and three tests and indicate the tradeoff associated with these two parameters.

Since high confidence levels cannot easily be obtained by performing pyrotechnic shock tests on flight type structure, this type of test procedure is considered less desirable for qualifying equipment for flight. Instead a separate facility, such as the LMSC Barrel, which can produce a larger overtest factor, should be used.

III.B.2.3 Prediction of Peak G Shock Levels of Similar Full Ring Separation Joints

Data from the barrel tester was used to predict peak g levels when explosive size and joint thickness are varied. This data was especially suitable since it documents the same accelerometer locations for a series of tests in which the two essential parameters were varied: joint thickness and number of grains per foot. Table III.B.5 lists the basic data (peak g's recorded for each acceleration time history).

Various attempts were made to determine an empirical relationship between the test levels. The best results were obtained from this analysis by comparing the average ratio between tests for similar joints to the non-dimensional parameter:

$$\left[\frac{t_2}{t_1} \; \frac{G_2}{G_1}\right]$$

where

t = thickness of joint

G = number of grains/foot

The average ratio was obtained by ratioing the levels between tests for each accelerometer and obtaining the arithmetic mean of this sample. This data is tabulated in Table III.B.6 and plotted in Figure III.B.12.

Examination of Figure III.B.12 indicates that an expression of the form

$$f = \left[\frac{t_2}{t_1} \; \frac{G_2}{G_1}\right]^{1/3}$$

where f = average factor between tests

fits the data reasonably well. It is important to note that a large amount of scatter is considered reasonable because of the deviation expected per test as described in Section II.B.2.1.

Further analysis indicated that a better fit could be obtained by altering the above expression to

$$f = K\left[\frac{t_2}{t_1} \; \frac{G_2}{G_1}\right]^{1/3}$$

where

K = correction factor dependent on grain size ratio

Table III.B.7 presents the K values which were determined based on the above test data. Plotted in Figure III.B.13 is

$$f/K \text{ vs } \left[\frac{t_2}{t_1} \quad \frac{G_2}{G_1}\right]$$

and shows the improvement achieved with this alteration.

The above expression indicates the relative insensitivity of shock levels to the parameters examined. Thus, as mentioned in Section III.B.2.2 it is difficult to obtain large overtest factors without changing the joint design.

Of interest is the accuracy with which this empirical relation can predict peak g levels for a given accelerometer location when grain size and thickness are varied. This was accomplished by ratioing the actual factor between tests at each accelerometer location to the predicted factor for identical joints. This data is plotted in Figure III.B.14 as a frequency distribution for octave bands of the grain and thickness ratio. Figure III.B.14 shows the close agreement between predictions and actual data which can be achieved by the above method for extrapolating data.

A similar comparison was made by comparing the predicted ratio to actual ratio for two dissimilar joints, using the above relationship. The results are plotted in Figure III.B.15 and show that a shift in overall levels occurred because of joint design and in addition that a considerable increase in deviation is noticed. Thus the above extrapolation technique is not considered applicable for predicting shock levels for joints of dissimilar design.

III.B.2.4 CONSIDERATIONS FOR QUALIFICATION TESTING

In the present State of the Art, the establishment of qualification test criteria is defined in a different manner by each contractor.

In order to provide a common basis for the definition of these criteria, one possible procedure is presented on Figure III.B.16 which shows in a compact form the various parameters and their relationship.

III.B.3 CONCLUSIONS

An estimate of ± db (1.59 factor) deviation was derived from shock test repeatability. Based on this estimate, it was shown that high confidence level testing on flight type structure is undesirable because of the large number of tests, and/or large overtest factors necessary (Figure III.B.8).

A method for predicting shock levels for similar joints has been derived using joint thickness and explosive content as parameters. The results of this analysis indicate the difficulty in obtaining large overtest factors without redesigning the joint.

Until the Industry establishes some suitable guidelines for the establishment of pyrotechnic shock qualification criteria, this area remains dependent on the experience and on the methods of each individual Contractor. Therefore, it appears necessary to provide a common basis for establishing qualification criteria. Figure III.B.16 shows one possible method.

Although the analysis shows that it is difficult to obtain high overtest levels in tests using flight hardware, it is, however considered that performing flight level testing significantly improve confidence in the ability of the vehicle to survive flight.

TABLE III.B.1

BASIC SHOCK SPECTRUM DATA FROM ONE LOCATION
AND 22 TESTS ON LMSC BARREL TESTER

PEAK SHOCK SPECTRA RESPONSE g's O-P

LONGITUDINAL

One location - 22 Tests

1/3 octave center frequency - Hz -

Test	Firing	200	250	320	400	500	630	800	1000	1250	1600	2000	2500	3200	4000	5000	6300	8000
Chg. Controller 538-3	1	115	129	176	376	675	1699	1423	999	1518	3214	2719	2471	4173	3336	1935	1139	963
	2	112	158	284	333	485	1744	1769	915	1363	1725	3265	2251	3312	3204	1889	1804	1389
Flap J-Box 555	1	212	285	297	340	430	738	2525	880	840	1400	1800	2900	3200	3000	4100	4800	2900
	2	125	170	251	280	250	1129	2400	1120	2550	2300	1650	3400	4350	5600	1050	7000	3600
Flt Cont. Elec. 520	1	145	206	448	426	528	1301	4384	1760	2821	2622	4231	4402	4571	3502	8823	3832	2869
	2	128	238	348	411	502	1177	3545	1603	2737	2338	4335	4317	5356	3691	7315	3576	2421
CLU Develop. 487	1	120	160	253	405	555	1393	4284	1359	1273	1608	5800	5745	3114	5206	6556	6207	3179
	2	83	122	172	250	418	869	3267	1399	1140	1354	3006	5784	3378	2341	4067	5452	3270
AC Pwr & TLM J-Box 528-3	1	87	100	186	284	731	1217	1751	775	991	1099	2407	2674	3139	5112	2239	2452	1423
	2	80	132	138	236	560	925	1909	701	686	960	2921	2083	2358	4229	1606	1717	1034
CMD logic 422-3	1	221	329	254	389	596	1122	2310	1068	1760	2167	4884	6065	4205	7451	4473	3074	2209
	2	172	229	252	437	652	1745	1773	1227	1241	1744	2549	3993	2137	2141	1927	1284	984
TDM & RDM 353-3	1	82	154	290	447	812	1583	1671	959	1879	2130	6208	3813	2794	3512	2892	2774	4054
	2	80	129	297	499	870	1383	1627	1276	1384	2882	4959	4096	2081	3011	2972	1743	2807
L-System 470	1	135	186	272	289	406	650	2414	836	920	1271	3884	7081	2709	2926	5206	3722	2557
	2	125	174	254	283	385	939	1965	1103	977	2025	4957	7826	3256	3642	6777	3461	3082
Blt Can & J-Box 540	1	246	266	346	469	697	1207	1448	797	913	1361	4566	2869	3500	5762	4713	2932	2064
	2	280	258	389	477	803	1242	1422	438	930	1406	3745	2885	2790	5311	4977	3610	2602
Unit G & I 534	1	199	263	255	464	886	1723	2196	1350	1710	3425	3560	4581	3838	4658	2892	2180	3681
	2	190	144	253	348	344	882	3284	1088	910	1089	1921	3567	2863	6575	2768	2859	1935
CMD Relay 465	1	32	43	135	192	325	652	834	499	722	1430	1582	4946	3129	4126	2369	1658	1789
	2	168	243	283	266	265	269	431	628	1278	1463	3362	2962	3313	2714	3175	2779	2897
R A D I A L																		
Chg. Controller 538-3	1	157	461	527	782	1031	1604	1802	1560	2770	6560	5173	3806	5125	4429	3978	2920	1864
	2	131	393	396	751	1454	1487	1762	1958	4221	3647	4525	2594	5415	3973	3917	4412	2292
555 Flap J-Box	1	390	480	555	650	1100	1203	2600	1600	2600	2775	3200	2200	2675	2500	2800	2970	2000
	2	130	270	500	600	1000	2073	3000	2500	2870	3850	5500	4500	3210	4050	4300	4500	2700
Flt. Cont. Elec. 520	1	150	213	279	398	899	1808	3741	3068	3191	4565	6507	4100	3964	3208	4456	4156	2760
	2	113	192	257	438	889	1952	3652	3038	3416	4358	6323	3862	3484	3187	4424	3574	3139
CLU Develop. 487	1	79	122	392	598	596	934	3469	1725	2985	2511	3778	2048	1829	2515	2452	1581	1493
	2	54	105	290	391	783	1252	2994	2575	2217	3004	4744	2772	2220	2982	4774	3841	3079
AC Pwr & TLM J-Box 528-3	1	95	217	519	556	707	976	1785	1704	2983	2655	3481	2313	3576	3799	4053	4414	2745
	2	106	139	316	570	825	569	1939	1959	2616	2454	3681	2443	3474	4002	4018	4428	2848

TABLE III.B.1(cont.)

RADIAL (Cont'd)

Test	Firing	200	250	320	400	500	630	800	1000	1250	1600	2000	2500	3200	4000	5000	6300	8000
GND Logic	1	119	241	293	445	673	918	2549	1295	2830	2977	3920	4524	2994	3567	4938	5003	3010
422-3	2	151	277	407	812	929	3800	1557	1601	1994	2798	2978	2581	1811	2339	1843	1288	1203
TRM & RRM	1	80	265	218	359	860	1235	1373	2118	3826	3567	4216	4799	4455	3600	4037	3289	2908
353-3	2	[illegible]	136	224	444	440	732	1517	1103	3544	3852	6521	7122	4014	4443	4736	3688	2967
L-System	1	105	179	300	358	870	639	2543	2069	4807	4163	5264	3680	2455	5068	5406	3778	2455
470	2	98	214	321	297	597	699	2534	2220	4805	3852	4907	3993	2537	5088	5446	3479	2453
Blt Can & J-Box	1	251	333	595	708	1210	2201	1172	2716	3399	3366	2857	2053	3098	3615	3806	3869	1878
540	2	264	340	537	650	1344	2487	1772	2264	3586	3781	2886	2036	2304	4011	4040	2835	1886
Unit G & I	1	302	412	549	725	968	2423	3875	3015	5191	7004	10576	8282	7264	5957	9983	9135	4445
534	2	254	171	407	570	975	1284	4517	2189	3124	4489	4938	4690	5256	6120	5319	6429	5744
GND Relay	1	86	201	288	285	794	1095	1656	1115	3551	2326	2847	3239	2804	2603	3371	2493	2816
465	2	132	258	484	703	904	923	1281	1075	3651	2253	2918	3014	2772	2459	2819	2537	3184

TANGENTIAL

Test	Firing	200	250	320	400	500	630	800	1000	1250	1600	2000	2500	3200	4000	5000	6300	8000
Chg. Controller	1	76	109	146	180	234	211	444	805	1761	1675	1070	2087	2784	2982	3009	3589	1824
538-3	2	65	147	127	163	259	298	484	809	1613	2005	4245	2836	2936	3086	3569	3043	1919
SSS Flap J-Box	1	970	1150	1225	1240	1140	1025	910	870	1000	1470	1405	2550	2190	2700	3950	3640	2500
	2	80	120	120	170	165	250	290	310	460	650	800	1400	1600	2420	2900	3170	2300
Flt Cont. Elect.	1	51	76	142	144	200	212	550	368	263	698	1183	1254	1714	2362	2149	1758	2165
520	2	89	92	132	180	195	236	505	366	479	891	1168	1298	2386	2872	2482	3372	1988
CLU Develop	1	60	142	140	144	343	181	316	632	1111	2381	1828	3239	2847	2343	6156	3182	1890
487	2	67	92	112	131	374	298	510	581	1070	1642	1437	2257	2592	3359	6043	3632	3186
AC Pwr & TLM J-Box	1	93	95	177	154	274	359	480	715	1459	2231	3666	4292	3748	3172	5779	4227	2451
508-3	2	83	72	194	97	277	343	424	574	1031	1903	2984	3751	3903	3232	6102	4434	2165
GND Logic	1	135	128	158	236	198	354	454	783	1866	1724	4274	5278	4299	3882	3803	3705	2172
422-3	2	56	139	128	104	163	405	703	711	1576	1128	3407	4310	5410	4487	5755	4192	2707
TRM & RRM	1	53	74	127	97	209	185	331	366	1383	2176	3929	5536	3967	2339	4363	4216	2649
353-3	2	74	103	193	111	186	174	503	614	1360	2174	3168	3980	5916	2717	4735	5331	4025
L-System	1	135	163	168	202	296	405	420	578	1197	1797	1610	2162	2341	2605	3447	3666	1850
470	2	219	193	247	218	340	375	431	1050	1317	1646	1686	2583	3435	2510	4757	2936	2143
Blt Can & J-Box	1	115	157	262	259	345	463	419	519	1150	1583	1887	2844	3196	4534	2895	3069	2145
540	2	126	191	155	185	344	408	448	598	1195	1260	1970	2577	4515	3889	2889	2812	1833
Unit G & I	1	242	166	216	198	321	491	586	887	1365	1971	3180	5009	11639	8333	9599	10654	7206
534	2	252	137	242	270	275	266	427	868	998	1941	2891	3526	4351	4659	4396	5204	5804
GND Relay	1	168	243	283	266	265	249	431	628	1278	1463	3362	2962	3313	2724	3175	2779	2097
465	2	188	197	275	306	373	312	452	790	1324	1473	3086	3075	3074	2554	3189	4112	3158

TABLE III.B.2

LOG-MEAN , + 1 SIGMA AND DEVIATION OF BASIC
SHOCK SPECTRUM DATA FROM LMSC BARREL TESTER

1/2 Oct Center Frequency	50 Percentile	84 Percentile + 1 sigma	16 Percentile - 1 sigma	Deviation ± db	50 Percentile	84 Percentile + 1 sigma	16 Percentile - 1 sigma	Deviation ± db	50 Percentile	84 Percentile + 1 sigma	16 Percentile - 1 sigma	Deviation ± db
200	125	220	72	4.90	133	238	75	4.98	109	238	50	6.65
250	163	282	94	4.73	233	380	146	4.11	112	250	74	5.75
320	241	370	157	3.73	375	490	330	3.14	187	375	105	5.04
400	334	500	222	3.59	525	760	370	3.16	188	345	102	5.38
500	518	81-	332	3.89	872	1200	550	2.71	276	440	175	4.07
650	1141	1610	805	3.03	1302	2300	740	4.90	312	500	197	4.00
800	2046	3400	1250	4.34	2281	3600	1500	3.70	467	625	350	2.52
1000	1601	1470	690	3.26	1986	2800	1300	3.22	563	1050	300	5.40
1250	1235	2020	750	4.32	3280	4350	2500	2.38	1100	1900	650	4.64
1600	1750	2685	1180	3.55	3514	5000	2500	3.01	1554	2170	1030	3.51
2000	3264	5300	2100	4.03	4357	6500	3000	3.38	2194	3950	1250	5.02
2500	3913	6000	2300	3.61	3390	5300	2200	3.89	2886	4700	1800	4.20
3200	3220	4250	2400	2.40	3275	5000	2200	3.55	3373	5600	2100	4.30
4000	3956	5600	2800	[illegible]	3655	5050	2650	2.79	3180	4600	2250	3.04
5000	3305	6250	1880	5.47	4088	6000	2800	3.31	4045	6150	2700	3.61
6300	2776	5000	1550	4.99	3539	5600	2300	3.97	3708	5500	2500	3.31
8000	2225	3700	1250	4.27	2576	3800	1760	3.35	2569	3900	1700	3.60

TABLE III.B.3

BASIC SHOCK SPECTRUM DATA FROM 22 LOCATIONS
AND 2 TESTS ON A FULL SCALE VEHICLE

Frequency -Hz-	ACCELERATION 13R Test 1	ACCELERATION 13R Test 2	ACCELERATION 13R RATIO Test 1 / Test 2	ACCELERATION 16R Test 1	ACCELERATION 16R Test 2	ACCELERATION 16R RATIO Ratio 1/2	ACCELERATION 18X Test 1	ACCELERATION 18X Test 2	ACCELERATION 18X RATIO Ratio 1/2	ACCELERATION 20Y Test 1	ACCELERATION 20Y Test 2	ACCELERATION 20Y RATIO Ratio 1/2
200	6.8	7.2	.95	9.6	8.3	1.16	8.4	1.0	.82	5.6	5.2	1.06
250	9.4	9.7	.97	15.0	14.2	1.06	7.8	1.0	.76	4.6	4.5	1.09
320	13.5	10.8	1.26	22.5	18.5	1.22	13.3	1.0	1.29	5.1	7.0	.74
400	38.8	19.5	1.97	31.1	39.6	.79	11.7	14.2	.80	7.2	17.8	.41
500	63.3	62.9	1.01	48.5	58.6	.83	25.0	11.3	2.15	25.9	34.0	.76
630	53.2	60.3	.89	37.1	44.5	.84	28.6	30.7	.91	24.9	34.7	.72
800	74.0	85.4	.87	38.7	97.0	.40	57.8	54.2	1.04	22.4	28.5	.79
1000	121.	184.	.66	104.	148.	.70	72.4	75.5	.94	30.0	27.5	1.09
1250	141.	165.	.86	123.	101.	1.22	76.2	89.2	.84	22.0	19.0	1.15
1600	262.	316.	.83	106.	82.6	1.29	268.	247.	1.06	16.6	31.2	.54
2000	380.	322.	1.18	124.	114.	1.08	268.	265.	.99	21.9	58.5	.38
2500	225.	267.	.84	92.	101.	.92	310.	382.	.79	51.9	46.6	1.11
3200	205.	179.	1.14	119.	93.1	1.28	567.	675.	.82	61.1	90.8	.68
4000	349.	252.	1.38	111.	103.	1.08	489.	948.	.51	110.	189.	.58
5000	474.	321.	1.47	393.	347.	1.13	445.	425.	1.03	217.	387.	.57
6300	242.	200.	1.21	303.	357.	.85	224.	219.	1.00	299.	190.	1.57
8000	201.	182.	1.10	630.	507.	1.24	199.	242.	.80	134.	173.	.78
10,000	176.	161.	1.20	748.	757.	.99	294.	309.	.93	122.	213.	.58

TABLE III.B.3

(cont.)

Frequency -Hz-	ACCELERATION 5R Test 1	ACCELERATION 5R Test 2	ACCELERATION 5R RATIO Test 1 / Test 2	ACCELERATION 7R Test 1	ACCELERATION 7R Test 2	ACCELERATION 7R RATIO Ratio 1/2	ACCELERATION 8R Test 1	ACCELERATION 8R Test 2	ACCELERATION 8R RATIO Ratio 1/2	ACCELERATION 9R Test 1	ACCELERATION 9R Test 2	ACCELERATION 9R RATIO Ratio 1/2
200	12	13	.94	10	13	.77	31	14	2.2	82	80	1.03
250	28	21	1.34	13	19	.71	49	32	1.53	114	116	.99
320	61	46	1.34	34	32	1.08	82	43	1.90	163	126	1.29
400	83	67	1.24	50	79	.64	113	132	.86	232	294	1.08
500	109	122	.90	166	146	1.13	120	181	.68	322	290	1.11
800	234	211	1.11	124	142	.85	293	221	1.32	369	481	.77
1000	180	177	1.02	365	547	.67	367	550	.67	493	541	.97
1250	243	274	.89	317	392	.81	497	319	1.55	628	398	1.57
1600	322	379	.85	639	664	.96	465	459	1.01	714	532	1.34
2000	403	370	1.09	503	437	1.15	545	614	.89	547	586	.93
2500	587	693	.85	388	507	.76	580	720	.81	639	553	1.15
3200	624	481	1.30	413	330	1.25	445	416	1.07	675	471	1.43
4000	563	551	1.02	577	435	1.32	784	668	1.17	596	580	1.03
5000	605	593	1.02	820	805	1.02	985	608	1.61	759	681	1.11
6300	523	176	3.01	699	428	1.63	724	429	1.68	982	986	1.00
8000	515	599	.86	550	393	1.46	412	331	1.24	814	781	1.04
10,000	399	681	.59	480	339	1.24	335	272	1.23	791	647	1.22

TABLE III.B.3

(cont.)

Frequency -Hz-	ACCELERATION 2X Test 1	Test 2	RATIO Test 1 / Test 2	ACCELERATION 3X Test 1	Test 2	RATIO Ratio 1/2	ACCELERATION 4X Test 1	Test 2	RATIO Ratio 1/2	ACCELERATION 4T Test 1	Test 2	RATIO Ratio 1/2
200	65	95	.69	18	16	1.11	16	22	.76	32	33	.99
250	80	77	1.04	25	28	.89	22	26	.89	67	50	1.33
320	145	90	1.60	45	40	1.12	27	39	.73	209	139	1.50
400	280	150	1.88	138	130	1.06	94	158	.61	891	694	1.28
500	458	257	1.77	139	126	1.10	174	194	.92	249	468	.54
630	600	560	1.07	373	434	.86	328	471	.72	272	321	.85
800	600	466	1.28	610	562	1.07	639	567	1.15	459	502	.92
1000	570	642	.89	774	803	.97	305	343	.91	488	422	1.15
1205	753	501	1.50	629	577	1.09	216	269	.82	425	422	1.01
1600	988	683	1.14	691	577	1.20	317	521	.63	522	683	.77
2000	783	767	1.02	824	722	1.14	645	643	1.02	716	633	1.13
2500	834	798	1.05	1293	1157	1.12	553	534	1.06	432	425	1.02
3200	1610	1249	1.29	1929	1622	1.19	393	428	.94	441	393	1.12
4000	2349	1655	1.41	2246	1865	1.20	423	464	.93	558	470	1.25
5000	3055	2543	1.24	1194	1021	1.17	543	851	.66	1322	1027	1.28
6300	2935	3227	.91	1592	1288	1.23	806	894	.92	866	817	1.06
8000	4335	2793	1.54	1555	1182	1.31	700	606	1.18	501	578	.87
10,000	5941	3978	1.49	842	649	1.29	391	418	.96	436	515	.85

TABLE III.B.3

(cont.)

Frequency -Hz-	ACCELERATION 35X Test 1	Test 2	RATIO Test 1 / Test 2	ACCELERATION 36X Test 1	Test 2	RATIO Ratio 1/2	ACCELERATION 36R Test 1	Test 2	RATIO Ratio 1/2	ACCELERATION 1R Test 1	Test 2	RATIO Ratio 1/2
200	138	98	1.43	81	45	1.78	137	109	1.25	147	113	1.29
250	195	233	.85	132	51	2.54	305	212	1.43	245	163	1.50
320	195	164	1.21	144	97	1.48	286	319	.90	193	163	1.18
400	346	331	1.07	413	228	1.80	854	695	1.23	240	278	.87
500	453	303	1.54	449	182	2.45	1494	908	1.64	331	404	.82
630	594	485	1.25	449	380	1.31	927	662	1.40	620	602	1.03
800	622	526	1.21	378	296	1.28	1326	878	1.50	1039	886	1.17
1000	622	575	1.10	445	438	.91	2040	2002	1.02	1834	1676	1.09
1250	522	581	.92	854	698	1.22	1929	999	1.92	3589	3566	1.01
1600	793	861	.94	836	1022	.82	1770	940	1.87	3261	3220	1.01
2000	1270	2020	.65	1101	1654	.67	1143	1160	.99	2092	2611	.81
2500	2216	2647	.86	2285	1888	1.21	2310	1013	2.26	1517	1986	.77
3200	4851	4801	1.03	4886	3547	1.37	1485	1089	1.34	3558	1639	.95
4000	10062	9778	1.14	4124	3174	1.30	2257	2322	.97	1949	2367	.83
5000	12503	7650	1.66	3525	3682	.96	3650	3477	1.05	3611	4900	.74
6300	7400	5499	1.37	3486	3677	.95	2932	3328	.88	6232	10437	.60
8000	4626	3451	1.37	2824	3174	.89	2614	2349	1.11	15204	13865	1.09
10,000	3557	3592	1.01	2015	2509	.81	4461	1640	2.69	14251	12550	1.13

TABLE III.B.3

(cont.)

