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TWR-18782

SPACE SHUTTLE

Solid Rocket Motors
Thiokol Corporation

Transportation Monitoring Unit Qualification Final Test Report

8 March 1990

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Transportation Monitoring Unit Qualification Final Test Report

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ABSTRACT

Transportation monitoring unit (TMU) qualification testing was performed between 3 March and 14 December 1989. The purpose of the testing was to qualify the TMUs to monitor and store temperature and acceleration data on redesigned solid rocket motor segments and exit cones while they are being shipped from Utah's Thiokol Corporation, Space Operations, to Kennedy Space Center.

TMUs were subjected to transportation tests that concerned the structural integrity of the TMUs only, and did not involve TMU measuring capability. This testing was terminated prior to completion due to mounting plate failures, high- and low-temperature shutdown failures, and data collection errors. Corrective actions taken by the vendor to eliminate high-temperature shutdowns were ineffective.

An evaluation was performed on the TMUs to determine the TMU vibration and temperature measuring accuracy at a variety of temperatures. This test demonstrated that TMU vibration measurements are not within specified tolerances, that TMU measured shock levels are high, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures.

It has been determined that modifications to the current TMU system, such that it could be qualified for use, would require a complete redesign and remanufacture. Because the cost of redesigning and remanufacturing the present TMU system exceeds the cost of procuring a new system that could be qualified without modification, it is recommended that an alternate transportation monitoring system be qualified.

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INTRODUCTION

This report documents the procedures, performance, and results obtained from the redesigned solid rocket motor (RSRM) transportation monitoring unit (TMU) Qualification test. The final series of testing was performed between 8 Nov and 14 Dec 1989 at Unisys Laboratories, Salt Lake City, Utah. Initial qualification testing was performed at the Wyle Test Facility, Norco, California, between 3 Mar and 5 Apr 1989. The purpose of the testing was to qualify the TMUs to monitor and store temperature and acceleration data on RSRM segments and exit cones while they are being shipped from Utah's Thiokol Corporation, Space Operations, to Kennedy Space Center (KSC). Testing was performed in accordance with CTP-0097, Transportation Monitor Unit Qualification Test Plan.

RSRM segments and exit cones are shipped to KSC on railcars. Each segment and exit cone-loaded railcar is instrumented to monitor acceleration and temperature during shipping. TMUs are mounted on each railcar to continuously store the temperature and acceleration data into temporary memory banks. This qualification testing was performed to demonstrate that TMUs can perform their required data gathering functions when subjected to temperatures and vibrations representative of the railcar environment.

1.1 TEST ARTICLE DESCRIPTION

The test article consisted of two TMUs, each assembled under 8U76218. TMU exterior configuration is shown in Figure 1. Specific information about the individual TMUs used at both the Wyle and Unisys test facilities is listed in Section 6, Results and Discussion. The TMUs were provided by vendor QSI Corporation, which refers to the TMUs as "QDLM-2" units.

TMU accelerometers are set for measurements in the longitudinal, vertical, and tangential (lateral) axes. Each axis has a programmed triggering operation which is set to function at 1.0-g longitudinal, 1.0-g vertical, and 0.5-g tangential threshold levels. Each accelerometer channel level is set to be recorded onto the main memory every time a preset acceleration level is exceeded. The main memory is also set to continuously store channel readings so that data are available for

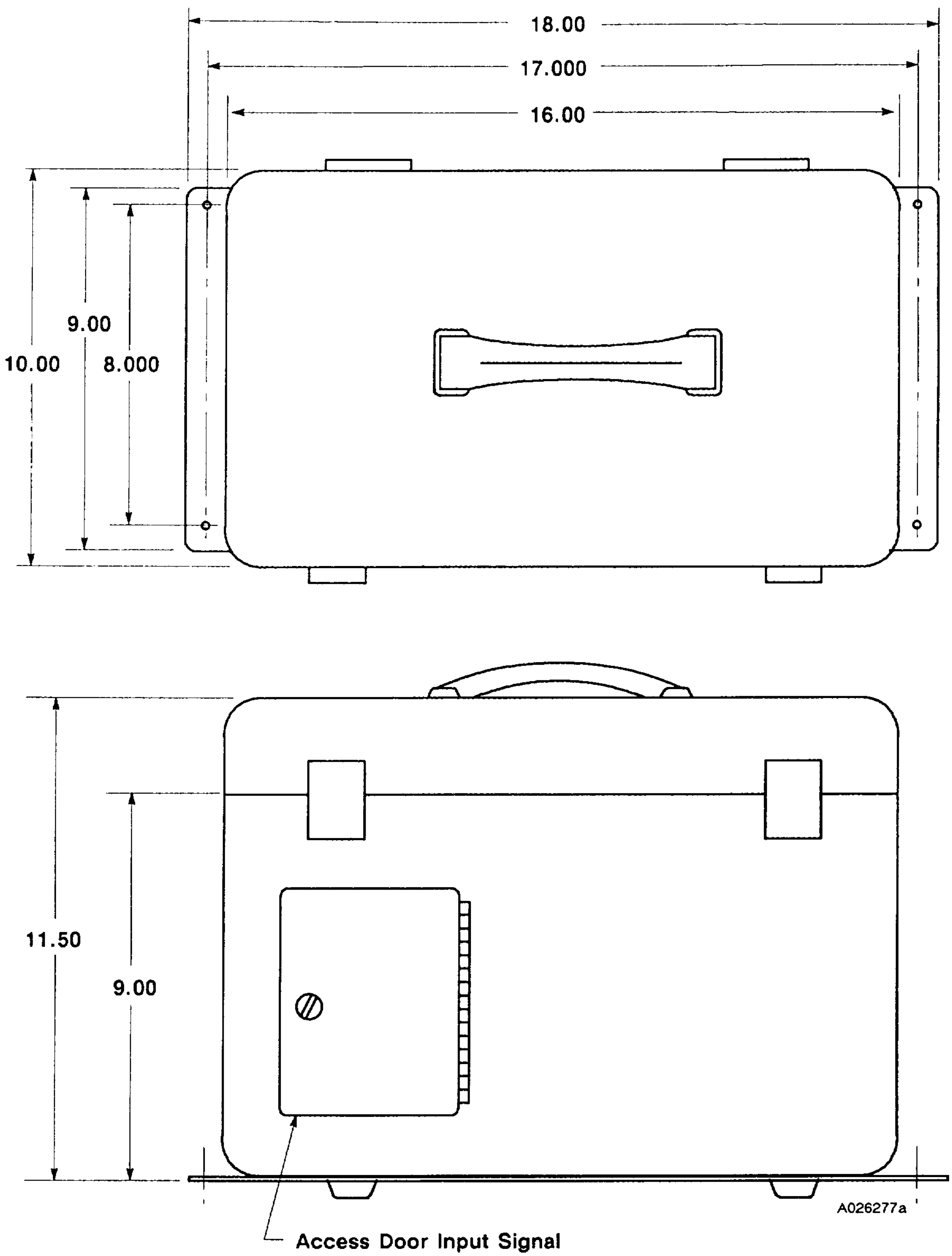

Figure 1. TMU Dimensions

recording 1 sec before and 10 sec after a triggered event. If acceleration levels are not exceeded, TMUs are set to automatically record each accelerometer level every 6 hr. Temperature levels are set to be recorded every 0.5 hr. TMUs are designed to store approximately 280 11-sec events. TMU and associated instrumentation placement on railcars is shown in Figures 2 and 3.

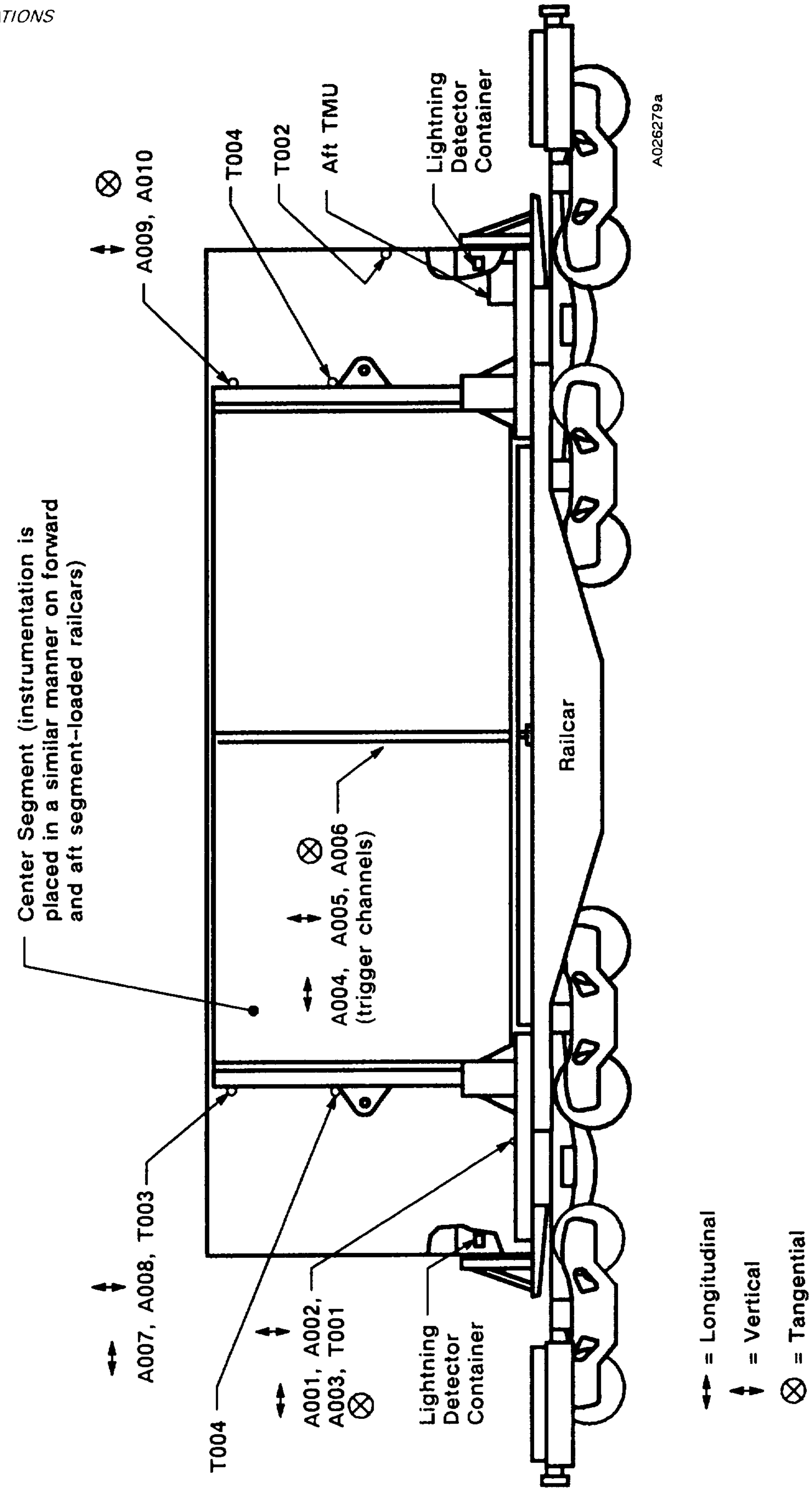

Figure 2. Instrumentation Locations on Segment-Loaded Railcar

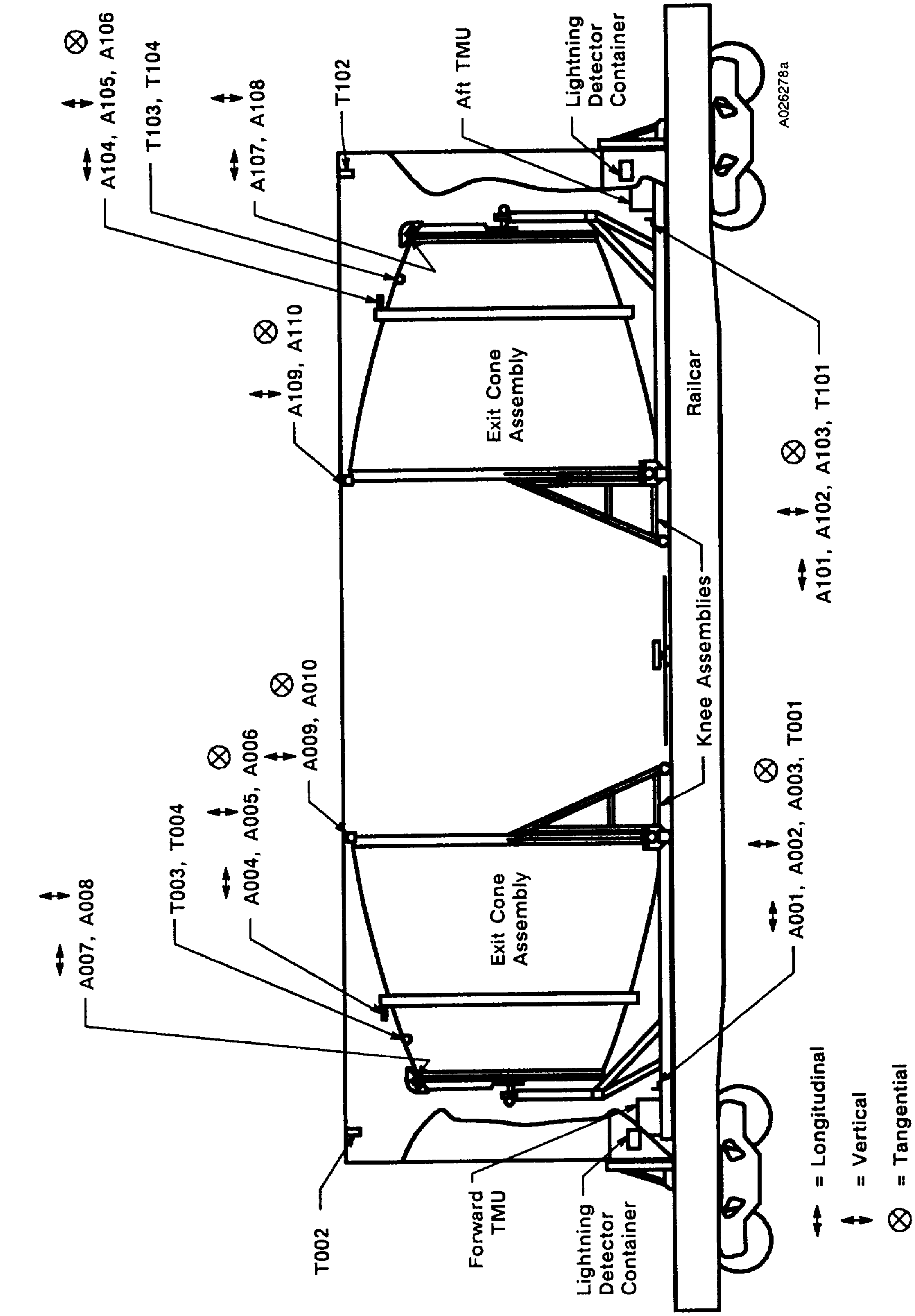

Figure 3. Instrumentation Locations on Exit Cone-Loaded Railcar

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OBJECTIVES

The objectives of test plan CTP-0097 Rev D were derived to satisfy the requirements of the contract end item (CEI) Specification CPW1-3600 Para 3.2.8.b, and the railcar instrumentation identification item Specification CDW2-3454 as listed below.

The qualification objectives of the test were:

A. Verify the general performance in accordance with CDW2-3454 Para 3.2.1.1.

B. Verify the functional performance in accordance with CDW2-3454 Para 3.2.1.2.

The specific objectives of the test were:

C. Certify that the unit scanner will record accelerations 1 sec before and 10 sec after each trigger.

D. Certify that the TMU will record the 3-min timed event to assure clock accuracy.

E. Certify that the TMU will record the temperature and internal parameters every 0.5 hr, starting at 1 min.

F. Certify that the TMU will record a timed event every 6 hr starting with the first timed event at 3 min.

G. Certify that the three accelerometer channels will trigger all other channels.

H. Certify that the triggering systems operate at 1.0-g longitudinal, 1.0-g vertical, and 0.5-g tangential threshold levels.

I. Certify acceleration and temperature accuracy throughout the operating temperature range.

J. Certify the unit scanner recording capability through various vibration inputs.

K. Certify that a nonoperational triggering channel will not affect the remaining channels and result in only one recorded event.

L. Certify that the self-contained power source can successfully operate for a minimum of 17 days.

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EXECUTIVE SUMMARY

3.1 SUMMARY

TMUs were subjected to transportation tests that concerned the structural integrity of the TMU only, and did not involve the measuring capability of the units. This testing was terminated prior to completion due to mounting plate failures, high- and low-temperature shutdown failures, and data collection errors.

An additional test for evaluation only was performed on the TMUs to determine the TMU vibration and temperature measuring accuracy at a variety of temperatures. This test demonstrated that TMU vibration measurements are not within specified tolerances, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures.

The functional qualification tests were not performed, and none of the objectives of CTP-0097 were adequately addressed during the test. Results showed that TMUs do not perform to the requirements of the following documents: STW3-3662, CDW2-3454, TWR-17049 Rev A, nor the qualification testing of CTP-0097. A complete discussion of the test results is presented in Section 6.

3.2 CONCLUSIONS

Corrective actions taken by the vendor to eliminate high-temperature shutdowns were ineffective. The corrective actions are outlined in Appendices C and D.

The additional engineering evaluation demonstrated that TMU vibration measurements are not within specified tolerances, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures. Because the TMU measured shock levels were higher than the input levels, it is likely that all the TMU measured shock levels are higher that what occurs at the accelerometers.

It has been determined that modifications to the current TMU system, such that it could be qualified for use, would require a complete redesign and remanufacture.

3.3 RECOMMENDATIONS

Because the TMUs failed to survive their simulated use environment, and because the cost of redesigning and remanufacturing the present TMU system exceeds the cost of procuring a new system that could be qualified without modification, it is recommended that an alternate transportation monitoring system be qualified to monitor RSRM segment and exit cone shipments.

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INSTRUMENTATION

Instrumentation used and recording system trigger levels were as listed in CTP-0097. All reference, control, and response instruments were zeroed and calibrated in accordance with MIL-STD-45662.

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PHOTOGRAPHY

Photographs of the test setup at Wyle Laboratories and the broken TMU mounting plate are included in Appendix A, Pages A-71 and A-72.

Photographs of the test setup at Unisys were also taken, and are shown in Figures 4 through 6.

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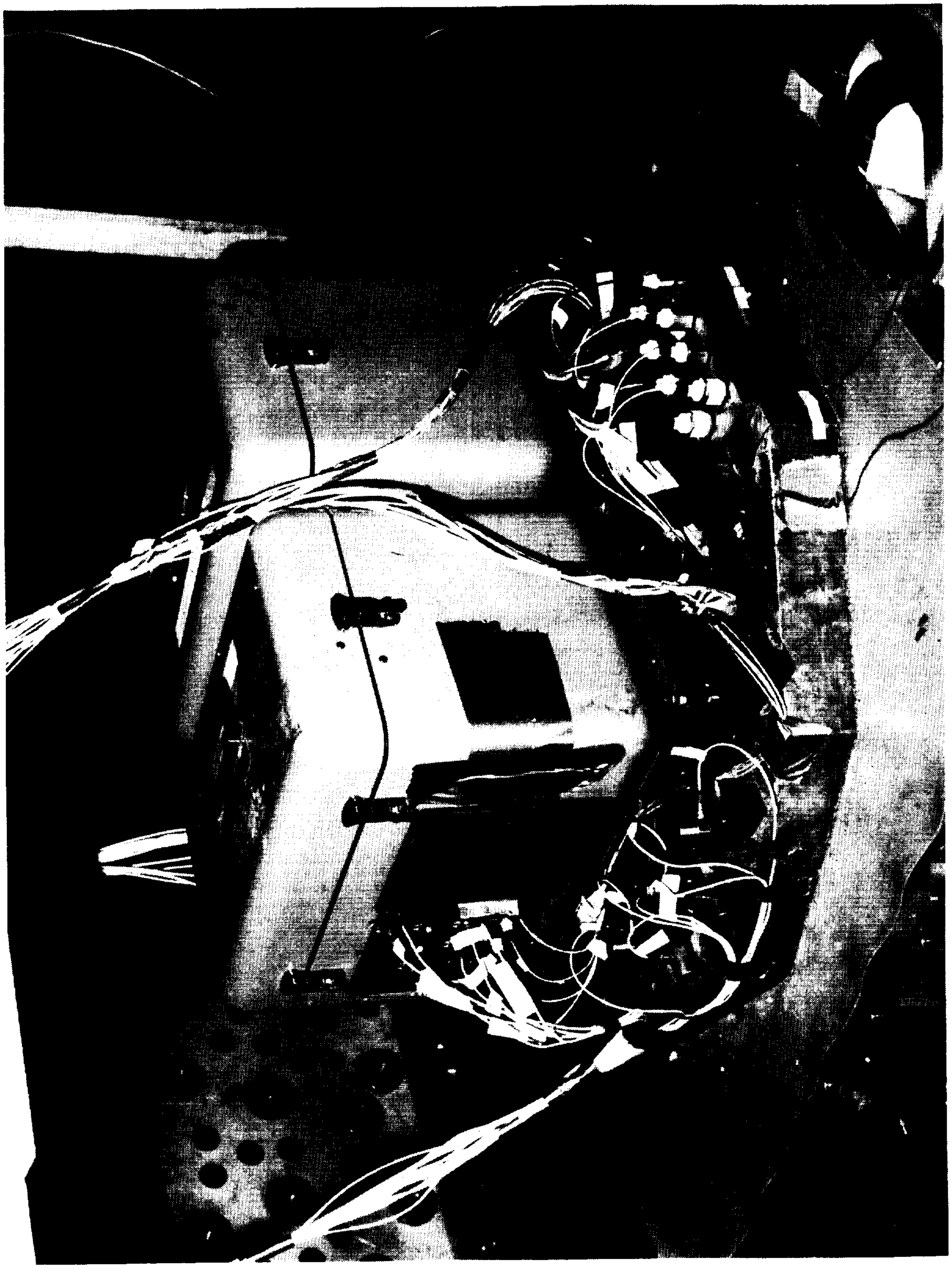

Figure 4. TMU Test at Unisys—Test Setup

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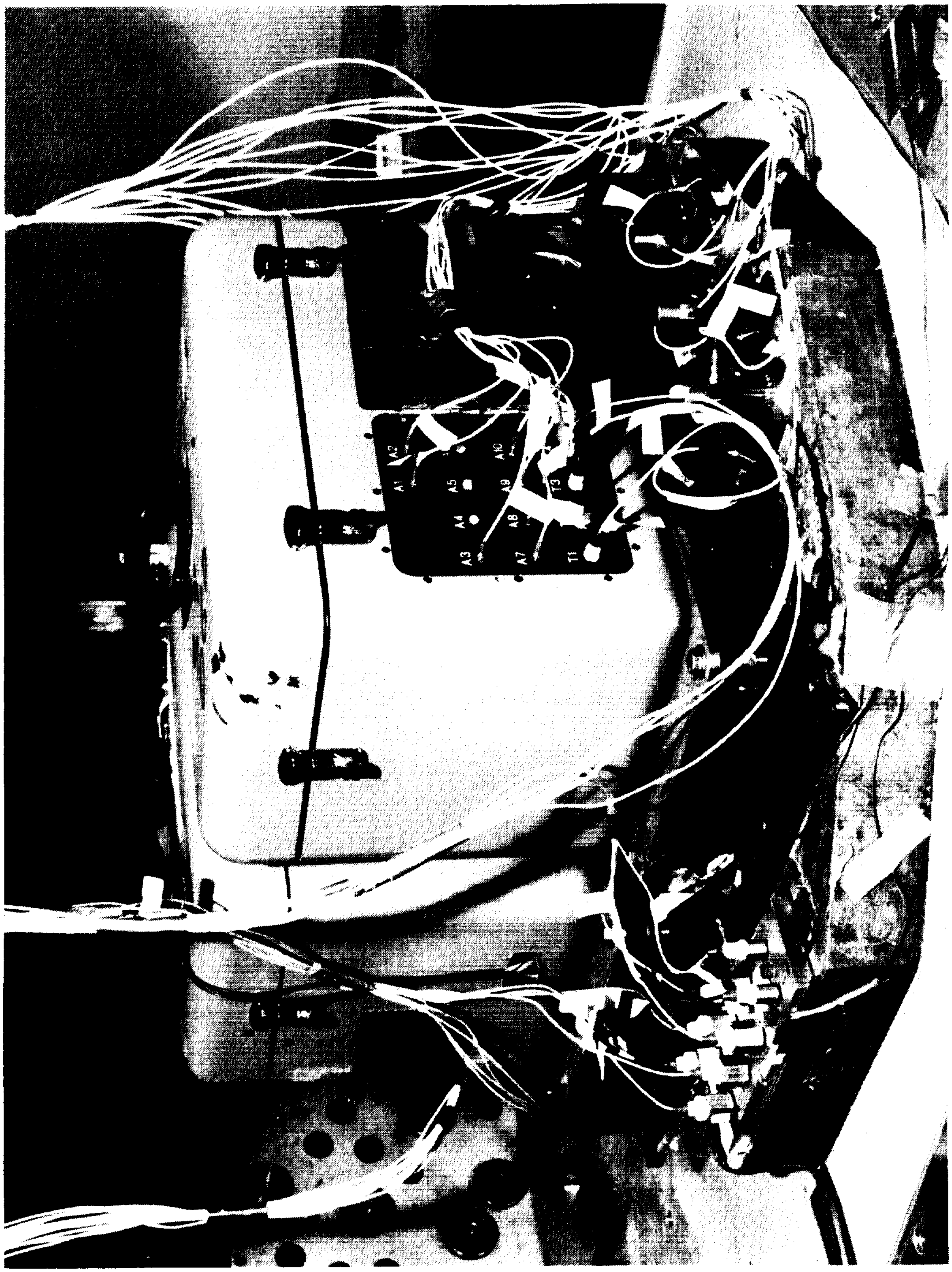

Figure 5. TMU Test at Unisys—Test Setup

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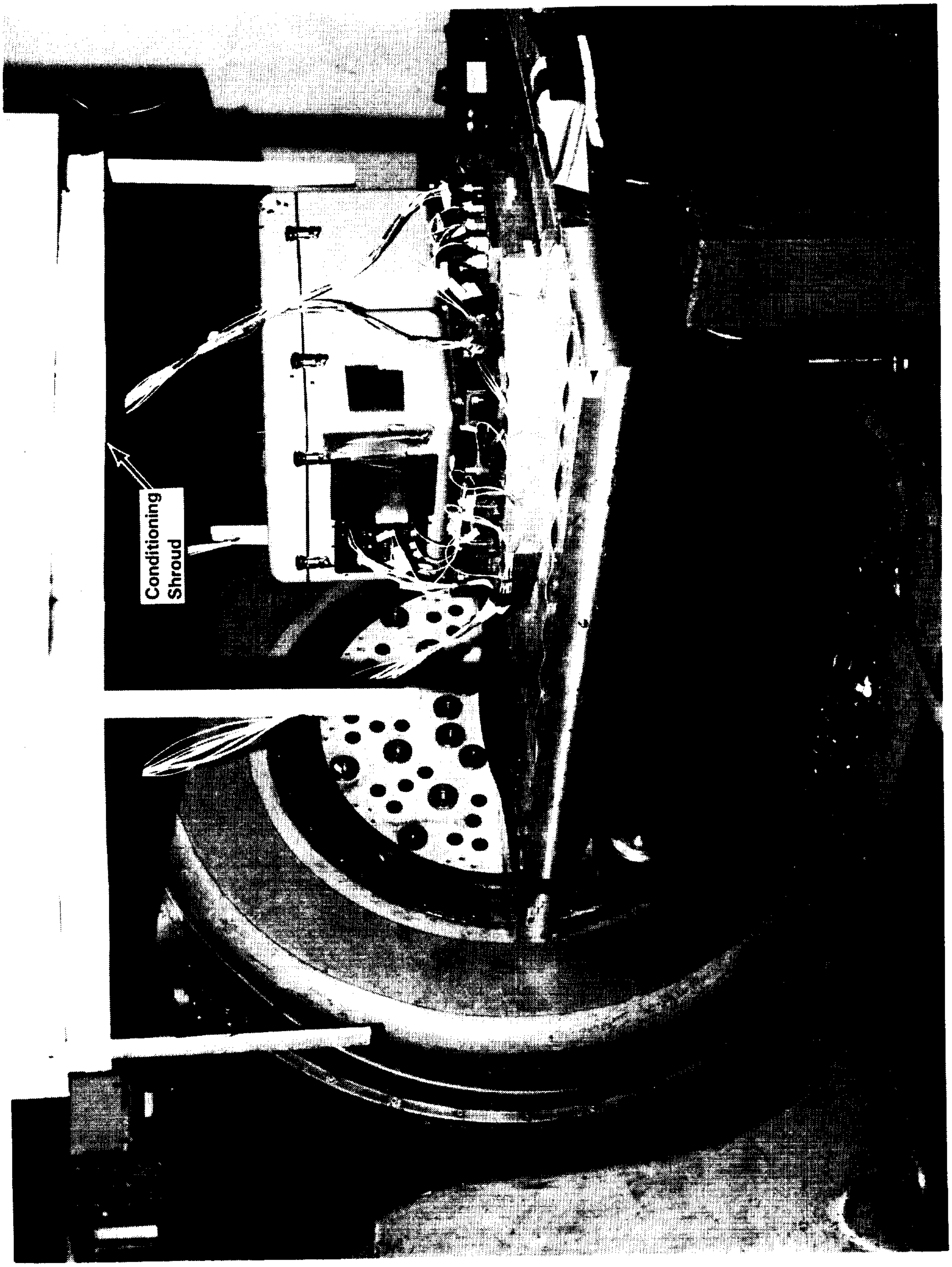

Figure 6. TMU Test at Unisys—Test Setup

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RESULTS AND DISCUSSION

6.1 TESTING AT WYLE LABORATORIES

This portion of testing was performed between 3 Mar and 5 Apr 1989 at the Wyle Test Facility, Norco, California. A representative from Systems Loads and Environments witnessed the majority of testing.

Wyle prepared a test report which includes plots of the test results. This report is included as Appendix A. Section 6.1 summarizes the Wyle test report and provides additional information and conclusions.

6.1.1 Test Article Description

The test article consisted of two TMUs, prototype units No. 1 (S/N 0006) and No. 2 (S/N 0013). Both TMUs were subjected to the same testing. The TMU shock mounts were fastened to "U" channels and then secured to an electrodynamic exciter. Thermocouples and accelerometers were then mounted on the TMU and shaker table as shown on Page 5 of the Wyle test report. Test configuration was as specified in CTP-0097.

For temperature conditioning, a 3-foot-square insulated plywood box was placed around the TMU. Hot air or CO_2 was forced into the box for heating and cooling, respectively.

6.1.2 Transportation Testing

6.1.2.1 Introduction. Testing began by addressing the transportation portion of CTP-0097. This was a structural test of the TMU components and housings, designed to verify extended operation of the TMU in the intended environment of railcar operation.

This testing consisted of subjecting the TMUs to sine sweep vibrations to determine the TMU resonant frequencies, subjecting the TMUs to sinusoidal dwell vibrations at the resonant frequencies, and subjecting the TMUs to shock spectra testing.

This testing began with sinusoidal sweep vibrations applied to the TMUs to determine the resonant frequencies for each unit. Sine sweep vibrations were applied in accordance with SE-019-049-2H, "Solid Rocket Booster Vibration, Acoustic

and Shock Design and Test Criteria," and the test criteria for determining resonant frequencies is listed in Table 1. Resonant frequencies for each TMU were determined by greater than 2-to-1 amplification ratios between any response accelerometer (mounted on the outside surface of the top of the TMU) and the control accelerometer (mounted on top of the shaker table). Resonant frequencies were to be found in the longitudinal, tangential, and vertical axes at -20°, 70°, and 163°F. Response accelerations that were measured in the same axis as the control input axis were used to determine resonant frequencies.

Table 1. TMU Transportation Test Criteria--Control Inputs for Determining Resonant Frequencies (sine sweep through the below range at 5-2,000-5 Hz at 1 octave/minute)

- 5 to 130 Hz at 1.2-g peak
- 130 to 185 Hz at 0.0014-in. double amplitude
- 185 to 2,000 Hz at 2.5-g peak

Once resonant frequencies were determined, TMUs were then subjected to sinusoidal dwell testing for 15 min at the approximate sine sweep amplitudes for each resonant frequency. No more than three sine dwells were applied in a single axis for a given temperature.

The TMUs were also to be subjected to five shocks in each direction in the longitudinal, tangential, and vertical axes at -20°, 70°, and 163°F. The shock spectra levels are defined in Table 2.

Table 2. TMU Transportation Shock Test Criteria

- 20 to 160 Hz at +6 decibel/octave
- 160 to 340 Hz at 10-g peak
- 340 to 400 Hz at -6 decibel/octave

The data acquisition system and TMU zero reference (located on TMU display panel) were to be verified prior to testing, after completion of each test. Memory modules were to be removed and replaced each time that TMUs were turned off.

TMU accelerometer trigger channels were not connected for measurements. Temperature measurements were taken by the TMU internal and external instrumentation throughout the tests.

6.1.2.2 Transportation Testing With Original Shock Mounts and Mounting Plate. Initial testing was performed with the original design TMU shock mounts which consisted of two bolts enclosed within a rubber grommet. The original design 0.125-in. thick aluminum mounting plate was used.

TMU Time Check Sequence Test. Prior to testing, a time check sequence was run on each TMU. Both units were run continuously for 6 hr. Each TMU recorded at the 0.5- and 6-hr intervals.

-20°F Testing. TMU No. 1 was conditioned to -20°F and run through a longitudinal sine sweep. Once sine sweep testing began, it was evident that the shock mounts significantly increased the vibration amplitudes that were input to the TMUs from the shaker table. Regardless of the high amplitudes, it was decided to proceed with testing. Two resonant frequencies were found at approximately 22 and 31 Hz (Page 12 of the Wyle test report). The unit was then subjected to sine dwell vibration testing at these frequencies (at -20°F) for 15 min with no structural damage occurring.

(Frequency versus acceleration plots, included in the Appendix A, consist of control and response accelerations. Plots for resonant sine dwell tests were not taken, as these were pass/fail tests.)

TMU No. 1 was then subjected to shock spectra testing in the longitudinal axis at -20°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

TMU No. 2 was then conditioned to -20°F and run through a longitudinal sine sweep. Two resonance frequencies were found at approximately 28 and 39 Hz (Page 12 of the Wyle test report). The unit was then subjected to sine dwell vibration testing at these frequencies (at -20°F) for 15 min with no structural damage occurring.

TMU No. 2 was then subjected to shock spectra testing in the longitudinal axis at -20°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

During these cold transportation tests, both the Wyle control thermocouple and the TMU internal temperature sensor indicated approximately -20°F, while the four TMU external temperature sensors indicated approximately 0°F. Since the vibration table was significantly larger than the conditioning chamber, it was not possible to lower the table surface temperature below 0°F. The table surface temperature probably influenced the attached TMU external temperature sensor readings. Also, probe measurements were probably inaccurate because they were uninsulated and became coated with ice from the carbon dioxide. Prior to additional testing, this temperature difference was eliminated by insulating the temperature probes from the vibration table with a 2-in. thick layer of fiberglass insulation between the probes and the shaker table surface.

<u>70°F Testing</u>. TMU No. 1 was subjected to shock spectra testing in the longitudinal axis at 70°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

Sine sweep testing of TMU No. 2 in the longitudinal axis at 70°F resulted in a resonant frequency at approximately 19 Hz (Page 20 of the Wyle test report). The unit was then sine dwell tested at approximately 19 Hz for 15 min and no structural damage occurred. Post-test inspection revealed that two mounting screws had loosened during the sine dwell test. The loose mounting screws were retightned.

TMU No. 2 was then subjected to shock spectra testing in the longitudinal axis at 70°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

Sine sweep testing of TMU No. 1 in the longitudinal axis at 70°F resulted in a resonant frequencies at approximately 16, 21, and 32 Hz (Page 24 of the Wyle test report). The peak acceleration loads for the 16-Hz resonance frequency were relatively high at 50 g. When the unit was subjected to sine dwell vibration at approximately 14.5 Hz and 1.2 g input, the mounting plate fractured prior to completion of the 15 min sine dwell. A photo of the broken mounting plate is shown on Page 72 of the Wyle test report.

Testing was then terminated and effort was directed toward improving the mounting plate and shock mounts to withstand the vibration test levels.

6.1.2.3 <u>Transportation Testing with Redesigned Shock Mounts and Mounting Plate</u>. As a result of the mounting plate failure during the initial testing at the Wyle test

facility, the shock mounts and mounting plate were redesigned and installed, and testing was started over. The improved mounting plate was made from 0.125-in. thick stainless steel, reinforced at each end with additional 0.125-in. thick stainless steel. The improved shock mounts consisted of a single bolt with an external rubber grommet, as compared to the original dual bolt design.

For the cold temperature testing, plastic was loosely taped around the temperature probes to prevent surface condensation and frost. Also, a 2-in. layer of insulation was wrapped around the accelerator connections with Teflon® tape, and unused accelerometer connections were wrapped with Teflon® tape to avoid shorts due to condensation.

<u>TMU Time Check Sequence Test</u>. Prior to testing, a time check sequence was run on each TMU. Both units were run continuously for 18 hr. Each TMU recorded at the 0.5-hr and 6-hr intervals.

<u>Tangential Axis Testing</u>. Because tangential vibrations subjected the TMUs to the largest amplitude response (the TMUs were most likely to fail due to loads in this direction), it was decided to test in the tangential direction first.

TMU No. 1 was conditioned to -20°F and run through a tangential sine sweep. One resonant point was found at approximately 17 Hz (Page 28 of the Wyle test report). The unit was then subjected to sine dwell vibration testing at this frequency for 15 min at -20°F with no structural damage occurring.

Tangential sine sweep testing of TMU No. 1 at 70°F resulted in resonant points at approximately 16 and 55 Hz (Page 32 of the Wyle test report). The unit then passed sine dwell testing at these levels with no structural damage occurring.

Sine sweep testing of TMU No. 2 at 70°F resulted in one resonance point at approximately 28 Hz (Page 40 of the Wyle test report). The unit then passed sine dwell testing at these levels with no structural damage occurring.

TMU No. 1 was then conditioned overnight to 163°F. The next morning, the unit was subjected to sine sweep testing in the tangential direction, with resonance points found at approximately 14.5 and 43 Hz (Page 37 of the Wyle test report). The TMU was then subjected to sine dwell testing at these resonance points, and no structural damage to the TMU occurred. Results showed that resonant frequencies decreased as temperatures increased. This is because the shock mounts became less stiff at higher temperatures, causing larger TMU response amplitudes and more time between peaks.

When the TMU was removed from the conditioning chamber after the sine dwell tests, it was not running. The TMU had stopped recording data when the heat conditioning began. Upon cooling to ambient temperature, the unit was restarted. Vibration testing per CTP-0097 was then halted to further investigate why unit No. 1 shut down.

High-Temperature Failure Testing. In an effort to determine the TMU shutdown temperature, both TMUs were placed in the conditioning chamber and then the chamber was heated to 120°F. Because the TMU lids were left open, the modules of each TMU may have been subjected to a more severe environment than the railcar environment. Both units continued to run for 5 to 10 min at the chamber temperature of 120°F. The temperature of the chamber was then increased to 150°F. After approximately 5 min, TMU No. 1 shutdown, while TMU No. 2 continued to run. Testing was then terminated to preclude further damage to the TMUs, since it was evident that the units could not withstand the specified upper temperature limit.

Further evaluation of the TMUs by QSI Corporation revealed that a bad component within the TMUs caused the high-temperature TMU failure. QSI Corporation changed the TMU components as explained in Section 6.2.1.

Truncated Data Failure. In addition to the high-temperature failure, approximately 1 percent of all TMU acceleration response data collected randomly during the Wyle test was incomplete. The incomplete data were the result of a truncation error. QSI Corporation determined that the truncation error was related to the TMU software. QSI made software modifications to fix the truncation errors, as explained in Section 6.2.1.

Summary. As a result of the termination of testing (due to the mounting plate, high-temperature shutdown, and data collection errors), the transportation testing was incomplete. The functional and electromagnetic interference (EMI) tests were not performed, and none of the objectives of CTP-0097 were adequately addressed during the Wyle test. Further testing was planned.

6.2 TESTING AT UNISYS

This portion of testing was performed between 8 and 28 Nov 1989 at Unisys Laboratories, Salt Lake City, Utah. A representative from Systems Loads and Environments witnessed the majority of testing.

Unisys prepared a test report which includes portions of the test procedures, test logbooks, and test result plots for the qualification portion of testing. This report is included as Appendix B. Section 6.2 summarizes the Unisys test report and provides additional information and conclusions.

Test Criteria Changes Since Wyle Testing. Prior to the Unisys testing, the following changes were made to test plan CTP-0097 and to the TMU product specification STW3-3662:

- Objective L was added to CTP-0097, which required the TMUs to be capable of continuously running, under their own power source, for 17 days.
- Because NASA did not expect the TMUs to be subjected to EMI during the shipping process, the EMI requirements of STW3-3662 were deleted.
- The test temperature limits were changed to meet the STW3-3662 requirements of -30° to 153°F. The minimum and maximum temperature requirements were adjusted to -40° ±10°F and 163° ±10°F.
- It was also determined that the dwell tests were significantly more harsh than the railcar environment, and therefore the option to replace each shock mount after each axis test was instated.

6.2.1 Test Article Description

The test article consisted of two TMUs: one TMU (S/N 5000007) was used for qualification, and the other TMU (S/N 5000017) was used for engineering evaluation to gather and reduce data during the test. The TMUs were assembled under the requirements of drawing 8U76218.

The TMU mounting plate was again changed. The new mounting plate was made from solid 0.250-in. thick steel.

The Unisys test facility provided the test fixture, reference/control accelerometer, reference temperature sensor, response accelerometers, and associated data acquisition systems. The TMUs were configured as shown in Figures 4 through 6.

QSI Corporation determined that the Wyle TMU test failures were related to TMU software errors (data truncation error) and a TMU internal component failure (high-temperature failure). QSI made improvements to the TMUs prior to the Unisys testing. The QSI improvements are outlined in the memo, QDLM-2 Failure

Analysis (Wyle Laboratories qualification testing), and the report, Failure Analysis of TMUs No. 0006 and No. 0013, included as Appendices C and D, respectively.

6.2.3 Transportation Testing

Refer to Section 6.1.2.1 for information about transportation testing.

TMU Time Check Sequence Test. Prior to testing, a time check sequence was run on each TMU. Both units were run continuously for 6 hr. Each TMU recorded at the 0.5-hr and 6-hr intervals.

-40°F Testing. Both TMUs were placed inside the conditioning chamber and were conditioned to approximately -40°F. Sine sweep vibrations were then applied in the longitudinal axis (plots of longitudinal vibration testing at -40°F are shown in Appendix B of the Unisys test report). Two resonant frequencies were found at approximately 46 and 95 Hz. The units were then subjected to sine dwell vibration testing at these frequencies (at -40°F) for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the longitudinal axis at -40°F. Both TMUs continued to run while subjected to the shock tests.

Orientation of the TMUs was then changed for vibration testing in the tangential axis (plots of tangential vibration testing at -40°F are shown in Appendix C of the Unisys test report). Both TMUs were conditioned to approximately -40°F and were subjected to sine sweep vibrations in the tangential axis. One resonant frequency was found at approximately 38 Hz. The units were subjected to sine dwell vibration testing at this frequency for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the tangential axis at -40°F.

Upon removal of the conditioning chamber after the shock testing, the TMUs were found to have shut down. The 17-day continuous-running requirement was not met because the TMUs had only run for 14 days. TMU measured results show that the battery voltage dropped below the required level and caused the TMUs to fail approximately 18 hr into the cold conditioning period. Figure 7 shows the cold temperature TMU failure on a time versus temperature plot. Thiokol concluded that the alkaline batteries within the TMU could not provide the TMUs with adequate voltage within a -40°F environment.

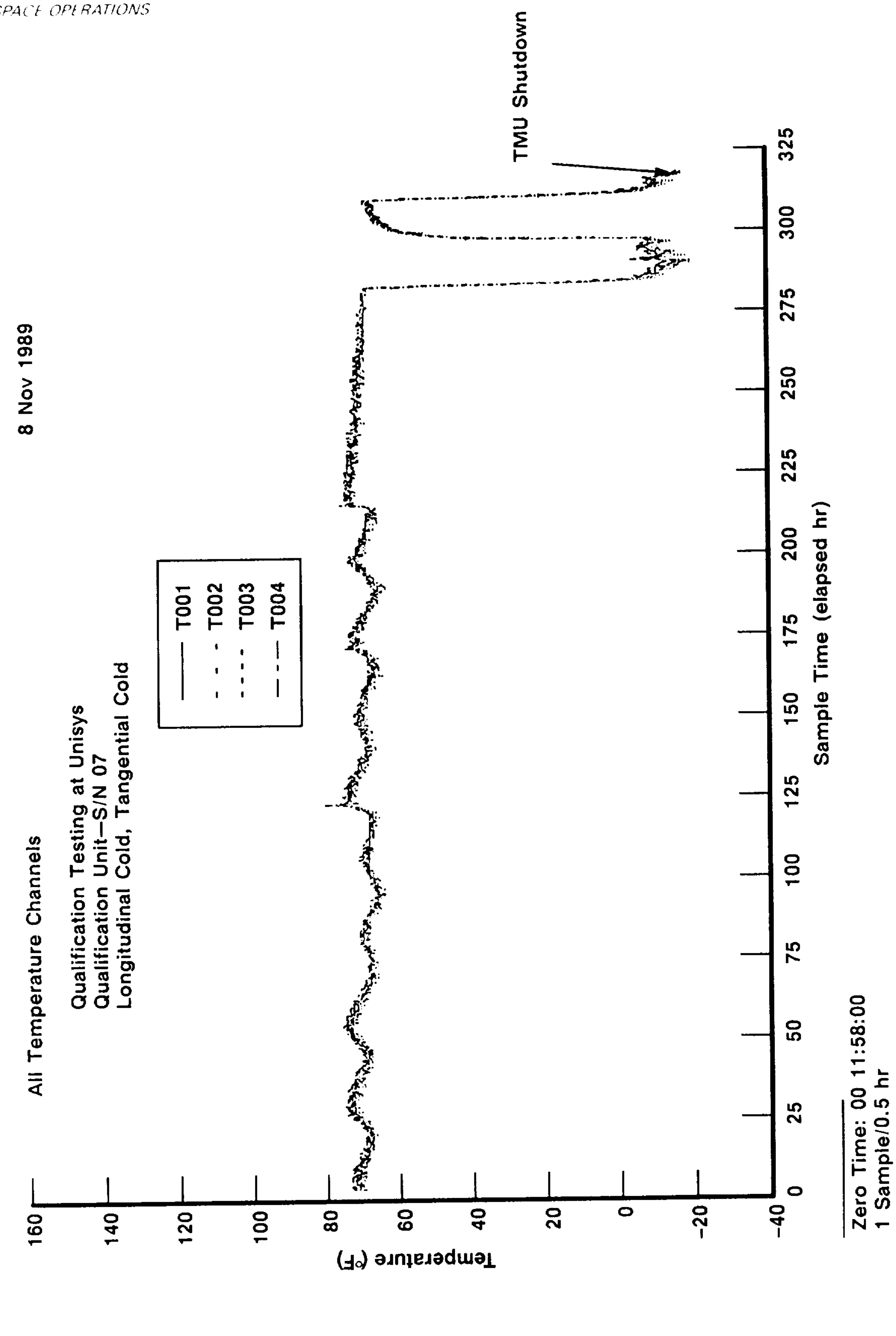

Figure 7. TMU Temperature Response Versus Time—Cold Temperature Failure

It was determined that the TMUs would be restarted and testing would be continued, provided that the TMUs were not subjected to cold environments for an extended amount of time. New batteries were installed, and the TMUs were started again, beginning a new 17-day test.

70°F Testing. Prior to the ambient temperature testing, each of the TMU shock mounts was replaced. Both TMUs were conditioned to approximately 70°F. Sine sweep vibrations were then applied in the tangential axis (plots of tangential vibration testing at 70°F are shown in Appendix D of the Unisys test report). Two resonant frequencies were found at approximately 26 and 86 Hz. The units were then subjected to sine dwell vibration testing at these frequencies (at 70°F) for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the tangential axis at 70°F. Both TMUs continued to run while subjected to the shock tests.

Orientation of the TMUs was then changed for vibration testing in the longitudinal axis (plots of longitudinal vibration testing at 70°F are shown in Appendix E of the Unisys test report). Both TMUs were conditioned to approximately 70°F and were subjected to sine sweep vibrations in the longitudinal axis. One resonant frequency was found at approximately 35 Hz. The units were subjected to sine dwell vibration testing at this frequency for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the longitudinal axis at 70°F. Both TMUs continued to run while subjected to the shock tests.

163°F Tests. The TMUs were then conditioned to approximately 163°F for 4 hr. Sine sweep vibrations were then applied in the longitudinal axis (plots of longitudinal vibration testing at 163°F are shown in Appendix F of the Unisys test report). Three resonant frequencies were found at approximately 33.4, 71, and 93 Hz. The units were then subjected to dwell vibration testing at these frequencies (at 163°F) for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing at 163°F.

After the vibration testing in the longitudinal axis, the conditioning shroud was removed, and the TMUs were not running. TMU data revealed that both TMUs shut down during the 4 hr of hot conditioning, prior to the actual vibration testing. Figure 8 shows the TMU high-temperature failure on a time versus temperature

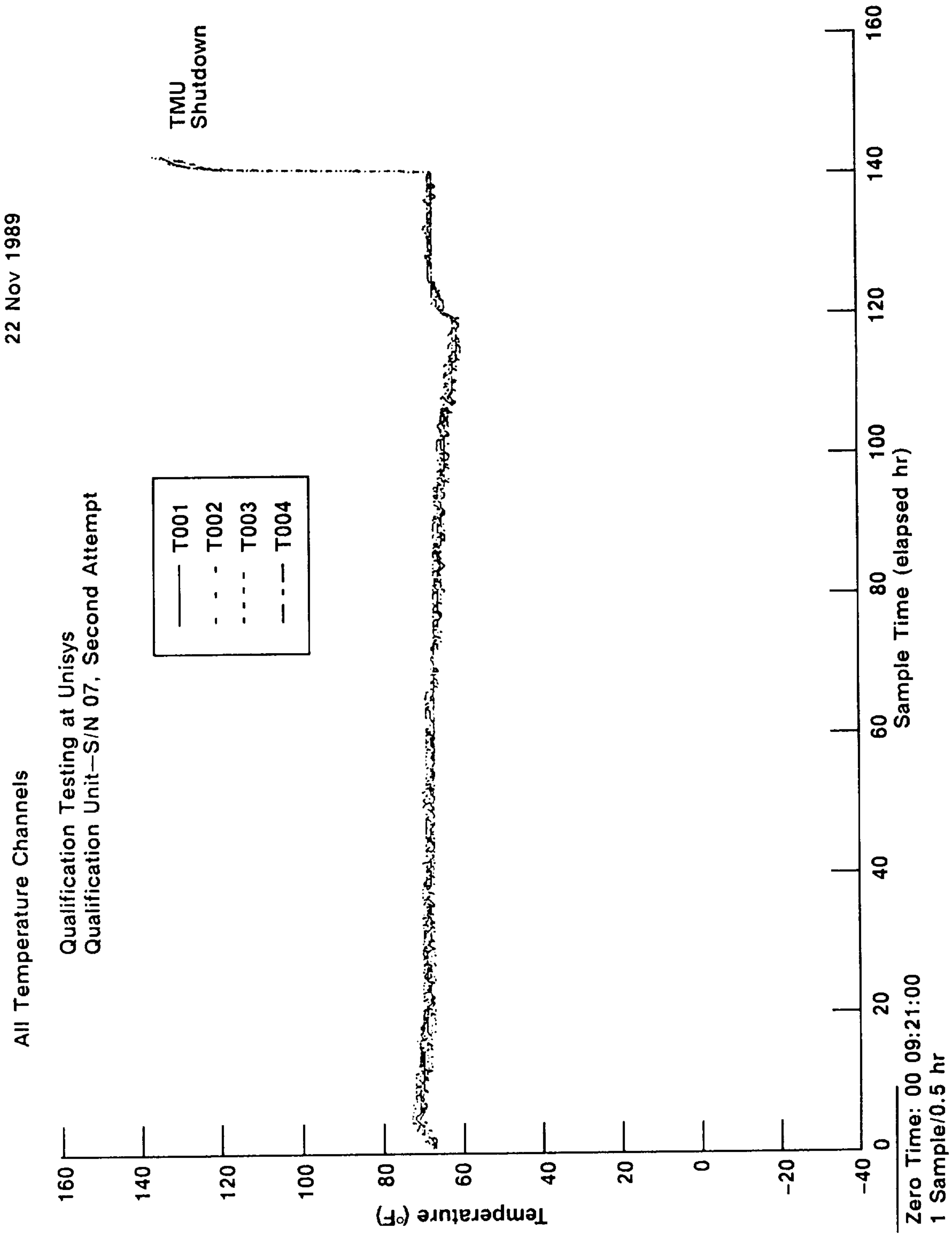

Figure 8. TMU Temperature Response Versus Time—High-Temperature Failure

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plot. The applied temperature of 150°F caused an internal electronic failure in each TMU. This failure caused each TMU to go into a continuous-triggering mode, filling each TMU memory module. This failure was similar to the failure that occurred at Wyle Laboratories during the first qualification test, indicating that the QSI internal TMU improvement was not sufficient. Because the TMUs failed due to the heat conditioning, qualification testing per CTP-0097 was terminated.

Summary. As a result of the termination of the qualification testing (due to the high-temperature shutdown and data collection errors), the transportation testing was incomplete. The functional tests were not performed, and none of the objectives of CTP-0097 were adequately addressed during the Unisys test.

6.2.3.1 Conclusion. The results of this test support the conclusion that the corrective actions taken by the vendor to eliminate high-temperature shutdowns were ineffective.

6.2.4 Testing for Engineering Evaluation Only

On 6 Dec 1989, TMU testing at Unisys was restarted for engineering evaluation only. The purpose of this testing was to determine the TMU vibration and temperature measuring accuracy at a variety of temperatures.

The tests consisted of sine dwell and shock testing at a range of temperatures, designed to simulate the transportation testing outlined in Section 6.1.2.1. The sine dwells were applied at approximately 10 Hz and 1.5 g for approximately 1 min. The shocks were half sine waves at approximately 2.0 g with a 0.08-sec duration. This testing was conducted at the following temperatures, listed in the sequence that they were tested: 130°, 140°, 150°, 70°, and -32°F.

Appendix E shows Unisys control input shock and dwell vibration plots, TMU response data (tabular form), and percent error calculations. Calculations were made using peak-to-peak values from the Unisys control input shock wave plots and the TMU tabular response data. Two shocks were used (at each temperature measurement) for the shock test comparison. Sine dwell plots were compared to the TMU tabular data.

Shock Tests. Results of the calculations from the shock tests are shown in Table 3. None of the TMU measured shock levels were within the specified tolerance of ±10 percent. Measured shock level errors decreased as temperatures increased.

The shock pulse inputs at 130°F were above the TMU cutoff frequency of 30 Hz. These inputs were at 37 Hz and above, and the TMU internal 30-Hz band pass filter eliminated all data above 30 Hz. This resulted in large differences between the input and TMU measured levels, and gave negative percent errors.

Table 3. Shock Test Comparison--Shaker Table Control Input Vibration Compared to TMU Measured Response Vibration

Temperature (°F)	Shock No. 1 Error (%)	Shock No. 2 Error (%)	Average Error (%)
-32	49.8	44.2	47.0
70	22.7	19.2	21.0
130	-8.7	-10.7	-9.7
140	11.9	13.2	12.5
150	7.1	16.6	11.8

The levels measured at 70° and 140°F indicate that the TMU would have had an average error between 12.5 and 21 percent at 130°F, if the cutoff frequency had not been exceeded.

Except for the testing at 130°F, the TMU measurement errors were positive. The positive errors were a result of the TMUs measuring levels that were higher than what was actually input to the accelerometers.

Sine Dwell Tests. Results of the calculations from the sine dwell tests are shown in Table 4.

Table 4. Sine Dwell Vibration Comparison--Shaker Table Control Input Vibration Compared to TMU Measured Response Vibration

Temperature (°F)	Sine Dwell No. 1 Error (%)	Sine Dwell No. 2 Error (%)	Average Error (%)
-32	17.8	23.7	20.8
70	-2.9	-2.9	-2.9
130	-4.2	NA	-4.2
140	-7.3	-7.7	-7.5
150	-12.9	-12.5	-12.7

Sine dwell testing at 70°, 130°, and 140°F were the only temperatures that gave results within the specified allowable ±10 percent error. These errors were -2.9, -4.2, and -7.5 percent, respectively.

TMU measured responses for vibration testing at all other temperatures were not within the specified allowable ±10 percent of the input vibrations.

TMU Measured Zero Drift. The TMU measurements from the -32°F series of tests show a large zero drift to the positive side. Figure 9 shows that the TMU at rest measured an approximately 0.5-g level at the low temperature. This condition was determined to be unacceptable. Error calculations were performed with peak-to-peak values, and were not affected by the drift error.

Summary. Results from the additional engineering evaluation showed that the TMU did not perform to the requirements of the following documents: STW3-3662, CDW2-3454, TWR-17049 Rev A, nor the qualification testing of CTP-0097.

6.2.4.1 Conclusion. This test demonstrated that TMU vibration measurements are not within specified tolerances, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures. Because the TMU measured shock levels were higher than the input levels, it is likely that all TMU measured shock levels are higher than what occurs at the accelerometers.

A026056a

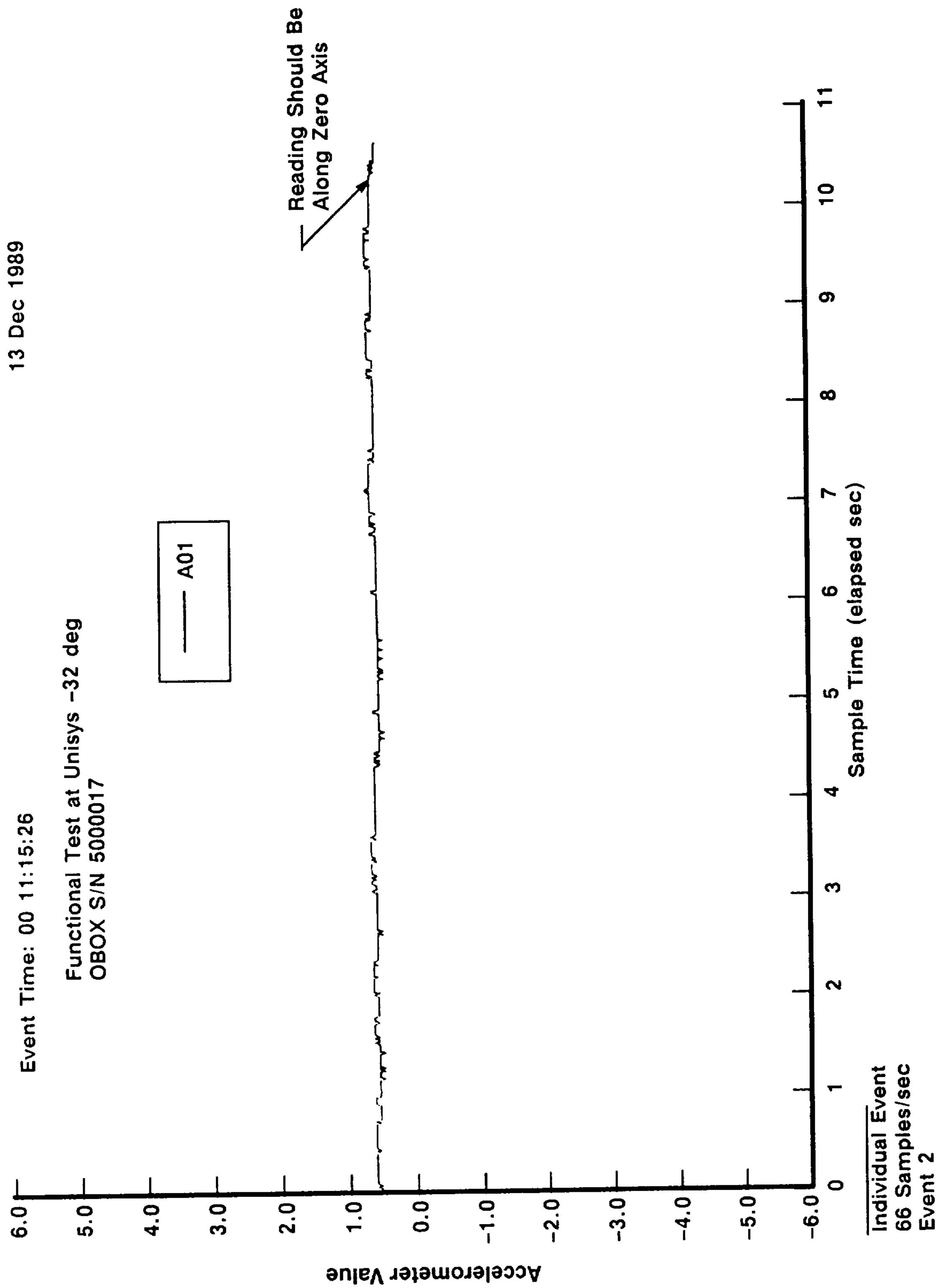

Figure 9. TMU Measure g-Level Versus Time—Cold Temperature Zero Drift

7

APPLICABLE DOCUMENTS

Document No.	Title
CDW2-3454	Performance, Design, and Verification Requirements Instrumentation Systems--Railcar Model Designator P77-0480
CPW1-3600	Prime Equipment Contract End Item (CEI) Detail Specifications
CTP-0097	Transportation Monitor Unit Qualification Test Plan
DPD 400	Data Procurement Document
SL-E-0002	NSTS Specification, EMI Characteristics, Requirements for Equipment
SW-E-0002	Space Shuttle GSE General Design Requirements
STW3-3662	Transportation Monitor Unit Product Specification
TWR-15723	Redesign D&V Plan
TWR-17049 Rev A	Transportation Monitoring System SRM Railcars
SE-019-049-2H	Solid Rocket Booster Vibration, Acoustic and Shock Design and Test Criteria
Military Standards	
MIL-STD-45662	Calibration System Requirements
MIL-STD-461A	Electromagnetic Interference Characteristics
MIL-STD-462	EMI Test Procedures
Drawing No.	
8U76218	Transportation Monitoring Unit--Kit

APPENDIX A

Wyle Laboratories TMU Test Report No. 53976

TEST REPORT

REPORT NO. 53976

OUR JOB NO. DE 53976

CONTRACT NAS8-30490

YOUR P. O. NO. 9MG021

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
WESTERN OPERATIONS, NORCO FACILITY

MORTON THIOKOL, INC.
Space Operations
Highway 83
Brigham City, Utah 84302-0707

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DATE 26 June 1989

This is to certify that the enclosed test data sheets contain true and correct data obtained in the performance of the test program as set forth in your purchase order.

Test methods, results, and equipment used are recorded on these data sheets.

Where applicable, instrumentation used in obtaining this data has been calibrated using standards which are traceable to the National Bureau of Standards.

SUMMARY:

Two SRM Segment Transportation Monitoring Units, Prototype, Units 1 and 2, were submitted for test in accordance with Morton Thiokol Document No. CTP-0097, Revision B, dated 12 January 1989. The specimens completed shock testing in the longitudinal axis at -20 and +70F, and transportation vibration as recorded on the test data sheets. As documented in Notice of Deviation No. 1, Test Unit No. 1 suffered structural damage during ambient temperature transportation dwell test at the first mode. During the high temperature transportation vibration test, both specimens stopped functioning at approximately +150F. At the direction of Morton Thiokol, testing was discontinued. (See Notice of Deviation No. 2.) Test setup is shown in Photograph 1, and the broken mounting plate of Test Unit No. 1 is shown in Photograph 2.

STATE OF CALIFORNIA
COUNTY OF RIVERSIDE } ss.

W. D. Peters, being duly sworn, deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

W. D. Peters

SUBSCRIBED and sworn to before me this 27th day of June, 19 89

Catherine C Kelty

Notary Public in and for the County of Riverside, State of California

My Commission expires 23 July, 19 91

OFFICIAL SEAL
CATHERINE C KELTY
NOTARY PUBLIC - CALIFORNIA
RIVERSIDE COUNTY
My comm. expires JUL 23, 1991

W-867A

DEPARTMENT DYNAMICS/ENVIRONMENTAL

DEPT. MGR. J J Anderson
J. J. Anderson

TEST ENGINEER C C Lee
C. C. Lee

REGISTERED PROFESSIONAL ENGINEER

DCAS—QAR VERIFICATION

QUALITY ASSURANCE L Housteau
L Housteau

ORIGINAL PAGE IS OF POOR QUALITY

DATA SHEET

Customer MORTON THIOKOL Job No. 53976

Date 2-27-88

Specimen TRANSPORTATION UNITS

RECEIVING INSPECTION

No. of Specimens Received: TWO

Record identification information exactly as it appears on the tag or specimen:

Manufacturer MORTON THIOKOL

Part Numbers PROTOTYPE

How does identification information appear: (name plate, tag, painted, imprinted, etc.)

Serial Numbers:* UNIT 1

2

Examination: Visual, for evidence of damage, poor workmanship, or other defects, and completeness of identification.

Inspection Results: There was no visible evidence of damage to the specimens unless noted below.

* If additional space is required for serial numbers, use an additional page, or reference first functional test data sheet (if applicable).

Inspected By [signature]

Sheet No. ______ of ______

Approved C.C. [signature] Date: 2-27-89

W-614

Q.C. Form Approval [initials]

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

TEST TITLE SINE / VIBRATION RESONANT DWELLS

CUSTOMER M.T.I. Job No. 53976

Specimen T.M.U Date Started 2-28-89

Part No. PROTOTYPE Serial No. UNITS I & II Date Comp. 4-5-89

Spec. MTI TP CTP-0097 Par. 8 Photo YES Amb. Temp. 70°F ± 10°

THE TEST SPECIMENS WERE MOUNTED TO "C" CHANNEL USING SHOCK MOUNTS PROVIDED BY CUSTOMER IN TURN WERE SECURED TO AN ELECTRO DYNAMIC EXCITER TEMPERATURE CONDITIONED FOR A MINIMUM OF FOUR HOURS, AND SUBJECTED TO THE FOLLOWING AXIS, AND TEST LEVELS

SINUSOIDAL VIBRATION - LONG AND TANGENTIAL

5 TO 2000 TO 5 HZ

5 - 130 HZ	1.2 G's
130 - 180 HZ	.0014 " DA
180 - 2000 HZ	2.5 G's

RESONANCE DWELLS - AT THE TWO MAJOR RESONANCES DURING SINE VIBRATION

TEMPRETURES - -20°F ± 10°
AMBIENT +70°F ± 10°
+163°F ± 10°

Tested by M. Nigon / M. Olein

Engineer CCL

W614A-82 QA Form Approval LH

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

TEST TITLE SINE / VIBRATION RESONANT DWELLS Date 4-5-89

Customer M.T.I. Job No. 53976

Specimen T.M.U. Technician [signature]

Part No. PROTOTYPE Serial No. UNITS I & II Engineer CC [signature]

TEST RESULTS:

3-6-89 DWELL #1 LONG AXIS

TEST WAS STOPPED WHEN MOUNTING PLATE WAS DISCOVERED BROKEN (REF. NOD No. 1)

4-5-89

UNIT II

HOUR 0830

TEMP CONDITIONING AT 163° F OVER NITE CUSTOMER'S SPECIMEN FAIL TO RESPOND CORRECTLY

UNIT II

HOUR 1125

TEMP CONDITIONING WAS RESUMED ON UNIT II STARTING AT APPROX 120 DEGREES WHEN AT 150 DEGREES AFTER RAISING TEMP FROM 120°F UNIT THEN FAILED AT ABOUT 45 MIN E.T. APPROX.

(REF. NOD No. 2)

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Report No. 53976

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

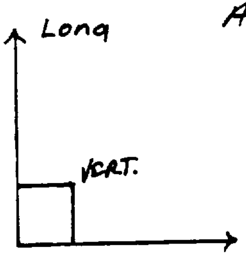
Page No. 5

TEST TITLE TRANSPORTATION ; FUNCTIONAL Date 2-28-89

Customer MORTON THIOKOL Job No. 53976

Specimen TRANSPORTATION MONITOR UNIT Technician M. Oh

Part No. See Rec Insp. Serial No. See Rec Insp. Engineer C.C. [illegible]



ACCELEROMETER

(A) A001 Long
A002 VERT.
A003 TAN.

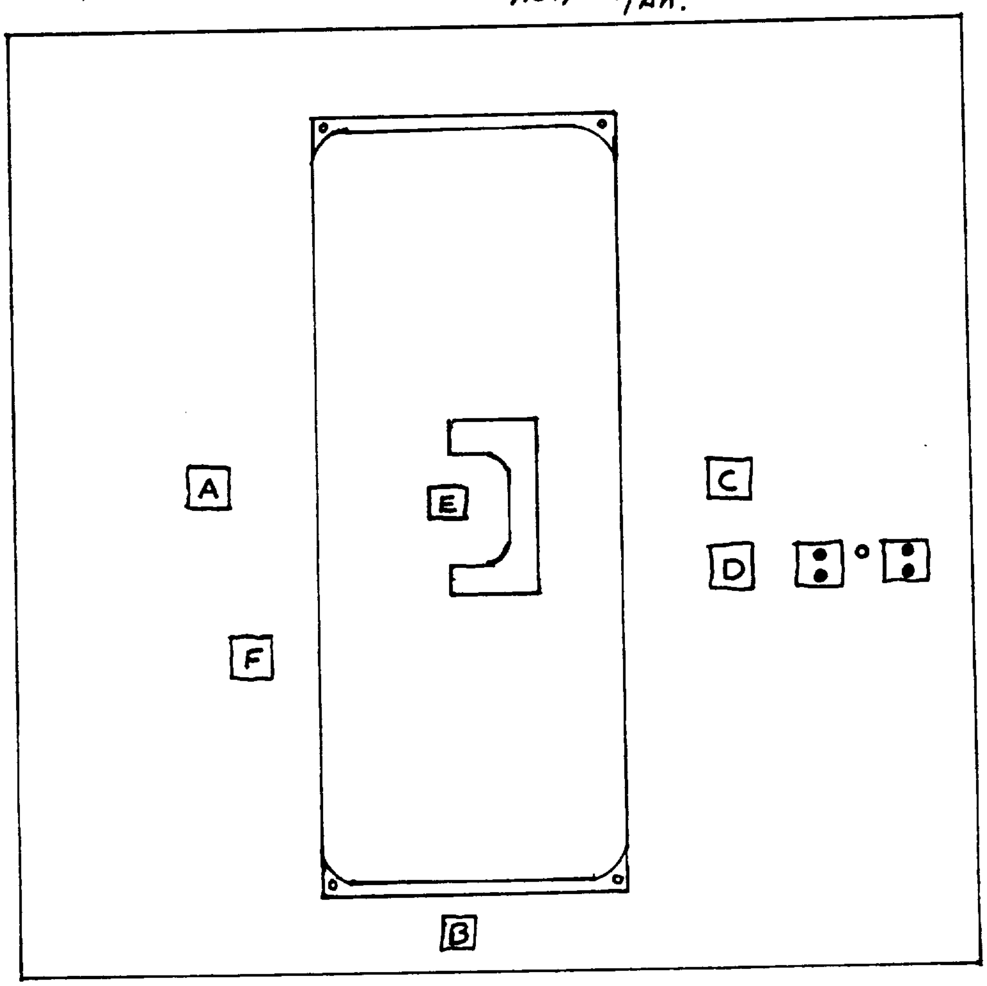
(B) A004 Long
A005 VERT.
A006 TAN.

(C) A007 Long
A008 VERT
A010 TAN.

(D) A009 VERT.

(E) A012 Long
A013 VERT
A014 TAN.

(F) A011 CONTROL



THERMOCOUPLE

COUSTOMER • T001
T002
T003
T004

CONTROL o

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

TEST TITLE TRANSPORTATION ; FUNCTIONAL Date 2-28-89
Customer MORTON THIOKOL Job No. 53976
Specimen TRANSPORTATION MONITOR UNIT Technician M. Ela
Part No. See Rec. Insp. Serial No. See Rec. Insp. Engineer CChu

ACCELLEROMETER	S/N	
A001	21161	
A002	20947	
A003	21509	
A004	21628	
A005	21387	
A006	22329	
A007	21412	
A008	21624	
A009	21650	
A010	21172	
A011	CONTROL	WYLE ACCELS
A012	RESPONSE	WYLE ACCELS
A013	RESPONSE	WYLE ACCELS
A014	RESPONSE	WYLE ACCELS

W614B-82 QA Form Approval LH

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DYNAMICS SECTION
VIBRATION TEST DATA SHEET

Job No. 53976
Sheet ____ of ____

Customer MORTON THIOKOL Specimen SCANNER / RECORDER P/N ____ S/N 1 & 2

Date	Time	Axis	Temp (°F)	SINUSOIDAL Freq. (HZ)	Disp. ("DA)	Accel. (± G)	Test Time (Min.)	Comments
1989	NOTED	NOTED	NOTED	5 TO 2000 TO 5	NOTED	NOTED	*	
								* CYCLE FROM 5 TO 2000 TO 5 HZ. AT
				5 TO 130	—	1.2g		ONE OCTAVE PER MIN. FOR A TOTAL OF
				130 TO 185	.0014	—		ONE CYCLE PER AXIS / PER. TEMP. MO
				185 TO 2000	—	2.5g		
3/3	0908	LONG	-20°F	5 TO 2000	"	"		START CYCLING UNIT #1
	0927						19 min	COMPLETED M.O.
3/3	1623	LONG	-20°	—	—	—		START CYCLING UNIT #2
	1641						18 MIN	COMPLETED M.O.
3/6	0918	LONG	+70°	—	—	—		START CYCLING UNIT #2
	0937						19 MIN	COMPLETED M.O.
3/6	1120	LONG	-70°	—	—	—		START CYCLING UNIT #1
	1139						19 MIN	COMPLETED M.O.

Signed: C C hn

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WYLE LABORATORIES SC... C SERVICES & S... EMS GROUP

Job No. 53976

DYNAMICS SECTION
VIBRATION TEST DATA SHEET

Customer M.T.I. Specimen TMU P/N S/N

Date	Time	Axis	Temp (°F)	SINUSOIDAL Freq. (HZ)	Disp. ("DA)	Accel. (±G)	Test Time (Min.)	Comments
1989	NOTED	NOTED	NOTED	NOTED	NOTED	NOTED	NOTED	
				5-130	—	1.2		
				130-180	.0014	—		
				180-2000	—	2.5		
3-31	1057	TANG	-20°	—	—	—		START SINE CYCLE UNIT #1
	1112						15	COMPLETE GMJN
4-3	1330	TANG	+70°	—	—	—		START SINE CYCLE UNIT #1
	1903						15	COMPLETE ACCUMULATED TIME GMJV
4-4	0904	TANG	+163°	—	—	—		START SINE CYCLE UNIT #1
	0919						15	COMPLETE GMJN
4-4	1138	TANG	+70°	—	—	—		START SINE CYCLE UNIT #2
							15	COMPLETE GMJV

W589A QA Form Approval LH

Signed: C.C.L.

