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Aerospace Systems Pyrotechnic Shock Data

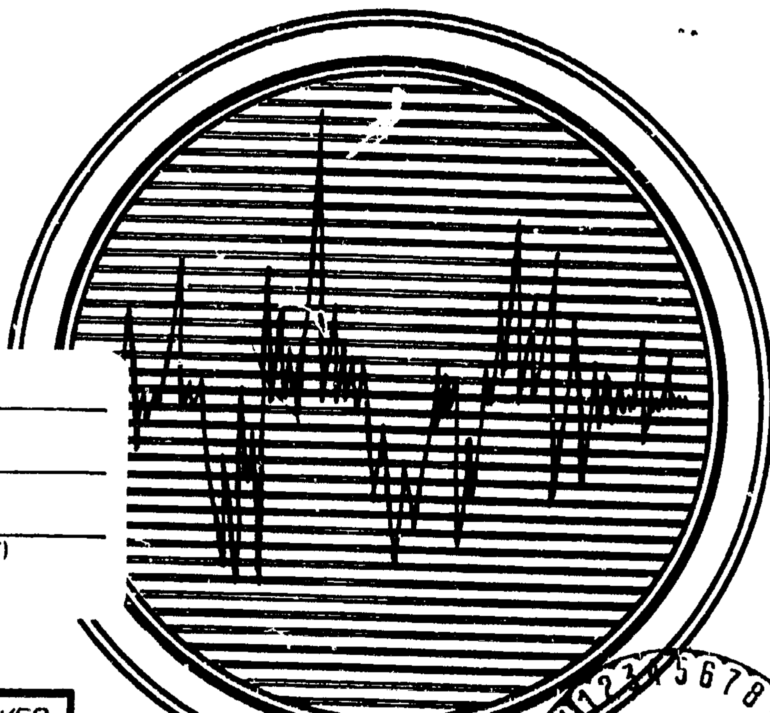
(Ground Test and Flight)

Volume VII

Investigation of Mass Loading Effects

Final Report

ovember 12, 1970



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for

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

Final Report

For

Investigation of Mass Loading Effects

(12 May to 12 November 1970)

Contract NAS5-21241

Addendum to:

Aerospace Systems Pyrotechnic Shock Data
(Ground Test and Flight)
Contract NAS5-15208

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PREFACE

This report presents a description of the work performed under contract NAS5-21241 during the period from 12 May to 12 November 1970. The program was conducted to determine the effect of weight variation in mounted subassemblies on the pyrotechnic shock environment at the interface of the subassembly and the mounting structure. The effect of weight variation was investigated for both airframe and truss mounted subassemblies.

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1.0 INTRODUCTION

1.1 Scope

This report presents the results of work accomplished under Contract NAS5-21241, Review, Evaluation and Compilation of Aerospace Systems Pyrotechnic Shock Data, during the period from 12 May through 12 November 1970. Efforts during this period included the preparation of a program plan and the performance of a test and analysis program to determine the effect of weight variations in mounted subassemblies on the pyrotechnic shock environment for two types of aerospace mounting structures.

a. Airframe, skin and stringer
b. Truss structure

The specific tasks accomplished in the performance of this program were as follows:

a. **Conduct a test and analysis program to determine the effect of weight variation in mounted subassemblies on the pyrotechnic shock environment at the interface of the subassembly and the mounting structure. This effect, designated herein as "mass loading", is to be studied for two (2) types of aerospace mounting structures:**

   1. **Airframe, skin and stringer structure.**

   2. **Truss structure.**

b. Mounted equipment is to be simulated with masses constructed so as not to affect the stiffness of the mounting structure. Single mass loading will be studied on the air frame structure and both single mass and distributed mass loading will be studied on the truss structure.

c. An explosive device shall be used as a controlled source of shock to the unloaded and loaded structures. Mass loading for the three (3) configurations will be applied in incremental steps with repetitive testing performed, if required. High frequency accelerometers (up to 24) and associated electronics giving a frequency capability to 20,000 Hz will be used.

d. The Contractor shall analyze the data to determine the relationship between the shock environment and the weight of the equipment. The Contractor shall discuss methods of extending the results of this test program to other cases and an attempt will be made to develop a generalized technique which will be suitable as a design guide.

e. The Contractor shall deliver the results of the above as an addendum report to the final report delivered under Contract NAS5-15208.

1.2 Summary

A test and analysis program was conducted to determine the relationship between the shock environment and the weight of mounted equipment. The configurations tested and analyzed were separated into three phases as listed in Table 1.

Table 1. Test Configurations

		Airframe (Skin and Stringer Structure)	Truss
Phase I	Single Mass Loading (Prototype Components)	0* Weight 1 Weight 2 Weight 3	0* Weight 1 Weight 2 Weight 3
Phase IA	Single Mass Loading (Steel Dummy)		Weight 1 Weight 2 Weight 3
Phase II	Distributed Mass Loading (Prototype Components)		Weight 1 Weight 2 Weight 3

*Bare Structure

This report presents a complete description of the test installation, instrumentation utilized, methods of analysis, and results for each phase of the program. Conclusions relative to the installation of components and the effect of weight on the pyrotechnic shock environment are presented.

2.0 PROGRAM DESCRIPTION

2.1 Test Program

2.1.1 General

The test program was conducted at the Martin Marietta Corporation's Acoustic Test Facility, Denver, Colorado. A Titan IIIC transtage skirt with guidance truss installed was utilized as the test fixture. Photographs of the skirt/truss assembly are shown in Figures 1 and 2.

2.1.2 Pyrotechnic Source

Shock transients were produced by the detonation of a Dupont No. 6 blasting cap and 50 grains of RDX explosive (cyclotrimethylenetrinitramine) contained in a small plastic vial. The vial containing the explosive was inserted in a steel receptacle bolted to a longeron as shown in the photograph in Figure 2. A minimum of two shocks were conducted for each configuration to insure repeatability of data.

2.1.3 Instrumentation

Twenty-four (24) Endevco Type 2225 accelerometers were installed at component mounting points, at a reference location, and at selected locations on the guidance truss as described in Table 2. The accelerometer output signals were recorded on magnetic tape utilizing an Ampex FR-600 and an Ampex FR-1300 recorders (FM, 108 KHz, 60 IPS). For quick-look data review, the recorded shock transients were played back at a reproduce speed of 15 IPS to a direct writing oscillograph (Honeywell Model 1508) utilizing high frequency galvanometers (Honeywell Model M-5000). The resulting acceleration time histories enabled the test conductor to evaluate each measurement and insure that valid data were obtained.