Frequency - Hz -	ACCELERATION 22R Test 1	Test 2	RATIO Test 1 / Test 2	ACCELERATION 26X Test 1	Test 2	RATIO Ratio 1/2	ACCELERATION 29R Test 1	Test 2	RATIO Ratio 1/2	ACCELERATION 31R Test 1	Test 2	RATIO Ratio 1/2
200	5.5	2.6	2.16	19.5	28.6	.68	23.4	18.8	1.21	20.0	20.1	1.00
250	9.9	3.3	2.94	20.8	26.1	.80	18.4	12.9	1.38	16.2	13.0	1.25
320	6.3	3.9	1.63	17.0	20.1	.85	37.1	24.1	1.50	18.8	14.7	1.27
400	7.8	8.1	.95	40.5	56.1	.72	63.8	23.0	2.68	22.8	21.0	1.08
500	33.2	23.1	1.43	55.3	47.8	1.16	67.3	45.8	1.43	31.3	23.8	1.31
630	13.8	13.5	1.02	69.4	74.1	.94	66.0	50.9	1.26	37.3	45.1	.83
800	20.7	14.1	1.47	153.	206.	.75	96.4	61.6	1.52	54.9	56.3	.98
1000	58.8	48.9	1.20	87.7	83.1	1.05	156.	112.	1.36	46.8	31.6	1.48
1250	44.5	44.5	1.00	102.	91.6	1.11	109.	77.	1.38	45.3	33.7	1.34
1600	58.8	48.2	1.22	54.6	52.7	1.04	120.	147.	.80	85.1	76.1	1.11
2000	117.	70.0	1.66	62.1	55.9	1.11	230.	218.	1.03	130.	139.	.94
2500	85.7	76.4	1.12	132.	136.	.97	208.	360.	.57	173.	176.	.99
3200	97.9	76.1	1.28	158.	155.	1.02	332.	464.	.70	136.	130.	1.05
4000	147.	136.	1.08	210.	210.	1.00	366.	503.	.71	437.	347.	1.26
5000	243.	176.	1.38	367	309.	1.19	379.	484.	.77	778.	580.	1.34
6300	161.	167.	.97	328.	351.	.94	316.	344.	.90	378.	350.	1.08
8000	138	108.	1.28	428.	558.	.77	639	831.	.75	643.	433.	1.48
10,000	118	121.	.98	230.	293.	.79	490.	1074.	.45	107.	106.	1.00

TABLE III.B.3

(cont.)

Frequency - Hz -	ACCELERATION 10R Test 1	ACCELERATION 10R Test 2	ACCELERATION 10R RATIO Tests 1/2	ACCELERATION 12R Test 1	ACCELERATION 12R Test 2	ACCELERATION 12R RATIO Tests 1/2
200	35	15	2.34	11	13	.83
250	54	22	2.39	12	18	.67
320	880	42	1.90	17	16	1.01
400	134	119	1.34	27	26	1.02
500	147	86	1.71	37	22	1.65
630	125	134	.94	61	26	2.28
800	245	565	.44	54	56	.97
1000	441	294	1.49	147	191	.77
1250	428	468	.92	102	504	.20
1600	547	635	.86	175	254	.69
2000	462	440	.92	419	306	1.36
2500	859	672	1.27	377	255	1.47
3200	577	734	.79	427	344	1.23
4000	572	549	1.04	702	656	1.07
5000	741	632	1.17	746	623	1.20
6300	949	624	1.51	535	307	1.73
8000	762	580	1.31	606	616	.98
10000	397	248	1.59	481	278	1.72

TABLE III.B.4

LOG-MEAN AND DEVIATION OF BASIC SHOCK SPECTRUM DATA FROM FULL SCALE VEHICLE TESTS

SUMMARY OF RESULTS

RATIO OF TWO TESTS

Frequency Band	50th Percentile	Deviation ±dB
50	1.184	5.35
63	1.135	6.39
80	1.066	4.45
100	.972	3.44
125	1.272	3.92
160	1.187	2.94
200	1.123	3.64
250	1.181	4.01
320	1.230	2.54
400	1.055	4.24
500	1.169	3.92
630	1.016	2.52
800	.987	3.44
1000	.978	2.36
1250	1.030	4.33
1600	.962	2.73
2000	.970	2.91
2500	1.003	2.74
3200	1.080	2.13
4000	1.027	2.59
5000	1.088	2.71
6300	1.039	3.81
8000	1.084	2.28
10000	1.044	3.86

TABLE III.B.5

ACCELERATION-TIME HISTORY PEAK G READINGS FROM
22 BARREL TESTS

ACCELERATION G's (0 - PEAK)

TEST NUMBER

LOCATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	376	450	585	830	850	1430	810	850	700	1050	785	1070	614	1190	1575
2	605	680	830	870	860	1350	900	698	1160	915	715	1070	420	726	974
3	755	1110	955	1350	1430	1990	1610	860	1060	1360	1500	2630	653	1273	1386
4	570	665	570	712	785	1300	430	550	594	750	800	1400	594	674	1310
5	430	685	740	623	623	1000	506	545	684	570	760	1060	427	563	1200
6	280	260	330	540	440	810	384	384	630	435	465	720	294	494	816
7	290	290	270	251	1000	475	416	350	485	470	450	470	197	414	473
8	386	540	500	675	596	790	424	465	667	530	550	805	331	615	722
9	212	310	348	540	770	830	308	348	440	575	605	1230	375	506	900
10	309	348	425	580	570	720	292	390	490	470	624	663	434	690	945
11	386	405	540	540	887	750	276	296	396	614	636	775	315	650	906
12	290	425	388	560	376	950	317	337	436	445	419	597	256	650	780
13	199	300	270	310	360	440	266	358	342	316	367	405	220	426	574
14	139	168	191	209	300	282	190	150	338	358	248	340	137	283	283
15	133	157	186	244	299	318	165	220	208	295	314	332	151	336	404
16	179	191	277	333	374	697	270	284	299	364	338	468	226	426	575

LOCATION	29	30	31	33	34	36	37	38	39	40	47
1	1640	—	1880	4520	5200	—	—	—	—	4800	4400
2	1160	1440	1000	2000	1640	—	—	—	—	5300	3020
3	520	1360	1000	1540	3280	2100	2200	2100	2200	2470	2170
4	520	720	520	2430	1400	1770	1880	2040	1990	1990	2980
5	—	—	—	—	—	—	—	—	—	—	—
6	380	800	880	1400	1150	2430	2270	2480	2330	2110	2070
7	360	410	450	880	1320	1150	1010	1150	865	2230	1680
8	280	380	440	730	600	1550	1400	1440	1530	1420	1650
9	—	—	—	—	—	—	—	—	—	—	—
10	380	340	330	960	940	—	—	—	—	—	—
11	270	520	450	660	700	1930	1760	2080	2080	2190	1880
12	380	480	380	660	630	1350	1350	1230	1250	1110	1580
13	207	253	384	577	590	1700	1590	1440	1540	1480	1410
14	294	340	423	714	536	1300	1130	1470	1240	970	970
15	280	333	193	587	527	1080	965	935	1080	840	974

TABLE III.B.6

CALCULATION OF PEAK G RATIOS

Joint	Test Ratio	Grain Ratio G_2/G_1	Thickness Ratio t_2/t_1	$(G_2/G_1 \cdot t_2/t_1)$	K	$f = K(G_2/G_1 \cdot t_2/t_1)^{1/3}$	Actual Ratio of Averages	Actual f
B	2/1	1.00	1.515	1.515	1.00	1.15	1.07	.93
	3/1	2.00	1.515	2.303	.95	1.25	1.33	1.06
	4/1	2.00	2.68	5.36	.95	1.62	1.58	.98
	5/1	3.00	2.68	8.04	1.00	2.00	1.62	.81
	6/1	3.00	3.78	11.34	1.00	2.24	2.26	1.01
	3/2	2.00	1.00	2.00	.95	1.20	1.27	1.06
	4/2	2.00	1.84	3.68	.95	1.47	1.49	1.01
	5/2	3.00	1.84	5.52	1.00	1.77	1.53	.86
	6/2	3.00	2.50	7.50	1.00	1.96	2.12	1.08
	4/3	1.00	1.84	1.84	1.00	1.22	1.20	.98
	5/3	1.50	1.84	2.76	1.00	1.40	1.27	.91
	6/3	1.50	2.50	3.75	1.00	1.55	1.72	1.11
	5/4	1.50	1.00	1.50	1.00	1.15	1.03	.91
	6/4	1.50	1.36	2.04	1.00	1.27	1.43	1.12
	6/5	1.00	1.36	1.36	1.0	1.11	1.42	1.28
D	30/29	1.50	1.36	2.04	1.00	1.27	1.50	1.18
	31/29	1.50	1.70	2.55	1.00	1.37	1.37	1.00
	33/29	3.00	1.70	5.10	1.50	2.58	2.76	1.07
	31/29	3.00	2.07	6.21	1.50	2.76	2.82	1.02
	31/30	1.00	1.25	1.25	1.00	1.08	0.94	.88
	33/30	2.00	1.25	2.50	1.50	2.04	1.92	.94
	34/30	2.00	1.52	3.04	1.50	2.17	1.88	.87
	33/31	2.00	1.00	2.00	1.50	1.90	2.12	1.11
	31/31	2.00	1.22	2.44	1.50	2.02	2.10	1.04
	31/33	1.00	1.22	1.22	1.00	1.07	1.04	.97