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

TEST TITLE RESONANCE DWELL
DATE 3-6-89
Customer MTI
Job No. 53976
Specimen TMU
Technician NISPORIC
Part No. PROTOTYPE Serial No. UNIT 1 & 2
Engineer C.C. [illegible]

Date	Time	Axis	Test	Comments
1989	NOTED	NOTED	DWELL	
				DWELL AT THE 3
				MAJOR RESONANCES FOR
				15 MIN EACH RESONANCE
3-3	1016	LONG	DWELL #1	START AT 20 HZ UNIT 1
	1031			COMPLETE - 20 °F
3-3	1033	LONG	DWELL #2	START AT 27.5 HZ UNIT 1
	1048			COMPLETE - 20 °F
3-3	1644	LONG	DWELL #1	START AT 20.0 HZ UNIT 2
	1659			COMPLETE - 20 °F
3-3	1705	LONG	DWELL #2	START AT 35 HZ UNIT 2
	1720			COMPLETE - 20 °F
3-6	0939	LONG	DWELL #1	START AT 19 HZ UNIT 2
	0954			COMPLETE AMBIENT
3-6	1300	LONG	DWELL #1	START AT 19.5 UNIT 1
	1336			INCOMPLETE AMBIENT
				STOP TEST MOUNTING
				PLATE BROKE IN HALF

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

TEST TITLE RESONANT DWELLS
DATE 4-4-89
Customer M.T.L.
Job No. 53976
Specimen T.M.U.
Technician NISORIC
Part No. PROTOTYPE
Serial No. UNITS 1&2
Engineer C C L

Date	Time	Axis	Test	Comments
1989	NOTED	NOTED	DWELL # / TEMP	DWELL AT THREE MAJOR
				FREQUENCYS FOR 15 MIN
				EACH RESONANCE
3-31	1532	TANG	DWELL #1 / -20°	START DWELL 17HZ UNIT #1
	1545			COMPLETE ACCUMULATED TIME
				MJV
4-3	1436	TANG	DWELL #1 / +70° AMBIENT	START DWELL 16 HZ UNIT #1
	1446			COMPLETE MJV
4-3	1450	TANG	DWELL #2 / +70° AMBIENT	START DWELL 55 HZ UNIT #1
	1505			COMPLETE MJV
4-4	0938	TANG	DWELL #1 / +163°	START DWELL 14.5 HZ UNIT #1
	0953			COMPLETE MJV
4-4	1020	TANG	DWELL #2 / +163°	START DWELL 43 HZ UNIT #1
	1035			COMPLETE MJV
4-4	1312	TANG	DWELL #1 / +70° AMBIENT	START DWELL 28 HZ UNIT #2
	1327			COMPLETE MJV

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

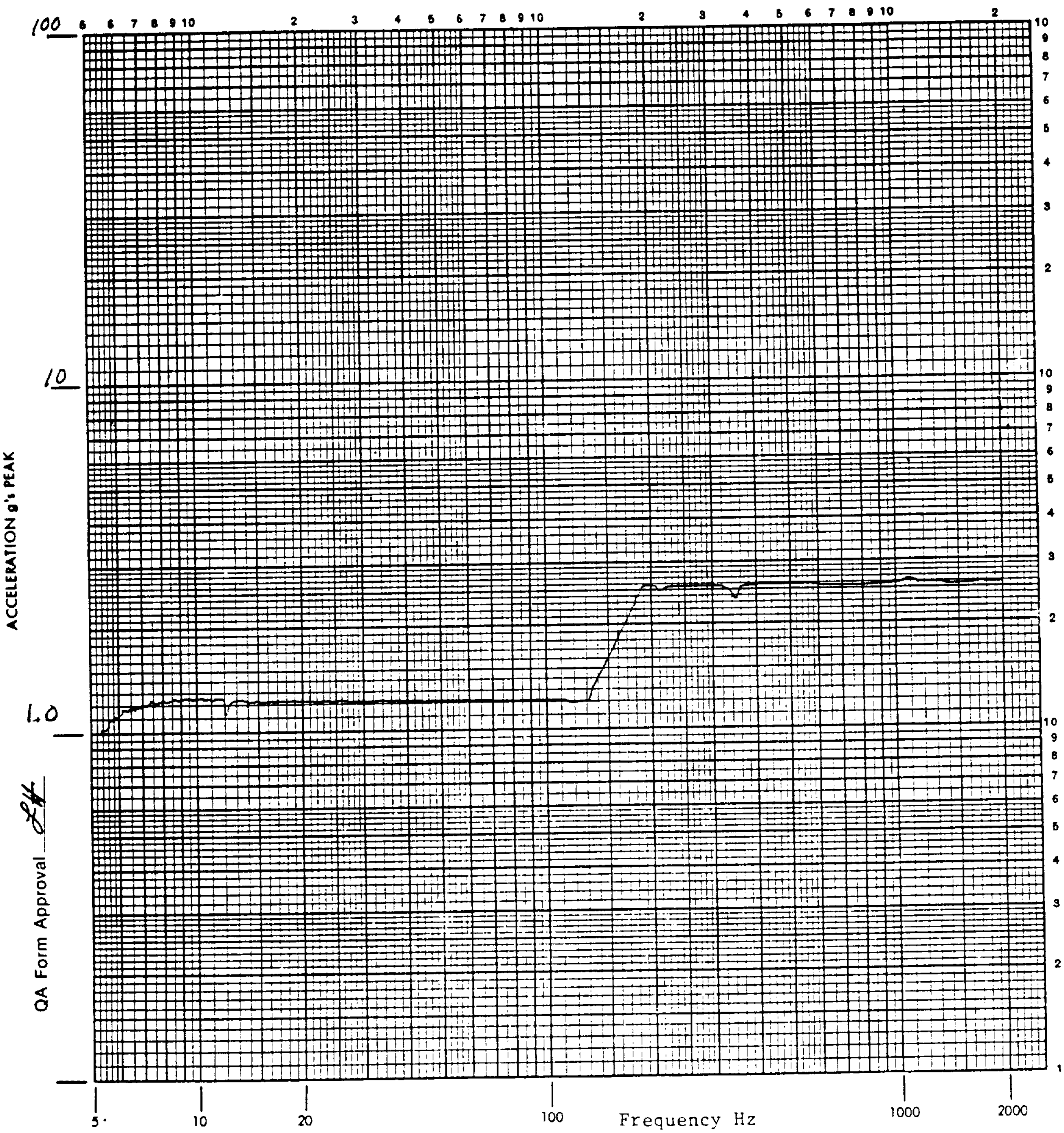
CUSTOMER MTI Job No. 53976 Date 3 MAR 89

Specimen T.M.V. specimen #1 Axis of Test Long

Accel. No. #1 Control (X) Response ( ) acl. Full Scale 100 g

Operator M Cl Engineer cc hu -20°F

SINUSOIDAL



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CUSTOMER M.T.I. Job No. 53976 Date 3 MAR 89

Specimen T.M.U. SPECIMEN #1 Axis of Test LONG

Accel. No. #2 (LONG) Control ( ) Response (X) Full Scale 100 g

Operator M.C. Engineer C.C.

-20°F

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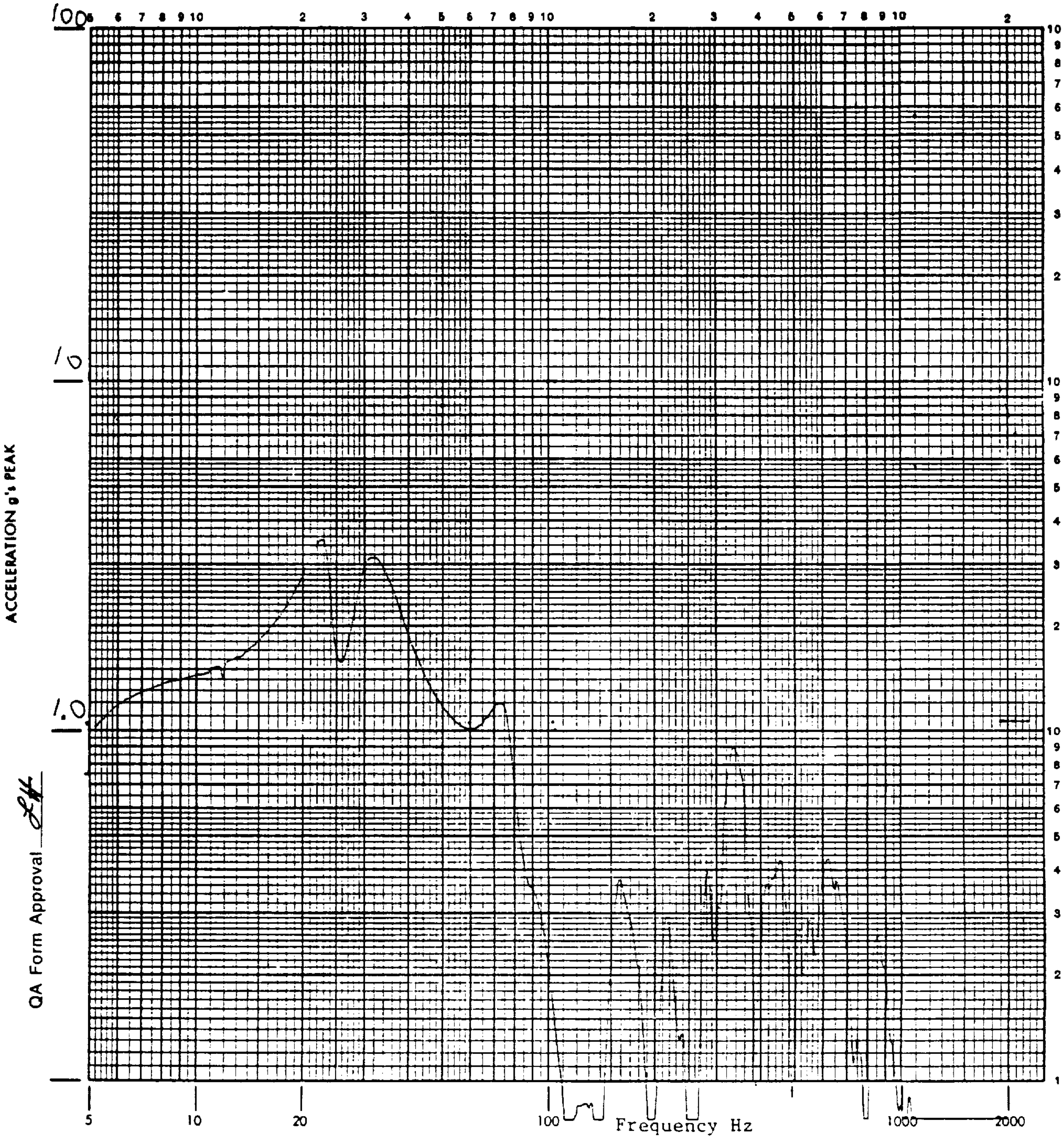
SINUSOIDAL



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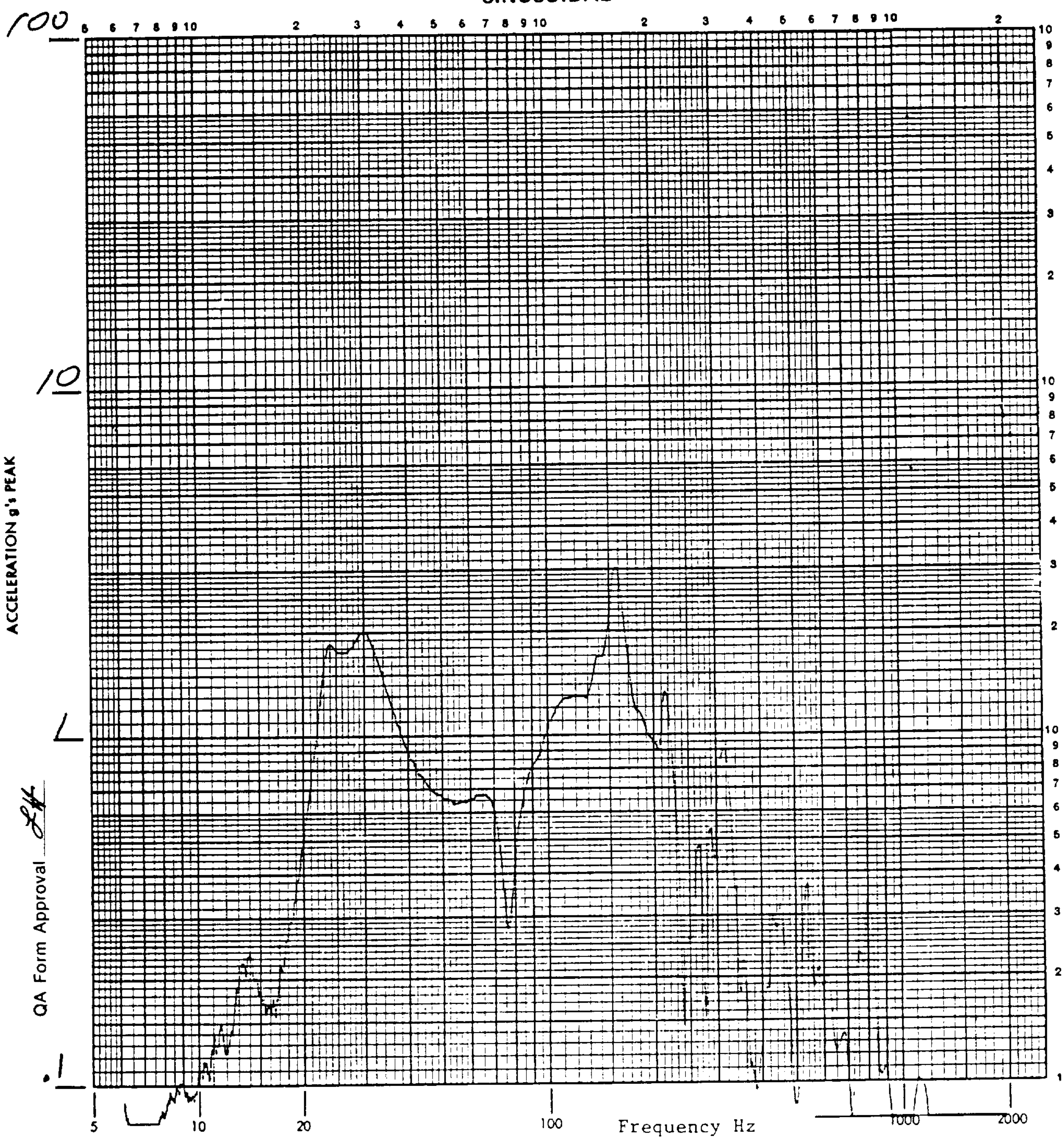
CUSTOMER M.T.I Job No. 53976 Date 3-3-89

Specimen IMU Axis of Test LONG

Accel. No. 3 ~~(VERT)~~ VERT. Control ( ) Response (X) Full Scale 100 g

Operator [illegible] Engineer [illegible] -20°F

SINUSOIDAL



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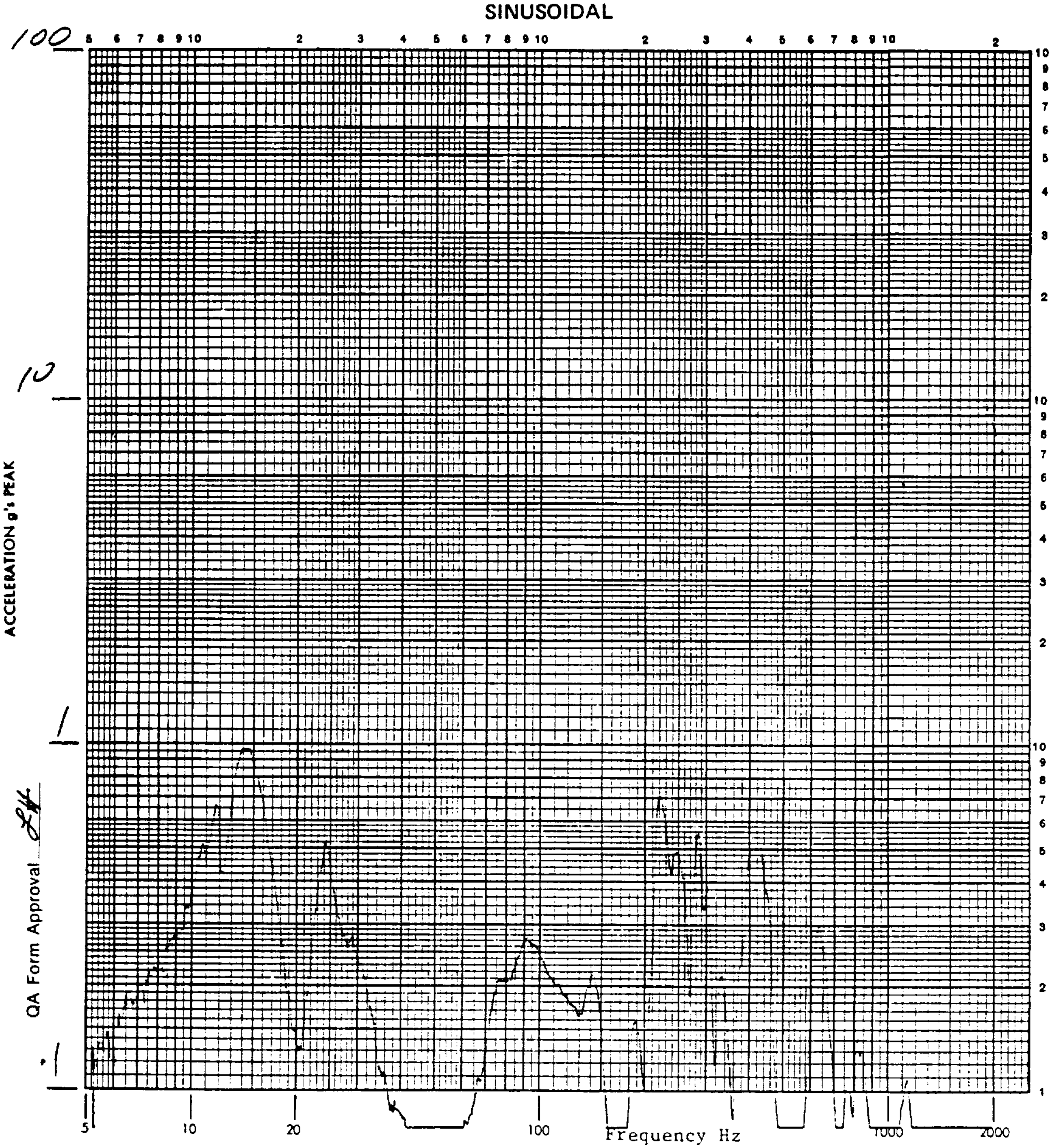
CUSTOMER MTI Job No. 53976 Date 3-3-89

Specimen TMV UNIT #1 Axis of Test LONG

Accel. No. 4 Control ( ) Response (X) Full Scale 100 g

Operator MCh Engineer CCJm -20°F

SINUSOIDAL



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

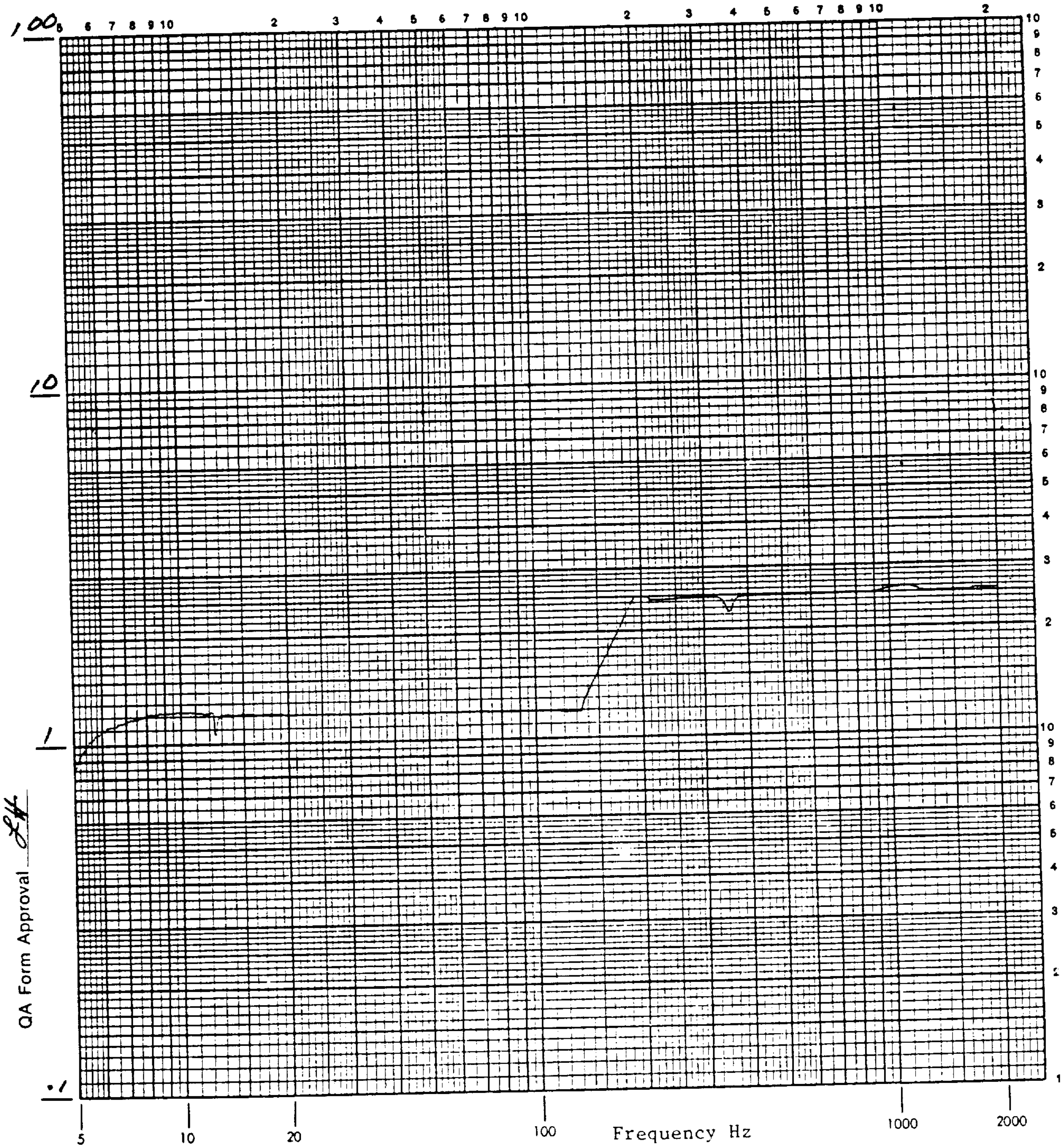
CUSTOMER MTI Job No. 53976 Date 3-3-89

Specimen T.M.V. UNIT #2 Axis of Test Long

Accel. No. 1 Control (✓) Response ( ) Full Scale 100 g

Operator M. Ou Engineer CChu -20°F

SINUSOIDAL



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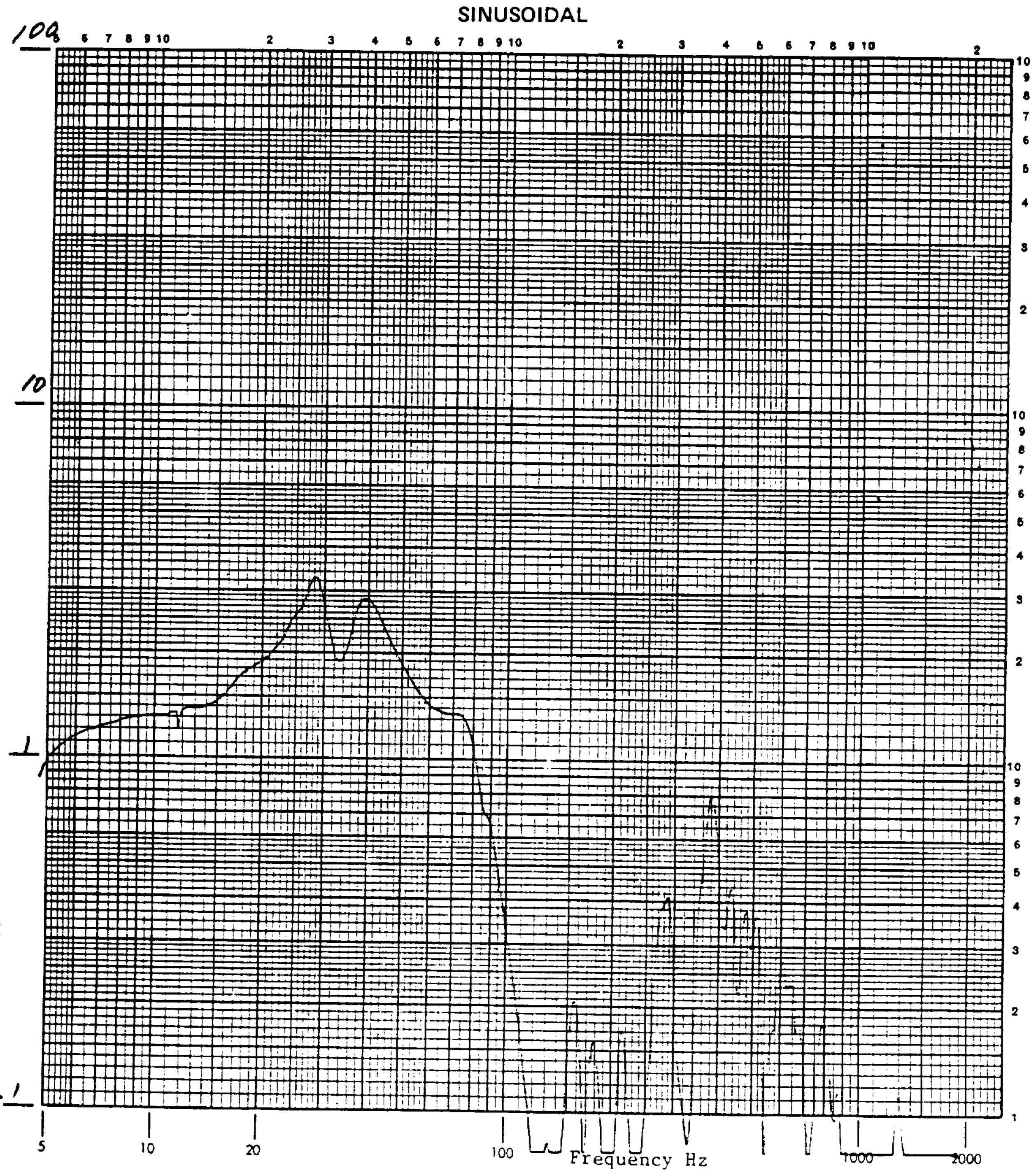
CUSTOMER MTI Job No. 53976 Date 3-3-89

Specimen T.M.V. UNIT #2 Axis of Test Long

Accel. No. 2 Control ( ) Response (✓) Full Scale 100 g

Operator [illegible] Engineer [illegible]

-20°F



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

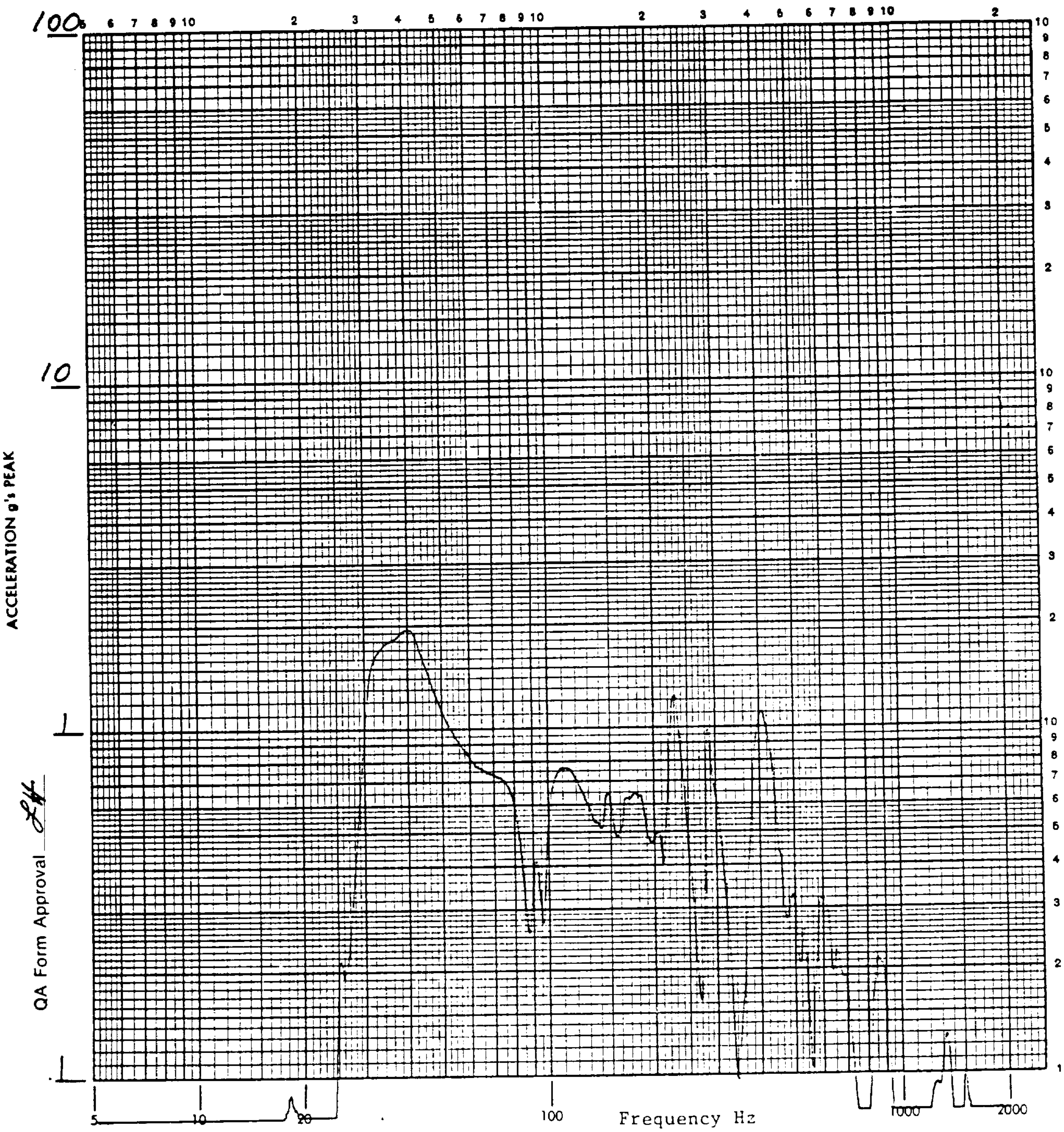
CUSTOMER Morton THIOKOL Job No. 53976 Date 3-3-89

Specimen T.M.V. UNIT #2 Axis of Test LONG

Accel. No. 3 Control ( ) Response (X) Full Scale 100 g

Operator MCh Engineer CClm -20°F

SINUSOIDAL



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Report No. 53976

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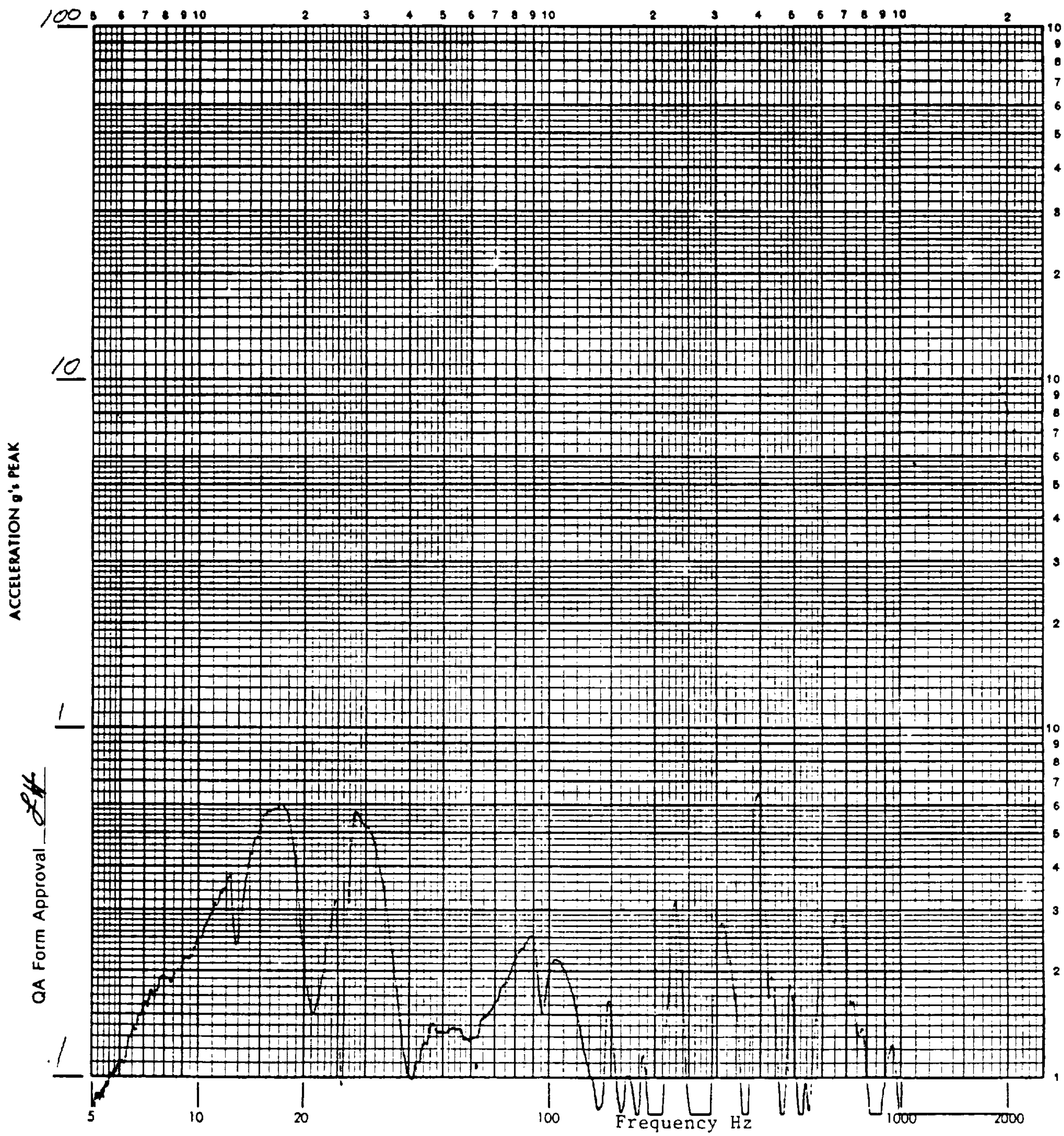
CUSTOMER Morton Thiokol Job No. 53976 Date 3-3-89

Specimen T.M.V. Unit #2 Axis of Test Long.

Accel. No. 4 Control ( ) Response (✓) Full Scale 100 g

Operator M Ow Engineer C C hn -20°F

SINUSOIDAL



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Report No. 53976

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3-6-89

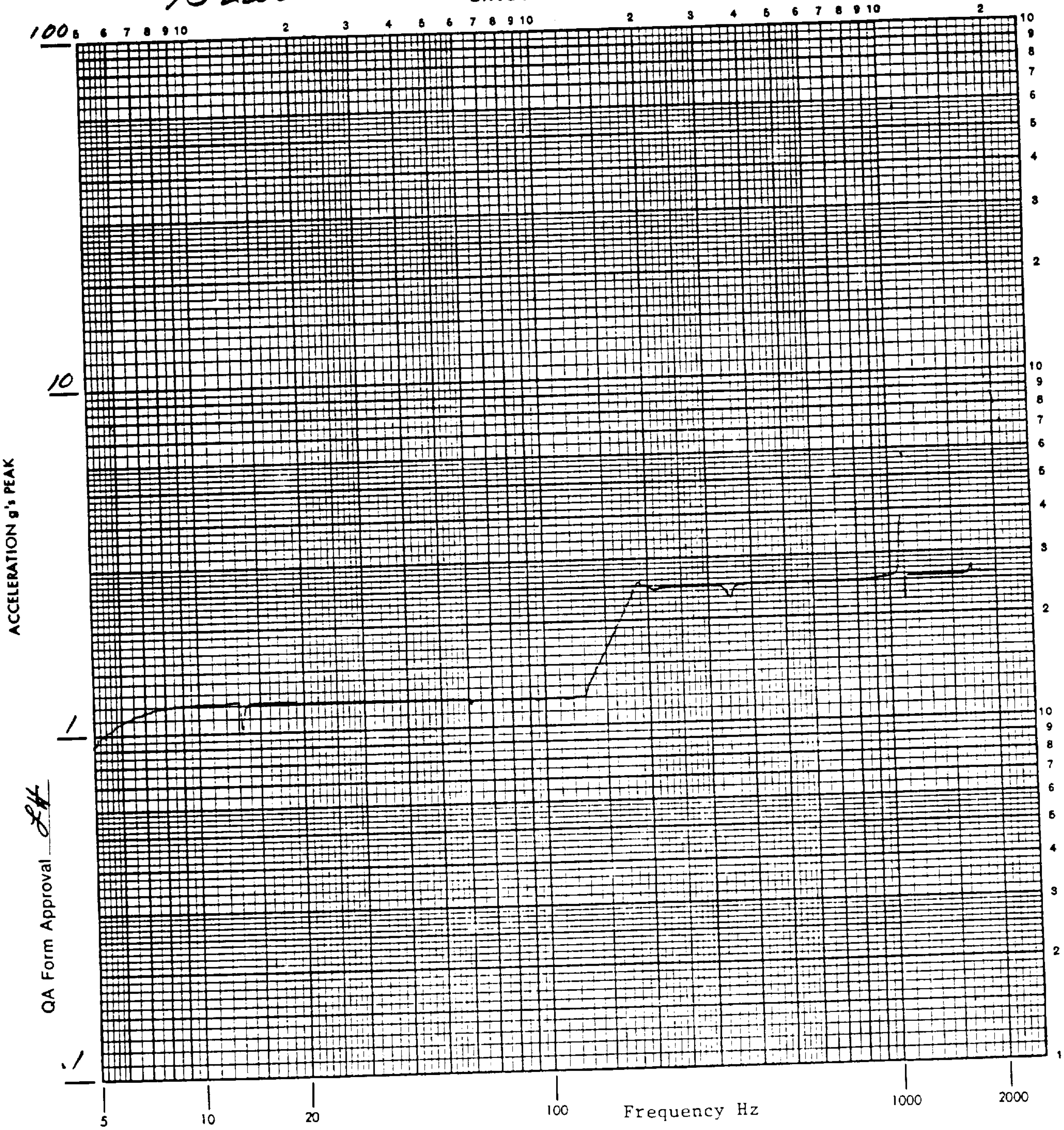
Specimen UNIT # 2 Axis of Test Long

Accel. No. 1 Control (✓) Response ( ) Full Scale 100 g

Operator M. Okii Engineer C.C. [illegible]

AMB.

1/3 LEVEL DOWN SINUSOIDAL



QA Form Approval [illegible]

W-784 S

CUSTOMER MTI Job No. 53976 Date 3-6-89

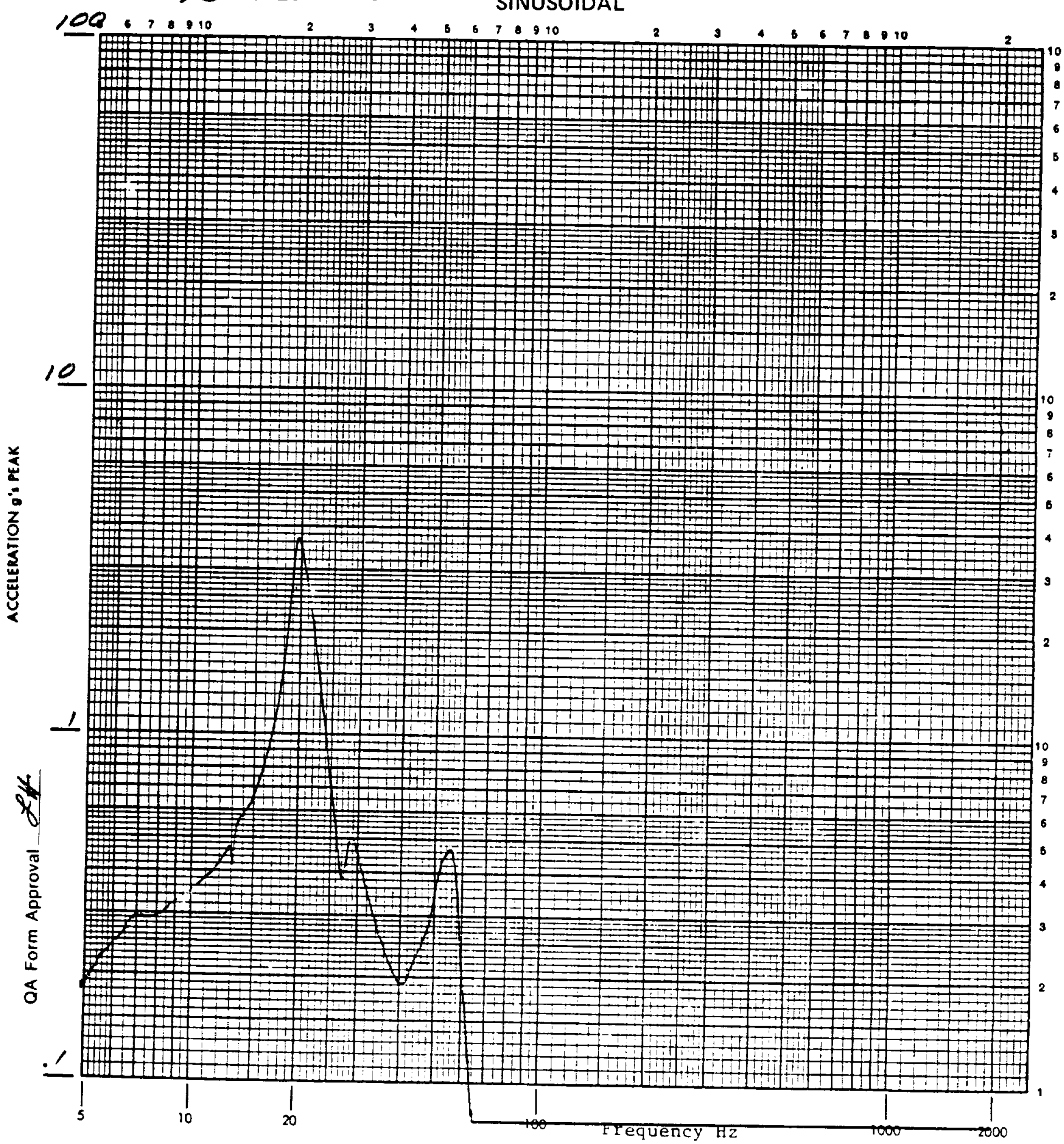
Specimen UNIT # 2 Axis of Test Long

Accel. No. 2 Control ( ) Response (✓) Full Scale 100 g

Operator M. Oh Engineer CChn

1/3 LEVEL DOWN AMB.

SINUSOIDAL



Report No. 53976

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

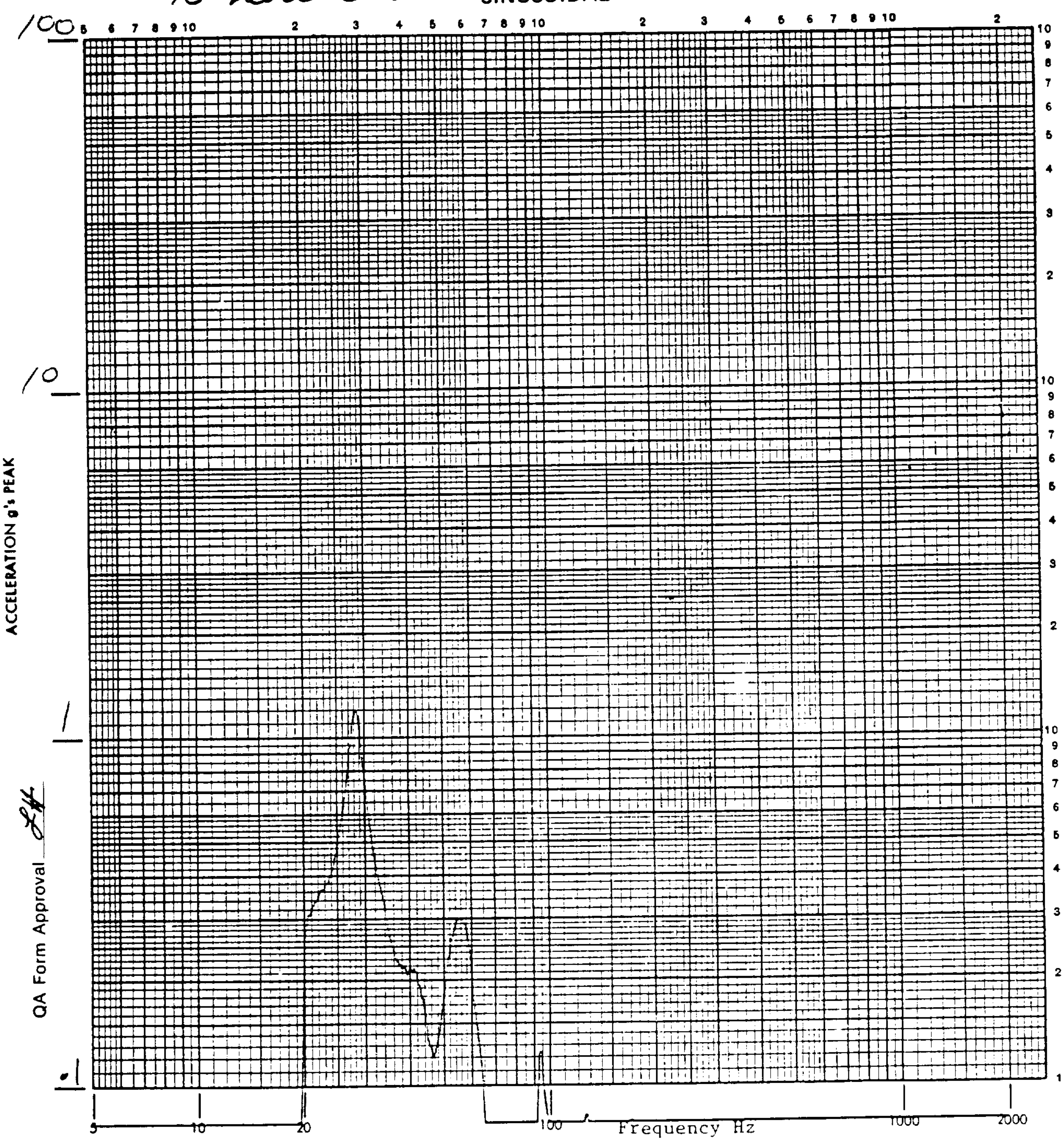
CUSTOMER MTI Job No. 53976 Date 3-6-89

Specimen UNIT 2 Axis of Test LONG

Accel. No. 3 Control ( ) Response (X) Full Scale 100 g

Operator MOL Engineer CCL AMB

1/3 LEVEL DOWN SINUSOIDAL



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3-6-87

Specimen UNIT 2 Axis of Test LONG

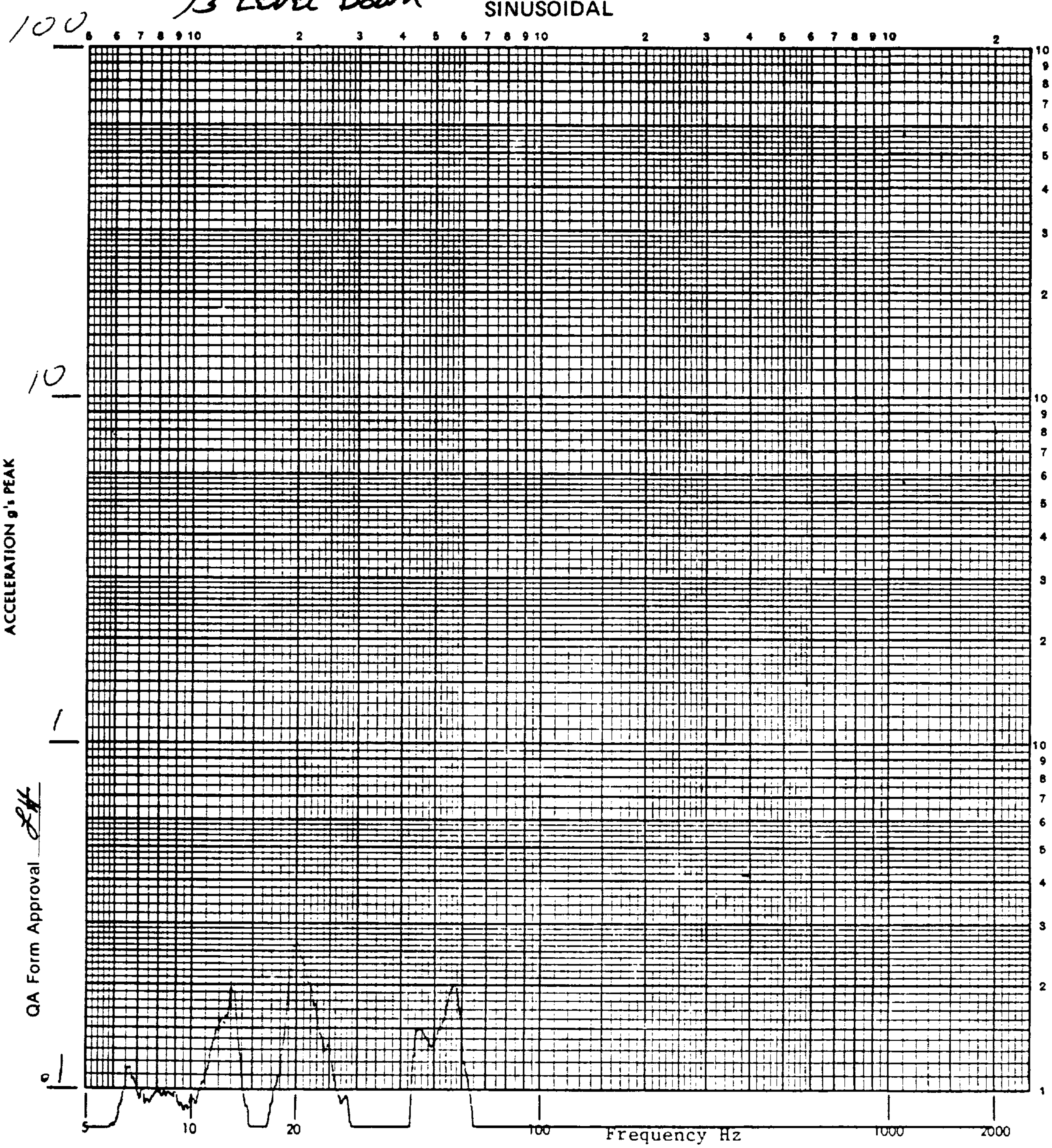
Accel. No. 4 Control ( ) Response (X) Full Scale 100 g

Operator M.C. Engineer CC

AMB

1/3 LEVEL DOWN

SINUSOIDAL



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Report No. 53976

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

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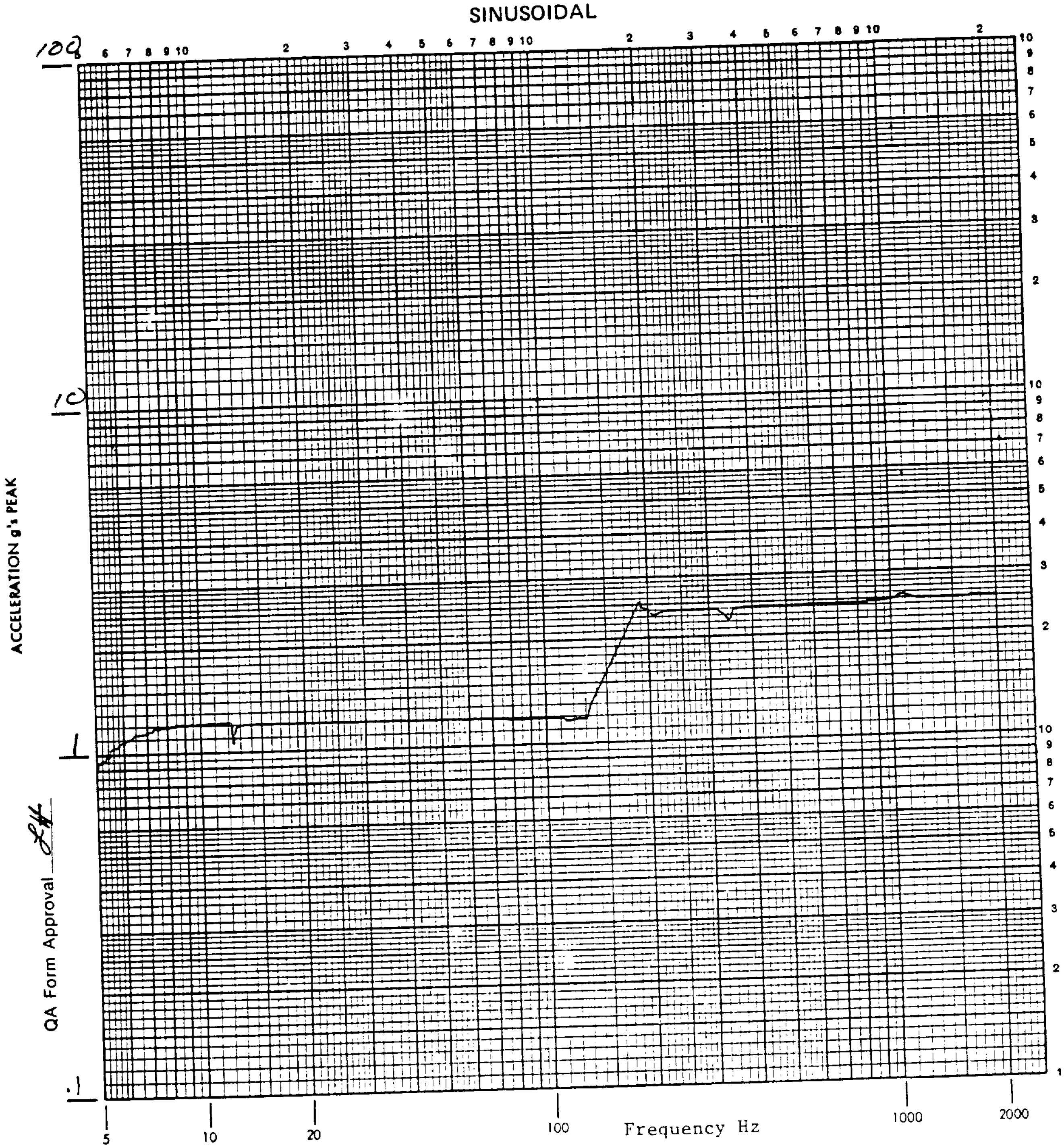
CUSTOMER MTI Job No. 53976 Date 3-6-89

Specimen UNIT # 1 Axis of Test Long

Accel. No. 1 Control (✓) Response ( ) Full Scale 100 g

Operator M.O. Engineer CC AMB

SINUSOIDAL



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

Page No. 24

CUSTOMER MTI Job No. 53976 Date 3-6-89

Specimen Unit # 1 Axis of Test Long

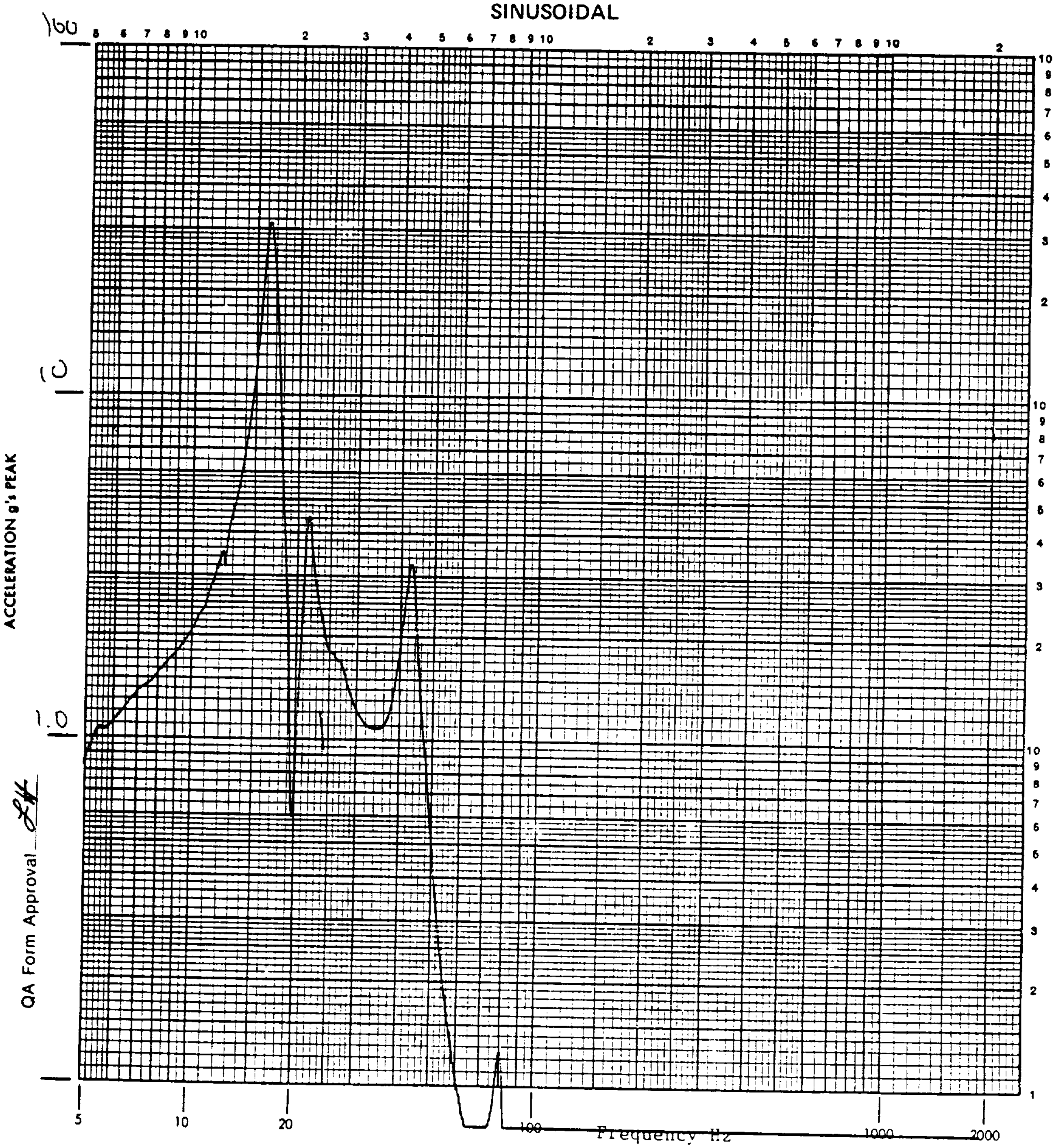
Accel. No. 2 LONG Control (4th Response (4)

Full Scale 100 g

Operator MCh Engineer CCh

AMB

SINUSOIDAL



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

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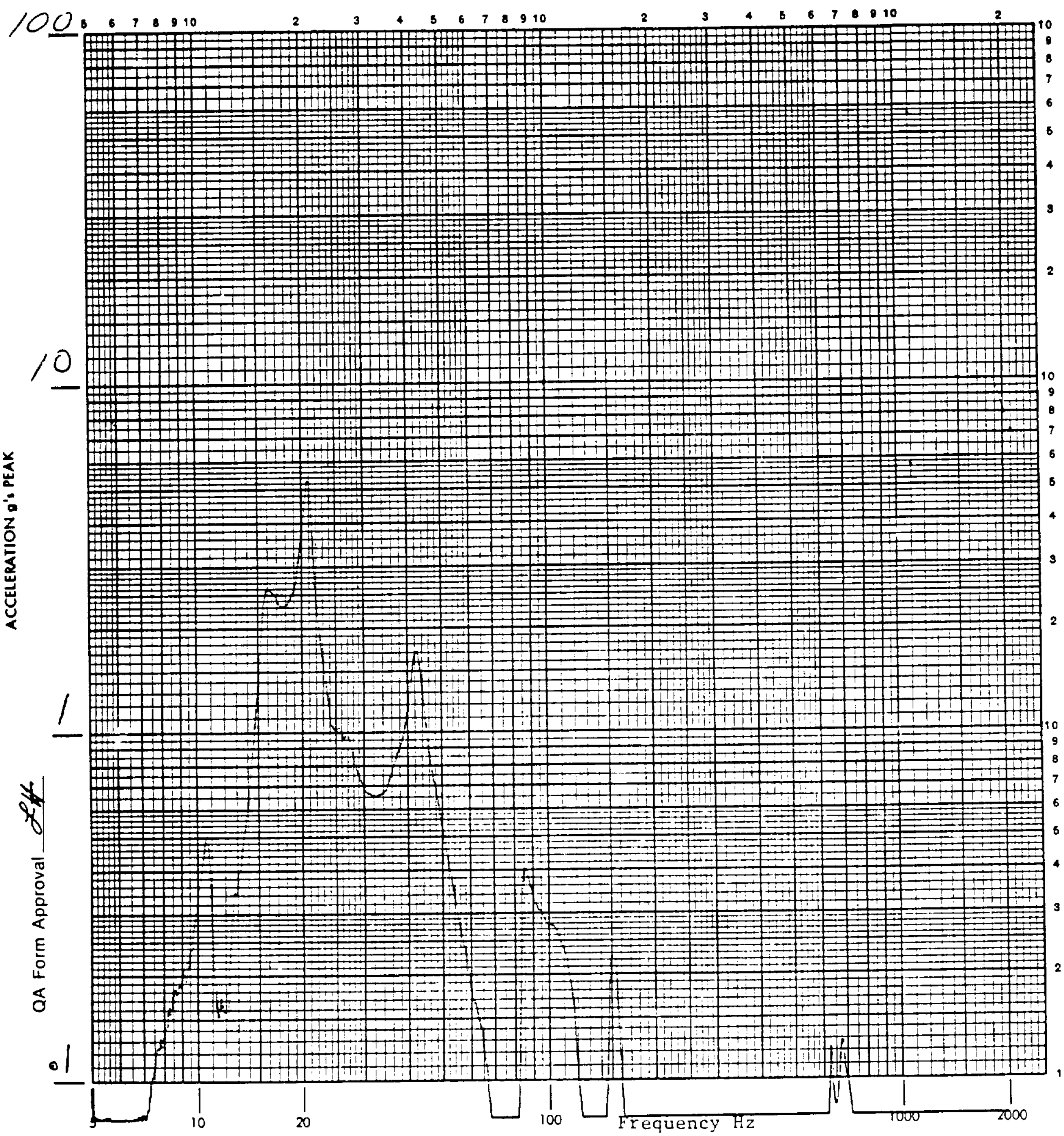
CUSTOMER M T I Job No. 53976 Date 3-6-89

Specimen UNIT 1 Axis of Test LONG

Accel. No. 3 Control ( ) Response (X) Full Scale 100 g AMB.

Operator MO Engineer CC

SINUSOIDAL



QA Form Approval

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3-6-89

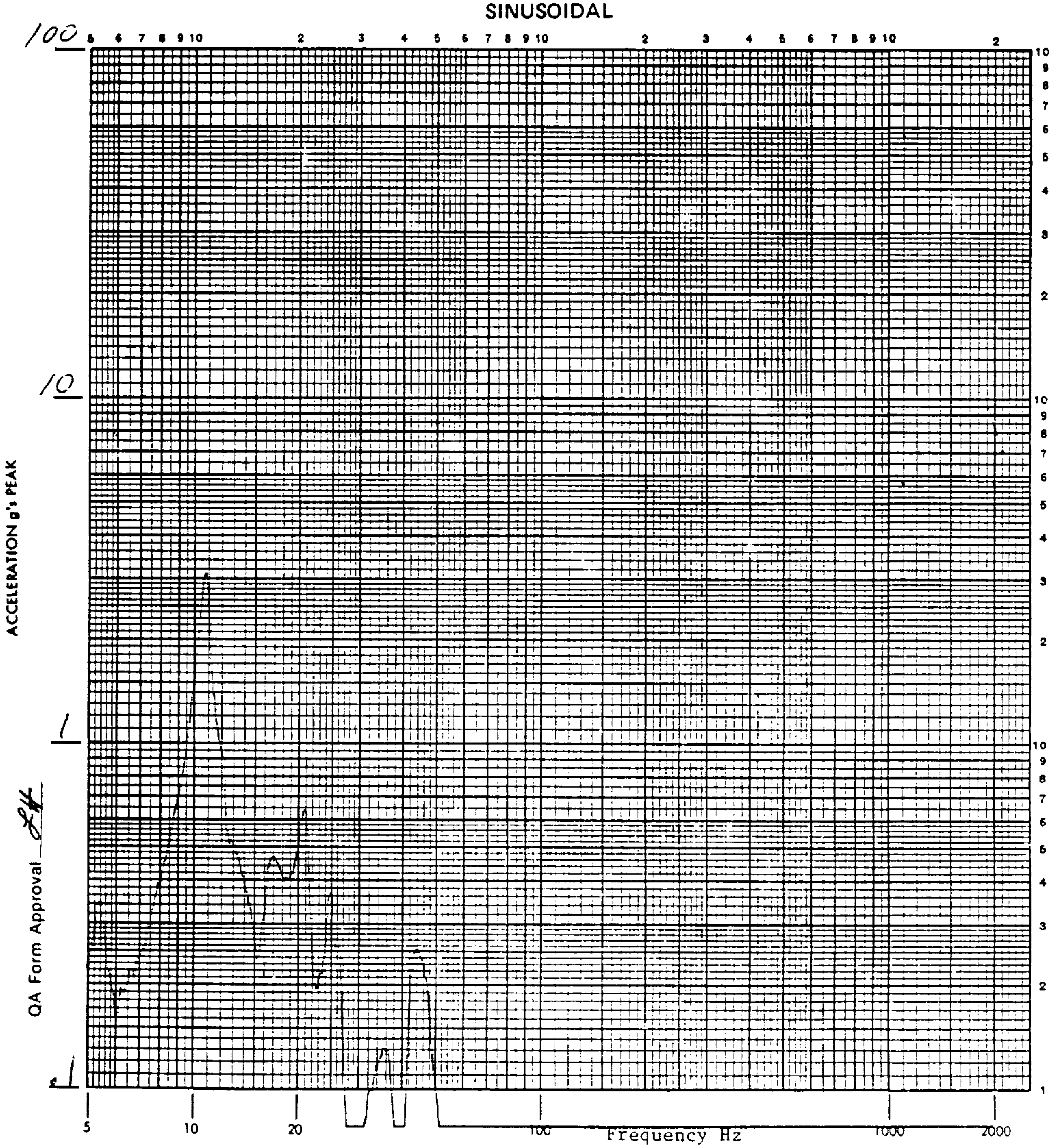
Specimen UNIT #1 Axis of Test LONG

Accel. No. 4 Control ( ) Response (✗) Full Scale 100 g

AMB

Operator MO. Engineer C.C.h.

SINUSOIDAL



QA Form Approval

W–784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

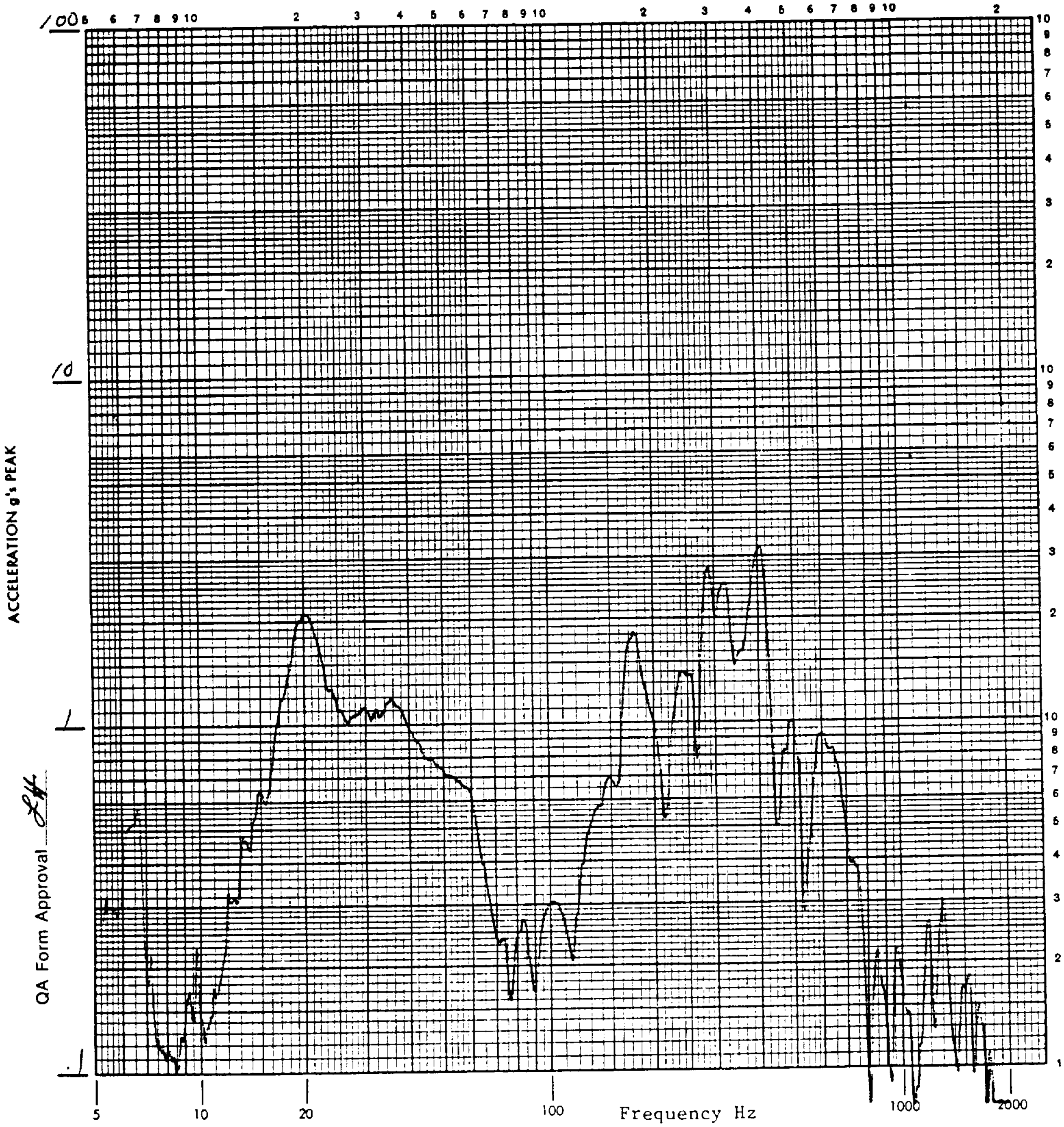
CUSTOMER MORTON THIOKOL Job No. 53976 Date 3-31-89

Specimen T. M U. Axis of Test TANG

Accel. No. 2 Control ( ) Response (X) Full Scale 100 g

Operator NISPORIC Engineer CChn

SINUSOIDAL



QA Form Approval LH

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

Page No. 28

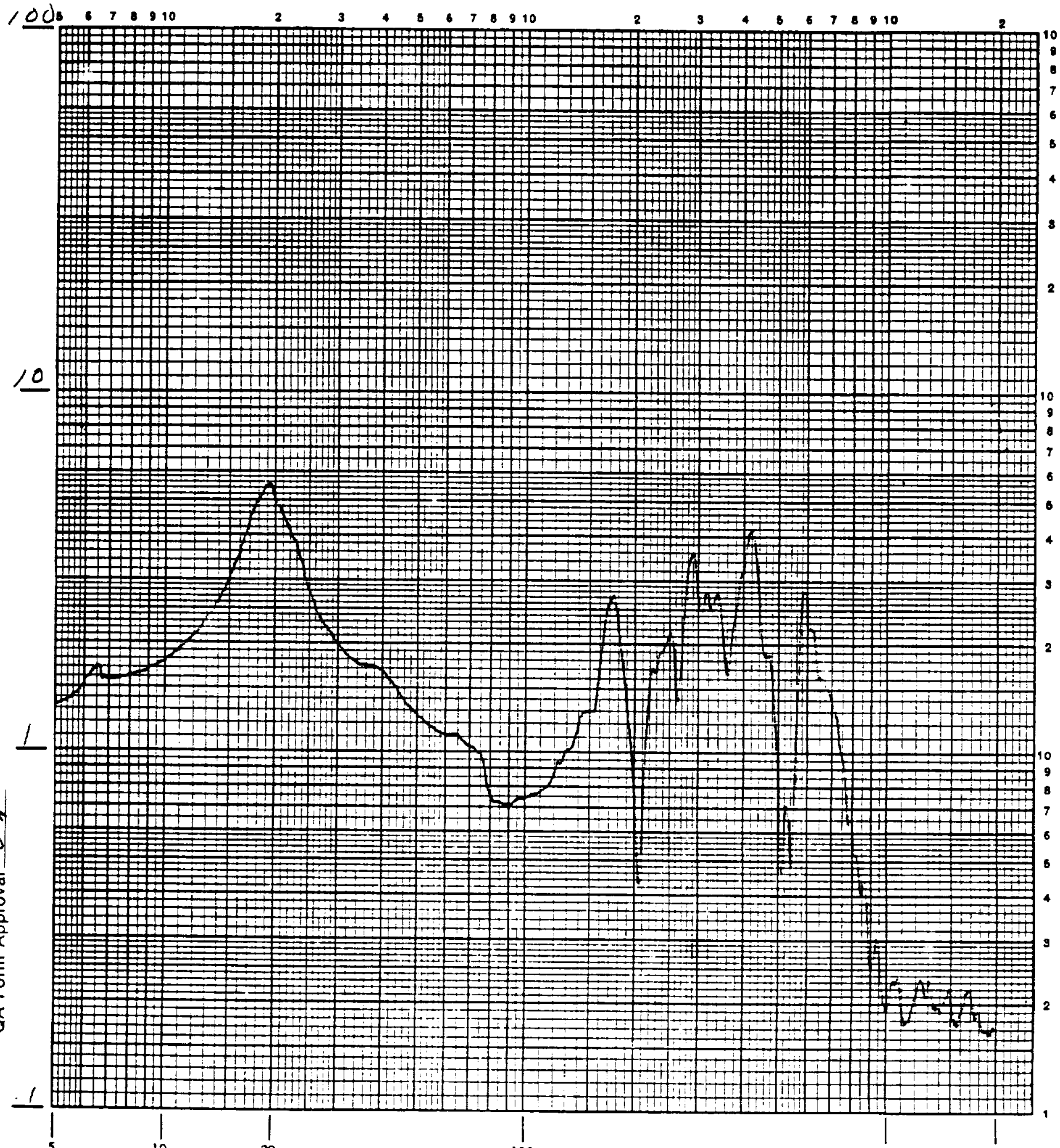
CUSTOMER MORTON THIOKOL Job No. 53976 Date 3-31-87

Specimen T. M. U. Axis of Test TANG

Accel. No. 3 Control ( ) Response (*) Full Scale 100 g

Operator [signature] Engineer [signature]

SINUSOIDAL



QA Form Approval [initials]

W–784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

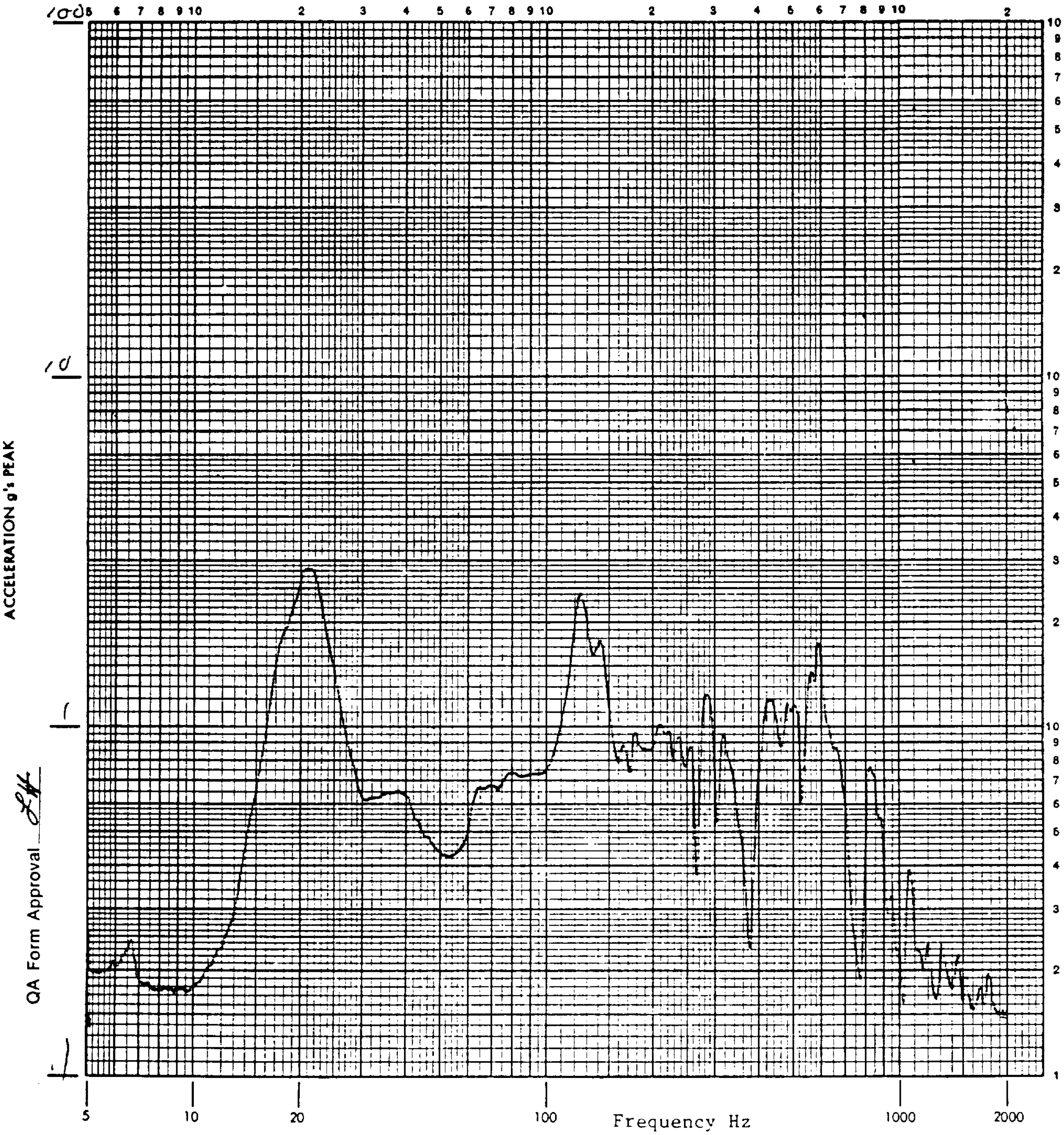
CUSTOMER MORTON THIOKOL Job No. 53976 Date 3-31-89

Specimen T-M-U. Axis of Test TANG

Accel. No. 4 Control ( ) Response (X) Full Scale 100 g

Operator [signature] Engineer CCL

SINUSOIDAL



QA Form Approval LH

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

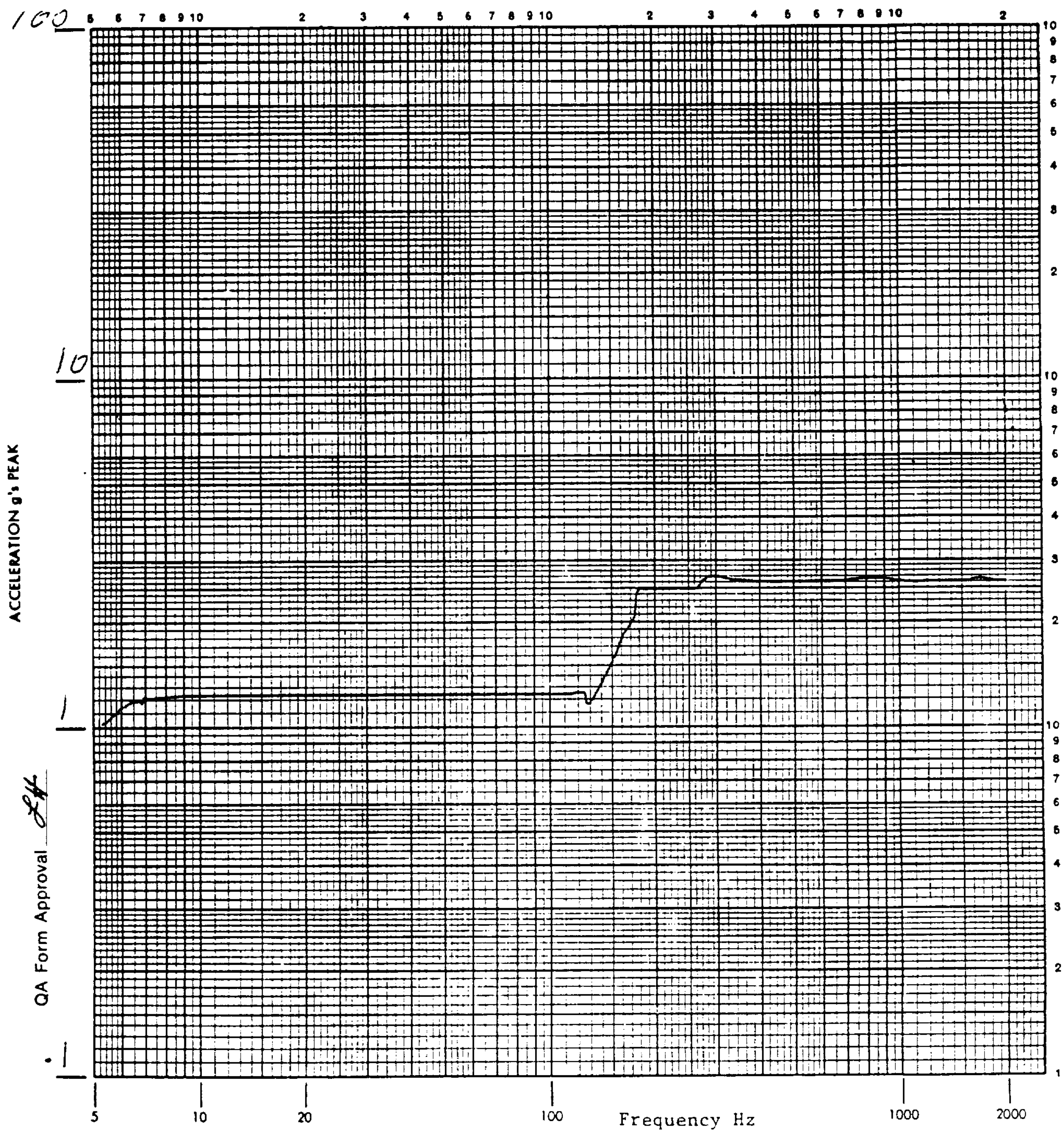
CUSTOMER MORTON THIOKOL Job No. 53976 Date 3-31-89