Preliminary shock spectra analyses were performed utilizing the Ling ASRA-40 shock spectrum analyzer set for 5 percent damping (Q=10).

2.1.4 Phase I - Single Mass Loading

The locations of components utilized for the single mass loading test series are shown in Figure 2. A summary of the weight configurations tested is presented in Table 3.

Changes in weights of the two components were accomplished by the addition of small steel plates distributed throughout the equipment chassis to simulate electronic modules in actual equipment. An interior view of the airframe mounted component showing the typical installation of weights is shown in Figure 3.

Measurement locations for the Phase I test series are shown in the photographs in Figures 4 and 5.

Table 2. Accelerometer Locations and Orientations

Accel. No.	Location			Orientation
1	1	Airframe (ref.)		Radial
2	1	Airframe		Tangential
3	1	Airframe		Longitudinal
4	2	Airframe	Component A Mounting Point	Radial
5	2	Airframe		Tangential
6	2	Airframe		Longitudinal
7	3	Truss	Component T Mounting Point (Inboard)	Vertical
8	3	Truss		Lateral
9	3	Truss		Longitudinal
10	4	Truss	Component T Mounting Point (Outboard)	Vertical
11	4	Truss		Lateral
12	4	Truss		Longitudinal
13	5	Truss		Vertical
14	5	Truss		Lateral
15	5	Truss		Longitudinal
16	6	Truss		Vertical
17	6	Truss		Lateral
18	6	Truss		Longitudinal
19	7	Truss		Vertical
20	7	Truss		Lateral
21	7	Truss		Longitudinal
22	8	Truss		Vertical
23	8	Truss		Lateral
24	8	Truss		Longitudinal

Table 3. Weight Configurations

	Component Weight	
	Component A Airframe Mounted	Component T Truss Mounted
*Bare Structure	0	0
Weight 1	11.5 lbs	10.0 lbs
Weight 2	23.0 lbs	20.0 lbs
Weight 3	46.0 lbs	40.0 lbs

*Note: The total weight of the truss and skirt was 485 pounds.

2.1.5 Phase IA - Steel Dummy Mass (X Member)

The mounting point impedance and dynamic response characteristics of a rigid steel mass differ significantly from those of a typical equipment package. This test phase was conducted to obtain a comparison between the pyrotechnic shock environment at the mounting point of a prototype equipment package and the environment measured for a simple steel dummy installed at the same location.

Component T was removed from the truss and a steel X member was installed in the same location as shown in Figure 6. Steel bars were clamped to the X member to produce the same weights as those used for component T during Phase I (Refer to Table 3). Component A was loaded to the same weight configurations used in Phase I in order to minimize the possibility of altering the shock input to the truss. In other words, Phase IA was simply a repetition of Phase I with the steel "dummy" mass substituted for a prototype package (Component T) mounted on the truss.

2.1.6 Phase II - Distributed Mass

Eight (8) prototype components were installed on the guidance truss at locations selected to produce a relatively uniform weight distribution over the truss. Photographs of the truss showing locations of components and accelerometers are shown in Figures 7 and 8. The letters B through I were assigned to the 8 components as shown in the sketch in Figure 9. The weights of each component and the total weight added to the truss for each weight configuration are tabulated in Table 4. Note that the component weights were increased by factors of 2 and 3 times the initial weight for weight configurations 2 and 3 respectively. The total weight (534.5 lbs) added to the truss in weight configurations 3 exceeded the initial weight (485 lbs) of the skirt and truss assembly.

Table 4. Phase II Test Summary

		Component										
Test Date	Shock No.	A	B	C	D	E	F	G	H	I	Total Wt.	
7-6-70 7-6-70	21 22	Bare Structure Calibration shot for 24 accelerometers									0	
7-20-70 7-20-70	25 26		20	7	27	5.5	62	9	21	26.5	173	Weight 1
7-22-70 7-22-70	27 28		40	14	54	11	124	18	42	53	356	Weight 2
7-23-70 7-23-70	29 30		60	21	81	16.5	186	27	63	80	534.5	Weight 3

2.2 Data Analysis

The recorded shock transients were digitized at a sample rate of 100,000 samples per second and digital shock spectrum analyses were performed utilizing a damping ratio of 5%. For each accelerometer, comparison plots were made of the spectra obtained from the bare structure and the three different weight configurations. The results for all three phases of the test are presented in the Appendix, Figures 1A through 48A.

In order to minimize the possibility that anomalies in the shock spectra could result from variations in the input shock transient, each shock spectrum was normalized by the input shock spectrum at the reference accelerometer location (accelerometer 1, longitudinal). That is, for each shot and each accelerometer in the test series, the shock spectrum amplitude at each frequency was divided by the shock spectrum amplitude (at the same frequency) from accelerometer 1. These normalized shock spectra are presented in the Appendix, Figures 49A through 96A.

An examination of the shock spectra presented in the Appendix indicates that major changes in the shock environment can occur when an equipment item is installed on previously unloaded structures (e.g., see Figures 53A, 60A, and 65A). Further, the data indicate that the addition of weight to components has relatively little effect on the shock environment.

The results from this preliminary analysis were contrary to expectations. Prior to the test, it was anticipated that the shock environment at component mounting points would be affected by weight changes. Since variations in the shock spectra for the different weight configurations are observable in the data, further analyses were performed to determine whether or not a predictable relationship existed between the shock spectra variations and equipment weight. For each phase, the shock spectra at each location were further normalized with the weight 1 spectrum as the normalizing factor. At each frequency, the shock spectra amplitudes obtained for weight 2 and weight 3 configurations were divided by the corresponding amplitude obtained from the weight 1 test. For each phase, composite plots of the normalized spectra are presented in Figures 10 through 17. The average values of the shock amplitude ratios are represented by the closed symbols on each graph. Figures 10 through 17 include the data measured in all axes at component mounting points. For example, Figures 10 and 11 include the data from the tri-axial accelerometer location (accelerometers 4, 5, and 6) at the mounting point of Component A. Both inboard and outboard mounting points were instrumented for component T and the steel X-member (See Figures 5 and 6). Therefore, Figures 12-15 include the shock amplitude ratios calculated for six accelerometers. In phase II, six tri-axial accelerometer locations were distributed throughout the truss. Figures 16 and 17 include the shock amplitude ratios for all 18 accelerometers located on the truss.