TABLE III.B.7

VALUES TO BE USED FOR ("K") CORRECTION FACTOR

GRAIN SIZE OF BASELINE JOINT	GRAIN SIZE OF PREDICTED JOINT	K
5	10	0.95
5, 10	15	1.00
5, 10, 15	30	1.50

NOTE: If Grain sizes are equal K = 1.00

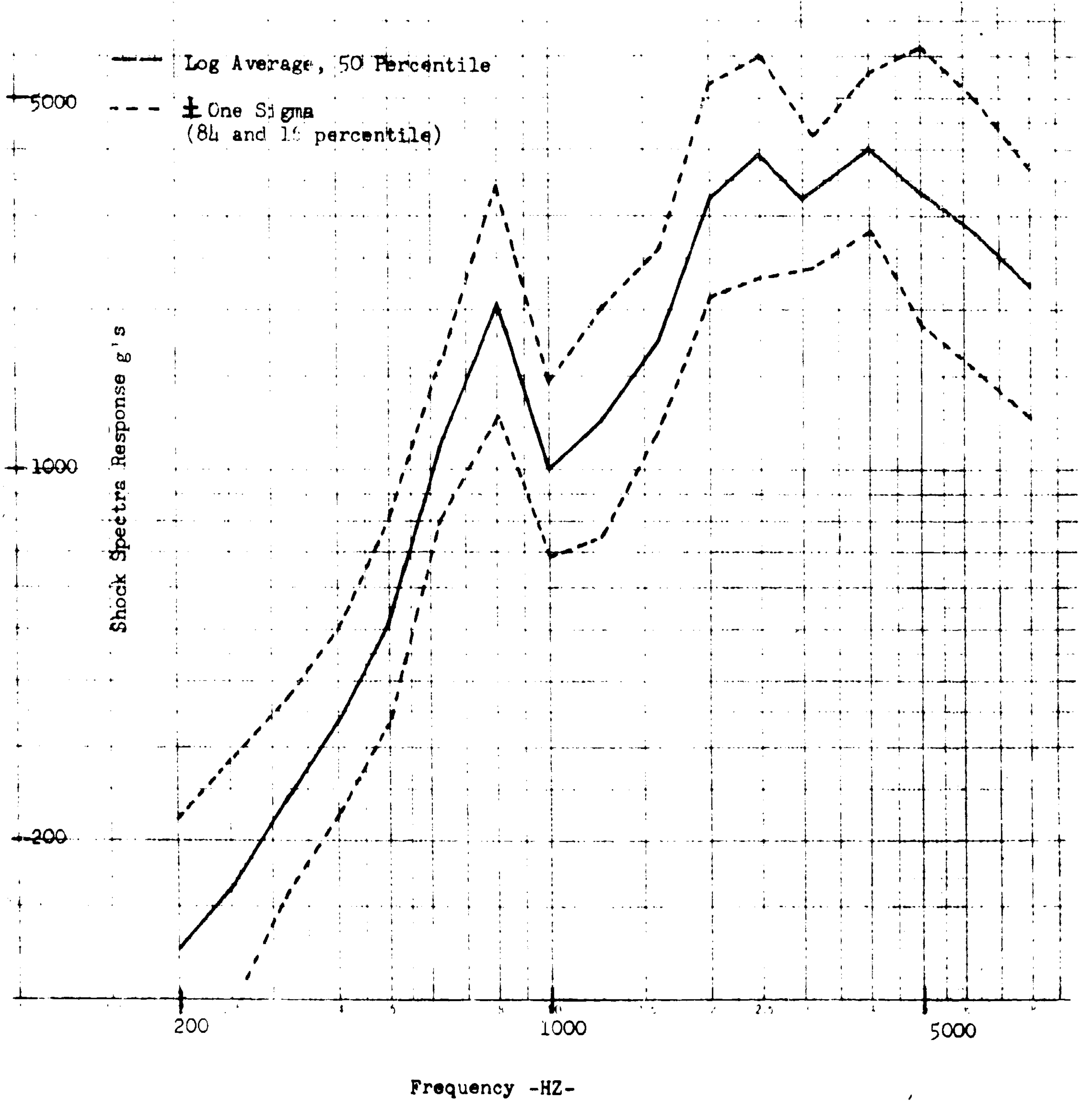


Figure III.B.1 DEVIATION OF SHOCK SPECTRA DATA, ONE LOCATION - 22 TESTS, LONGITUDINAL AXIS

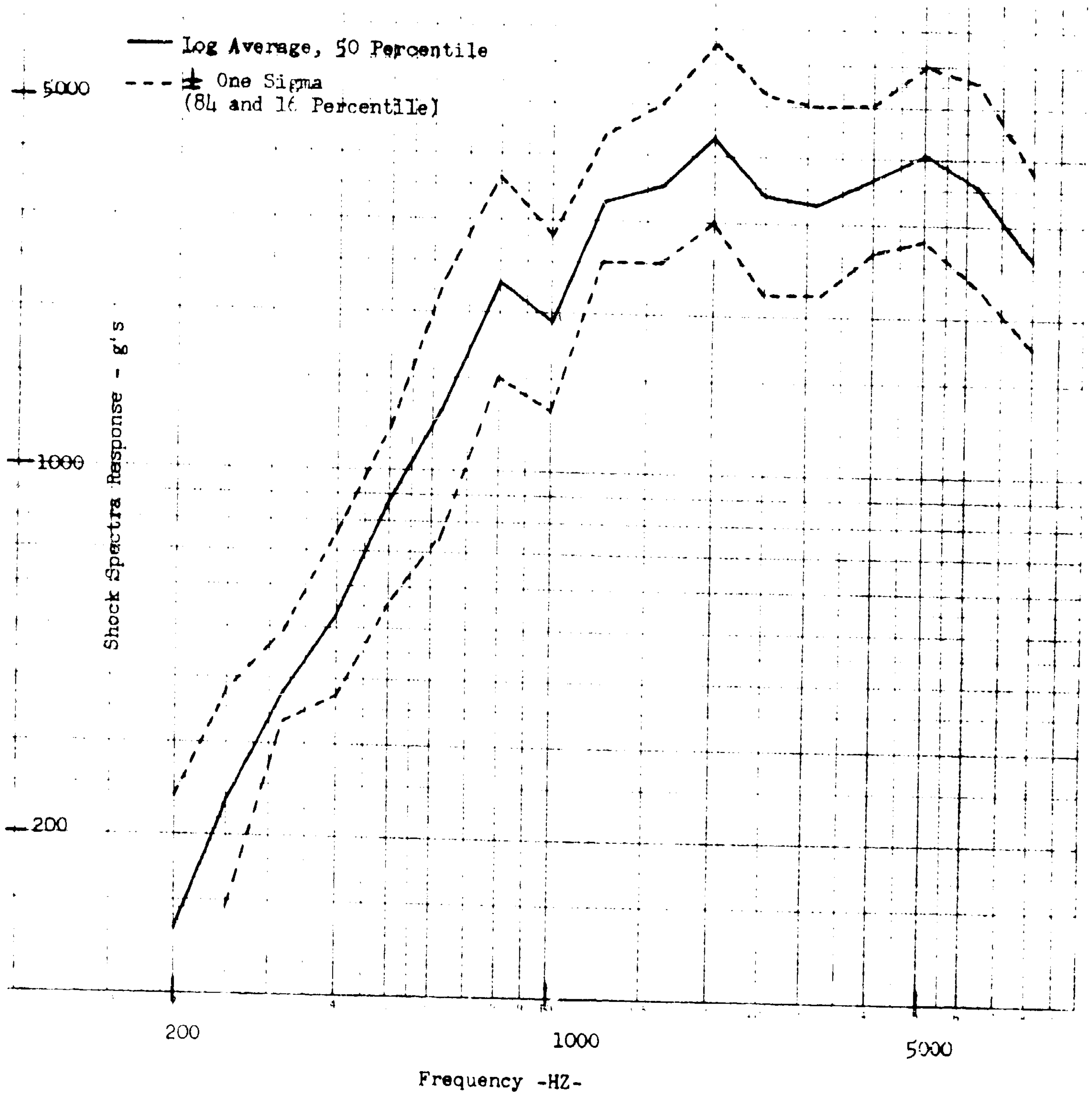


Figure III.B.2 DEVIATION OF SHOCK SPECTRA DATA, ONE LOCATION - 22 TESTS, RADIAL AXIS

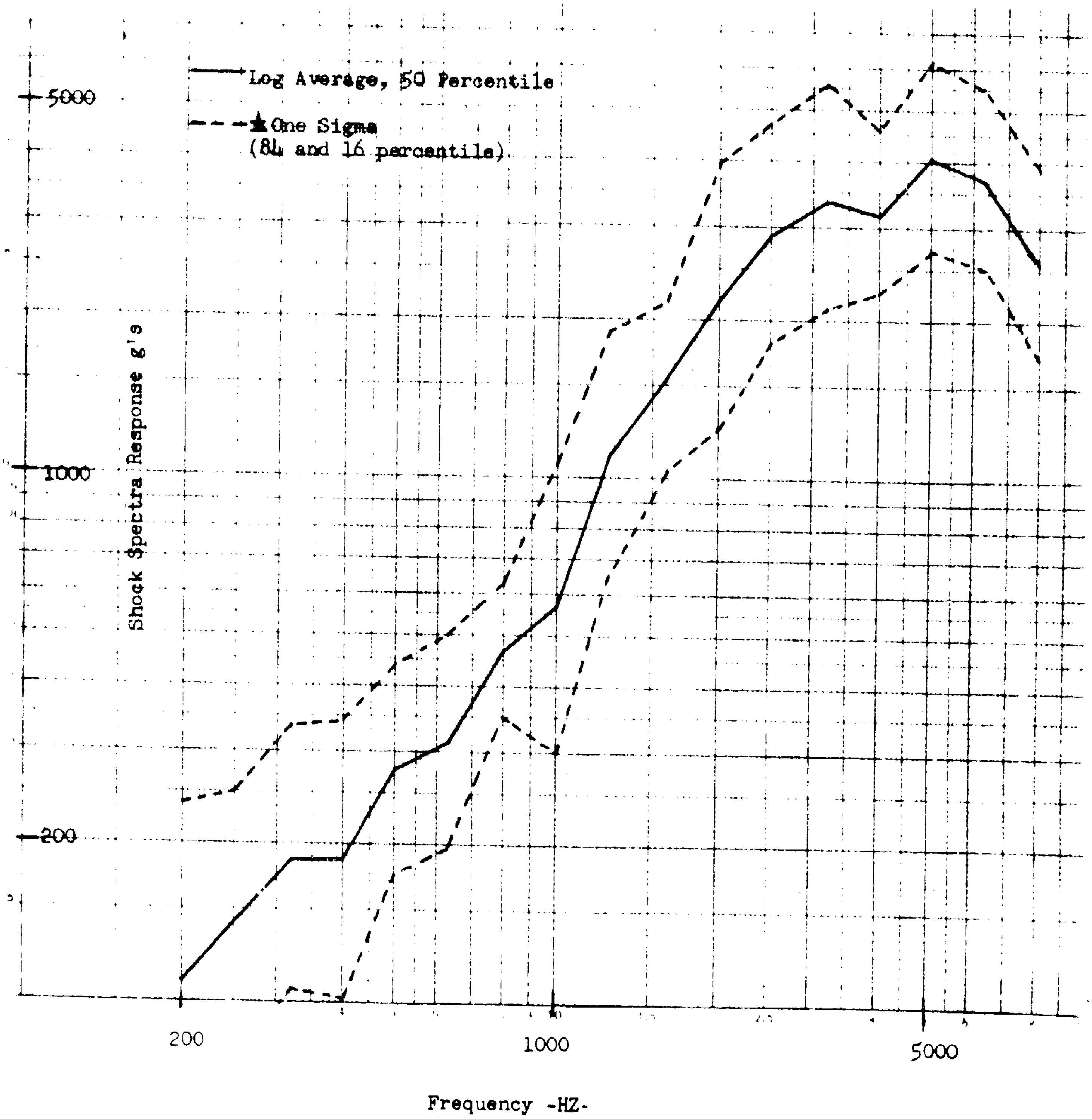


Figure III.B.3 DEVIATION OF SHOCK SPECTRA DATA, ONE LOCATION - 22 TESTS, TANGENTIAL AXIS

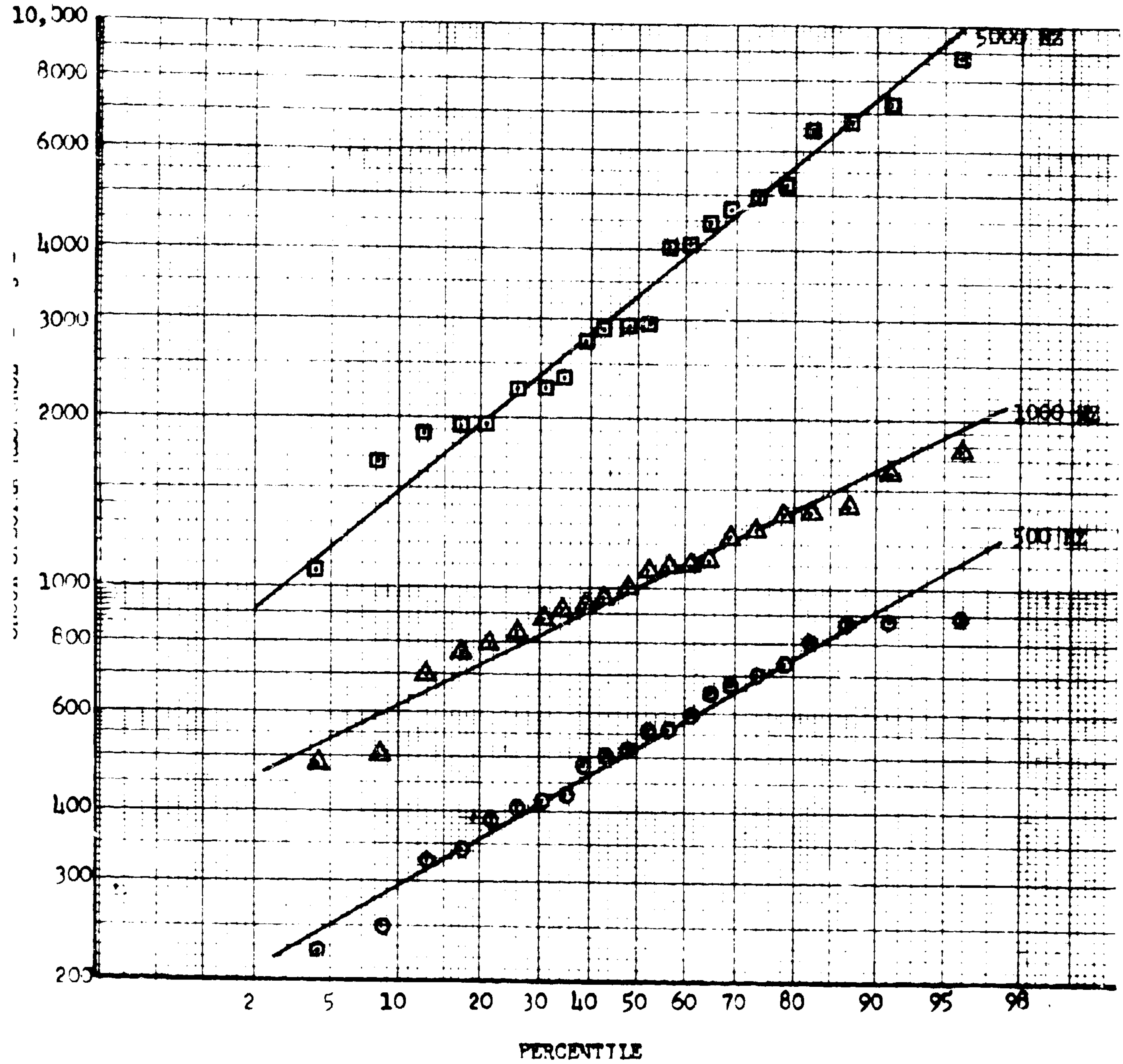


Figure III.B.4 TYPICAL DISTRIBUTION OF DATA POINTS

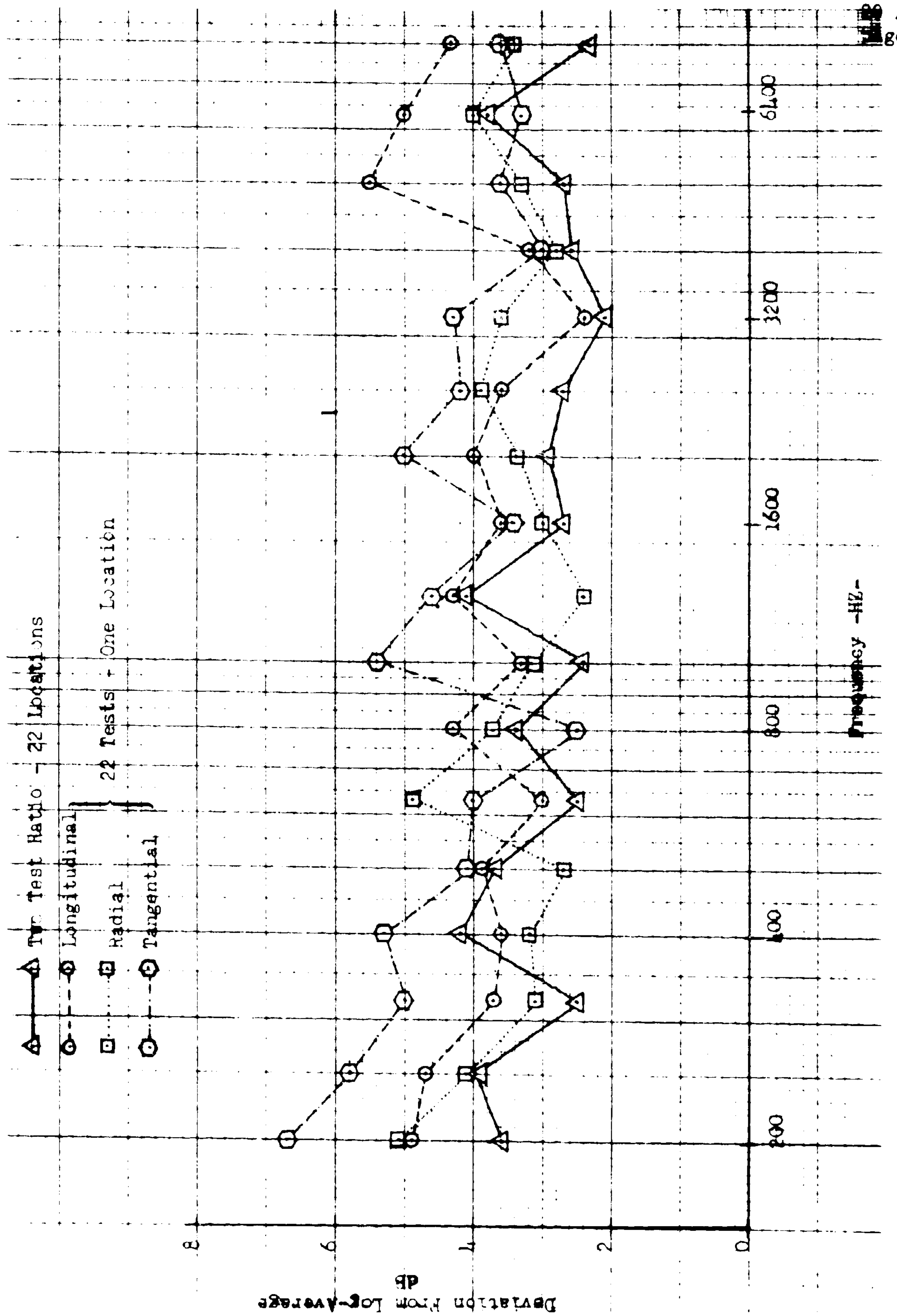


Figure III.B.5 STANDARD DEVIATION EXPRESSED AS DB

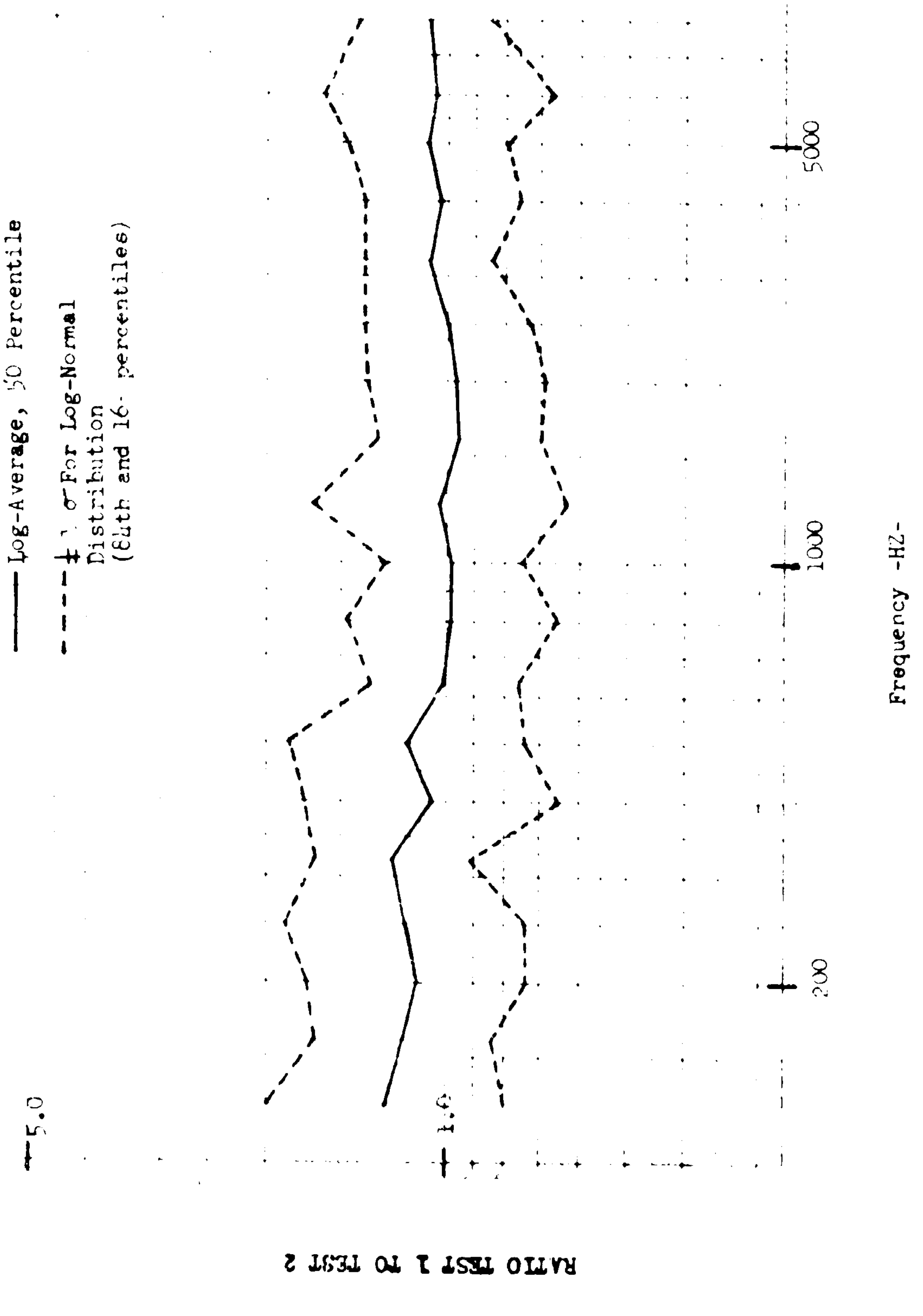


Figure III.P.6 SHOCK SPECTRUM RATIO TWO TESTS - 22 LOCATIONS

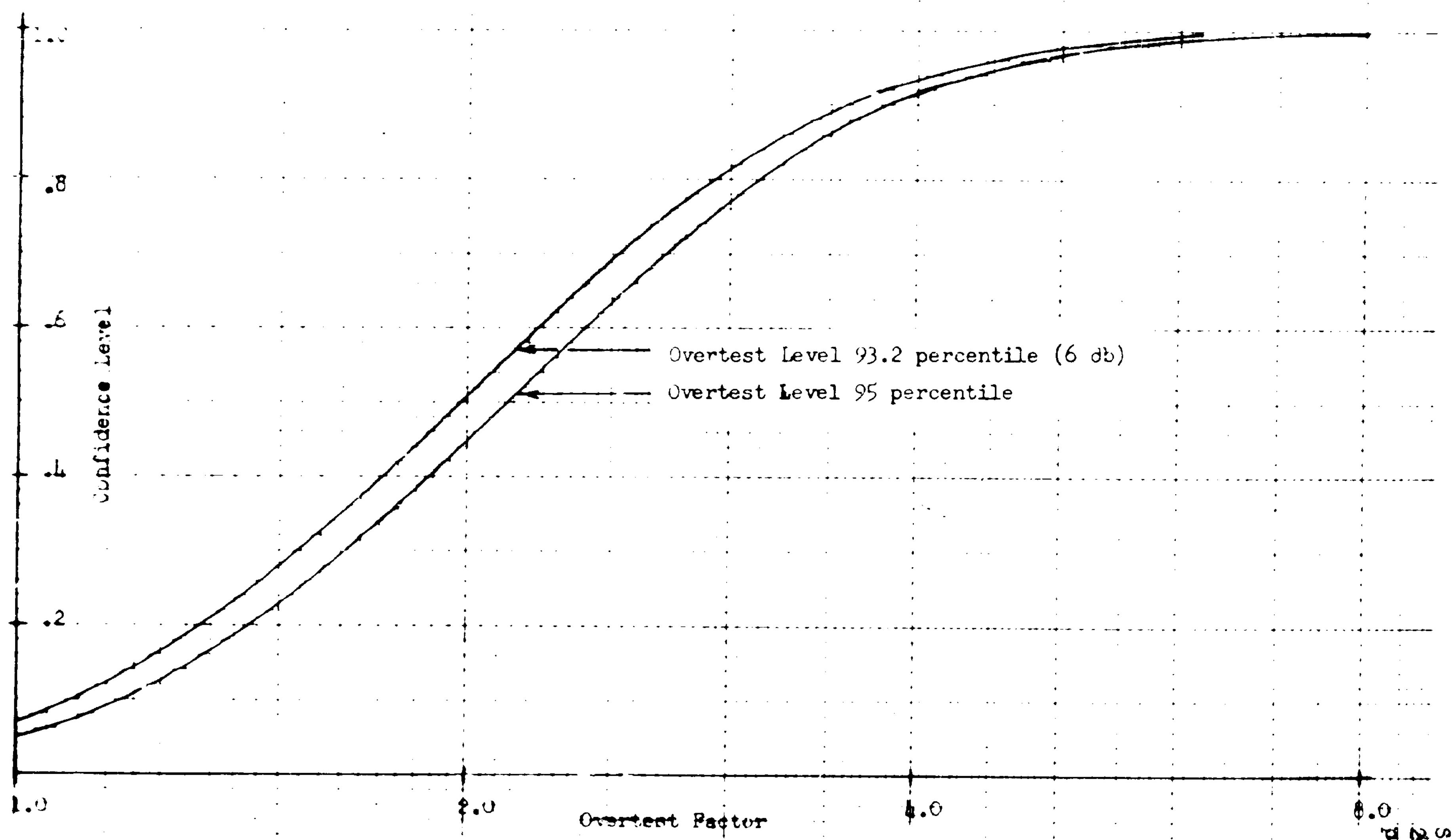


Figure III.B.7 CONFIDENCE LEVEL VERSUS OVERTEST FACTOR FOR ONE TEST

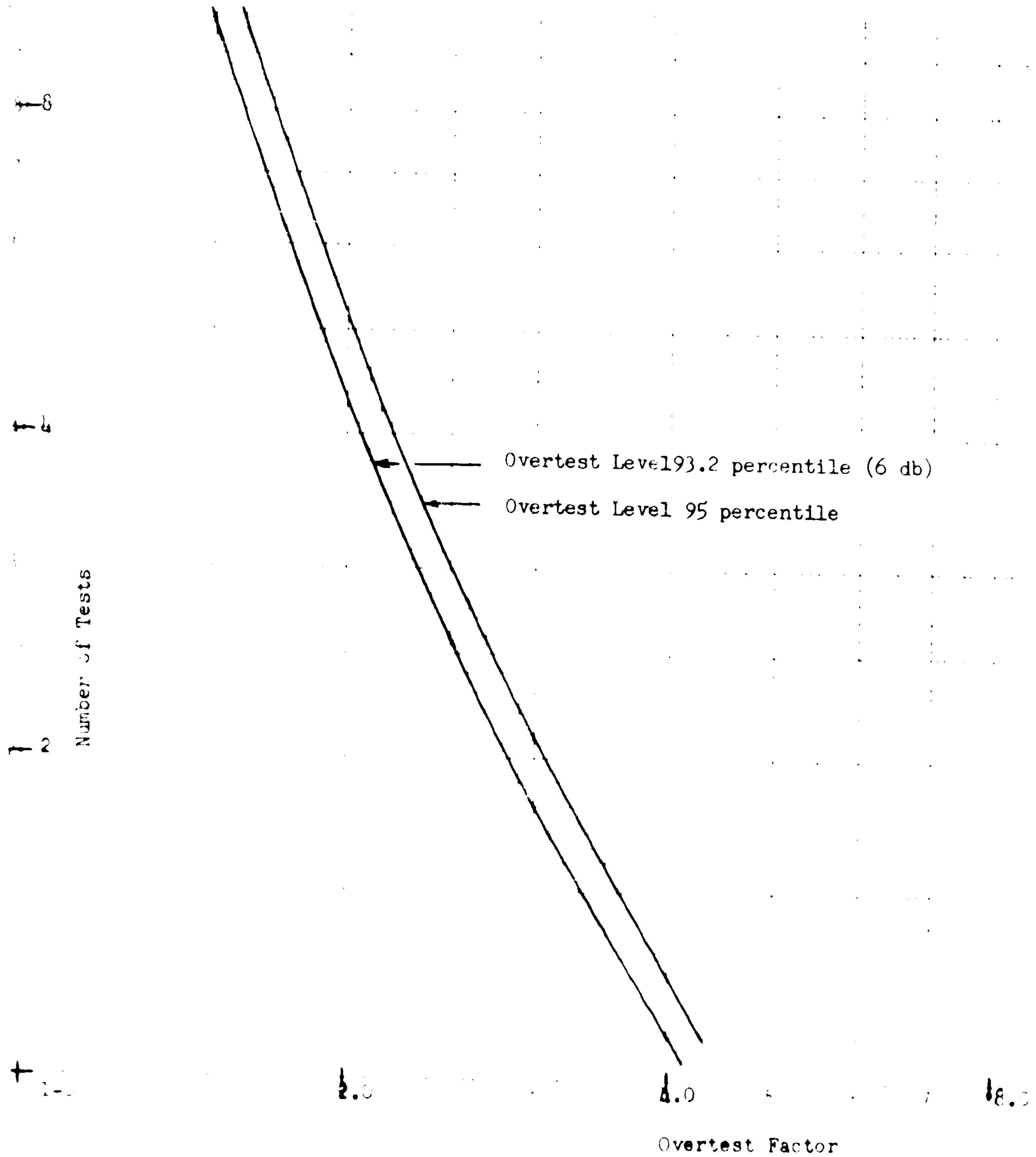


Figure III.B.8 NUMBER OF TESTS REQUIRED FOR .95 (95%) CONFIDENCE LEVEL

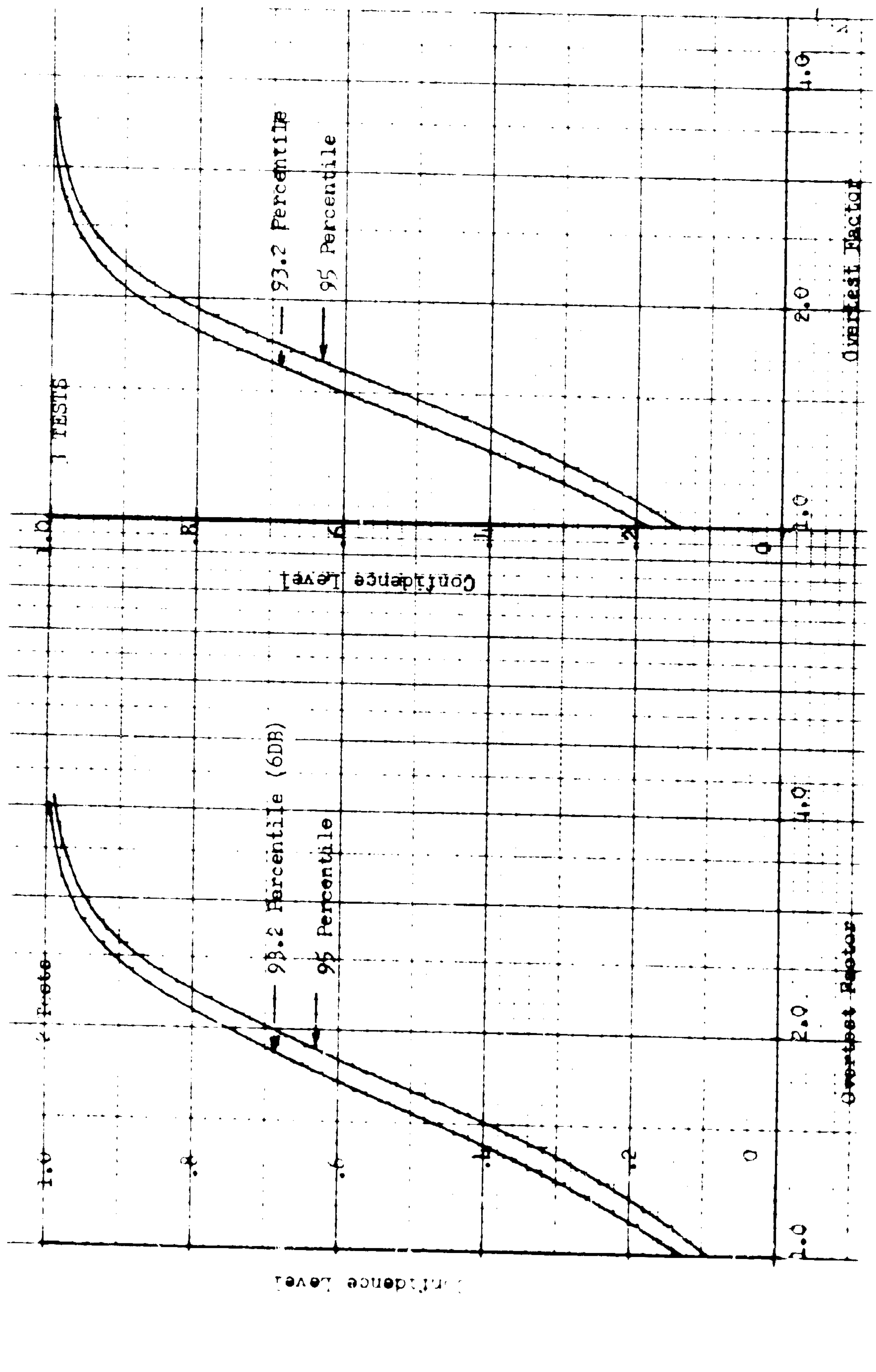


Figure III.B.9 CONFIDENCE LEVEL FOR TWO AND THREE TESTS