Specimen T. M U. Axis of Test TANG

Accel. No. 1 Control (X) Response ( ) Full Scale 100 g

Operator [illegible] Engineer CC LEE

SINUSOIDAL



QA Form Approval [illegible]

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

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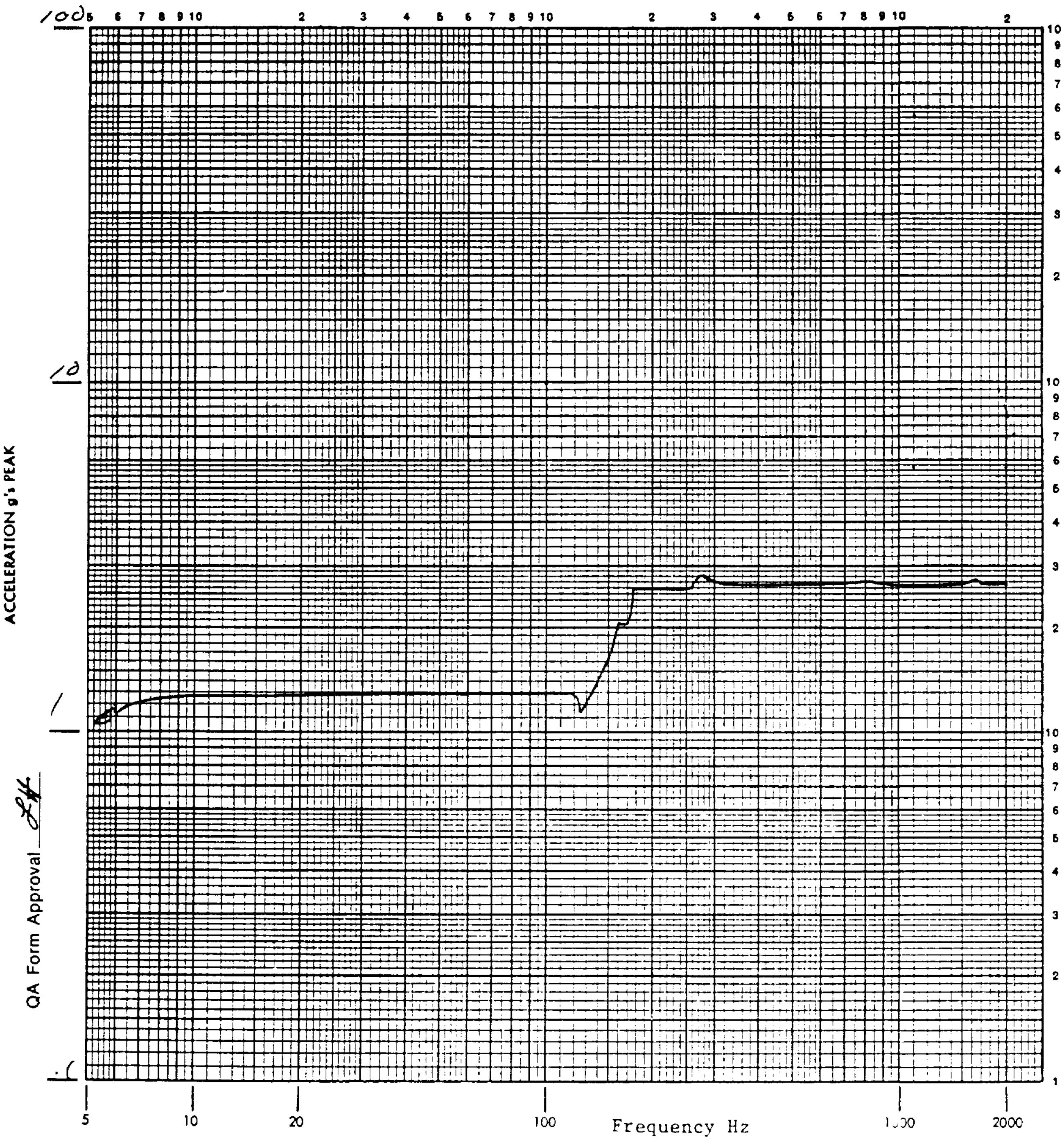
CUSTOMER MORTON T Job No. 53976 Date 4-3-84

Specimen T.M.J. UNIT #1 AMB Axis of Test TANG

Accel. No. 1 Control (X) Response ( ) Full Scale 100 g

Operator [signature] Engineer CC[signature]

SINUSOIDAL



QA Form Approval [signature]

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

Page No. 32

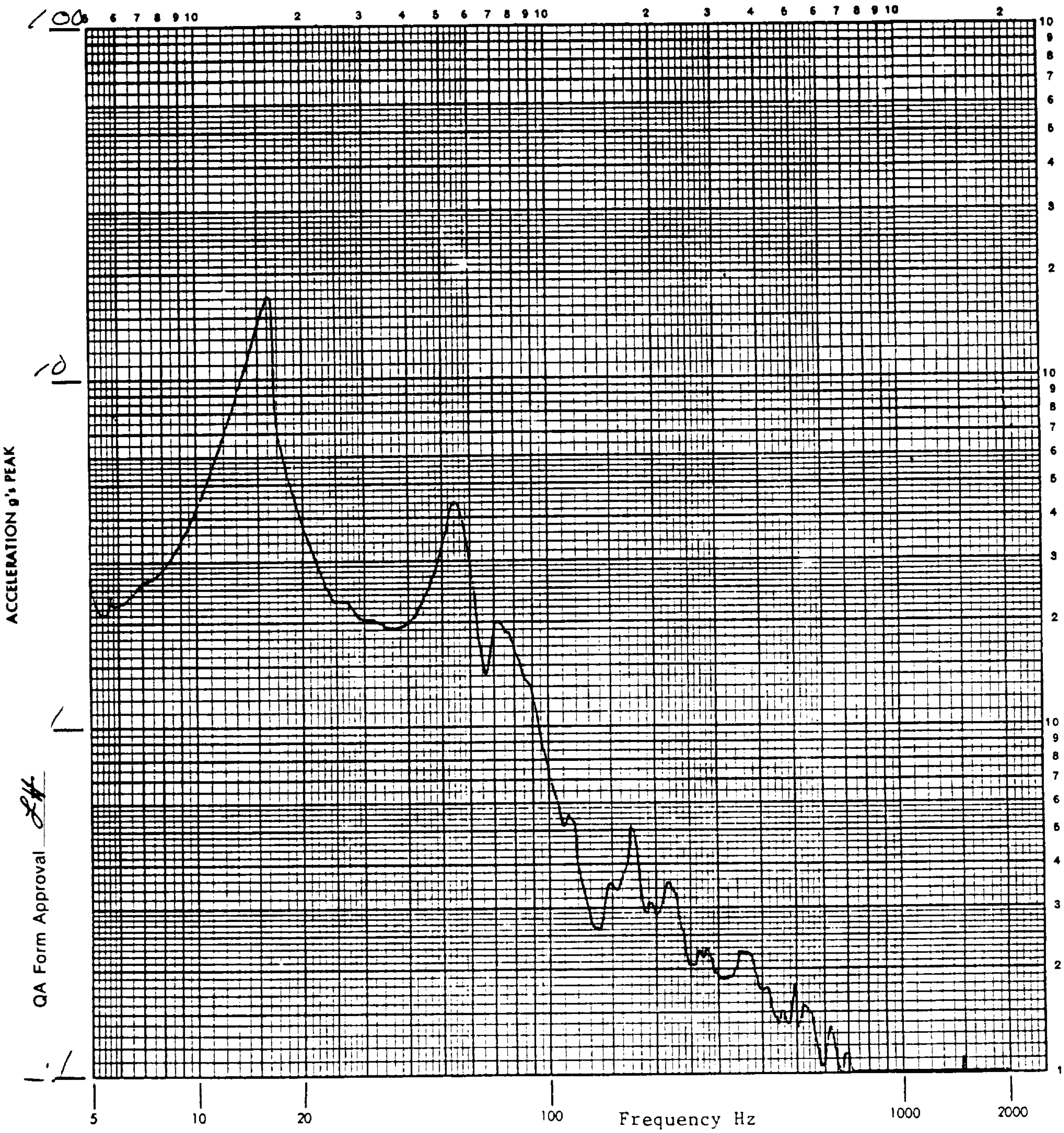
CUSTOMER MTI Job No. 53976 Date 4-3-84

Specimen TMJ UNIT #1 AMB Axis of Test TANG

Accel. No. 3 Control ( ) Response (X) Full Scale 100 g

Operator [illegible] Engineer CCL

SINUSOIDAL



W–784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

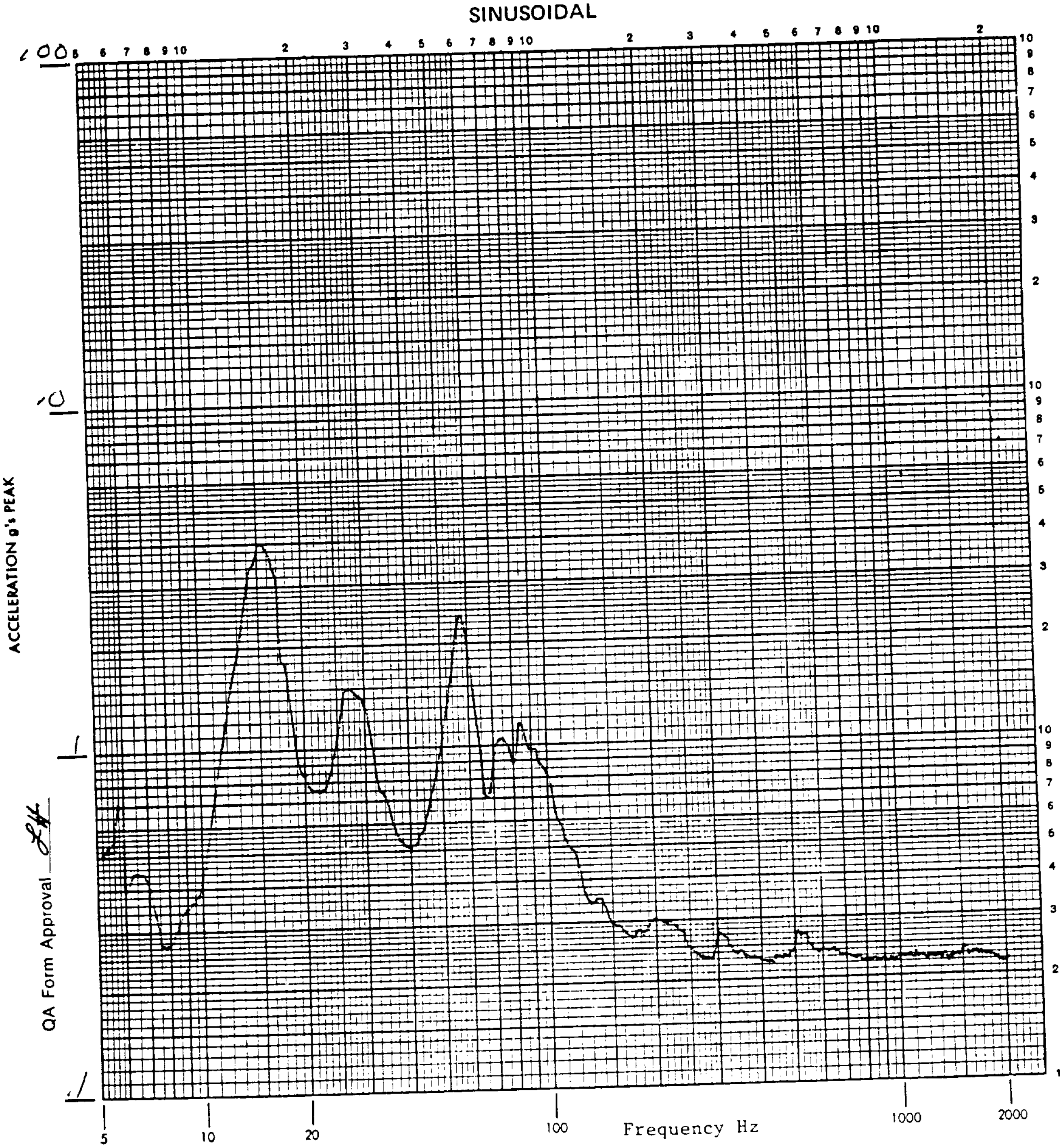
CUSTOMER MTI Job No. 53976 Date 4-3-89

Specimen TMU Axis of Test TANG

Accel. No. 2 Control ( ) Response (X) Full Scale 100 g

Operator [illegible signature] Engineer CC[illegible]

SINUSOIDAL



QA Form Approval [illegible initials]

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

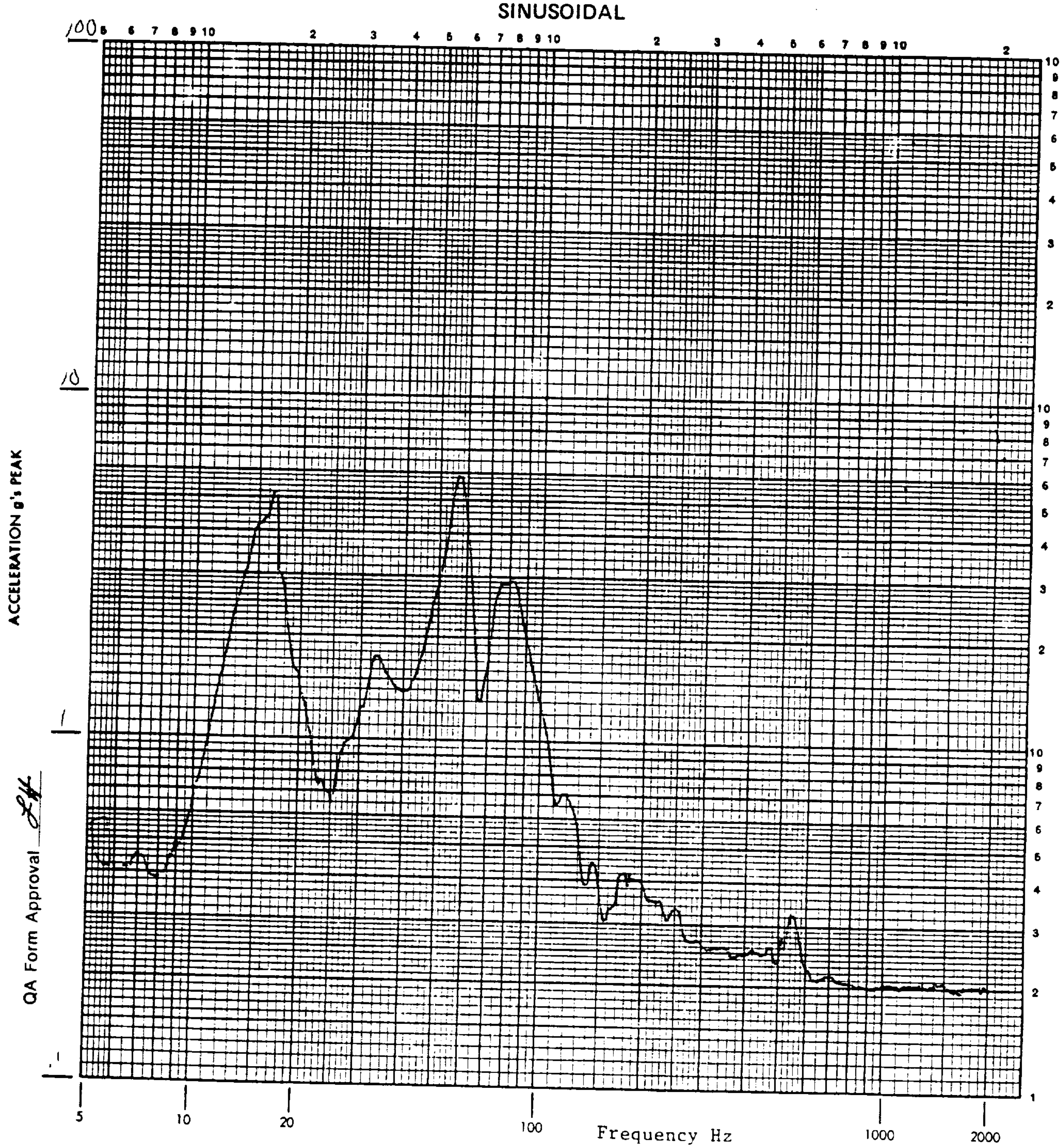
CUSTOMER MTI Job No. 53976 Date 3 4-3-89

Specimen TMU UNIT #1 AMB Axis of Test TANG

Accel. No. 4 (VERT) Control ( ) Response (✱) Full Scale 100 g

Operator M [illegible] Engineer CC [illegible]

SINUSOIDAL



QA Form Approval [illegible]

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

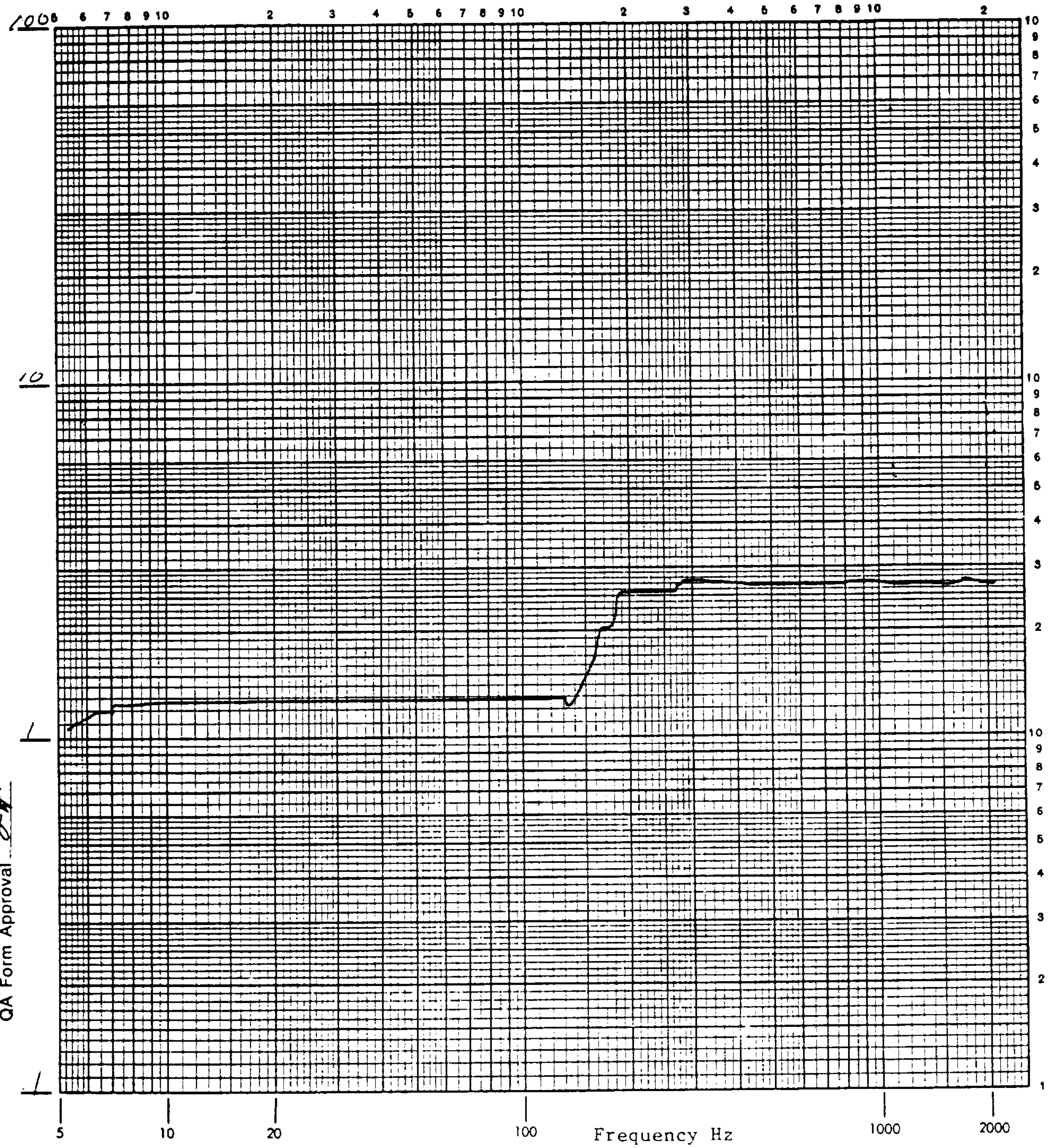
CUSTOMER MTI Job No. 53976 Date 4-4-89

Specimen TMU UNIT #1 +163°F Axis of Test TANG

Accel. No. 1 Control (X) Response ( ) Full Scale 100 g

Operator [signature] Engineer CC[signature]

SINUSOIDAL



QA Form Approval [initials]

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

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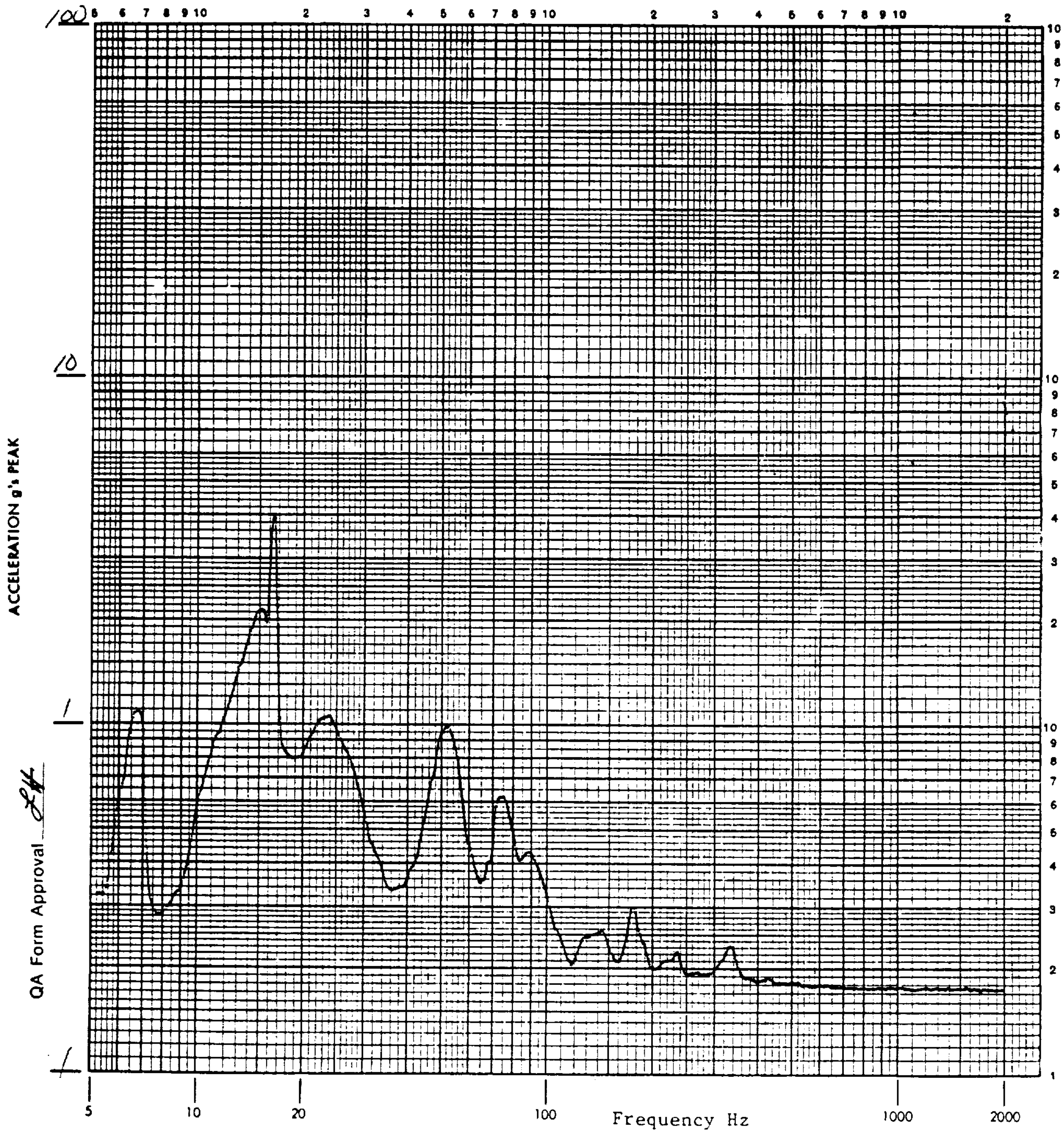
CUSTOMER MTI Job No. 53976 Date 4-4-84

Specimen TMU Axis of Test TANG

Accel. No. 2 Control ( ) Response (✱) Full Scale 100 g

Operator [signature] Engineer [signature]

SINUSOIDAL



QA Form Approval [signature]

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 4-4-89

Specimen TMU UNIT #1 +163°F Axis of Test TANG

Accel. No. 3 Control ( ) Response (✗) Full Scale 100 g

Operator [signature] Engineer [signature]

SINUSOIDAL

QA Form Approval [initials]

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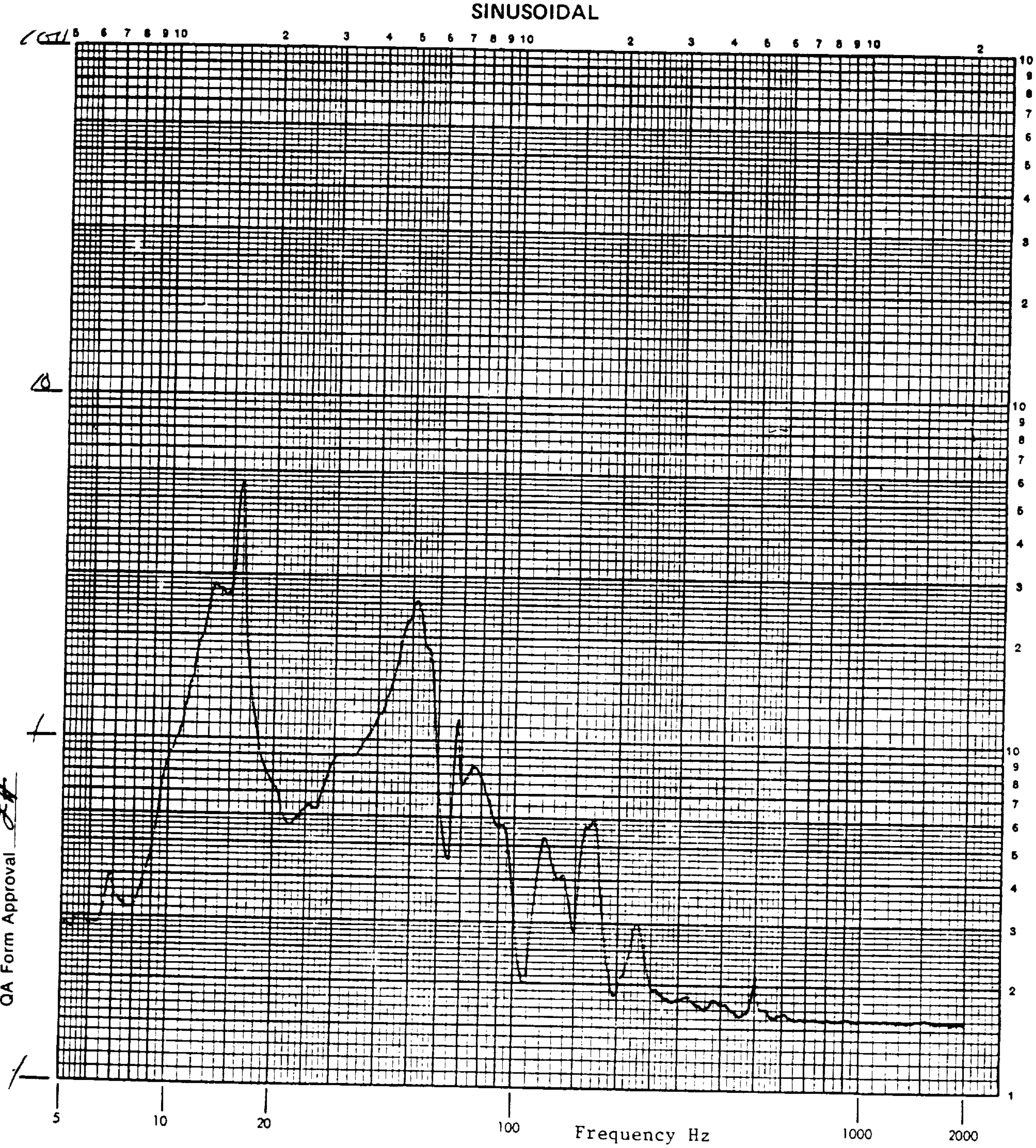
CUSTOMER MTI Job No. 53976 Date 4-4-84

Specimen TMU VERT Axis of Test TANG

Accel. No. 4 Control ( ) Response (*) Full Scale 100 g

Operator [signature] Engineer [signature]

SINUSOIDAL



QA Form Approval

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

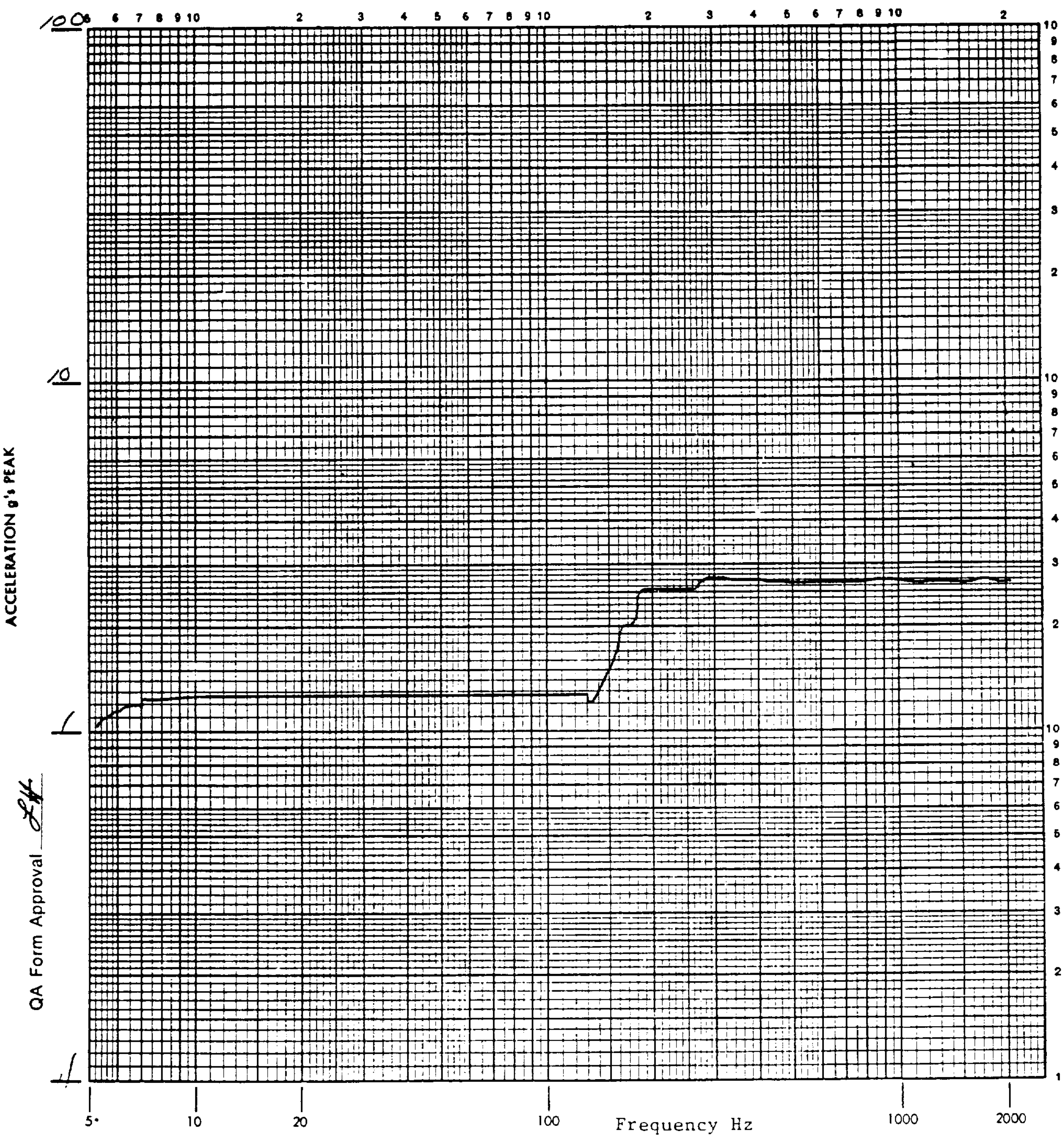
CUSTOMER MT I Job No. 53976 Date 4-4-84

Specimen T.M.U. Axis of Test TANG

Accel. No. 1 Control (*) Response ( ) Full Scale 100 g

Operator [illegible] Engineer [illegible]

SINUSOIDAL



QA Form Approval [illegible]

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

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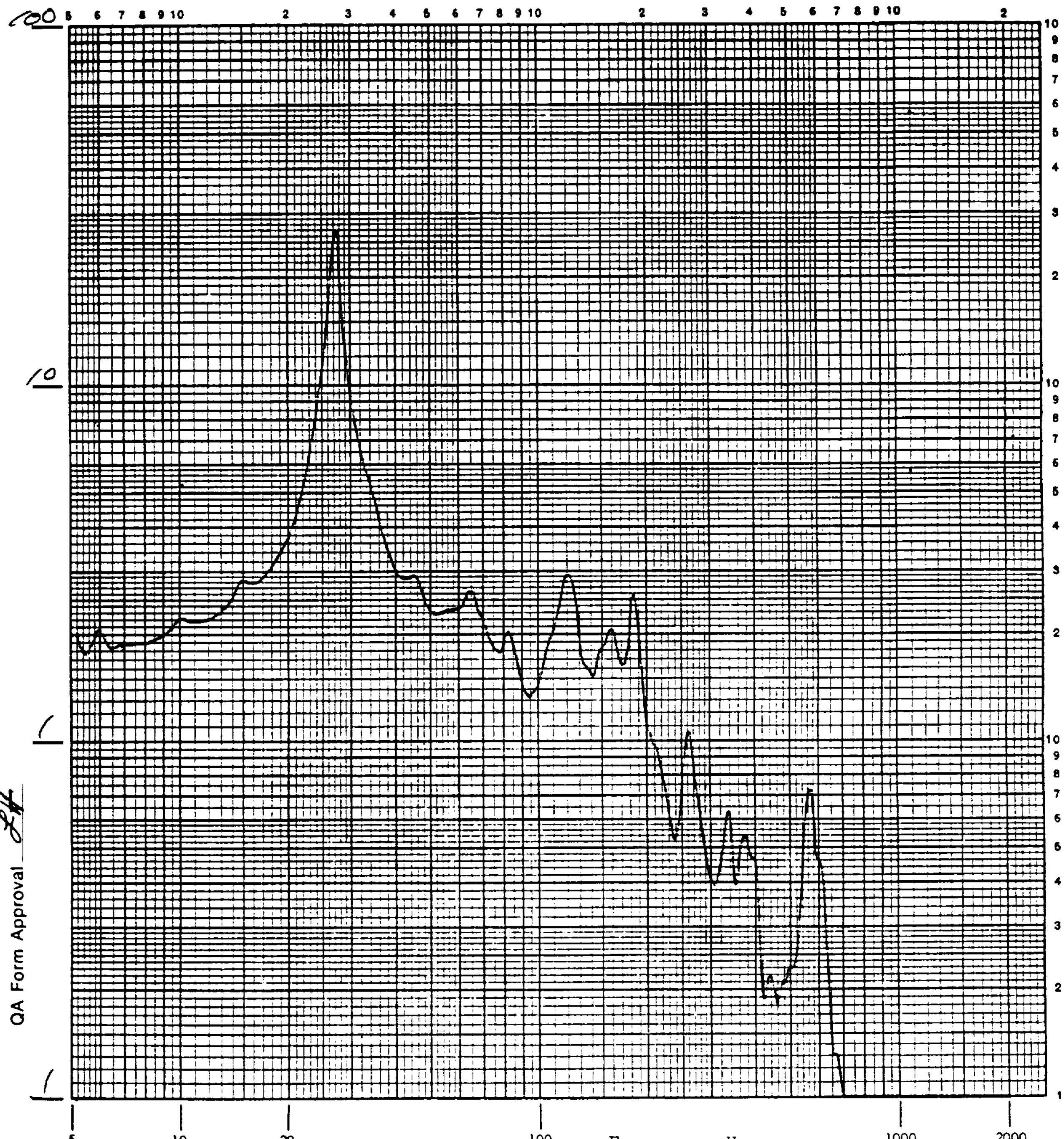
CUSTOMER MT 1 Job No. 53976 Date 4-4-89

Specimen T.MU Axis of Test TANG

Accel. No. 3 Control ( ) Response (X) Full Scale 100 g

Operator [signature] Engineer [signature]

SINUSOIDAL



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 4-4-89

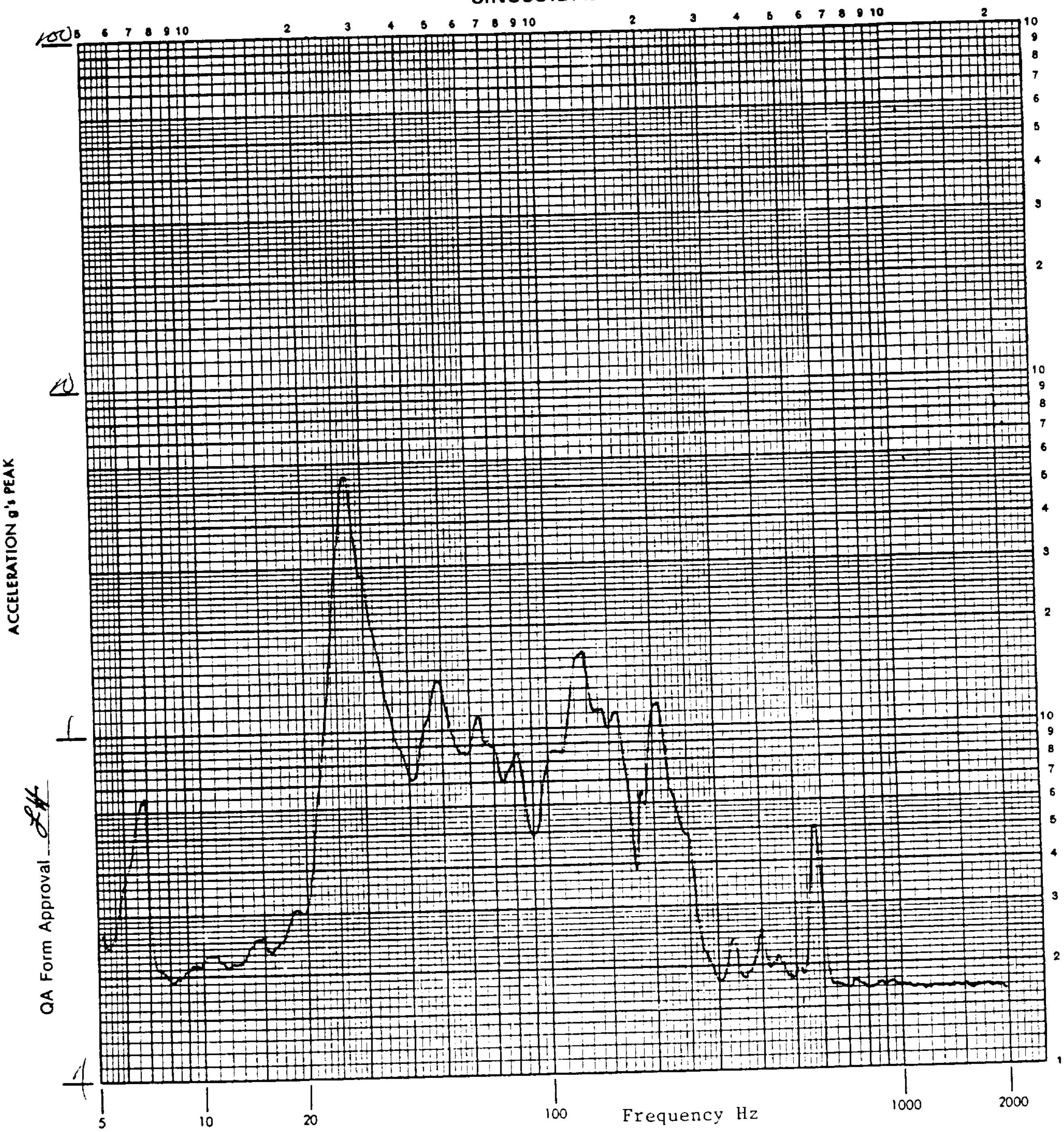
Specimen TMU UNIT #2 Axis of Test TANG

Accel. No. 2 Control ( ) Response (X) Full Scale 100 g

Operator [signature] Engineer CC[signature]

AMB 70°F ± 10°

SINUSOIDAL



QA Form Approval [initials]

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

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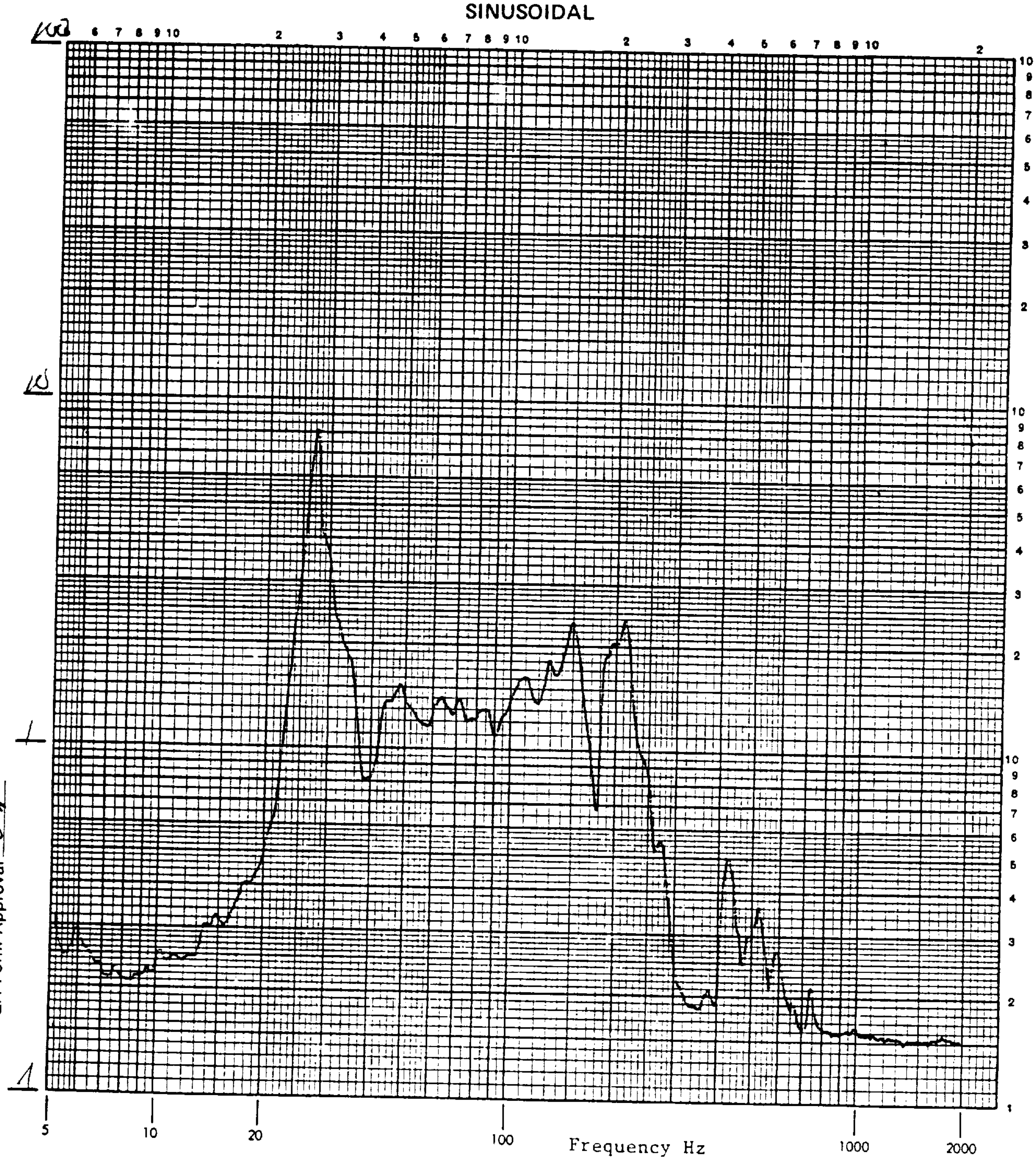
CUSTOMER MTI. Job No. 53976 Date 4-4-88

Specimen T.M.U. Axis of Test TANG

Accel. No. 4 Control ( ) Response (X) Full Scale 100 g

Operator [signature] Engineer [signature]

SINUSOIDAL



QA Form Approval

W-784 S

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

TEST TITLE SHOCK

CUSTOMER M.T.I. Job No. 53976

Specimen T.M.U. Date Started 3-25-85

Part No. PROTYPE Serial No. UNITS I & II Date Comp. 4-5-89

Spec. MTI TP CTP-0097 Par. 8 Photo YES Amb. Temp. 70°F ± 10°

THE TEST SPECIMENS WERE MOUNTED TO SHOCK MOUNTS PROVIDED BY CUSTOMER THEN ATTACHED TO A VIBRATION FIXTURE (SLIP PLATE) WHICH IN TURN WAS SECURED TO AN ELECTRO DYNAMIC EXCITER TEMPRETURE CONDITIONED FOR A MINIMUM OF FOUR HOURS AND SUBJECTED TO THE FOLLOWING TEST LEVELS

SHOCK LEVELS :

20 - 160 HZ		+6 DB/OCT
160 - 340 HZ		10 G PEAK
340 - 400 HZ		-6 DB/OCT

TEMPRETURE CRITERIA TOL

	−20°F	± 10°
AMBIENT	+70°F	± 10°
	+163°F	± 10°

Tested by [signature]

Engineer [signature]

W614A-82 QA Form Approval [initials]

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET

TEST TITLE TRANSPORTATON SHOCK
DATE 3-6-89
Customer MTI
Job No. 53976
Specimen T.M.U.
Technician MO
Part No.
Serial No. UNIT 1-2
Engineer C.C. LEE

Date	Time	Axis	Test	Comments
1989	NOTED	NOTED	TEMPRETURE	
3-3	1450	LONG	-20°F	SHOCK #1 UNIT #1
	1451			#2
	1452			#3
	1453			#4
	1454			#5
3-3	1612			SHOCK #1 UNIT #2
	1613			#2
	1614			#3
	1615			#4
	1616			#5
3-6	1025		+70 AMBIENT	SHOCK #1 UNIT #2
	1027			#2
	1028			#3
	1029			#4
	1031			#5
3-6	1105			SHOCK #1 UNIT #1
	1107			#2
	1109			#3
	1110			#4
	1112			#5

W-985 QC Form Approval JS Sheet___of___

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date ~~2-25~~-85 3-3

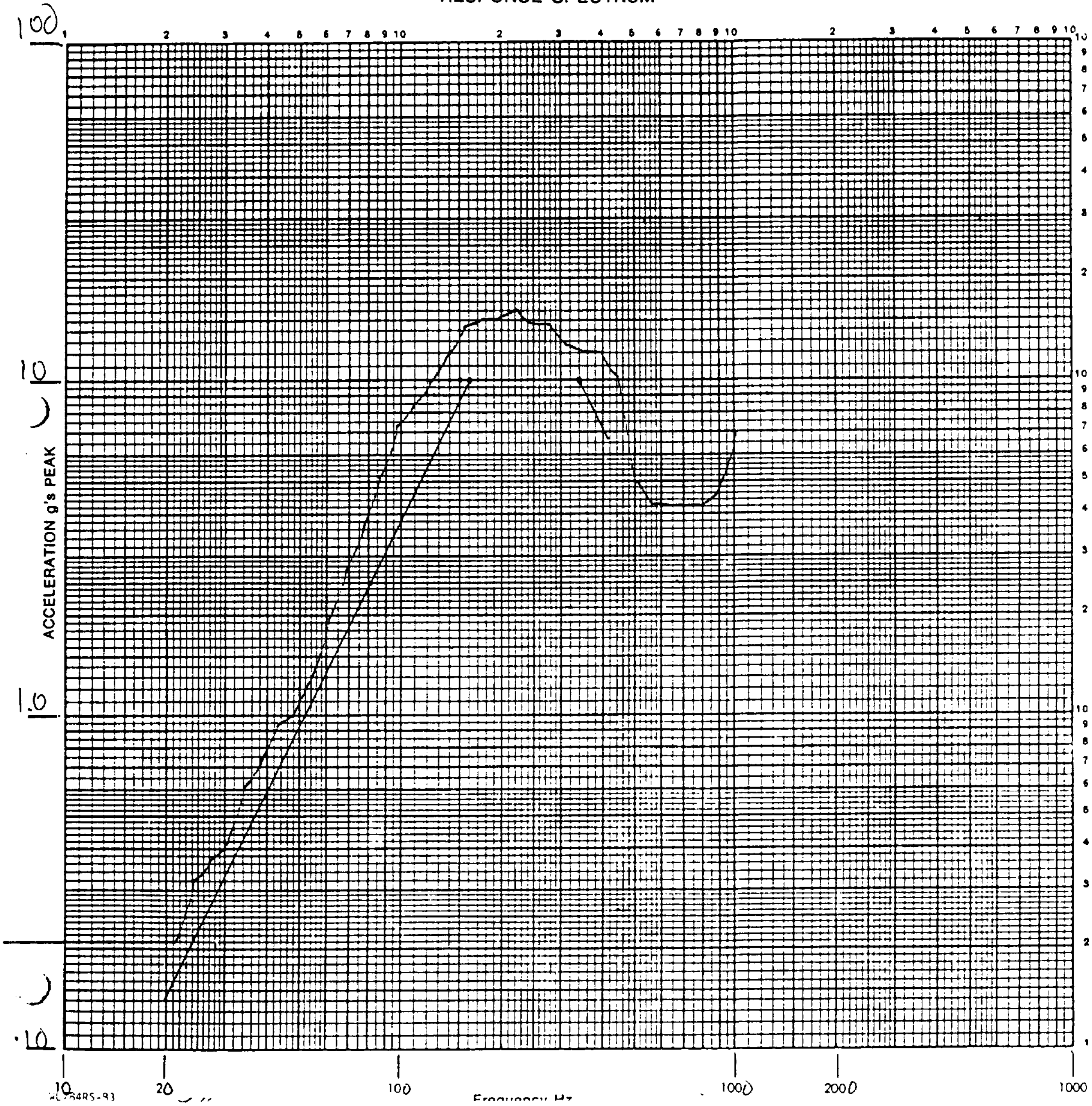
Specimen TRANSPORTATION UNIT Axis of Test LONG.

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. CAL NO. 1

Operator Engineer C C. -20°F

RESPONSE SPECTRUM



WL 84RS-93

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

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CUSTOMER MTI Job No. 53976 Date 3-3-85

Specimen TRANSPORTATION UNIT Axis of Test LONG.

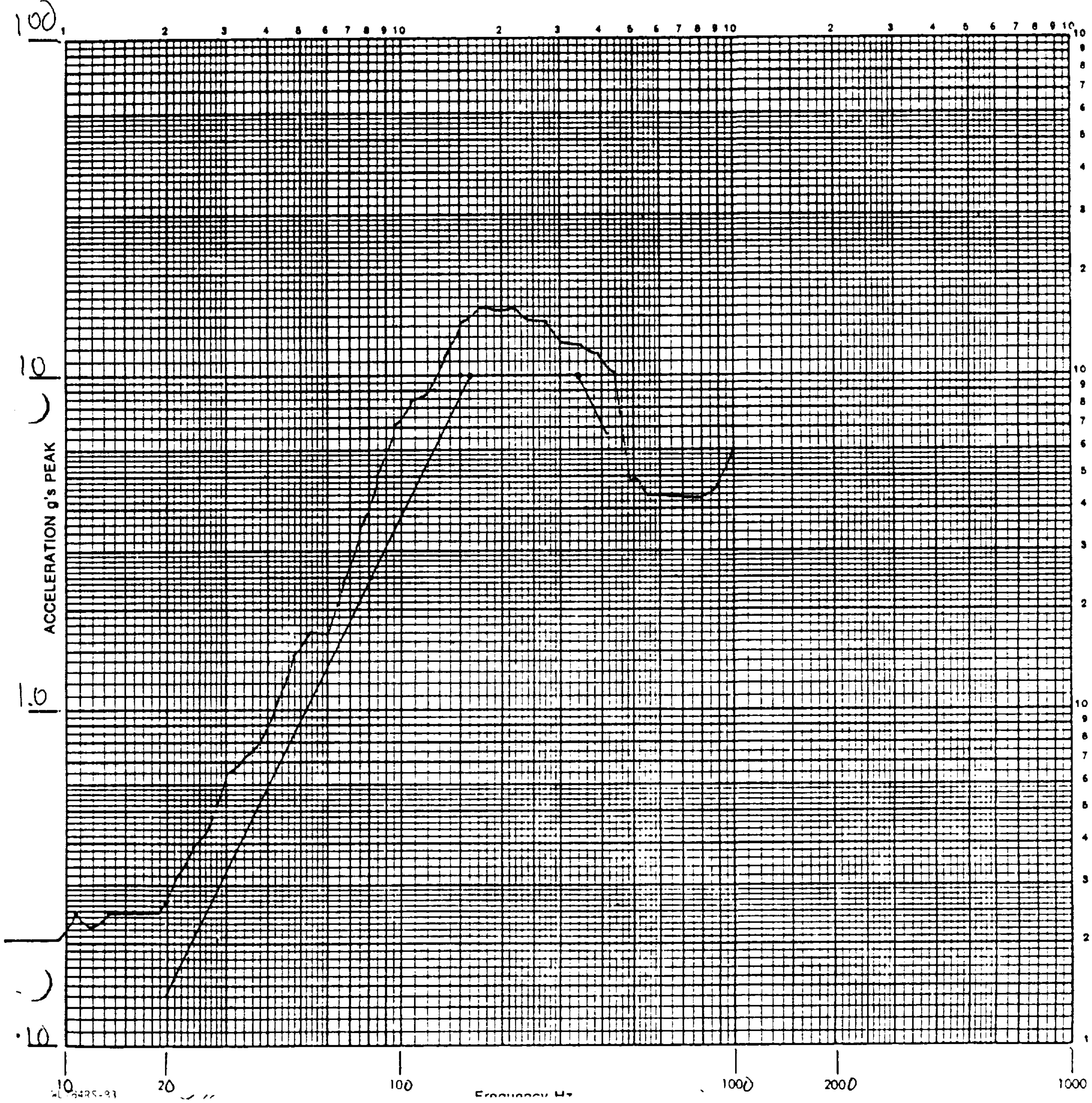
Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. CAL NO.2

Operator M Cl Engineer CC

-20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date ~~2-25~~ 3-3-85

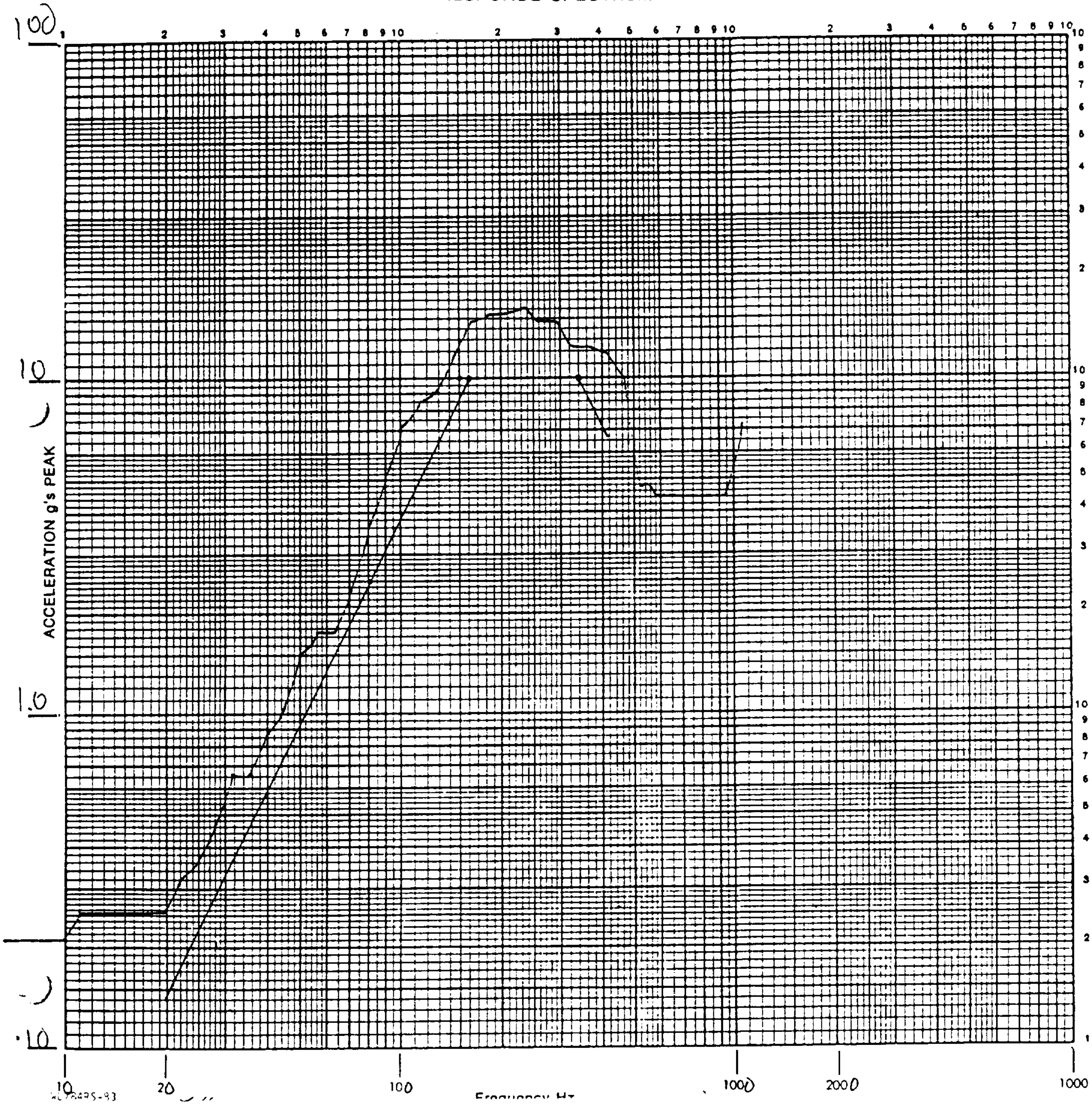
Specimen TRANSPORTATION UNIT #1 Axis of Test LONG

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #1

Operator MCr Engineer CCh -20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

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CUSTOMER MTI Job No. 53976 Date ~~2-25~~ 3-3-85

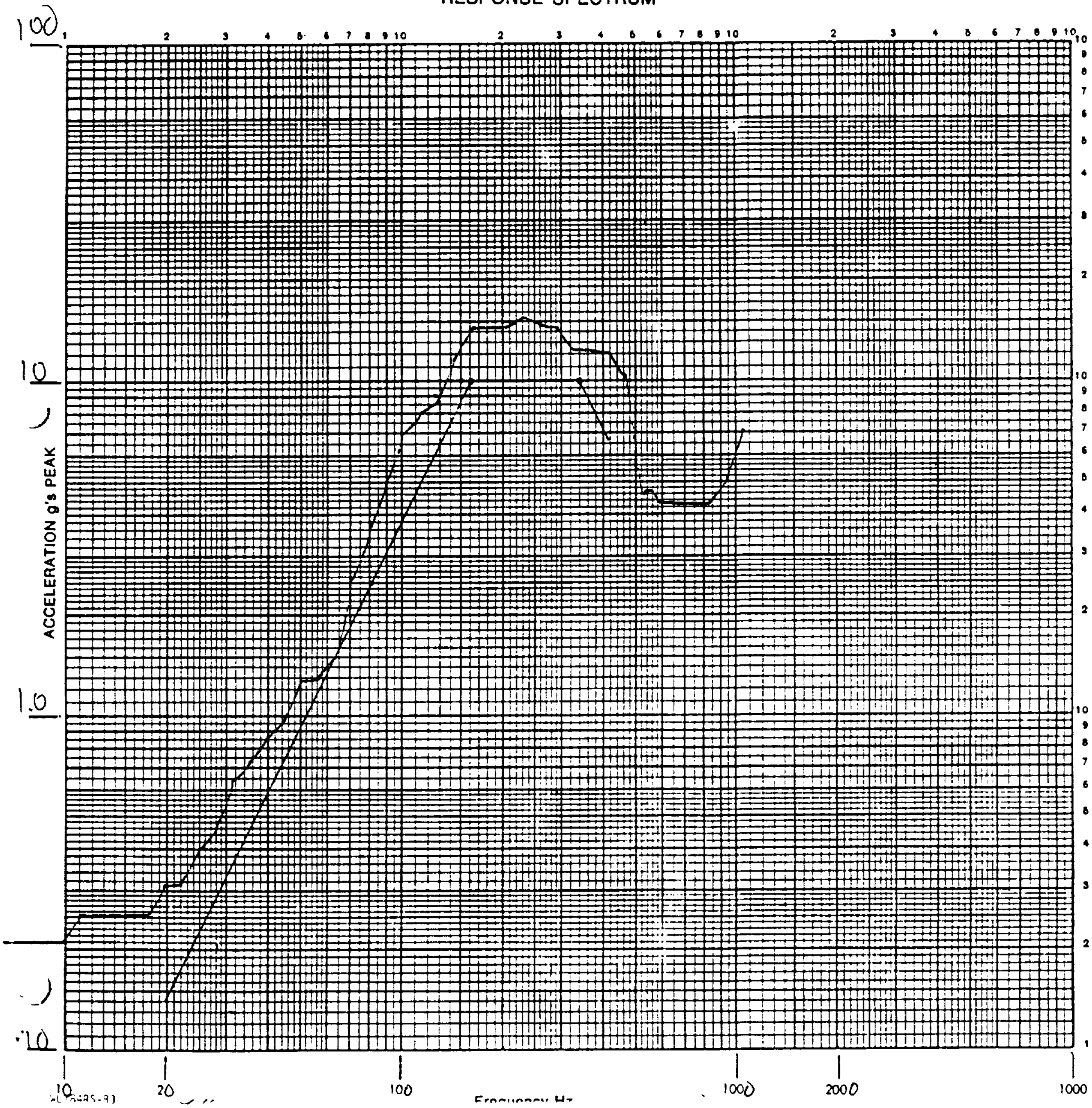
Specimen TRANSPORTATION UNIT #1 Axis of Test LONG

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #2

Operator [illegible] Engineer [illegible] -20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3-3-85

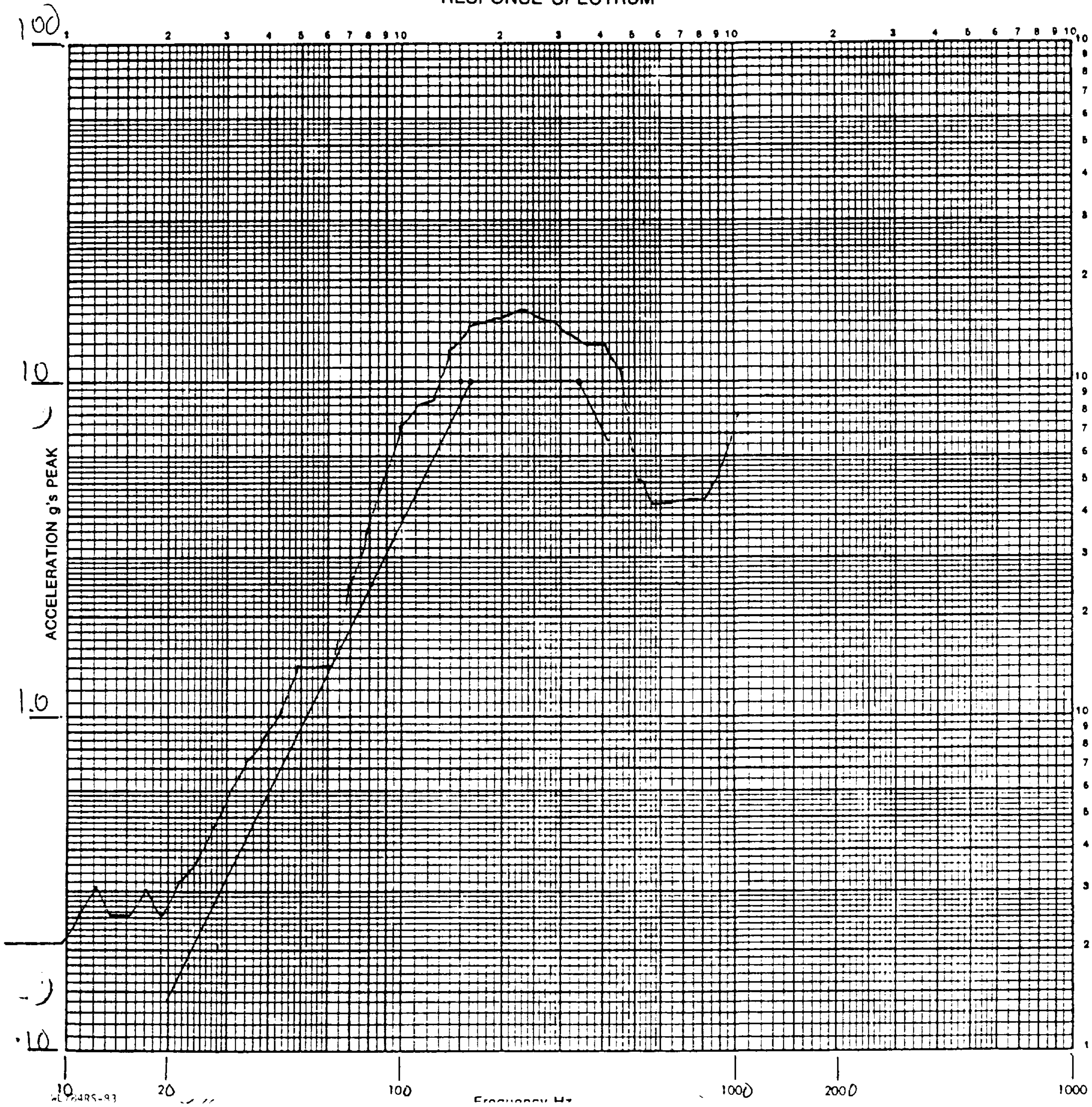
Specimen TRANSPORTATION UNIT #21 Axis of Test LONG

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #3

Operator MCa Engineer CC/ -20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3-3 ~~2-25~~-85

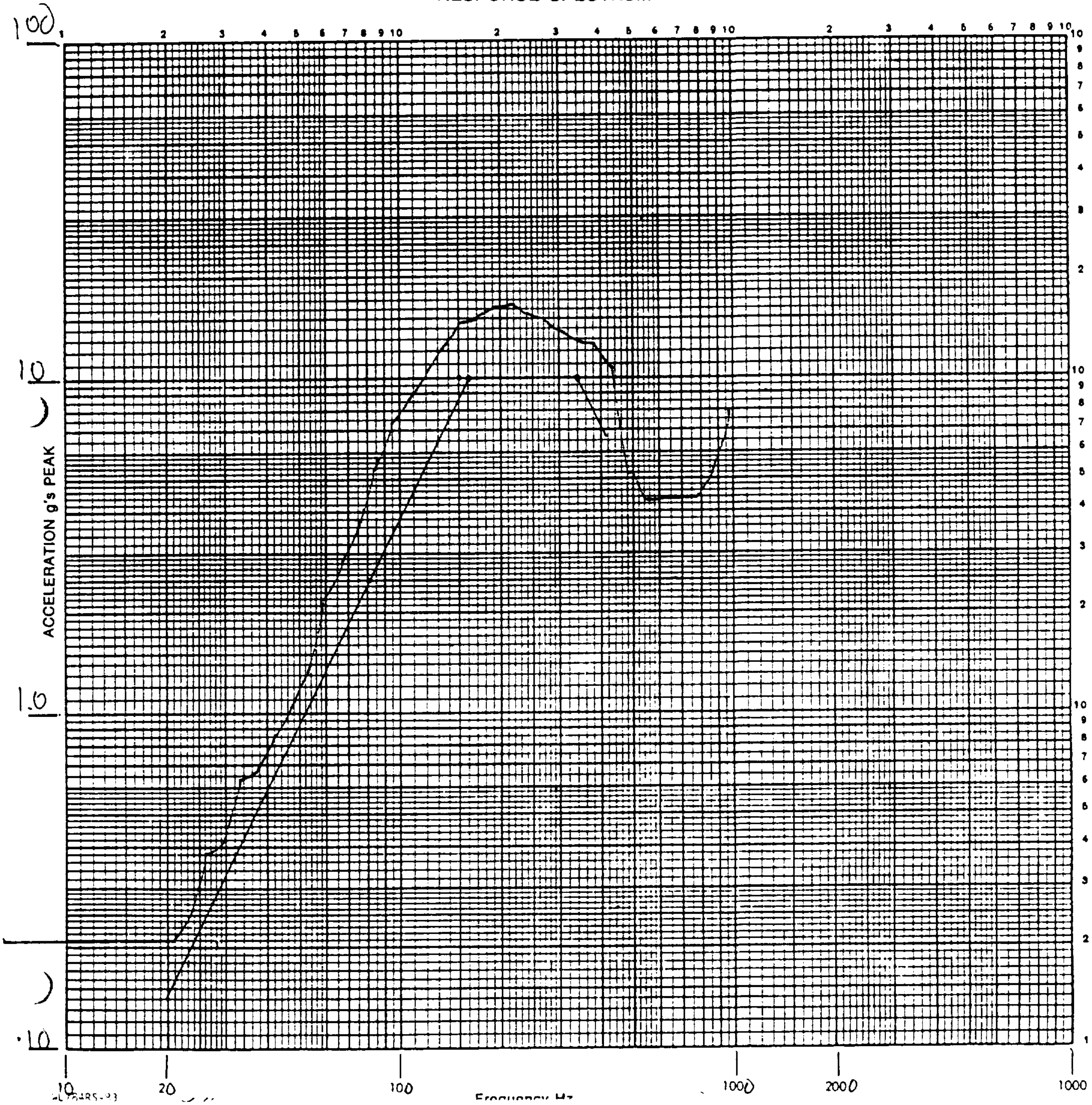
Specimen TRANSPORTATION UNIT #1 Axis of Test LONG

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #21

Operator MO Engineer C Ch -20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3-3-85

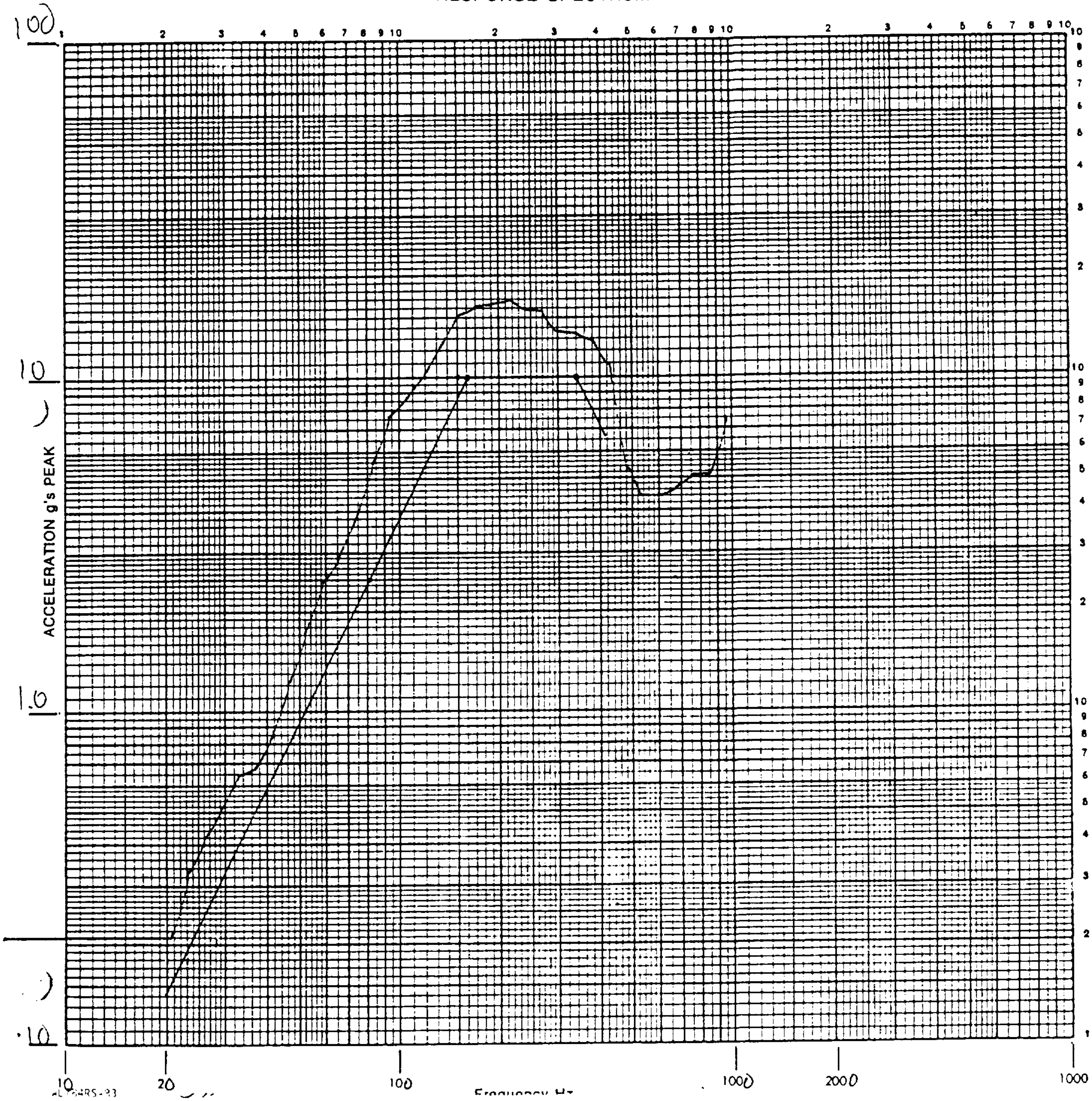
Specimen TRANSPORTATION UNIT #1 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #5

Operator MOL Engineer CC -20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

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CUSTOMER MTI Job No. 53976 Date ~~2-25-89~~ CCL 3-3

Specimen TRANSPORTATION UNIT #2 Axis of Test Long

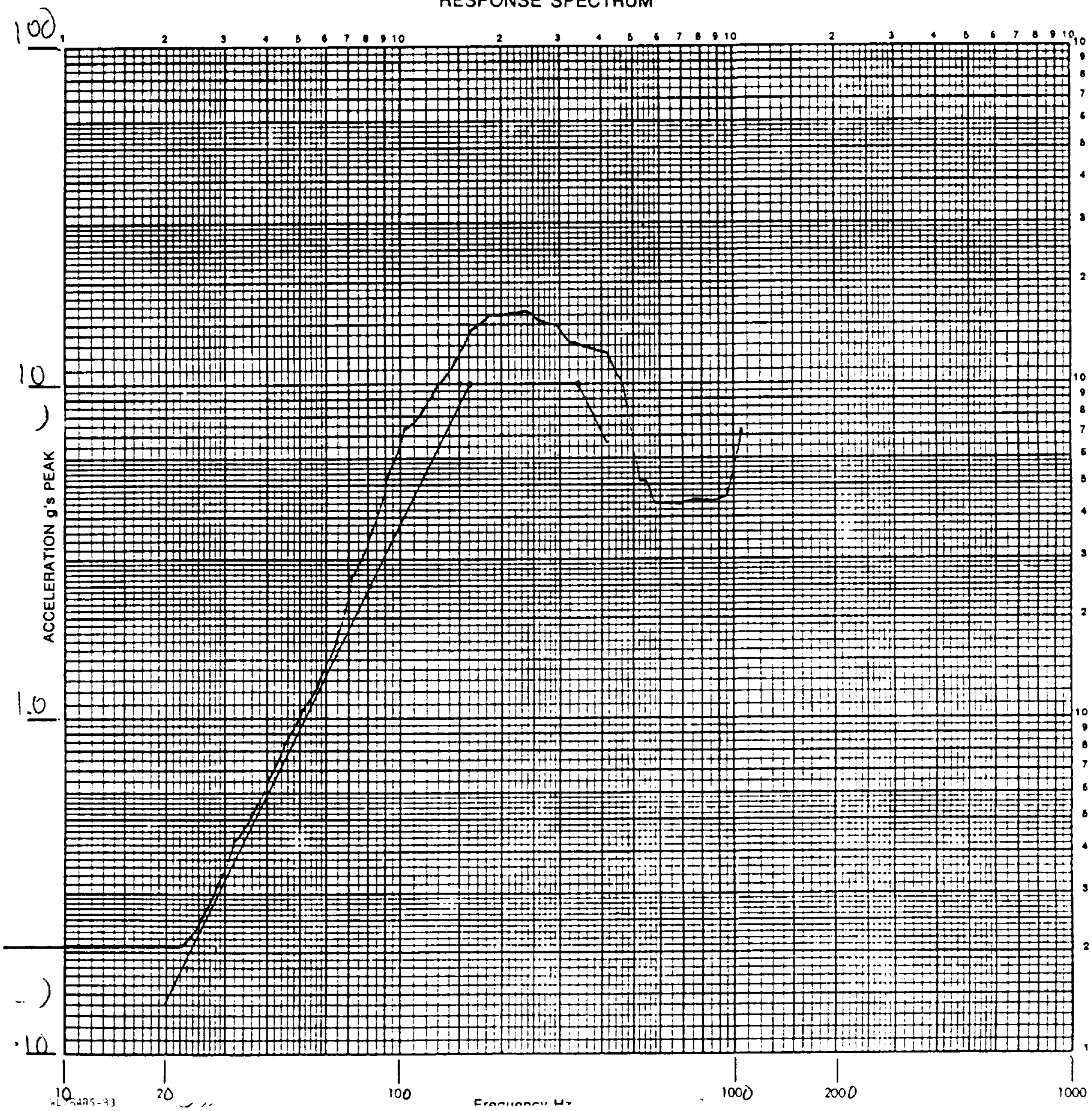
Accel. No. 1 Axis LONG Control (✓) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #1