2.2.1 Phase I Results

The shock amplitude ratios for the single mass loading condition are presented in Figures 10 through 13. For both component A (airframe) and component T (truss), the shock amplitude ratios for the weight 3/weight 1 condition exhibit an increase in scatter and magnitude in the high frequency region (2000 to 10,000 Hz) when compared to the weight 2/weight 1 data. However, no definite relationship between shock amplitudes and weight can be defined.

2.2.2 Phase IA Results

Comparisons of the data obtained with the steel X-member (Figures 14 and 15) with corresponding data for component T (Figures 12 and 13) indicate that for the heaviest weight condition (weight 3), greater shock spectrum amplitudes are produced at high frequencies (3150 to 10,000 Hz) with the prototype component mounted than with the steel dummy. The effect is evident in the normalized shock spectra presented in the Appendix. For example, compare Figure 56A with 68A, and 57A with 69A. The effect is not observed at all frequencies and no specific relationship can be defined.

2.2.3 Phase II Results

The shock amplitude ratios for all accelerometer locations on the truss with distributed masses are shown in Figures 16 and 17. Comparison of these data indicate that no specific relationship can be defined for shock spectrum amplitude as a function of distributed mass.

3.0 NEW TECHNOLOGY

Not applicable for this report.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 A good simulation of the pyrotechnic shock produced by airborne ordnance devices can be obtained by the use of relatively inexpensive explosives. However, the reader is cautioned that utilization of such devices as a test method for simulating pyrotechnic shock involves a "trial and error" process to produce desired changes in shock spectra. Therefore, the decrease in cost of explosives may be more than offset by an increase in time and manpower.

4.2 The primary effect on the shock environment occurs when an equipment item is installed; i.e., from an unloaded structure to a loaded structure. Therefore, it is important to include prototype or "dummy" components in full scale tests if the correct pyrotechnic shock environment is to be achieved.

4.3 Changing component weight produces changes in the shock environment which are relatively small and would not allow a correction factor to be applied to a shock test specification. Furthermore, the results of this study indicate that a predictable relationship does not exist between the shock environment and the weight of mounted subassemblies. The implication of this conclusion is that the results of early development tests conducted to define shock specifications may not be invalidated by design changes in equipment weights, assuming that the structural and mounting configurations do not change.

4.4 Changes in the shock environment occur when a rigid dummy mass is substituted for a prototype component. These changes are relatively small and unpredictable as to frequency and amplitude effects. Therefore, it is recommended that prototype components be used wherever possible in full scale pyrotechnic shock tests. When "dummy" masses must be used, it is recommended that a greater margin of safety be utilized in establishing shock specifications than would normally be applied when the environment is measured utilizing prototype components.

4.5 No relationship between the shock environment and the weight of mounted equipment can be defined from the results of this study. Consequently, the results of this program cannot be extended to other cases nor can a generalized technique suitable as a design guide be developed.