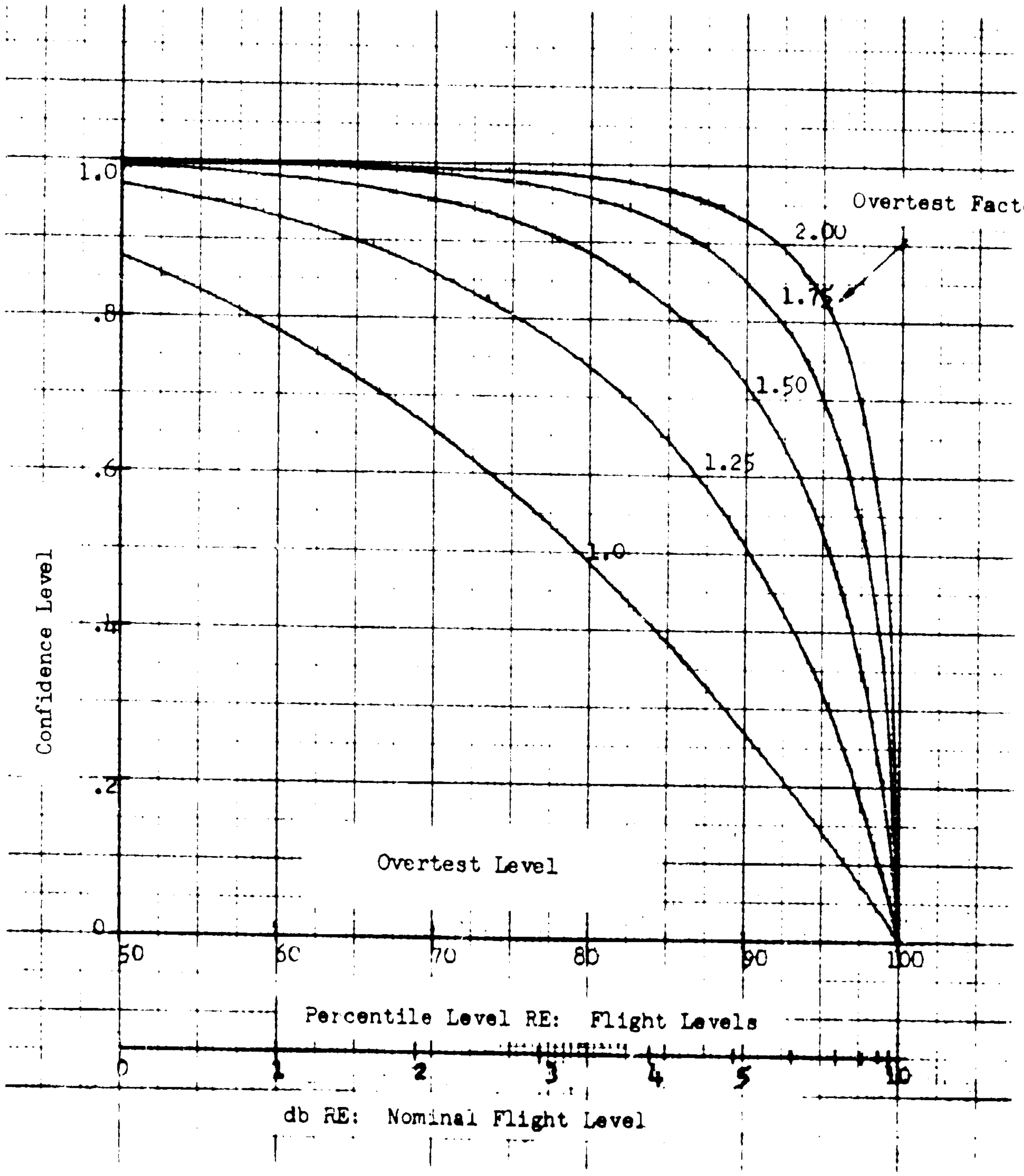


Figure III.B.10 CONFIDENCE LEVEL VERSUS OVERTEST LEVEL FOR THREE TESTS

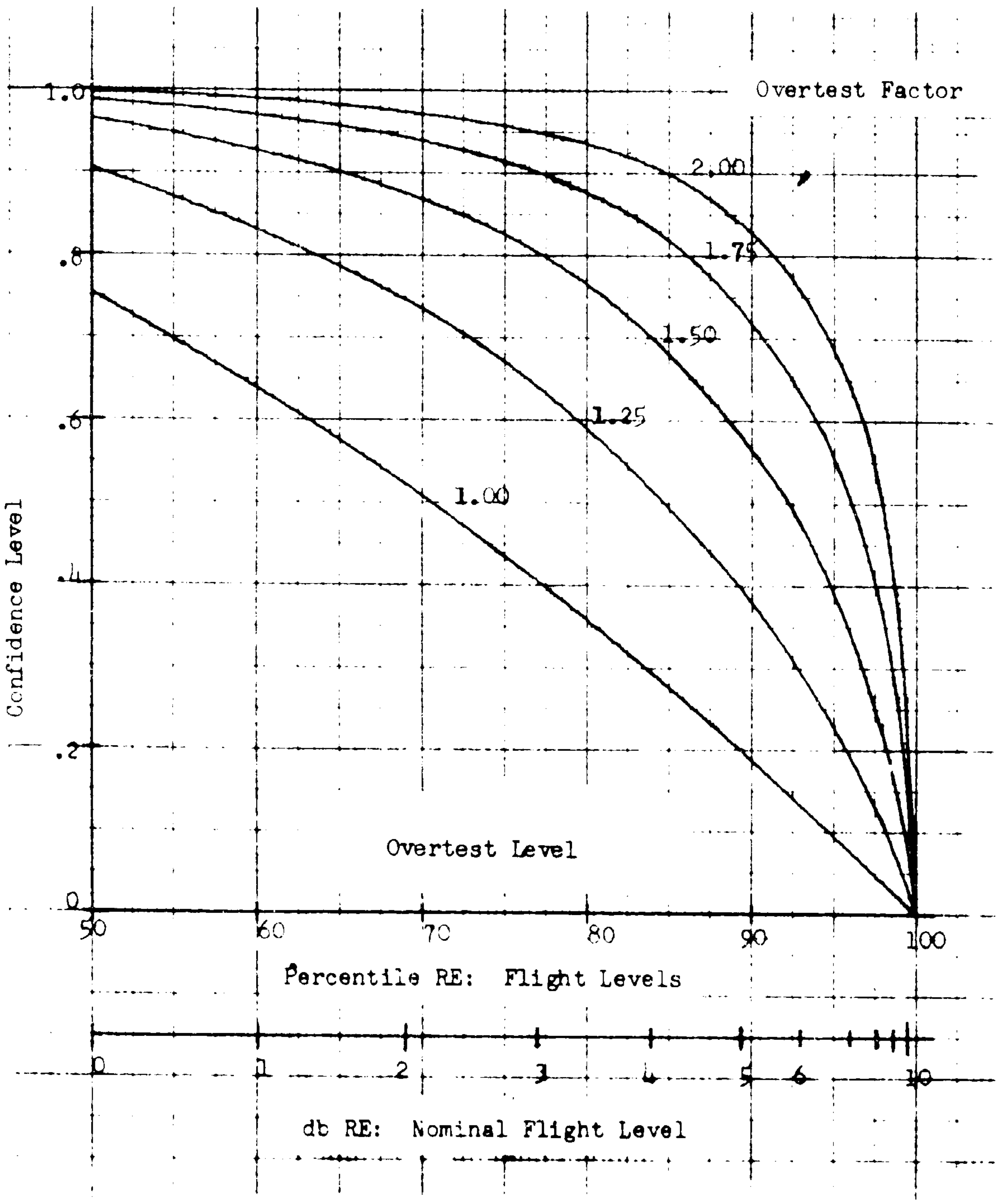


Figure III.B.11 CONFIDENCE LEVEL VERSUS OVERTEST LEVEL FOR TWO TESTS

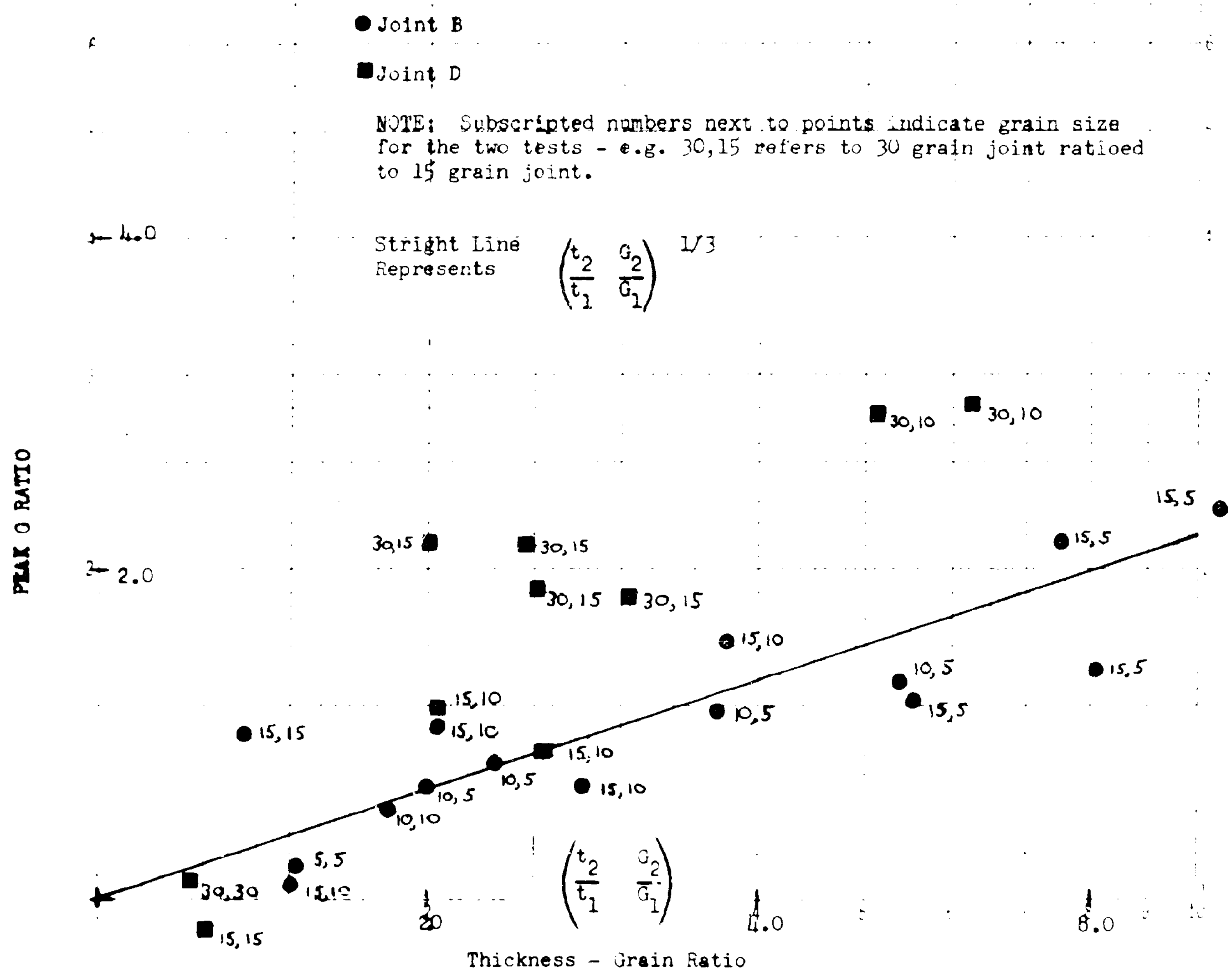


Figure III.B.12 AVERAGE PEAK G RATIO VERSUS GRAIN - THICKNESS RATIO

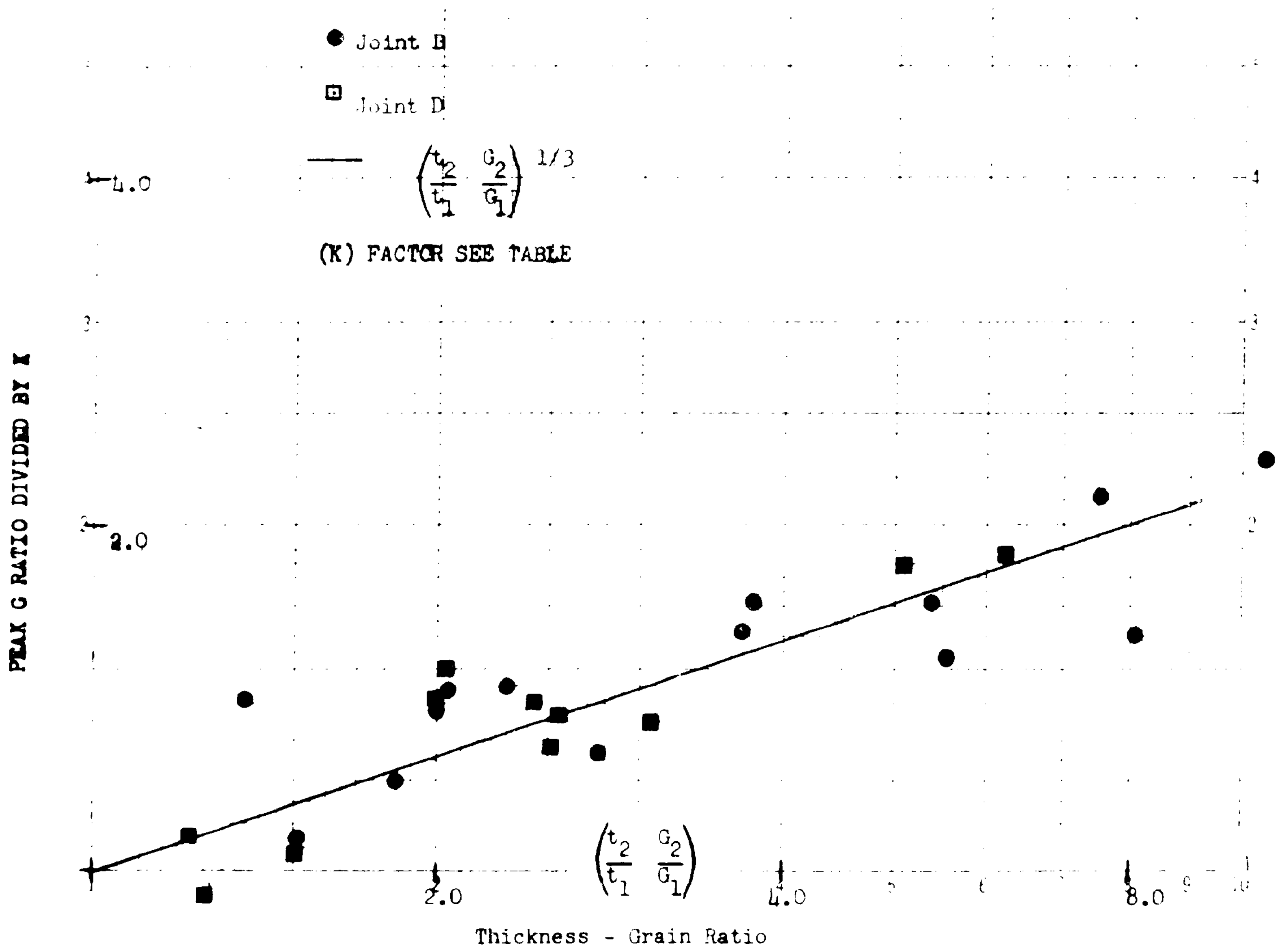


Figure III.B.13 AVERAGE PEAK G RATIO NORMALIZED BY K (GRAIN SIZE) FACTOR

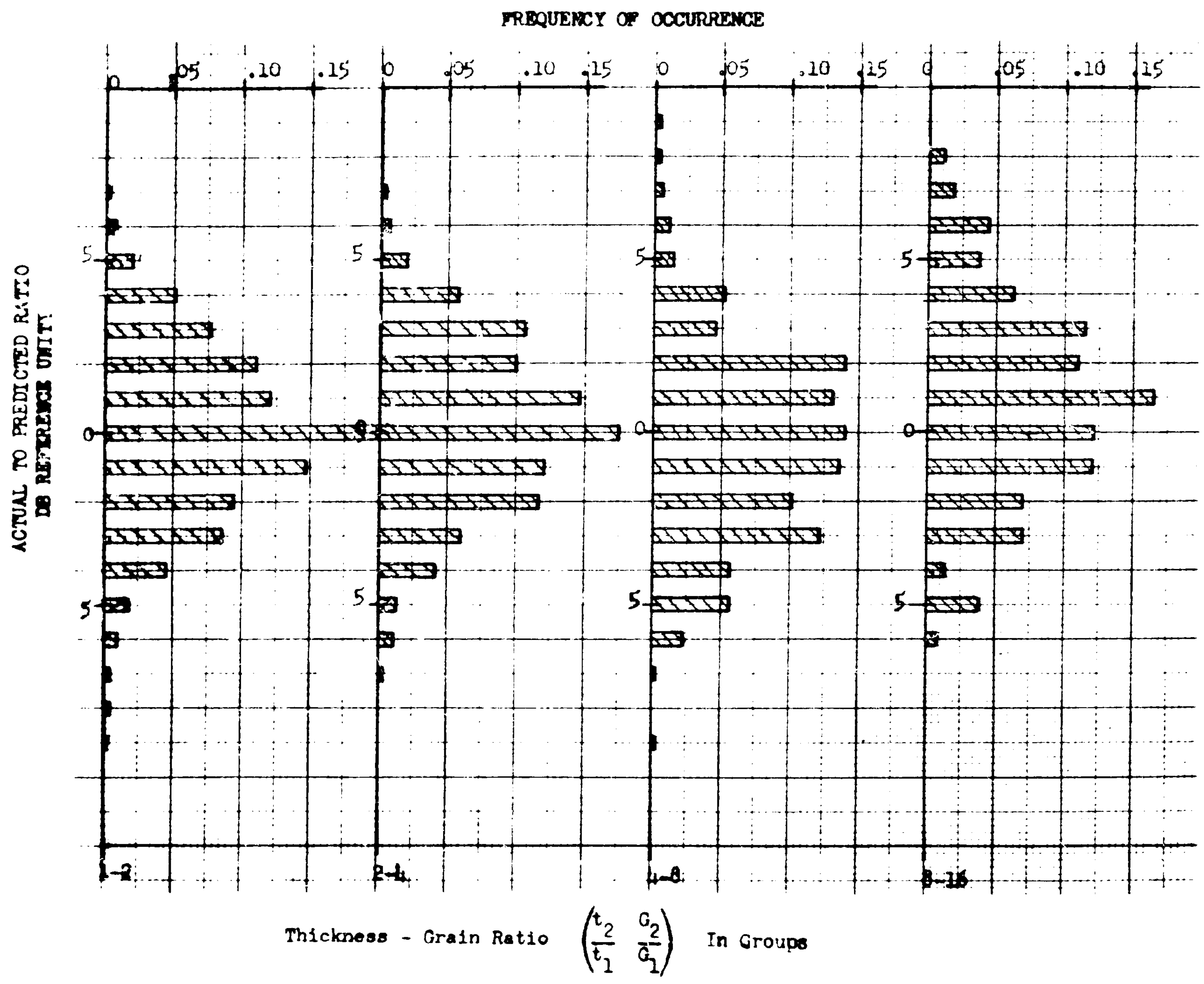
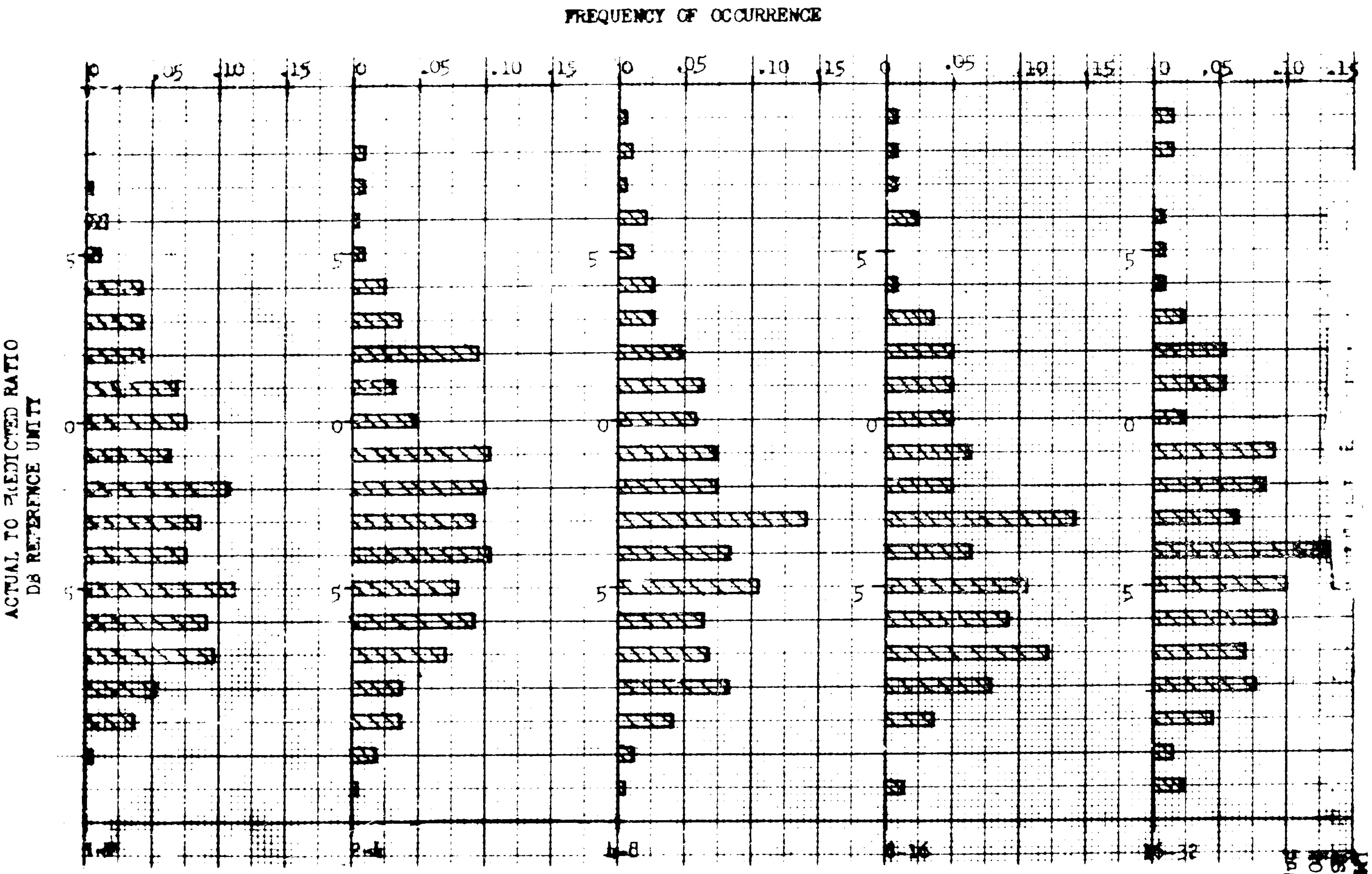


Figure III.B.14 DISTRIBUTION OF ACTUAL TO PREDICTED G LEVEL FOR SIMILAR JOINTS



Thickness - Grain Ratio $\left(\frac{t_2}{t_1} \; \frac{G_2}{G_1}\right)$ In Groups

Figure III.B.15 DISTRIBUTION OF ACTUAL TO PREDICTED G LEVEL RATIO FOR DISSIMILAR JOINTS

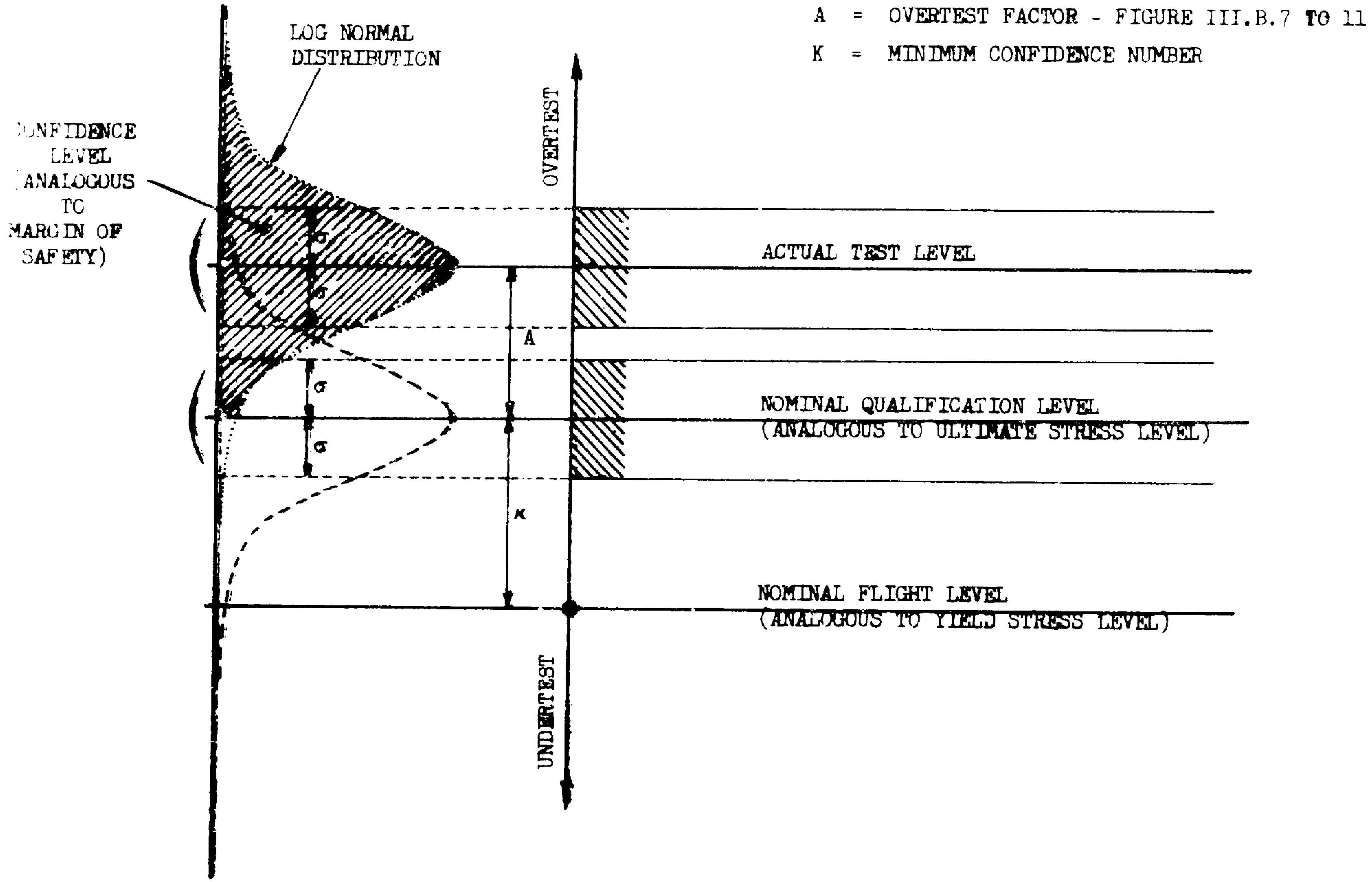
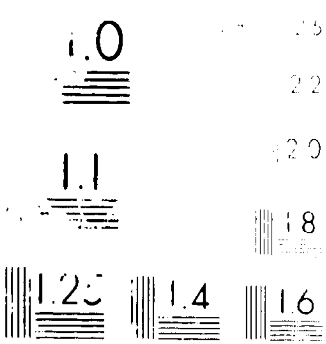


FIGURE III.B.16 - METHOD FOR ESTABLISHING QUALIFICATION CRITERIA

III.C CONCLUSIONS

The analyses presented in this report is intended to add clarity to the enclosed pyrotechnic shock data, these analyses form a background from which can be grasped the work which may be done in order to derive full benefit of the available data.