Operator MA Engineer CC/L

-20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date ~~2-25-85~~ 3-3-85

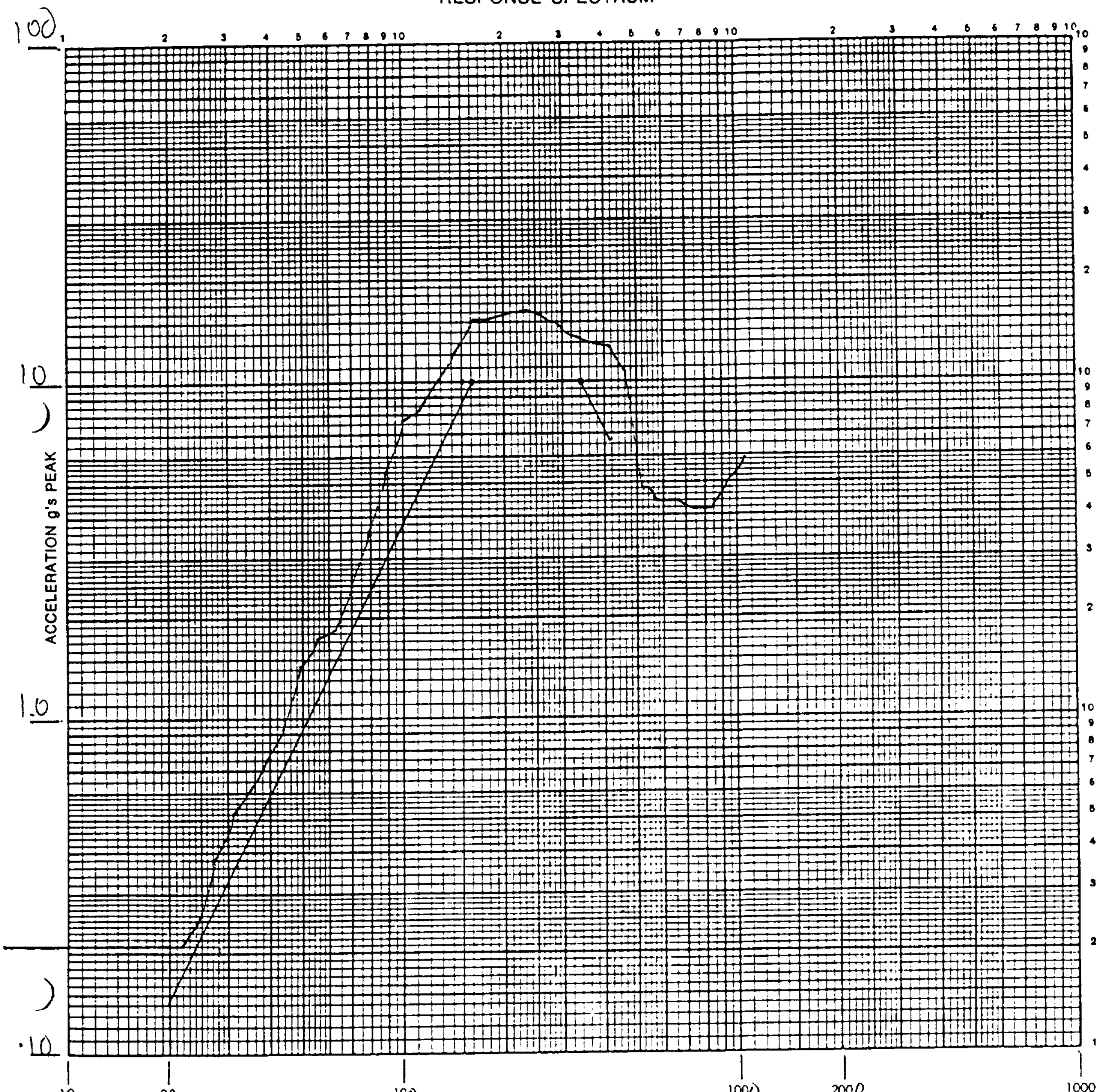
Specimen TRANSPORTATION UNIT #2 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #2

Operator Engineer -20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date ~~2-25-89~~ CCL 3-3

Specimen TRANSPORTATION UNIT #2 Axis of Test Long

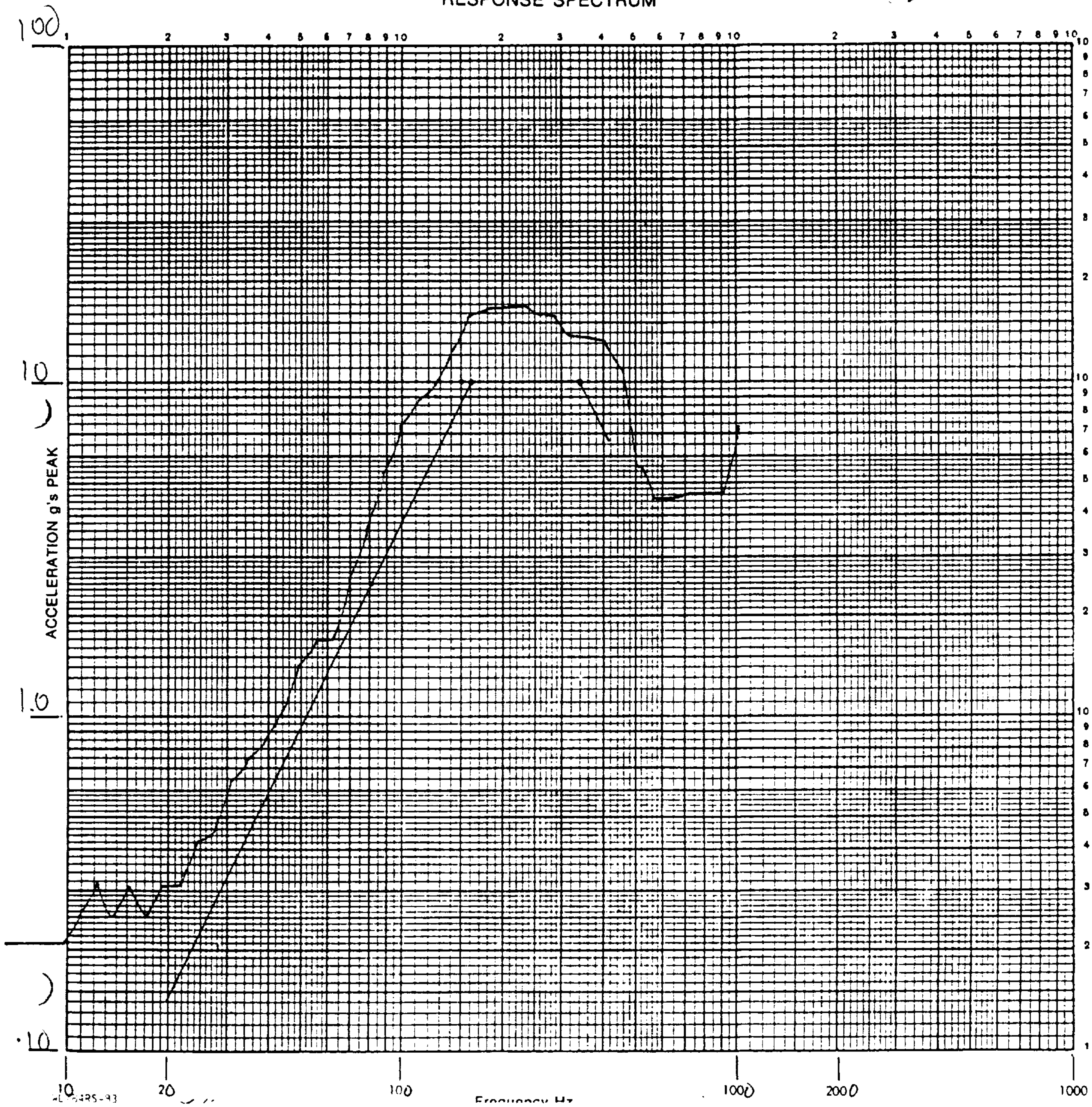
Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #3

Operator MC Engineer CCL

-20°F

RESPONSE SPECTRUM



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date ~~2-25-~~ 3-3-89

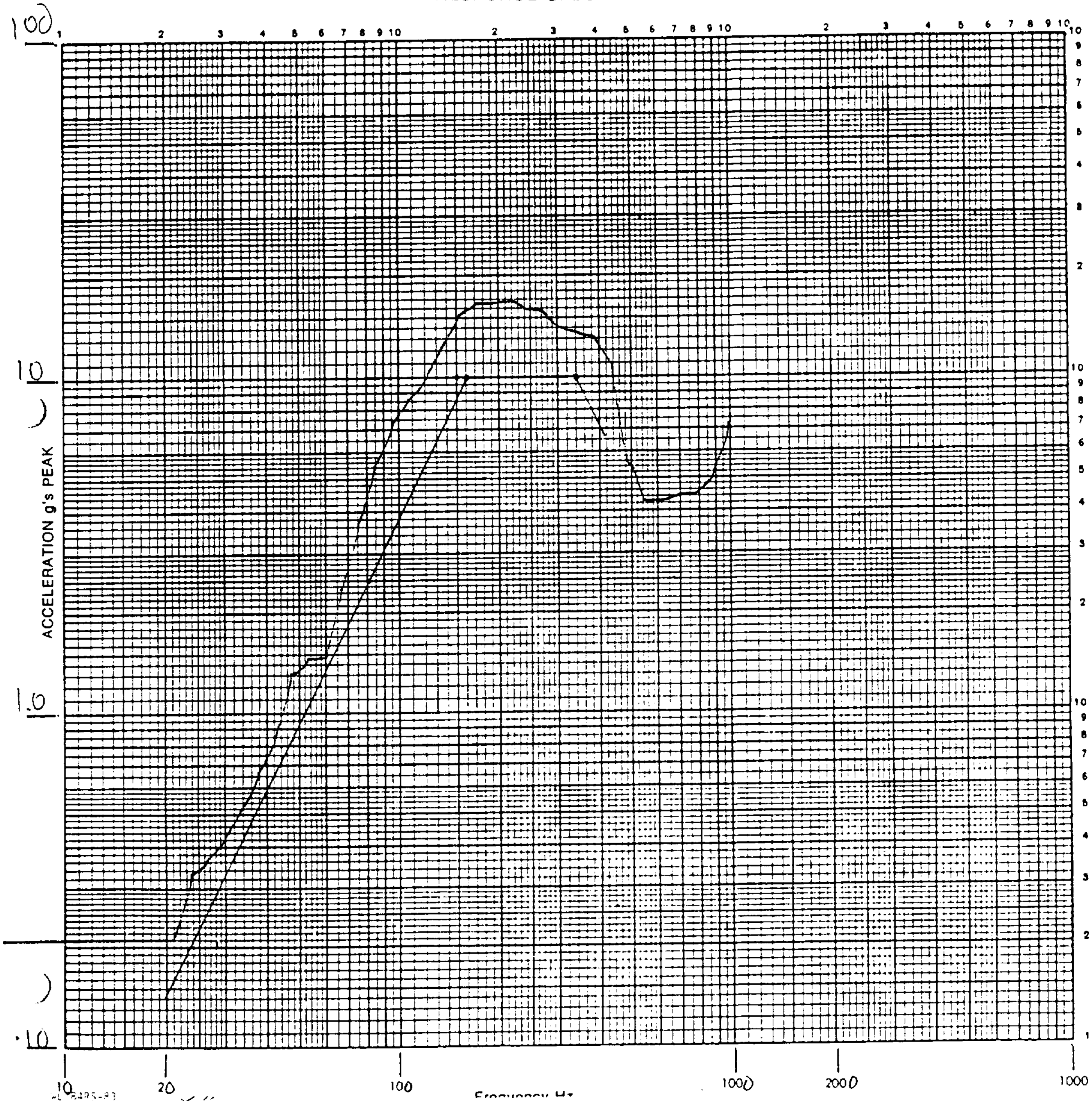
Specimen TRANSPORTATION UNIT #2 Axis of Test Long

Accel. No. 1 Axis LONG. Control (✓) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #4

Operator Engineer CC -20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date ~~2-25-89~~ 3-3 ccl-89

Specimen TRANSPORTATION UNIT #2 Axis of Test Long

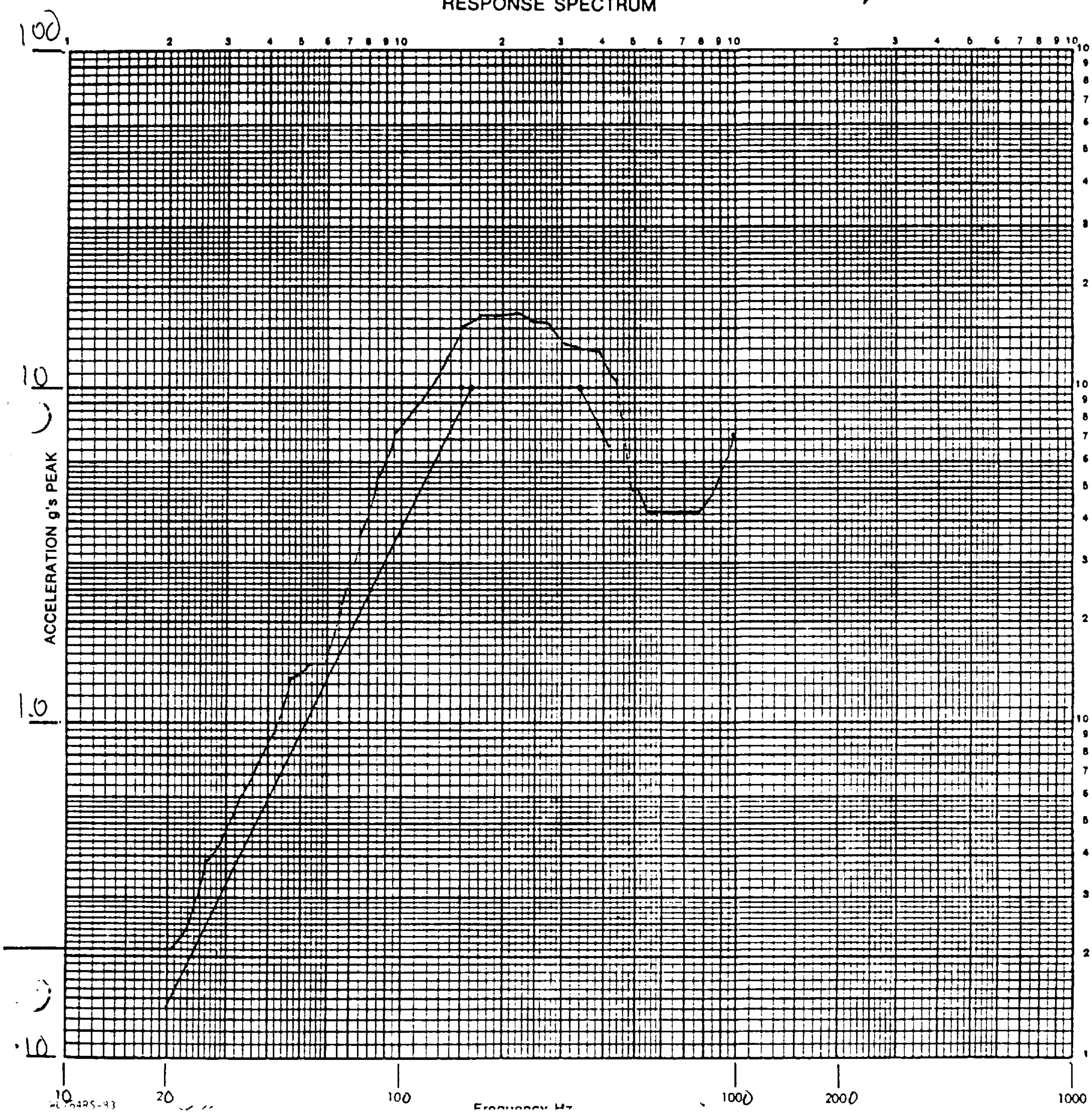
Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. #5

Operator MA Engineer CC Lm

-20°F

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date ~~2-24-85~~ 3-6 CCL

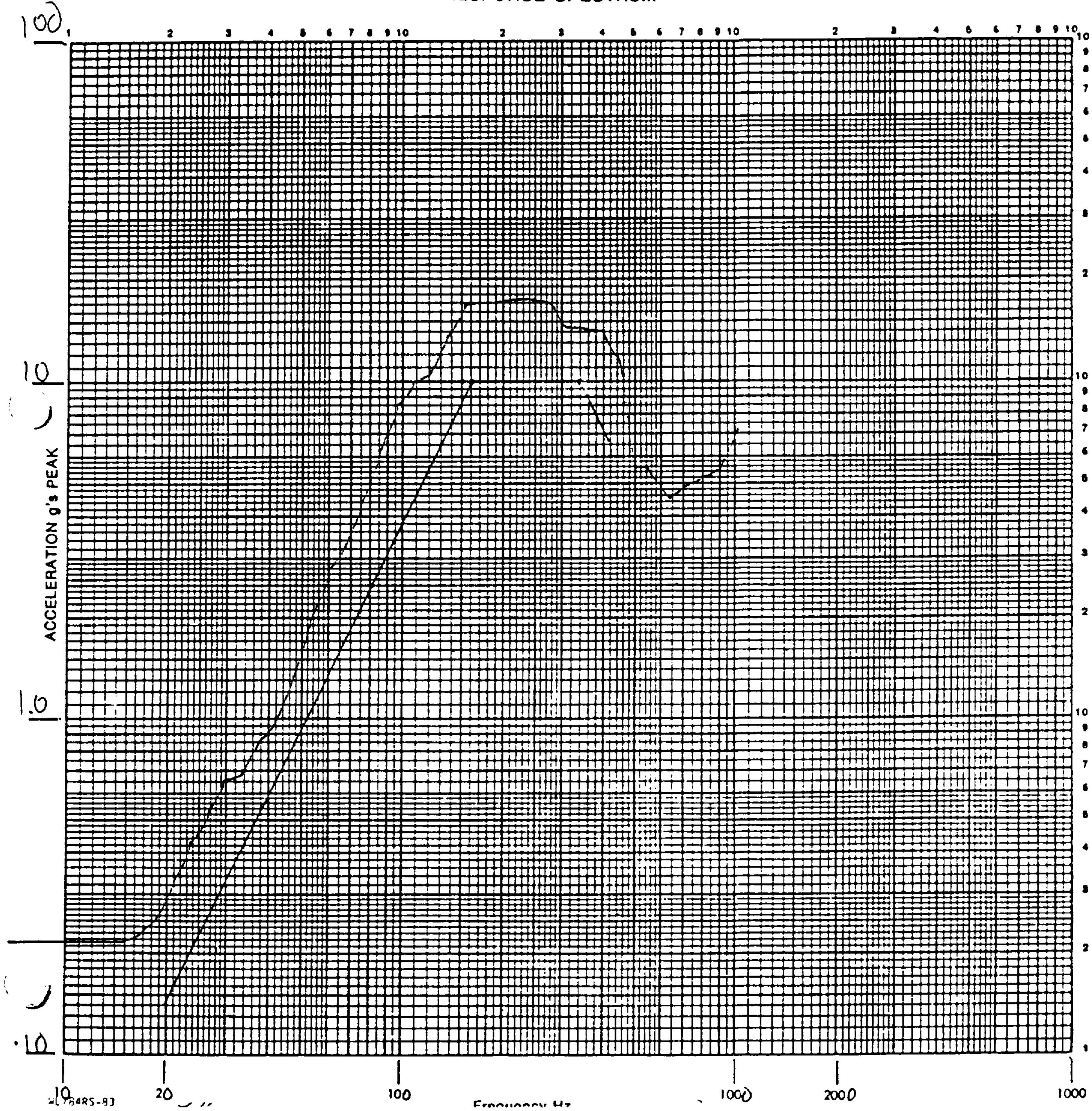
Specimen TRANSPORTATION UNIT #2 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. ~~X~~ 1 CCL

Operator MCh Engineer CCh AMB

RESPONSE SPECTRUM



WL 764RS-83

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3-6

CUSTOMER MTI Job No. 53976 Date 2-25-85

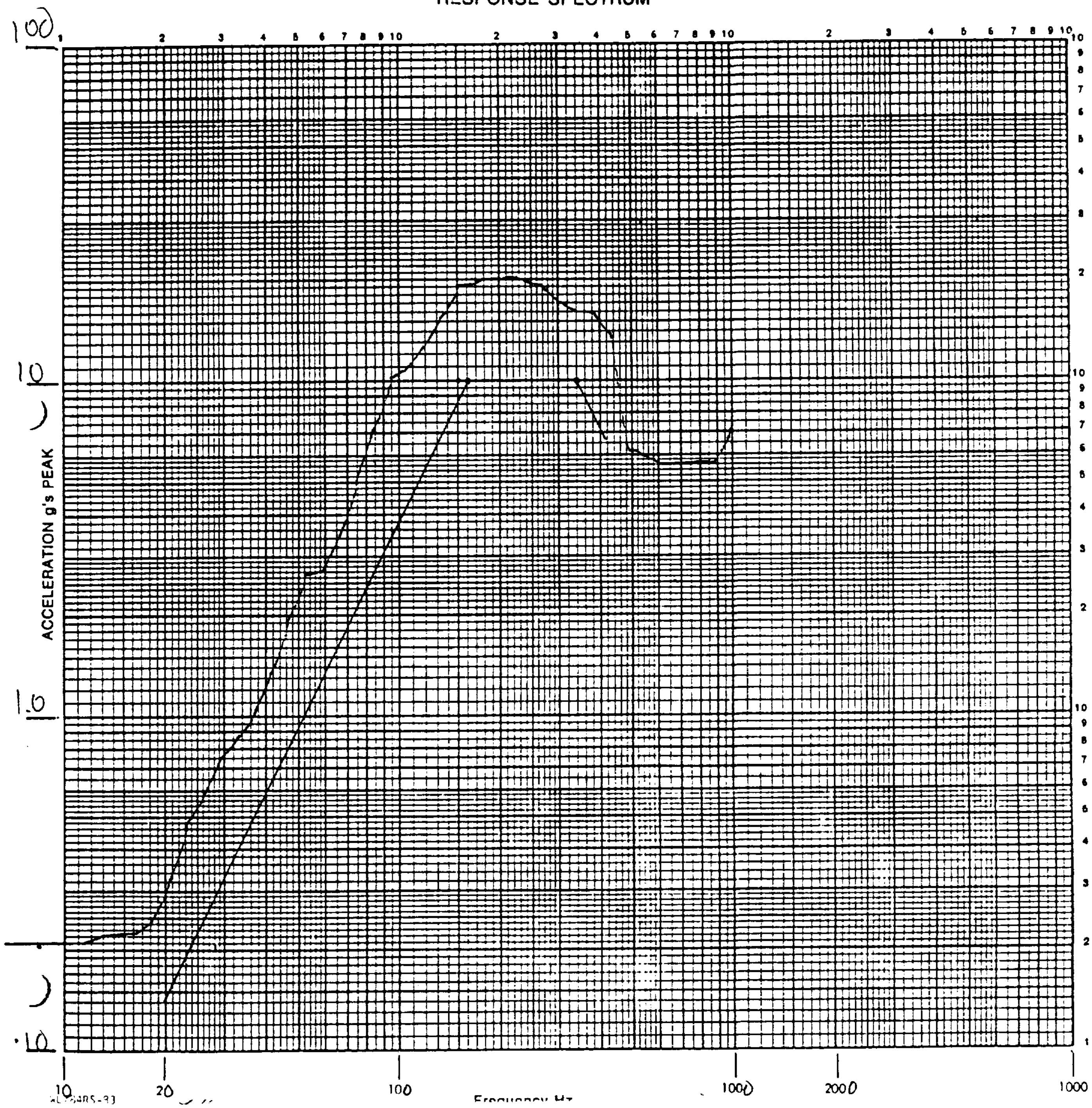
Specimen TRANSPORTATION UNIT #2 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 3.2

Operator MM Engineer CGh AMB

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

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CUSTOMER MTI Job No. 53976 Date ~~2-25-89~~ 3-6-89

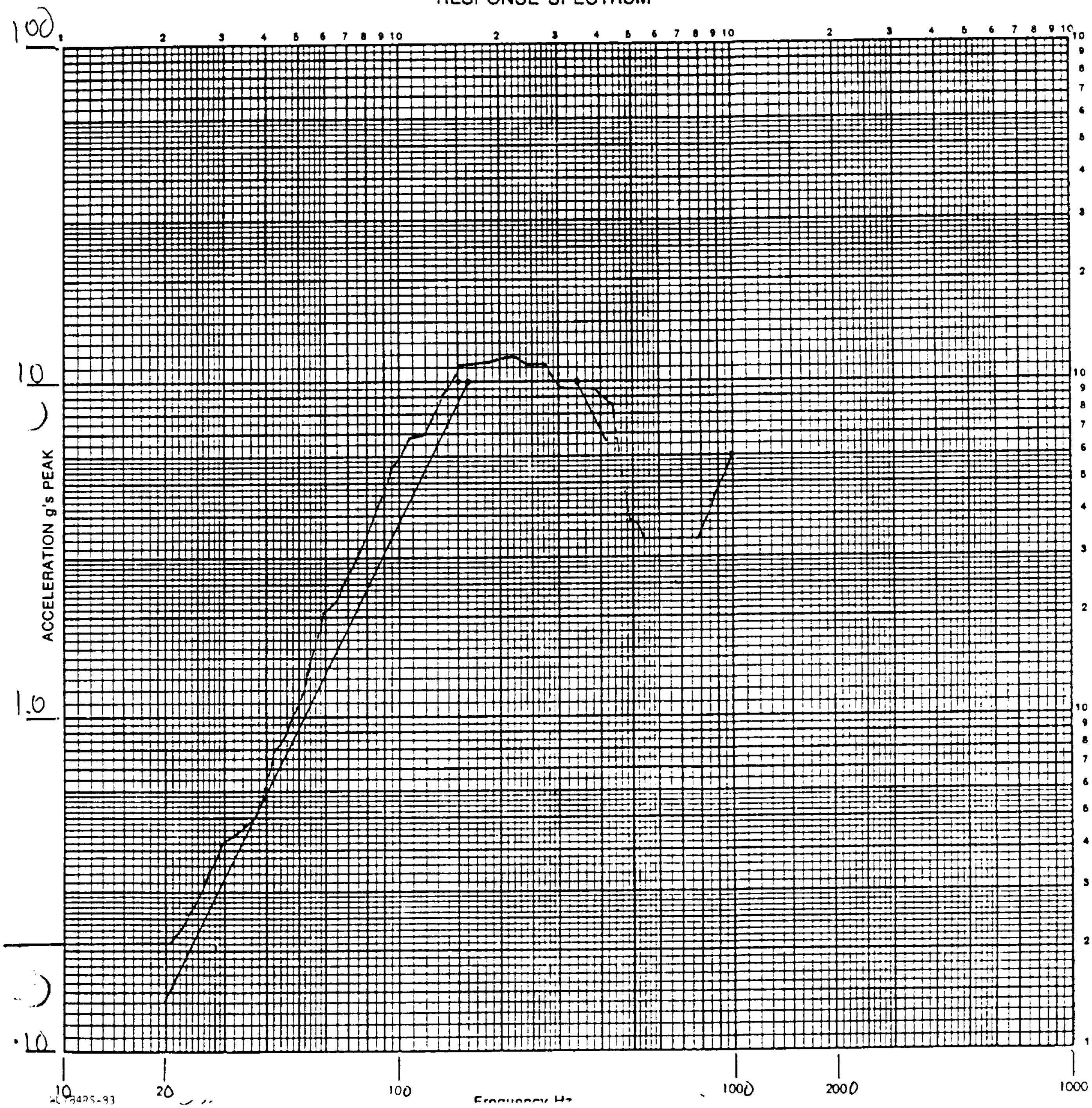
Specimen TRANSPORTATION UNIT #2 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 3

Operator MC Engineer CC AMB

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

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CUSTOMER MTI Job No. 53976 Date ~~2-25~~ 3-6-89 cch

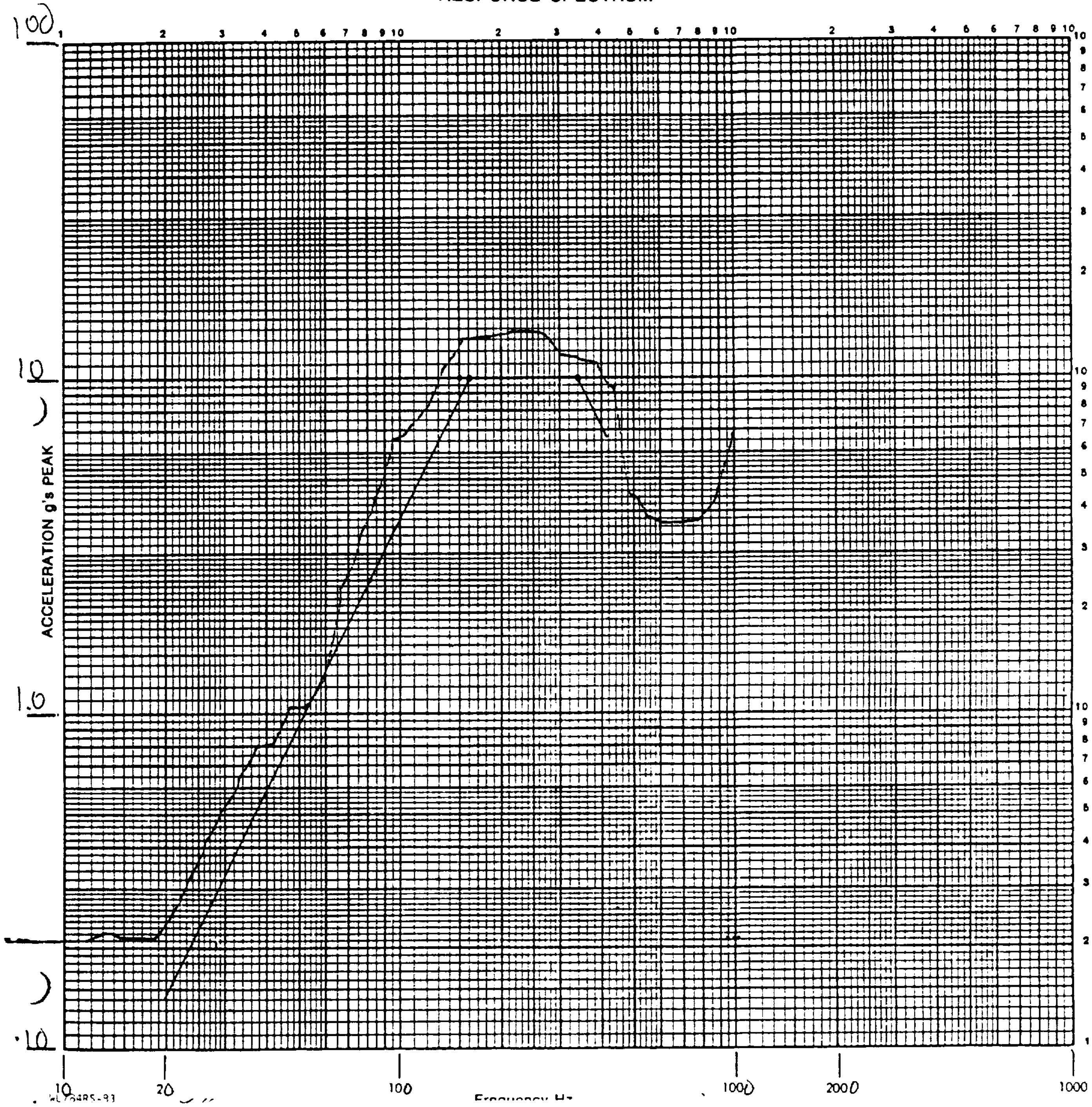
Specimen TRANSPORTATION UNIT #2 Axis of Test LONG

Accel. No. 1 Axis LONG Control (✓) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. SHOCK #4

Operator MA Engineer CCh AMB

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

Page No. 61

CUSTOMER MTI Job No. 53976 Date ~~2-24~~ 3-6-85

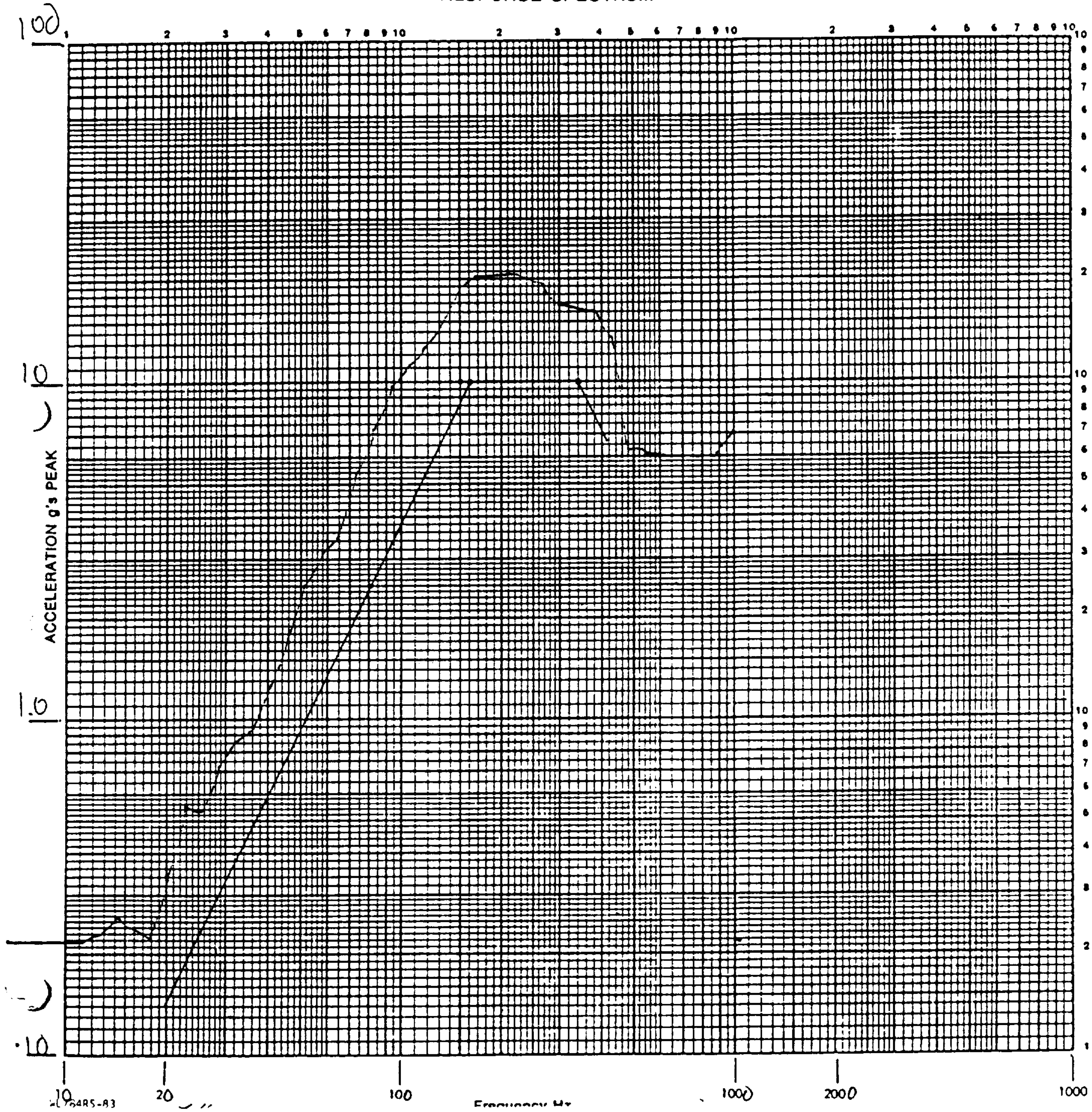
Specimen TRANSPORTATION UNIT #2 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 5

Operator MC Engineer CChn AMB

RESPONSE SPECTRUM



L 764R5-83

CUSTOMER MTI Job No. 53976 Date 3-6-89

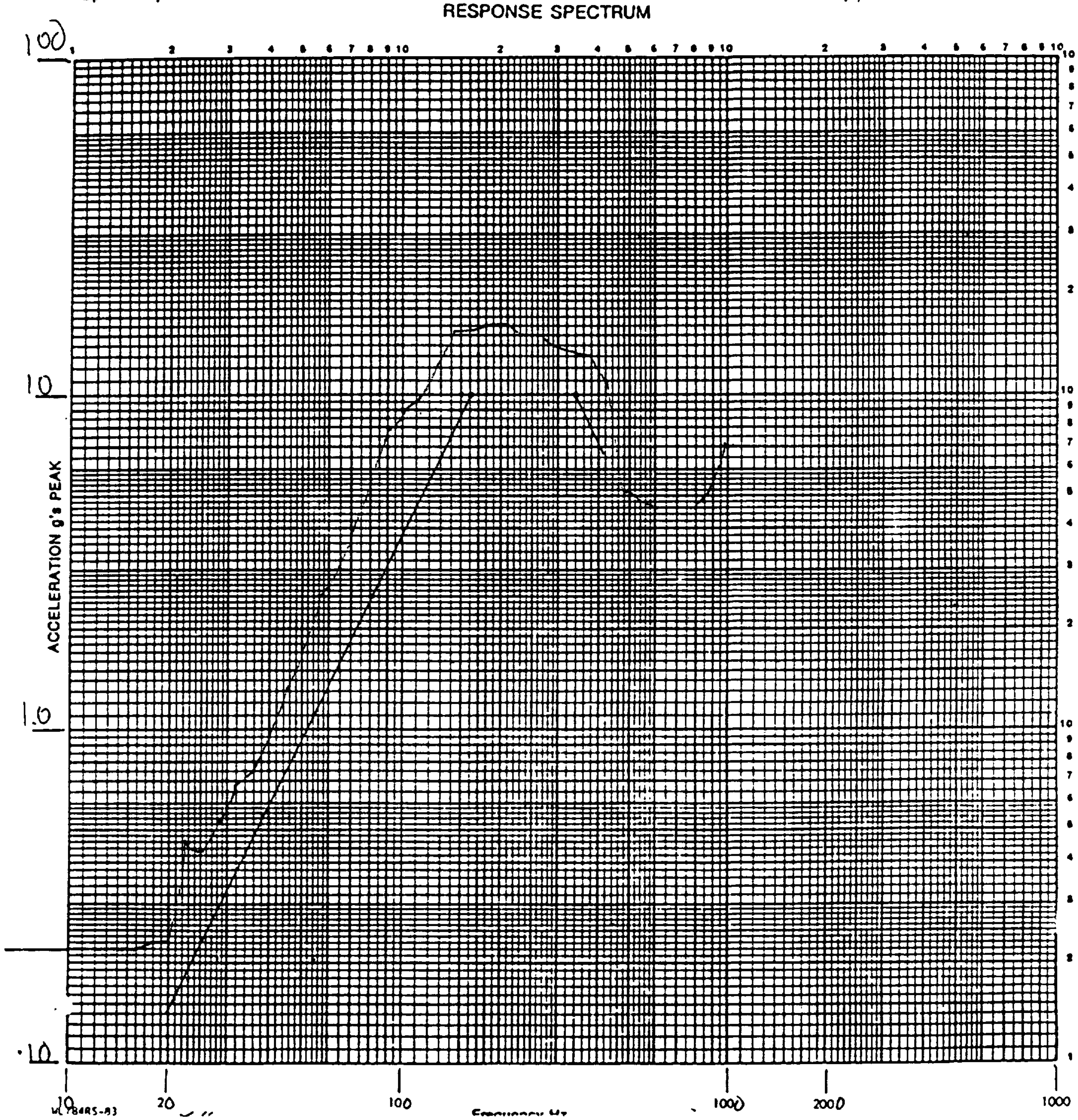
Specimen TRANSPORTATION UNIT #1 Axis of Test Lag

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 1

Operator M. Ch Engineer C.C.h AMB

RESPONSE SPECTRUM



WL 784RS-83

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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3/6-6-89

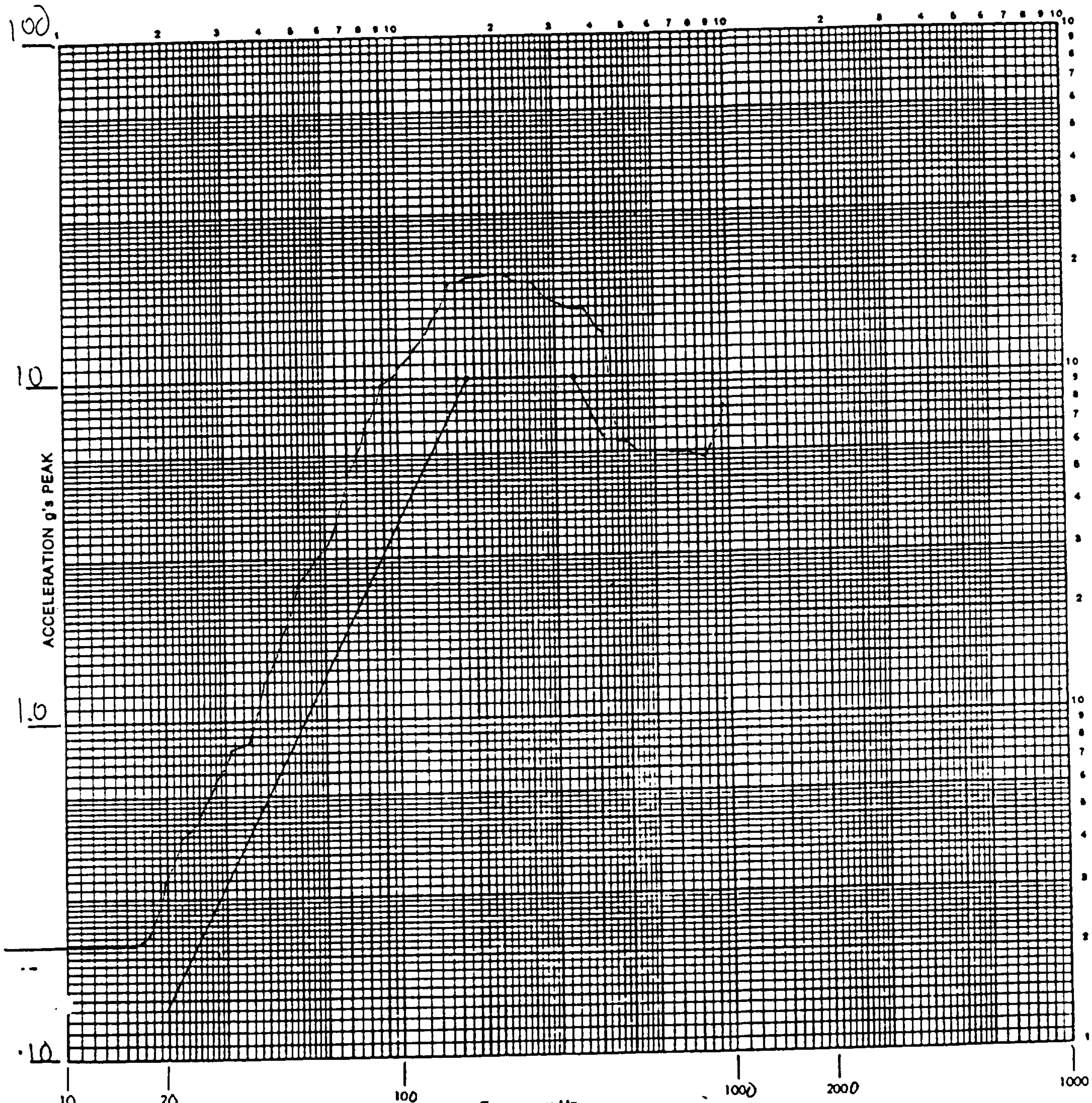
Specimen TRANSPORTATION UNIT #1 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 2

Operator MO Engineer CCh Long - Axis

RESPONSE SPECTRUM



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3/6-6-89

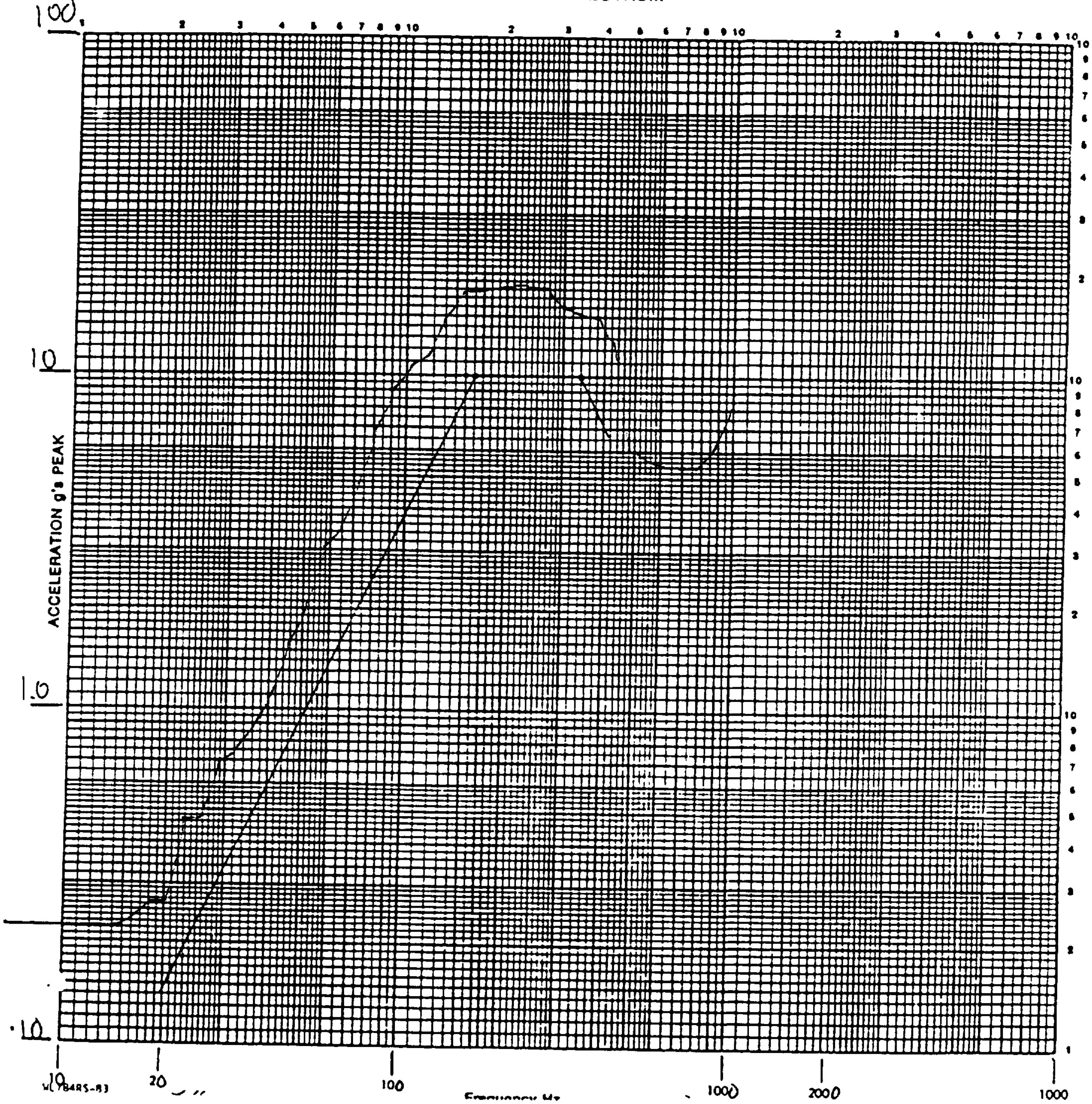
Specimen TRANSPORTATION UNIT #1 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 3

Operator MCW Engineer CCLu AmB

RESPONSE SPECTRUM



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI Job No. 53976 Date 3-6-89

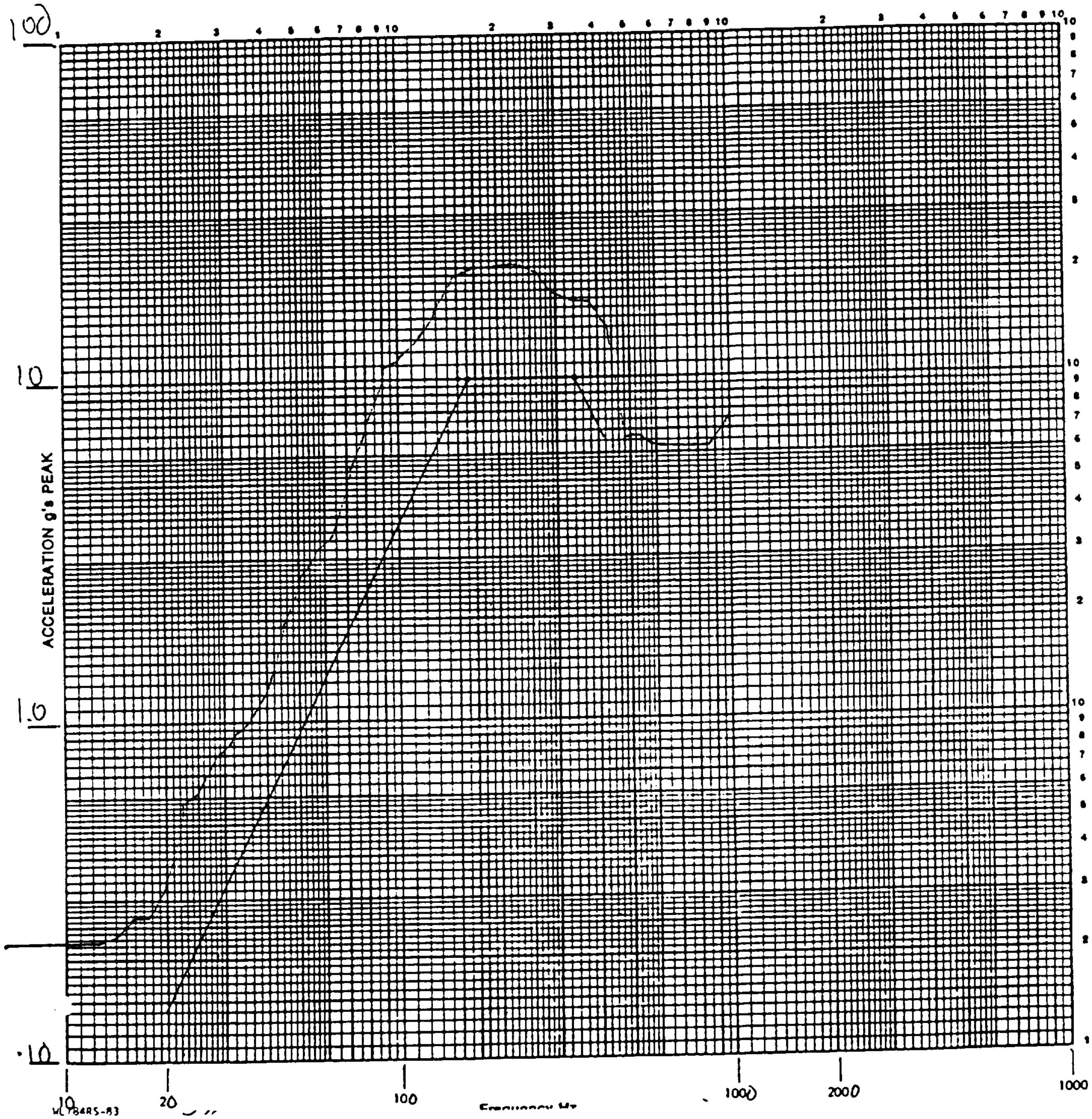
Specimen TRANSPORTATION UNIT #1 Axis of Test Long

Accel. No. 1 Axis ~~CCho~~ Long Control (/) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 4

Operator MC Engineer ~~to~~ CCh AMB.

RESPONSE SPECTRUM



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WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

Page No. 66

CUSTOMER MTI Job No. 53976 Date 3-6-89

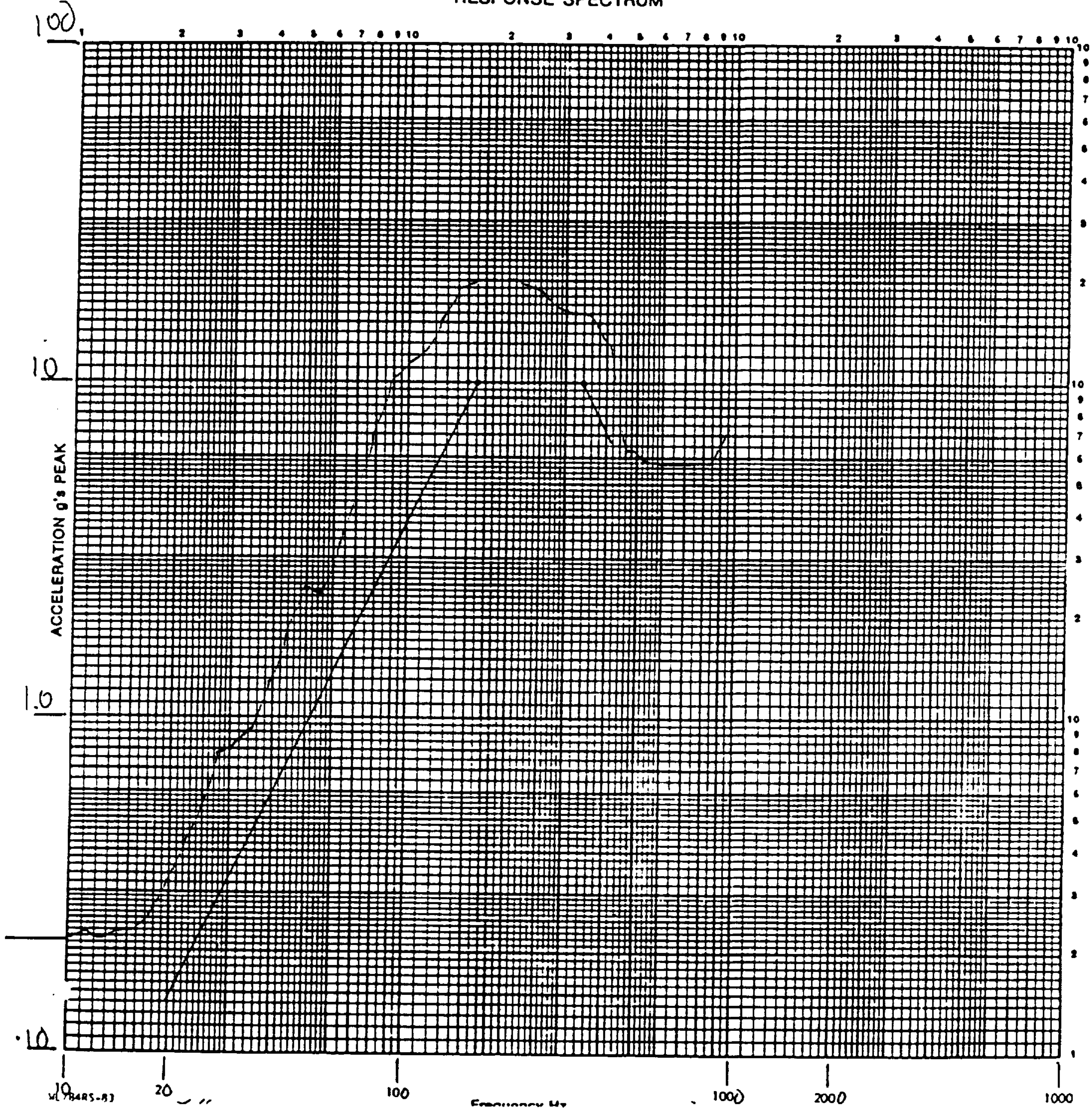
Specimen TRANSPORTATION UNIT #1 Axis of Test Long

Accel. No. 1 Axis LONG Control (✓) Response ( ) OBE ( ) SSE ( ) DBE ( )

Full Scale 100 g Damping 5 % Run No. 5

Operator MCR Engineer CCL AMB

RESPONSE SPECTRUM



WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

TEST TITLE TRANSPORTATION & FUNCTIONAL/SHOCK

CUSTOMER MORTON THIOKOL Job No. 53976 Date 2-28-89

Specimen TRANSPORTATION UNIT Technician M. O[illegible]

Part No. PROTOTYPE Serial No. 1 + 2 Engineer C C[illegible]

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
ACCELEROMETER	ENDEVCO	7704-50	0-1000 g.	10166	1-16-89	4-16-89	± 2%
ACCELEROMETER	ENDEVCO	7704-50	0-1000 g.	10456	1-16-89	4-16-89	± 2%
ACCELEROMETER	ENDEVCO	7704-50	0-1000 g.	10165	1-16-89	4-16-89	± 2%
ACCELEROMETER	ENDEVCO	7704-50	0-1000 g.	10447	1-16-89	4-16-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D-22	0-1000 g	10675	9-6-88	3-9-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D-22	0-1000 g	10673	9-6-88	3-9-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ-DICKIE	D-22	0-1000 g	10674	9-6-88	3-9-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D-22	0-1000 g	10654	9-6-88	3-9-89	± 2%
VOLT METER	B&K	2416	.01-1000V.	30873	12-21-88	4-16-89	± 5% RNG.
OSCILLOSCOPE	LEADER	514A	DUAL TRACE	9621	PRIOR TO USE		
POWER AMPLIFIER	Lmg	PP 200/350	200KW	31346	N/A	N/A	N/A
EXCITER	Lmg	249	5-2000 HZ. 30,000 FORCE LB.	6702	N/A	N/A	N/A
DIGITAL CONTROL SYS.	SPECTRAL DYNAMICS	1500	5-2000 HZ.	10640	PRIOR TO USE		
TEMP. RECORDER	L&N						

QA Form Approval [illegible]

W614D-82

Where applicable, the listed test equipment has been calibrated using standards which are traceable to the National Bureau of Standards. Certificates and reports of all calibrations are retained in the Wyle Laboratories (. \ files and are available for inspection upon request.

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

TEST TITLE SINE SWEEP / RESONANT DWELL / SHOCK

CUSTOMER MORTON THIOKOL Job No. 53976 Date 3-31-89

Specimen I.M.U Technician NISPORIC

Part No. SEE REC INSP Serial No. SEE REC INSP Engineer C.C. [illegible]

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
ACCELEROMETER	ENDEVCO	7704-50	0-1000 GS	10165	1-16-89	4-16-89	± 2%
ACCELEROMETER	ENDEVCO	7704-50	0-1000 GS	10447	1-16-89	4-16-89	± 2%
ACCELEROMETER	ENDEVCO	7704-50	0-1000 GS	10456	1-16-89	4-16-89	± 2%
ACCELEROMETER	ENDEVCO	7704-50	0-1000 GS	10166	1-16-89	4-16-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000 GS	10675	3-13-89	9-17-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000 GS	10673	3-13-89	9-17-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000 GS	10674	3-13-89	9-17-89	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000 GS	10654	3-13-89	9-17-89	± 2%
SWEEP OSCILLO SERVO	SPECTRAL DYNAMICS	SD 114	0-5000 HZ	10096	11-8-88	5-14-89	± 2%
TEMP. RECORDER	KAYE	DIGISTRIP II	-500 TO +3000°F	W8594	12-29-88	7-2-89	LABEL
TEMP RECORDER	LAN	105	-100 TO +300°F	30153	3-29-89	7-30-89	± 2%

QA Form Approval [illegible]

W614D-82

Where applicable, the listed test equipment has been calibrated using standards which are traceable to the National Bureau of Standards. Certificates and reports of all calibrations are retained in the Wyle Laboratories QA files and are available for inspection upon request.

Report No. 53976

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NOTICE OF DEVIATION

WYLE LABORATORIES

WYLE JOB NO. 0E 53976
NOD NO. 1
PO NO. 9MG021
DATE 10 March 1989
GOV'T. CONT. NO. NA58-30490

TO: MORTON THIOKOL, INC.

ATTN: Miles Brown

PART NAME Transportation Monitoring Unit

PART NO. Prototype ~~SERIAL~~ NO. Test Unit No. 1

TEST: Transportation Vibration, ambient temperature, longitudinal axis

SPECIFICATION MTI Doc. CTP-0097, Rev. B PARAGRAPH NO. 8.2

NOTIFIED CUSTOMER: Charlie Mondall DATE: 7 March 1989 VIA: In person

NOTIFIED DCAS-QAR: Not required DATE:

SPECIFICATION REQUIREMENTS:

Subject specimens to transportation vibration test. Visually inspect test specimens for physical damage.

DATE OF DEVIATION: 6 March 1989
TYPE OF DEVIATION: Specimen anomaly
DESCRIPTION OF DEVIATION:

During ambient temperature transportation vibration resonance dwell test at first mode (14.5 Hz, 1.2g input) resonance,structural damage was noted on the test specimen. The bottom mounting plate was fractured, and several mounting screws came loose.

SPECIMEN DISPOSITION: Test was discontinued.

COMMENTS - RECOMMENDATIONS:

TEST WITNESS: ______ TEST ENGINEER C. C. Lee
C. C. Lee

REPRESENTING ______ DEPT. MANAGER J. J. Anderson
J. J. Anderson

QUALITY ASSURANCE J. G. Graper
J. G. Graper

DISTRIBUTION:
ORIGINAL: DEPARTMENT
3 COPIES: CUSTOMER
1 COPY : DEPARTMENT
1 COPY : QUALITY CONTROL
1 COPY : CONTRACTS
Ø COPIES: DCAS-QAR

QC FORM APPROVAL [illegible]

WL-109A

NOTICE OF DEVIATION

WYLE LABORATORIES

WYLE JOB NO. DE 53976
NOD NO. 2
PO NO. 9MG021
DATE 6 April 1989
GOV'T. CONT. NO. NAS8-30490

TO: MORTON THIOKOL, INC.

ATTN: Miles Brown, Purchasing

PART NAME Transportation Monitoring Unit

PART NO. Prototype SERIAL NO. Units 1 and 2

TEST: Transportation Vibration, +163F

SPECIFICATION MTI QTP CTP-0097 PARAGRAPH NO. 8.2

NOTIFIED CUSTOMER: Charlie Mondale DATE: 5 April 1989 VIA: In person

NOTIFIED DCAS-QAR: Not required DATE:

SPECIFICATION REQUIREMENTS:

Subject test specimen to transportation vibration test at 163F. Specimen shall remain functional during test.

DATE OF DEVIATION: 5 April 1989
TYPE OF DEVIATION: Specimen anomaly
DESCRIPTION OF DEVIATION:

Both test specimens stopped functioning at approximately +150F temperature.

SPECIMEN DISPOSITION: Test was discontinued.

COMMENTS - RECOMMENDATIONS:

DISTRIBUTION:
ORIGINAL: DEPARTMENT
3 COPIES: CUSTOMER
1 COPY : DEPARTMENT
1 COPY : QUALITY CONTROL
1 COPY : CONTRACTS
0 COPIES: DCAS-QAR

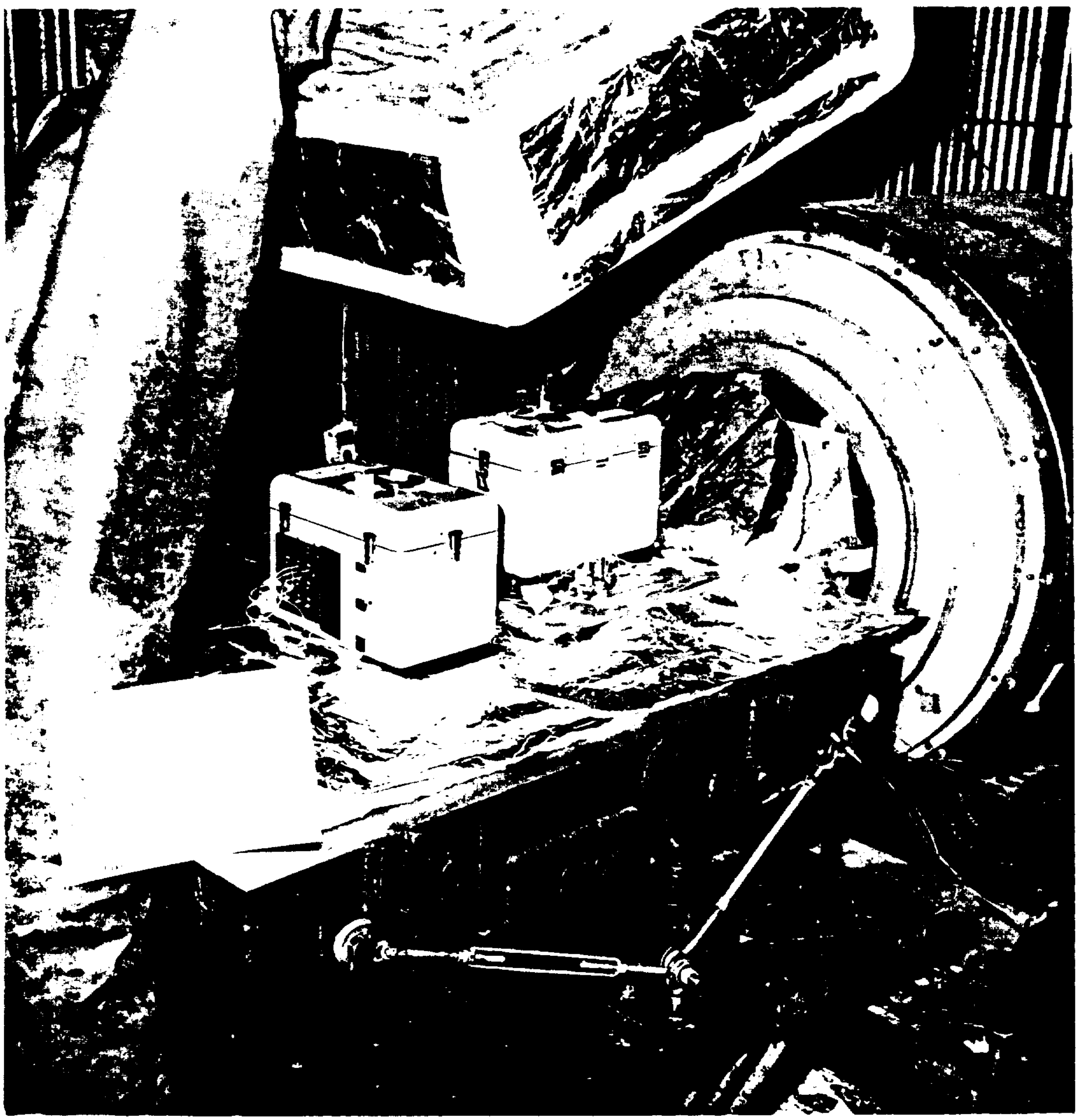
TEST WITNESS: ______ TEST ENGINEER C C Lee
C. C. Lee

REPRESENTING ______ DEPT. MANAGER J J Anderson
J. J. Anderson

QUALITY ASSURANCE J G Graper
J. G Graper

QC FORM APPROVAL [illegible]

WL-109A



PHOTOGRAPH 1

TRANSPORTATION VIBRATION TEST SETUP
LONGITUDINAL AXIS (Typical)

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PHOTOGRAPH 2

BROKEN MOUNTING PLATE ON TEST UNIT NO. 1
(Reference Notice of Deviation No. 1)

APPENDIX B

Unisys Final Test Report for Qualification Testing of Thiokol's Transportation Monitoring Unit

UNISYS

FINAL TEST REPORT

FOR

QUALIFICATION TESTING

OF

THIOKOL'S

TRANSPORTATION MONITORING UNIT

UNISYS FINAL TEST REPORT
QUALIFICATION TESTING ON THIOKOL'S
TRANSPORTATION MONITORING UNIT

****

R. C. NYBO

ENVIRONMENTAL LAB MANAGER

****

H. VARD LEANY

TEST ENGINEER

H. Vard Leany
****

Brad Gallon
UNISYS QUALITY ASSURANCE

BRAD GALLON

TABLE OF CONTENTS

APPENDICES

1.0 INTRODUCTION

Qualification testing of the Thiokol Transportation Monitoring Units (TMU) was started on November 8, 1989. The testing was conducted in accordance with Thiokols document CFP-0097 Rev. D. A detailed test procedure was written by Unisys Corp. STP-360 Rev. A.

The TMU's were started on November 8, 1989 to begin the required non-stop operation of 17 days running time. Due to fixturing problems and facility scheduling problems the actual shaking of the TMU's didn't start until November 20, 1989.

The testing was observed by a Thiokol Engineer at all times during the testing procedure.

The Qualification testing was set up to be conducted in two parts. The first part was a transportation test, to determine if the TMU System would withstand the intended environment. The second part was a functional test to determine the accuracy of the TMU System. The second part of the test was never conducted due to the system failures described in Section 3.0.

2.0 DETAILED TEST LOGS

There are two test logs which were kept during the qualification testing of the Thiokol transportation monitoring units. The first is a facility log kept by the test engineer of all the activity that occurred on the shaker. The second test log was kept by the Thiokol engineering representative of all activities that occurred during the entire test procedures. This second log was also used by Unisys Quality assurance to ensure that all the activities accomplished by Unisys were according to Thiokol's (TP-0097-1).

2.1 FACILITY LOG

2.2 DAILY ACTIVITY LOG UNISYS QUALITY ASSURANCE

2.1

FACILITY LOG

UD1-9818

FACILITY: C-200	ENVIRONMENTAL DATA SHEET ENVIRONMENTAL LABORATORY — DEPT. 9253	
A.O.	ENV. TECH.	TEST SCHED.
ENGINEER OR Q.C.	PHONE	TEST COMPLETED
TECHNICIAN	PHONE	TEST REMOVED
UNIT TITLE TRANSPORTATION MONITOR UNIT	SER. 7, 17 QTY.	TOTAL UTILIZATION

INSTRUCTIONS TO OPERATOR

TEST TO TERMINATE: BY:

ENVIRONMENTAL LABORATORY SUPERVISORS APPROVAL

TEST TEMPERATURE/VIBRATION

SPEC.

PAR.

SIGNATURE

DATE

DATE	TIME	CHRONOLOGICAL RECORD OF TEST	INITIALS (PRINT)
11:17	10:00	Began mounting TMU on Vib. fixture in the Longitudinal Axis	HVL
	13:39	Finished mounting TMU on Vib. fixture	HVL
	14:30	Sealed shroud over TMU	HVL
11:20	6:45	Began conditioning TMU to -40F	HVL
	12:59	Raised shroud to install response accel. and verify operation of TMU	HVL
	15:20	Began Sine Sweep Test (5-2000-5 Hz)	HVL
	15:57	Began Res. Dwell at 46 Hz to 54 Hz	HVL
	16:13	Began Rēs. Dwell at 95 Hz	HVL
	19:39	Performed shock test per specified spectra (5 shocks)	HVL
	20:30	Raised shroud, returned TMU to room temp.	HVL
11:21	7:19	Began to change TMU from Longitudinal to Lateral Axis	HVL
	9:35	Began conditioning TMU to -40^{o}F in the Lateral Axis	HVL
	14:18	Began Sine Sweep Test (5-2000-5 Hz)	HVL
	14:41	Began Res Dwell at 38 Hz	HVL
	15:00	Performed shock test per specified spectra (5 shocks)	HVL
	17:23	Raised shroud, returned TMU to Ambient Temp.	HVL
11:22	9:55	Finished changing shock mounts	HVL
	10:07	Began Sine Sweep Test (5-2000-5 Hz) 70^{o}F Lat. Axis	HVL
	10:43	Began Sine Dwell at 26 Hz	HVL
	11:01	Began Sine Dwell at 86 Hz	HVL
	13:08	Performed shock test per specified spectra (5 shocks)	HVL

VERIFIED & RELEASED BY: ______ Q.C. OR PROGRESS ______ COGNIZANT ENGINEER

2.2

DAILY ACTIVITY LOG

UNISYS QUALITY ASSURANCE

QUALIFICATION TEST LOG FOR TMU
TMU'S #7 AND #17
IN ACCORDANCE WITH CTP-0097.

TMU #7 Qualification Unit
TMU #17 Thiokol Engineering Evaluation Unit

Memory Mod	1	2
TMU #7	0000004	0000024
TMU #17	0000013	0000021

Date	Time	
11-8-89	11:20	- Memory module check - Ok
11-8-89	11:30	- Battery check of TMU #7 & #17.
		- All packs measured 9.37 volts.
	11:37	- System self check on #7 Ok
	11:44	- System self check on #17 Ok
	11:57	- Started both TMU's (#7 & #17).
	12:00	- 3 minute timed event.

UNISYS 15 FINAL TEST

R.S. Bergen Unisys Quality Assurance
Phone - 594-7614

11-9-89	12:00	- Observed recorder red light (#1 Recorder) Illuminate for approximately 11 seconds on both S/N 0007 and S/N 0017 of QDLM-2 Acceleration Monitor System.
	13:00	- Moved #17 to shake table for fitting.

UNISYS 15 FINAL TEST

11-10-89	14:45	- Returned #17 back to lab table
11-10-89	11:59:54	- 6-hour timed event occurred: Observed recorder red light (#1 recorder) Illuminated for approximately 10 seconds on both S/NO-007 and S/N0017 of QDLM-2 Acceleration Monitoring System.

UNISYS 15 FINAL TEST

11-10-89	14:36	- Moved Box 0017 to test fixture
11-10-89	15:12	- Replaced Box 0017.
11-13-89	11:59	- Observed recorder #1 red light illuminate for S/N 0007 only of QDLM-2 acceleration monitoring system.S/N 0017 was turned off 1158 for removal of recording modules (#1000013 #2 & 21. Replace original modules with recorder #1 S/N 000014 and recorder #2 S/N000035. Started unit #0017 at 1202.

UNISYS 15 FINAL TEST

TEST CONTINUING

11-13-89	15:14	- Checking and sealing trigger channels on both boxes also sealing temperature channels CFM.
11-14-89	11:58:41	- Observed recorder #1 red light illuminate for approximately 10 seconds for QDLM-2- Acceleration monitoring system S/N 0007. S/N0017 Recorder #1 Red light Illuminated and then extinguished at 12:01:30. Test Continuing

UNISYS 15 FINAL TEST

11-14-89	12:45	- Moved TMU's to check fixture to ensure proper set up
	13:10	- Moved TMU's back to table in safe while fixturing was being completed.
11-15-89	11:57:35	- Observed recorder #1 Red Light illuminate for approximately 11 seconds for QDLM-2 acceleration monitor system S/N0007. UNISYS 15 FINAL TEST
	12:03:10	- Observed recorder #1 Red Light illuminate for approximately 10 seconds for QDLM-2 Acceleration Monitor System S/N 0017. UNISYS 15 FINAL TEST
		TEST CONTINUING:
11-16-89	11:57.05	- Observed Recorder #1 Red Light illuminate for approximately 10 seconds for QDLM-2 acceleration monitor system S/N 0007. UNISYS 15 FINAL TEST
	12:02:38	- Observed Recorder #1 Red Light Illuminated for approximately 11 seconds for QDLM-2 acceleration monitor system S/N 0017. UNISYS 15 FINAL TEST
		TEST CONTINUING:
11-17-89	10:00:00	- Started to mount hardware on shaker this movement and operation may cause some non-real events.
	13:39:00	- Finished installation of TMU';s 0017, 0007 to shaker. CFM Disregard any events on 11-16-89 between 10:00:00 - 13:39:00.
	14:30	- Sealed UUTS within shroud. UNISYS 12 FINAL TEST BJGollor
11-20-89	06:45	- Shroud put into conditioning stable around -35°.
	12:59	- Unsealed shroud and verified operation of both units. Total out-of-condition period 25:50 min/sec. make up conditioning shall be 45 minutes. UNISYS 12 FINAL TEST
		- Longitudinal transportation test -40°F ± 10°F.
	14:10	- Conditioning tone made up. CFM Longitudinal Sine Sweep -40°F. - Starting Longitudinal cold Sine Sweep -40°F
	15:20	- 5-2000-5 at 1 Oct/Min - CFM. Resonant frequencies - 46 Hz 95 Hz UNISYS 12 FINAL TEST BJGollor
	15:38	- Completed Sine Sweep
		Longitudinal cold dwells -40°F
	15:51	- Started 1st Sine Dwell 46 Hz hold for 15 min. 2 min. 46 Sec. Chased Peak to 54 Hz. 2.5 G's to 2.7 G's. .015 Disp.

16:13 - Started 2nd Sine Dwell 95 Hz Hold for 15.
2.5 G .0055 Disp.
Longitudinal Shocks -40°F

19:39 - Preformed shock No. 1 CFM

20:16:38 - Preformed Shock No.2. CFM

20:20:53 - 3rd Shock CFM

20:25:03 - 4th Shock CFM

20:29:07 - 5th Shock CFM

20:30:00 - Lifted shroud and verified TMU operation. Both TMU's still operating shutting down for the evening. CFM

11-21-89 07:19 - Started moving into tangential axis. Disregard any events until operation is completed. CFM

08:40:00 - Stopped box 0017 to look at data. CFM

08:48:00 - Started Box 0017 QSTH - new memory
Modules 007 - Slot 1 0038 - Slot 2 CFM

08:51:00 - 3 Minute Event occurred. CFM

08:59:00 - Completed Axis turn system now in Tangential Axis. CFM

09:20:00 - Pictures of Tangential setup

09:35:00 - Conditioning started. Tangential Axis cold -40

10:00 - Reviewed test data obtained on 11/20 with the electrical engineer that performed the tests. Verified that the test data correlate with the requirements of the test procedure.

UNISYS 12 FINAL TEST

TANGENTIAL AXIS TRANSPORTATION TEST -40°F ± 10°F.

TANGENTIAL AXIS SINE SWEEP -40°F

14:18 - Started Tangential Sine Sweep (cold)

14:39 - Completed Sine Sweep 5-2000-5
38 Hz, 4.8 G's = DA = .07

14:41:00 - Started 38 Hz Resonance Dwell 4.8 G's .07 Disp.

14:56:00 - End Dwell. Only one resonant point Dwelled.

15:00 - Started First Shock - Tangential Axis (cold)

15:05 - Started Second Shock

15:09 - Third Shock

15:13 - Fourth Shock

15:17 - Fifth Shock

11-22-89 08:30 - The test data obtained on 11-20-89 was re-reviewed by the Unisys Electrical engineers that performed the testing. It was determined that the Shock Spectra Tests were performed to the wrong tolerances. The actual tolerance was +40% to -30% and should have been +40% to -20%. This testing error occurred while the TMU's were in the longitudinal axis, at -40°F. This test will be repeated and documented by test data to verify implementation of the correct test tolerance.