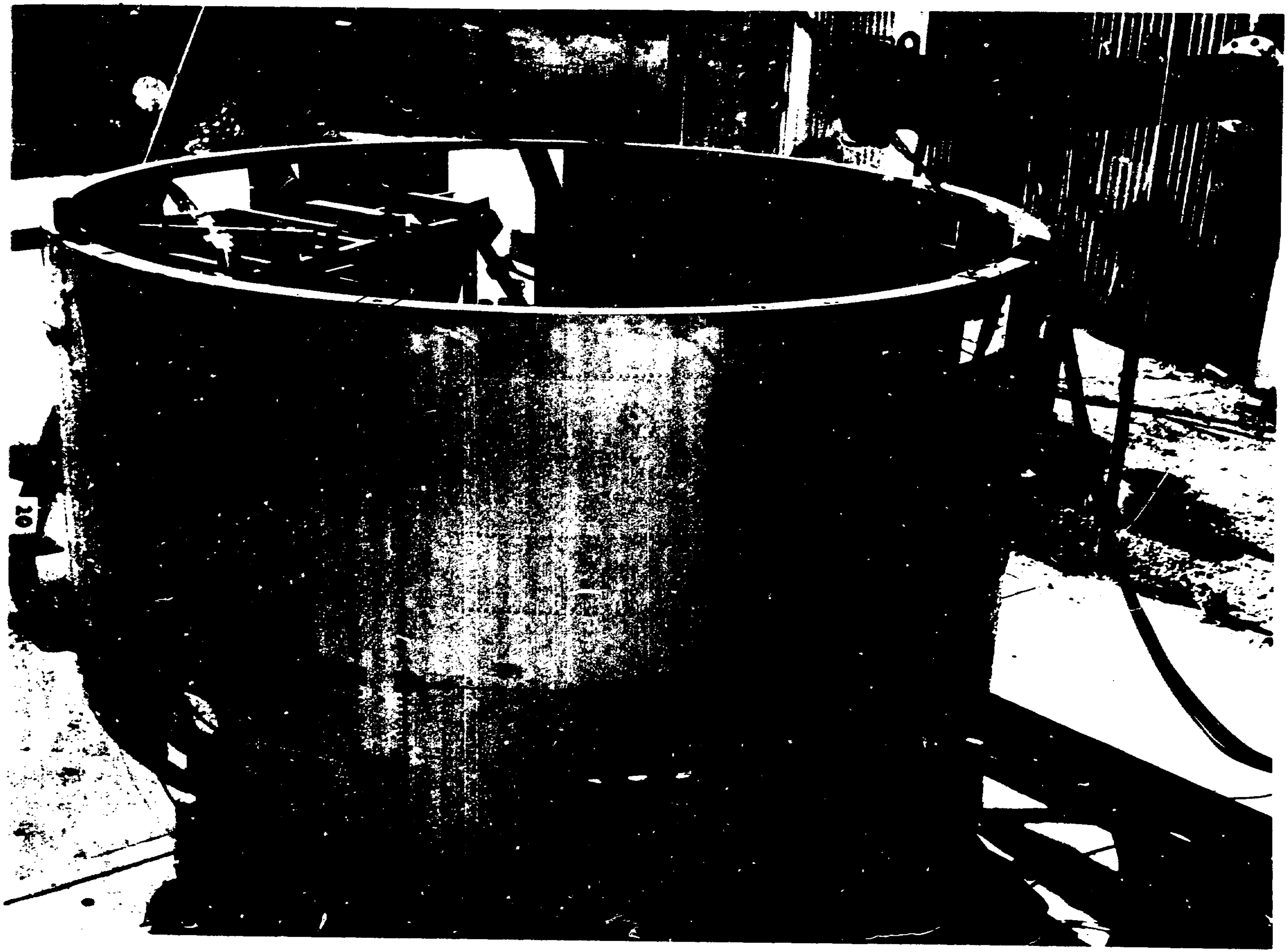


Figure 1. Titan IIIC Transtage Skirt With Guidance Truss Installed

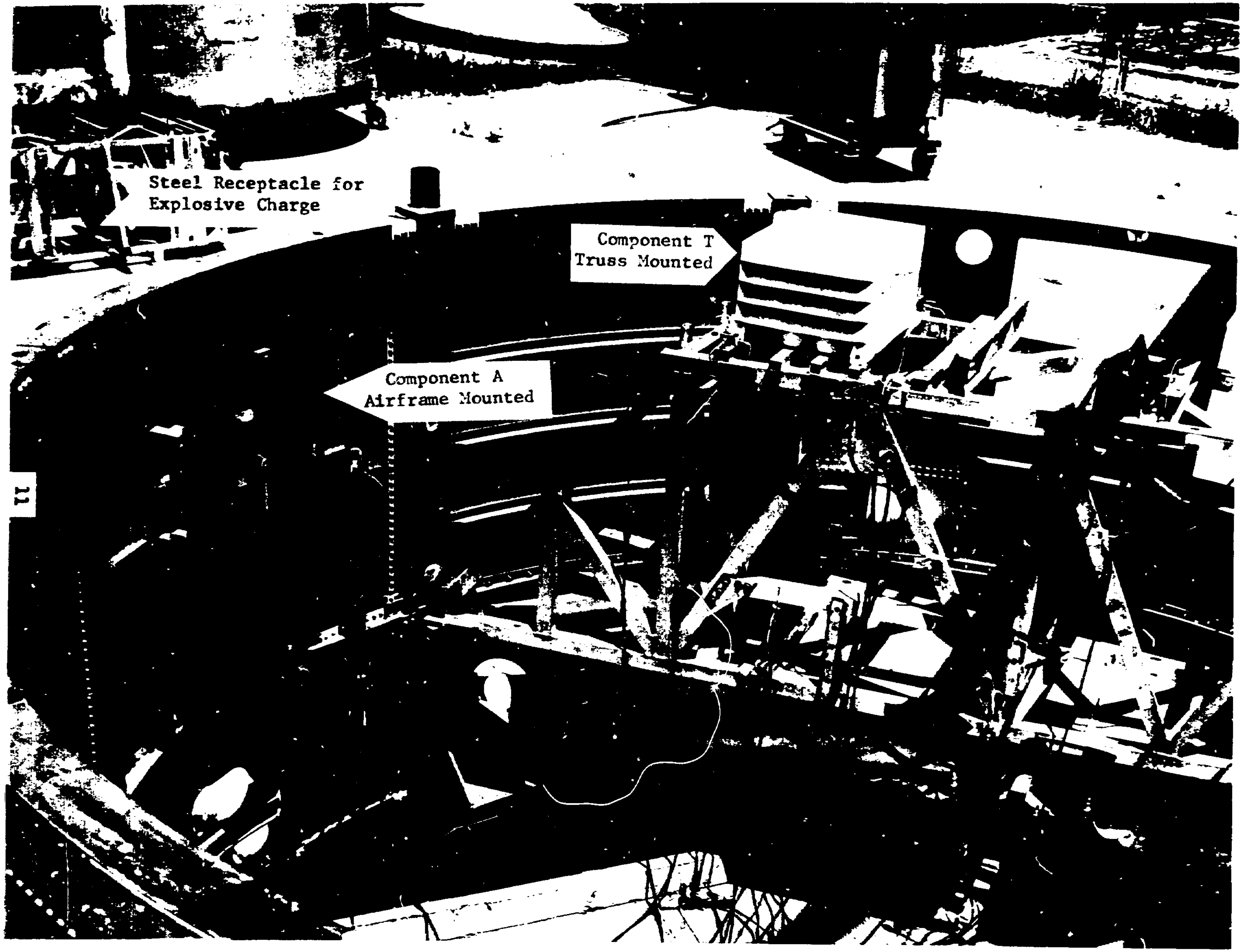


Figure 2. Locations of Equipment Installations and Shock Source