LMSC is of the opinion that the Pyrotechnic Shock Data Compilation must not be an end in itself but must be expanded in order to further the State of the Art up to a practical point. Section VII of this report is devoted to some LMSC's recommendations for further Pyrotechnic Shock Study.



2.2
2.0
1.1
1.8
1.25
1.4
1.6

SECTION NO. IV

SUBJECT:

LMSC METHODS FOR DEALING WITH PYRO SHOCK

SECTION IV

SUMMARY

This section is devoted to LMSC's methods for dealing with pyro shock. Included are a brief discussion of the history of space vehicle pyro shock studies and the characteristics of the pyro event. This is followed by the various approaches which LMSC explored toward a solution of the pyro shock problem. Briefly considered were equipment modification and analysis while more emphasized discussion evolved out of consideration of shock isolation and testing methods.

Shock mounting has been one of the more successful solutions here at LMSC and the shock mounting technique which is used is explored in relation to design considerations and performance.

The need for a test method whereby equipment could be qualified for the pyro shock environment prompted LMSC to investigate the feasibility of various test methods. To establish test criteria which would provide the basis for choosing a test facility, measurements were made on flight vehicles both in-flight and on the ground. Various types of test facilities were then evaluated to determine which facility was best suited to equipment qualification. Among the test methods and test facilities considered were: full scale vehicle tests, shakers, drop and impulse testers, transfer tables and barrel testers.

The barrel tester best simulated the vehicle environment and a test program was initiated to produce a facility which would meet LMSC needs. Once the barrel test facility was completed, a test program was devised which would produce qualified equipment.

Over 125 separate items of flight hardware have been qualified by the barrel tester in the past five years.

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IV.1.0 HISTORY

The pyrotechnic shock environment has been present in military vehicles since the introduction of armament. Recently, explosive devices have been used in space vehicles to perform such functions as staging, nose fairing ejection, valve operation, antenna erection, satellite separation, and the like. Explosives have been used in primacord, jet cord, pin pullers, pin pushers, and squib operated valves to perform these functions.

High reliability, low weight, and a long shelf life are advantages that make these devices applicable to many designs. A disadvantage, however, is that they use explosives which have rapid burning rates and produce high shock input to the vehicle structure.

The shock environment generated by the detonation of explosive actuated devices has been overlooked as a potentially damaging environment in many equipment specifications. Failure to recognize this potential equipment hazard has in many cases been rationalized on the basis of the short time history of the event and the flexible structure over which the energy must be transmitted to reach equipment. In some specifications, when the environment was known, unrealistic test criteria were adopted because suitable testing facilities were not available.

IV.2.0 CHARACTERISTICS OF PYRO SHOCK

The immediate effect of a detonation occurs within the first few microseconds when stresses are produced in the structure in the vicinity of the pyrotechnic device. The stress waves are quickly transmitted throughout the structure and, as they are attenuated, the original impulse energy in the detonation is converted into vibrational energy in the structure. This latter effect occurs approximately 500 microseconds after the detonation.

A second source of shock occurs when the detonation forces rapidly fracture vehicle structure, bolts, or nuts during a stage or nose-fairing separation. This fracturing of metal is followed by a third source of shock which occurs when the expanding gases from the detonation, or the release of stored tension or compression forces, produce rapid structural distortions near the pyrotechnic device. The combination of these shock sources (and possibly several additional sources) produces what is considered the pyrotechnic shock environments.

The description of a pyrotechnic shock environment required definition of excitation that is considered unmeasurable (or measurable only by highly specialized laboratory techniques) as well as excitation that is measurable by ordinary instrumentation techniques.

IV.2.1 Unmeasurable Shock

This shock is in the form of stress waves and is characterized by a "jump" or discontinuity in the parameters of the materials. In most isotropic structural materials, shock waves will develop during propagation of compression waves above the yield point of the material. Shock waves will not form, however, nor be maintained, during propagation of tensile stress, no matter how great that stress. A shock wave induced by a pyrotechnic separation device can cause a jump in pressure in the detonation area to several hundred atmospheres in a few nano seconds.

Unmeasured shock is beyond ordinary instrumentation capability of laboratory test equipment, but can cause damage to equipment and vehicle structure.

IV.2.2 Measurable Shock

Measurable shock can be defined as a high amplitude, complex vibration transient which decays from a maximum amplitude to 10 percent amplitude in approximately 10 milliseconds. The general characteristics of the complex vibration transient are peak amplitudes reaching 10,000 g's and higher with a predominant frequency between 2,000 and 8,000 Hz. Simultaneously present with the high frequency vibration are the several lower amplitude and lower frequency components necessary to complete the complex vibration transient. Although this shock activity level is present within 5 to 10 inches of the device, shocks of lower amplitude are present throughout the vehicle.

In general, test results indicate that oscillogram transients and shock spectrum frequency distribution show significant reduction in the amplitude of the shock as the distance from the shock source increases.

IV.3.0 APPROACHES TO A SOLUTION OF THE PYRO SHOCK PROBLEM

IV.3.1 Equipment Modification

Sometimes, the only practical means of solving a shock problem is by modifying the equipment. The following are some typical modifications:

- Place relay circuits in an energized rather than de-energized state during shock to decrease the tendency toward relay chatter or transfer.
- Increase command-circuit time constants to prevent activation from control circuits that display short duration chatter and transfer characteristics.
- Use timers to unlatch relays suspected of accidental latching during the shock event.

Equipment modifications add considerable flight confidence, although this is not considered as a method of equipment qualification unless the modified equipment is subsequently shock-tested.

IV.3.2 Analysis

Stress wave propagation in solids is very difficult to analyze because of the nonlinear stress-strain relationship of materials during plastic behavior above the yield point. High speed computers which have been employed to handle numerical techniques have yielded solutions to the one-dimensional wave propagation problem. Experimentally, techniques have been developed to gather data to establish stress wave parameter relationships (Hugoniot curves), obtain damage threshold levels, establish data about damage mechanism and strain rate effects, and to verify the solutions obtained by the analysts. Various workers have recently attempted to obtain a solution to the two-dimensional problems; however, data of real value to the design engineer are not readily available.

IV.3.3 Shock Isolation

There are basically two methods of isolating pyro shock. It may be isolated at its source or susceptible equipment may be isolated from the source.

Isolation at the source is accomplished at LMSC by either shock mounting the source as has been done with pin pullers, or by redesign of the shock generating mechanism as has been done by various LMSC programs in exercises which reduced the shock from separation joints by redesign of the joints. Source shock isolation of pin pullers as well as other squib activated devices is documented in another section of this report.

IV.3.3.1 Shock Mounts

An isolation scheme which has proved to be an effective method of improving equipment performance during a shock event is shock isolation by means of shock mounting. It is, however, only a means of improving equipment confidence unless the mount is shock-tested in combination with the equipment.

IV.3.3.1.1 Potential Shock Mount Problems

Commercially available shock mounts generally will do an excellent job of isolating equipment. There are several considerations, however, in addition to shock isolation itself. Among these are the following:

Installation frequency
Installation space
Weight
Heat dissipation or absorption
Equipment alignment
Universal application

Installation Frequency

Vehicle structural vibrations, which range from a few cycles a second to more than 10,000 cps, have been analyzed and incorporated into qualification test specifications for all equipment.

Equipment installation frequencies that coincide with structural frequencies will usually cause equipment flight vibrations in excess of qualification levels. Before installing shock mounts on equipment that have previously been qualified when hard-mounted to a structure, several calculations are necessary to determine the installation frequency. When these calculations indicate frequencies close to dangerous flight vibrations, shake tests or pull tests are necessary to check the installation frequency.

Installation Space

Discovery of a shock-sensitive component often entails the installation of a shock mount where adequate space is not available. Shock mounts should therefore be as small as possible, and should require little additional installation space.

Weight

One of the objections to the extensive use of shock mounts is the resulting increase in spacecraft weight. Wherever possible, therefore, equipment is qualified for flight without shock mounts.

Heat Dissipation or Absorption

The amount of heat dissipated or absorbed by equipment must be controlled so that operating temperature limits do not exceed qualification levels. A shock mount, when used on high-heat-producing equipment, adds to the thermal problem by acting as an insulator. Shock mounts, therefore, are to be avoided in these cases except where equipment is scheduled to operate for short periods only. A moderate amount of equipment-produced heat may be dissipated by the use of flexible conducting straps between the equipment and the vehicle structure. Such straps are feasible, however, only for equipment that produces a limited amount of heat.

Equipment Alignment

Alignment of equipment which contains optical or tracking systems is difficult when combined with a requirement for shock mounting. This equipment is costly, often one of a kind, and requires maximum shock protection without being subjected to the abuse of testing. The shock mount must maintain accurate dimensional stability once aligned and simultaneously provide the maximum possible shock reduction.

Universal Application

Although less important than performance, universal application is of considerable importance from a cost-reduction standpoint. Each installation should therefore require a minimum of modification to equipment and to the vehicle, as well as a minimum of analysis and testing prior to use.

IV.3.3.1.2 General LMSC Shock Mounting Technique

The type of shock-mount technique generally used at LMSC for equipment protection is shown in Figure IV.1.

The mount configuration consists of two silicone rubber washers and a length of plastic shrink tubing. The washers isolate the equipment package mounting flange from the vehicle structure. The shrink tubing placed around the mounting bolt completes the isolation of the equipment from the vehicle structure. The washers are semi rigid, and are in the 50 to 60 durometer range. The installation is completed by use of a gage to control the compression of the washers from an initial 0.125 inch to a 0.090 inch thickness.

This configuration, in addition to providing good shock isolation, has well satisfied requirements relative to structurel vibrations, space limitations, weight, equipment alignment, and universal application.

Heat dissipation requirements, when not excessive, are solved by use of conducting straps similar to those used with standard mount systems. Vehicle structural vibrations have not presented any significant problems since the weight and installation configuration of most equipment produces installation frequencies between 100 and 200 cps. This frequency range is ideal for separating equipment vibrations from major vehicle structural vibration while the installation acts simultaneously as a typical vibration isolator for the higher frequency vehicle vibrations. Considering the vibrations generated during the pyrotechnic shock, it also is reasonable to predict substantial reductions of the measured pyrotechnic shock. With respect to the unmeasured portion of the pyrotechnic shock environment (i.e., stress waves in the structure) it is theorized that the shock reaching the equipment will be significantly attenuated by the impedance mismatch between the vehicle structure and the rubber mounts.

IV.3.3.1.3 Shock Mount Performance

Although the concept of the simplified LMSC shock mount seemed practical, the mounts were subjected to pyrotechnic shock tests before being accepted for vehicle use. The equipment tested was a small package containing several relays that controlled functions in the vehicle guidance system. Two tests were performed with and without shock mounts. The equipment was instrumented with vibration transducers to measure the shock during both tests. In addition, instrumentation was placed on the facility to ensure that shocks generated during both tests were equal.

The equipment was activated in its functional mode and all control circuits were monitored by an oscillograph which was capable of detecting chatter or transfer in the order to 400 μsec. The performance of the shock mounts was then evaluated in terms of the reduction in the measured shock and in terms of improved equipment operating performance (which is also a function of the unmeasured shock).

The results from the measured portion of the spectrum are shown in Figure IV.2 as a reduction of the shock spectrum response and also as a reduction of the peak amplitude of the transient vibration. The results in both forms of data analysis clearly indicate substantial attenuation of the shock environment.

The results of the functional portion of the test program are more significant than the shock spectrum reduction since improved functional performance is the only justification for the use of shock mounts. Figure IV.3 shows an oscillograph record of the relay chatter and transfer characteristics when tested with and without shock mounts installed on the equipment package.

The shock mount represents an excellent method for protecting equipment against the effect of a pyrotechnic event and thereby improves its performance. Equipment modification has also proved useful. However, LMSC experience in this area has indicated that testing is the most reliable method of assuring equipment flight qualification.

IV.3.4 Testing

In general, commercial type shock isolators can be used to obtain protection from the explosive environment. The extensive use of isolators in space vehicles, however, can be extremely costly in terms of installation area and payload capability. The requirement is, therefore, to guarantee that the equipment package or component will perform satisfactorily, unprotected, in the pyrotechnic shock environment. Since the nature of the environment has defied qualification by analysis, the only practical solution was to devise a test to simulate the pyrotechnic environment.

IV.3.4.1 Data Acquisition and Definition of Shock Environment

IV.3.4.1.1 Measuring Program

Before a qualification test environment could be specified, it was required that environmental data be obtained from the flight vehicle during the shock event. A measuring program was initiated to obtain shock measurements over the entire vehicle structure during a typical staging separation.

The two part program required that an extensive data sample be taken during a ground test program concurrently with specifically duplicated measurements from two vehicles in flight. A correlation study performed on the ground and flight test data showed that the shock environment occurring in near vacuum conditions was duplicated at atmospheric conditions (Section II.A.1). It was, therefore, established that the shock environment could be simulated realistically at atmospheric conditions.

Instrumentation used during the ground test program consisted essentially of shock type piezoelectric accelerometers and an FM magnetic tape recorder. All shock data were recorded at 60 ips. The data reduction to oscillograms was obtained by playing the tape system back at 15 ips into a recording oscillogram which contained a 2500 cps galvanometer. The recorder paper speed was 100 ips which rendered vibration data to 10,000 cps. The total instrumentation system capability was 10,000 cps.

Nose Fairing Separation

Data was collected on the pyrotechnic shock environment associated with removal of the vehicle nose fairing. The data obtained is classified and is not included in this report. The nose fairing was separated by 10 grain/foot MDF located circumferentially and longitudinally around the fairing. Accelerometers were located throughout the forward equipment rack and the data obtained from those locations were analyzed with the shock spectrum routine.

Vehicle/Booster Separation

The shock environment associated with the separation of the vehicle from the booster by means of the primacord joint was described by the tests documented in Section II.A.2 and II.A.6. During these ground tests, measurements were made on the engine cone skin, engine mounting ring and in the forward equipment rack. Additional measurements were made during flight to substantiate the validity of these ground test measurements (Section II.A.1).

Horizon Sensor Fairing Jettison

Test data for the horizon sensor fairing jettison are contained in Section II.A.2. The data were obtained from a ground test of the standard fairing ejection system mounted on the forward rack section. The data from this test described the forward rack environment which is a result of the horizon sensor fairing ejection.

IV.3.4.2 Data Analysis Methods

Once the shock event was recorded, it was necessary to convert the transient structure response into equipment qualification test criteria. The methods of shock spectra analysis were used to show the response of hypothetical single degree of freedom systems to the shock transient.

IV.3.4.3 Development of Test Criteria

From the onset of the investigation of the pyrotechnic shock environment, major interest was focused on the development of a test capability by which equipment qualification could be established. It therefore became necessary to establish tentative criteria for equipment qualification.

The criteria were based on a comparison of the peak g levels over the frequency spectrum from 200 to 10,000 cps and on a graphical integration of the shock spectrum curve in each octave band. An acceptable qualification test was achieved when the following requirements were satisfied:

- The peak acceleration at any frequency on the shock spectrum curve of the flight measurement would not be exceeded by more than a factor of 2.5 at the same frequency during the qualification test.
- The octave band areas for the test should exceed the same octave band area obtained from the flight data.
- The complex vibration transient should be similar in peak amplitude, shape, and total duration to the actual vehicle measurements.

The pyrotechnic shock qualification criteria were established for various equipment location areas in the vehicle during nose fairing separation, vehicle/booster separation and horizon sensor fairing jettison. The criteria are stated in terms of response area (g's x cps) versus octave frequency bands.

IV.3.4.4 Test Facility Requirements

Once the vehicle shock environment due to the various pyrotechnic devices which are flown was identified, it was necessary to develop a testing facility with the capability of generating an environment that would fulfill the three prime objectives of the test criteria. It was also felt that if the objectives were met, a realistic simulation for the pyrotechnic shock environment would be available.

The requirements for the testing facility were that it be capable of providing a pyrotechnic environment that simulated the pyrotechnic separation of the vehicle/booster and nose fairing. It should, in addition, be of a design and construction representative of the vehicle and the environment should be created by the detonation of pyrotechnics similar to those used in flight.

IV.3.4.5 Choosing a Test Facility

With the definition of the criteria, it was possible to consider the test methods which would best satisfy the criteria. The several methods included:

Full scale vehicle tests
Electrodynamic shakers
Drop and impulse testers
Transfer-table system
Barrel tester system

IV.3.4.5.1 Full Scale Test

Full scale tests were the [illegible] method of generating the pyrotechnic shock environment. Full scale vehicle tests, however, are very expensive and time consuming. Furthermore, achieving the desired overtest can prove to be quite difficult. See Section III.A. In addition, these tests do not allow flexibility in substituting modifications of equipment which occur continually on satellite programs. For these reasons, it was determined that, in general, the method of overtesting for the upper stage vehicle systems should allow for testing of individual components. In the present State-of-the-Art, full scale vehicle testing at flight levels appears, however, to be a practical method of increasing system confidence.

IV.3.4.5.2 Shakers

Shakers were unable to satisfy the requirements of high peak acceleration and transient vibration waveform. This method of testing is seldom used at LMSC.

IV.3.4.5.3 Drop and Impulse Testers

Drop and impulse testers which were commercially available were not used because they produce severe overtests in the lower frequencies and are difficult to control to the desired test spectrum. The rigid test fixtures and the nonpyrotechnic shock source also discourage their use.

IV.3.4.5.4 Transfer-Table System

A transfer-table system was developed to produce a complex vibration on a drop tester without producing excessive low frequency damage to equipment. See Section II.F.1. The table consisted of a flat aluminum plate (3 x 12 x 12 inches). Attached along each of the twelve inch sides were support legs (2 x 10 x 12 inches). The legs, in turn, were fastened to the original large mass which was furnished with the basic drop machine.

The measuring techniques and instrumentation used to obtain the flight data were duplicated during the development of the transfer table. Although the objectives originally specified were reasonably accomplished, there existed several additional secondary considerations which required evaluation before the final selection of a testing facility. They were as follows:

1. The inability of the transfer table to produce an overtest of the maximum vehicle environment.

2. The degree of control over the amplitude of the shock environment was limited.

3. The size of the test component was restricted to approximately that of a ten inch cube.

4. The excitation at the test equipment interface is dependent on the mode shape of the table. Small components would, therefore, be less affected than large.

5. The simulation of a pyrotechnic explosive event by a drop table was not from a pyrotechnic source.

IV.3.4.5.5 Barrel Tester

Although the results obtained from the transfer table were encouraging, the limitations which were present suggested that another approach could possibly improve on the environmental simulation. The second approach (the barrel tester) was an attempt to duplicate the environment by similarity. The similarity existed between the diameter and skin thicknesses used on the barrel tester and flight vehicle. The similarity of the flexibility between the two structures would provide for essentially the same path for the pyrotechnic shocks to travel to component packages while the transfer-table structure was a relatively rigid plate. In addition, the mechanism of excitation would be similar to that in the vehicle system in that both would use explosives and fracture a metallic separation joint, while the environment at the transfer table resulted from the impulsive loading by the drop tester table. See Figure IV.5 for details of the barrel tester.

A shock generating joint was developed which would function repeatedly without degradation in performance and whose action was similar to the flight vehicle staging joint (see Section II.F.?). The barrel environment was then evaluated to determine if the requirements specified in the test criteria could be accomplished. It was also necessary to determine if the barrel could improve on the limitations of the transfer table - i.e., the degree of control over the shock amplitude and size of components which could be tested. The barrel already accomplished the simulation of the shock by explosives.

The control over the shock amplitude is obtained by positioning equipment along the barrel structure and by the proper combination of explosives and separation joint thickness. Several tests performed showed that varying the amplitudes did not change the transient vibration shapes. The transient vibrations measured were also shown to be similar to vehicle flight data.

The shock environment created by the barrel tester was found to be very similar to the vehicle data. Figures II.F.7 and II.F.8 compare the flight environments to the barrel environments as determined from 22 of the most recent barrel tests.

IV.3.4.5.6 Comparison of Barrel Tester and Transfer Table

The environments generated by the barrel tester and transfer table were both reasonable simulations of the flight event, as initially required in the test criteria. The inability to produce an overtest for the maximum flight shock, the limited amplitude control and the artificial generation of the explosive shock proved to be the primary deciding factors in the selection of the barrel tester over the transfer table as a standard qualification facility for equipment. The transfer table, although not a qualification tool, is presently being used for equipment development testing and correlation studies.