UNISYS 12 FINAL TEST

11-22-89 08:30 - Qualification TMU #0007 shut down over night due to low batteries. This is a failure of the Qualification test because the TMU only ran for 14 days, and not the required 17 days. Thiokol Corporation informed NASA and it was agreed to restart TMU #0007 and continue testing. CFM

11-22-89 09:20 - TMU #7 Qualification Unit was restarted with Unisys QA to Verify. New Memory

Mod	7	2
TMU #7	0000013	0000021

New batteries checked out OK. Both at 9.37V. System self check - OK. Light flashing every 5 seconds.

Observed recorder red light illuminate for 11 seconds on TMU S/N 7 upon restart after battery replacement

UNISYS 12 FINAL TEST

TMU Transportation Test Tangential Axis 70°F ± 10°F.

TANGENTIAL AXIS SINE SWEEP - 70°F

10:07 - Started sine sweep in the lateral axis (or Tangential). 70°F.

TANGENTIAL AXIS SINE DWELLS - 70°F

10:30 - Completed Sine Sweep 5-2000-5.

10:43 - Started 26 Hz Resonance Dwell 16G's = DA = 4 inch.

10:58 - Completed 26 Hz Dwell.

11:01 - Started 86 Hz Resonance Dwell 3.5G = DA = >o

11:16 - Completed 86 Hz REsonance Dwell.
Tangential Axis Shocks 70°F

13:08 - Started first shock

13:11 - Second Shock

13:22 - Third Shock

13:27 - Fourth Shock

13:32 - Fifth Shock

14:00 - Observed both TMU's to verify LEDs flashing at 5 second interval and sealed the shroud for the weekend.

UNISYS 12 FINAL TEST

11-27-89 08:30 - Removed seals from shroud and verified both LEDs flashing at 5 second intervals. Unisys Electrical Engineers began changing TMUs to the longitudinal axis for testing at +70°F.

UNISYS 12 FINAL TEST

10:20 - Finished Rotation of test article preparing the longitudinal Sine Sweep.

TMU Longitudinal Transportation Test
+70°F ± 10°F.
Longitudinal Sine Sweep - 70°F

10:38 - Started Sine Sweep - 5-2000-5 Hz

11:02 - Finished Sine Sweep - 1 REsonance 35 Hz.
6.5 G's at 39 Hz approximately .085 Disp.

11:05 - Started Dwell at 39 Hz.

11:20 - Finished Dwell

11:21 - CK Both TMU's all OK.

Longitudinal Shocks - 70°F

11:35 - First Shock

11:40 - Second Shock

11:46 - Third Shock

11:49 - Fourth Shock

11:54 - Fifth Shock

11:57 - Finished longitudinal Ambient Transportation phase, insufficient time to condition and test today.

11-28-89 08:00 - Checked TMU's both operational, have been in condition for 2 1/2 hours at +163°F ± 10°F will start test about 9:30:00.

Verified the above statement. UNISYS 12 FINAL TEST BJGollor

TMU LONGITUDINAL TRANSPORTATION TEST 163°F ± 10°

LONGITUDINAL SINE SWEEP 163°F

09:53 - Started Sine Sweep 5-2000-5
Resonances 33.4 Hz 71 Hz 7

10:34 - 33.4 Hz Sine Dwell started .067 Disp.
10:49 - Finished Sine Dwell at 33.4 Hz
Longitudinal Sine Dwells 163°F

10:56 - Started 71 Hz Dwell 3.2G's = .0125 Disp.

11:11 - Started 93 Hz Dwell - 3.2G's = .0077 Disp.
Longitudinal Shocks 163°F

11:26 - First Shock

11:28 - Second Shock

11:32 - Third Shock

11:35 - Fourth Shock

11:39 - Fifth Shock

11:45 - The Shroud was raised and it was determined that both units failed. All memory modules were removed for the purpose of examination. UNISYS 12 FINAL TEST BJGollor

3.0 TEST RESULTS

The qualification testing that was conducted by Unisys on the Thiokol TMU system was not completed due to the two system failures which occurred during the testing.

The first failure occurred when TMU #0007 shutdown on November 22, 1989. The CTP-0097-D required that the TMU System run for 17 days of continuous operation. The shut down of the TMU occurred after only 14 days of operation. The cause of the shut down was low battery voltage, this was determined by the Thiokol Engineering Representative. Thiokol decided to restart the 17 day test and continue on with the testing of the TMU system.

The second failure occurred during the Longitudinal transportation testing at 160°F ± 10°F. This testing was conducted on November 28, 1989. After the testing was completed the environmental shroud was raised and both TMU units had stopped running.

The qualification testing was concluded at this point. The control and response data from all the testing conducted on the transportation monitoring units are located in appendices B through F.

3.1 ADDITIONAL TMU TESTING

Thiokol Corporation requested that some additional testing be conducted to determine the accuracy of the TMU system at a variety of temperatures.

Two tests were conducted at five different temperature levels. The tests consisted of a 10 Hz Sine Dwell at 1.5G's and a series of low level shocks. These two tests were conducted at the following temperatures: -30°, 70°F, 130°F 140°F AND 150°F.

This additional testing was not part of the qualification testing. The only requirement for Unisys was to conduct the required tests and provide Thiokol with the control data. This test data was given to the Thiokol Engineering Representative that was present during the testing.

APPENDIX A

TRANSPORTATION MONITORING

UNIT

TEST PROCEDURE

STP - 360 - A

STP-360
Revision: A

TRANSPORTATION MONITOR UNIT
TEST PROCEDURE

Prepared By: W. R. Cooper 11/14/89
Standards Engineering

Approved By: R. C. Nybo 11/14/89
Manager Standards Engineering

The two transportation monitor units (TMU) serial number 7, qualification unit, and serial number 17, engineering control unit, shall be subjected to the following test procedures. The qualification unit shall be operated continuously for 17 days. The engineering evaluation unit can be stopped and started as directed by Thiokol personnel. During this period of operation the TMU's shall be subjected to the following sequence of testing per the following procedures. Thiokol's TRANSPORTATION MONITOR QUALIFICATION TEST PLAN, CTP-0097 REVISION C, shall be used for definition of test axes, test conditions, and test durations.

1. The MD C200 vibration system shall be set for testing of the TMU, in the horizonal axis. The test equipment shall set up and checked out per Unisys Standard Laboratory Procedure (USLP) E-200, Sinusoidal Vibration Testing; General Procedure and USLP E-300 Shock Testing; General Procedure.

2. Install the TMU's for testing in the longitudinal axis and condition for four hours at -40 +/- 10 °F.

3. Perform sine sweep test per requirements of CTP-0097C, Table II.

4. Perform sine dwell test per requirements of CTP-0097C, Table II.

5. Perform shock test per the requirements of CTP-0097C, Table II.

6. Change shock mounts and rotate TMU's to the lateral axis and recondition at cold condition for 1.5 hours for each hour or part of an hour the temperature was above -30 °F during the axes change but not longer than four hours.

7. Repeat step 3.

8. Repeat step 4.

9. Repeat step 5.

10. Change shock mounts leaving TMU's in the lateral axis and condition at 70 +/- 10 °F for four hours.

11. Repeat step 3.

12. Repeat step 4.

13. Repeat step 5.

14. Change shock mounts and rotate TMU's to the longitudinal axis while maintaining the 70 +/- 10 °F temperature.

15. Repeat step 3.

16. Repeat step 4.

17. Repeat step 5.

18. Change shock mounts leaving TMU's in the longitudinal axis and condition for four hours at 163 +/- 10 °F.

19. Repeat step 3.

20. Repeat step 4.

21. Repeat step 5.

22. Change shock mounts and rotate TMU's to the lateral axis and recondition at hot condition for 1.5 hours for each hour or part of an hour the temperature was below 153 °F during the axes change but not longer than four hours.

23. Repeat step 3.

24. Repeat step 4.

25. Repeat step 5.

26. The MD C200 vibration system shall be set for testing of the TMU, in the vertical axis. The test equipment shall set up and checked out per Unisys Standard Laboratory Procedure (USLP) E-200, Sinusoidal Vibration Testing; General Procedure and USLP E-300 Shock Testing; General Procedure.

27. Install the TMU's with new shock mounts for testing in the vertical axis and condition for four hours at -40 +/- 10 °F.

28. Repeat step 3.

29. Repeat step 4.

30. Repeat step 5.

31. Change shock mounts leaving TMU's in the vertical axis and condition at 70 +/- 10 °F for four hours.

32. Repeat step 3.

33. Repeat step 4.

34. Repeat step 5.

35. Change shock mounts leaving TMU's in the vertical axis and condition for four hours at 163 +/- 10 °F.

36. Repeat step 3.

37. Repeat step 4.

38. Repeat step 5.

39. The MD C10 vibration system shall be set for testing of the TMU accelerometers, in the vertical axis. The test equipment shall set up and checked out per Unisys Standard Laboratory Procedure (USLP) E-100, Random Vibration Testing; General Procedure and USLP E-300 Shock Testing; General Procedure.

40. Mount the accelerometers so the vertical accelerometers are in the vertical axis. Condition the accelerometers and TMU's for four hours at -40 +/- 10 °F.

41. Perform the functional test sequence CTP-0097C Figure 4.

42. Change the accelerometers so the lateral accelerometers are in the vertical axis and recondition at cold condition for 1.5 hours for each hour or part of an hour the temperature was above -30 °F during the axis change but not longer than four hours.

43. Repeat step 41.

44. Change the accelerometers so the longitudinal accelerometers are in the vertical axis and recondition at cold condition for 1.5 hours for each hour or part of an hour the temperature was above -30 °F during the axis change but not longer than four hours.

45. Repeat step 41.

46. Mount the accelerometers so the vertical accelerometers are in the vertical axis. Condition the accelerometers and TMU's for four hours at 70 +/- 10 °F.

47. Perform the functional test sequence CTP-0097C Figure 4.

48. Change the accelerometers so the lateral accelerometers are in the vertical axis while maintaining 70 +/- 10 oF temperature.

49. Repeat step 47.

50. Change the accelerometers so the longitudinal accelerometers are in the vertical axis while maintaining 70 +/- 10 °F temperature.

51. Repeat step 47.

52. Mount the accelerometers so the vertical accelerometers are in the vertical axis. Condition the accelerometers and TMU's for four hours at 163 +/- 10 °F.

53. Perform the functional test sequence CTP-0097C Figure 4.

54. Change the accelerometers so the lateral accelerometers are in the vertical axis and recondition at hot condition for 1.5 hours for each hour or part of an hour the temperature was below 153 °F during the axis change but not longer than four hours.

55. Repeat step 53.

56. Change the accelerometers so the longitudinal accelerometers are in the vertical axis and recondition at hot condition for 1.5 hours for each hour or part of an hour the temperature was below 153 °F during the axis change but not longer than four hours.

57. Repeat step 53.

58. After TMU functional test data has been reduced from qualification unit serial number 7 by Thiokol as witnessed by Unisys, the following data points per CTP-0097C figure 4 shall be verified for qualification.

    a. During quiet periods the TMU did not trigger.

    b. During low frequency 0.2 g shocks the TMU did not trigger.

    c. During low frequency 2.0 g shocks the TMU did trigger on each event and recorded level was within +/- 10% of the control accelerometer.

    d. During high frequency 20.0 g shocks the TMU did not trigger.

    e. During the 0.17 grms random vibration the TMU did not trigger.

    f. During the 0.55 grms random vibration the TMU did trigger on each event and recorded level was within +/- 10% of the control accelerometer.

    g. During disconnection of an accelerometer channel only one triggered event occurred.

    h. During testing all TMU recorded temperatures were within +/-5 °F of actual test conditions.

    i. TMU serial number 7 functioned continuously for a minimum of 17 days.

REVISION RECORD

REVISION	DESCRIPTION OF CHANGE	APPROVAL	DATE
A	Changed steps 2, 27, and 40 temperatures From: -30 °F maximum to -40 °F minimum. To: -40 +/- 10 °F. Changed steps 18, 35, and 52 temperatures From: 153 °F minimum to 163 °F maximum. To: 163 +/- 10 °F.	uuc	11/17/89

APPENDIX B

UNISYS CONTROL AND RESPONSE DATA

FROM LONGITUDINAL AXIS TRANSPORTAION

TEST (-40°F ± 10°F)

ORIGINAL PAGE IS
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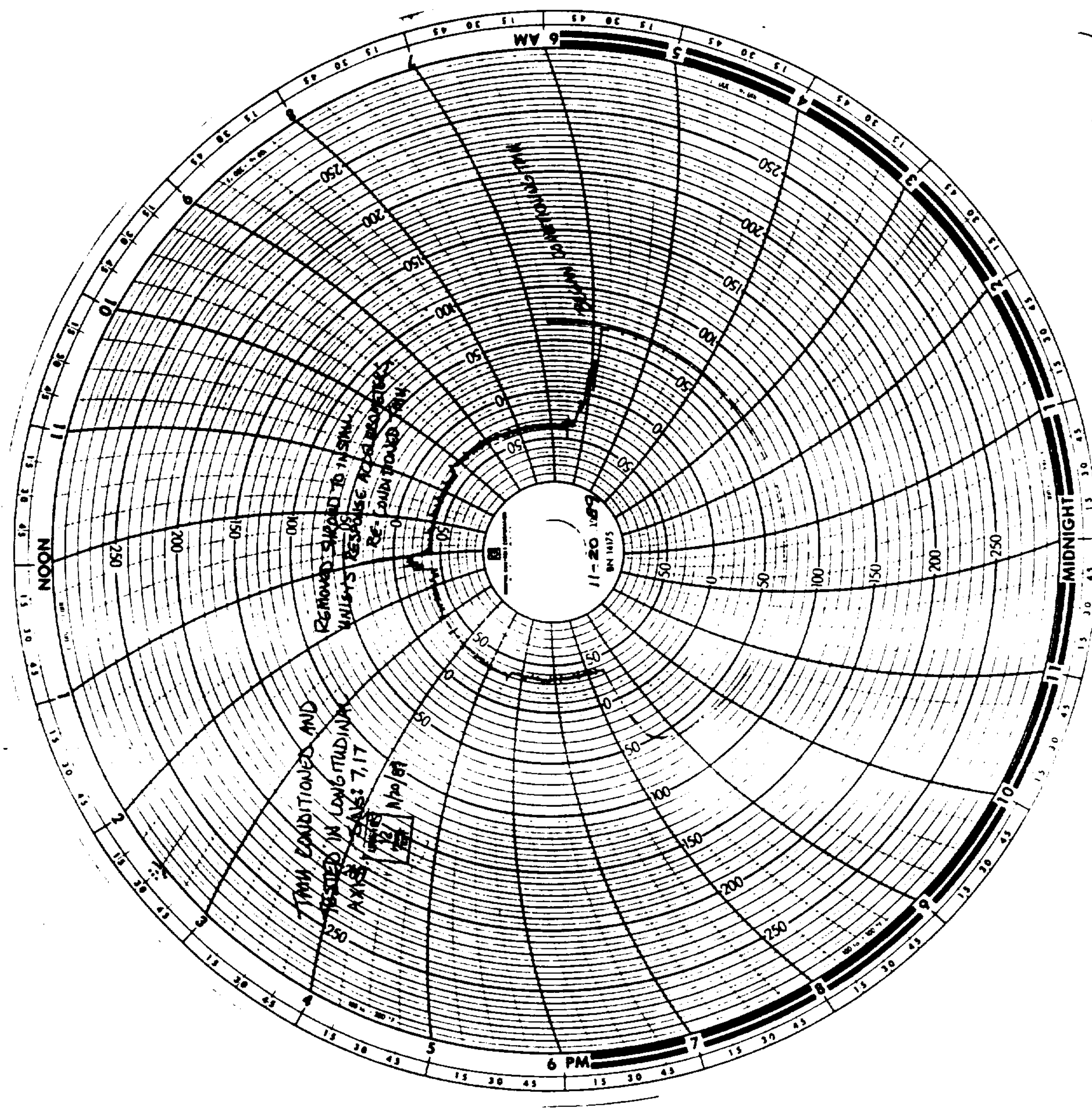
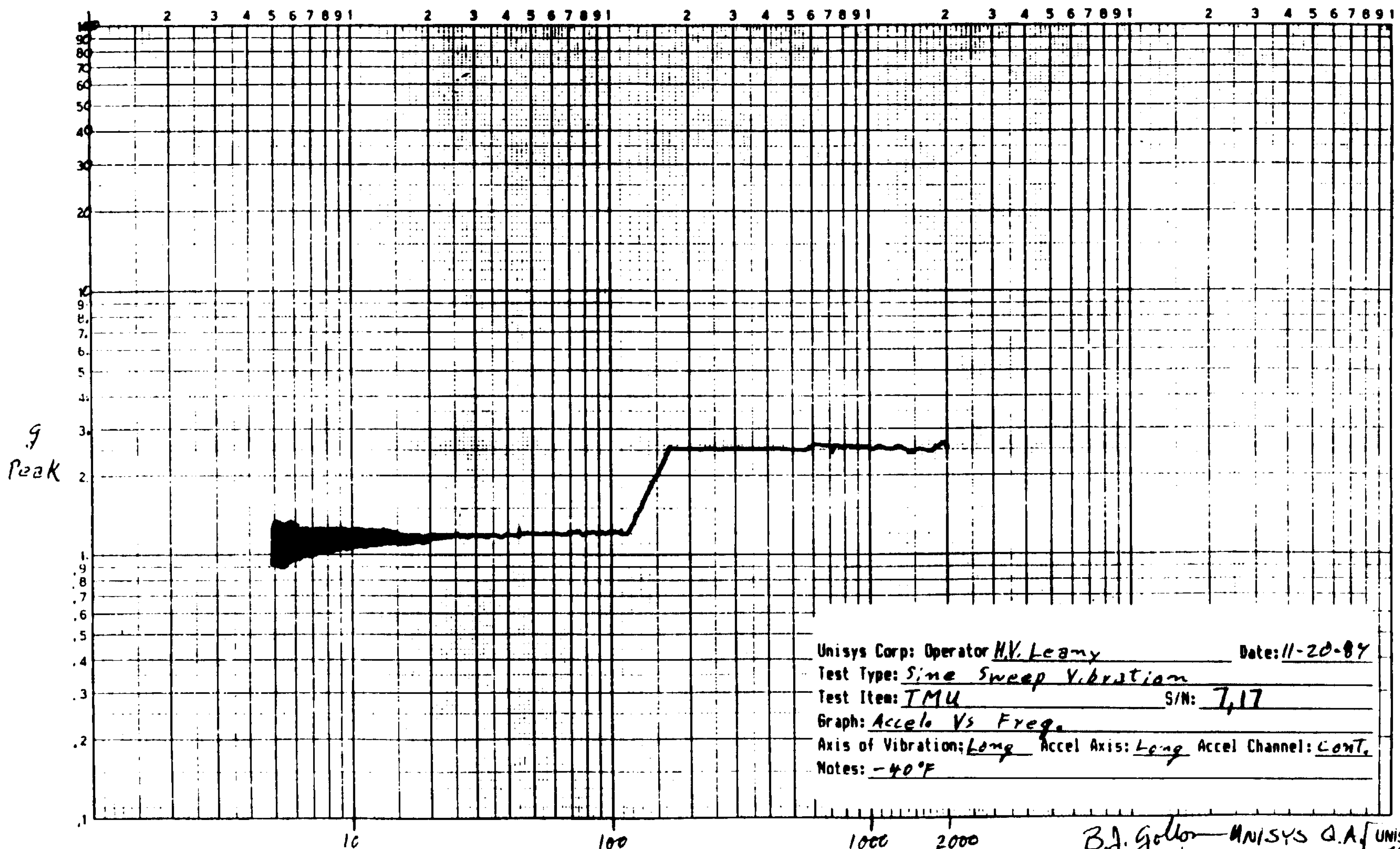


TMU conditional for
longitudinal axis



Frequency HZ

B.J. Gollon UNISYS Q.A.
11/21/89

UNISYS
12
FINAL
TEST

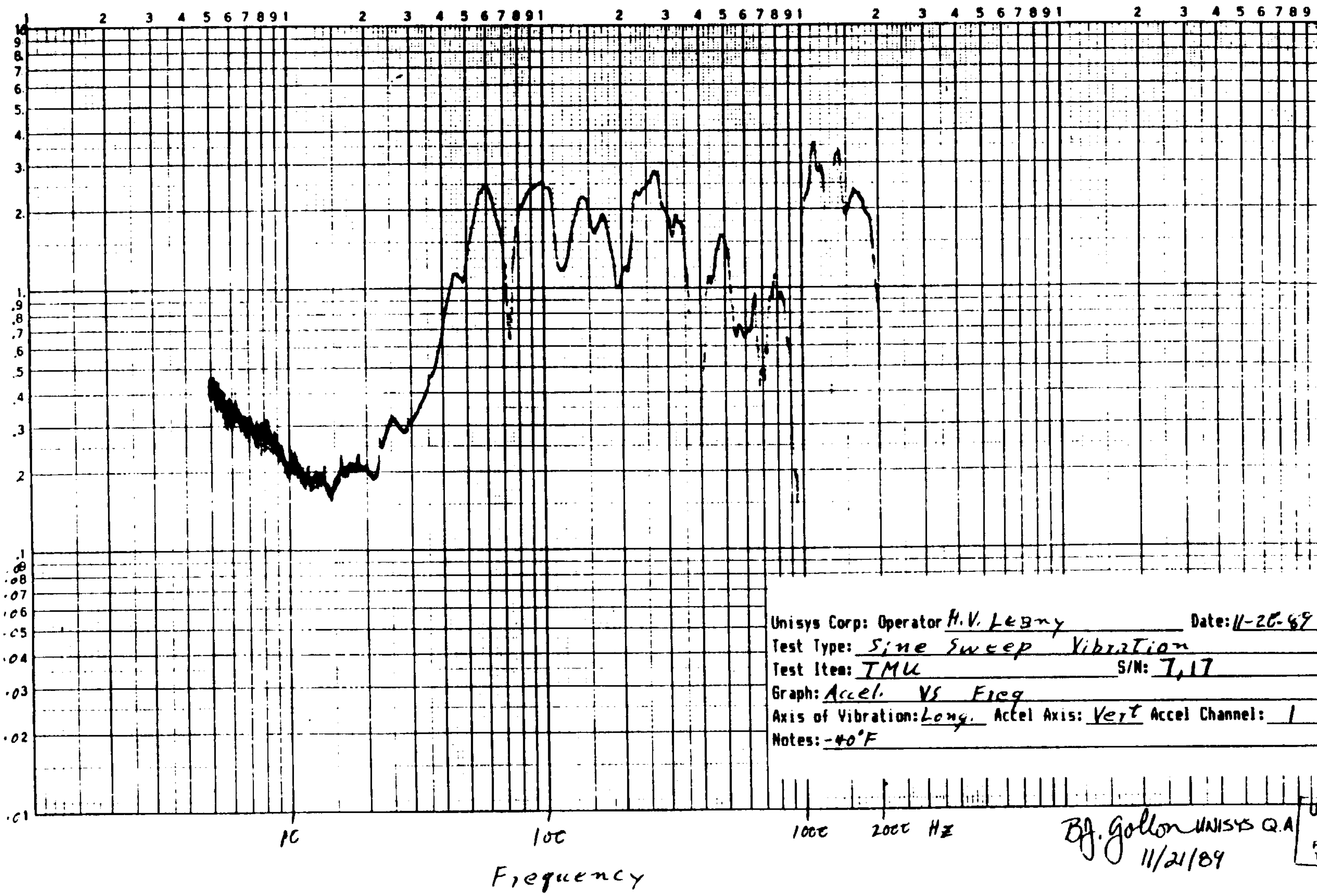
B-2

Dwell Input (Sweep)

ORIGINAL PAGE IS OF POOR QUALITY

CH 1

K&E LOGARITHMIC 358-125 KEUFFEL & ESSER CO. 3 X 5 CYCLES



BJ. Gollon UNISYS Q.A 11/21/89

UNISYS 12 FINAL TEST

Dwell Response B-3 (Sweep)

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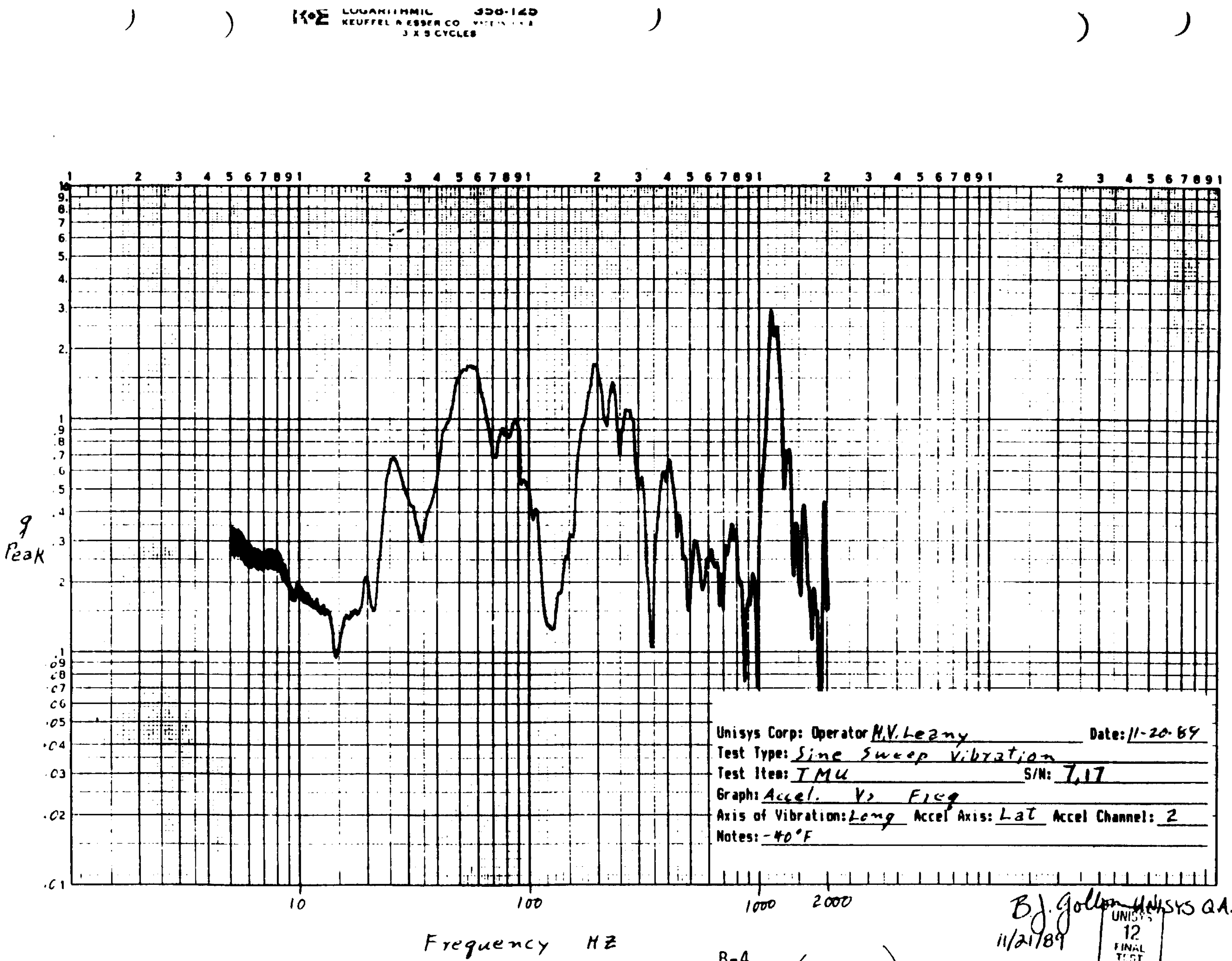
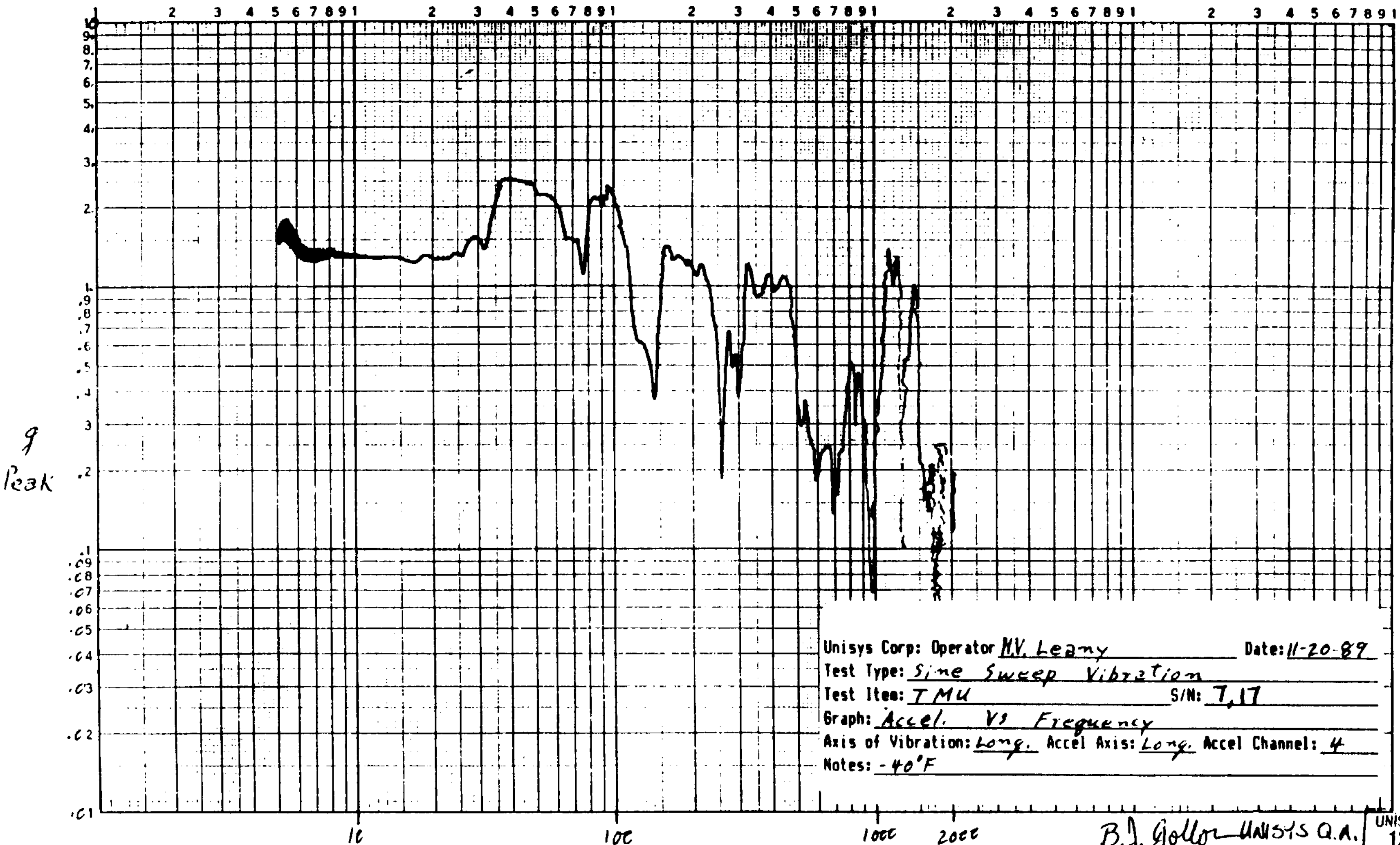


B-4

Dwell Response (sweep)

ORIGINAL PAGE IS OF POOR QUALITY

K&E LOGARITHMIC 358-125
KEUFFEL & ESSER CO.
3 X 5 CYCLES



Unisys Corp: Operator M.V. Leany Date: 11-20-89
Test Type: Sine Sweep Vibration
Test Item: TMU S/N: 7,17
Graph: Accel. Vs Frequency
Axis of Vibration: Long. Accel Axis: Long. Accel Channel: 4
Notes: -40°F

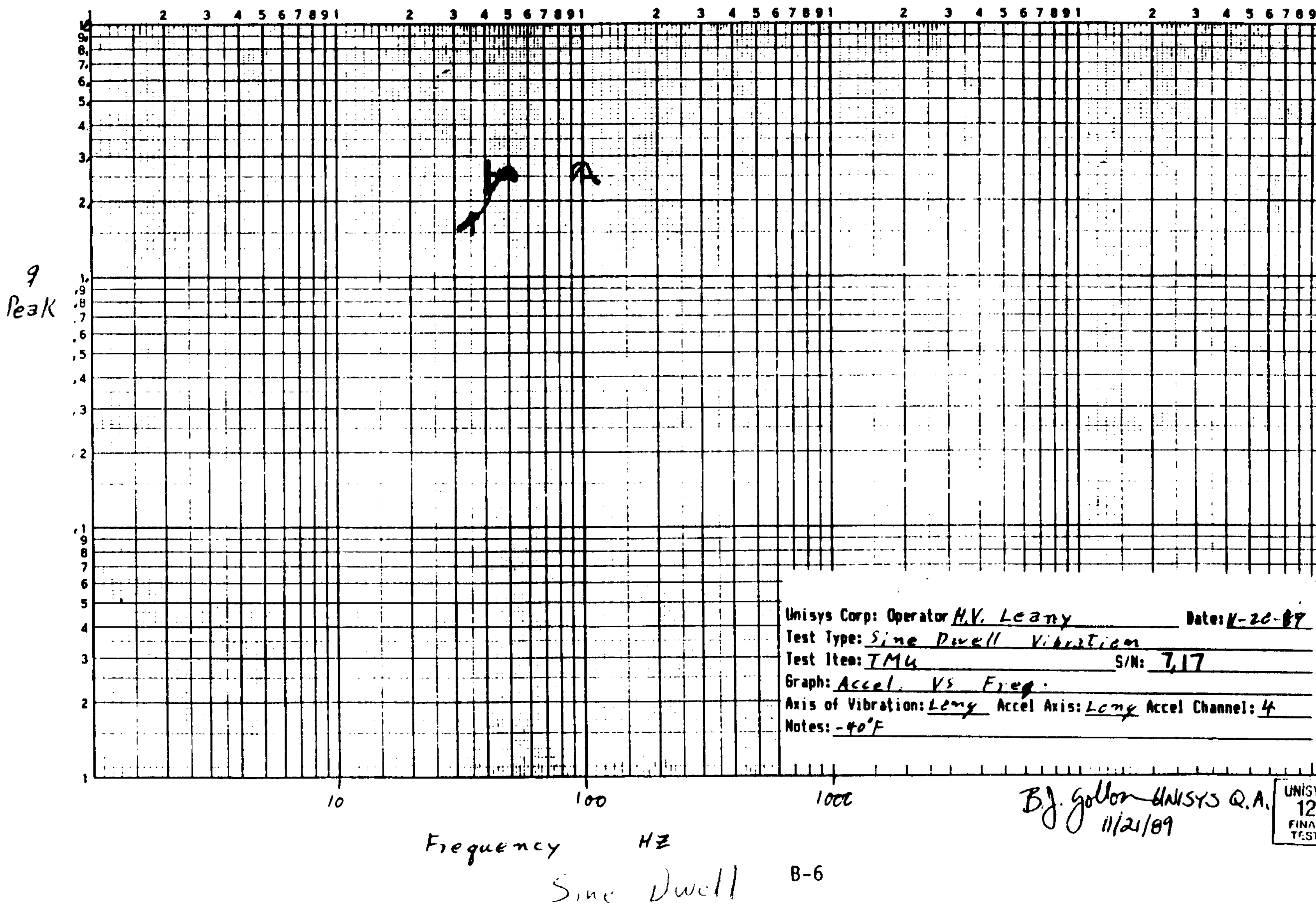
B.J. Gollor UNISYS Q.A.
11/21/89

UNISYS 12 FINAL TEST

Frequency HZ B-5

Dwell Response (Sweep)

K•E LOGARITHMIC 358-125
KEUFFEL & ESSER CO.
3 X 5 CYCLES



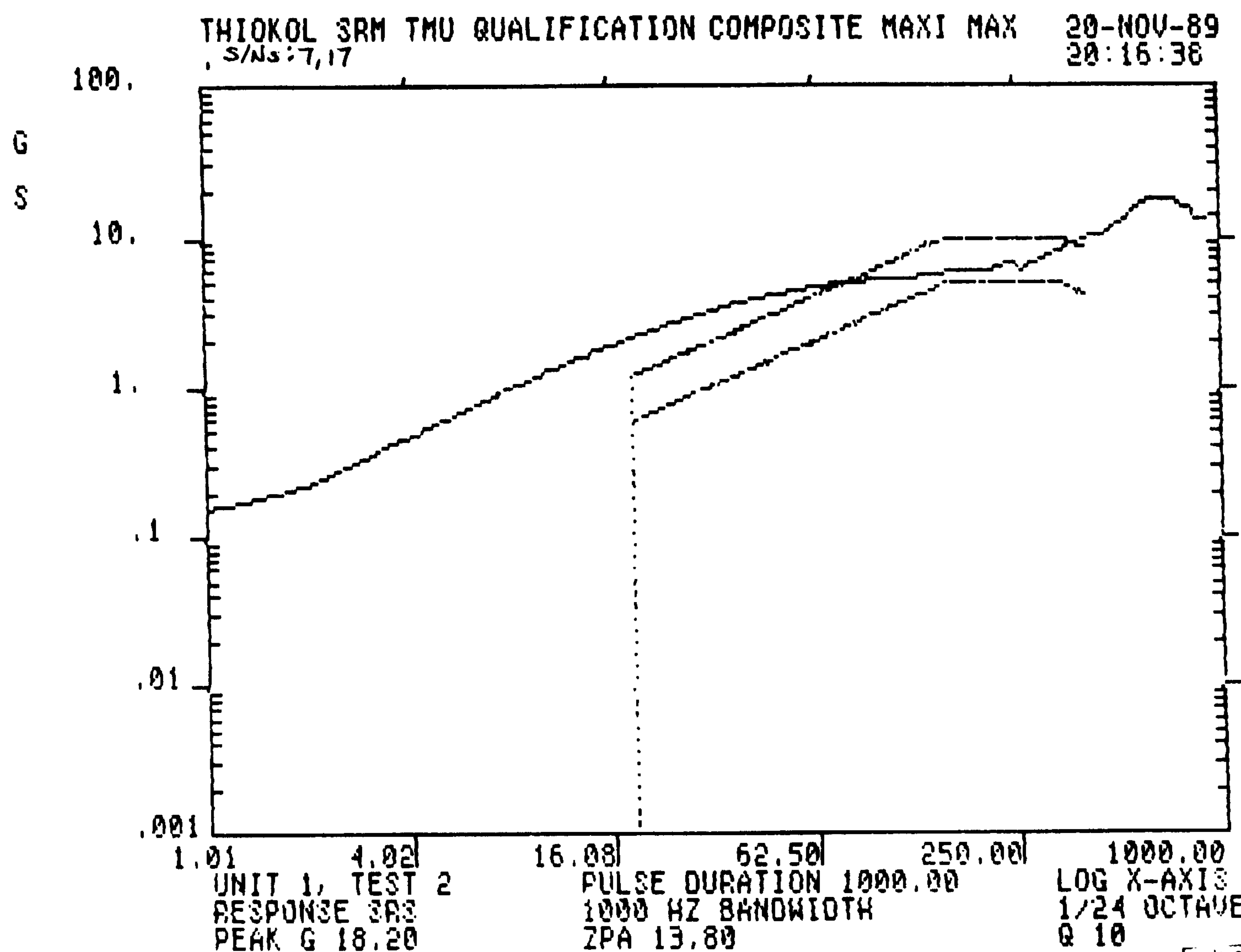
Unisys Corp: Operator H.V. Leany Date: 11-20-89
Test Type: Sine Dwell Vibration
Test Item: TMU S/N: 7,17
Graph: Accel. Vs Freq.
Axis of Vibration: Long Accel Axis: Long Accel Channel: 4
Notes: -40°F

B.J. Gollon UNISYS Q.A. 11/21/89

UNISYS 12 FINAL TEST

B-6

ORIGINAL PAGE IS OF POOR QUALITY

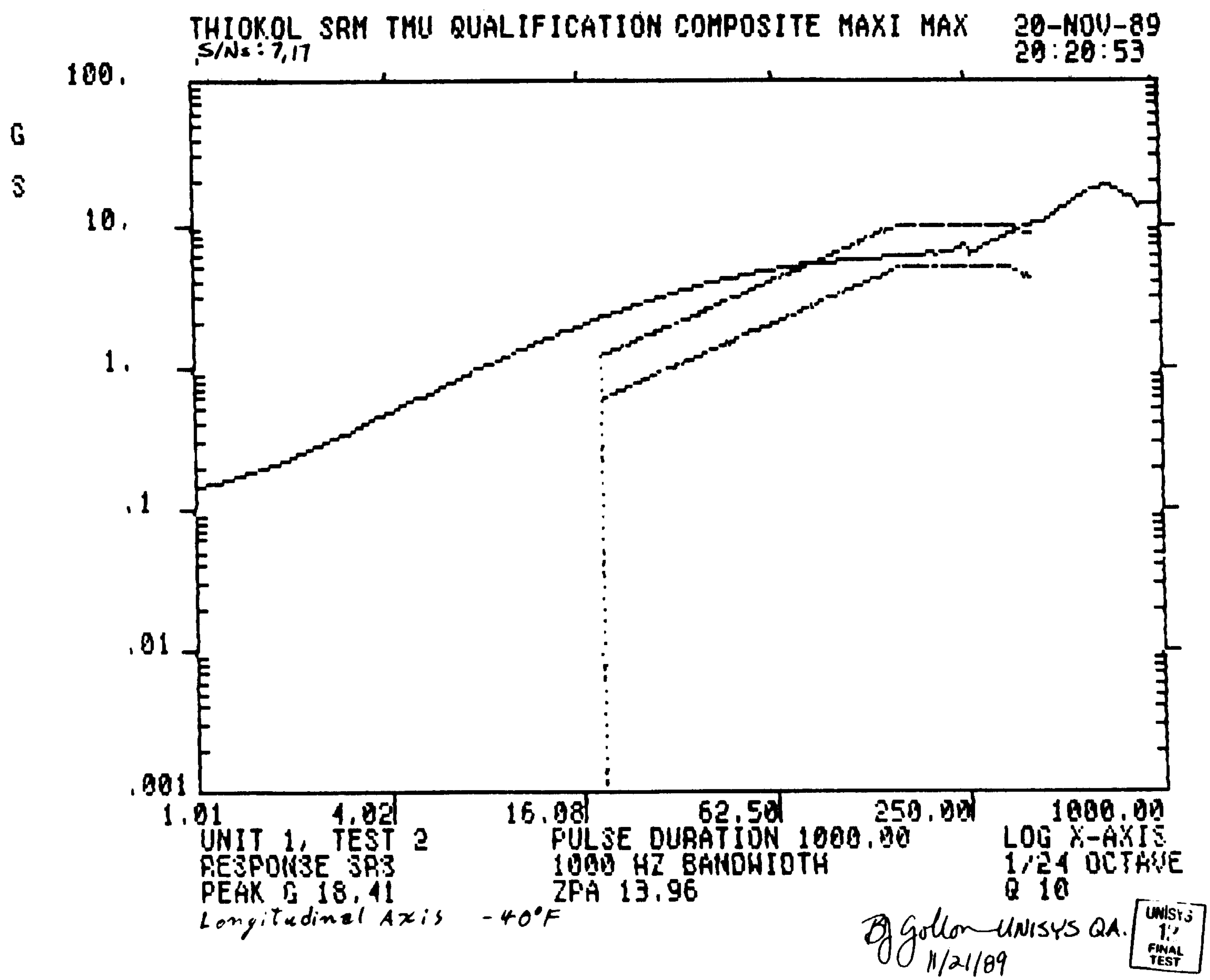


Longitudinal Axis -40°F

B.J. Gollon UNISYS QA 11/21/89

UNISYS 12 FINAL TEST

Shock 1

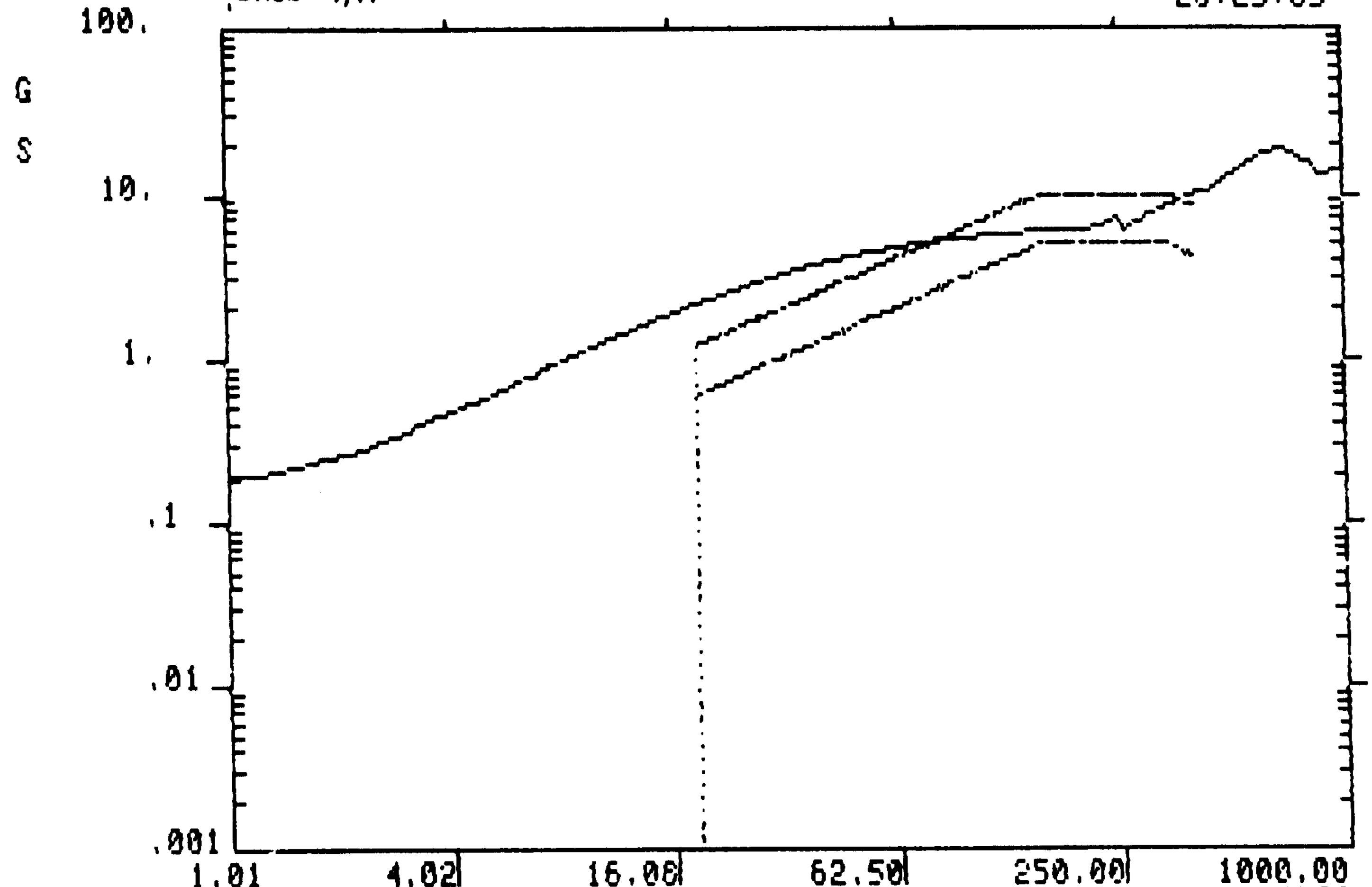


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
S/Ns: 7,17
20-NOV-89
20:20:53
100.
10.
1.
.1
.01
.001
G
S
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE SR3
PEAK G 18.41
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 13.96
LOG X-AXIS
1/24 OCTAVE
Q 10
Longitudinal Axis -40°F
UNISYS QA.
11/21/89
FINAL TEST

Sh.k #2

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 20-NOV-89 20:25:03

S/Ns: 7,17



UNIT 1, TEST 2
RESPONSE 3R3
PEAK G 18.41

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 13.96

LOG X-AXIS
1/24 OCTAVE
Q 10

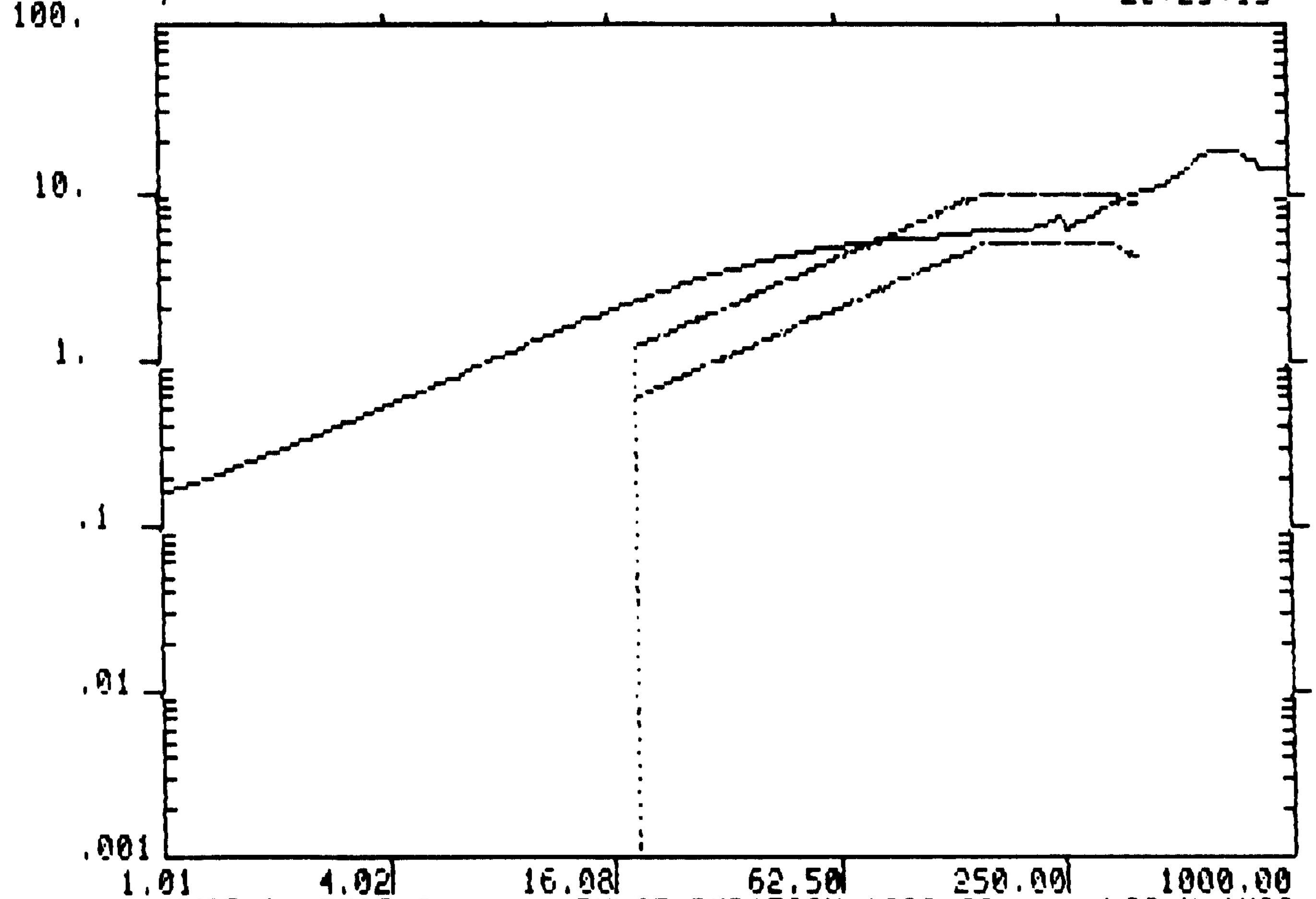
Longitudinal Axis -40°F

B.J. Gollon UNISYS Q.A. 11/21/89

UNISYS 12 FINAL TEST

Shock # 3

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 20-NOV-89
S/Ns: 7,17 20:29:19



UNIT 1, TEST 2
RESPONSE SR3
PEAK G 18.20
Longitudinal Axis -40°F

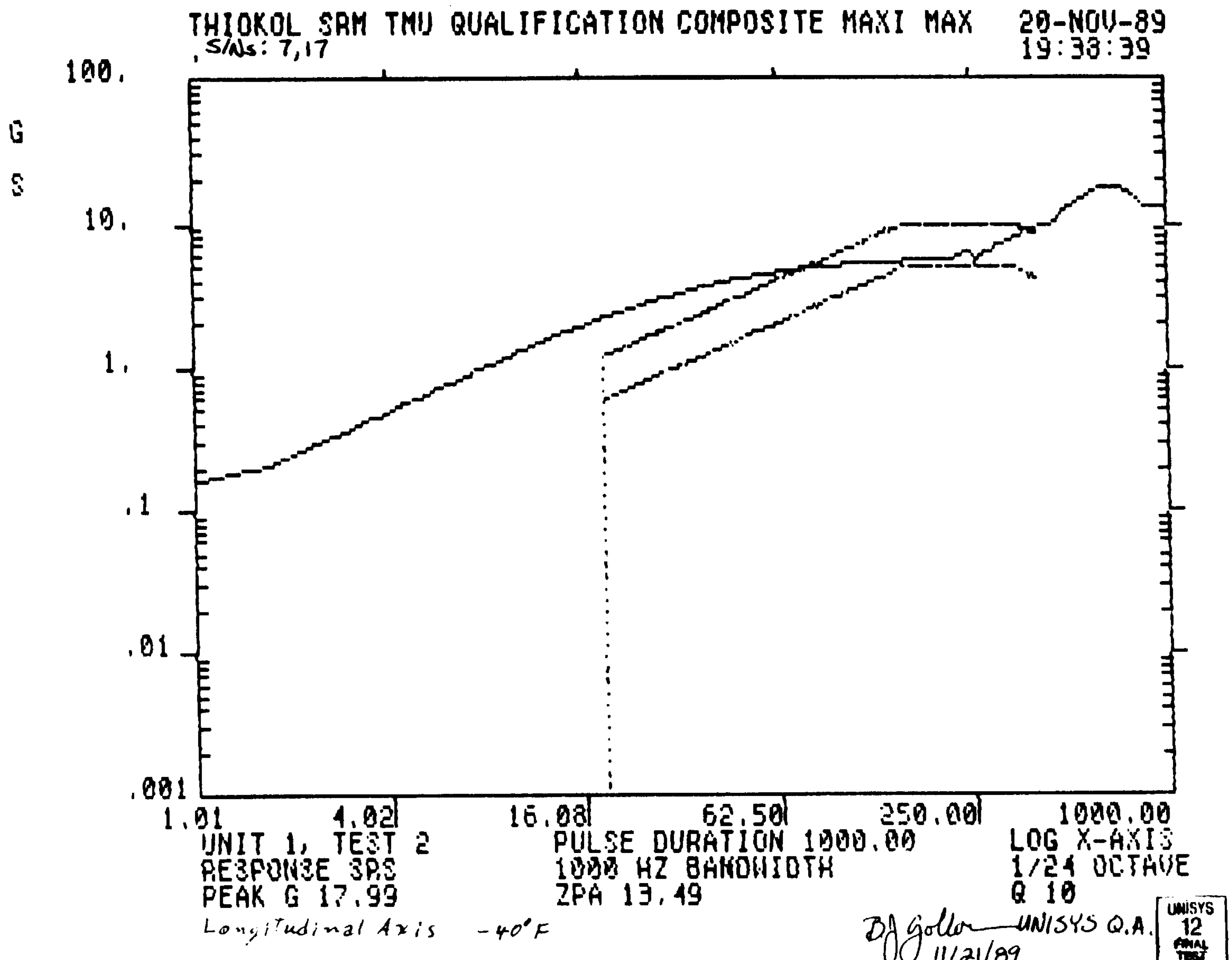
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 13.96

LOG X-AXIS
1/24 OCTAVE
Q 10

BJ Gollon UNISYS QA. 11/21/89

UNISYS 12 FINAL TEST

shock # 4


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
20-NOV-89
19:38:39
S/Ns: 7,17
G
S
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 17.99
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 13.49
LOG X-AXIS
1/24 OCTAVE
Q 10
Longitudinal Axis -40°F
BJ Gollor UNISYS Q.A.
11/21/89
UNISYS
12
FINAL
TEST

B-11

Shock #5

APPENDIX C

UNISYS CONTROL AND RESPONSE DATA FROM

TANGENTIAL AXIS TRANSPORTATION TEST

(-40°F ± 10°F)

ORIGINAL PAGE IS
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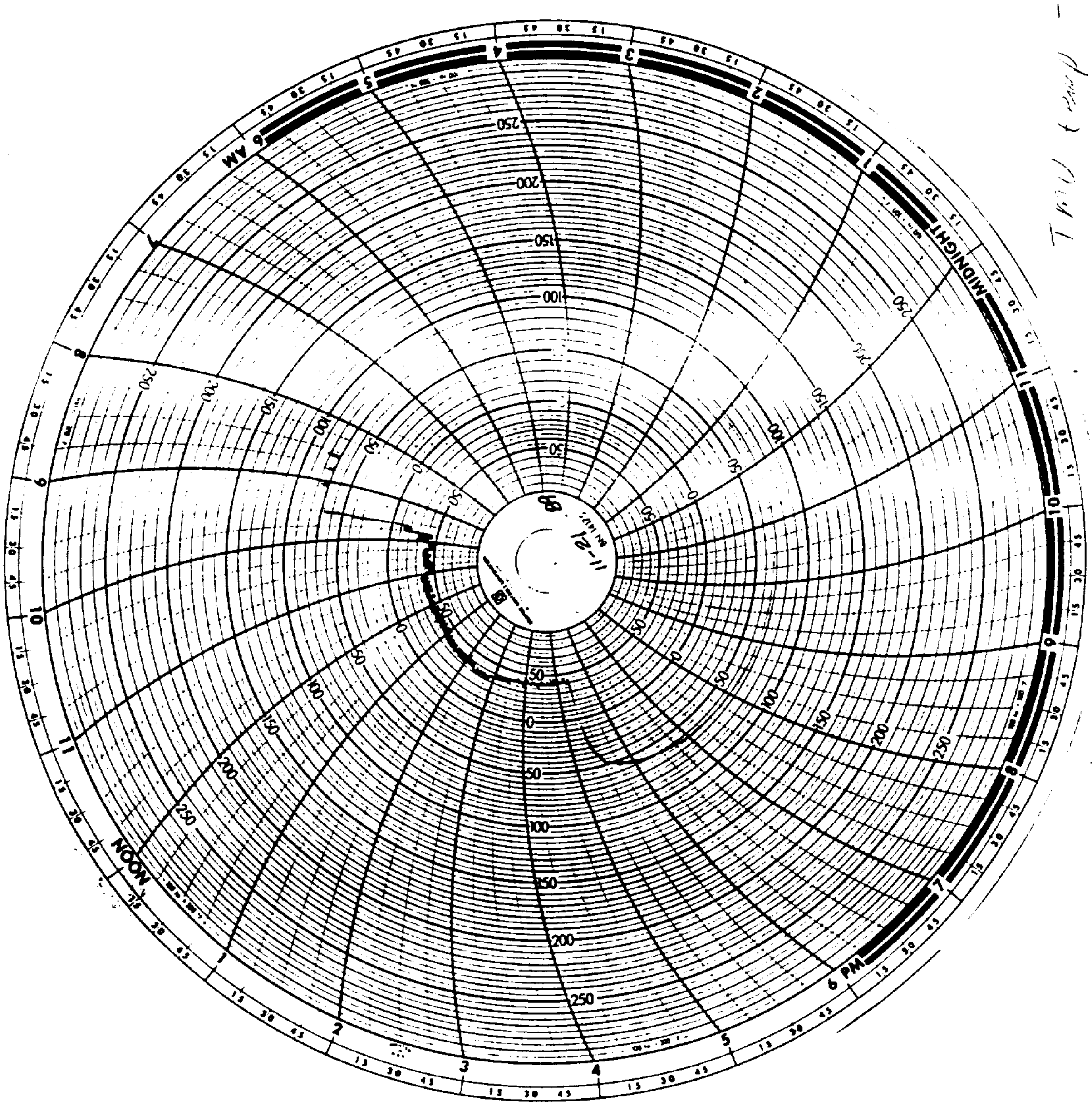
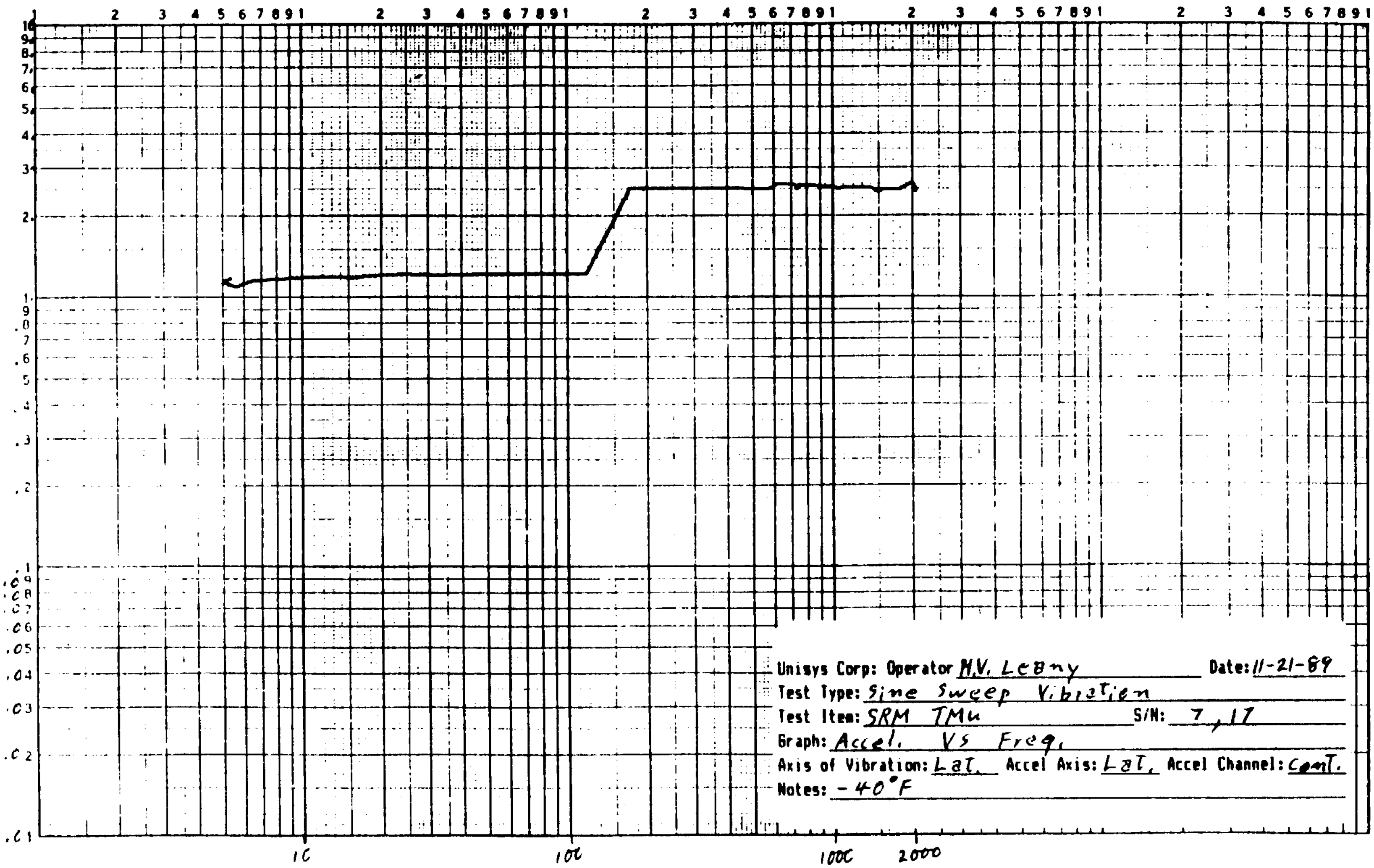
TMV temp -40°F tangential



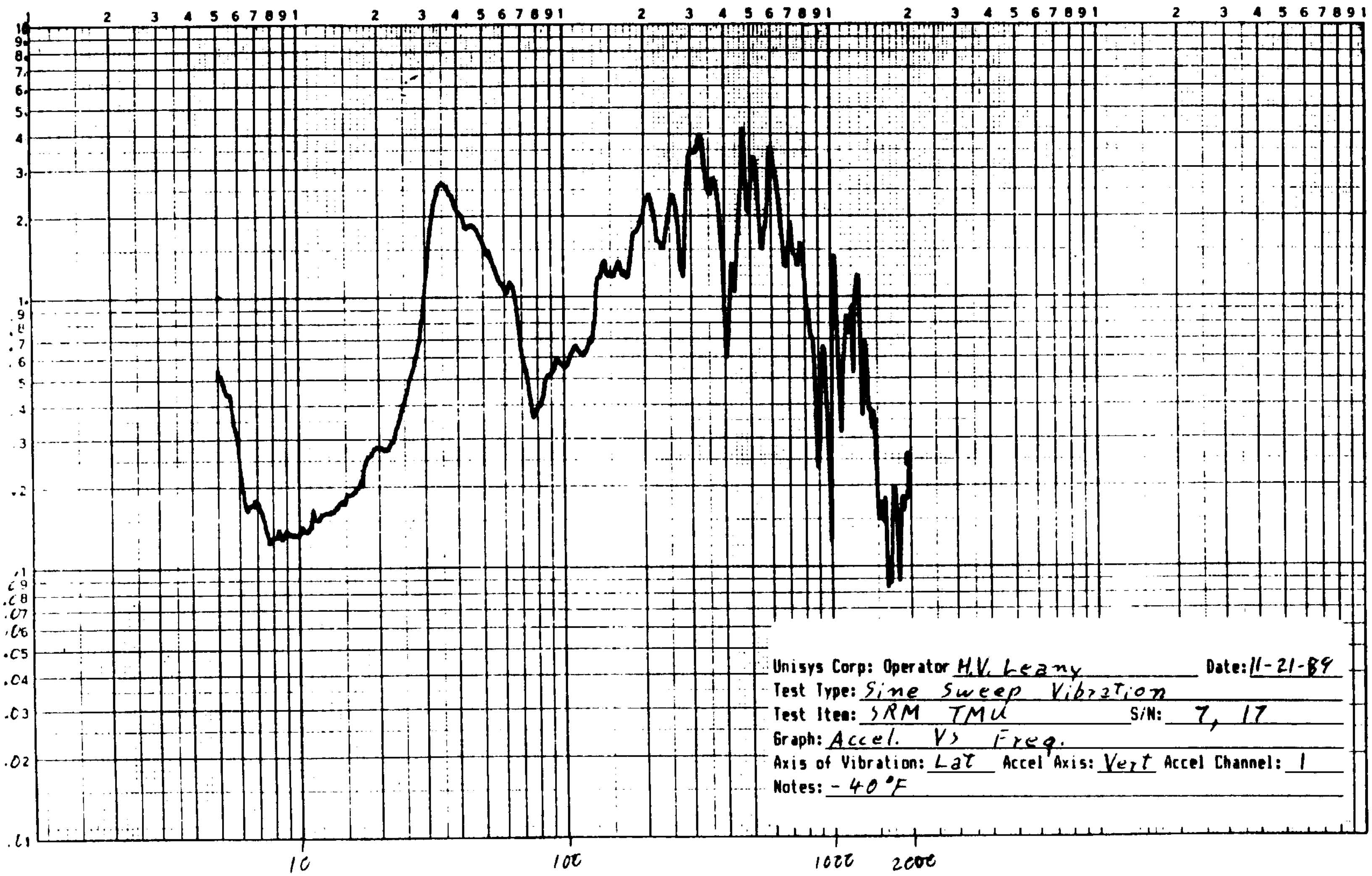


Unisys Corp: Operator M.V. Leany Date: 11-21-89
Test Type: Sine Sweep Vibration
Test Item: SRM TMu S/N: 7, 17
Graph: Accel. Vs Freq.
Axis of Vibration: Lat. Accel Axis: Lat. Accel Channel: Cont.
Notes: -40°F