Figure 3. Component A With Cover Removed Showing Installation of Weights

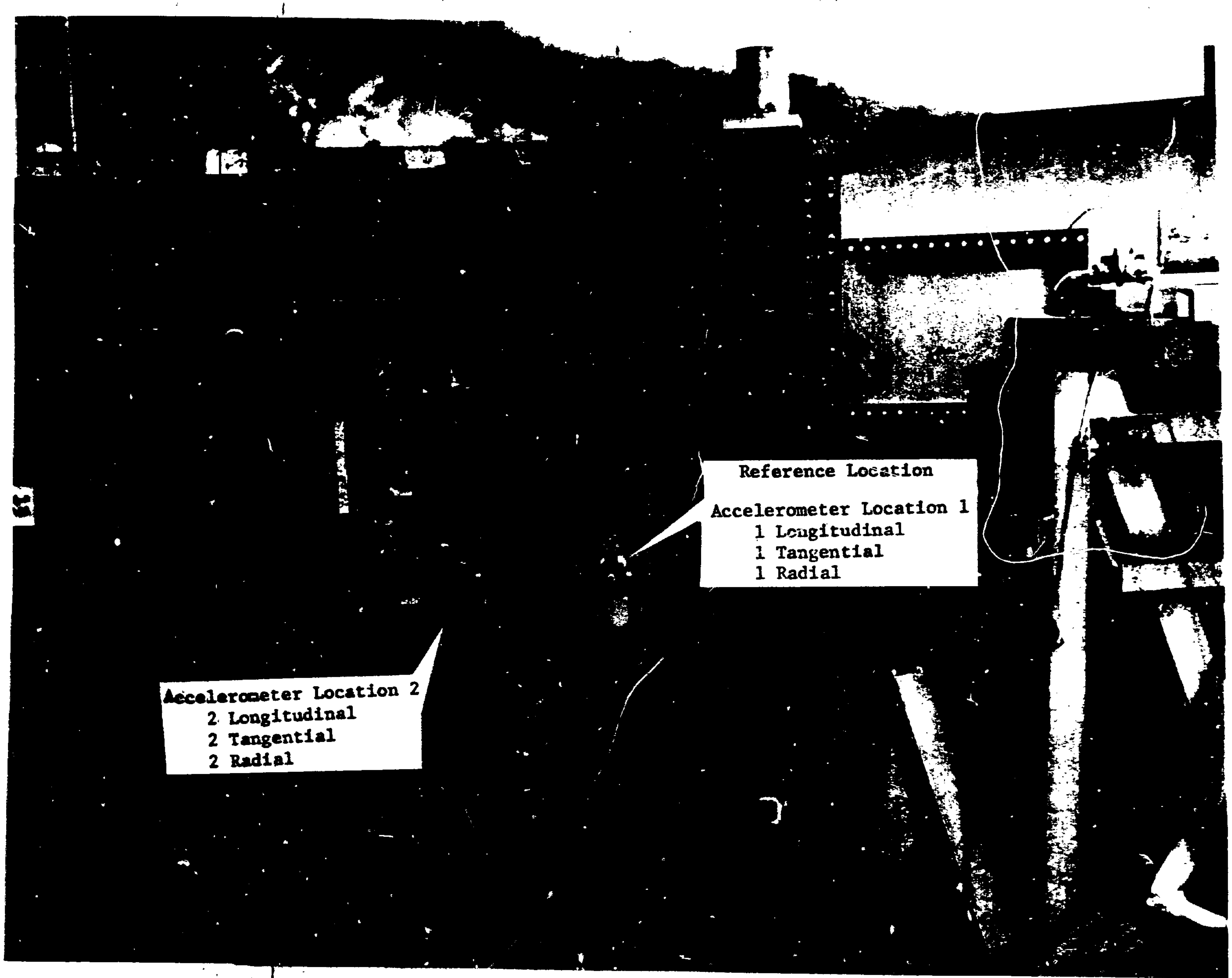


Figure 4. Triaxial Accelerometer Locations 1 (Reference) and 2