IV.3.4.6 Establishing a Test Program

IV.3.4.6.1 Creation of a Pyrotechnic Shock Specification

It was felt that further development of the barrel tester would result in an even closer attainment of the stated criteria goals; however, the simulation was judged adequate to begin qualification of equipment.

Since the only acceptable existing facility for pyrotechnic shock testing at LMSC was the "barrel tester," the criteria were directed to that facility. The limits of the criteria were determined by the necessity of achieving an overtest of the flight environment while remaining within the capability of the testing facility to generate the environment. A pyrotechnic shock specification change notice was written to incorporate that environment into the environmental specification. Figure IV.4 shows the vehicle zones and the appropriate environmental test area on the barrel tester for the various pyrotechnic events.

IV.3.4.6.2 Barrel Test Procedure and Test Methods

The following methods and procedures were established to qualify equipment for pyro shock on the barrel tester:

Equipment Installation

Test equipment should be mounted to the test fixture on metallic brackets with a minimum installation frequency of the bracket and equipment assembly of 80 cps. When equipment packages greater than 20 pounds are tested, a bracket installation frequency of 40 cps will be acceptable.

Equipment should be mounted in each test bay in the most practical forward position, i.e., in the position closest to the pyrotechnic joint. When actual equipment brackets are available, they should be used for the qualification testing. The installation frequency stated above is then waived, with the bracket stiffness then being determined by design to withstand the ascent vibration and acceleration environment.

Qualification Test Procedure

It is necessary to perform two tests to qualify each equipment package. The test environment shall be determined by the environmental conditions created by either the booster separation, nose fairing separation or horizon sensor fairing jettison, whichever is applicable. The tests shall be performed with the equipment centered in the most forward position of the required test bay. The second test shall be performed with the equipment in the same location as the first, but rotated 180° on its mounting bracketry. For large components which cover the major portion of the mounting panel, the entire panel may be rotated 180° for the second test.

The equipment should be located in either Bay I or Bay II of the "barrel tester" during qualification testing. The applicable testing bay and qualification environment applicable to the various vehicle locations can be determined from Figure IV.4.

Equipment Operation

The flight condition of the equipment package during the occurrence of the flight shock events should be duplicated during the qualification (e.g., operating or in a "hot" condition). Monitoring instruments should be provided for electrical and electromechanical equipment to determine intermittent operation during the shock event when such operation is detrimental to the vehicle flight. The equipment should be subjected to acceptance tests, performed in accordance with specification procedures, immediately prior to and following the shock tests.

Test Instrumentation

Instrumentation is to be provided during each shock test to determine the environmental simulation. The instrumentation should consist of Endevco 2225 or equivalent shock type transducers. The transducers should be fastened in three mutually perpendicular axes to a one inch cubic aluminum block. The block, in turn, is fastened to location A on the "barrel tester" (see Figure IV.5) for testing in Bay I and location B for testing in Bay II. The instrumentation locations specified are adequate for testing with equipment located in only one quadrant or with equipment in all four quadrants of each test bay.

The one-cubic-inch blocks are to be bolted and bonded to the barrel structure with the transducer axes orientated longitudinally, radially and tangentially with respect to the "barrel tester."

Data Analysis

The shock data obtained during each test should be analyzed according to the following procedure:

1. The data from each accelerometer is to be subjected to a shock spectrum analysis using a system damping = 2 percent or Q = 25.
2. The shock spectrum analysis should cover the frequency spectrum from 200 to 6400 cps.
3. The shock spectrum curves obtained from each of the three shock transducers located at point A or B are to be combined into a maximum envelope (composite) shock spectrum curve.
4. The area under the composite shock spectrum curve should then be computed in octave bands from 200 to 400, 400 to 800, etc. up to 6400 cps.
5. The computed area in octave bands from step 4 must then be compared with the applicable test environment in Figure IV.4 depending on the test conditions (booster separation or nose fairing separation, etc.) and equipment location (Figure IV.4). This comparison will determine whether the equipment has been subjected to a shock level of sufficient magnitude to establish qualification.

Shock Susceptible Equipment Considerations

Not all equipment is considered to be susceptible to the shock environment. Where the equipment is not susceptible, the pyrotechnic shock requirement may be waived.

Equipment which is considered to be susceptible to the pyrotechnic environment generally includes the following: electrical equipment, electromechanical equipment, mechanical equipment containing delicate subassemblies, and mechanical equipment containing nonmetallic elements such as ceramics, epoxies, phenolics, lenses, silicates, etc.

Design Consideration

The pyrotechnic shock criteria were intended only for qualification testing. In no way were these criteria to be interpreted by equipment design and development engineers as a means for determining loading conditions for prime equipment packages or subassembly structure.

Conversion of pyrotechnic shock criteria into design loads is presently beyond the state-of-the-art. Attempts to design structure for pyrotechnic shock will unnecessarily weight-penalize equipment packages.

IV.3.4.7 Barrel Tester Maintenance and Instrumentation

IV.3.4.7.1 Maintenance

To achieve the necessary repeatability of the shock spectrum, all the fasteners must be torqued to specified values before each shock. This technique is necessary to maintain surface-to-surface contact pressure at each joint such that the shock transmissibility is constant from shock to shock. The torquing of the magnesium-thorium clamp screws ensures an equal shear level around the periphery of the barrel so that the shock front is symmetrical at all locations around the barrel.

To minimize the damage to the explosive heat, a hardened steel insert strip is fastened to the aluminum head. This insert strip has a groove into which the MDF is installed. With each successive shock, this groove widens to the point where the shock level falls below acceptable standards. The loss of level as a result of this condition is avoided through the use of records which plot each shock in shock level values taken from the processed data. Through monitoring of this plot, it was established that 30 tests is the optimum number of tests which may be conducted before the insert requires replacement. Another record documents the complete history of the tests by date, environment provided, failures and accumulated shocks of the various parts of the facility.

IV.3.4.7.2 Instrumentation

On a given shock test, six (6) Endevco 2225 transducers are used to monitor the shock. They are set up in triaxial configurations with one set of three (3) as the primary data source and the second set as backup. The most prevalent problem with these measurements is a tendency of the transducers toward random zero shift on the higher level shocks. The major part of this zero shift can be removed in the data processing, although at additional cost.

Great care is exercised in the installation of the transducers to ensure maximum response. Light oil is applied under each transducer to aid in the surface-to-surface coupling. Torque checks are made before each shock on each transducer.

The transducers are coupled to solid state voltage amplifiers through 20 feet of Microdot cable. The amplifier output is then recorded on 14-track tape recorders. Calibration of the system is accomplished by relay switching the transducer out and injecting a simulated transducer signal of 50 percent and 100 percent of range at 1000 cycles.

IV.3.4.8 Update in Barrel Test Methods and Procedures

The Lockheed Pyrotechnic Shock Facility, now in its fifth year of operation, has been used for over 250 separate shocks which have been applied to a variety of aerospace flight equipment.

IV.3.4.8.1 Design Changes

The only significant change in the barrel structure has been the redesign of the separation joint in which a cutting edge has been added at the top of the separation ring. The life of the separation joint was previously limited by both the life of the joint explosive cavity and the life of the ring which was between 20 and 30 tests for both. While the explosive cavity is relatively easy to replace at small cost, the ring required extensive time to replace, at a much greater cost.

By the addition of a hardened steel cutting edge to the ring, the ring life was extended from 30 firings to well over 200 firings. This was accomplished without decreasing the barrel performance.

IV.3.4.8.2 Test Criteria

There have been no changes in the test criteria. Further flight data has verified the environments which were established in the developmental phase of the barrel tester.

IV.3.4.8.3 Data Processing

Although the barrel tester has had several minor modifications to improve its capability, the most significant change in the total testing technique has been the incorporation of a computer program for analysis. This analysis has resulted in completely automated data processing for the qualification test. The end product is a print-out sheet stating the qualification status of the equipment and the degree of overtest obtained.

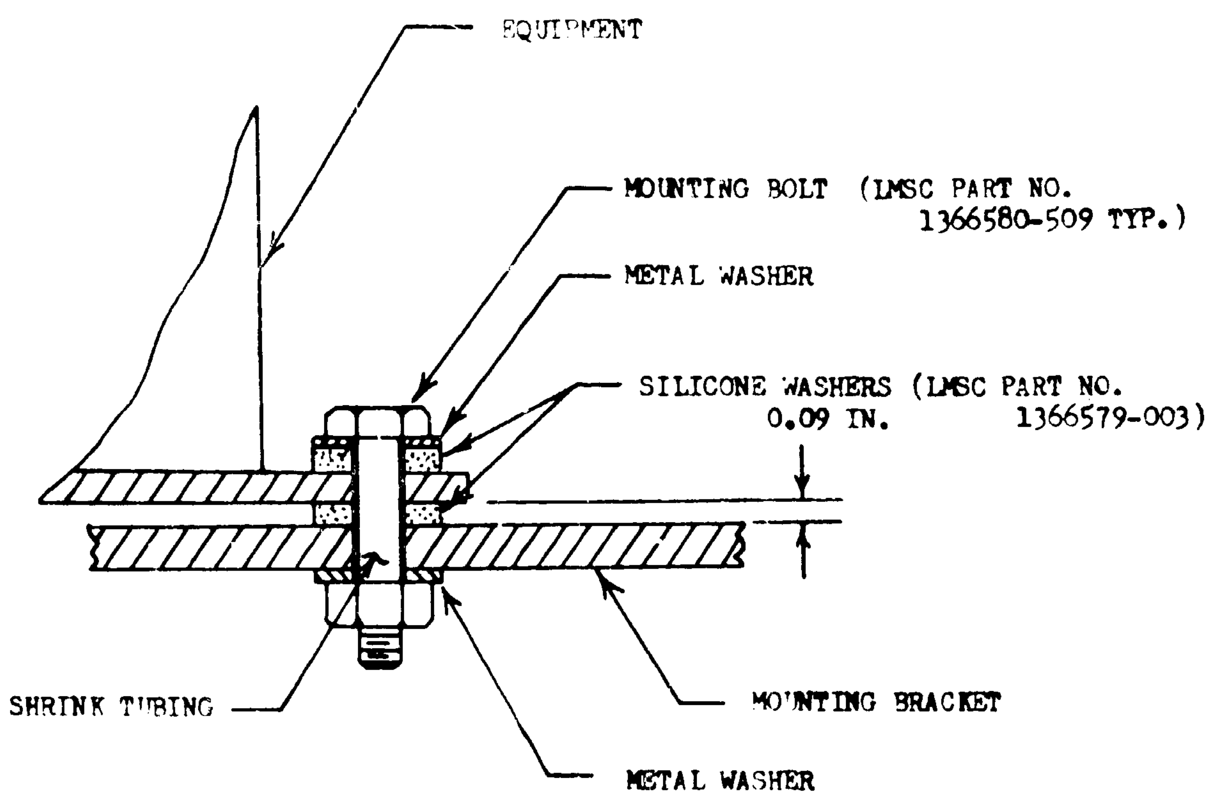


Figure IV.1 TYPICAL LMSC SHOCK MOUNT

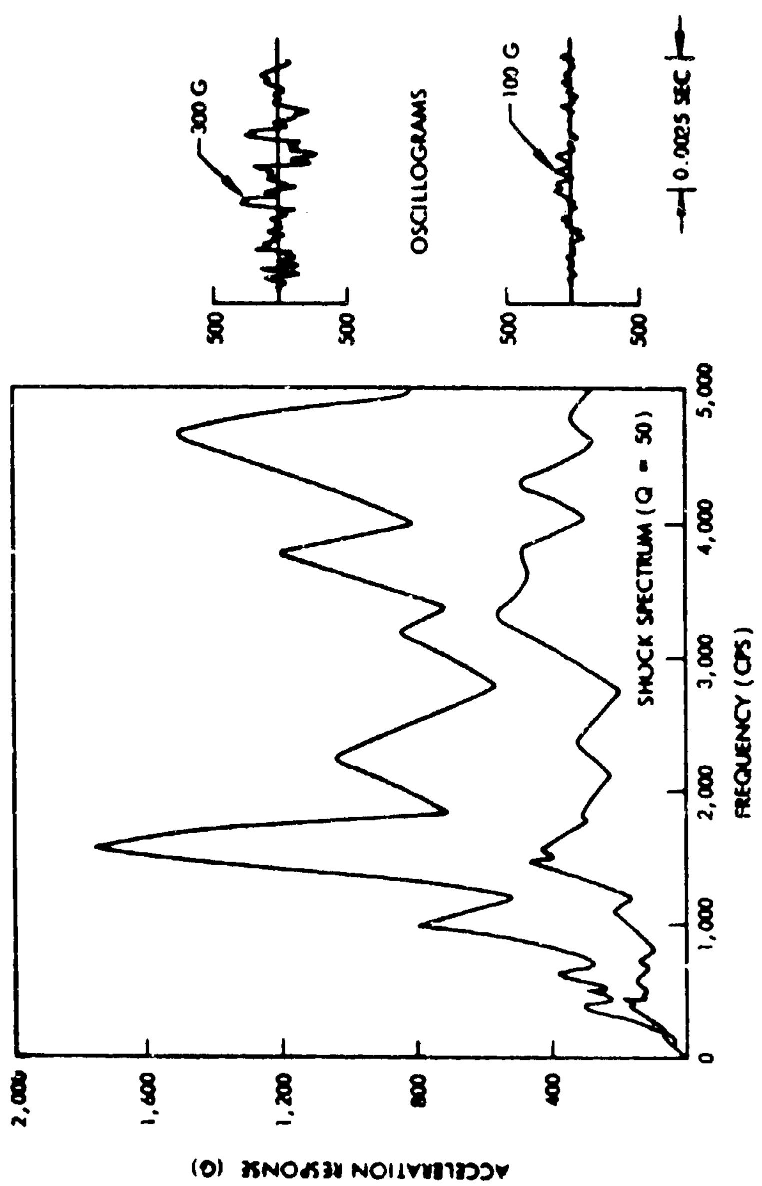
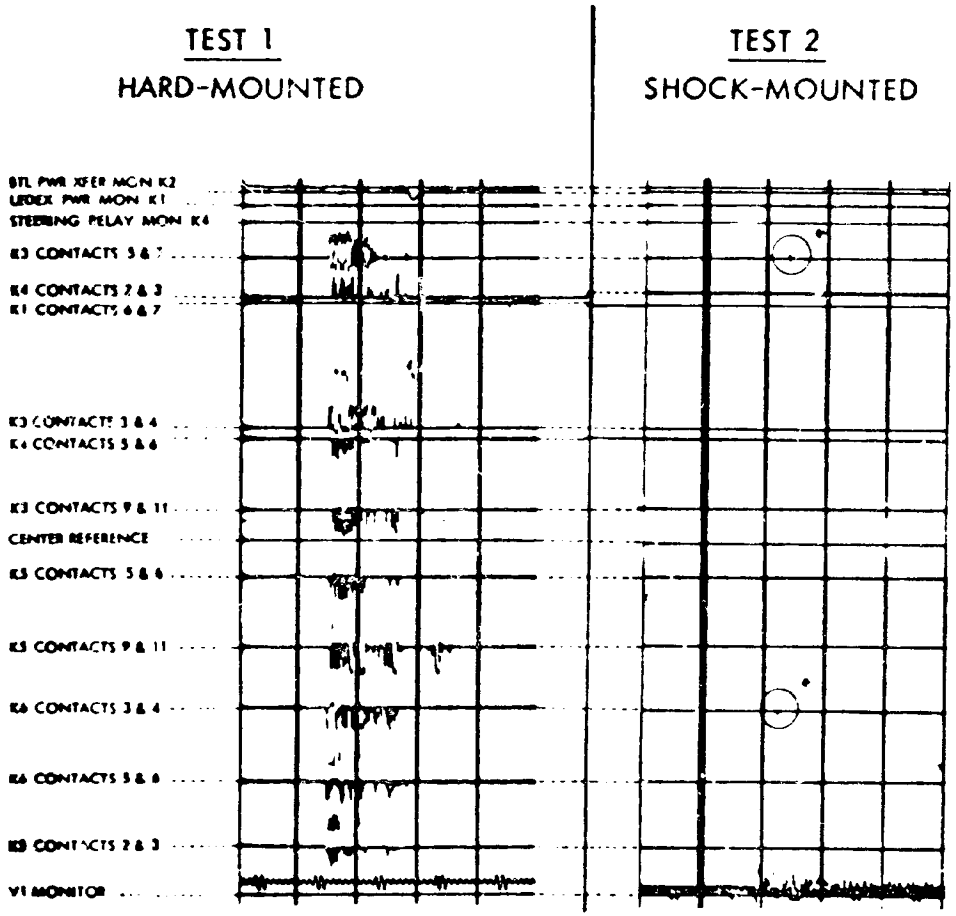
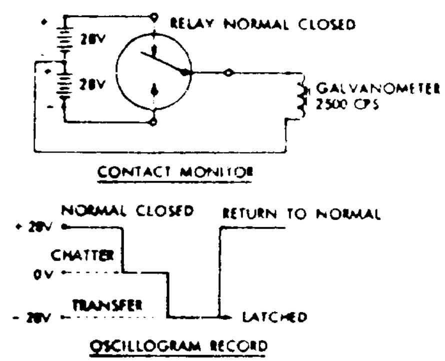


Figure IV.2 LMSC SHOCK MOUNT SHOCK REDUCTION

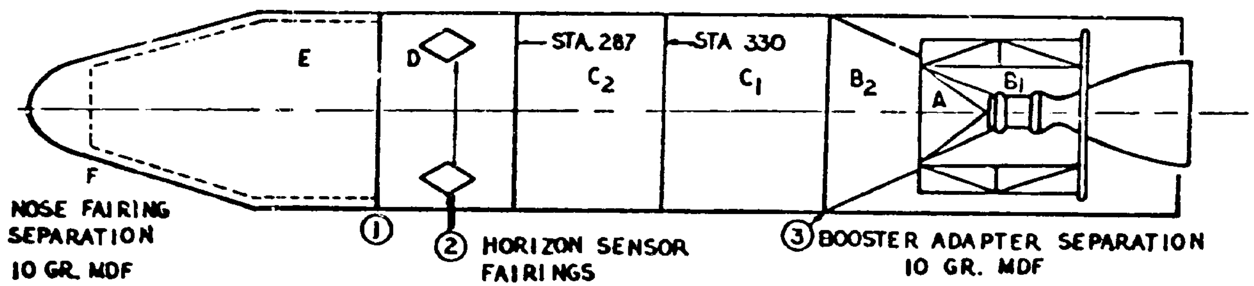




RELAY OPERATION

RELAY	CONTACTS	SHOCK MOUNTS	
		BEFORE	AFTER
K1	1	OK	OK
	6 & 7	CHATTER	OK
K2	1 & 2	CHATTER	OK
K3	5 & 7	CHATTER	*
	3 & 4	CHATTER	OK
		TRANSFER	OK
K4	1 -	CHATTER	OK
	2 & 3	CHATTER	OK
	5 & 6	CHATTER	OK
	9 & 11	CHATTER	OK
K5	5 & 6	CHATTER	OK
		TRANSFER	OK
	9 & 11	CHATTER	OK
	2 & 3	CHATTER	OK
K6	3 & 4	CHATTER	*
		TRANSFER	OK
	3 & 6	CHATTER	OK
		TRANSFER	OK

Figure IV.3 RELAY CHATTER AND TRANSFER WITH AND WITHOUT LMSC SHOCK MOUNTS



VEHICLE AREA	TEST ENVIRONMENT ①	②	③
A ENGINE	—	—	BAY II
B_1 AFT SECTION	—	—	BAY II
B_2 ENGINE CONE	—	—	BAY I
C_1 TANK STA. 330 AFT	—	—	BAY I
C_2 TANK STA. 287 to 330	BAY II	—	BAY I
D FORWARD SECTION	BAY I	BAY II	—
E PAYLOAD AREA	BAY I	BAY I	—
F NOSE FAIRING	BAY I	—	—

Figure IV.4 DESIGNATION OF TEST BAND AND TEST ENVIRONMENTS FOR EQUIPMENT LOCATIONS

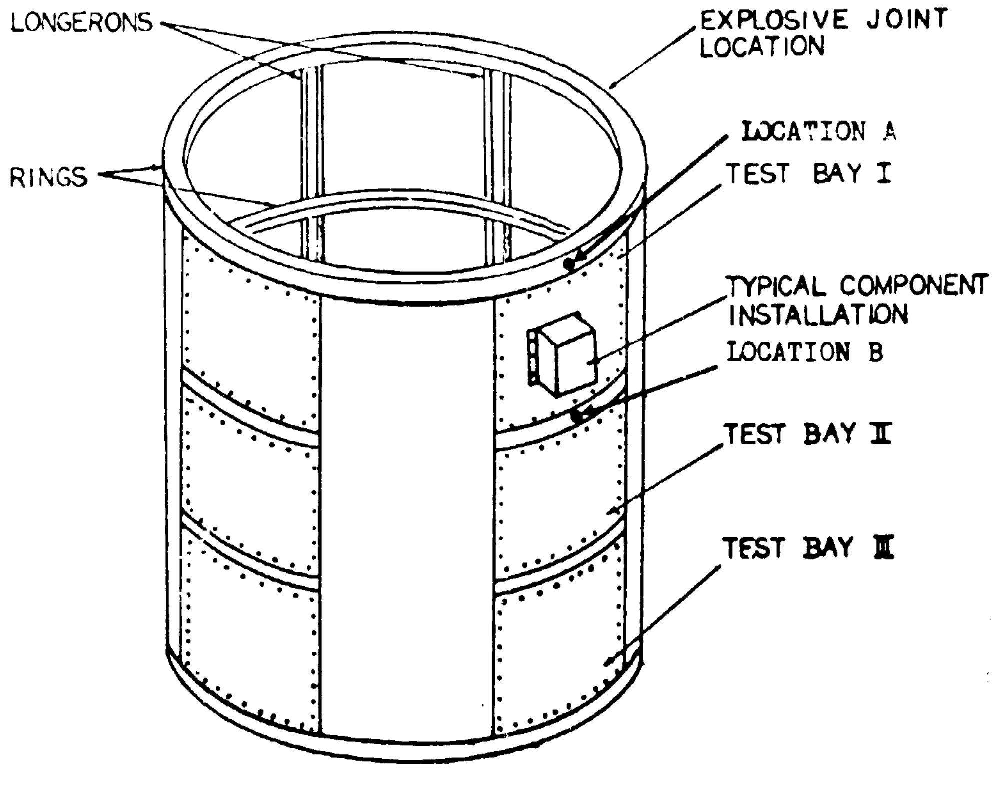


Figure IV.5 BARREL TESTER CONFIGURATION

SECTION NO. V

SUBJECT:

TEST INSTRUMENTATION

SECTION V

SUMMARY

This section contains a brief description of the instrumentation in use at LMSC for acquisition and data reduction of pyro shock environments.

Three LMSC laboratories are equipped for pyro shock testing: Santa Cruz Test Base (SCTB) and Buildings 102 and 104 at the Sunnyvale main plant. Due to somewhat different capabilities of the laboratories, the data acquisition systems vary in details but the data processing system is common to all.

Since each section of the compilation contains a description of the accelerometers installed on the specimen, only the general data acquisition and data processing systems are described here.