Frequency HZ

C-2

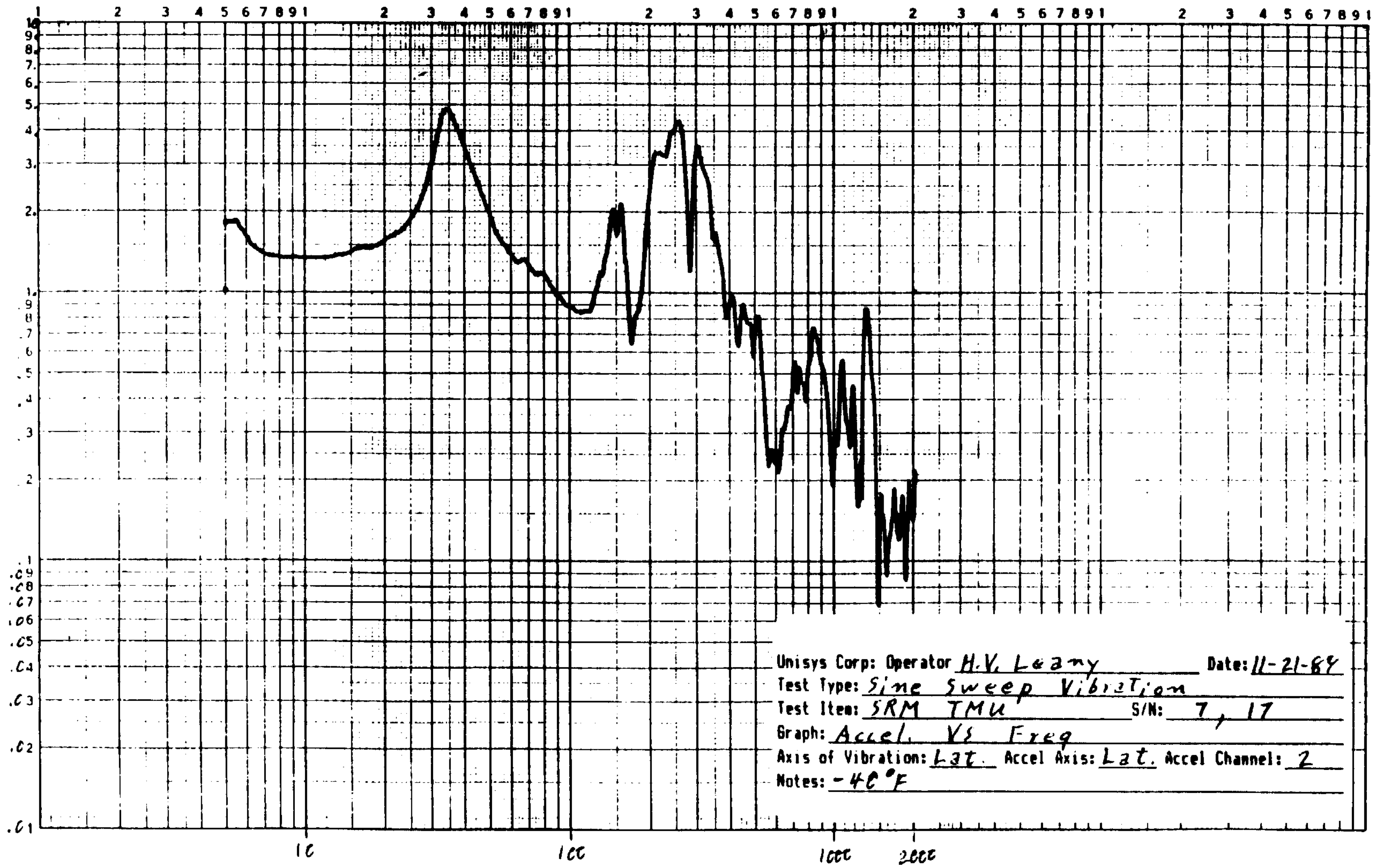
Sine Sweep Input



Frequency HZ

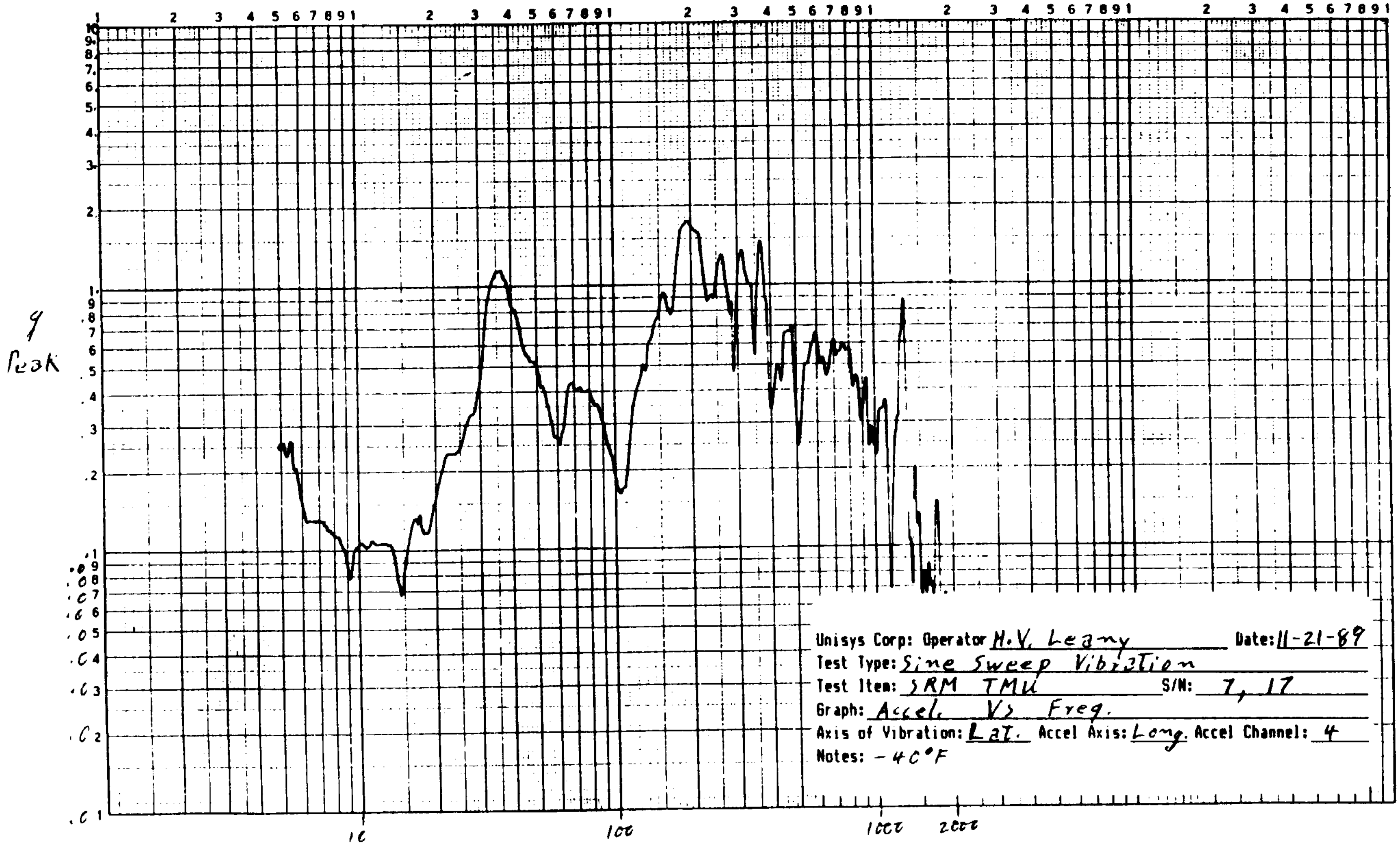
C-3

Sine Sweep Response



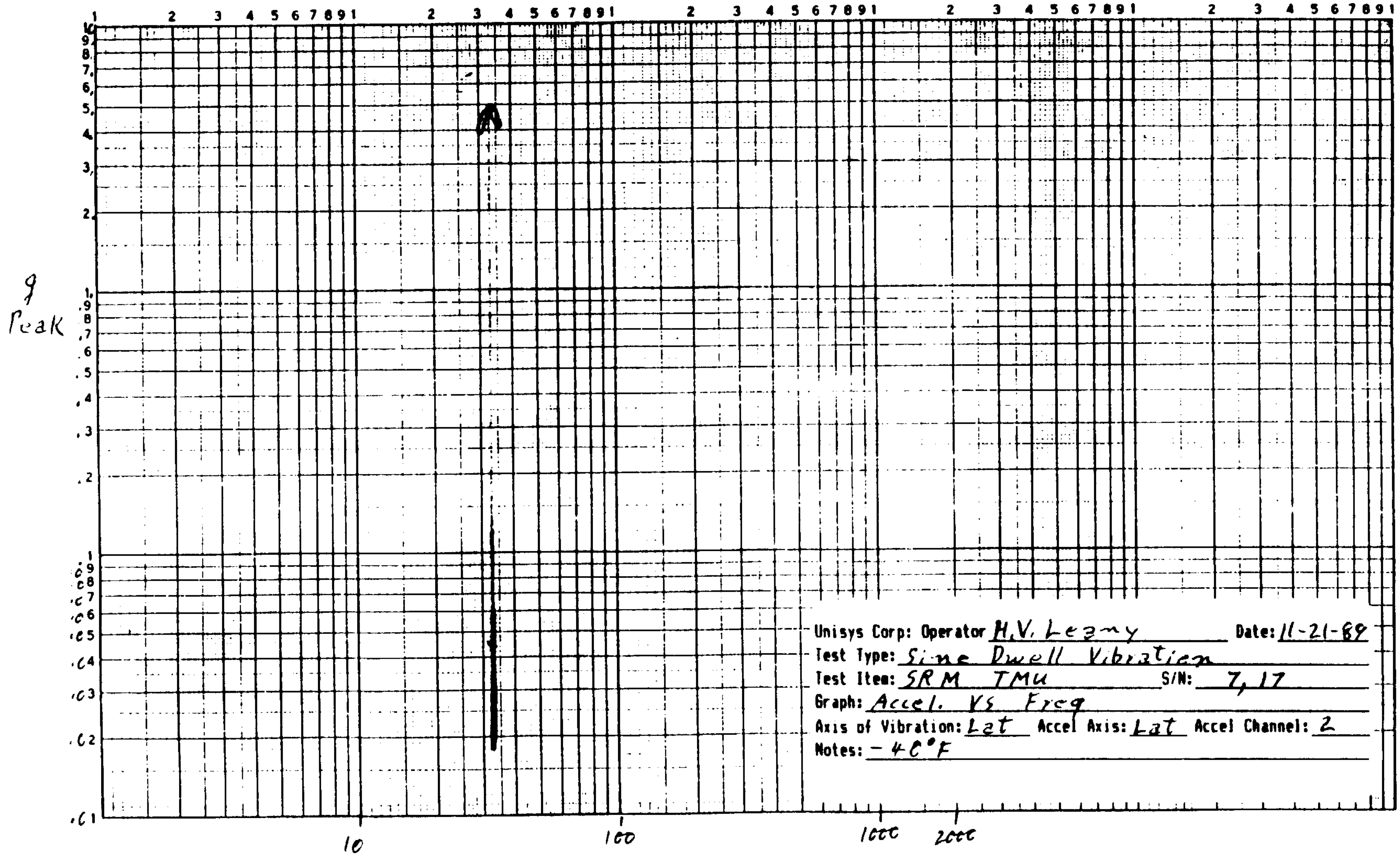
Frequency HZ

Sine Sweep Response



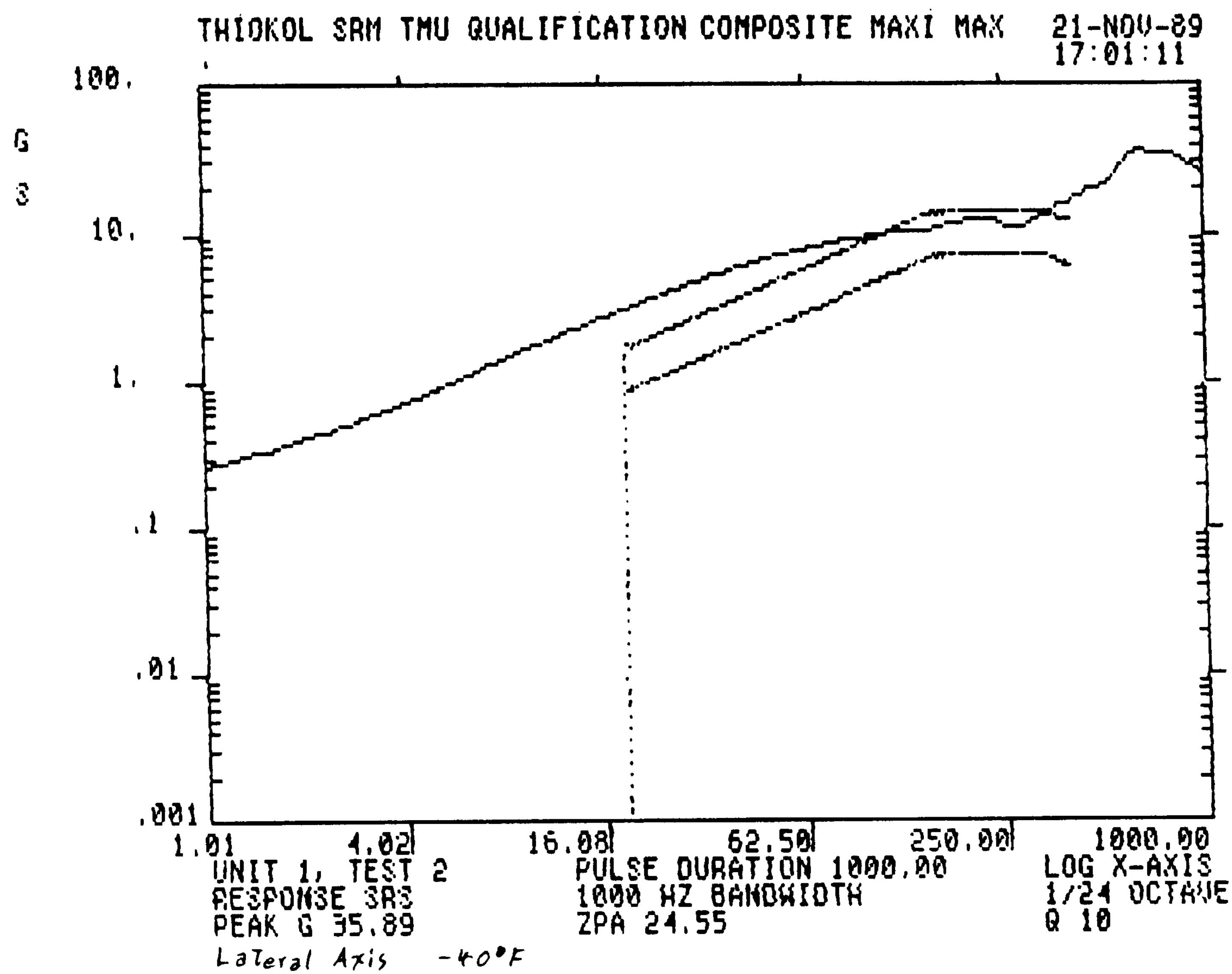
C-5

Sine Sweep Response

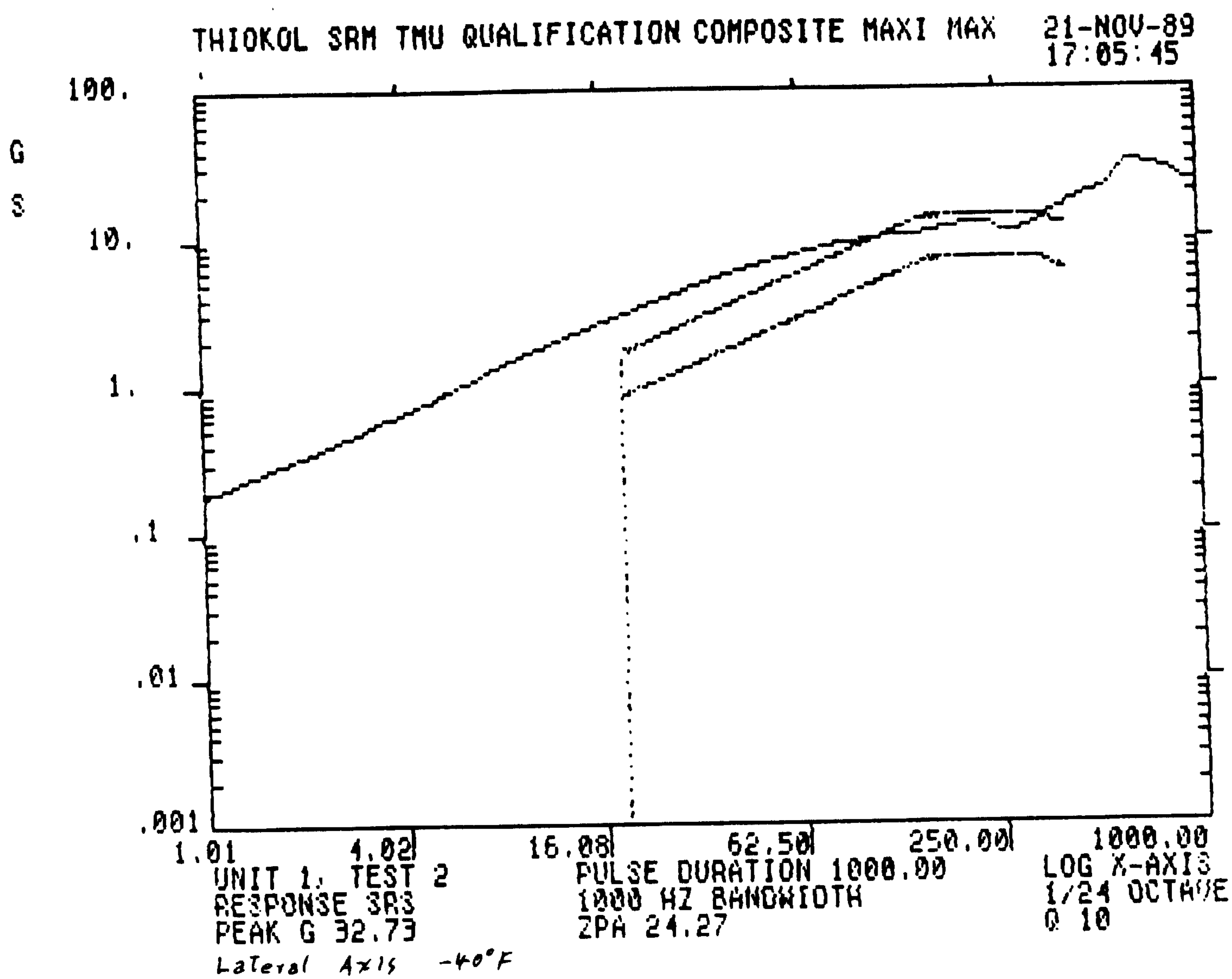


C-6

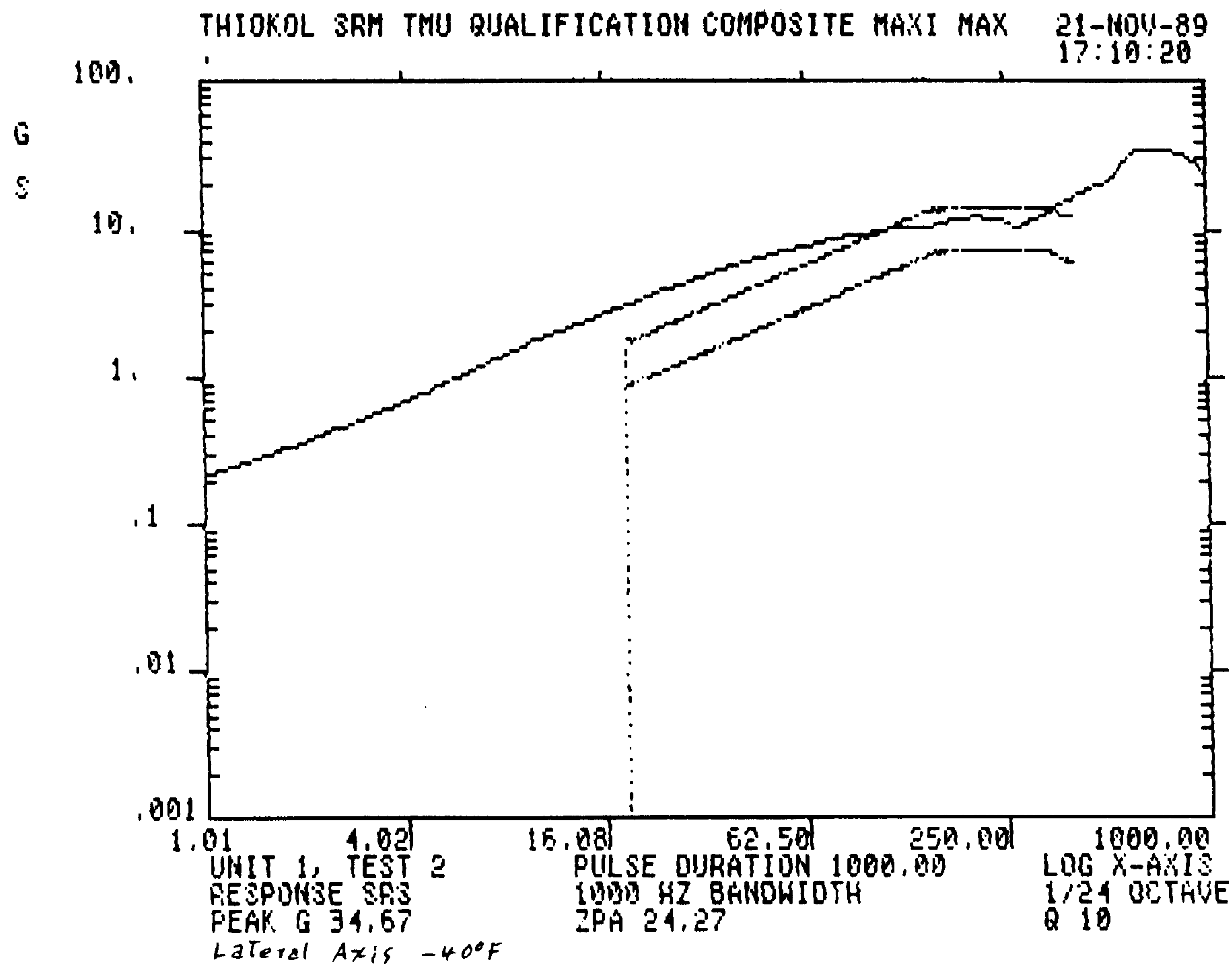
Sine Sweep Response


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
21-NOV-89
17:01:11
100.
10.
1.
.1
.01
.001
G
S
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 35.89
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 24.55
LOG X-AXIS
1/24 OCTAVE
Q 10
Lateral Axis -40°F

Shock #1

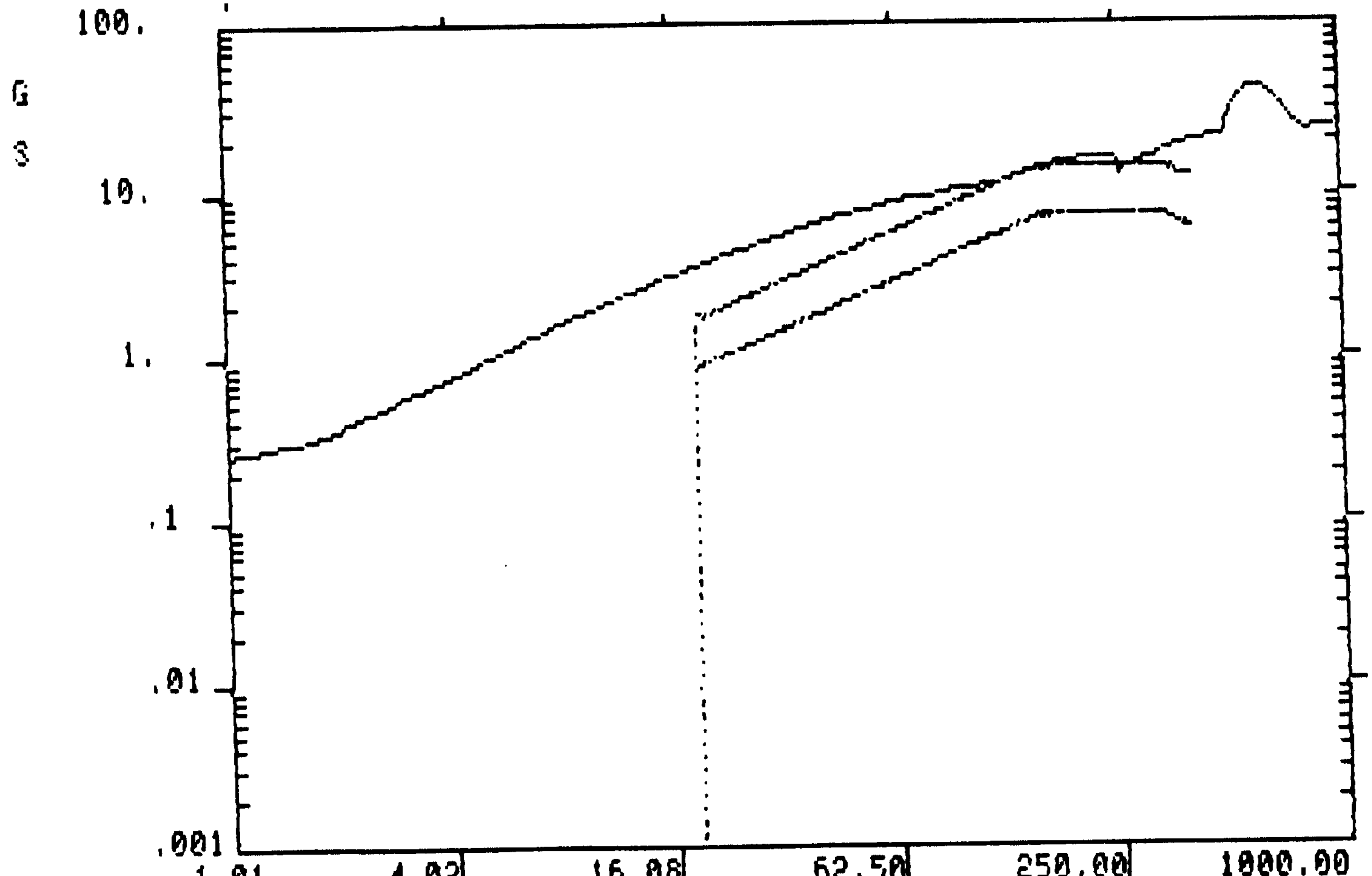

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
21-NOV-89
17:05:45
G
S
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 32.73
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 24.27
LOG X-AXIS
1/24 OCTAVE
Q 10
Lateral Axis -40°F

Shock #2


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
21-NOV-89
17:10:20
GS
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 34.67
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 24.27
LOG X-AXIS
1/24 OCTAVE
Q 10
Lateral Axis -40°F

Shock #3

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 21-NOV-89 17:16:09



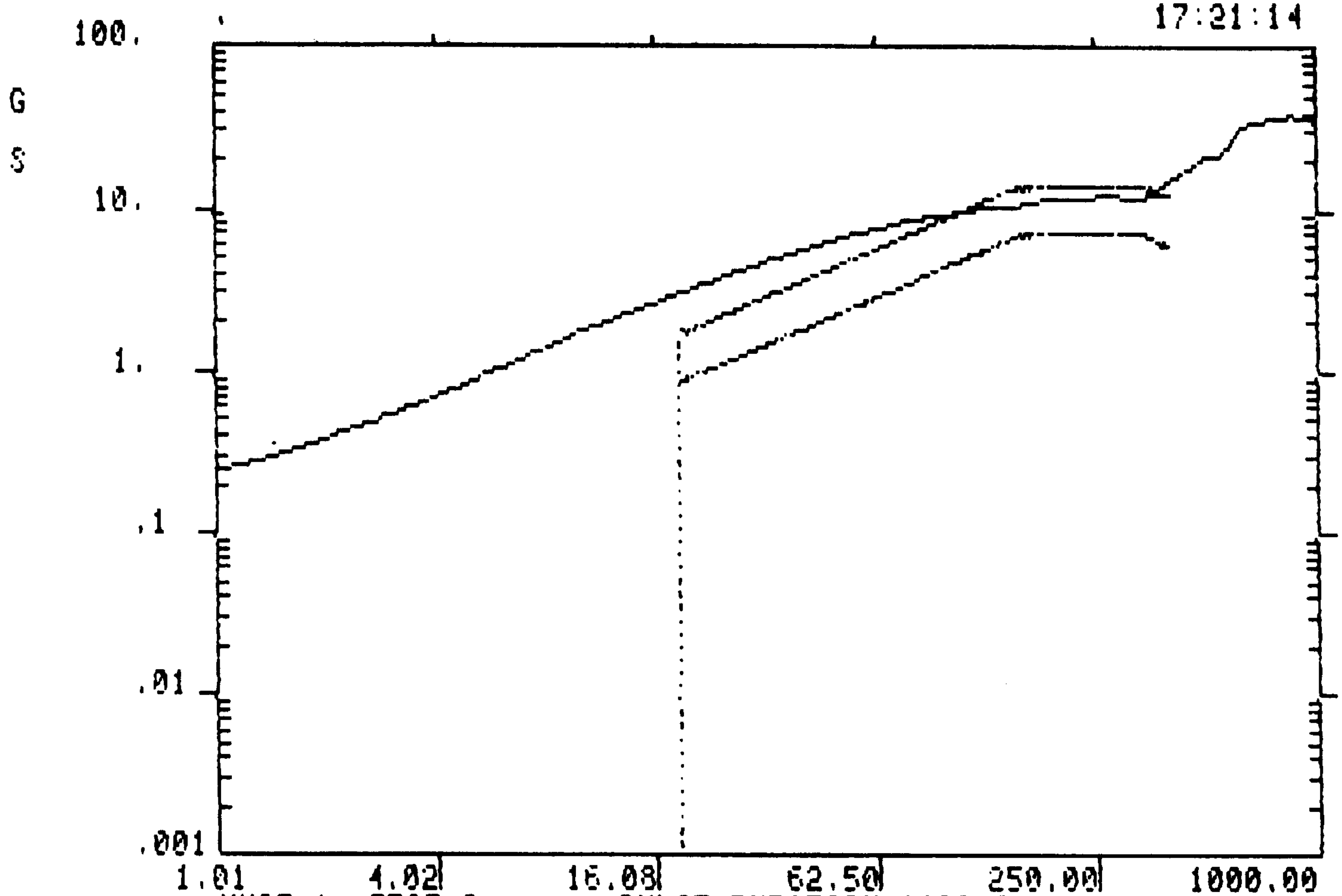
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 42.17
Lateral Axis -40°F

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 26.30

LOG X-AXIS
1/24 OCTAVE
Q 10

Shock #4

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 21-NOV-89 17:21:14



UNIT 1, TEST 2
RESPONSE SRS
PEAK G 38.46

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 35.08

LOG X-AXIS
1/24 OCTAVE
Q 10

Lateral Axis -40°F

Shock #5

APPENDIX D

UNISYS CONTROL AND RESPONSE DATA FROM TANGENTIAL AXIS TRANSPORTATION TEST

(70°F ± 10°F)

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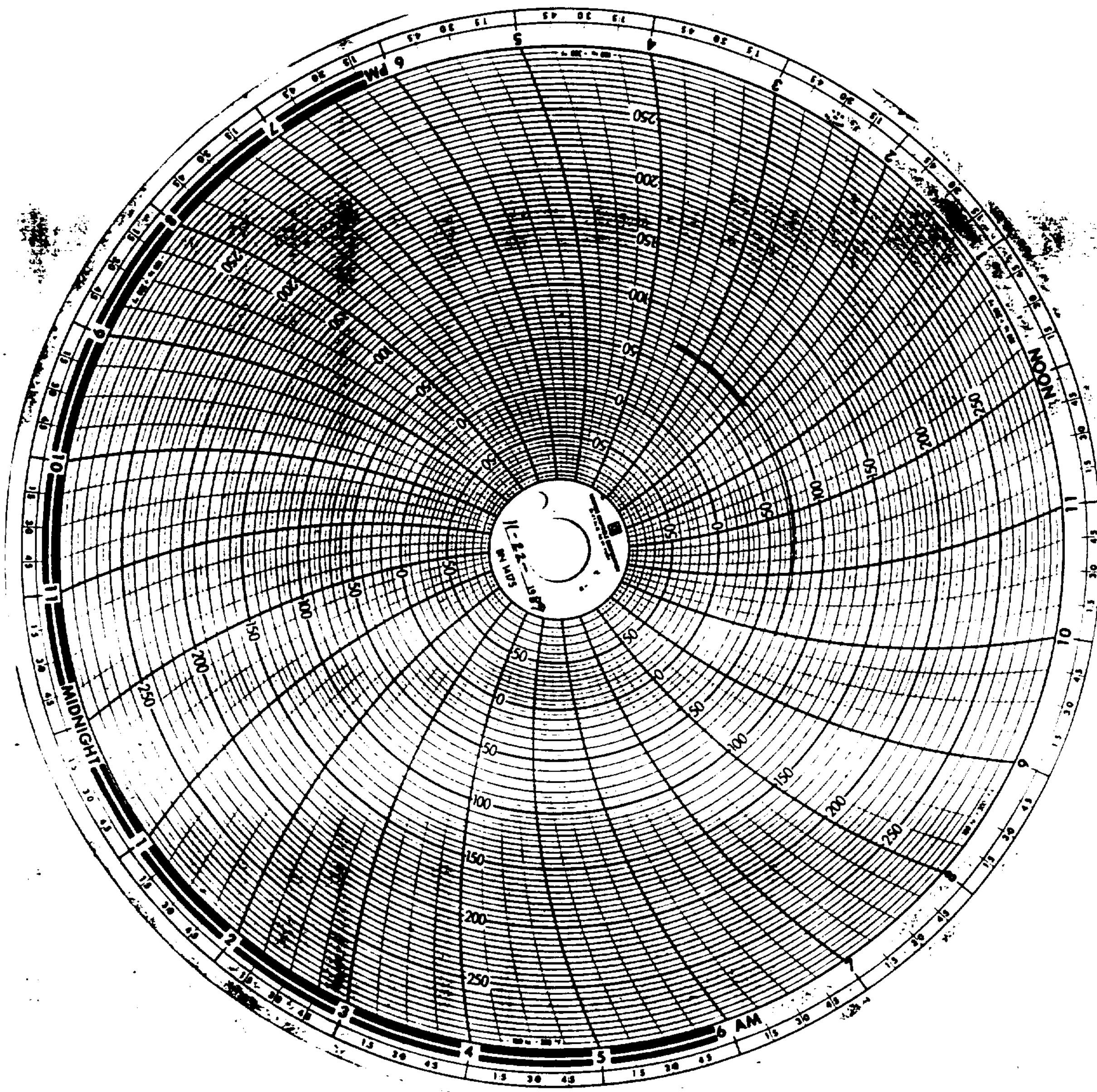

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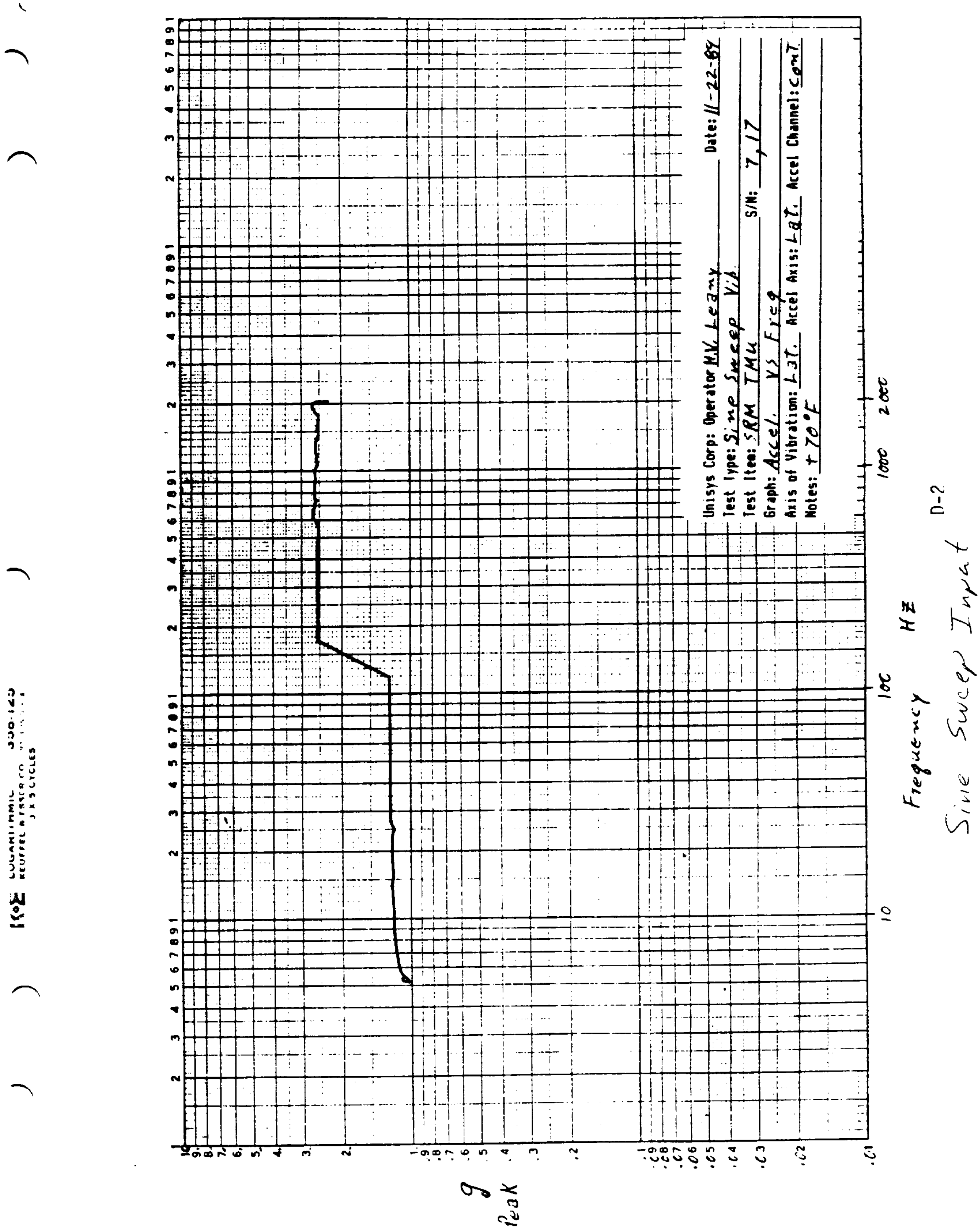
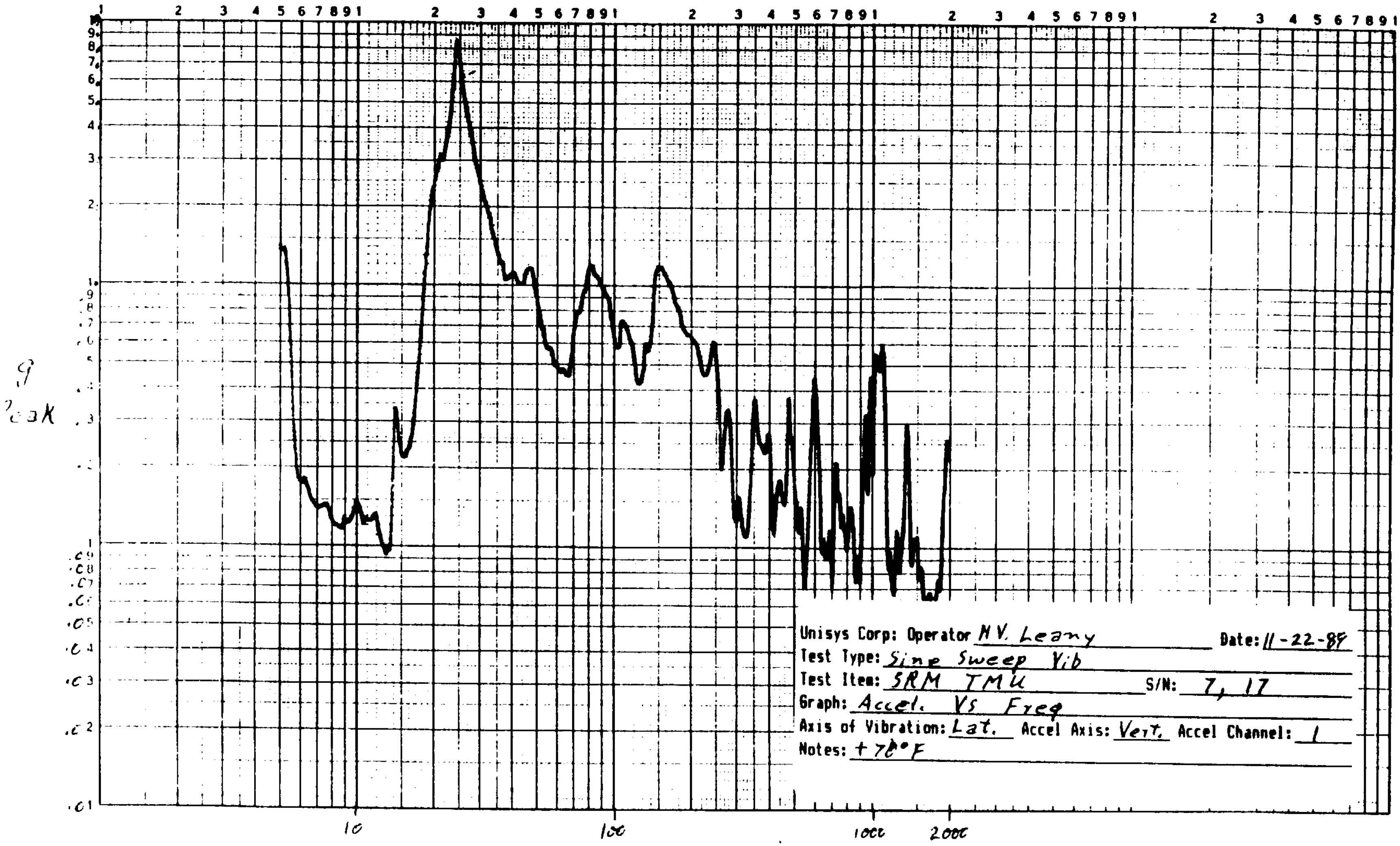
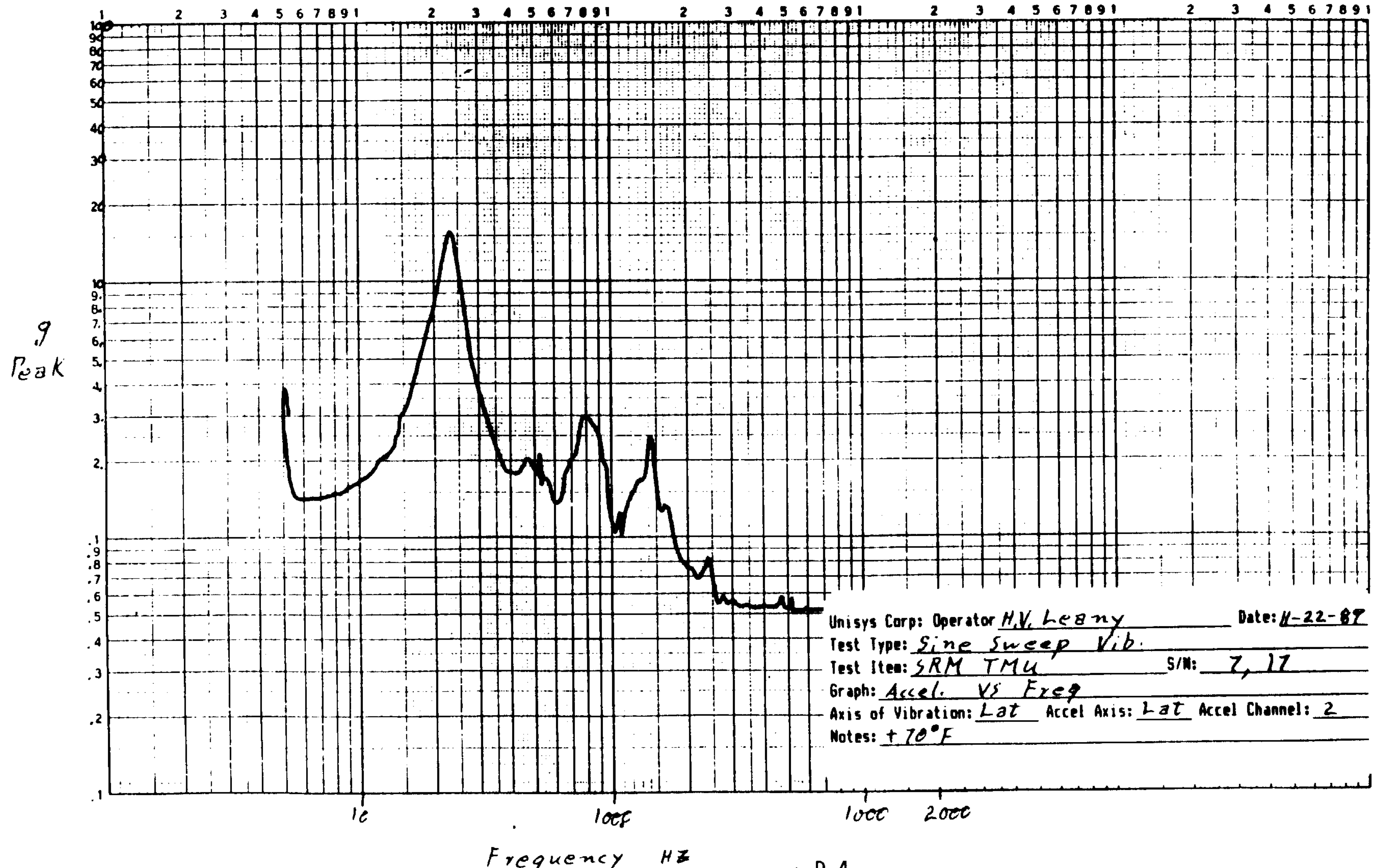




Frequency HZ

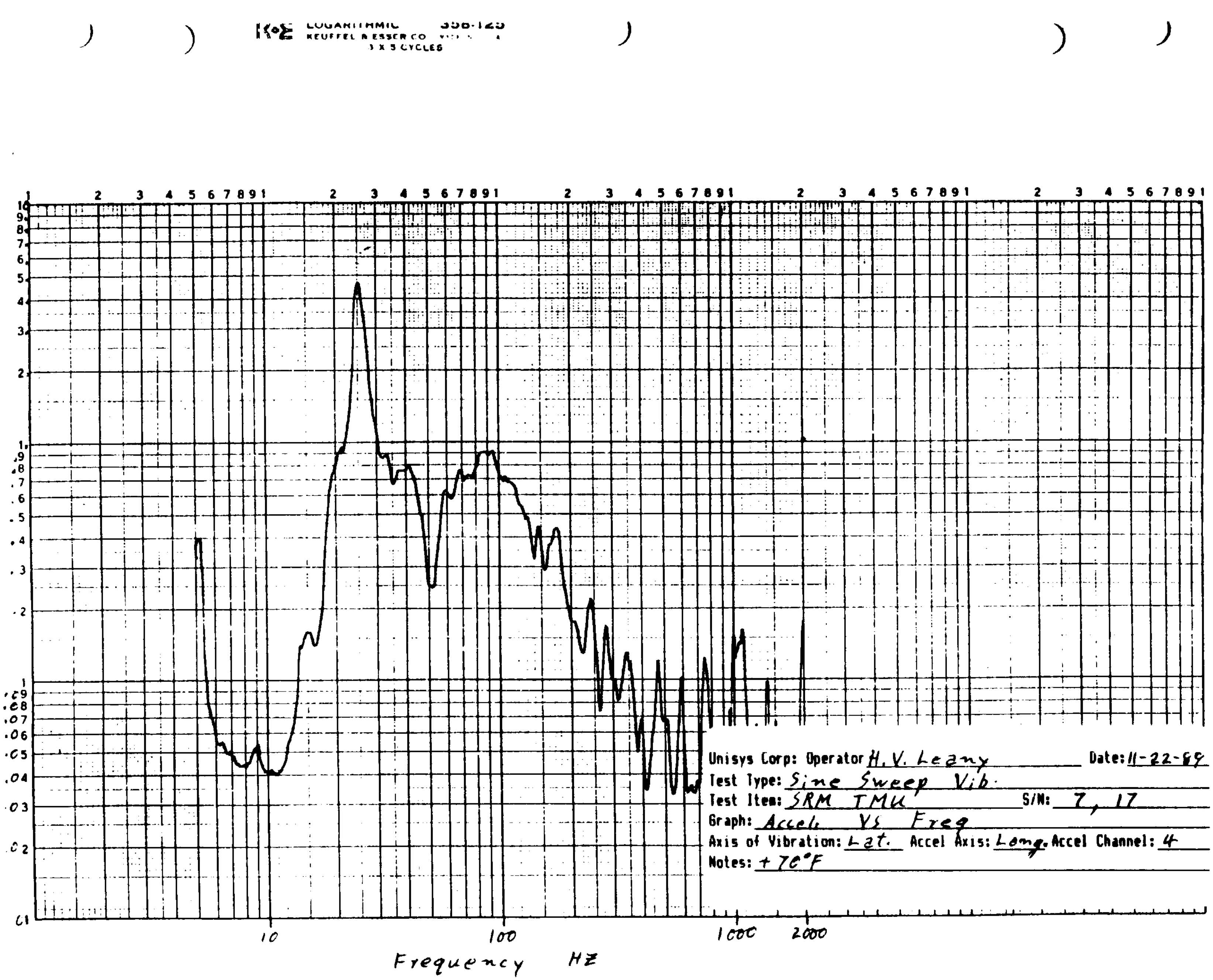
Sine Sweep Response

D-3



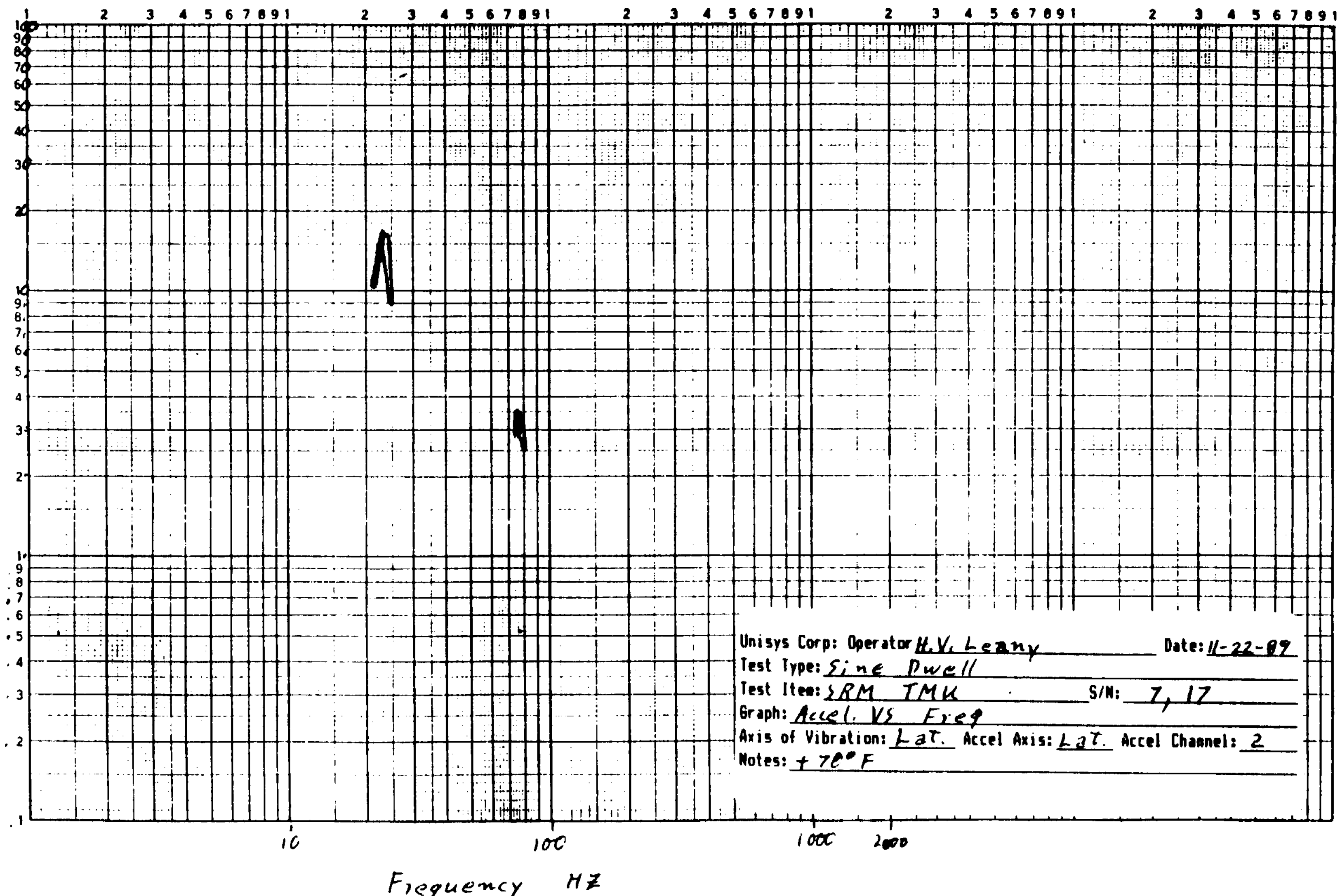
D-4

Sine Sweep Response



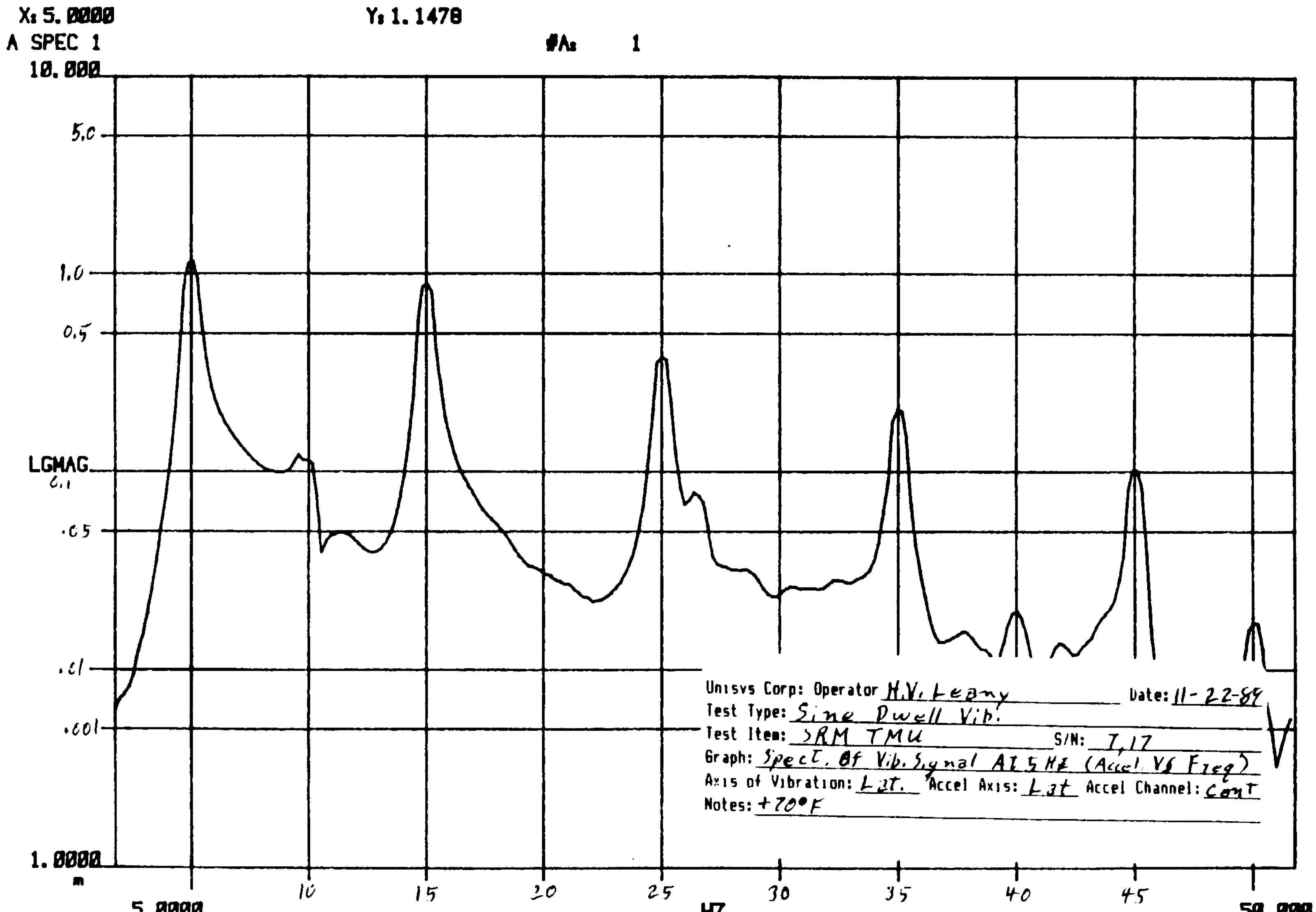
D-5

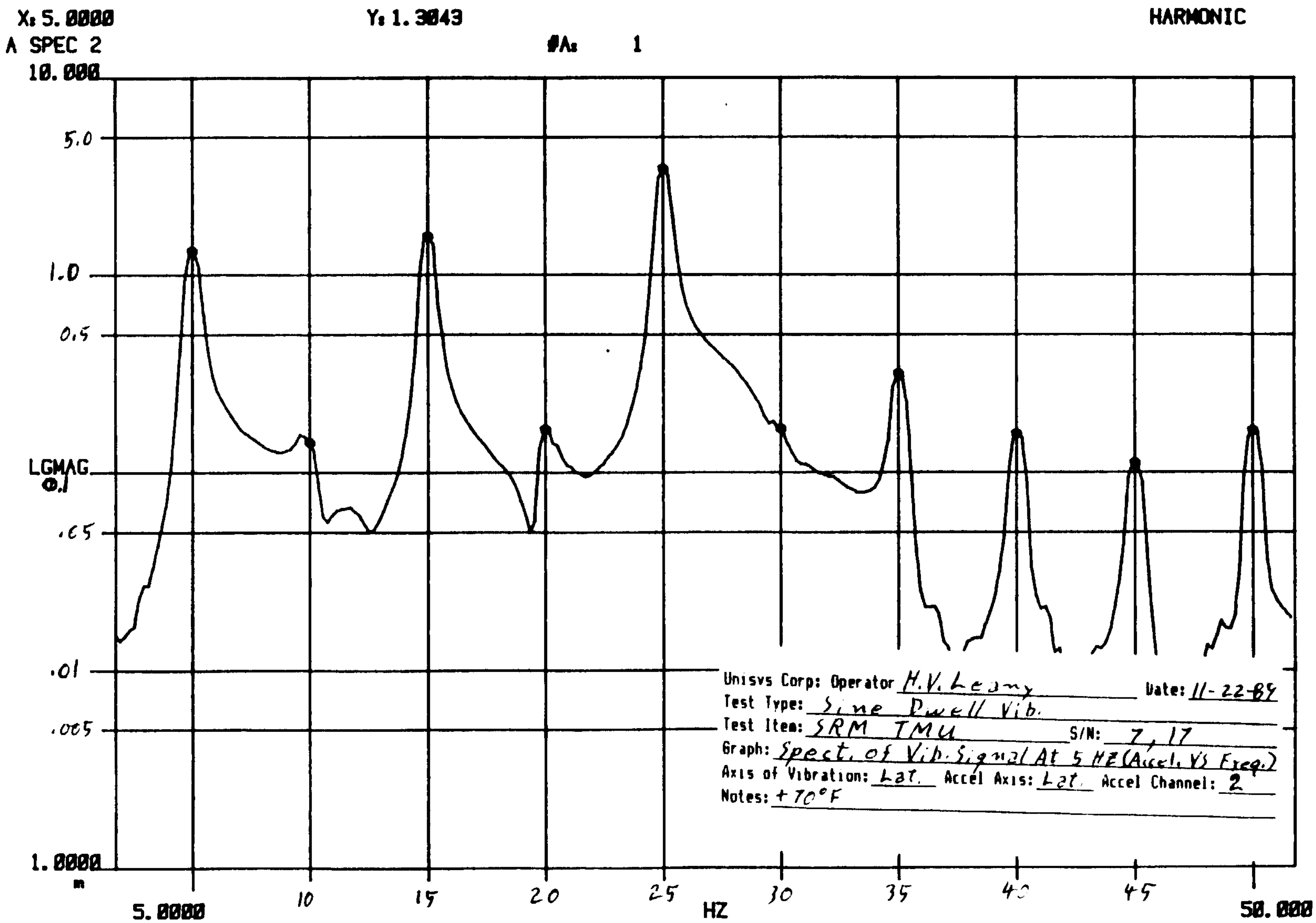
Sine Sweep Response



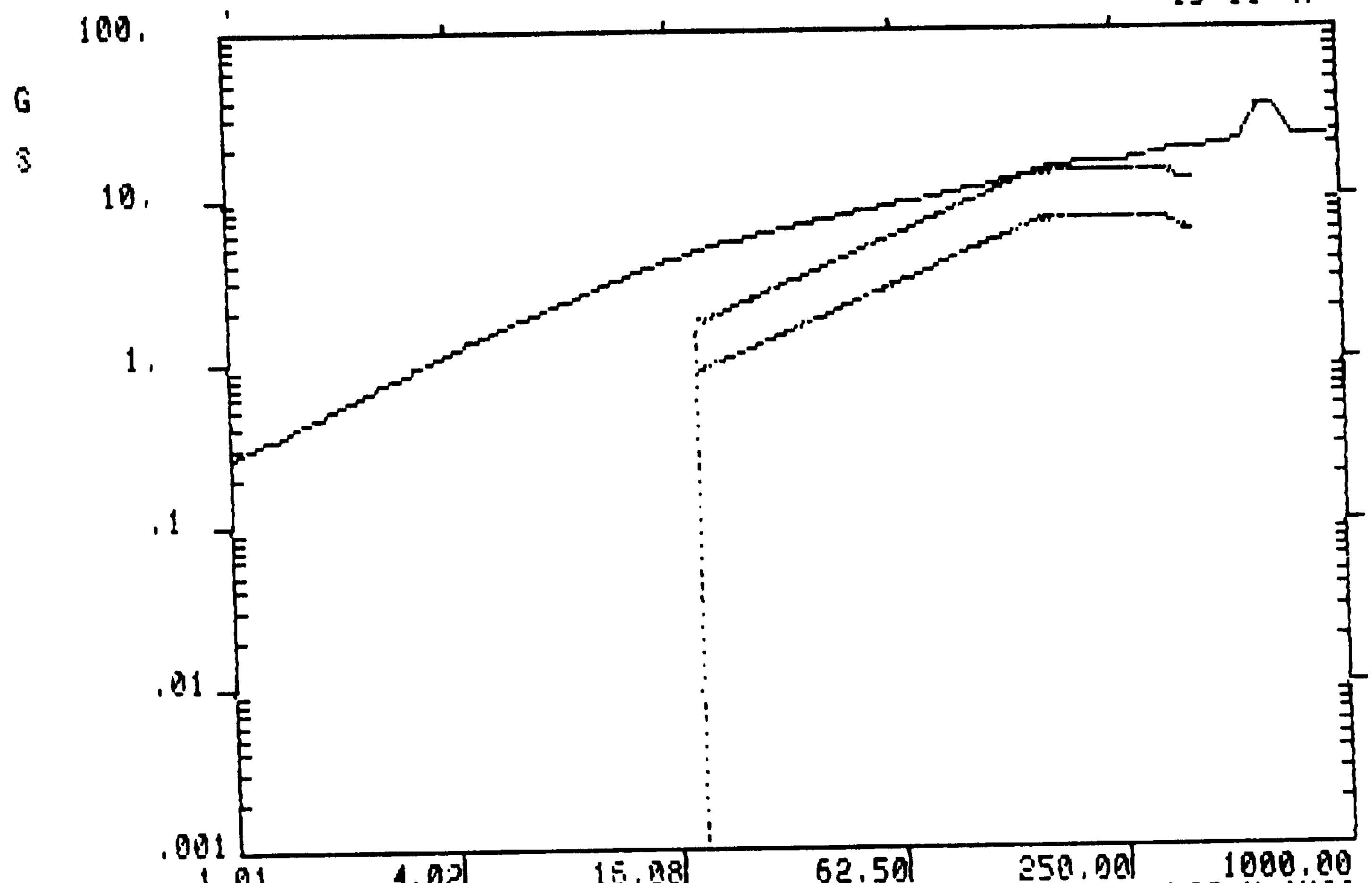
Unisys Corp: Operator H.V. Leany Date: 11-22-89
Test Type: Sine Dwell
Test Item: SRM TMK S/N: 7, 17
Graph: Accel. VS Freq
Axis of Vibration: Lat. Accel Axis: Lat. Accel Channel: 2
Notes: + 70°F

Sine Dwell


X: 5.0000
Y: 1.1478
A SPEC 1
#A: 1
10.000
5.0
1.0
0.5
LGMAG
0.1
.05
.01
.001
1.0000
m
5.0000
10
15
20
25
30
35
40
45
50.000
HZ
Unisys Corp: Operator H.V. Leany
Date: 11-22-89
Test Type: Sine Dwell Vib.
Test Item: SRM TMU
S/N: 7,17
Graph: Spect. of Vib. Signal AI 5 Hz (Accel. VS Freq)
Axis of Vibration: Lat.
Accel Axis: Lat
Accel Channel: cont
Notes: +70°F


X: 5.0000
Y: 1.3043
HARMONIC
A SPEC 2
#A: 1
10.000
5.0
1.0
0.5
LGMAG
0.1
.05
.01
.005
1.0000
m
5.0000
10
15
20
25
HZ
30
35
40
45
50.000
Unisys Corp: Operator H.V. Leany
Date: 11-22-89
Test Type: Sine Dwell Vib.
Test Item: SRM TMU
S/N: 7, 17
Graph: Spect. of Vib. Signal At 5 HZ (Accel. VS Freq.)
Axis of Vibration: Lat.
Accel Axis: Lat.
Accel Channel: 2
Notes: +70°F

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 22-NOV-89 13:11:47



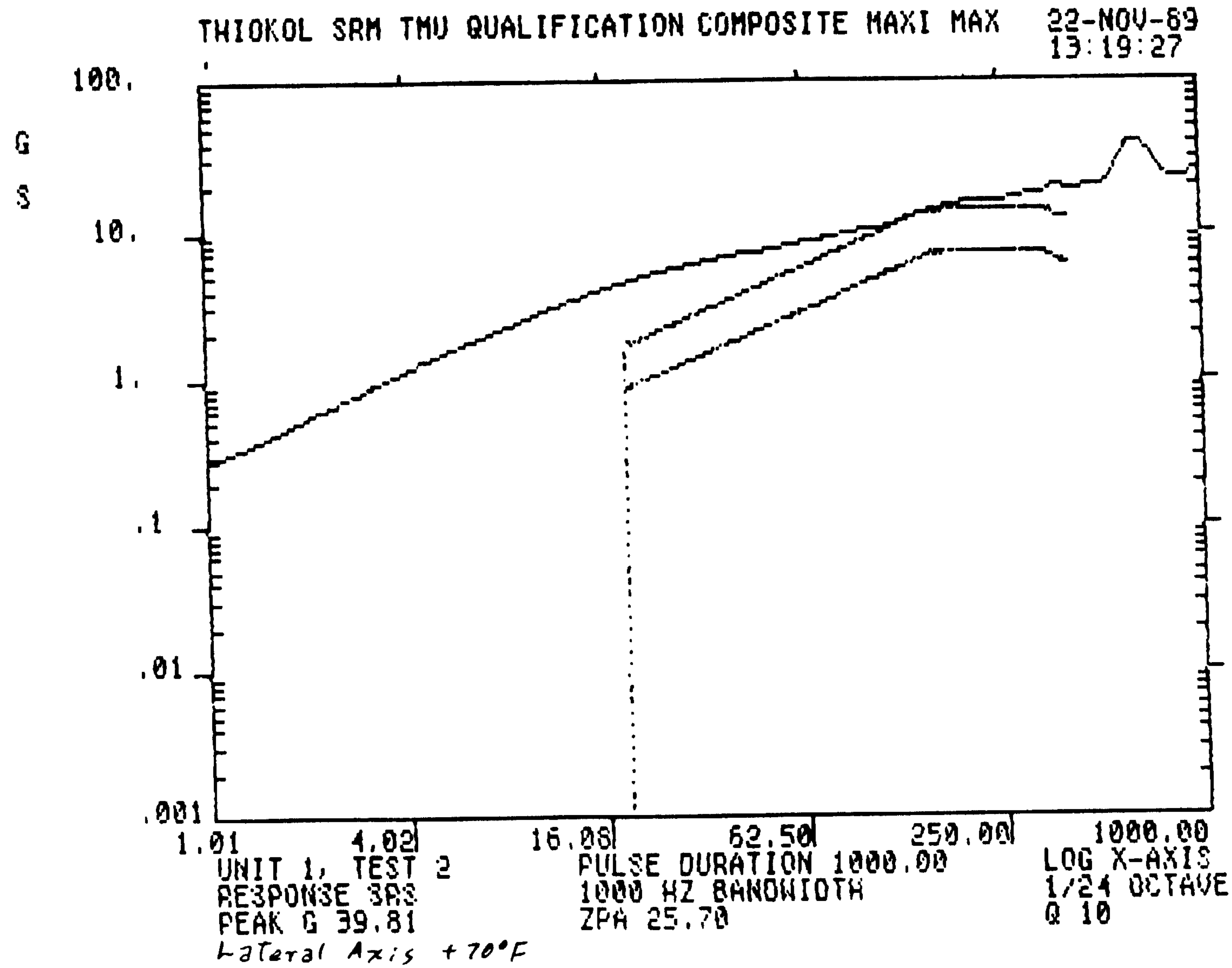
UNIT 1, TEST 2
RESPONSE 3R3
PEAK G 34.67

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 23.44

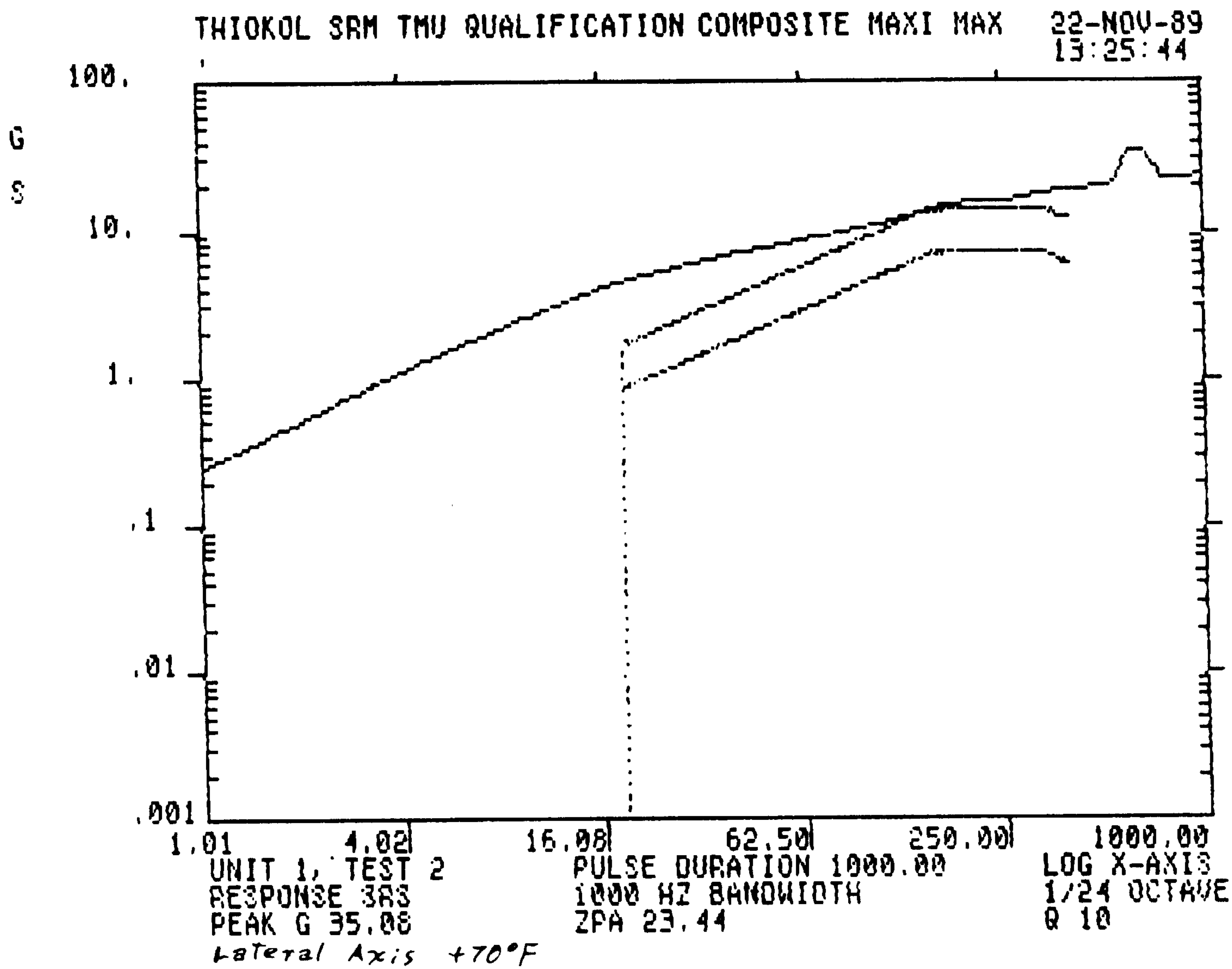
LOG X-AXIS
1/24 OCTAVE
Q 10

LaTeral Axis +70°F

Shock #1

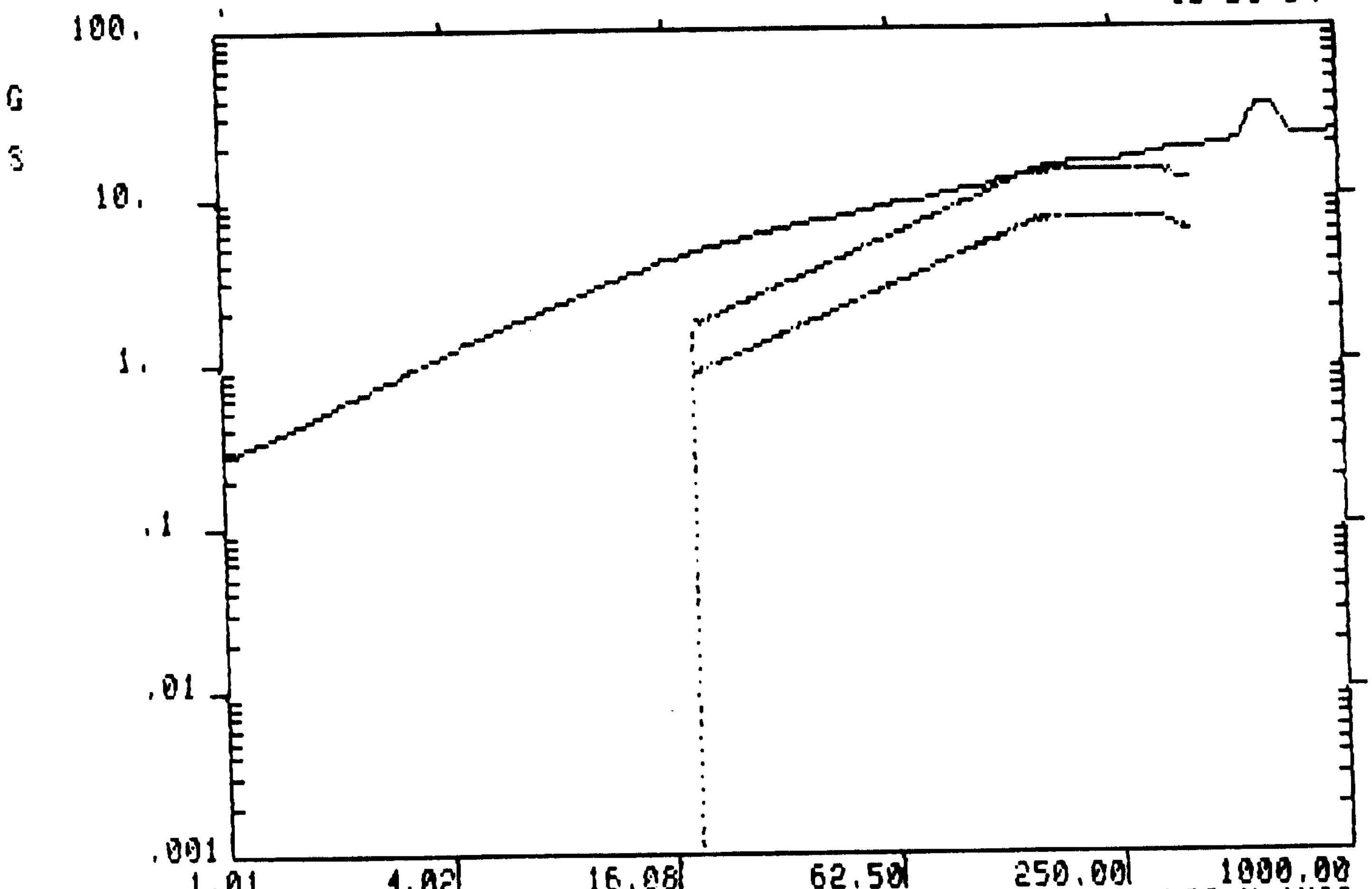

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
22-NOV-89
13:19:27
G
S
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE 3RS
PEAK G 39.81
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 25.70
LOG X-AXIS
1/24 OCTAVE
Q 10
Lateral Axis +70°F

Shock #2


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
22-NOV-89
13:25:44
G
S
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE 3A3
PEAK G 35.08
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 23.44
LOG X-AXIS
1/24 OCTAVE
Q 10
Lateral Axis +70°F

Shock # 3

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 22-NOV-89 13:30:34



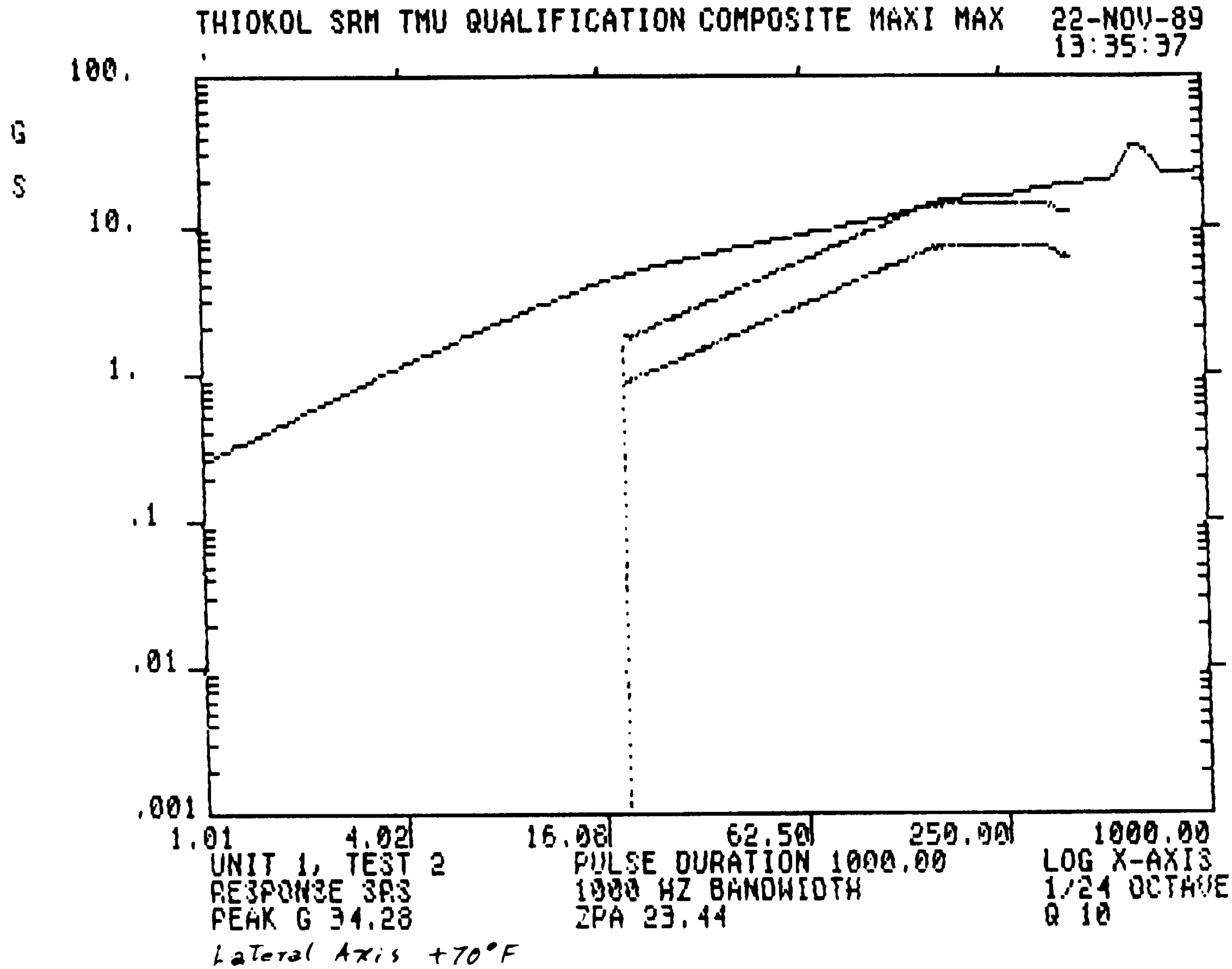
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 34.67

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 23.44

LOG X-AXIS
1/24 OCTAVE
Q 10

Lateral Axis +70°F

Shock #4


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
22-NOV-89
13:35:37
100.
10.
1.
.1
.01
.001
G
S
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 34.28
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 23.44
LOG X-AXIS
1/24 OCTAVE
Q 10
Lateral Axis +70°F

Shock #5

APPENDIX E

UNISYS CONTROL AND RESPONSE DATA FROM LONGITUDIAL AXIS TRANSPORTATION TEST

(70°F ± 10°F)

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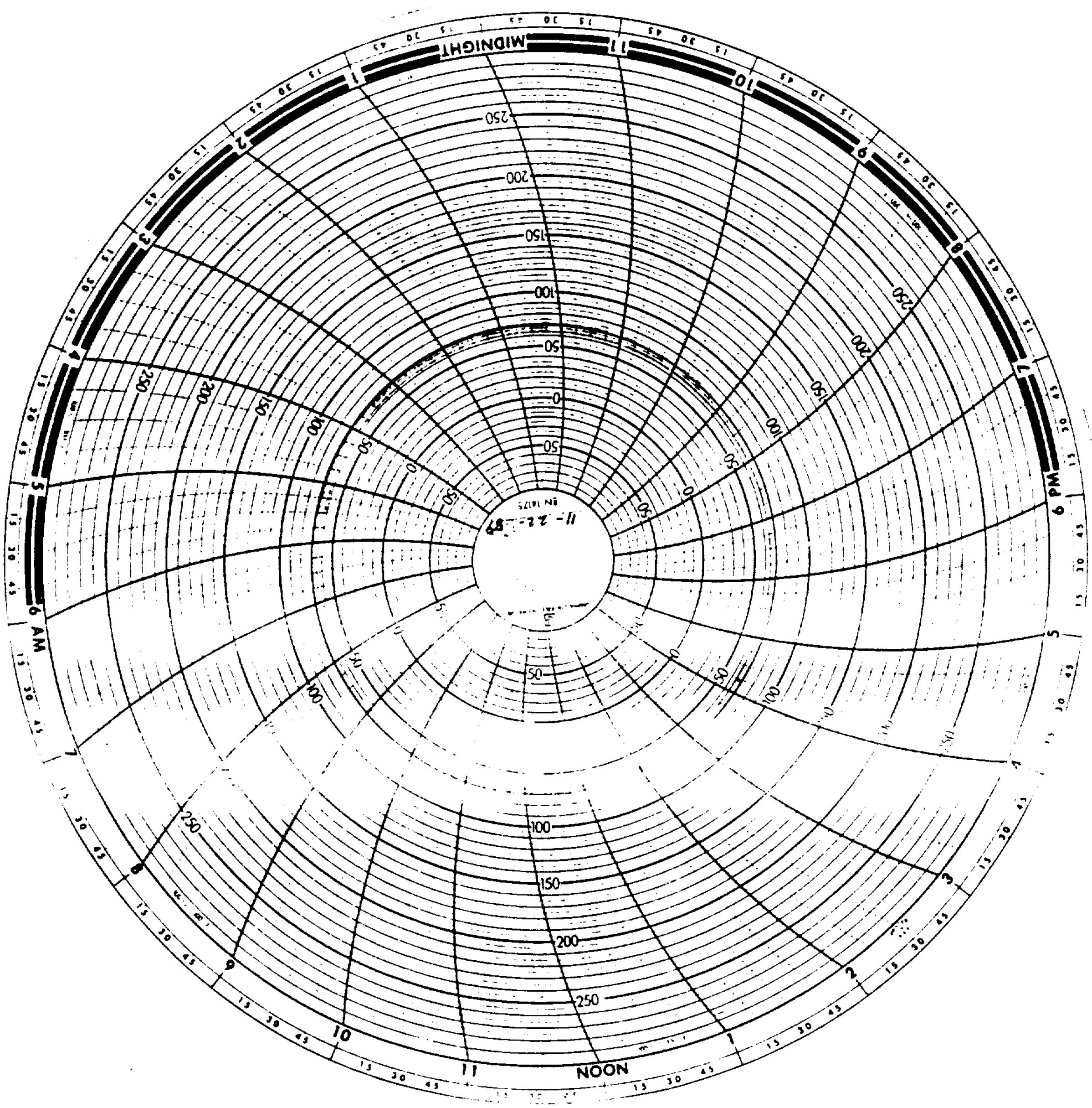

ORIGINAL PAGE IS
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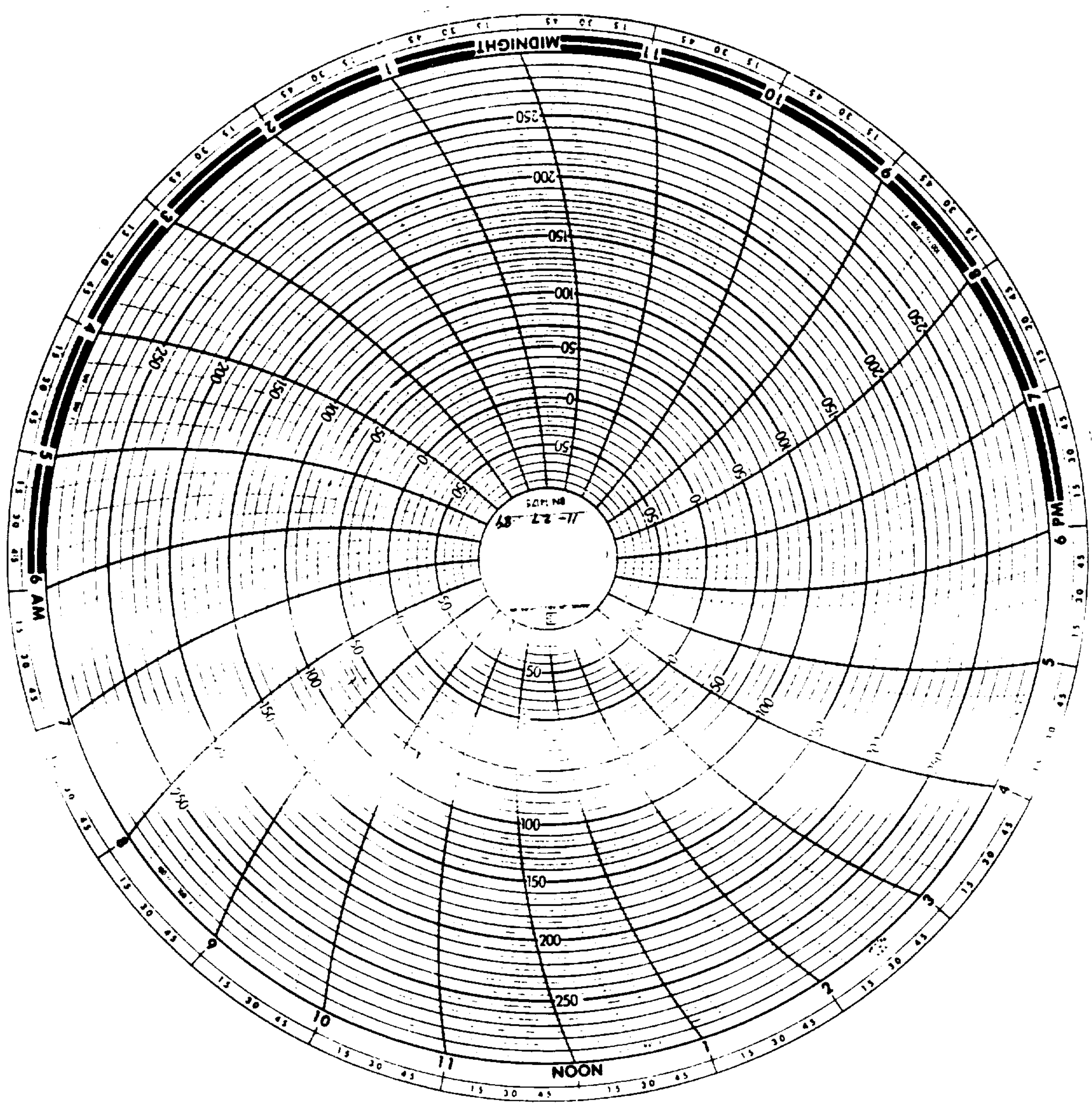