[illegible] Accelerometer Locations 3 and 4

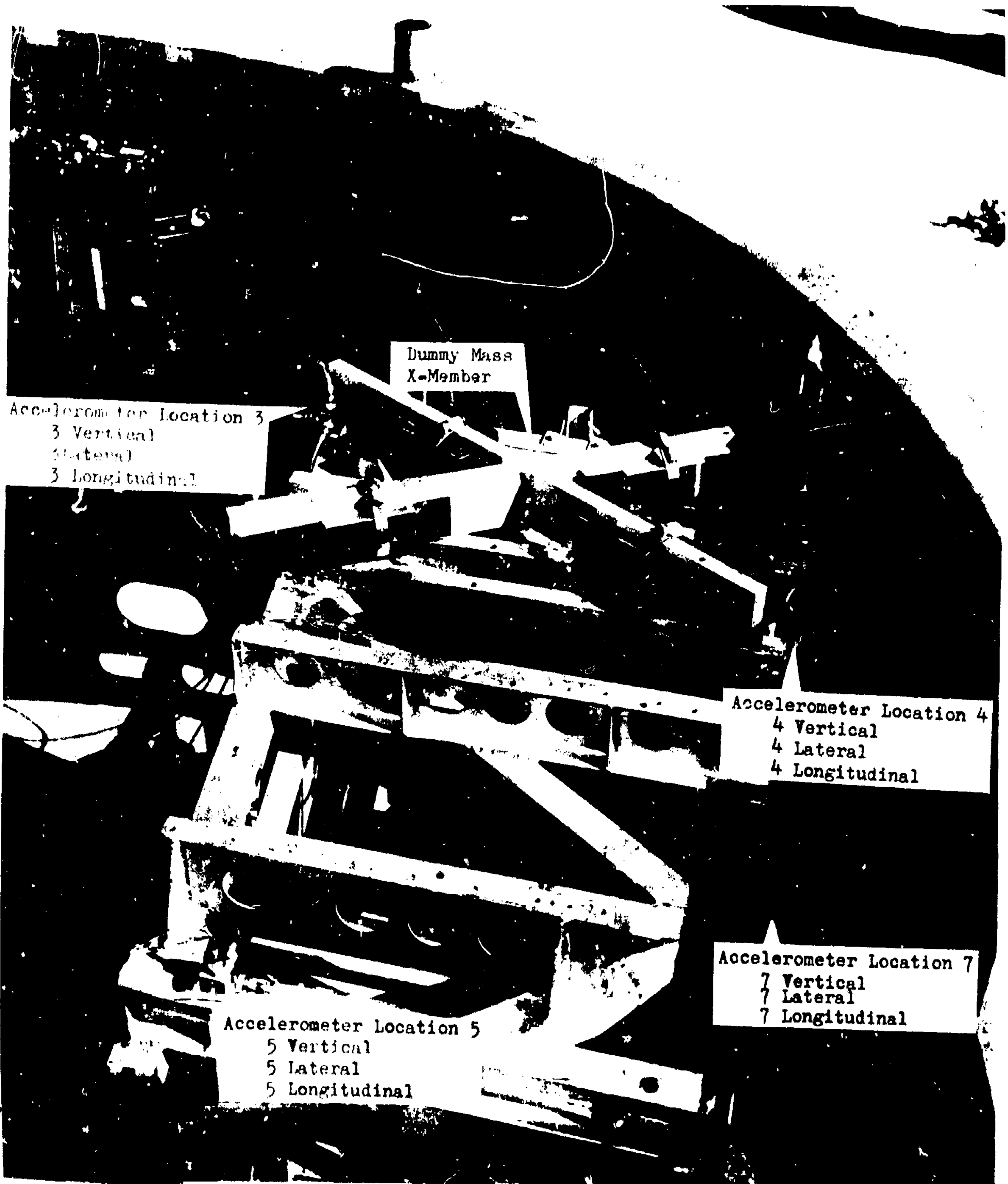


Figure 6. Steel X-Member Installation and Accelerometer Locations

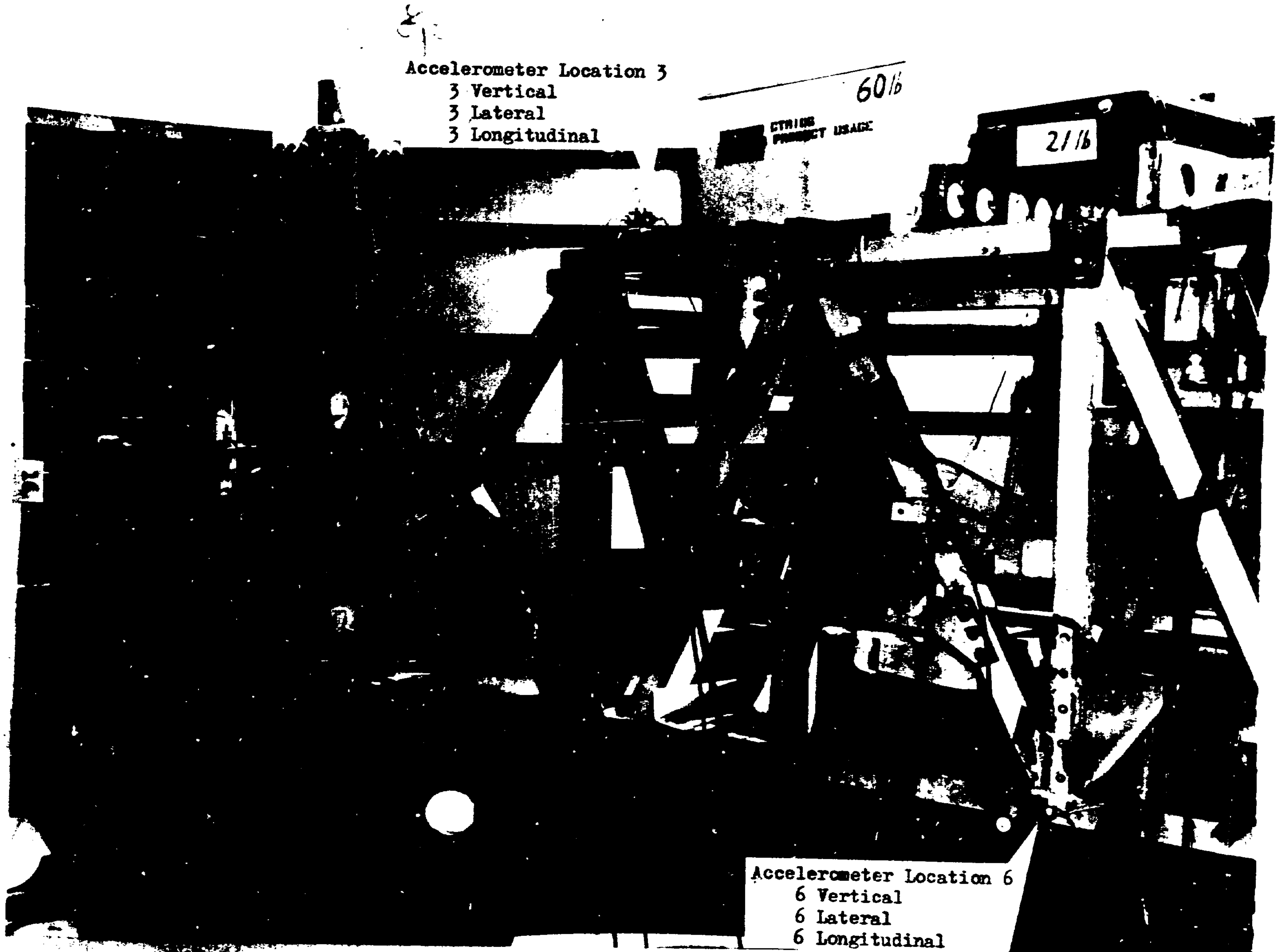