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V.1 INTRODUCTION

The data aquisition systems in use at the various LMSC Laboratories are basically identical. They differ only in details and type of equipment. Except for one special amplifier in use at SCTB all test equipment is commercially available. Frequency response curves of the data aquisition systems are presented in this report. For more complete data about this equipment, manufacturer documentation should be consulted.

All instrumentation in use by LMSC Laboratories is periodically calibrated by the Standard Laboratory. It is maintained at all times within manufacturer specifications.

V.2 DISCUSSION OF PYROTECHNIC SHOCK TEST INSTRUMENTATION

V.2.1 General

This discussion follows the general arrangement of test data reduction systems: accelerometers, data acquisition and data processing, which are dealt with separately.

V.2.2 Accelerometers

Each subsection of Section II of this report contains a description of the specimen instrumentation listing the type of accelerometers used and their locations. For rapid reference, Table V.1 gives a list of the subsections and the laboratories where the tests were performed. Table V.2 presents a list by manufacturers of all types of accelerometers which were used at LMSC for pyrotechnic shock tests.

V.2.3 Data Acquisition Systems

The basic data acquisition system amplifies the signal provided by the accelerometers and stores it on an analog magnetic tape. On-line plotting of oscillograms is also normally available. A schematic of the data acquisition system in use at SCTB is presented on Figure V.1. Similarly that of the Sunnyvale laboratories is shown on Figure V.2. SCTB has replaced the Glenite F410M by a LMSC (SCTB) solid state A.C. amplifier. This new amplifier has characteristics similar to that of the Glenite F410M. System frequency response curves are shown on Figure V.4 and V.5. All data recording is via magnetic tape recorders operating at 60 inches/second.

V.2.4 Data Processing System

The data processing system is shown on Figure V.5. The analog tapes prepared by the data acquisition systems are processed to provide either oscillograms or digital time plots and shock spectrums.

The production of oscillograms is a purely analog process which provides plotted records with optional filtering. The analog magnetic tape which was recorded at 60 inches/second is played back at 15 inches/second into a playback amplifier which in turn drives a galvanometer and a CEC (Consolidated Electronic Company) recording oscillograph. The galvanometers used in the oscillograph are either No. 361 or 362 made by CEC and the oscillograph is model 5-119 also made by CEC. The 1/4 playback speed plus the galvanometer and magnetic tape recorder characteristics must all be considered in establishing the frequency response of the oscillogram data.

The production of shock spectra and digital time plots involve digitization of the analog tape which is transcribed on a binary tape compatible with the Univac 1108 computer input. The computation is performed on the Univac 1108 by the special program LMSC 2W7006 whose output is a tape for input into the Stromberg-Carlson 4020 plotter.

Program LMSC 2W7006 has provision for data corrections such as piezo crystal shift. All reduction is normally performed for a 100 points with variable bandwidth to cover the range 0 to 10,000 cps.

V.2.5. Signal to Noise Ratio

The data acquisition and reduction systems in use at LMSC are capable of producing high signal to noise ratio data. Since each test presents its own peculiarities the signal to noise ratio varies between some limits. However, the data presented in this Compilation was selected for a high ratio which probably exceeds 95% in most cases.

Where oscillogram data is presented, more accurate approximation may be obtained by measuring the traces prior to and during shock.

V.3 CONCLUSION

The data acquisition and data processing systems in use at LMSC for pyrotechnic shock data reduction has been developed through several years of operation. It is reliable and provides high quality data.

The standard data reduction system is based on a 100 points representation with variable bandwidth covering the range 0 to 10,000 cps.

In order to satisfy the requirement of this contract, the standard 100 point data was read from plots at the specified 1/3 octave center frequencies.

Table V.1

LMSC PYROTECHNIC SHOCK LABORATORIES

Report	Section	Laboratory
606A	A.1	Flight Test
674	A.2	SCTB
768	A.3	SCTB
790	A.4	Sunnyvale - 102
1080	A.5	Sunnyvale - 102
1340	A.6	Sunnyvale - 104
1377	A.7	Sunnyvale - 102
794	B.1	SCTB
867	B.2	Sunnyvale - 102
1353	B.3	Sunnyvale - 104
1315	C.1	Sunnyvale - 102
1336	C.2	SCTB, Sunnyvale - 102
429	D.1	SCTB
447	D.2	SCTB
353	E.1	SCTB
456	E.2	SCTB
535	E.3	SCTB
543	E.4	SCTB
547	E.5	SCTB
562	E.6	SCTB
832	F.1	SCTB
837	F.2	Sunnyvale - 102

Table V.2

LIST OF ACCELEROMETERS USED IN PYROTECHNIC TESTING

Manufacturer	Model Number
Endevco	2220
	2225
	2223
	2951
Glenite	314 TMV
	A 314 TM
Kistler	802
Columbia	2231

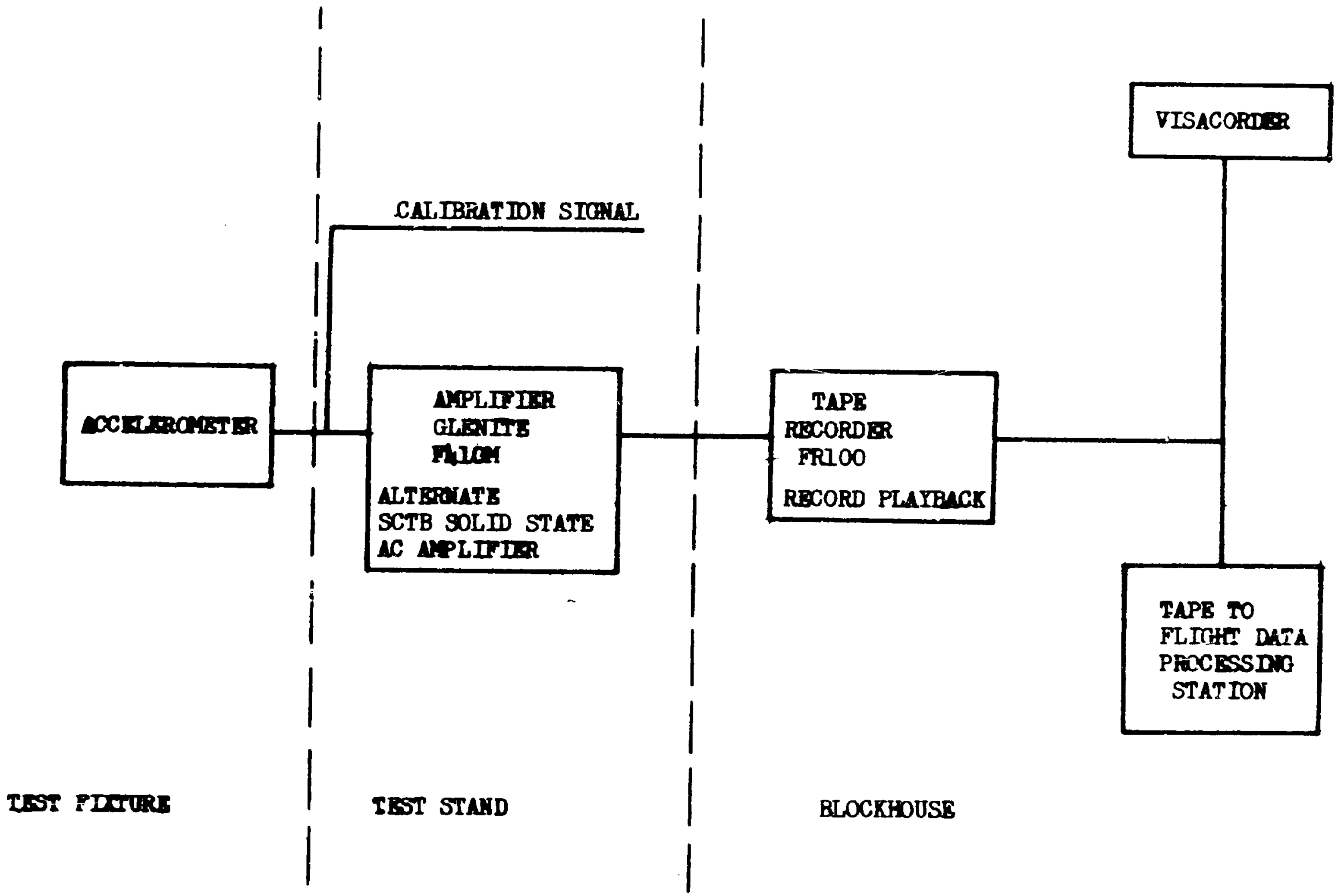


Figure V.1 - SCTB DATA AQUISITION SYSTEM

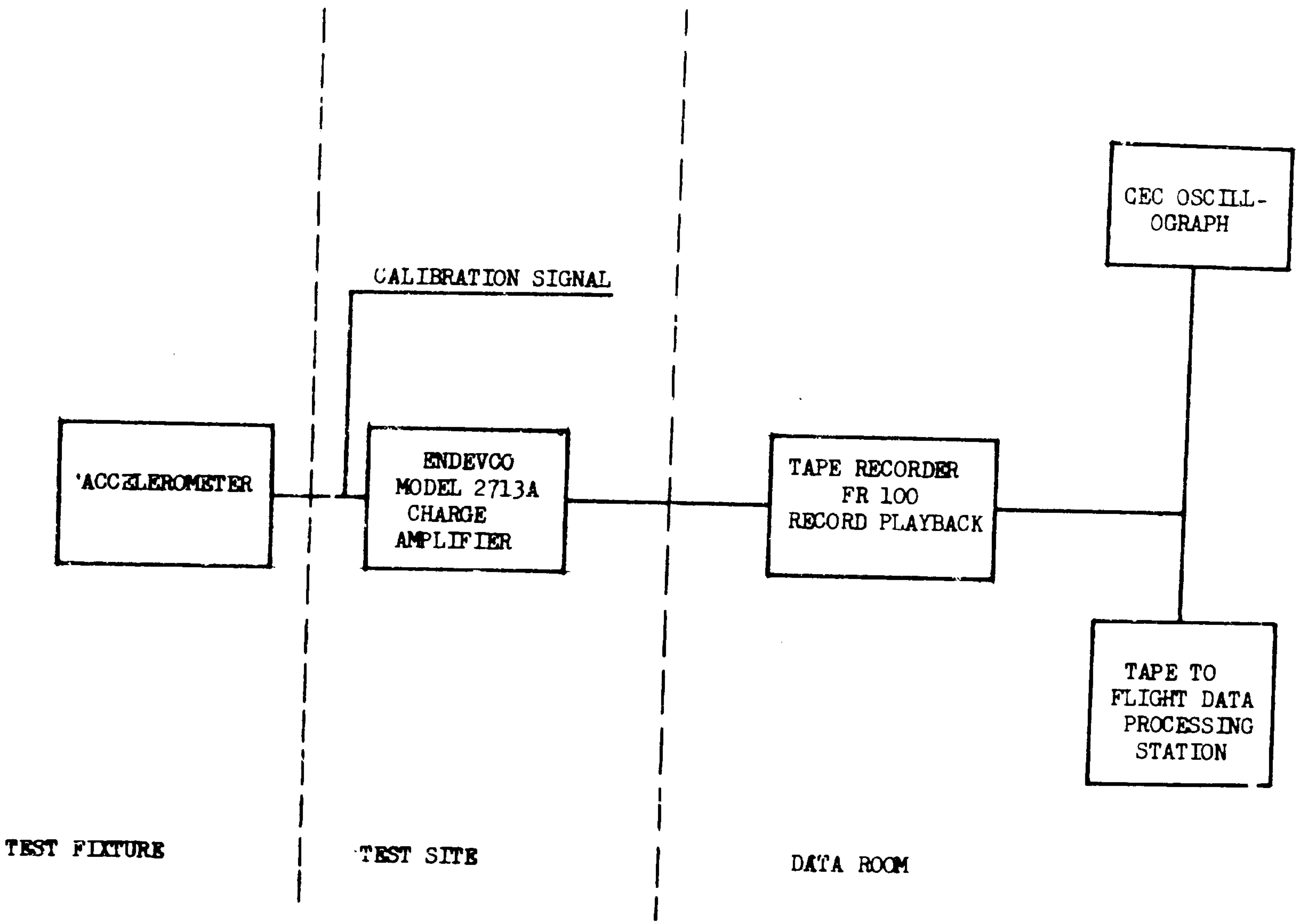
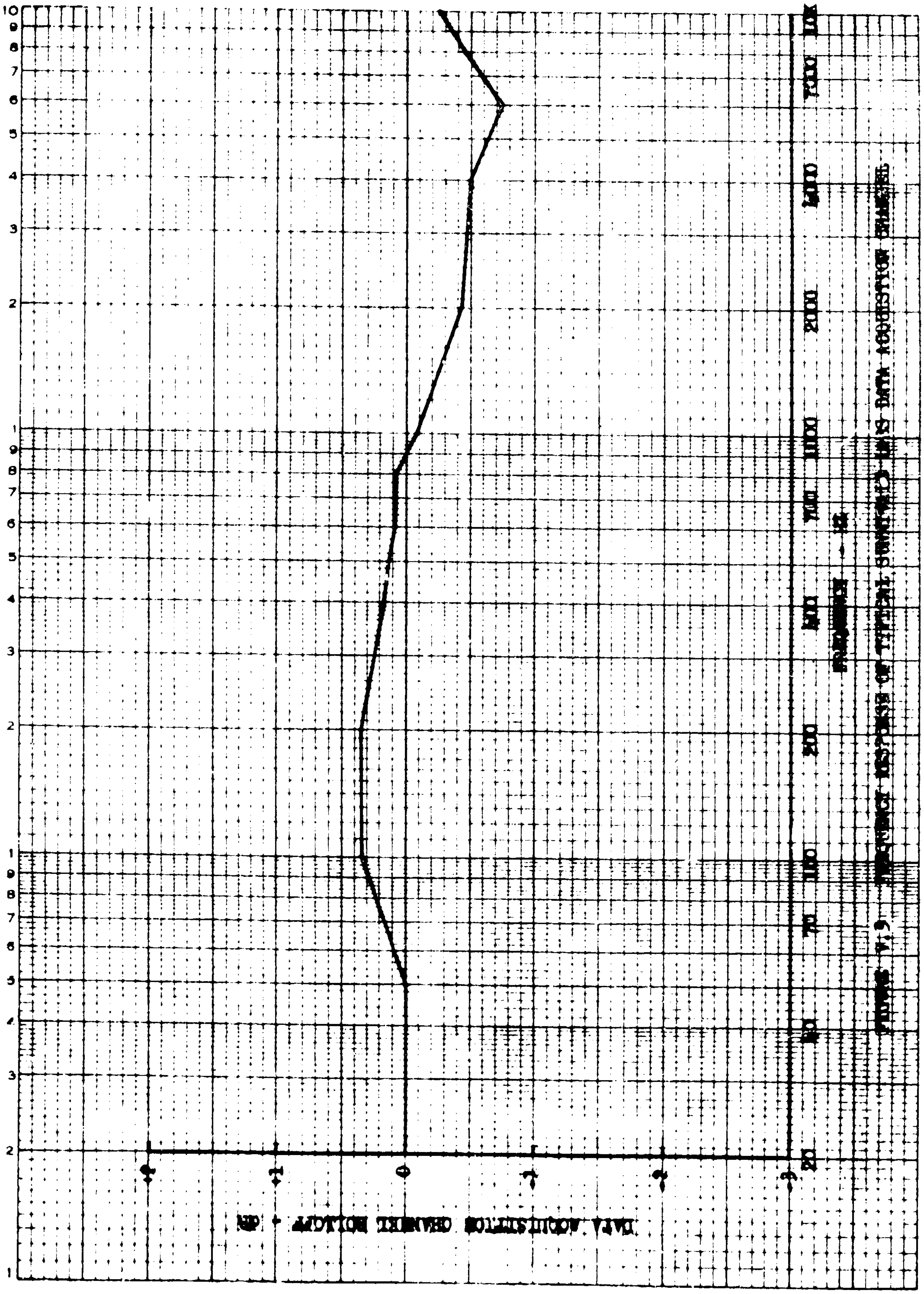


Figure V.2 - Sunnyvale Laboratories Data Acquisition System



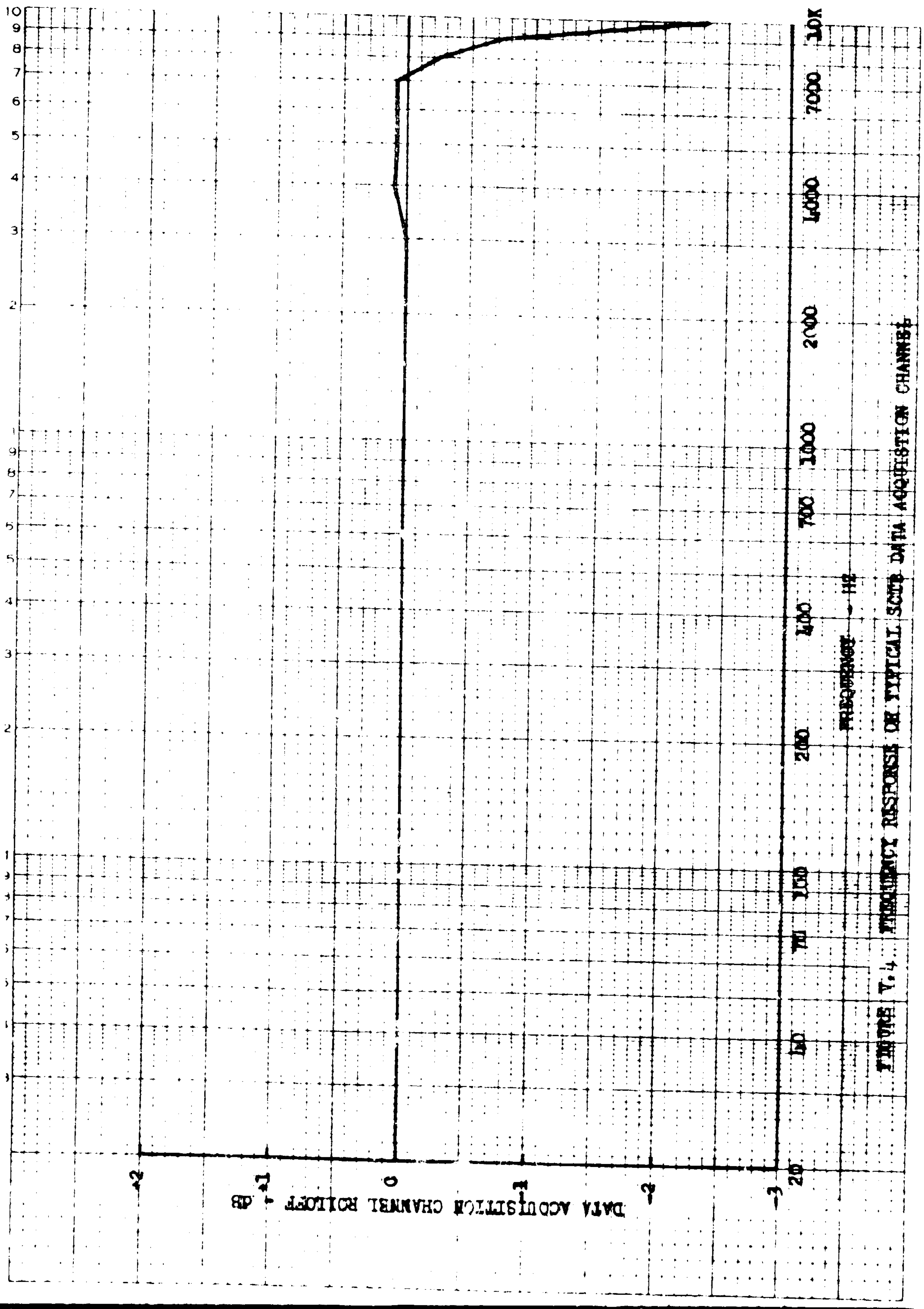


FIGURE V.4. FREQUENCY RESPONSE OF TYPICAL SCTB DATA ACQUISITION CHANNEL

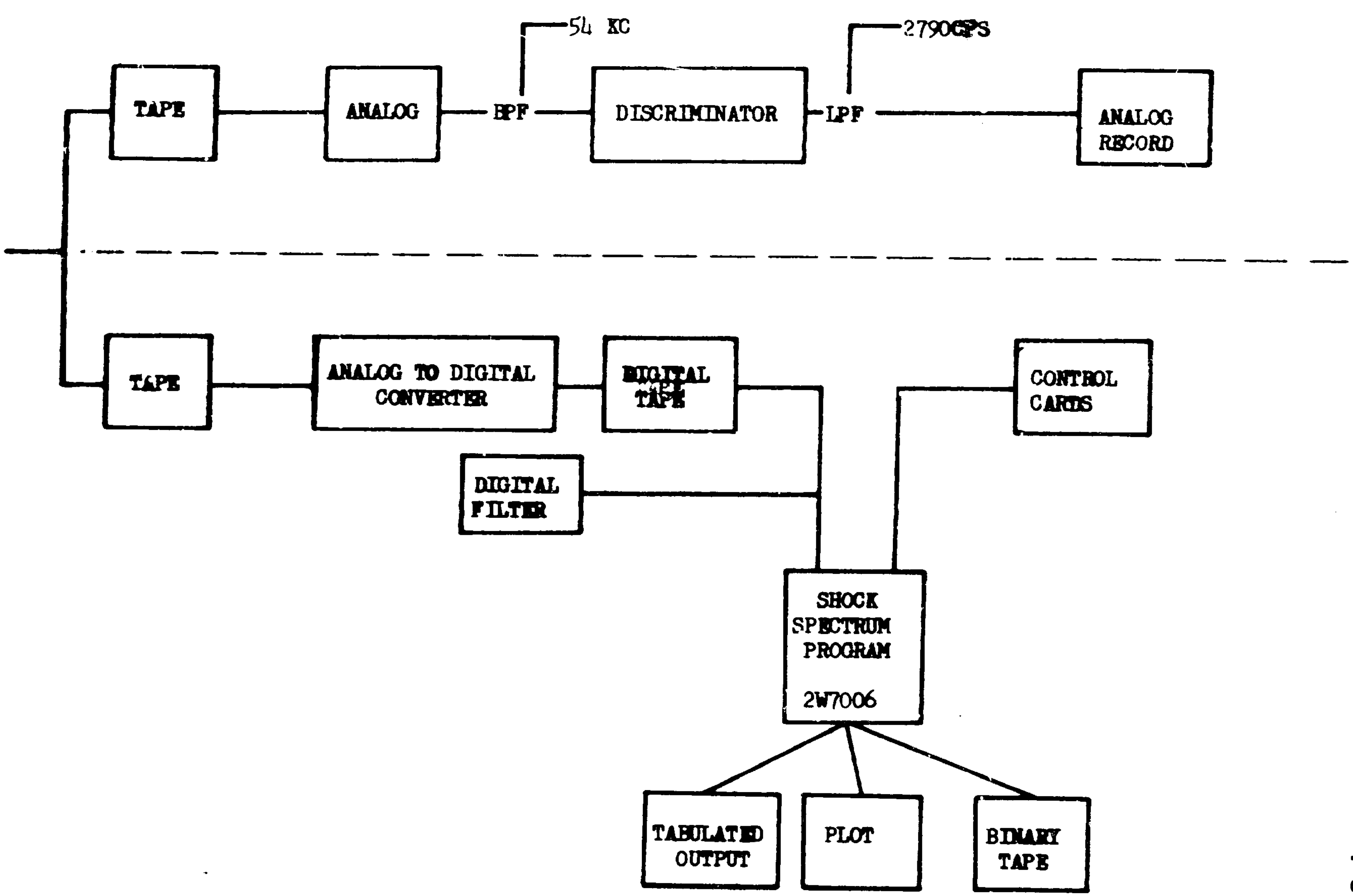


Figure V.5 - FLIGHT DATA PROCESSING STATION BLOCK DIAGRAM

SECTION NO. VI

SUBJECT:

PYRO SHOCK FAILURES

SECTION VI

SUMMARY

Out of 119 items of equipment which have been tested over the last five years on the Barrel Tester, 10 percent experienced failures which were traced to design or manufacturing defects. 13.5 percent of the 119 equipment items tested displayed relay chatter. In most instances, simple modifications to the faulty components enabled the equipment to perform satisfactorily when subjected to subsequent shock tests.