ORIGINAL PAGE IS
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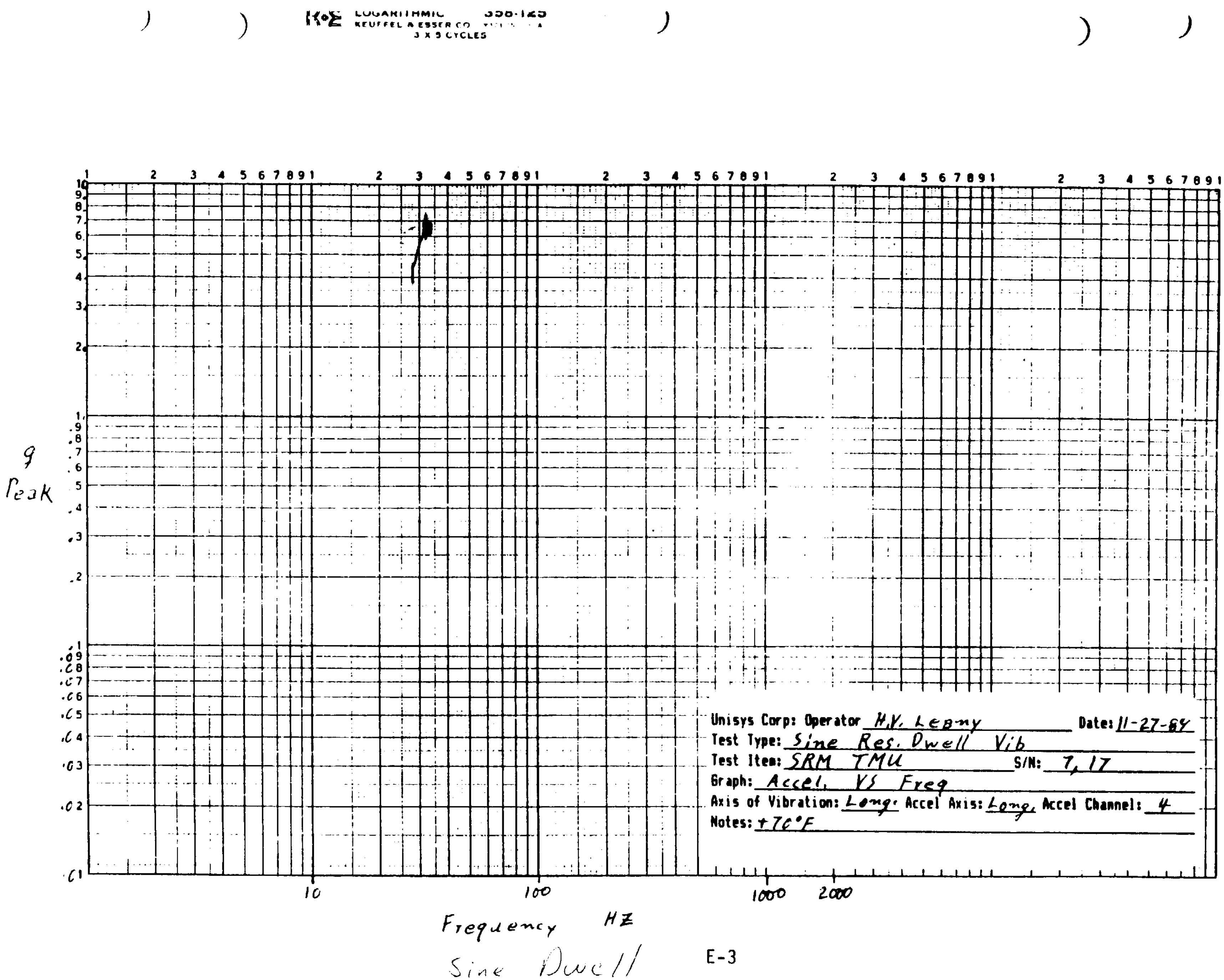

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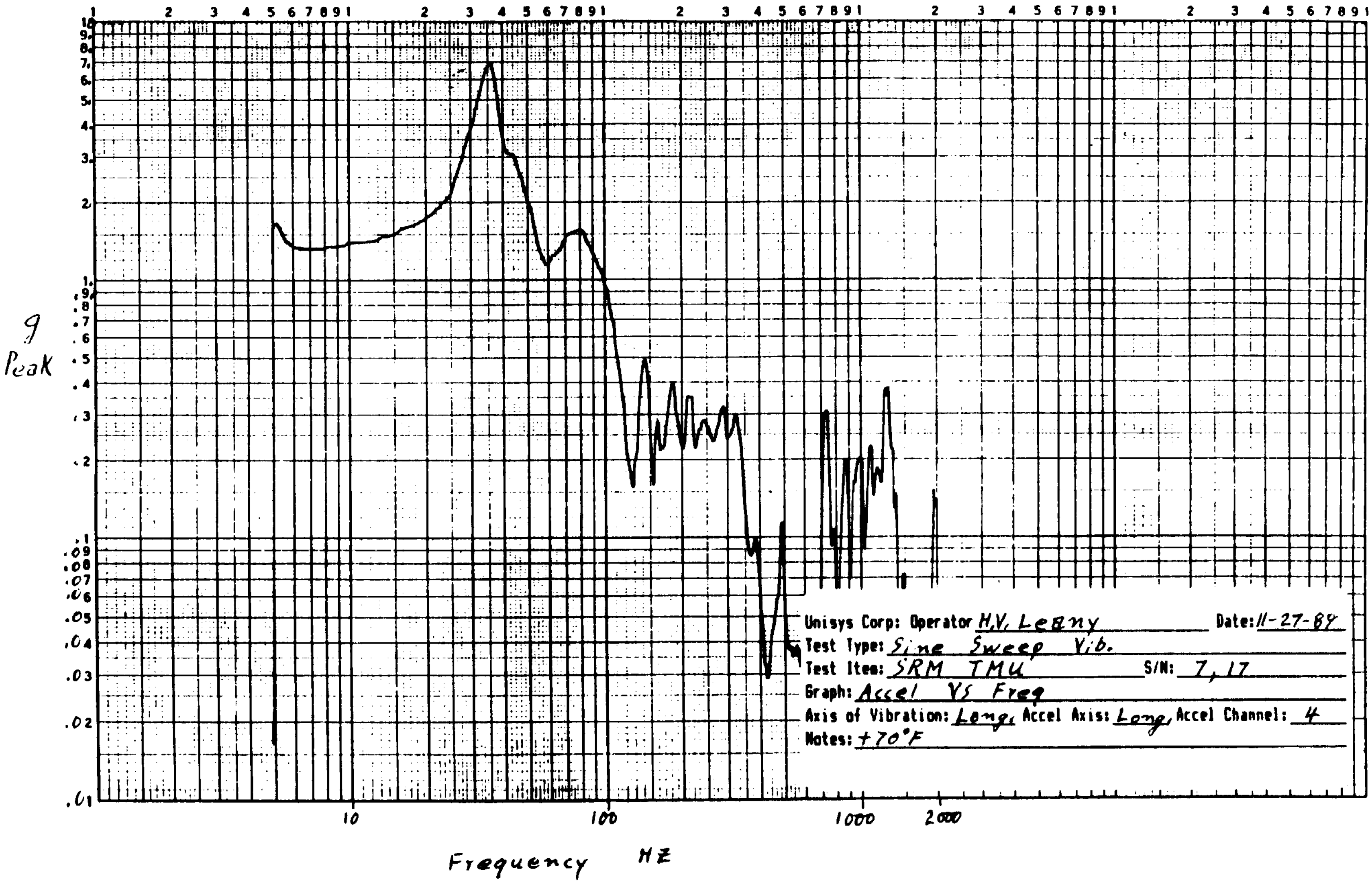
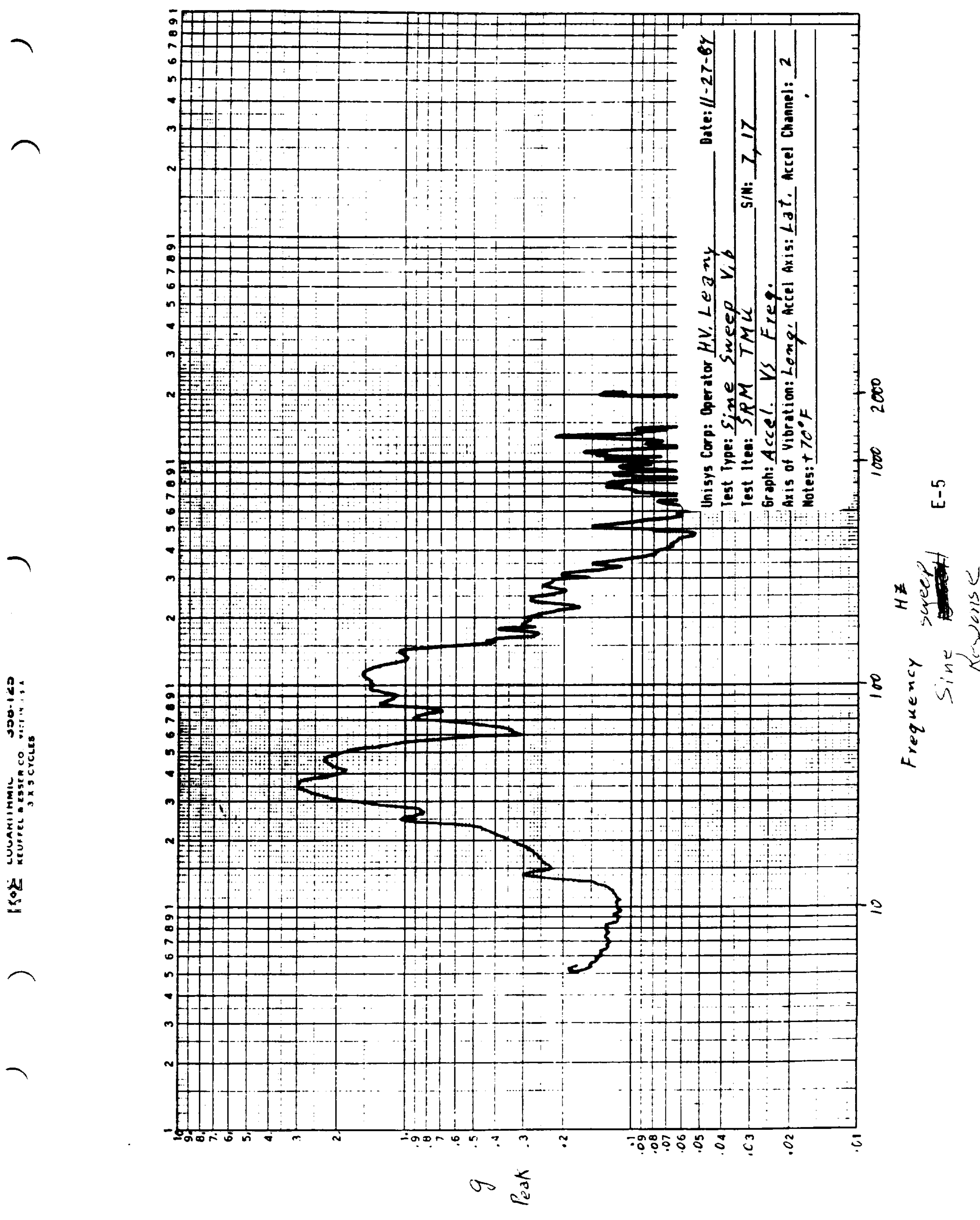
Sine ~~Freq~~ Sweep Response

E-4




Unisys Corp: Operator HV Leany
Date: 11-27-84
Test Type: Sine Sweep Vib
Test Item: SRM TMU
S/N: 7, 17
Graph: Accel. VS Freq.
Axis of Vibration: Long. Accel Axis: Lat. Accel Channel: 2
Notes: +70°F
Frequency HZ
Sine Sweep Response
g Peak
10
100
1000
2000
K&E LOGARITHMIC 358-123
KEUFFEL & ESSER CO.
3 X 3 CYCLES

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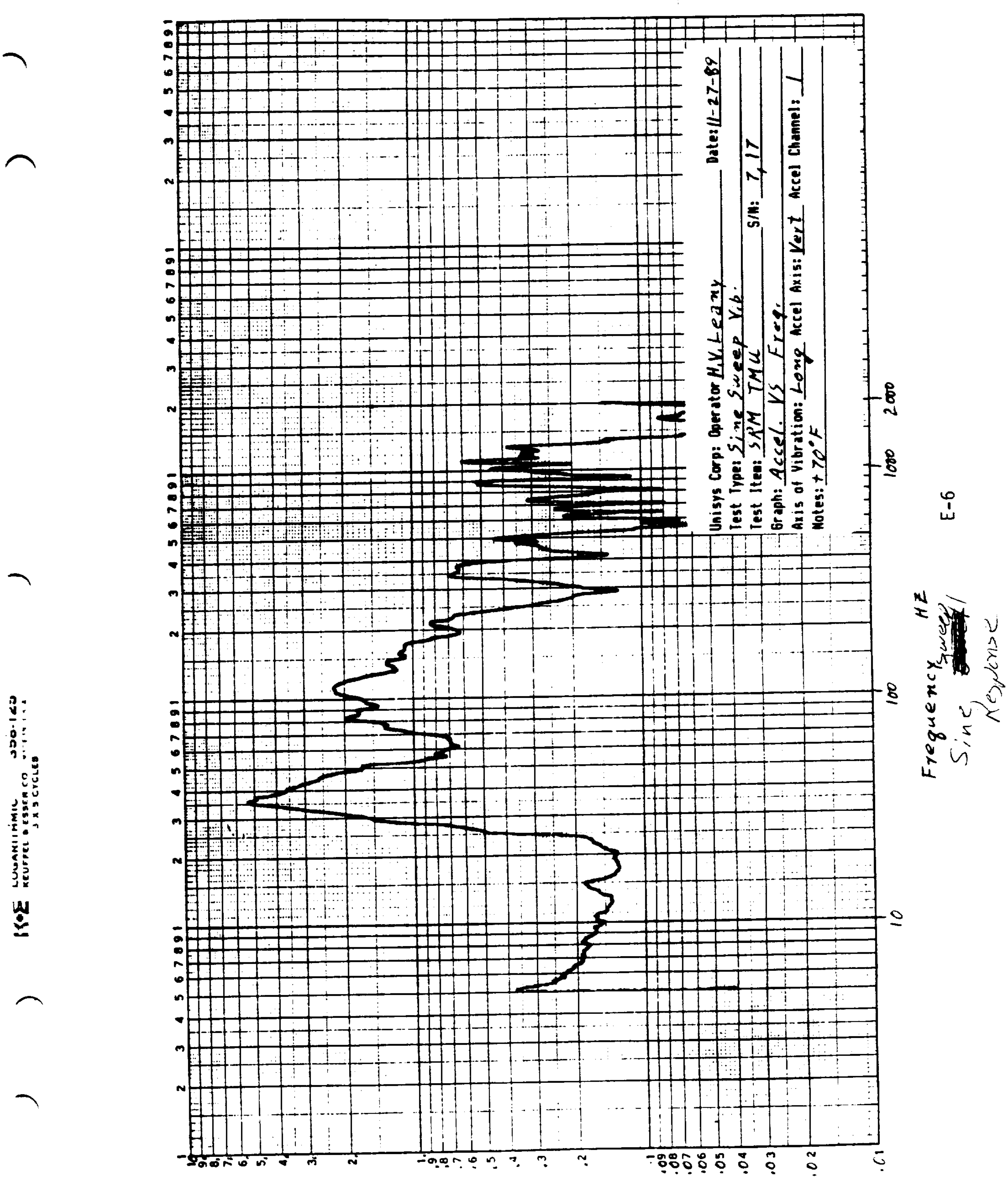
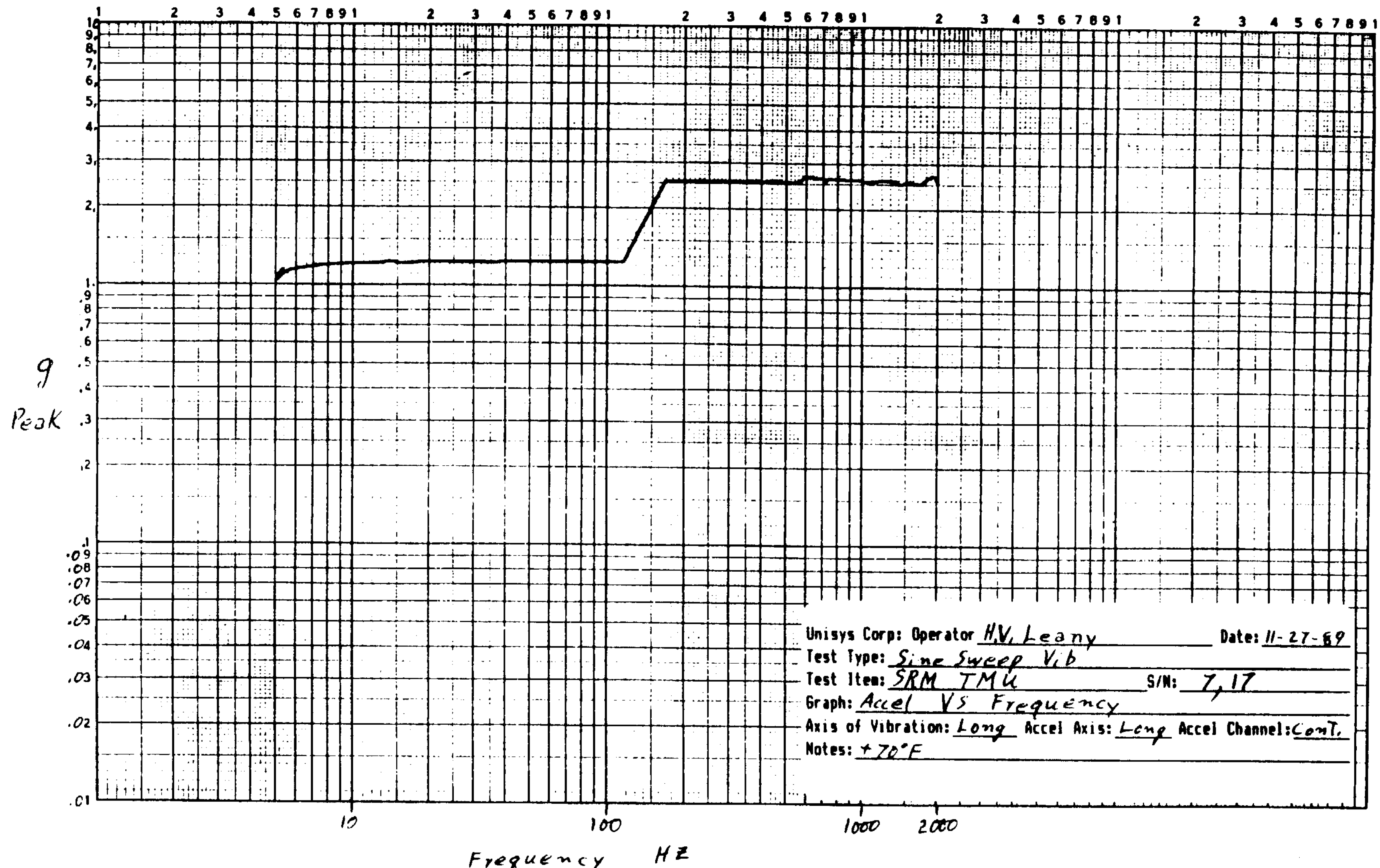
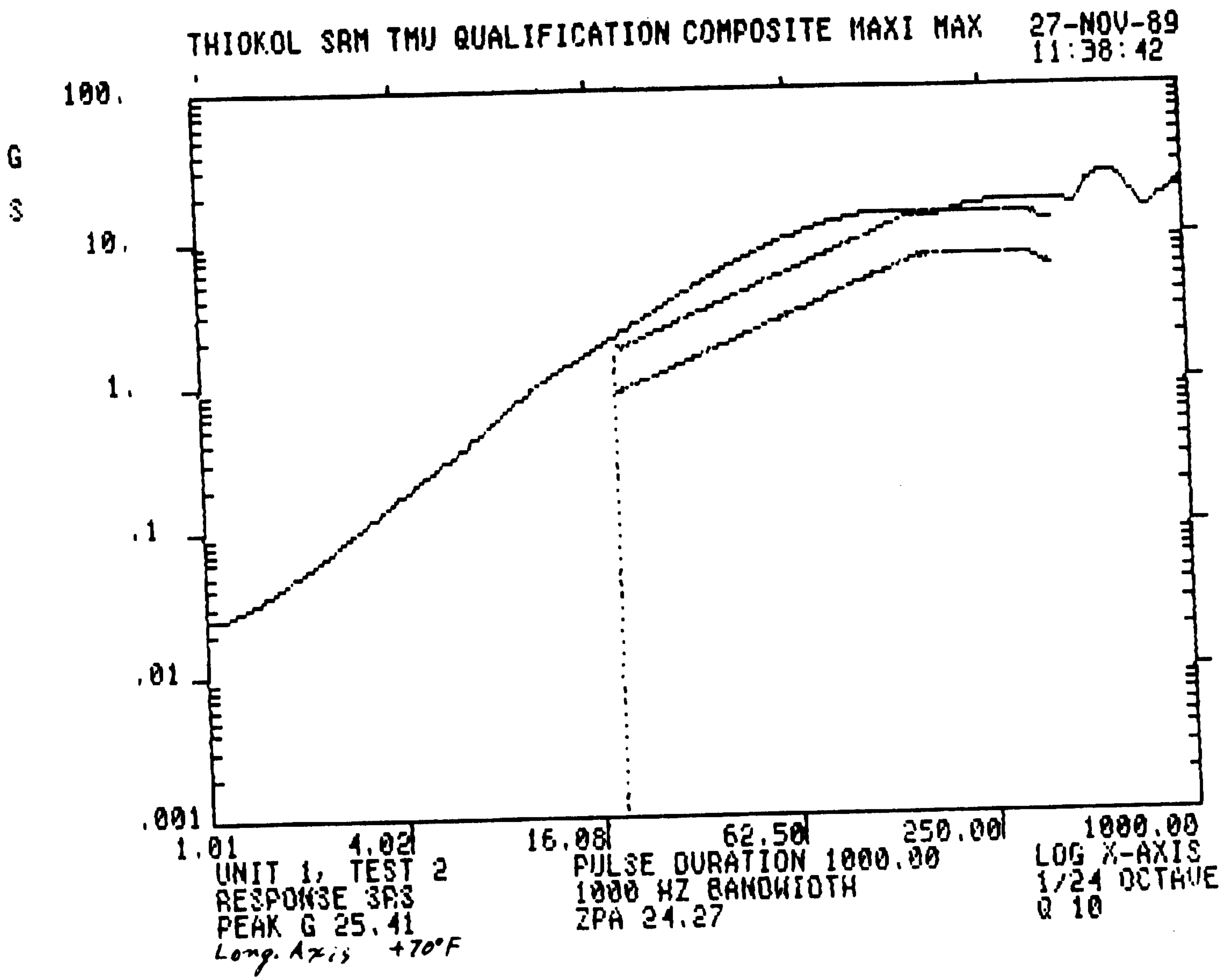
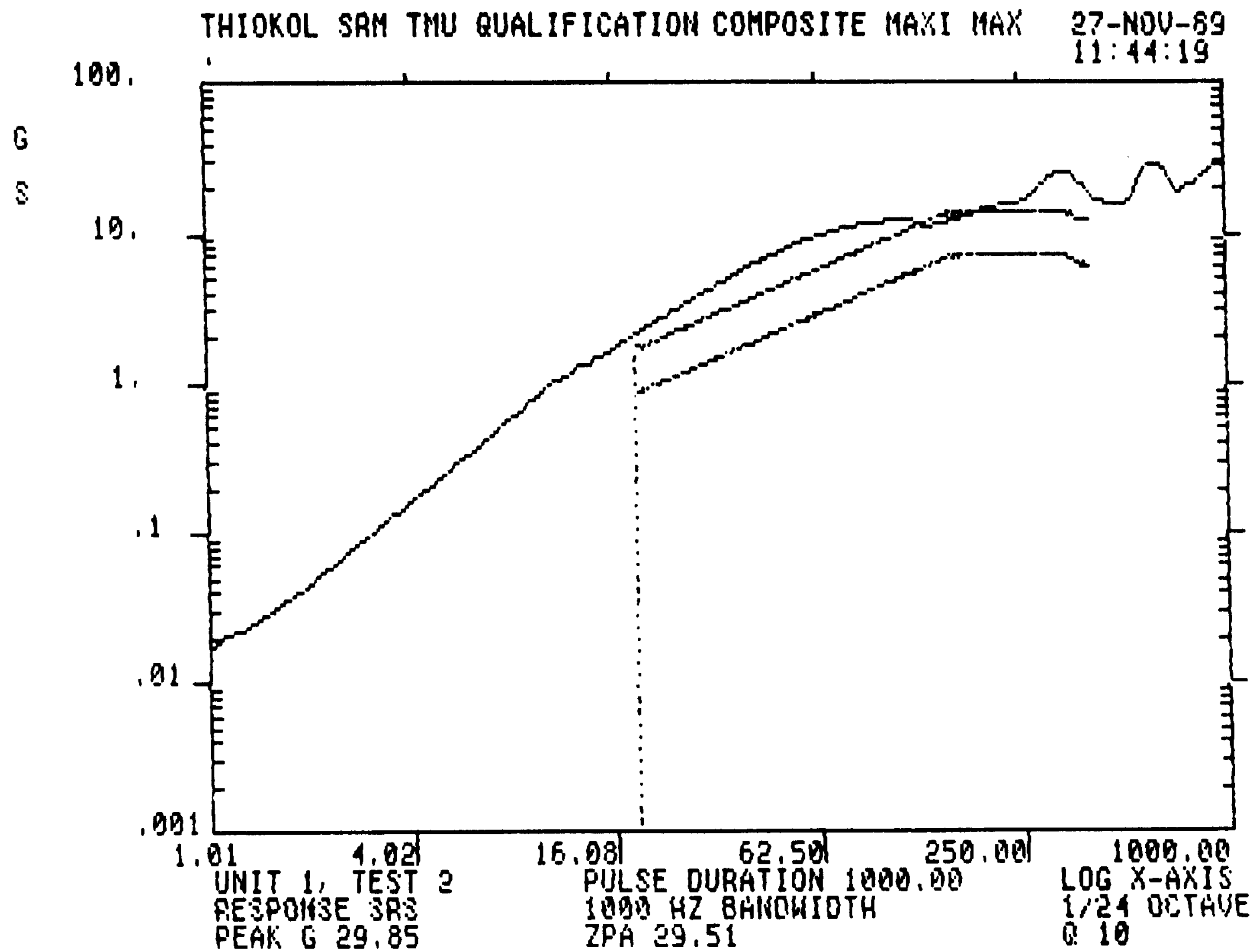




Sine Sweep Input

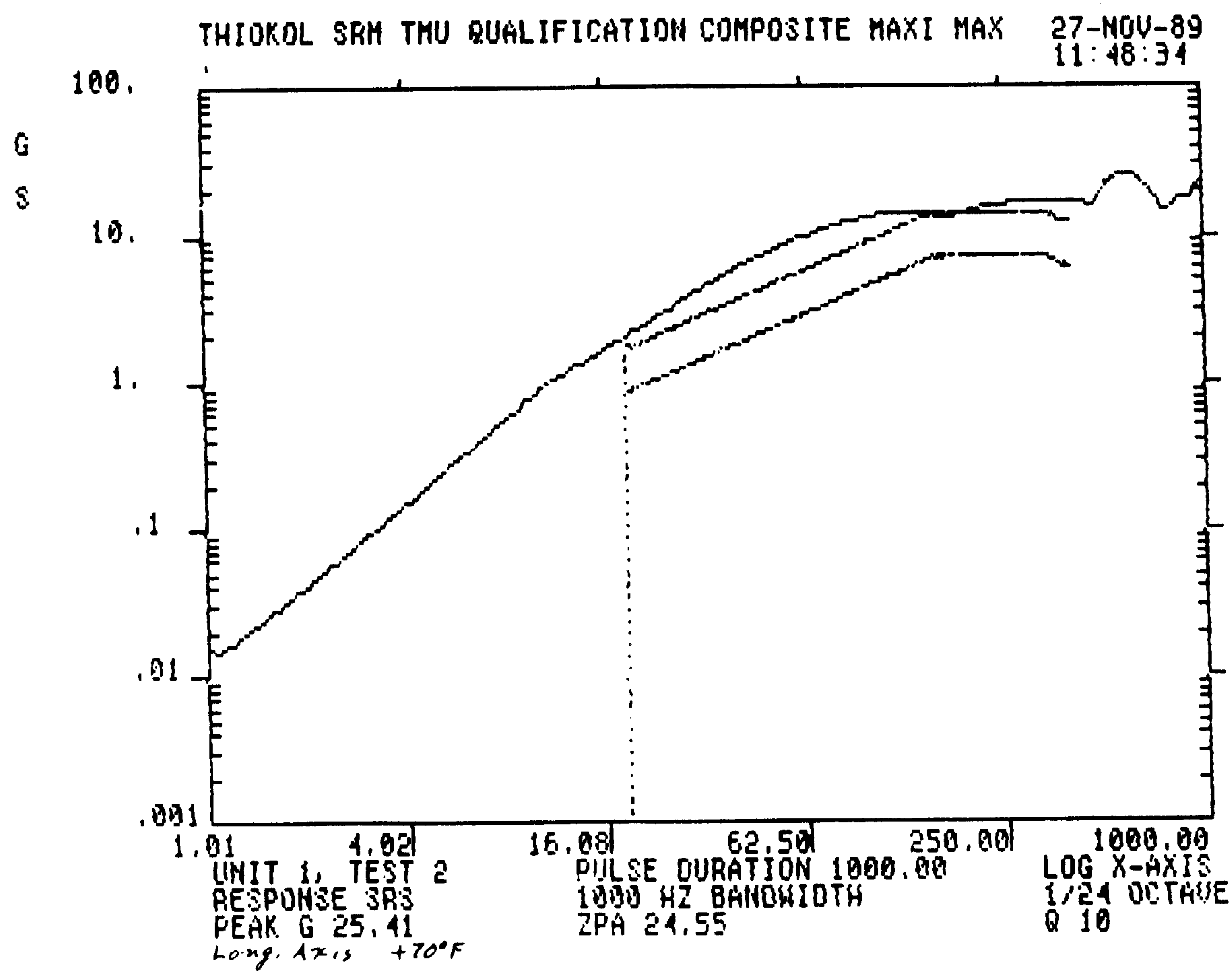

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
27-NOV-89
11:38:42
100.
10.
1.
.1
.01
.001
G
S
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE 3RS
PEAK G 25.41
Long. Axis +70°F
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 24.27
LOG X-AXIS
1/24 OCTAVE
Q 10

Shock #1



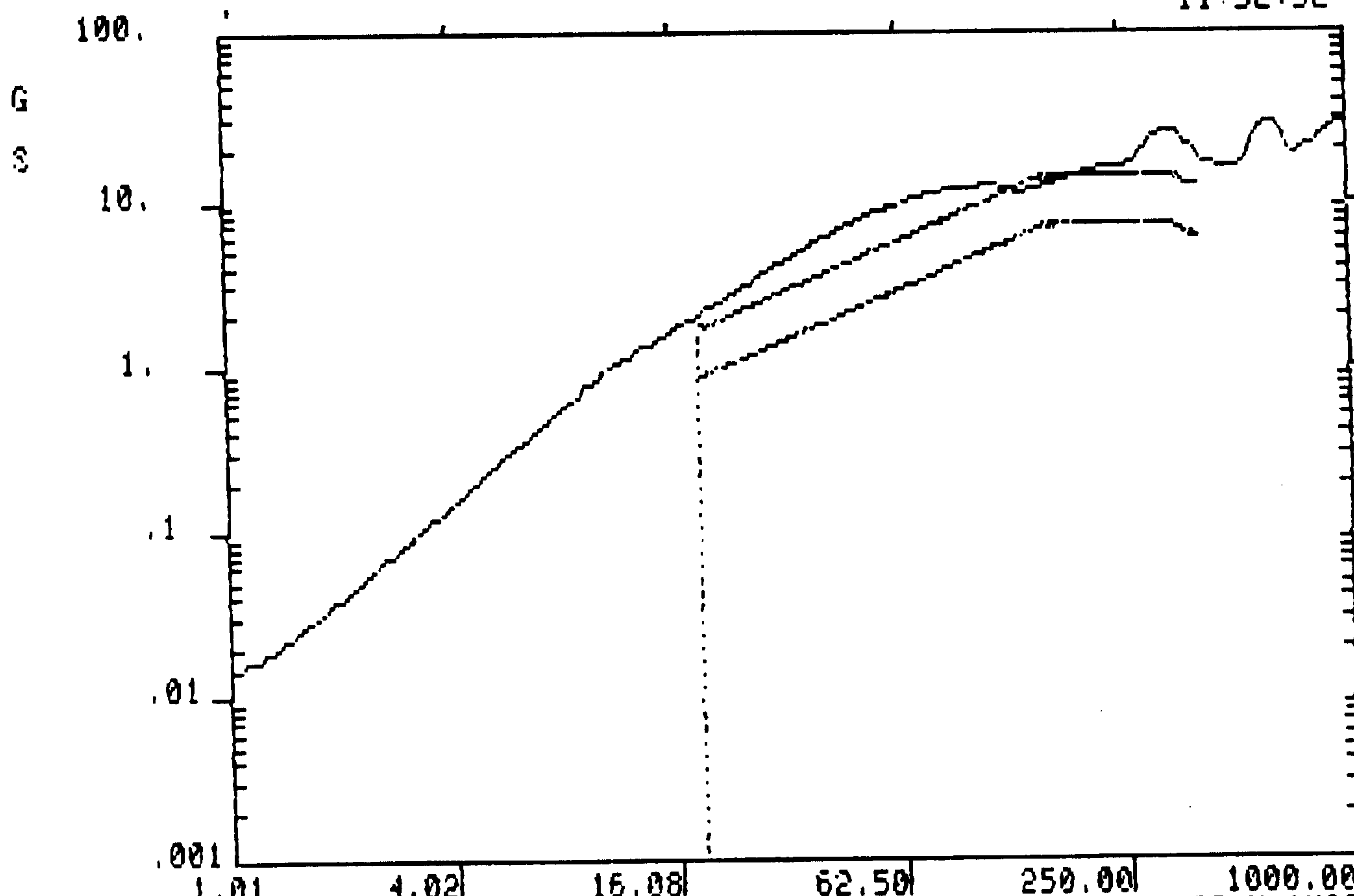
Long. Axis +70°F

Shock #2


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
27-NOV-89
11:48:34
G
S
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE 3RS
PEAK G 25.41
Long. Axis +70°F
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 24.55
LOG X-AXIS
1/24 OCTAVE
Q 10

Shock #3

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 27-NOV-89 11:52:52

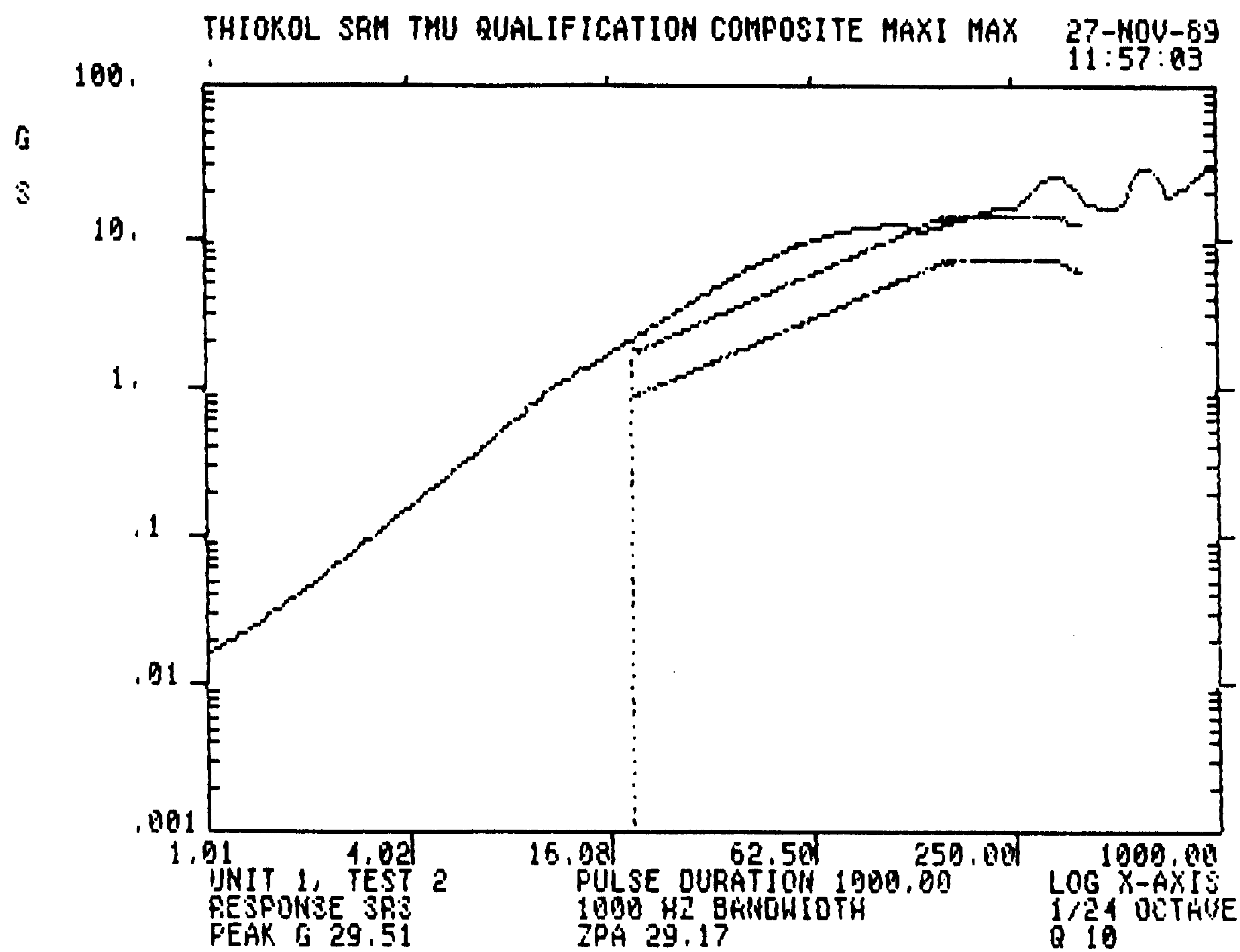


UNIT 1, TEST 2
RESPONSE 3R3
PEAK G 29.17
Long. Axis +70°F

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 29.17

LOG X-AXIS
1/24 OCTAVE
Q 10

Shock #4



Long. Axis +70°F

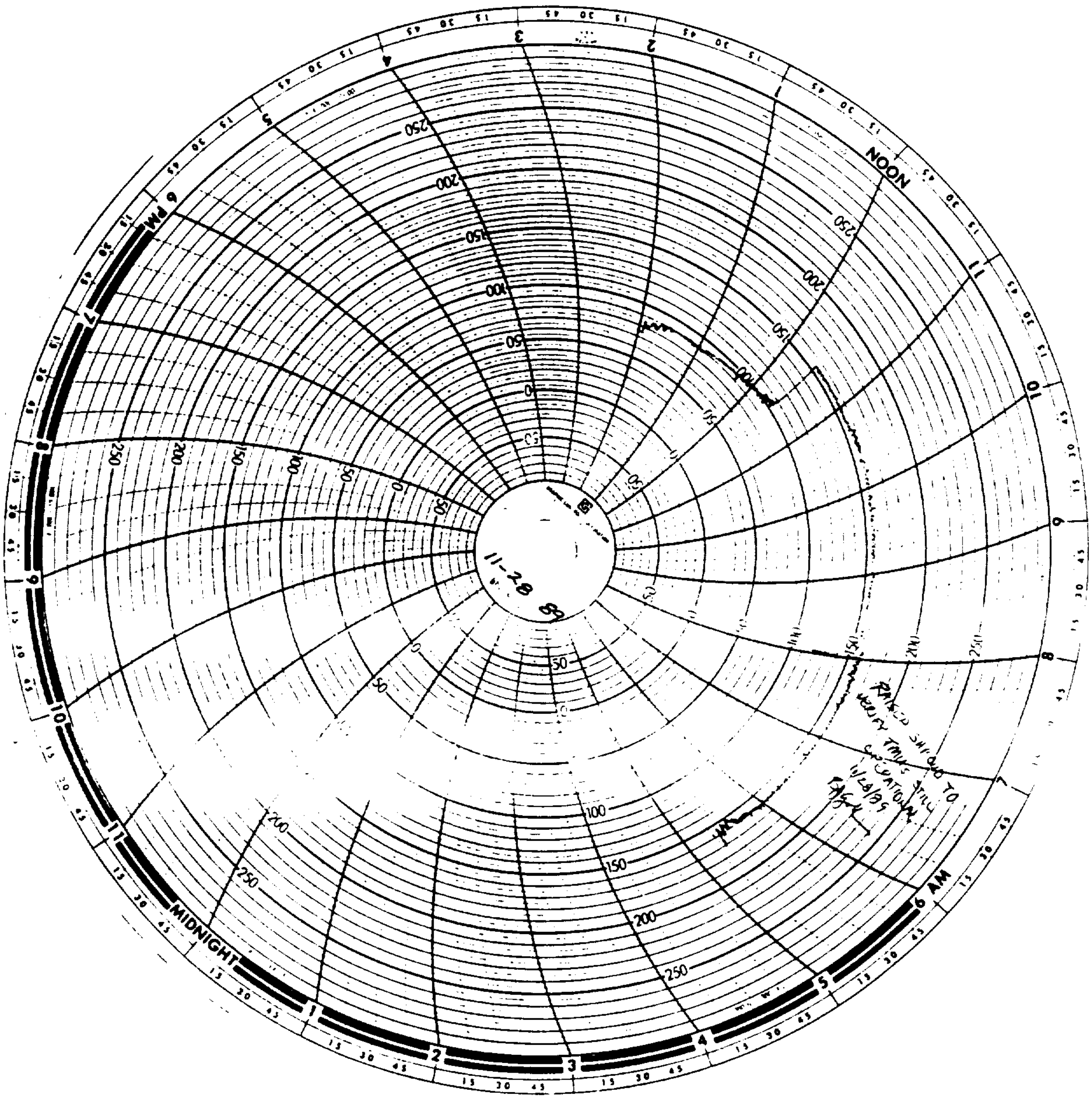
E-12

Shock #5

APPENDIX F

UNISYS CONTROL AND RESPONSE DATA FROM LONGITUDIAL AXIS TRANSPORTATION TEST

(163°F ± 10°F)


NOON
6 PM
MIDNIGHT
6 AM
11-28 85

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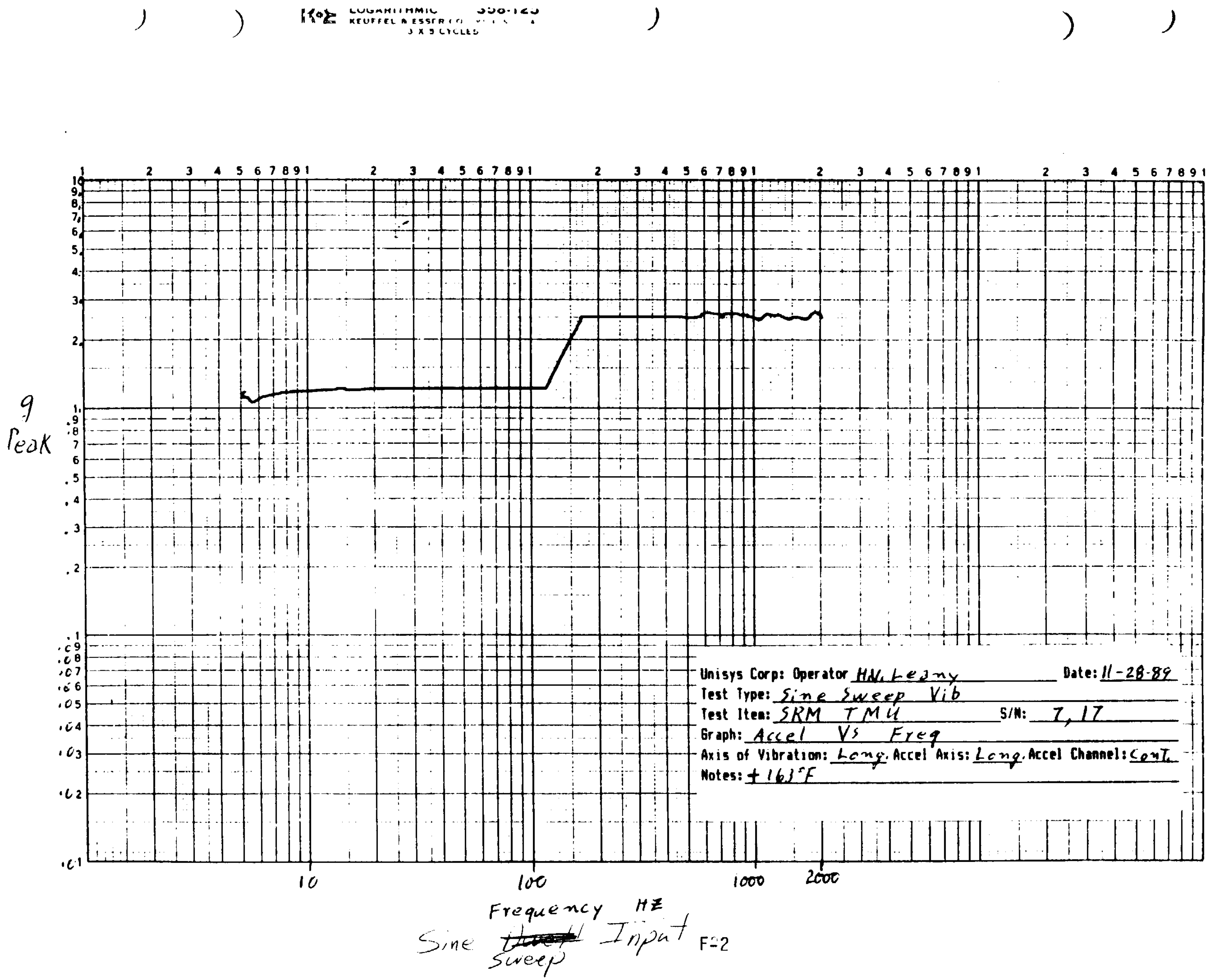
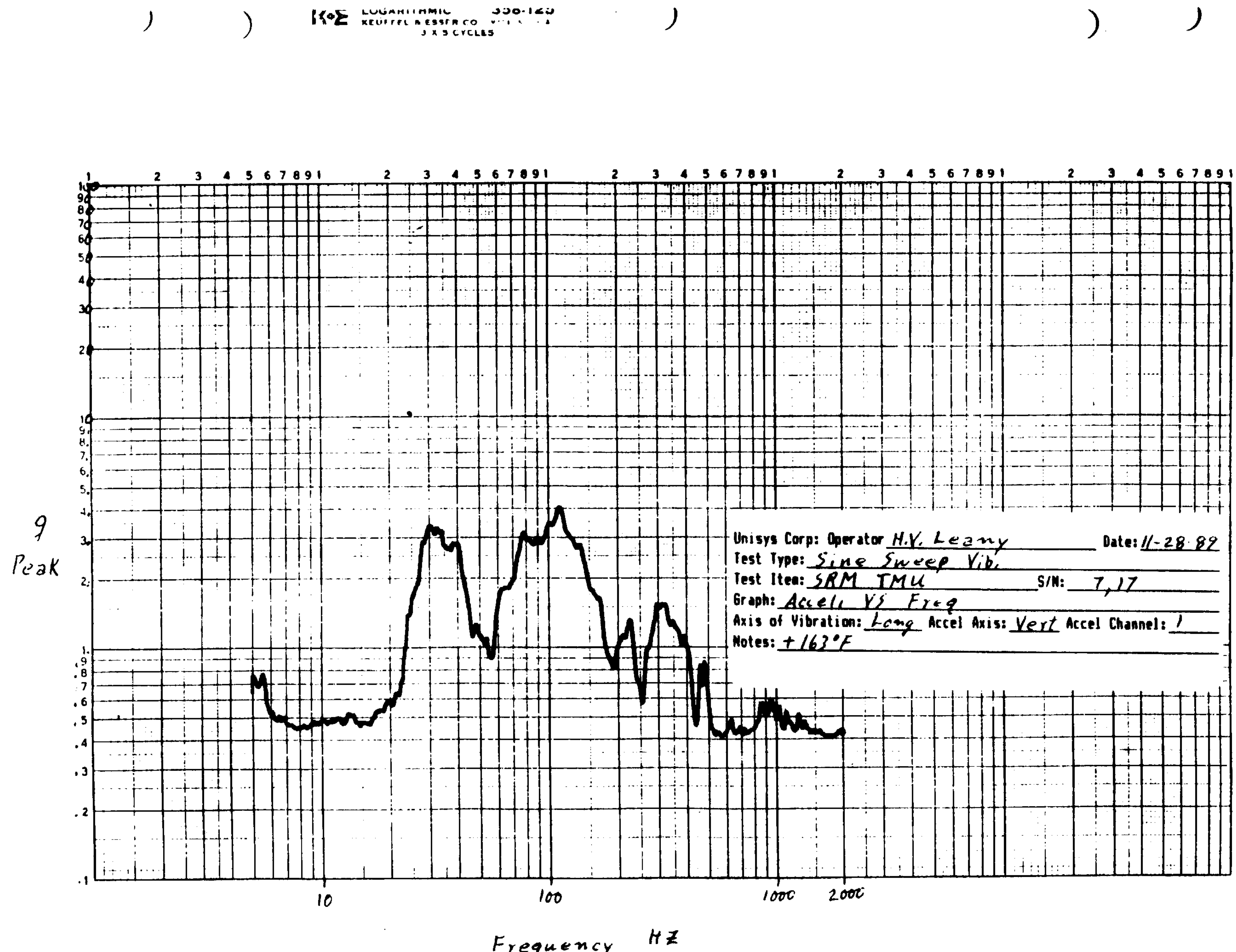
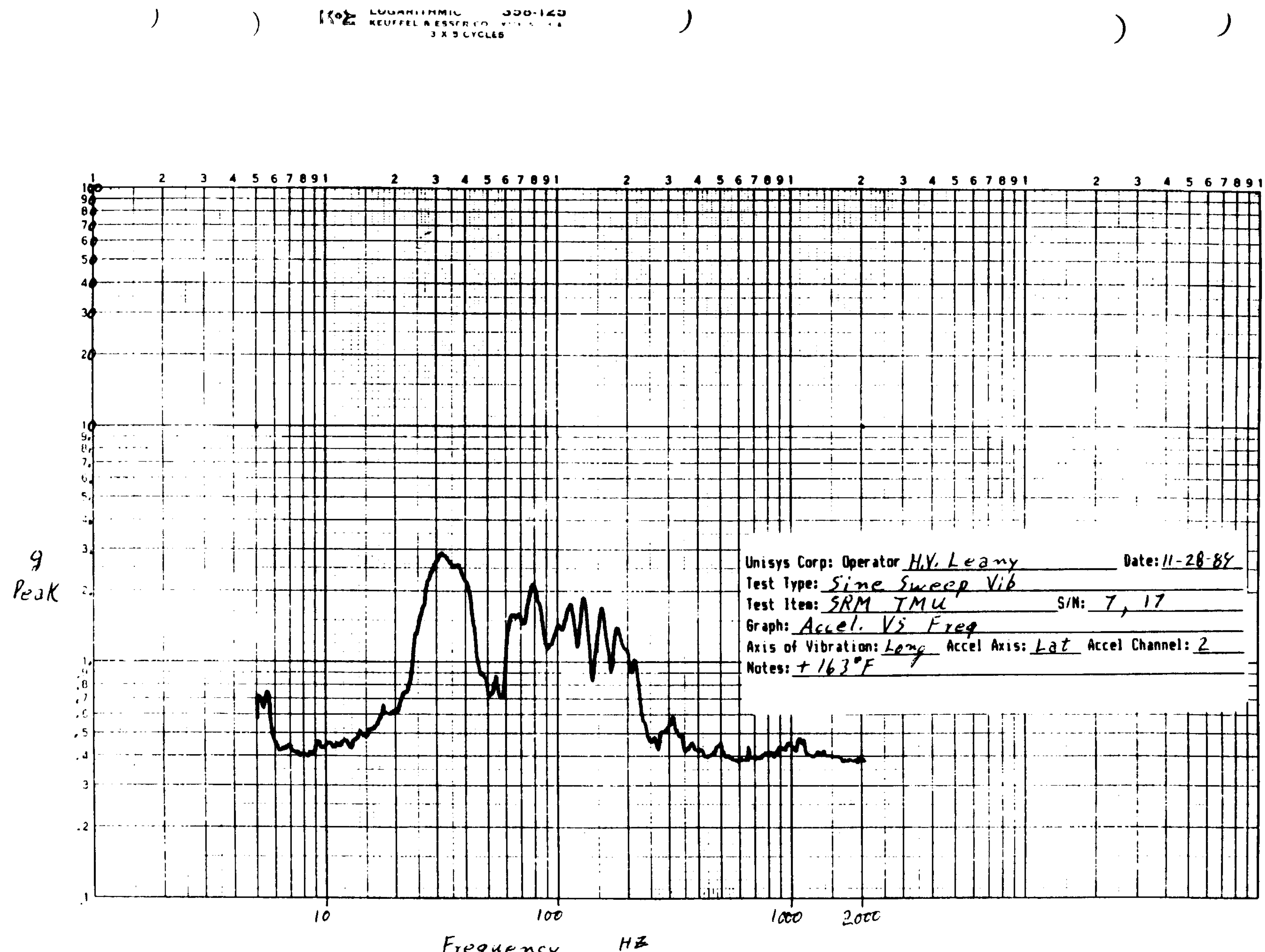


F-2

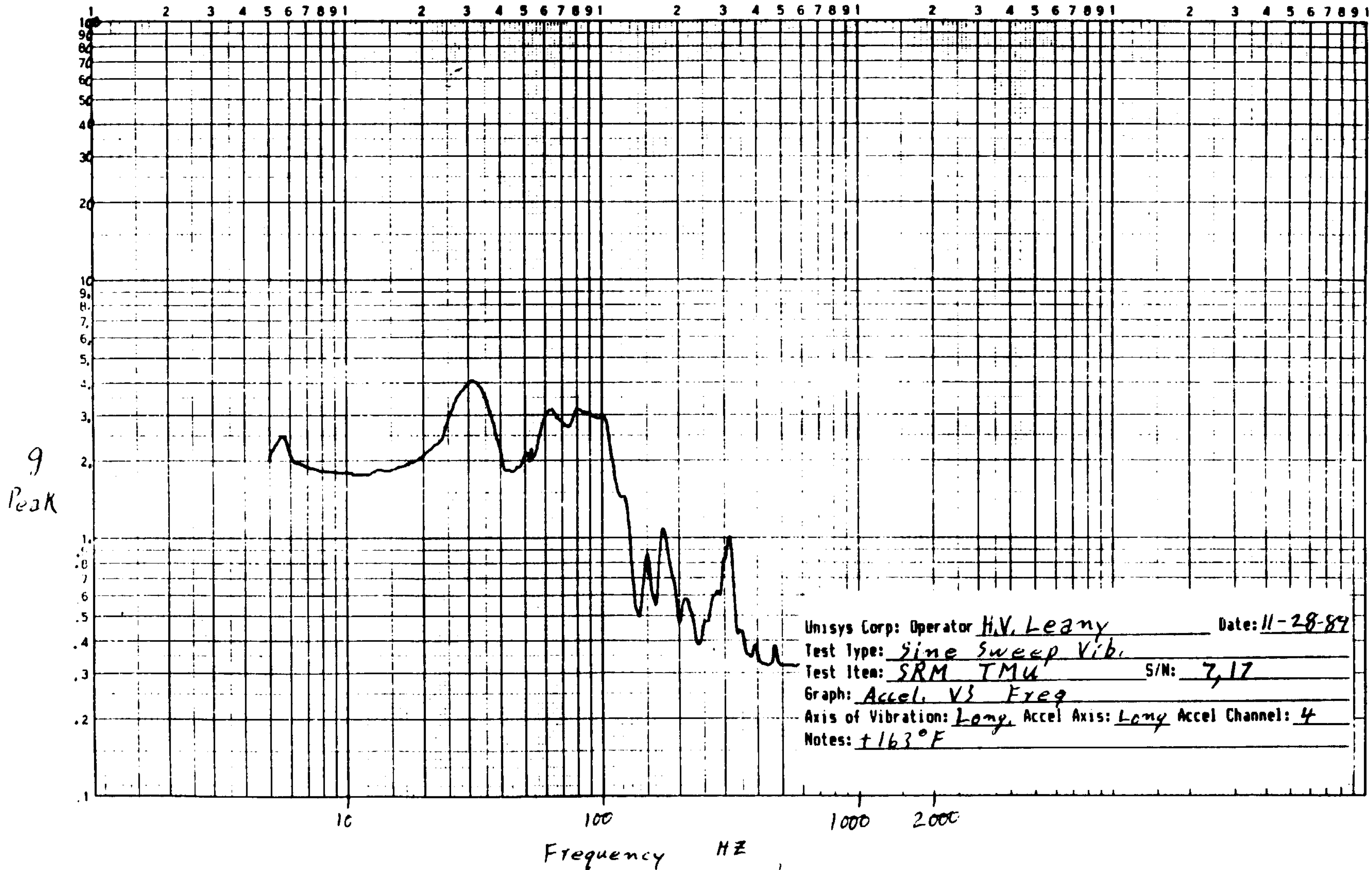


Sine Sweep Response F23

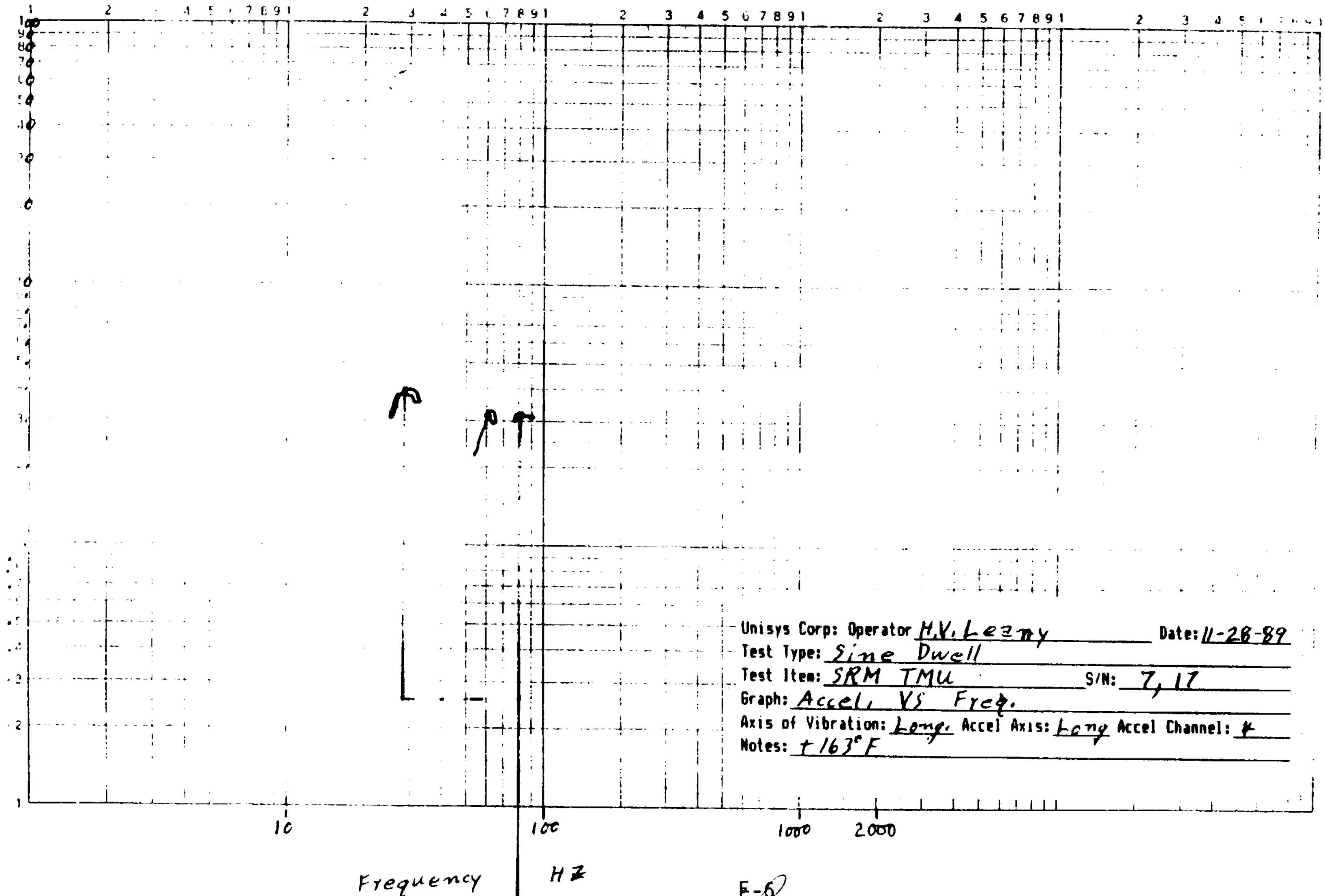


Sine Sweep Response

F-4



Sine Sweep Response F-5



Sine Sweep Response

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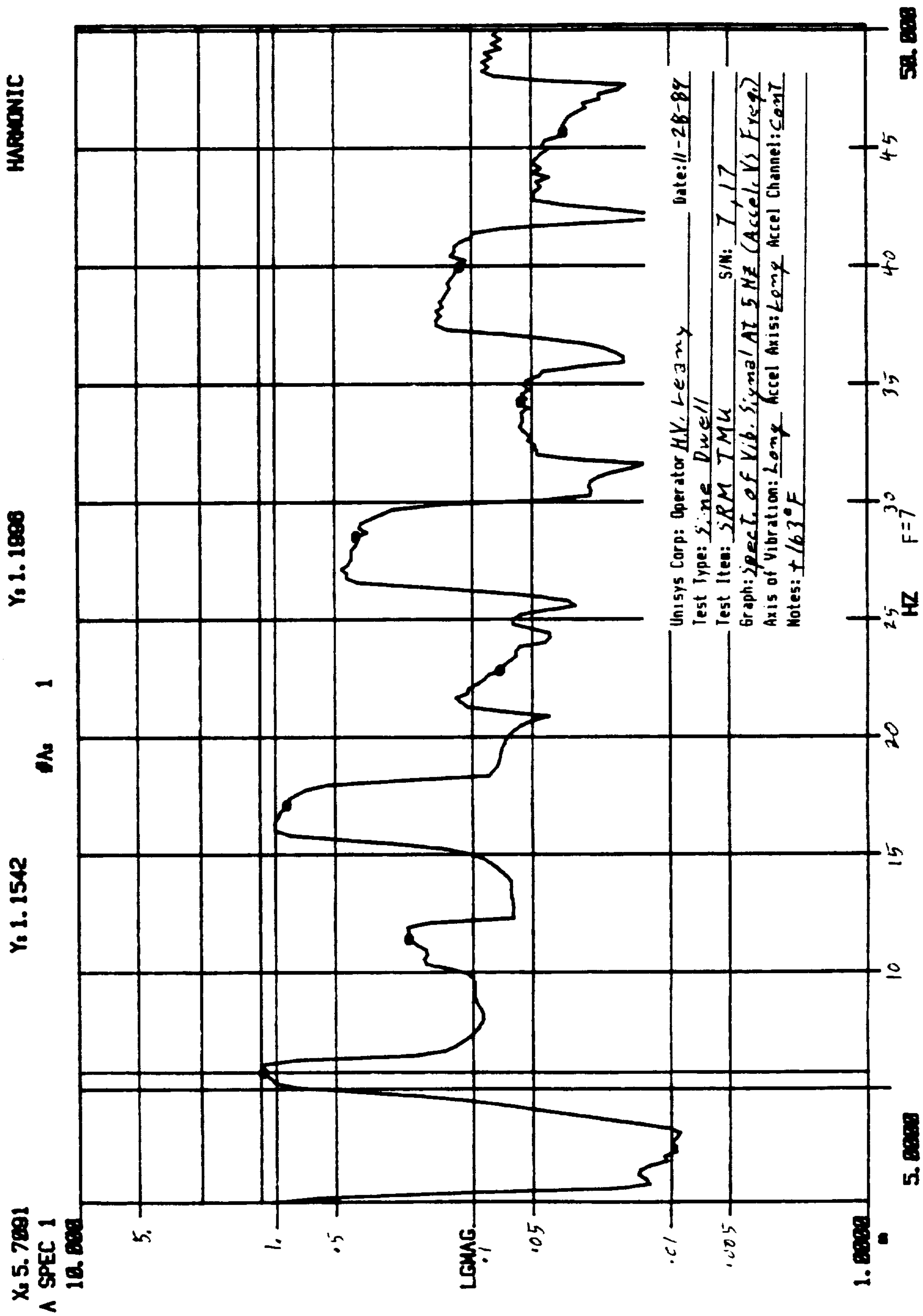

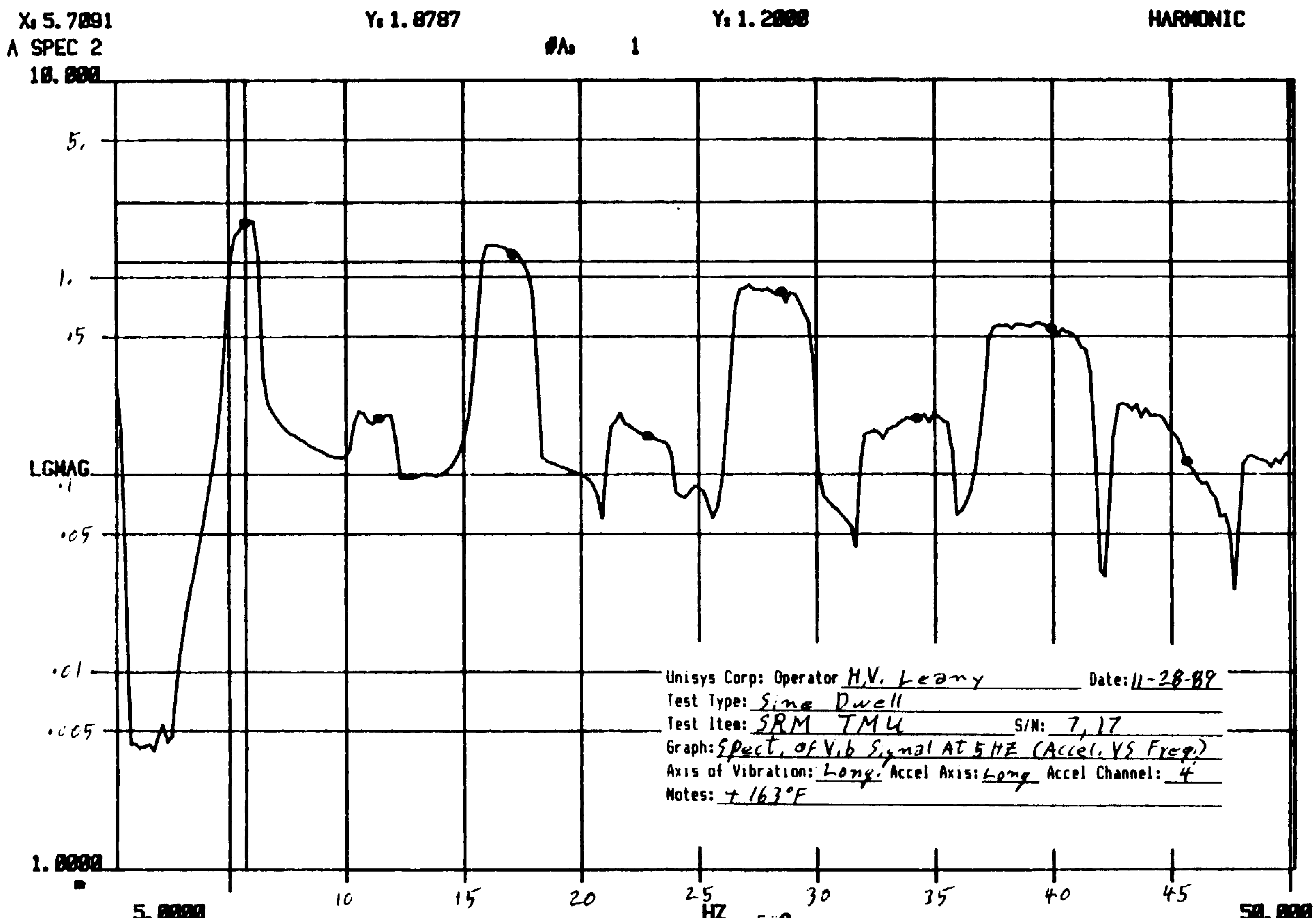

F-8

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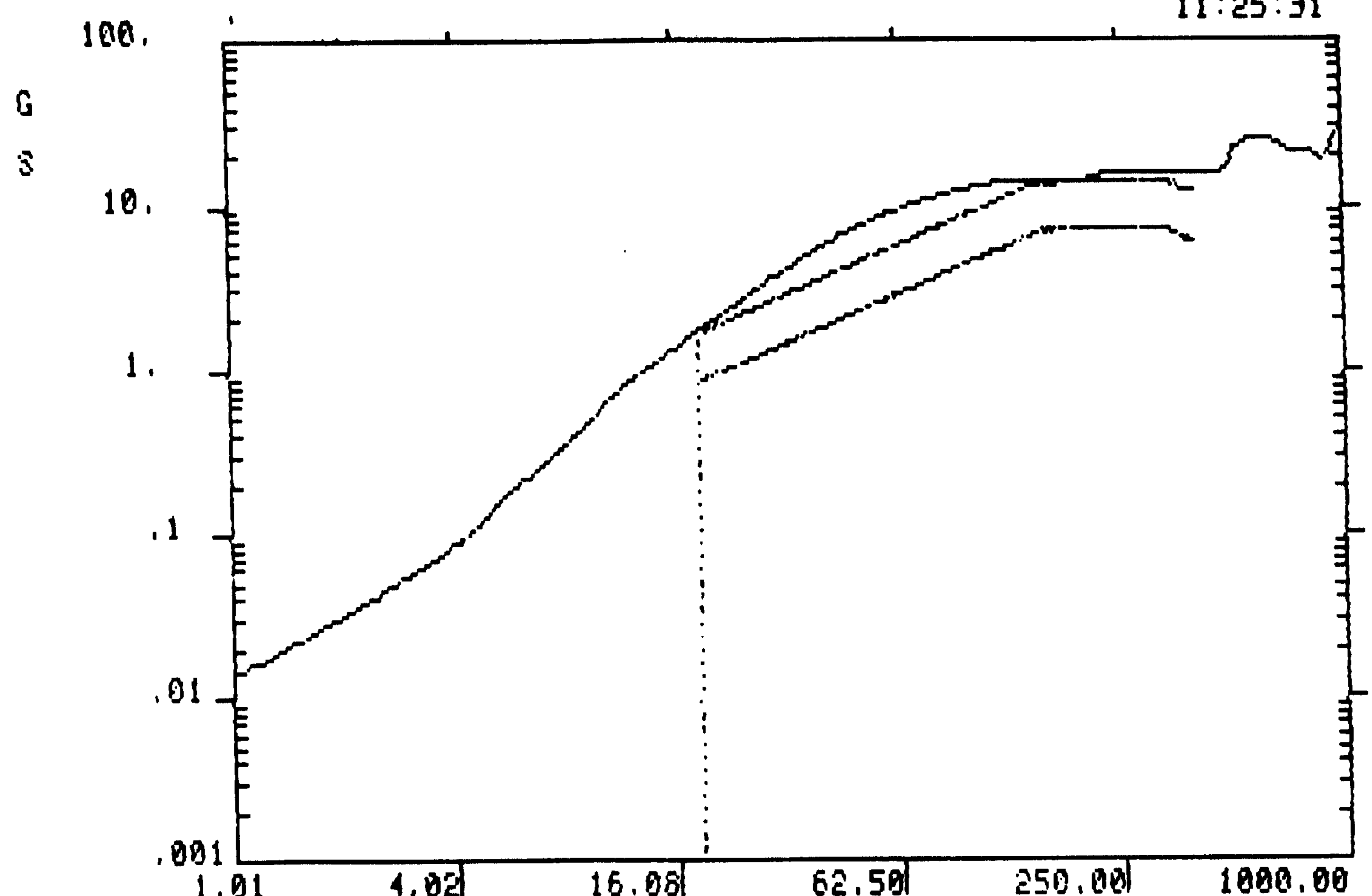
THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 28-NOV-89 11:25:31



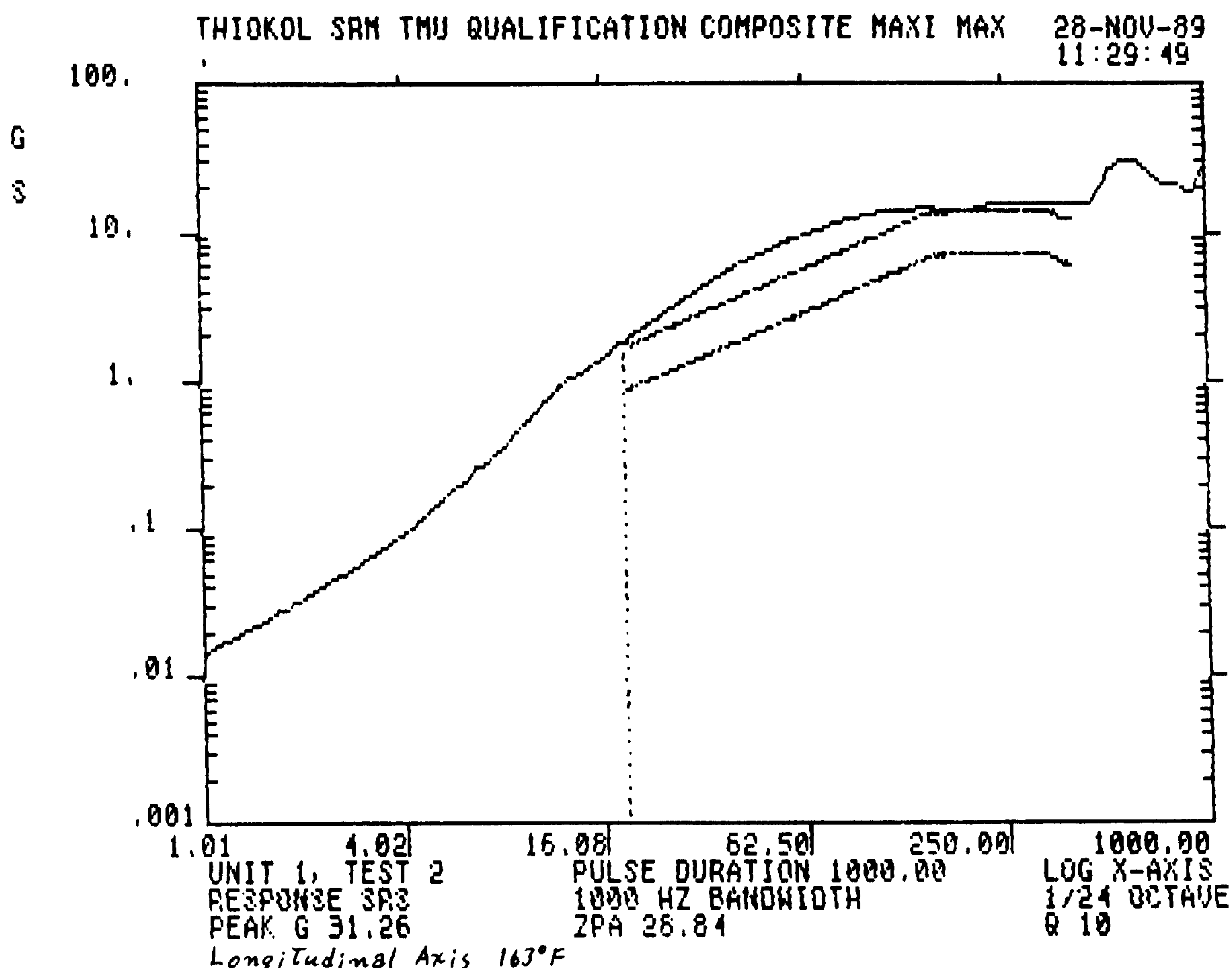
UNIT 1, TEST 2
RESPONSE SRS
PEAK G 28.84

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 28.84

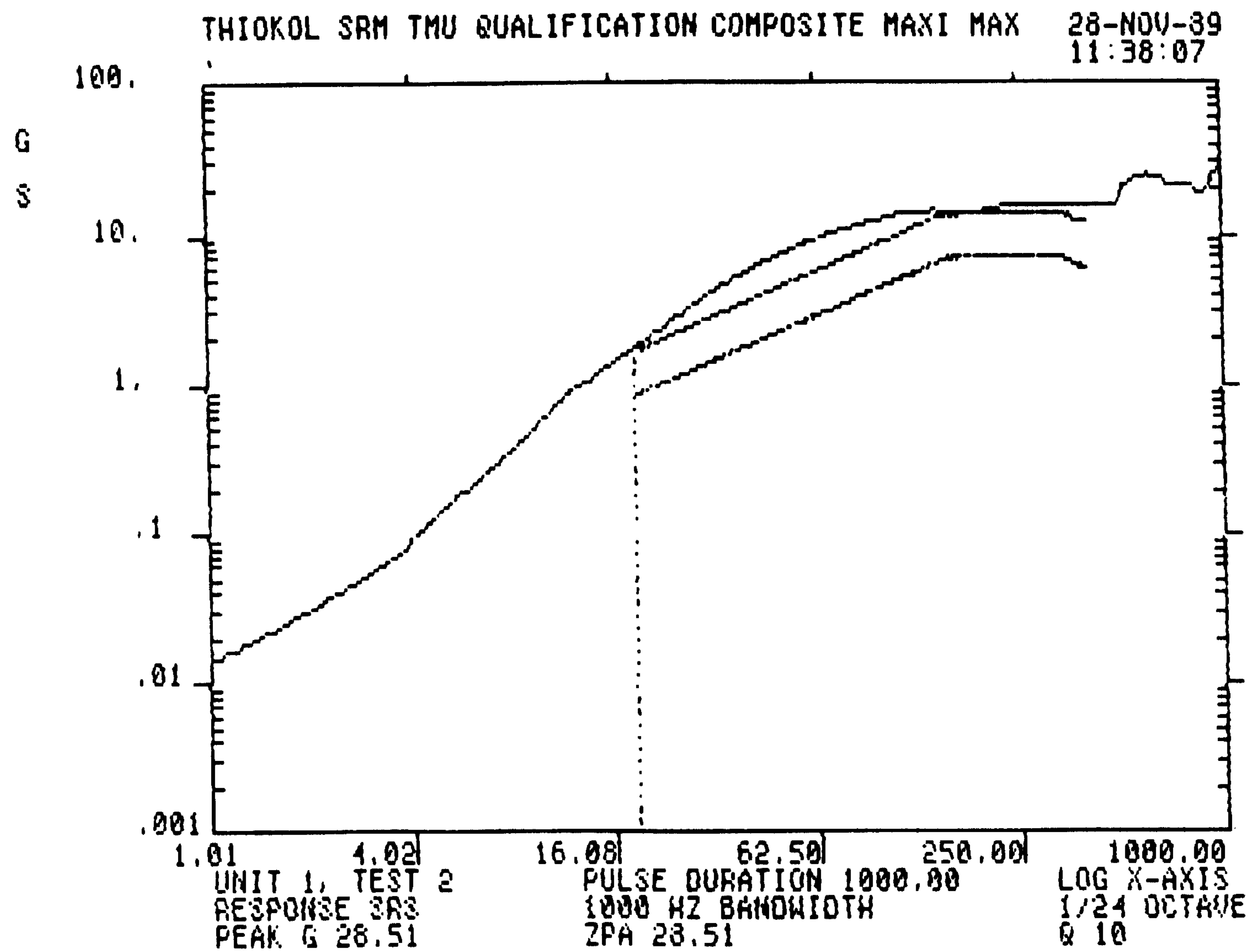
LOG X-AXIS
1/24 OCTAVE
Q 10

Longitudinal Axis 163°F

Shock #1

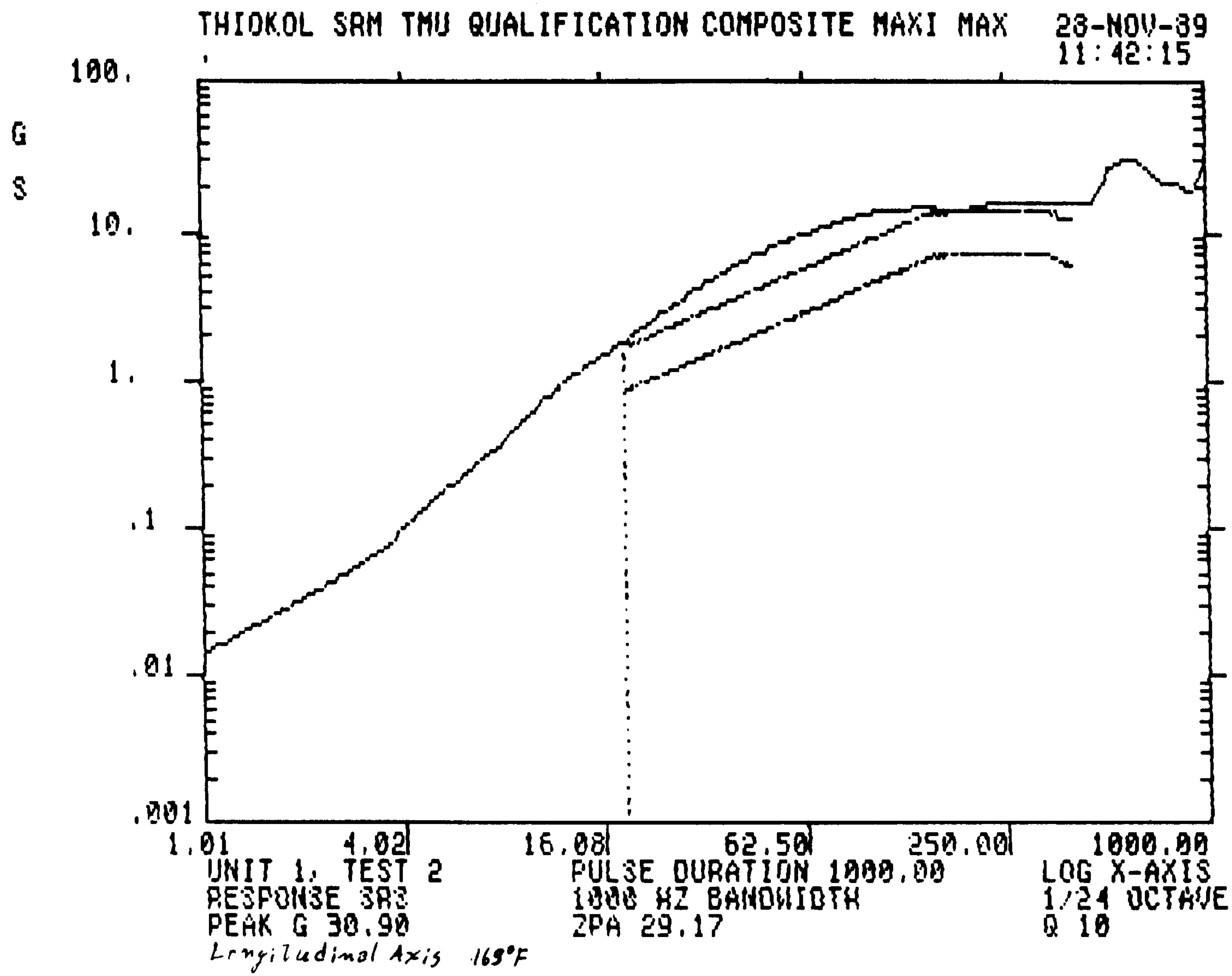

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
28-NOV-89
11:29:49
G
S
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE SR3
PEAK G 31.26
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 26.84
LOG X-AXIS
1/24 OCTAVE
Q 10
Longitudinal Axis 163°F

Shock # 2



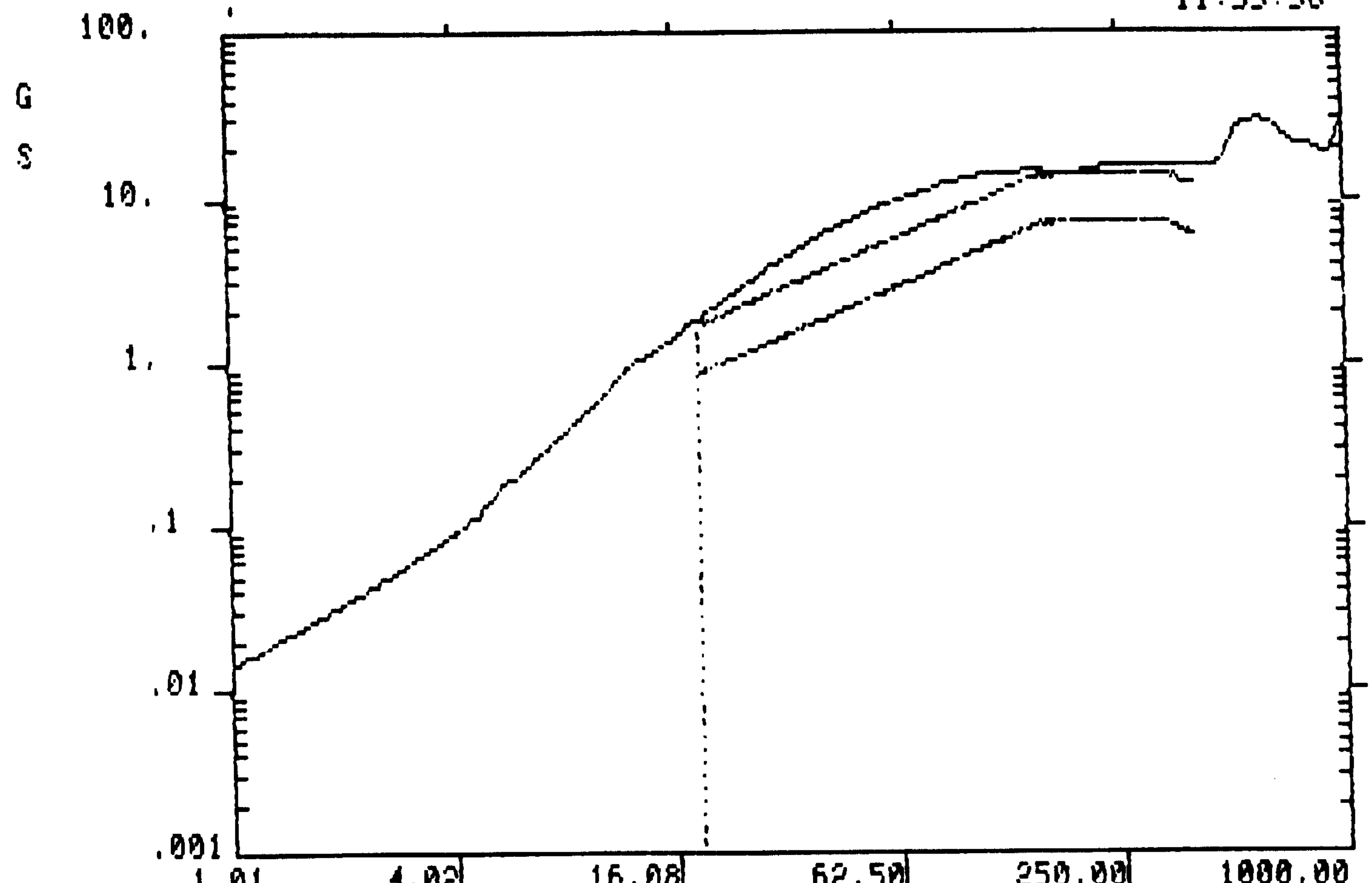
Longitudinal Axis 163°F

Shock #3


THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX
28-NOV-89
11:42:15
G
S
100.
10.
1.
.1
.01
.001
1.01
4.02
16.08
62.50
250.00
1000.00
UNIT 1, TEST 2
RESPONSE 3R3
PEAK G 30.90
PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 29.17
LOG X-AXIS
1/24 OCTAVE
Q 10
Longitudinal Axis 165°F

Shock #4

THIOKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 28-NOV-89 11:33:58



UNIT 1, TEST 2
RESPONSE 3RS
PEAK G 30.55

PULSE DURATION 1000.00
1000 HZ BANDWIDTH
ZPA 29.17

LOG X-AXIS
1/24 OCTAVE
Q 10

Longitudinal Axis 163°F

Shock #5

APPENDIX C

QSI Corporation Memo, QDLM-2 Failure Analysis
(Wyle Laboratories qualification testing), dated 19 Jun 1989

QSI CORPORATION

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June 19, 1989

Mr. Miles Brown MS-T03D
Morton Thiokol, Inc.
Space Operations
P.O. Box 707
Brigham City, UT 84302-0707

Re: QDLM-2 Failure Analysis (Wyle Lab qualification testing)

Dear Miles:

The problems with the two QDLM units at Wyle Laboratories can be broken down into two different types of failures. The first, and far worse type of failure, was the shutdown of the QDLM at approximately 160°F. The second type of failure was the occurrence of truncated events in the recorded data. I will discuss this failure first.