Figure 7. Component Installations on Guidance Truss - Left Side

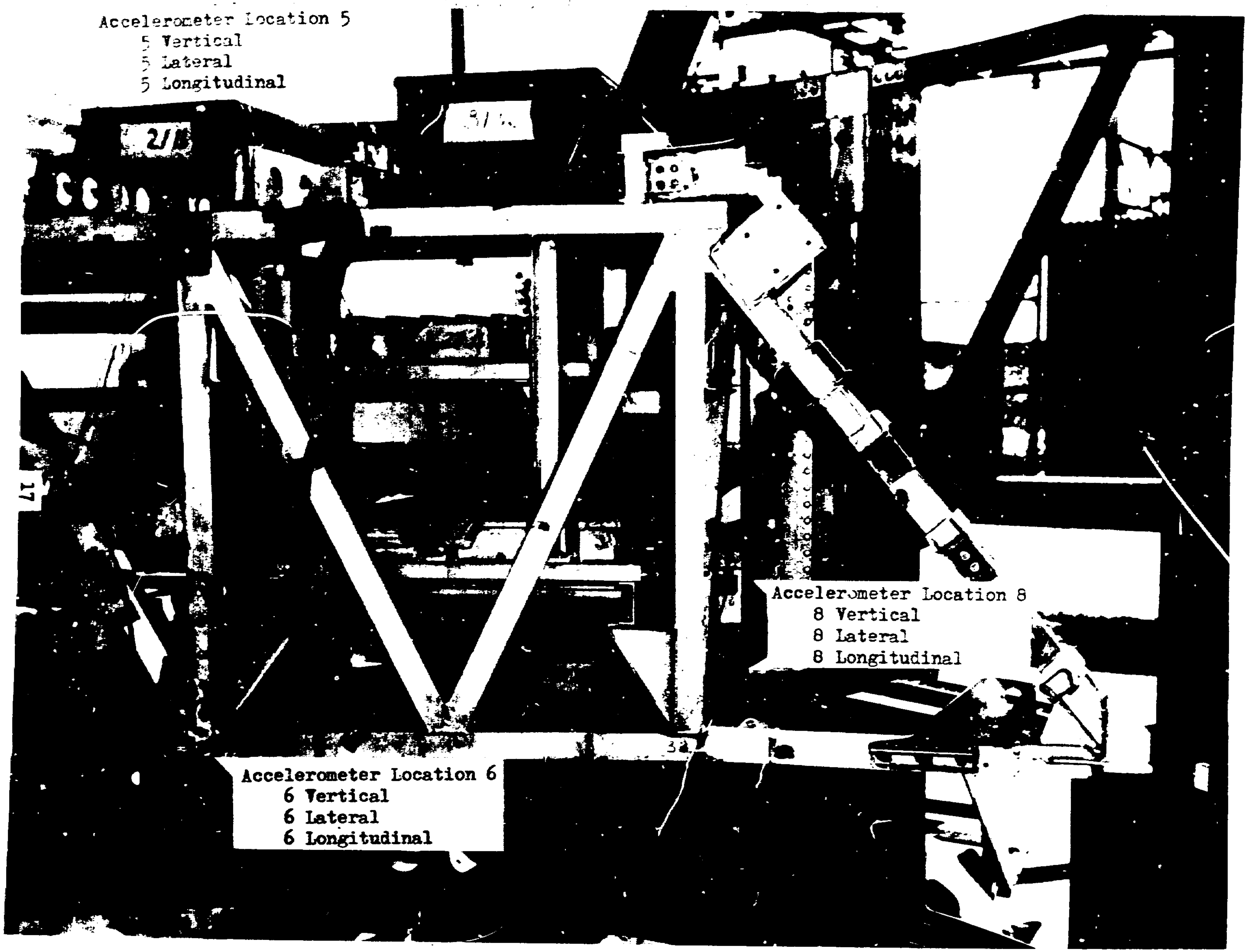


Figure 8. Component Installations on Guidance Truss - Right Side

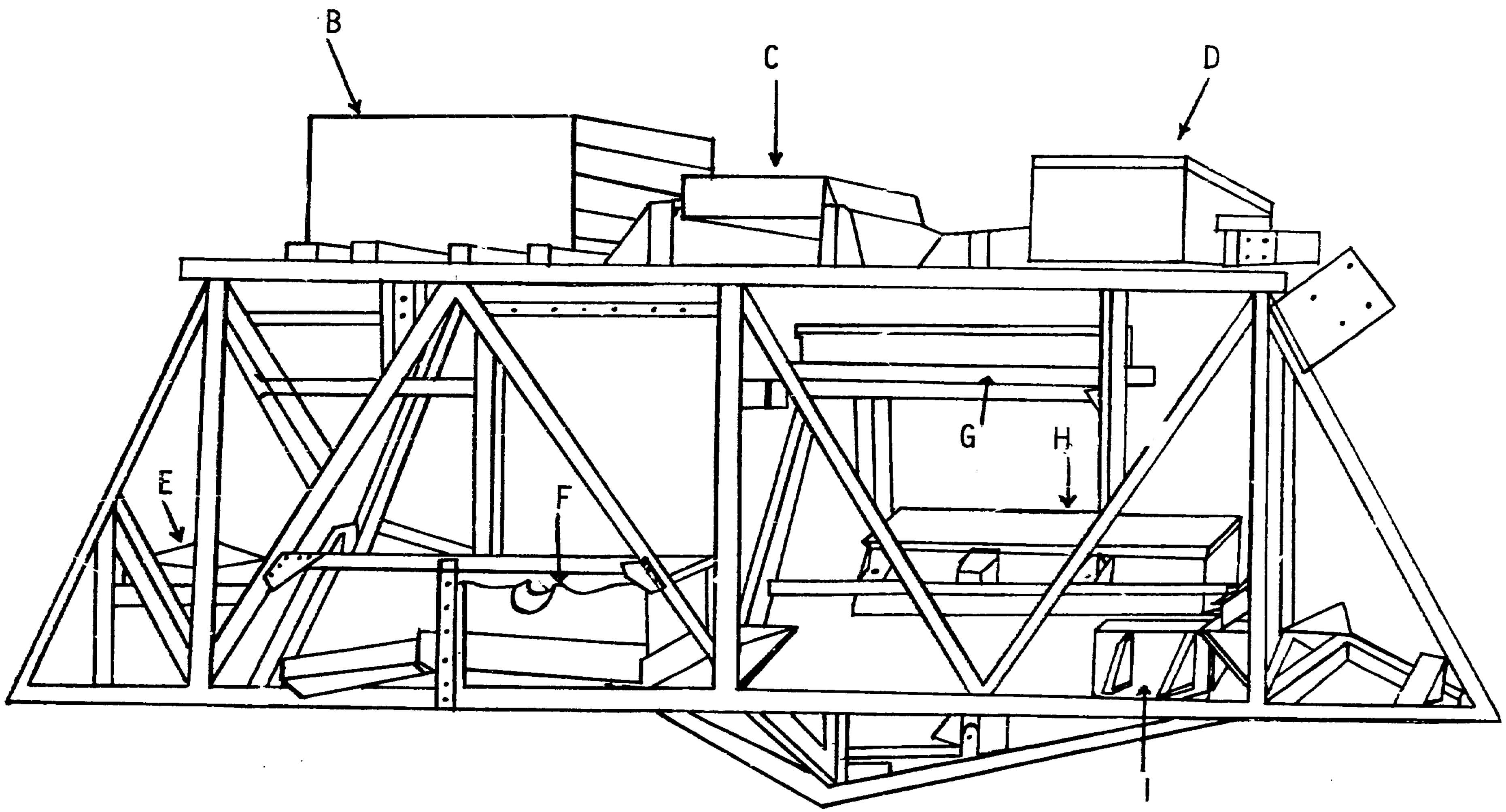