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VI.1 INTRODUCTION

In the course of the five years in which the Barrel Tester has been in operation, over 119 individual equipment items have been subjected to qualification pyro shock. The importance of the Barrel Tester as a qualification test facility becomes obvious when the failure history of that equipment is reviewed.

The barrel test environments which are used to qualify equipments for various vehicle pyro shock events have been shown to be very similar to the shock environments caused by those vehicle events. Procedures are carefully outlined and rigidly adhered to to assure the best duplication of the flight installation and flight environment and at the same time provide a qualification test which is practical, easily performed, and which will qualify equipment for any location in a vehicle zone (i.e., aft rack, engine cone, forward rack, etc.) such that relocating previously qualified equipment within a vehicle zone will not necessitate requalification of that equipment. Thus, failures which occur during pyro testing on the Barrel Tester are realistic failures which would have had a good probability of occurring in flight and possibly aborting a mission.

Environment levels in Bay 1 and Bay 2 of the barrel are described in details in section II.F.2

VI.2 DISCUSSION

Out of 119 pieces of equipment tested, 12 (10 percent) experienced failures which could be traced to design or manufacturing defects (see Table VI.1) and 16 (13.5 percent) displayed relay chatter.

The specific failures are listed below. The number designations may be referenced to the accompanying tables and may be used along with the test results to obtain additional information on the barrel shock environment to which the equipment was subjected, the equipment weight, the natural frequency of the barrel equipment mount installation, the manner in which the equipment was mounted to the barrel, and the equipment casing type.

TM J Box (1)

A bonded internal circuit board separated from its mountings during one of the shocks to which this box was exposed.

TM Tray Circulator Bracket (8)

During a test of a transmitter and RF Circulator, the circulator, which was bonded to the TM Tray, broke loose. The circulator was bolted to the tray and the test continued.

RF Circulator Bracket (15)

Three bonded brackets with mass simulators were tested. The bonding was applied under chemical laboratory conditions. Of the three brackets, two bonds broke during the shock. These tests are documented in more detail in Section II.E.3 (Report No. 535) of this compilation.

Transmitter Type 13 (17)

The transmitter was operated for this test. During the shock the transmitter turned off. The transmitter electronic switch circuit failed, rendering the transmitter inoperative. The control circuit was modified to maintain a constant "ON" voltage which eliminated the problem.

Digital Solar Aspect Sensor (20, 21 , 77, 101)

This device is constructed with a glass window which covers a light-sensitive cell. In the first shock the glass cracked. This problem was alleviated by replacing the hard-bonding cement with a soft epoxy. The second shock broke loose an electrical connection to the light-sensitive cell. On the third shock, one of the internal wiring connections separated.

106 Control Actuator (36)

The Control Actuator was mounted directly to the barrel panel. The shock failed the mechanical attachment (staking) of the monoball in the casting which dislodged an actuator bearing from its mounting.

RF Switch (37)

The center pin of an RF connector came loose during shock. The test had been conducted without the mating connector installed. On a repeat test, with the mate installed, the RF switch passed without failure.

Type 12 Transmitter (93)

This transmitter has a weld case cover. A poor weld opened during shock. It was re-welded and the transmitter retested satisfactorily.

Mod IIA Velocity Meter (119)

The Velocity Meter pulse output rate shifted beyond the specified tolerance when it was exposed to a low-environment shock. The Velocity Meter was shock-mounted and successfully qualified.

Chattor

The sixteen cases of relay chatter were detected with Lockheed-designed chatter detectors which were set for indication of chatter in excess of 10 microseconds. The 302 J Box (113, 114, 115) and 708 J Box (97, 108, 109) both required double shock mounting of the boxes to survive shock without chatter. See Section IV for the shock mount design.

VI.3 CONCLUSIONS

The failures which occurred during the barrel tests are typical of the type of failures which occur during pyro shock events. The barrel tests located these failure modes and eliminated flight hazards. In most cases, simple modifications enabled these equipment items to perform satisfactorily.

Table VI.1 SUMMARY OF PYRO SHOCK TESTS

	EQUIPMENT TESTED *	Environment 1, Bay I	Environment 2, Bay II	Weight in Pounds	Installation Natural Frequency	BARREL MOUNT: Bracket	BARREL MOUNT: Direct	BARREL MOUNT: Soft	EQUIPMENT CASING TYPE: Drawn Can	EQUIPMENT CASING TYPE: Milled Box	EQUIPMENT CASING TYPE: Cast Box	EQUIPMENT CASING TYPE: Fabricated Box	TEST RESULTS: Accepted For Flight	TEST RESULTS: Chatter	TEST RESULTS: Design Failure	TEST RESULTS: Manufacturing Failure
1	TLM J Box	x		8.0	82	x			x						x	
2	Spacecraft Control J Box	x		3.0	120	x			x				x			
3	Horizon Sensor Command Cont. J Box	x		7.9	82	x			x				x	x		
4	Charge Control		x	8.0	146	x			x				x			
5	"G" Unit 13		x	4.8	118	x				x			x			
6	"G" Unit 25		x	4.8	125	x				x			x			
7	"I" Unit 7		x	7.9	94	x				x			x			
8	TM Tray	x		5.0	156	x						x				x
9	BTL Can		x	17.0	80	x						x		x		
10	BTL J Box		x	3.0	133	x			x					x		
11	Otex A		x	11.0	95	x						x	x			
12	TLM AC Power J Box		x	8.5	129	x			x				x			
13	DC Power Control		x	3.0	120	x			x				x			
14	Transmitter Type 13	x		2.0	108	x				x			x			
15	RF Circulator (see section II.E.3)	x		0.5	106	x				x						x
16	CLU		x	17.0	190	x						x	x			
17	Transmitter Type 13	x		2.0	116	x				x					x	
18	F/C J Box	x		11.0	104	x						x	x			
19	Command Relay J Box	x		10.0	145	x			x				x			
20	Digital Solar Sensor		x	0.75	340	x				x					x	
21	Digital Solar Sensor		x	0.75	340	x				x					x	
22	Data Converter		x	2.7	104	x						x	x			
23	Amp Hour Meter		x	2.0	101	x						x	x			
24	CLU		x	17.0	90	x					x		x			
25	BTL Filter		x	0.5	130	x			x				x			
26	Electronic Timer	x		4.5	95	x						x	x			
27	10 Volt Power Supply	x		0.3	177	x				x			x			
28	OIP Box		x	12.25	146	x						x	x			
29	BTL J Box		x	3.0	133	x		x	x				x			
30	Launcher J Box		x	3.25	87	x						x	x			
31	V/M Counter		x	4.5	280	x						x	x			
32	607 J Box		x	10.3	100	x			x					x		
33	Launcher J Box		x	8.0	89	x			x				x			
34	Battery Simulator	x		16.0	130		x					x	x			
35	Battery Simulator	x		16.0	130		x	x				x	x			
36	106 Actuator	x		2.5	96		x				x				x	
37	R.F. Switch	x		0.75	83	x			x							x
38	Amp Hour Meter	x		3.0	180	x						x	x			
39	Amp Hour Sensor	x		2.0	200	x						x	x			

* ENVIRONMENT See Section II.F.2

Table VI.1 (Cont.) SUMMARY OF PYRO SHOCK TESTS

	EQUIPMENT TESTED *	Environment 1, Bay I	Environment 2, Bay II	Weight in Pounds	Installation Natural Frequency	BARREL MOUNT: Bracket	Direct	Soft	EQUIPMENT CASING TYPE: Drawn Can	Milled Box	Cast Box	Fabricated Box	TEST RESULTS: Accepted for Flight	Chatter	Design Failure	Manufacturing Failure
79	Type IV Transmitter	x		2.0	95	x						x	x			
80	4 PDT Relay	x		0.12	145	x				x				x		
81	4 PDT Relay	x		0.12	145	x				x				x		
82	4 PDT Relay	x		0.12	145	x				x				x		
83	Hydraulic Power Pack	x		9.0	95	x					x		x			
84	Guidance J Box	x		10.0	96	x						x	x			
85	PIV	x		9.0	60	x					x		x			
86	Magnetometer		x	1.5	126	x						x	x			
87	M Sensor		x	0.5	230	x						x	x			
88	Decoder 9	x		2.0	119	x						x	x			
89	703 J Box		x	5.5	130	x			x				x			
90	706 J Box		x	7.6	125	x			x				x			
91	702 J Box		x	5.15	155	x			x							
92	CLV		x	12.0	90	x						x	x			
93	Transmitter Type 12		x	12.0	155	x						x				x
94	701 J Box		x	8.0	109	x			x				x			
95	705 J Box		x	3.5	90	x			x				x			
96	707 J Box		x	2.15	125	x			x				x			
97	708 J Box		x	0.75		x		x	x							
98	709 J Box		x	3.02	107	x			x				x			
99	UHF Receiver II		x	3.00	93	x				x						
100	RF Switch	x		0.75	83	x			x				x			
101	Digital Solar Sensor		x	0.75	340	x				x					x	
102	Digital Solar Electronics		x	2.5	230	x						x	x			
103	601 J Box		x	8.0	112	x			x					x		
104	605 J Box		x	7.0	120	x			x					x		
105	Rate Gyro	x		4.0	120	x			x				x			
106	256 Programmer 2		x	7.0	110	x						x	x			
107	256 Programmer 1		x	6.5	107	x						x	x			
108	708 J Box		x	0.75		x		x	x					x		
109	708 J Box		x	0.75	160	x			x					x		
110	Mode Control J Box		x	11.0	150	x			x				x			
111	Amp Hour Meter	x		3.0	180	x				x			x			
112	Amp Hour Sensor	x		1.0	200	x				x			x			
113	302 J Box	x		5.0	150	x						x		x		
114	302 J Box	x		5.0		x		x				x		x		
115	302 J Box	x		5.0		x		x				x	x			
116	Decoder 23		x	8.0	105	x						x	x			
117	Rocket Selector J Box			8.0	130		x		x					x		
118	Signal Conditioner	x		4.0	207	x						x	x			
119	Mod IIA Velocity Meter			6.0	280						x				x	

* ENVIRONMENT See Section II.F.2

Table VI.1 (Cont.) SUMMARY OF PYRO SHOCK TESTS

	EQUIPMENT TESTED *					BARREL MOUNT			EQUIPMENT CASING TYPE				TEST RESULTS			
		Environment 1, Bay I	Environment 2, Bay II	Weight in Pounds	Installation Natural Frequency	Bracket	Direct	Soft	Drawn Can	Milled Box	Cast Box	Fabricated Box	Accepted for Flight	Chatter	Design Failure	Manufacturing Failure
40	Aft Safe Arm J Box	x		18.0	126	x						x	x			
41	L/B Flight Control J Box	x		3.6	100	x						x	x			
42	PCM 3	x		4.0	111	x				x			x			
43	FWD Safe Arm J Box	x		2.0	168	x				x				x		
44	Time Delay Module		x	1.0	115	x			x				x			
45	Relay Driver Module		x	0.01	118	x			x				x			
46	Flap J Box		x	12.0	159	x			x				x			
47	C Band Transponder	x		3.2	91	x					x		x			
48	Sequence Timer	x		8.5	91		x					x	x			
49	Multicoupler 16		x	1.75	125	x				x			x			
50	Solar Array J Box		x	6.0	120	x			x				x			
51	Earth Sensor	x		1.2	82		x	x			x		x			
52	Aft Safe Arm J Box		x	4.5	96	x			x				x			
53	PIV		x	9.0	56	x					x		x			
54	Charge Controller		x	8.0	142	x			x				x			
55	Command Relay		x	3.0	80	x			x				x			
56	PCM		x	17.0		x		x			x		x			
57	Transmitter		x	7.5		x		x			x		x			
58	Baseband U		x	6.0		x		x			x		x			
59	Sub-Multiplexer		x	18.5	140	x					x		x			
60	Aft Pyro J Box		x	8.0	220	x			x					x		
61	Programmer Type 20		x	30.0	132	x					x		x			
62	PCM		x	17.0		x		x			x		x			
63	Transmitter		x	7.5		x		x			x		x			
64	Base Band		x	6.0		x		x			x		x			
65	Sub-Multiplexer		x	5.4	140	x					x		x			
66	Sub-Multiplexer		x	18.5	137	x					x		x			
67	Receiver Demodulator		x	6.3	112	x		x			x		x			
68	DSU		x	93.0	84	x			x				x			
69	Electronic Timer	x		4.75	91	x				x			x			
70	Pyro Programmer	x		6.5	114	x			x				x			
71	Type 9 Beacon	x		3.2	106	x				x			x			
72	Earth Sensor	x		1.2	215		x				x		x			
73	Velocity Meter Counter	x		5.0	84	x			x				x			
74	Transmitter IV A	x		2.0	95	x						x	x			
75	607 J Box			10.3	100	x						x	x			
76	CIV			12.0	120	x						x	x			
77	Digital Solar Sensor		x	0.75	340	x				x					x	
78	Digital Solar Sensor		x	0.75	50		x			x			x			

* ENVIRONMENT See Section II.F.2

SECTION NO. VII

SUBJECT:

LMSC's RECOMMENDATIONS FOR FURTHER STUDIES

SECTION VII

SUMMARY

This section covers LMSC's recommendation for further studies in the field of pyrotecknic shocks. The areas in which additional pyroshock studies are needed extend beyond the limits of this Compilation Study.

Under the limitations of Contract RC9-43031, LMSC could not take full advantage of the available documentation. Further analysis of the compiled data is desirable.

It is LMSC's opinion that further work is needed in several areas, particularly: data analysis, equipment internal environments, component analysis and testing. Some of this work can be performed with the data available in this compilation while other investigation would require further experimental and analytical effort. It is obvious that complementary work of this nature would provide for a significant advance in the State of the Art.

This section of the report is devoted to examining several areas where further analytical and experimental effort should be applied.

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SECTION VII

VII.1 INTRODUCTION

Having over 10 years of experience with the design, use and testing of pyrotechnic devices, LMSC feels qualified to issue a set of recommendations regarding the use of the Pyrotechnic Data collected under this compilation. The experience acquired during the past 10 years is sufficient to provide adequate design guidelines when applied by very experienced personnel. However, the present State of the Art is not supported by sufficient analytical foundation. The present State of the Art is confined to a number of specific type of structures and pyrotechnic devices. A more precise and more generalized knowledge of these phenomenon is essential to provide a basis for further advances in this important field.

VII.2 GENERAL RECOMMENDATIONS

VII.2.1 Generalities

LMSC's recommendation for further Pyrotechnic Shock Studies can be conveniently subdivided into four main areas of interest: namely : Data Analysis, Equipment Analysis and Testing, Component Analysis and Testing, Analytical Methods. Recommendations pertinent to each of these four subjects are treated in detail below.

VII.2.2 Recommendation Regarding Data Analysis

The brief analysis conducted on the data which was collected and organized during this compilation was intended primarily to point out trends and substantiate specific test conclusions. These objectives were however, accomplished without using the majority of the data which is contained in the compilation. The data which was not used is however, considered essential to a more thorough study of pyrotechnic shock environments for equipment, shock transmission predictions, both on a peak "g" and shock spectrum basis, repeatability of test data, optimizing test programs, tests methods and design recommendations.

All shock data contained within this report was digitized from plots on a GERBER reader, punched on cards and computer plotted. This process, although relatively simple was time consuming because a variety of different shock spectrum formats required frequent re-setting of the data reader. The process involved in reading data in the standard format which is used by Martin Marietta Corporation and LMSC would, however, be a relatively inexpensive task. The total volume of data available from the combined study would then be available on punched cards or stored on tape or in a computer memory for rapid statistical analysis, trend evaluation, attenuation and transmission studies, normalizing, etc. Existing computer programs at LMSC would accomplish the majority of the effort; however, some additional simple calculating and plotting programs would be needed to complete

VII.2.2 Continued

the study.

Observations in the presented data trends with respect to shock spectrum predictions show that significant structural modal response is interacting with the local high frequency vibrations present in the vehicle frame. It is recommended that analysis be conducted on the basic shell and truss structures in an attempt to better understand vehicle shock transmission characteristics. The most expedient practical solution will probably require some combination of experimental and analytical results. This technique, when proven on existing data can then be confidently extended to new vehicle configurations.

VII.2.3 Equipment Analysis and Testing

There exists little information throughout the industry on shock environments internal to equipment such as electronic boxes, even though the failures occur at the component level. The LMSC Barrel Tester can be used to conduct a series of equipment tests over a wide range of shock levels in order to accumulate sufficient data on box internal environment. This information, when analyzed and scaled to vehicle shock environments could be used for box design improvement, establishment of component environment and testing methods for component qualifications.

A second part of this effort would involve testing of the equipments on standard drop testers and shaker systems to ascertain the effect of testing specimen subject to pyrotechnic shock environment on more conventional tester systems.

VII.2.4 Component Analysis and Testing

Once having established internal component environments under simulated flight conditions from the equipment analysis and testing programs, it is proposed that test data be obtained on a large number of component samples such as relays, diodes, transistors, etc. This information can then be used to determine

VII.2.4 Continued

the statistical failure rate of these kinds of components when subjected to a pyro shock environment. For example, a group of relays subjected to shock levels of increasing intensity on the Barrel Tester would provide an excellent sample since detection of their characteristics would be in the form of increasing chatter or transfer versus increasing shock level intensity.

The statistical data available from this kind of testing would be useful in establishing proper overtest factors for qualification test programs utilizing limited test samples. As was suggested for the equipment testing, these components should also be subjected to more conventional testing techniques to determine failure rate correlation under non-pyrotechnic shock environment 2.

VII.2.5 Analytical Method

Pyrotechnic shock analysis presented in this compilation are entirely based on oscillograms and shock spectra. However, alternate methods of analysis should be investigated to determine whether additional information could be extracted from the data. The Fourier Transform has received some attention at LMSC but more experience is needed to define its method of application and interpret its results.

VII.3 CONCLUSION

The Pyrotechnic Shock Data Compilation provides a large amount of well organized documentation. However, full benefit cannot be derived from this data unless it is more thoroughly analyzed. Drawing from experience in this field, LMSC recommends that further investigation and analytical effort be applied in the following areas:

1 - Transmission of shock through various types of structures - Influence of normal modes.

2 - Shock attenuation versus distance from shock source for various types of structures.

3 - Internal box environments at components and the mounting brackets.

4 - Alternate methods of simulating pyro shock and correlation with known vehicle environment.

5 - Evaluation of attenuation devices such as isolators, force limiting brackets, energy absorbers, snubbers, etc.

6 - Statistical analysis of failure rate from components which are shock sensitive (Relays, diodes, etc.)

7 - Other methods of analysis such as Fourier Transform.

Such investigations would provide for significant advances in the State of the Art so that better shock load predictions and improved design of structures and equipments may be achieved.

SECTION NO. VIII

SUBJECT:

GENERAL CONCLUSION

SECTION VIII

GENERAL CONCLUSION

Conclusions presented in this section cover the field of pyrotechnic shock in order to point out the areas of significance. The following general conclusions are a summary of the conclusions presented in each section of this report.

1. Although pyro shock environment has been considered extremely important by Lockheed Missiles & Space Company for a number of years, the severity of this type of event has been somewhat underestimated by the industry at large. It is hoped that this compilation will help in placing this important phenomena in proper focus.

2. The 1/3 octave band data reduction method imposed by contract No. RC9-439031 is considered by Lockheed Missiles & Space Company as an unconservative approach to the processing of shock spectrum levels. The method in standard use at Lockheed Missiles & Space Company uses 100 points with a variable bandwidth range from 0 to 10,000 cps.

3. Reasonable estimates can be made with respect to shock attenuation versus distance on a peak "g" basis.

4. Predicting shock spectra as a function of distance from shock source is subject to considerable error. Additional analysis which includes higher structural modal response will probably be required to improve predictions.

5. It is possible to design separation joints which can significantly reduce pyrotechnic shock environments.

6. Significant changes in both explosive content and separation joint thickness are required in order to show appreciable changes in shock levels.

7. Pyrotechnic shock spectra are generally repeatable to ± 4 db when either several locations are considered during two tests or when one location is considered for several tests.

SECTION VIII

GENERAL CONCLUSION (Cont.)

8. Full scale vehicle overtesting is impractical, if high confidence levels are required, because of the necessity to use either larger explosives with corresponding strengthening of the structure or a large number of nominal level tests.

   Since each contractor defines overtesting on the basis of his experience and methods, it would be desirable to provide for a common definition of this criterion. One possible procedure is pre[illegible]d on Figure III.B.16.

9. In the present state-of-the-art, full scale vehicle testing at flight levels appears to be a practical method of increasing system confidence.

10. Drop tables, shakers, transfer tables, etc. are generally considered, by Lockheed Missiles & Space Company, as inferior methods of pyrotechnic shock simulation.

11. Overtesting for pin actuator shocks can be accomplished by performing several tests using higher explosive contents squibs.

12. The Barrel Tester facility in use at Lockheed Missiles & Space Company has been demonstrated to be a reliable method for qualification testing of equipment.

13. The shock environments produced by fairing deployment systems have been significantly reduced by using pyrotechnic devices to release springs rather than directly propelling fairings with the explosive charge.

14. The mounting brackets used for installing equipment are shown to be significant pyroshock attenuation devices.

15. Stiff elastomer type isolation systems which do not significantly lower equipment installation frequencies are good shock attenuators.

16. Appropriate modifications to electrical equipment can significantly reduce problems associated with relays and other sensitive components (e.g., energized versus non-energized, etc.).

SECTION VIII

GENERAL CONCLUSION (Cont.)

17. The failures experienced during equipment testing were not unexpected. In the case of electronic equipment, some failures were such that they could jeopardize flight safety. Simple modifications, however, enabled these components to perform satisfactorily.

18. As its name implies, this compilation presents a large amount of pyrotechnic data. It is Lockheed Missiles & Space Company's opinion that, to derive full benefit from this compilation, further investigation and analysis is needed in the following areas.

   a. Transmission of shock through various types of structures. Influence of structural modes.

   b. Shock attenuation versus distance from shock source for various types of structures.

   c. Internal environment of components such as boxes. Shock levels reaching internal parts and effects of brackets.

   d. Alternate methods of simulating pyro shocks and correlation with known vehicle environment.

   e. Evaluation of attenuation devices such as isolators, force limiting brackets, energy absorbers, snubbers, etc. from shocks generated by pin actuators.

   f. Statistical analysis of failure rate from components which are proven to be shock sensitive (relays, diodes, etc.).

   g. Other methods of analysis such as Fourier transforms.

Such investigations would provide for significant advances in the state-of-the-art so that better shock load predictions and improved design of structures and equipment may be achieved.

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