Both boxes under test at Wyle showed occasional truncation errors. This failure was caused by a software error and means that parts of the data recorded during an acceleration event were lost or corrupted. The problem is not new, but up until a few weeks ago, QSI was unable to reproduce the failure in the laboratory making a rapid solution problematic. Although the error is software induced, it is possible that the vibration or temperature environment during testing exacerbated the existing condition. We now have discovered ways of forcing the failure and are converging on a solution to this failure mode.

The truncation error phenomenon, while chronic and undesirable, DOES NOT impugn the reliability of any data not indicated as 'truncated' by the DDR software. In other words, if the DDR software does not notify the user that an event is truncated, then the data in that event is reliable. The result of this malfunction is isolated to causing events marked as 'truncated'. Truncated events usually represent a very small part of the total data gathered in a run, so this type of error will not affect the reliability of the majority of data gathered by the QDLM-2. This problem should be corrected within the next two weeks. I will keep you informed of our progress in this area.

Premature shutdown of one of the QDLM units was a far worse failure in that it terminates the ability of the QDLM to gather any data at all. This failure, while serious, was traced to a simple cause. One of the logic ICs on the CPU board had a temperature sensitive failure mode which allowed it to operate properly below about 160°F, however, it would fail at higher temperatures. The IC was replaced and the board now functions correctly up to 185°F. I have tested both the QDLM units, which were sent to Wyle, at temperatures up to 185°F. Both units performed properly.

We do not expect this type of problem to occur in the future because all the circuit boards in the QDLM units are burned in at 185°F and are tested to prevent marginal chips from making it to the field. On very rare occasions though, an IC may make it through the battery of tests only to fail in the field. While there is really no way to absolutely guarantee that no ICs will fail in the field, the historical reliability of ICs, after burn in, is very good. We do not expect this failure mode to become an ongoing concern.

I hope this gives you what you need. If you have any questions, please call me.

Sincerely,

QSI CORPORATION

John J. Coffey
Project Engineer

Thiokol CORPORATION
SPACE OPERATIONS

APPENDIX D

QSI Corporation Report, Failure Analysis of TMUs
No. 006 and 0013, dated 4 Oct 1989

QSI
CORPORATION

October 4, 1989

Mr. Miles Brown
Thiokol Corporation
Space Operations
MS T44
PO Box 707
Brigham City, UT 84302

Dear Miles:

Enclosed with this letter is a Failure Analysis report prepared by John Coffey, concerning TMU units #0006 and #0013.

As the report indicates, TMU #0006 contained a metal flake which shorted channel 10, but the unit was otherwise functional. This short must have occurred after the unit shipped from QSI, since it passed its acceptance tests. TMU #0013 operated as required, and all data errors can be explained by improper application and installation.

We have spent approximately 750 man-hours this year, without any compensation, trying to find "failures" in these TMUs. We have located and fixed a couple of software problems (related to the truncated events), but to the best of our knowledge the most recent software we have been installing (Version 1.4) has no bugs or problems whatsoever. ?

For future reference, we will continue to be willing to analyze any suspicious data you retrieve from the TMU units, as follows:

- We must receive the TMUs and the unerased data modules. Supplying us with paper plots is not adequate for analysis.
- The actual cables and sensors used are not required, but will greatly simplify any failure analysis. Without these cables and sensors, we can never be sure we have truly identified the cause(s) of any problems.
- We must have a contract for the man-hours and materials used during the analysis.

If, during any data analysis, we find that a failure is due to original design problems, we will not charge for the analysis, and we will correct the problem in all units, without charge.

If we find a failed component in a TMU, we will request a contract for repair. There are two reasons for this: first, the warranty on these units has long since expired; second, we know

910120

of several instances where some units were exposed to environmental conditions well beyond those specified in the original contract.

If, as has been the case recently, the failures are due to installation or application, we will charge for the time spent doing the analysis.

We have offered to accept a contract for installation and checkout of the TMU units. We still believe that this would be the best route to achieving the performance of which these units are capable.

I have enclosed a disk with the latest DDR data recovery and reduction software. There are two differences between this Version 3.0 software and earlier versions (neither due to software bugs): first, this version clearly displays its version number on all initial menu screens, in all reports, and in all data files; second, the history file format has been improved to show both the maximum levels seen on any trigger channel and the trigger levels seen. Please make sure that your programmers get this new software for all future use, and that all older versions are deleted.

Finally, attached is a summary of where the twenty TMU units are in terms of software upgrades and baseplates. We are performing a complete calibration, as well as your acceptance test and our own (very rigorous) acceptance test at the time of the software upgrades.

Feel free to call me if you have any questions on any of this.

Sincerely,

QSI CORPORATION

James K. Elwell
President

JKE/mw
Enclosure

QDLM-2 (TMU) UPGRADE SUMMARY

October 4, 1989

Serial Number	Software Ver 1.4?	Baseplate Installed?
0001	no	no
0002	no	no
0003	no	no
0004	yes	no
0005	yes	no
0006	no	no
0007	yes	yes
0008	yes	no
0009	yes	yes
0010	no	no
0011	no	no
0012	no	no
0013	yes	no
0014	yes	no
0015	yes	no
0016	no	no
0017	yes	yes
0018	yes	no
0019	no	no
0020	no	no

FAILURE ANALYSIS

OF TMUs #0006 AND #0013

To:

Thiokol Corporation
Brigham City, UT 84302

From:

QSI CORPORATION
1740 Research Park Way
Logan, UT 84321
Telephone: 801-753-3657
FAX: 801-753-3822

October 4, 1989

FOREWORD

This report analyzes the apparent failure of TMUs #0006 and #0013 to gather reliable data during the shipment of eighth flight motors to KSC.

After examining both TMUs and the data acquired by TMU #0013, we feel that the problems seen on this run do not indicate a general failure of the TMU design. The problems encountered are primarily due to improper installation and data reduction errors.

A small metal flake was found in TMU #0006 which caused the malfunction of channel 10 on that unit. At the time of the SRM shipment, TMU #0006 had not been upgraded with the current revision of internal software. No other problems were found with unit #0006.

The unexpected truncated events in data gathered by TMU #0013 were caused by the use of obsolete DDR software in the data reduction stage. This problem was eliminated in later software releases (Version 2.3 or later), but an earlier version was used here.

Two other problems were found in the data acquired by TMU #0013: 1) unusual waveforms on channel 4; 2) unusual waveforms seen on channels 1, 2 and 3. The nature of the recorded data indicates that these problems are due to installation problems and/or bad or loose cables.

There is some question as to whether the accelerometers accompanying TMU #0013 were the ones actually used on the eighth flight shipment. Without the actual equipment used during a run, a thorough analysis of any apparently erroneous data is impossible.

1. Problems with TMU #0006.

TMU #0006 was found to contain a small metal flake in the vicinity of the channel 10 analog electronics. This metal flake shorted analog electronics within TMU #0006, causing channel 10 to become inoperative during the run.

The data recorded by TMU #0006 was not provided to us. The TMU contained old versions of internal software, so random truncated errors may occur in the data recorded by this unit.

The origin of the metallic flake is unknown but it could reasonably be expected to arise either within the SRM shipping environment or during assembly of the TMUs. TMU #0006 was thoroughly tested at the factory prior to its delivery to Thiokol, and was found to be fully operational.

2. Problems with TMU #0013.

2.1. Truncated Events.

The truncated events which occurred near event 144 in the recorded data are fictitious and do not exist in the actual data. They are the result of using obsolete (Version 2.2) DDR software to read the modules for this run. The use of current DDR software eliminates this problem.

The short truncations (less than 128 bytes) at the end of data from each set of modules are expected, and are the result of normal operation of the TMUs.

2.2. Unusual Waveforms - Channel 1, 2 and 3.

The waveforms seen on channels 1, 2 and 3, while unusual, are all quite similar in appearance and form, and correlate in time. This suggests a common cause in their generation. We do not believe these waveforms represent real accelerations experienced by the segment during shipment.

During simulation trials in the lab, we found we could generate similar waveforms (in three simultaneous channels, correlating in time, appearance and form), simply by loosening the bolts which hold the tri-axial mounting block to its support structure, then subjecting the support structure to low-level shocks.

Since no electronic failures could be found with the TMU, and since channels 1, 2 and 3 are connected to one tri-axial block during shipment, and since the waveforms are easily simulated as described, we can only conclude that the mounting block for these three channels was loose during shipment.

[What about 5 shipments ?]

2.3. Unusual Waveforms - Channel 4.

Channel 4 recorded numerous suspect waveforms, and was the cause of the large number of triggered events seen during the trip. Analysis of the data shows these items:

- Numerous events with waveforms typical of a discontinuity, i.e., large instantaneous voltage swings followed by a 2- to 4-second discharge curve. This indicates loose connector(s) or broken wires or both.

- Numerous events (sometimes coincident with those mentioned above) which show short, quick pulses, sometimes with DC offset levels. These are typical of a loose mounting, and are easily simulated in the lab by very light tapping on an accelerometer.

Because of the nature of the waveforms, and because they often were coincidental with waveforms on channels 1, 2 and 3, and because channel 5, which used the same ADC electronics, operated normally, and because the channel 4 electronics operated perfectly in post-run lab testing, we conclude that the channel 4 accelerometer was mounted loosely and had a loose or broken cable.

There is a possibility of an internal failure in the channel 4 accelerometer causing both types of invalid data, but this cannot be evaluated since we do not know which accelerometer was used for channel 4.

3. Channel 5 Through 10 Data.

After examining the data recorded by channels 5 through 10, we have no reason to suspect these waveforms represent anything other than the actual accelerations experienced by these accelerometers. The characteristics of these waveforms are fully consistent with the type, amplitude, and frequency of accelerations expected on a rail shipment such as this.

4. Trip-History/Recorded-Data Correlation.

The correlation between the trip history, as recorded by Agnello and Stone, and the data recorded by TMU #0013 is quite good. At no time, with one exception (discussed below), did the TMU continuously trigger while the train was stationary on the tracks.

There are a few isolated triggered events during idle periods, all triggered by channel 4. In all cases, the channel 4 waveform is typical of a loose or broken cable losing contact momentarily. There are many possible causes: a person brushing against the cable (if the loose connector is at the TMU, or if the cable is broken near where it can be touched), a slight jolt to cars being coupled or uncoupled, movement of the box while opening or closing the cover, etc.

We would *not* expect to see continuous triggering of events while the train was stationary, and indeed, this was not seen in the data. Continuous triggering of the TMU only occurred while the train was moving or being maneuvered to connect cars. Any vibration occurring during these periods would reasonably be expected to shake loose connectors or broken cables, thus causing triggered events by continually connecting/ disconnecting the accelerometer from the TMU.

The single exception mentioned above occurred on Saturday, September 2, from 20:00:41 to 20:14:54. The trip record indicates the train was stopped from 20:00 to 20:15 on this evening, but the TMU recorded essentially continuous events during this time. We would not expect this to happen if the only problem was a loose or broken cable. However, because of various indications in the data and in the trip record, we believe the train was moving during this period of time.

The first indication of this is the waveforms on channels 5 through 10. These are similar to those recorded during other portions of the trip when the train *was* moving. At all other times when the log shows the train stopped, there are no signals on channels 5 through 10.

The next indication is the waveforms on channels 1 through 3. Although the actual waveforms are suspect, these three channels never showed any activity except when the train was moving. They showed activity during this period, again indicating that the train *was* moving.

These facts, along with the general poor quality of the trip record (such as a time of 2453 being followed by a time of 0010) lead us to believe the train was, in fact, moving during this time.

5. Summary.

We believe the data recorded on channels 5 through 10 to be accurate and representative of actual accelerations experienced by the SRM segment during shipment.

The data indicates that the cable for channel 4 was broken or had one or more loose connectors, and was mounted loosely. The alternate cause, an internal failure of the accelerometer, cannot be evaluated.

The waveforms recorded by channels 1 through 3 were probably caused by a loose mounting block on the railcar.

The truncated events shown in the history file given to us were due to an obsolete version of one of the data reduction programs.

TMU #0006 developed an electrical short circuit during the trip. No other problems were found with the TMUs. They both ran flawlessly while undergoing complete and thorough testing in the lab.

APPENDIX E

Shock and Sine Dwell Testing at Unisys
(engineering evaluation only)--Results and Calculations

Temperature

-32 F

Shock #1 (Figure 1)

Input peak-to-peak (g)= 1.95
Input Shock Frequency =24 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.968	3.046	2.929	3.007	2.772	3.085	3.007	2.851	2.773	2.772
Percent Error=	52.2%	56.2%	50.2%	54.2%	42.2%	58.2%	54.2%	46.2%	42.2%	42.2%

Average Percent Error= 49.8% (10 channels)

Shock #2 (Figure 2)

Input peak-to-peak (g)= 1.89
Input Shock Frequency =24 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.733	2.811	2.77	2.85	2.616	2.811	2.772	2.694	2.538	2.655
Percent Error=	44.6%	48.7%	46.6%	50.8%	38.4%	48.7%	46.7%	42.5%	34.3%	40.5%

Average Percent Error= 44.2% (10 channels)

70 F

Shock #1 (Figure 3)

Input peak-to-peak (g)= 1.98
Input Shock Frequency =16 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.421	2.342	2.382	2.577	Bad	2.421	2.382	2.382	2.499	2.46
Percent Error=	22.3%	18.3%	20.3%	30.2%	N/A	22.3%	20.3%	20.3%	26.2%	24.2%

Average Percent Error= 22.7% (9 channels)

Shock #2 (Figure 4)

Input peak-to-peak (g)= 1.98
Input Shock Frequency =16 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.343	2.343	2.304	2.499	Bad	2.343	2.304	2.304	2.421	2.382
Percent Error=	18.3%	18.3%	16.4%	26.2%	N/A	18.3%	16.4%	16.4%	22.3%	20.3%

Average Percent Error= 19.2% (9 channels)

----

130 F

Shock #1 (Figure 5)

Input peak-to-peak (g)= 3.62
Input Shock Frequency =37 Hz

Peak-to-Peak Values (g)	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.358	3.28	3.241	3.397	3.241	3.358	3.28	3.241	3.358	3.28
Percent Error=	-7.2%	-9.4%	-10.5%	-6.2%	-10.5%	-7.2%	-9.4%	-10.5%	-7.2%	-9.4%

Average Percent Error= -8.7% (10 channels)

Shock #2 (Figure 6)

Input peak-to-peak (g)= 3.62
Input Shock Frequency =38 Hz

Peak-to-Peak Values (g)	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.28	3.28	3.202	3.28	3.163	3.28	3.241	3.163	3.241	3.202
Percent Error=	-9.4%	-9.4%	-11.5%	-9.4%	-12.6%	-9.4%	-10.5%	-12.6%	-10.5%	-11.5%

Average Percent Error= -10.7% (10 channels)

----

140 F

Shock #1 (Figure 7)

Input peak-to-peak (g)= 1.62
Input Shock Frequency =15 Hz

Peak-to-Peak Values (g)	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.796	1.874	1.796	1.835	1.835	1.835	1.757	1.796	1.796	1.796
Percent Error=	10.9%	15.7%	10.9%	13.3%	13.3%	13.3%	8.5%	10.9%	10.9%	10.9%

Average Percent Error= 11.8% (10 channels)

Shock #2 (Figure 8)

Input peak-to-peak (g)= 1.61
Input Shock Frequency =15 Hz

Peak-to-Peak Values (g)	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.796	1.874	1.796	1.835	1.826	1.835	1.835	1.796	1.835	1.796
Percent Error=	11.6%	16.4%	11.6%	14.0%	13.4%	14.0%	14.0%	11.6%	14.0%	11.6%

Average Percent Error= 13.2% (10 channels)

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150 F

Shock #1 (Figure 9)

Input peak-to-peak (g)= 1.02
Input Shock Frequency =23 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.092	1.014	1.092	1.132	1.132	1.092	1.053	1.132	1.093	1.093
Percent Error=	7.1%	-0.6%	7.1%	11.0%	11.0%	7.1%	3.2%	11.0%	7.2%	7.2%

Average Percent Error= 7.1% (10 channels)

Shock #2 (Figure 10)

Input peak-to-peak (g)= 0.92
Input Shock Frequency =18 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.092	1.092	1.053	1.092	1.092	1.053	1.053	1.053	1.053	1.092
Percent Error=	18.7%	18.7%	14.5%	18.7%	18.7%	14.5%	14.5%	14.5%	14.5%	18.7%

Average Percent Error= 16.6% (10 channels)

Temperature

-32 F

Event #1 (Figure 11)

Input peak-to-peak (g)=2.985
Input Shock Frequency =10 Hz

Peak-to-Peak Values (g)

	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.436	3.749	3.475	3.553	3.319	3.631	3.436	3.358	3.866	3.358
Percent Error=	15.1%	25.6%	16.4%	19.0%	11.2%	21.6%	15.1%	12.5%	29.5%	12.5%

Average Percent Error= 17.8% (10 channels)

Event #2 (Figure 11)

Input peak-to-peak (g)=2.985
Input Shock Frequency =10 Hz

Peak-to-Peak Values (g)

	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.514	3.671	3.475	3.513	3.397	3.67	3.553	3.436	5.312	3.397
Percent Error=	17.7%	22.9%	16.4%	17.7%	13.8%	22.9%	19.0%	15.1%	77.9%	13.8%

Average Percent Error= 23.7% (10 channels)

70 F

Event #1 (Figure 12)

Input peak-to-peak (g)=2.930
Input Shock Frequency =10 Hz

Peak-to-Peak Values (g)

	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.89	2.89	2.89	2.89	Bad	2.812	2.773	2.851	2.773	2.851
Percent Error=	-1.4%	-1.4%	-1.4%	-1.4%	N/A	-4.0%	-5.4%	-2.7%	-5.4%	-2.7%

Average Percent Error= -2.9% (9 channels)

Event #2 (Figure 12)

Input peak-to-peak (g)=2.930
Input Shock Frequency =10 Hz

Peak-to-Peak Values (g)

	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.89	2.89	2.851	2.89	Bad	2.812	2.812	2.851	2.773	2.851
Percent Error=	-1.4%	-1.4%	-2.7%	-1.4%	N/A	-4.0%	-4.0%	-2.7%	-5.4%	-2.7%

Average Percent Error= -2.9% (9 channels)

----

130 F

Event #1 (Figure 13)

Input peak-to-peak (g)= 3
Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.812	2.812	2.89	2.968	2.89	2.89	2.812	2.89	2.89	2.89
Percent Error=	-6.3%	-6.3%	-3.7%	-1.1%	-3.7%	-3.7%	-6.3%	-3.7%	-3.7%	-3.7%

Average Percent Error= -4.2% (10 channels)

Event #2 (Figure 13)

Input peak-to-peak (g)= 3
Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	N/A									
Percent Error=										

Average Percent Error= 0.0% (10 channels)

----

140 F

Event #1 (Figure 14)

Input peak-to-peak (g)=2.920
Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.734	2.734	2.734	2.734	2.695	2.695	2.695	2.656	2.734	2.656
Percent Error=	-6.4%	-6.4%	-6.4%	-6.4%	-7.7%	-7.7%	-7.7%	-9.1%	-6.4%	-9.1%

Average Percent Error= -7.3% (10 channels)

Event #2 (Figure 14)

Input peak-to-peak (g)=2.920
Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.734	2.734	2.695	2.734	2.656	2.695	2.695	2.656	2.734	2.617
Percent Error=	-6.4%	-6.4%	-7.7%	-6.4%	-9.1%	-7.7%	-7.7%	-9.1%	-6.4%	-10.4%

Average Percent Error= -7.7% (10 channels)

----
150 F

Event #1 (Figure 15)

Input peak-to-peak (g)=3.027
Input Shock Frequency =10 Hz

Peak-to-Peak Values (g)

	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.656	2.577	2.617	2.734	2.617	2.617	2.538	2.656	2.695	2.656
Percent Error=	-12.3%	-14.9%	-13.6%	-9.7%	-13.6%	-13.6%	-16.2%	-12.3%	-11.0%	-12.3%

Average Percent Error= -12.9% (10 channels)

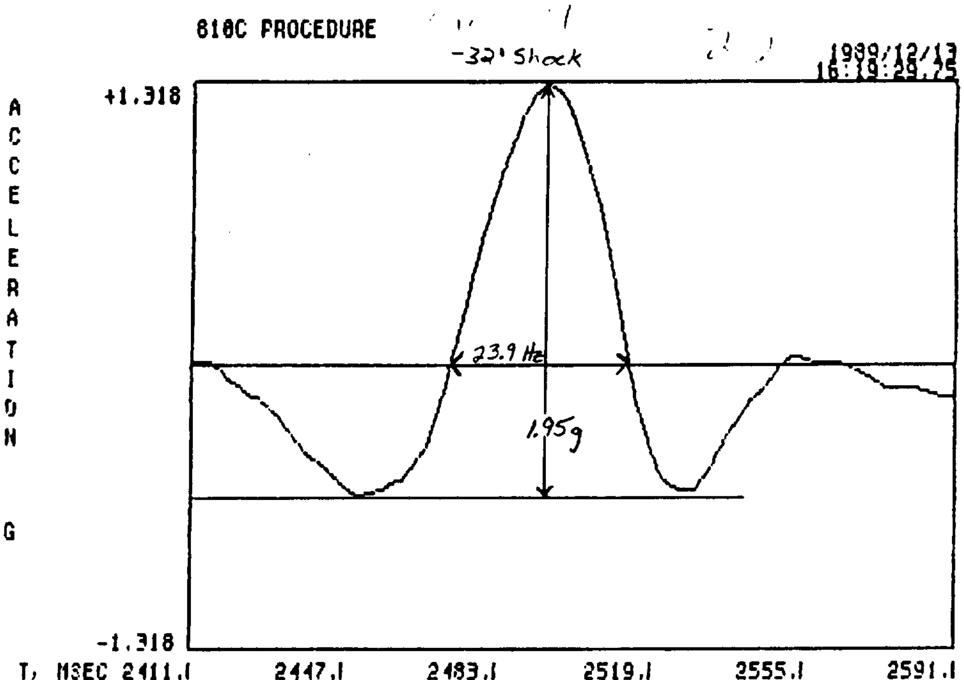
Event #2 (Figure 15)

Input peak-to-peak (g)=3.027
Input Shock Frequency =10 Hz

Peak-to-Peak Values (g)

	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.656	2.656	2.617	2.773	2.656	2.617	2.578	2.617	2.656	2.656
Percent Error=	-12.3%	-12.3%	-13.6%	-8.4%	-12.3%	-13.6%	-14.8%	-13.6%	-12.3%	-12.3%

Average Percent Error= -12.5% (10 channels)

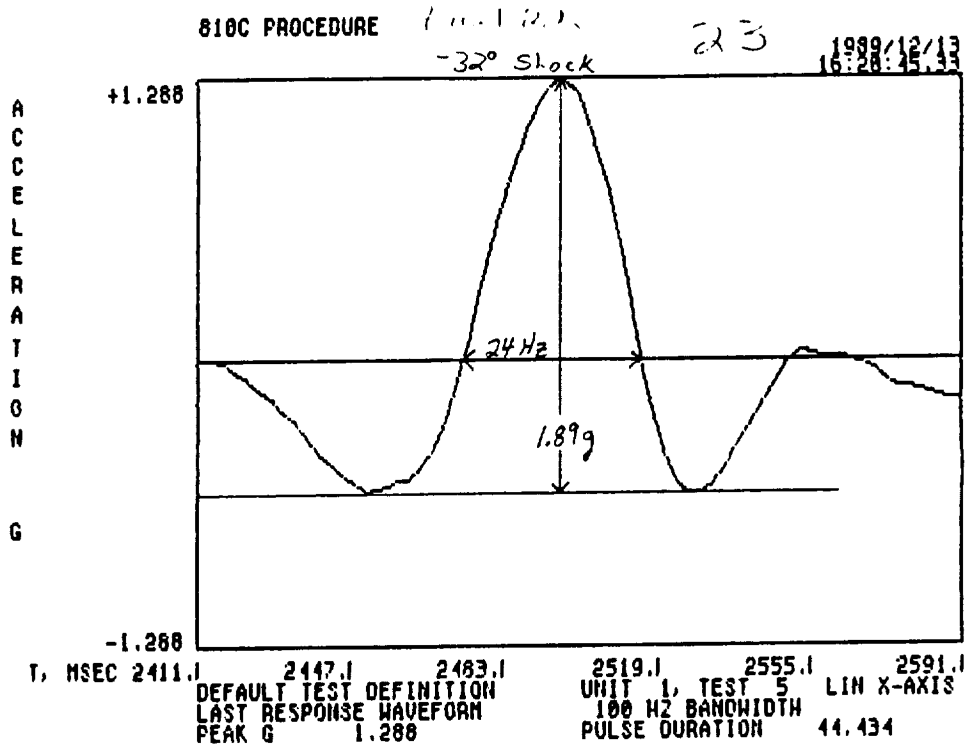


DEFAULT TEST DEFINITION UNIT 1, TEST 5 LIN X-AXIS
LAST RESPONSE WAVEFORM 100 HZ BANDWIDTH
PEAK G 1.318 PULSE DURATION 44.434

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
21	00 16:22:00	CHANNEL 1	-1.640	-0.031	1.328
		CHANNEL 2	-1.640	-0.034	1.406
		CHANNEL 3	-1.640	-0.018	1.289
		CHANNEL 4	-1.640	-0.011	1.367
		CHANNEL 5	-1.523	-0.017	1.249
		CHANNEL 6	-1.679	0.008	1.406
		CHANNEL 7	-1.640	-0.007	1.367
		CHANNEL 8	-1.562	-0.006	1.289
		CHANNEL 9	-1.406	0.004	1.367
		CHANNEL 10	-1.523	-0.004	1.249

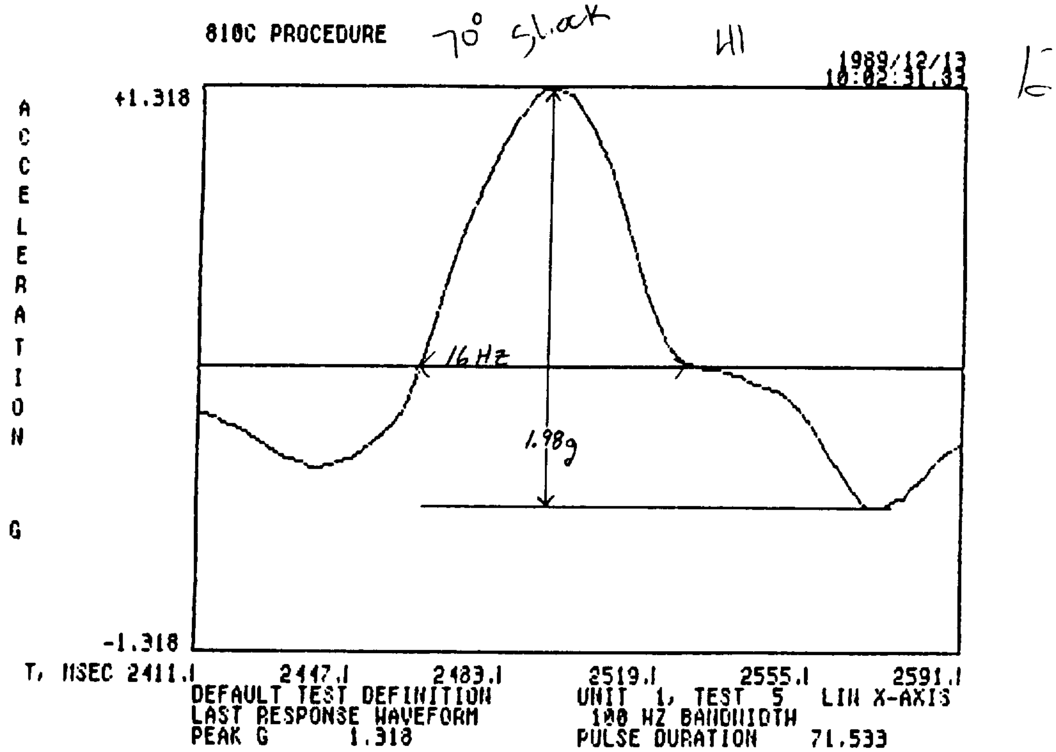
-32°F Shock



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
22	00 16:23:16	CHANNEL 1	-1.796	-0.018	0.937
		CHANNEL 2	-1.874	-0.028	0.937
		CHANNEL 3	-1.679	0.001	1.093
		CHANNEL 4	-1.757	0.004	1.093
		CHANNEL 5	-1.601	-0.011	1.015
		CHANNEL 6	-1.718	0.018	1.093
		CHANNEL 7	-1.718	-0.003	1.054
		CHANNEL 8	-1.757	-0.007	0.937
		CHANNEL 9	-1.445	0.016	1.093
		CHANNEL 10	-1.718	-0.011	0.937

-32° Shock



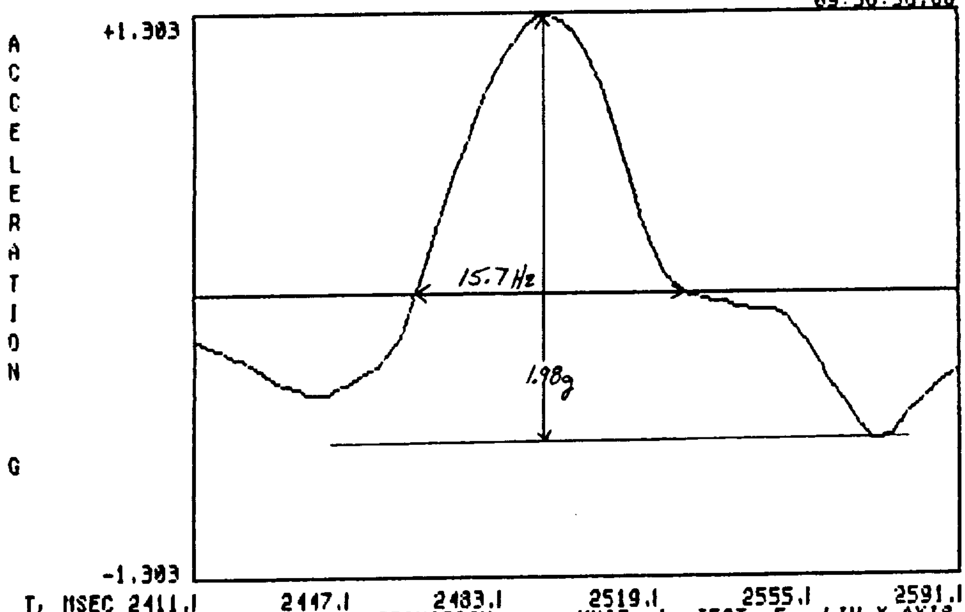
EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
41	01 10:02:02	CHANNEL 1 2,421	-1.093	0.007	1.328
		CHANNEL 2 2,542	-1.093	0.009	1.249
		CHANNEL 3 2,382	-1.093	0.011	1.289
		CHANNEL 4 2,577	-1.171	0.006	1.406
		CHANNEL 5	-0.039	-0.014	0.039
		CHANNEL 6 2.421	-1.093	0.007	1.328
		CHANNEL 7 2,382	-1.093	-0.001	1.289
		CHANNEL 8 2,382	-1.093	0.003	1.289
		CHANNEL 9 2,499	-1.132	0.003	1.367
		CHANNEL 10 2.460	-1.132	-0.001	1.328

70° shock

810C PROCEDURE 70° Shock 42

1989/12/13
09:58:56.68



DEFAULT TEST DEFINITION
LAST RESPONSE WAVEFORM
PEAK G 1.303

UNIT 1, TEST 5 LIN X-AXIS
100 HZ BANDWIDTH
PULSE DURATION 68.846

EVENT TIME SUMMARY ACROSS CHANNELS

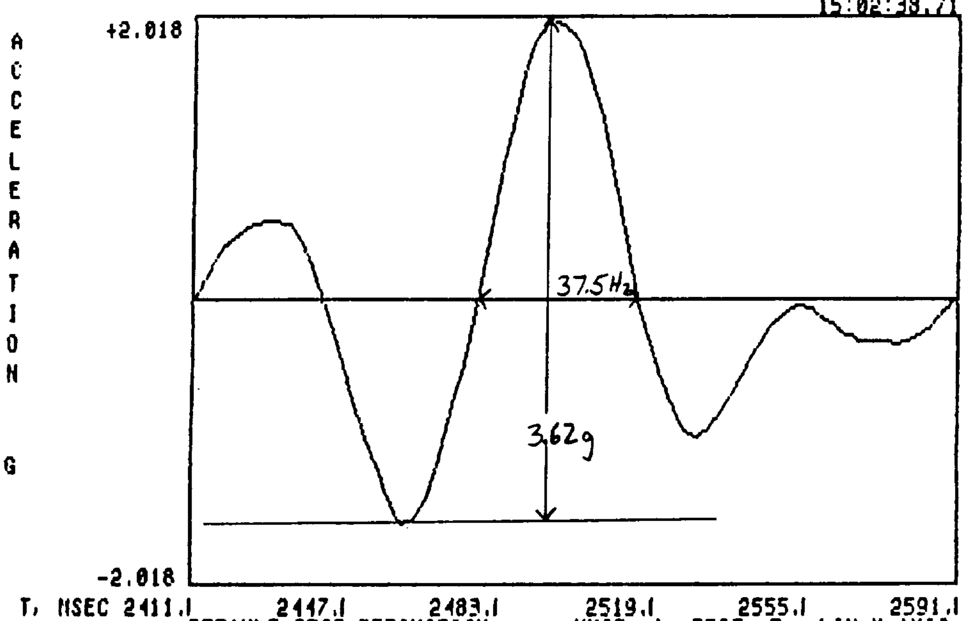
EVENT	Day/Time	Channel	Minimum	Average	Maximum
42	01 10:03:33	CHANNEL 1	2,343 -1.015	0.007	1.328
		CHANNEL 2	2,343 -1.015	0.011	1.328
		CHANNEL 3	2,304 -1.015	0.011	1.289
		CHANNEL 4	2,477 -1.093	0.005	1.406
		CHANNEL 5	Bad -0.039	-0.014	0.039
		CHANNEL 6	2,343 -1.015	0.009	1.328
		CHANNEL 7	2,304 -1.015	0.000	1.289
		CHANNEL 8	2,304 -1.015	0.002	1.289
		CHANNEL 9	2,421 -1.054	0.002	1.367
		CHANNEL 10	2,382 -1.054	0.000	1.328

70° Shock

810C PROCEDURE 23 12-8-89

1989/12/12
15:02:38.71

13'



DEFAULT TEST DEFINITION UNIT 1, TEST 5 LIN X-AXIS
LAST RESPONSE WAVEFORM 100 HZ BANDWIDTH
PEAK G 2.018 PULSE DURATION 40.039

130'

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
23	01 15:03:11	CHANNEL 1 3.358	-1.562	-0.032	1.796
		CHANNEL 2 3.280	-1.484	0.026	1.796
		CHANNEL 3 3.241	-1.484	-0.017	1.757
		CHANNEL 4 3.397	-1.562	-0.016	1.835
		CHANNEL 5 3.241	-1.484	-0.017	1.757
		CHANNEL 6 3.358	-1.523	-0.002	1.835
		CHANNEL 7 3.280	-1.484	-0.007	1.796
		CHANNEL 8 3.241	-1.484	-0.012	1.757
		CHANNEL 9 3.358	-1.523	-0.002	1.835
		CHANNEL 10 3.280	-1.484	-0.001	1.796

130° Shock

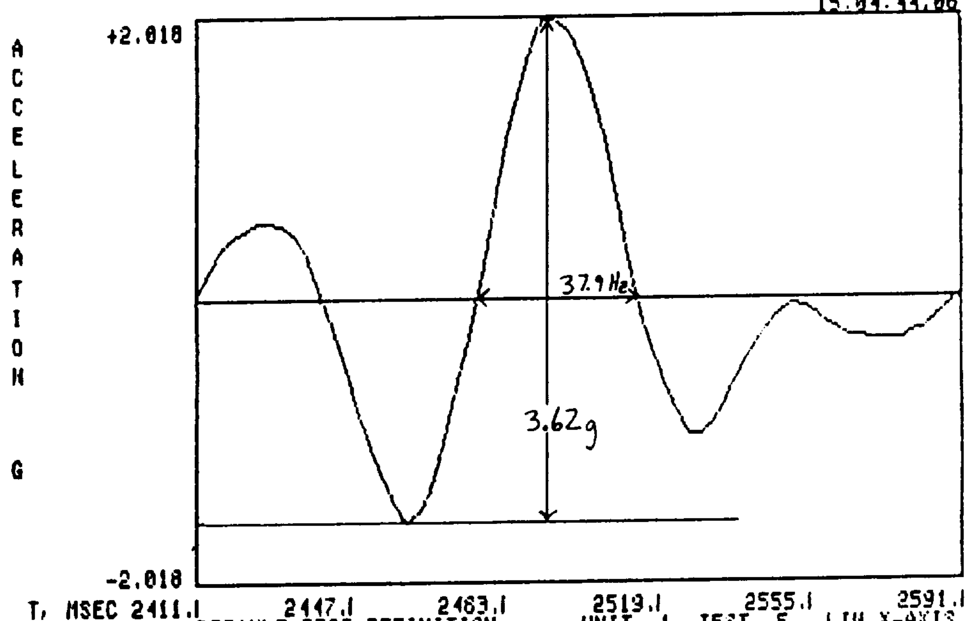
17-8-89

810C PROCEDURE

201

1989/12/12
15:04:44.06

130°



DEFAULT TEST DEFINITION
LAST RESPONSE WAVEFORM
PEAK G 2.018

UNIT 1, TEST 5 LIN X-AXIS
100 HZ BANDWIDTH
PULSE DURATION 40.283

EVENT TIME SUMMARY ACROSS CHANNELS

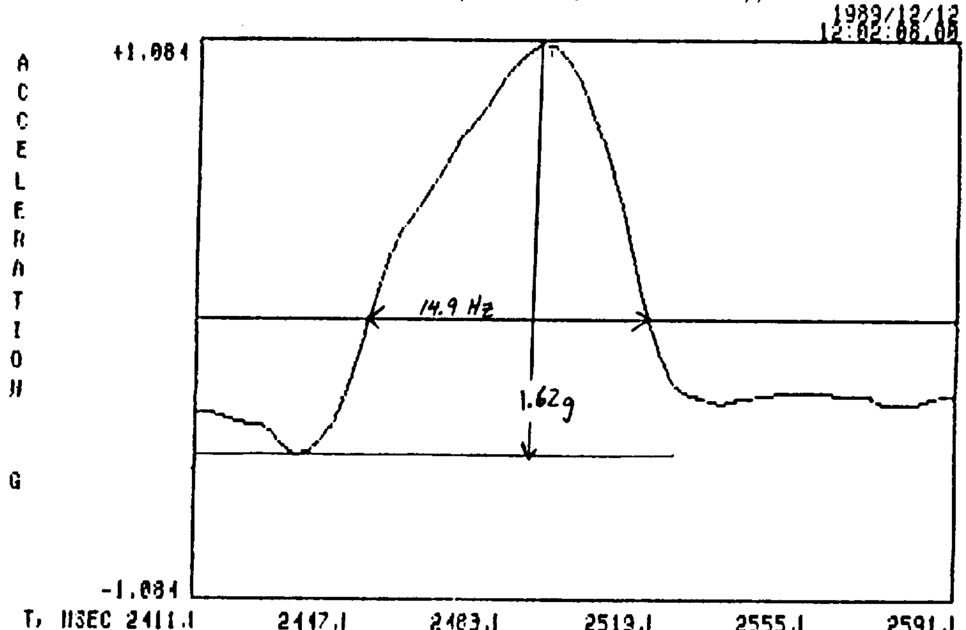
EVENT	Day/Time	Channel	Minimum	Average	Maximum
24	01 15:05:16	CHANNEL 1 3,280	-1.484	-0.031	1.796
		CHANNEL 2 3,280	-1.406	0.025	1.874
		CHANNEL 3 3,202	-1.406	-0.016	1.796
		CHANNEL 4 3,280	-1.445	-0.016	1.835
		CHANNEL 5 3,163	-1.406	-0.016	1.757
		CHANNEL 6 3,280	-1.445	-0.002	1.835
		CHANNEL 7 3,241	-1.445	-0.007	1.796
		CHANNEL 8 3,163	-1.406	-0.010	1.757
		CHANNEL 9 3,241	-1.406	-0.002	1.835
		CHANNEL 10 3,202	-1.406	0.000	1.796

130° 51.0c K

2

810C PROCEDURE

1989/12/12
12:02:08.08



DEFAULT TEST DEFINITION — UNIT 1, TEST 5 — LIN X-AXIS
LAST RESPONSE WAVEFORM — 100 HZ BANDWIDTH
PEAK G 1.084 — PULSE DURATION 70.312

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum	
23	01 11:51:21	CHANNEL 1	-0.781	-0.038	1.015	1,796
		CHANNEL 2	1.27 -0.703	0.037	1.171	1,874
		CHANNEL 3	-0.703	-0.018	1.093	1,796
		CHANNEL 4	-0.742	-0.017	1.093	1.835
		CHANNEL 5	-0.781	-0.017	1.054	1,835
		CHANNEL 6	-0.742	-0.007	1.093 10.9%	1,835
		CHANNEL 7	1.76 -0.703	-0.009	1.054	1,757
		CHANNEL 8	-0.742	-0.013	1.054	1,796
		CHANNEL 9	-0.703	-0.004	1.093	1,796
		CHANNEL 10	-0.703	-0.001	1.093 9.44%	1,796

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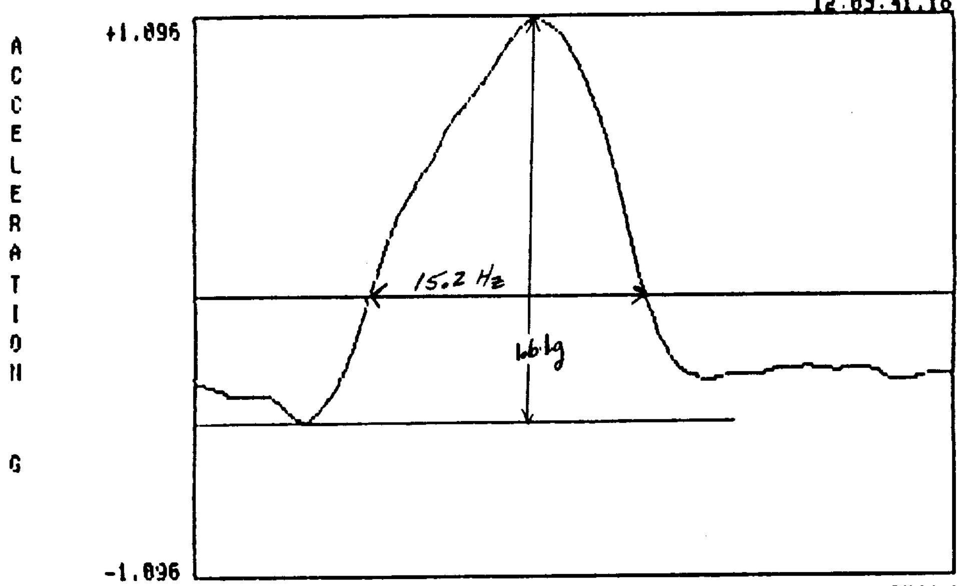
810C PROCEDURE 140° shock

1989/12/12
12:03:41.18



DEFAULT TEST DEFINITION
LAST RESPONSE WAVEFORM
PEAK G 1.096

UNIT 1, TEST 5 LIN X-AXIS
100 HZ BANDWIDTH
PULSE DURATION 69.580

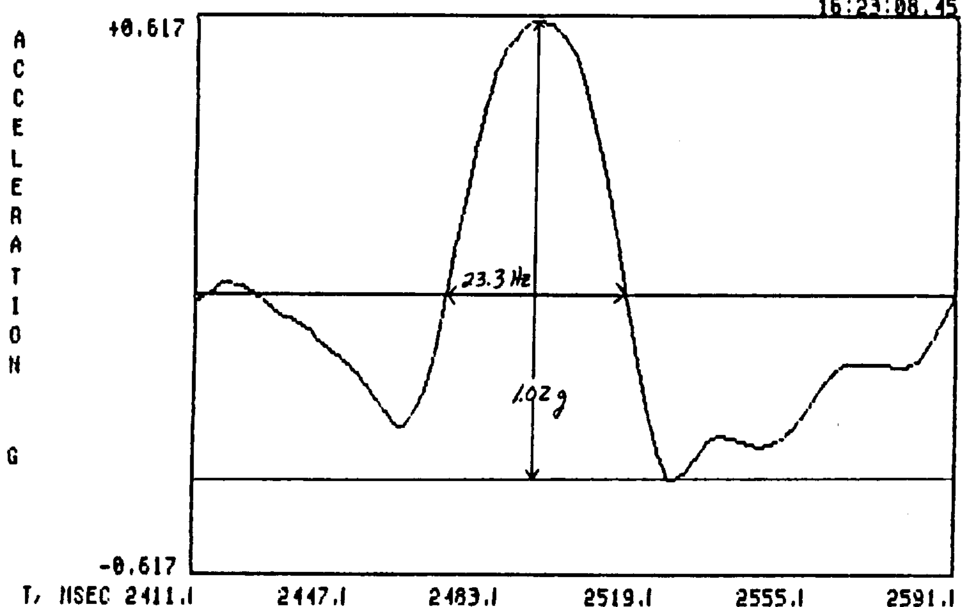
EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel		Minimum	Average	Maximum		
24	01 11:52:54	CHANNEL 1	1.80	-0.781	-0.033	1.015	9.44%	1.796
		CHANNEL 2	1.87	-0.781	0.044	1.093	[illegible]	1.874
		CHANNEL 3	1.80	-0.742	-0.016	1.054	[illegible]	1.796
		CHANNEL 4	1.93	-0.742	-0.017	1.093	10.9%	1.835
		CHANNEL 5	1.72	-0.781	-0.014	1.054	10.9%	1.826
		CHANNEL 6	1.93	-0.742	-0.001	1.093	10.9%	1.835
		CHANNEL 7	1.93	-0.742	-0.006	1.093	10.9%	1.835
		CHANNEL 8	1.8	-0.742	-0.008	1.054	9.44%	1.796
		CHANNEL 9	1.83	-0.742	-0.002	1.093	10.9%	1.835
		CHANNEL 10	1.8	-0.742	0.002	1.054	9.44%	1.796

140 Shock

Event 15

810C PROCEDURE 150° Shock 2 1989/12/12 16:23:08.45



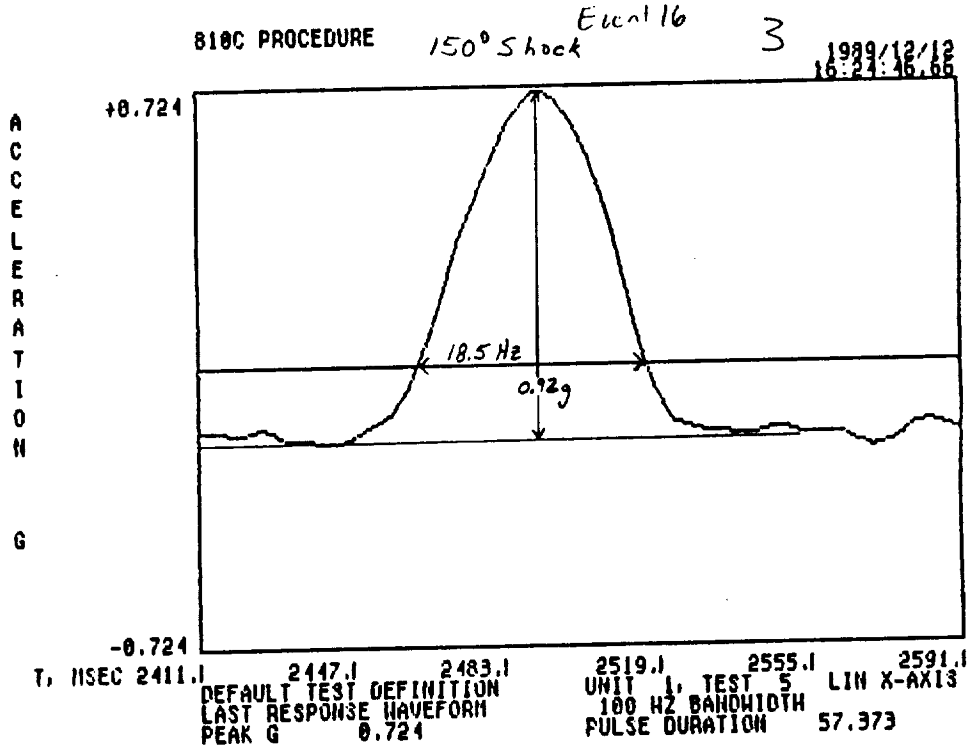
DEFAULT TEST DEFINITION UNIT 1, TEST 5 LIN X-AXIS
LAST RESPONSE WAVEFORM 100 HZ BANDWIDTH
PEAK G 0.617 PULSE DURATION 45.166

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel		Minimum	Average	Maximum
15	00 16:23:55	CHANNEL 1	1.092	-0.624	0.001	0.468
		CHANNEL 2	1.014	-0.546	0.008	0.468
		CHANNEL 3	1.092	-0.624	0.015	0.468
		CHANNEL 4	1.132	-0.664	0.011	0.468
		CHANNEL 5	1.132	-0.664	-0.001	0.468
		CHANNEL 6	1.092	-0.624	0.006	0.468
		CHANNEL 7	1.053	-0.624	0.002	0.429
		CHANNEL 8	1.132	-0.664	-0.001	0.468
		CHANNEL 9	1.093	-0.664	0.002	0.429
		CHANNEL 10	1.093	-0.664	-0.009	0.429

150° shock

Event 16 3



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel		Minimum	Average	Maximum
16	00 16:25:17	CHANNEL 1	1,092	-0.468	0.011	0.624
		CHANNEL 2	1,092	-0.468	0.024	0.624
		CHANNEL 3	1,053	-0.429	0.024	0.624
		CHANNEL 4	1,092	-0.507	0.015	0.585
150° shock		CHANNEL 5	1,092	-0.468	0.007	0.624
		CHANNEL 6	1,053	-0.429	0.020	0.624
		CHANNEL 7	1,053	-0.468	0.007	0.585
		CHANNEL 8	1,053	-0.468	0.011	0.585
		CHANNEL 9	1,053	-0.468	0.009	0.585
		CHANNEL 10	1,092	-0.468	0.002	0.624

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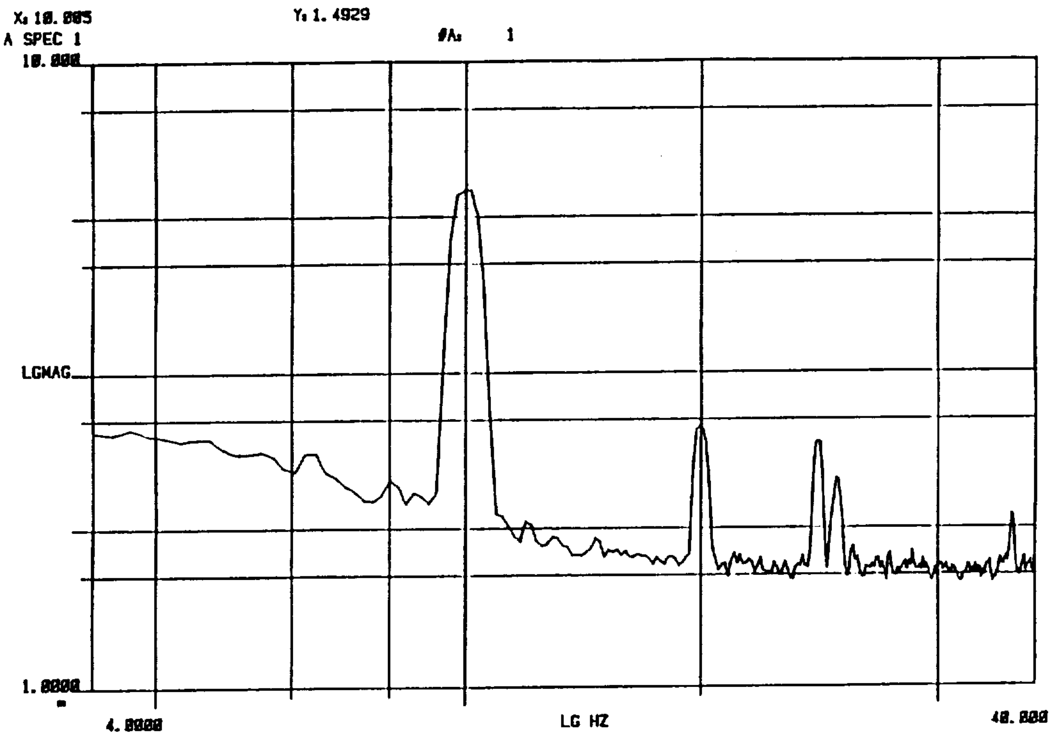
-32°F



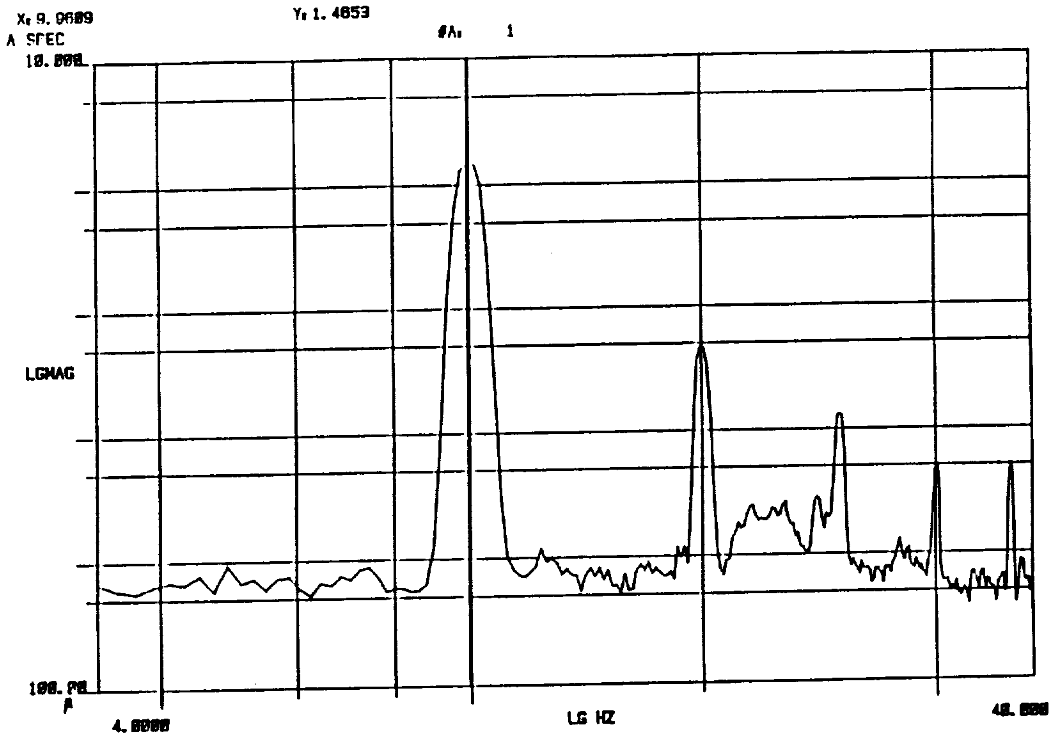
EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 1	Day/Time	Channel	Minimum	Average	Maximum
7	00 15:28:39	CHANNEL 1	3,436 -1.796	-0.072	1.640
		CHANNEL 2	3,749 -1.953	-0.058	1.796
		CHANNEL 3	3,475 -1.757	-0.028	1.718
		CHANNEL 4	3,553 -1.835	-0.029	1.718
		CHANNEL 5	3,319 -1.718	-0.037	1.601
		CHANNEL 6	3,631 -1.835	-0.006	1.796
		CHANNEL 7	3,436 -1.796	-0.022	1.640
		CHANNEL 8	3,358 -1.718	-0.025	1.640
		CHANNEL 9	3,866 -2.031	0.012	1.835
		CHANNEL 10	3,358 -1.718	-0.018	1.640

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2	Day/Time	Channel	Minimum	Average	Maximum
8	00 15:28:51	CHANNEL 1	3,514 -1.874	-0.053	1.640
		CHANNEL 2	3,671 -1.953	-0.064	1.718
		CHANNEL 3	3,475 -1.796	-0.037	1.679
		CHANNEL 4	3,513 -1.796	-0.038	1.718
		CHANNEL 5	3,397 -1.757	-0.046	1.640
		CHANNEL 6	3,670 -1.874	-0.016	1.796
		CHANNEL 7	3,553 -1.835	-0.035	1.718
		CHANNEL 8	3,436 -1.796	-0.040	1.640
		CHANNEL 9	5,312 -2.070	-0.031	3.242
		CHANNEL 10	3,397 -1.757	-0.028	1.640

70°F



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 1	Day/Time	Channel		Minimum	Average	Maximum
25	01 08:56:59	CHANNEL 1	2,890	-1.406	0.019	1.484
		CHANNEL 2	2,890	-1.406	0.016	1.484
		CHANNEL 3	2.890	-1.406	0.009	1.484
		CHANNEL 4	2,890	-1.406	0.005	1.484
		CHANNEL 5	Bad	-0.039	-0.013	0.039
		CHANNEL 6	2,812	-1.367	0.010	1.445
		CHANNEL 7	2,773	-1.367	-0.001	1.406
		CHANNEL 8	2.851	-1.406	0.000	1.445
		CHANNEL 9	2,773	-1.367	0.001	1.406
		CHANNEL 10	2,851	-1.406	-0.001	1.445

70° Sine

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2	Day/Time	Channel		Minimum	Average	Maximum
26	01 08:57:10	CHANNEL 1	2,890	-1.406	0.024	1.484
		CHANNEL 2	2,890	-1.406	0.017	1.484
		CHANNEL 3	2.851	-1.406	0.008	1.445
		CHANNEL 4	2.890	-1.406	0.005	1.484
		CHANNEL 5	Bad	-0.039	-0.012	0.000
		CHANNEL 6	2,812	-1.367	0.011	1.445
		CHANNEL 7	2,812	-1.406	0.000	1.406
		CHANNEL 8	2,851	-1.406	0.000	1.445
		CHANNEL 9	7,773	-1.367	0.001	1.406
		CHANNEL 10	[illegible].851	-1.406	0.002	1.445

70° Sine

130°F
Sine Dwell

Input 1.5g 10 Hz

'30 ~~[illegible]~~ Sine

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 1	Day/Time	Channel		Minimum	Average	Maximum
11	01 14:37:07	CHANNEL 1	2,812	-1.328	0.013	1.484
		CHANNEL 2	2,812	-1.328	0.024	1.484
		CHANNEL 3	2,890	-1.367	0.021	1.523
		CHANNEL 4	2,968	-1.406	0.012	1.562
		CHANNEL 5	2,890	-1.367	0.008	1.523
		CHANNEL 6	2,890	-1.367	0.015	1.523
		CHANNEL 7	2,812	-1.328	0.004	1.484
		CHANNEL 8	2,89	-1.367	0.008	1.523
		CHANNEL 9	2,89	-1.367	0.008	1.523
		CHANNEL 10	2,89	-1.367	0.000	1.523

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2	Day/Time	Channel	Minimum	Average	Maximum
12	01 14:43:58	CHANNEL 1	-0.468	0.008	0.546
		CHANNEL 2	-0.468	0.022	0.546
		CHANNEL 3	-0.507	0.022	0.546
		CHANNEL 4	-0.507	0.014	0.585
		CHANNEL 5	-0.507	0.010	0.507
		CHANNEL 6	-0.468	0.015	0.546
		CHANNEL 7	-0.468	0.004	0.546
		CHANNEL 8	-0.507	0.008	0.546
		CHANNEL 9	-0.507	0.010	0.546
		CHANNEL 10	-0.507	0.001	0.546

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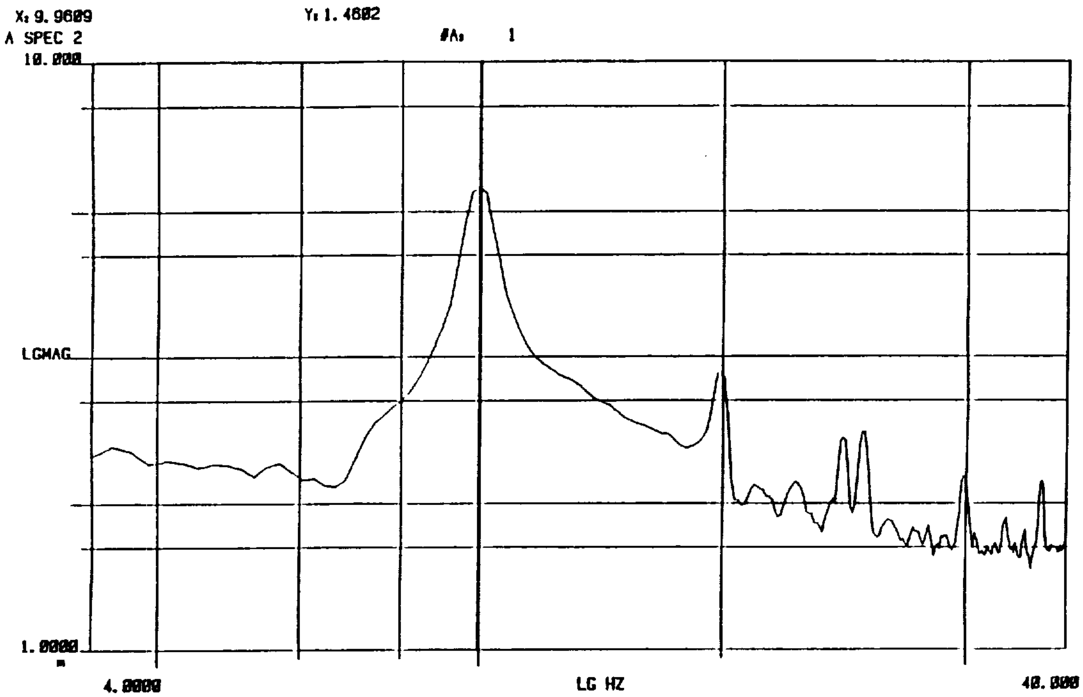

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 1	Day/Time	Channel	Minimum	Average	Maximum
9 1	01 10:52:00	CHANNEL 1 2.734	-1.406	-0.033	1.328
		CHANNEL 2 2.734	-1.328	0.038	1.406
		CHANNEL 3 2.734	-1.367	-0.017	1.367
		CHANNEL 4 2.734	-1.367	-0.019	1.367
		CHANNEL 5 2.695	-1.367	-0.017	1.328
		CHANNEL 6 2.695	-1.328	-0.001	1.367
		CHANNEL 7 2.695	-1.328	-0.003	1.367
		CHANNEL 8 2.656	-1.328	-0.008	1.328
		CHANNEL 9 2.734	-1.367	-0.001	1.367
		CHANNEL 10 2.656	-1.289	0.004	1.367

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2	Day/Time	Channel	Minimum	Average	Maximum
10	01 10:52:12	CHANNEL 1 2.734	-1.406	-0.035	1.328
		CHANNEL 2 2.734	-1.328	0.036	1.406
		CHANNEL 3 2.695	-1.367	-0.019	1.328
		CHANNEL 4 2.734	-1.367	-0.018	1.367
		CHANNEL 5 2.656	-1.328	-0.015	1.328
		CHANNEL 6 2.695	-1.328	-0.002	1.367
		CHANNEL 7 2.695	-1.328	-0.001	1.367
		CHANNEL 8 2.656	-1.328	-0.009	1.328
		CHANNEL 9 2.734	-1.367	0.001	1.367
		CHANNEL 10 2.617	-1.289	0.003	1.328

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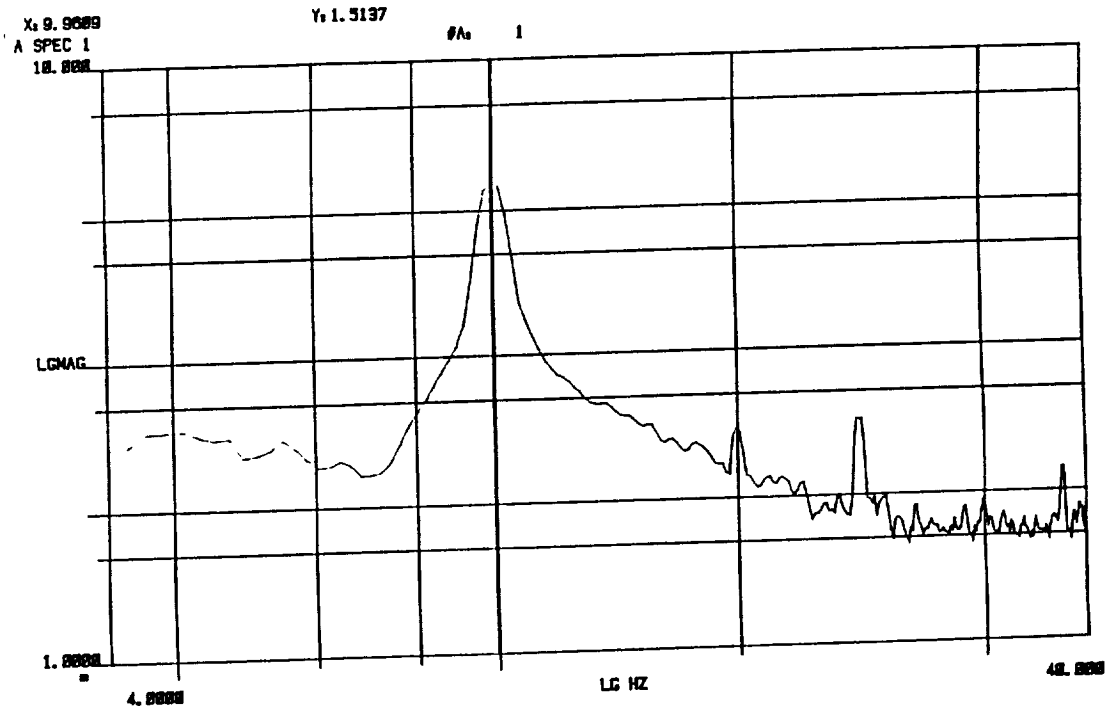

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT/	Day/Time	Channel	Minimum	Average	Maximum
3	00 16:03:47	CHANNEL 1	2.656 -1.328	0.013	1.328
		CHANNEL 2	2.577 -1.249	0.026	1.328
		CHANNEL 3	2.617 -1.289	0.022	1.328
		CHANNEL 4	2.734 -1.367	0.012	1.367
		CHANNEL 5	2.617 -1.289	0.006	1.328
		CHANNEL 6	2.617 -1.289	0.013	1.328
		CHANNEL 7	2.538 -1.249	0.004	1.289
		CHANNEL 8	2.656 -1.328	0.004	1.328
		CHANNEL 9	2.695 -1.328	0.004	1.367
		CHANNEL 10	2.656 -1.328	-0.004	1.328

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2	Day/Time	Channel	Minimum	Average	Maximum
4	00 16:03:58	CHANNEL 1	2.656 -1.328	0.012	1.328
		CHANNEL 2	2.656 -1.328	0.018	1.328
		CHANNEL 3	2.617 -1.289	0.025	1.328
		CHANNEL 4	2.773 -1.367	0.015	1.406
		CHANNEL 5	2.656 -1.328	0.008	1.328
		CHANNEL 6	2.617 -1.289	0.015	1.328
		CHANNEL 7	2.578 -1.289	0.003	1.289
		CHANNEL 8	2.617 -1.289	0.008	1.328
		CHANNEL 9	2.656 -1.328	0.009	1.328
		CHANNEL 10	2.656 -1.328	-0.002	1.328

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