Figure 9. Sketch of Guidance Truss Showing Component Locations

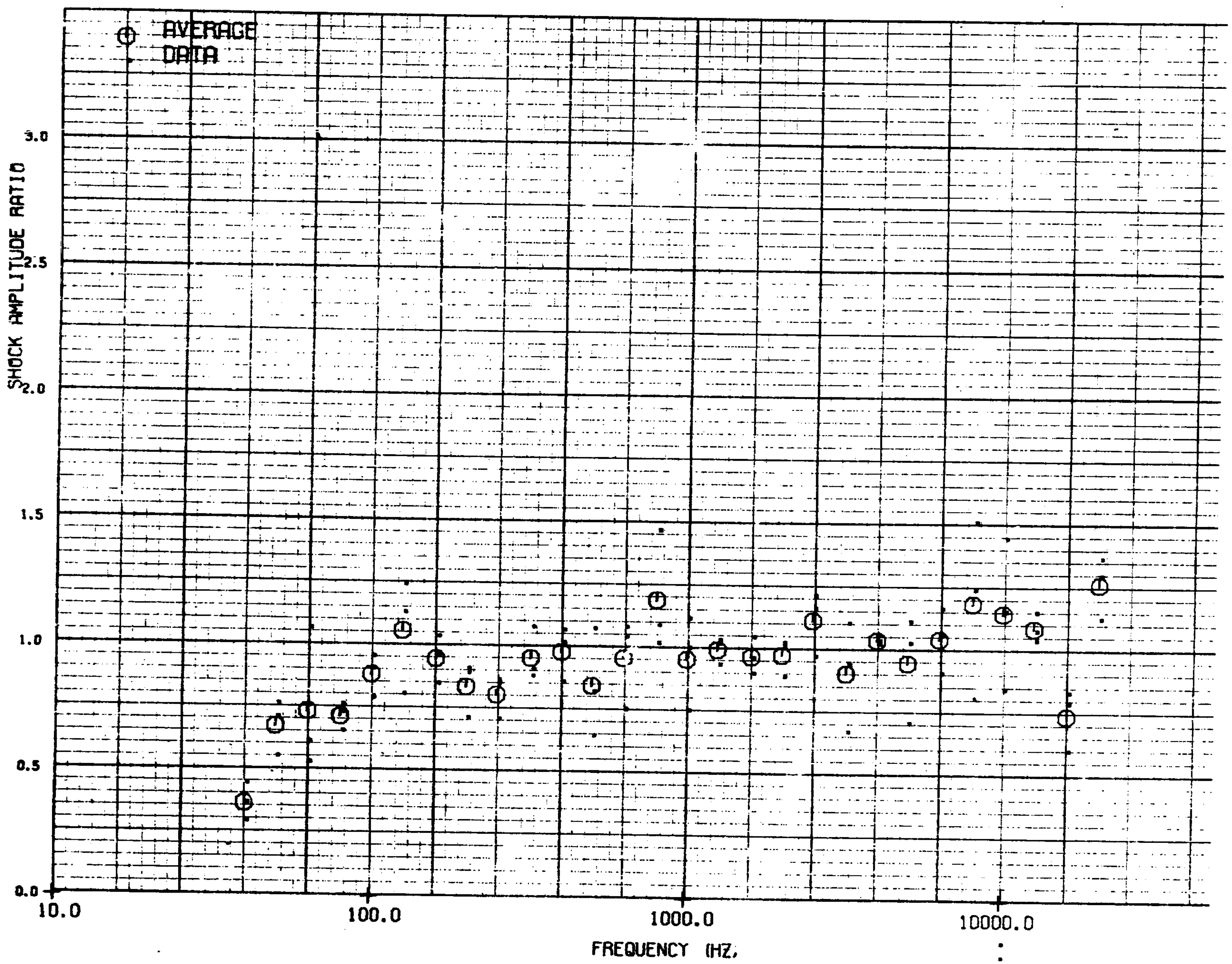


FIGURE 10. SHOCK AMPLITUDE RATIO (WEIGHT 2 / WEIGHT 1) - COMPONENT A (PHASE I)

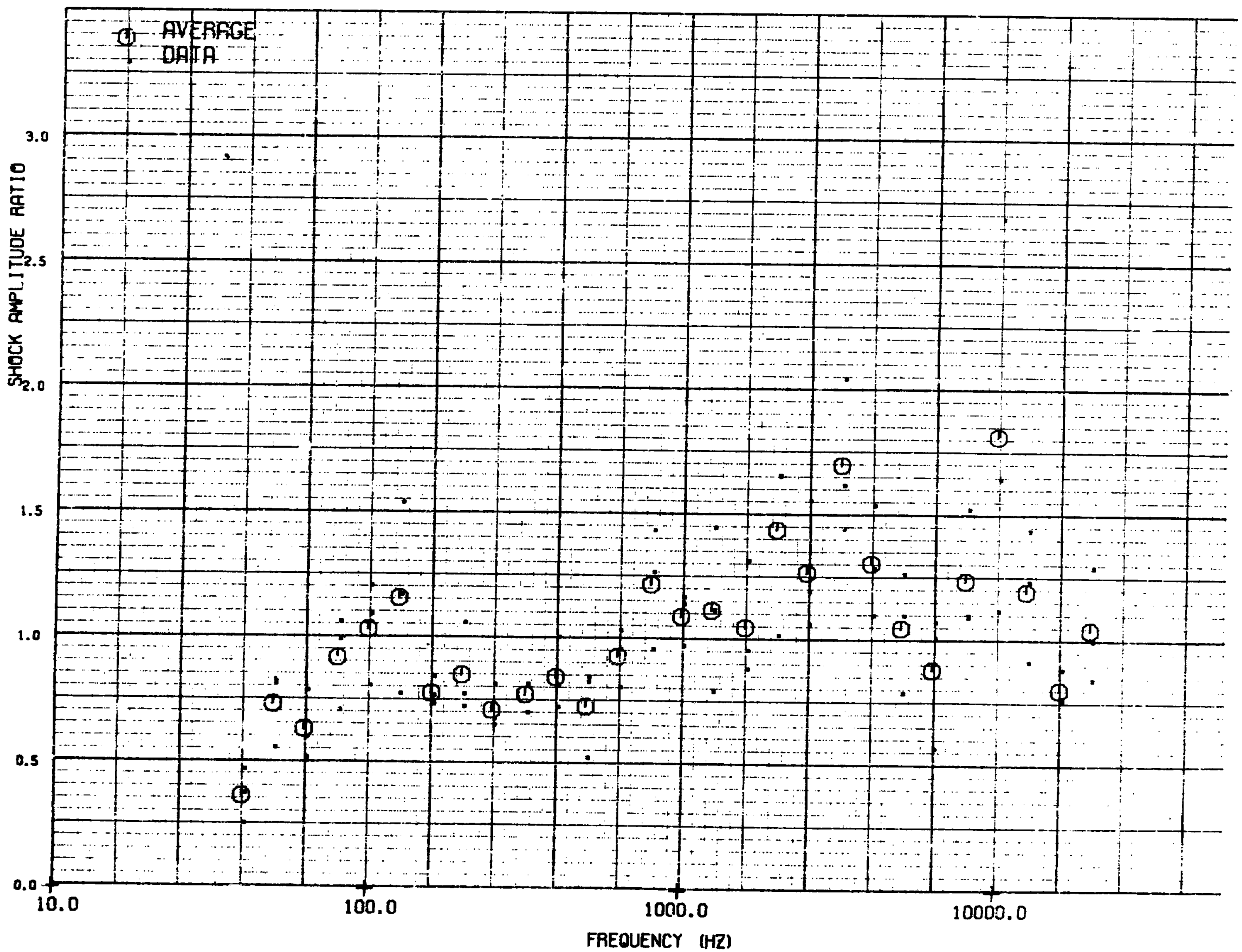
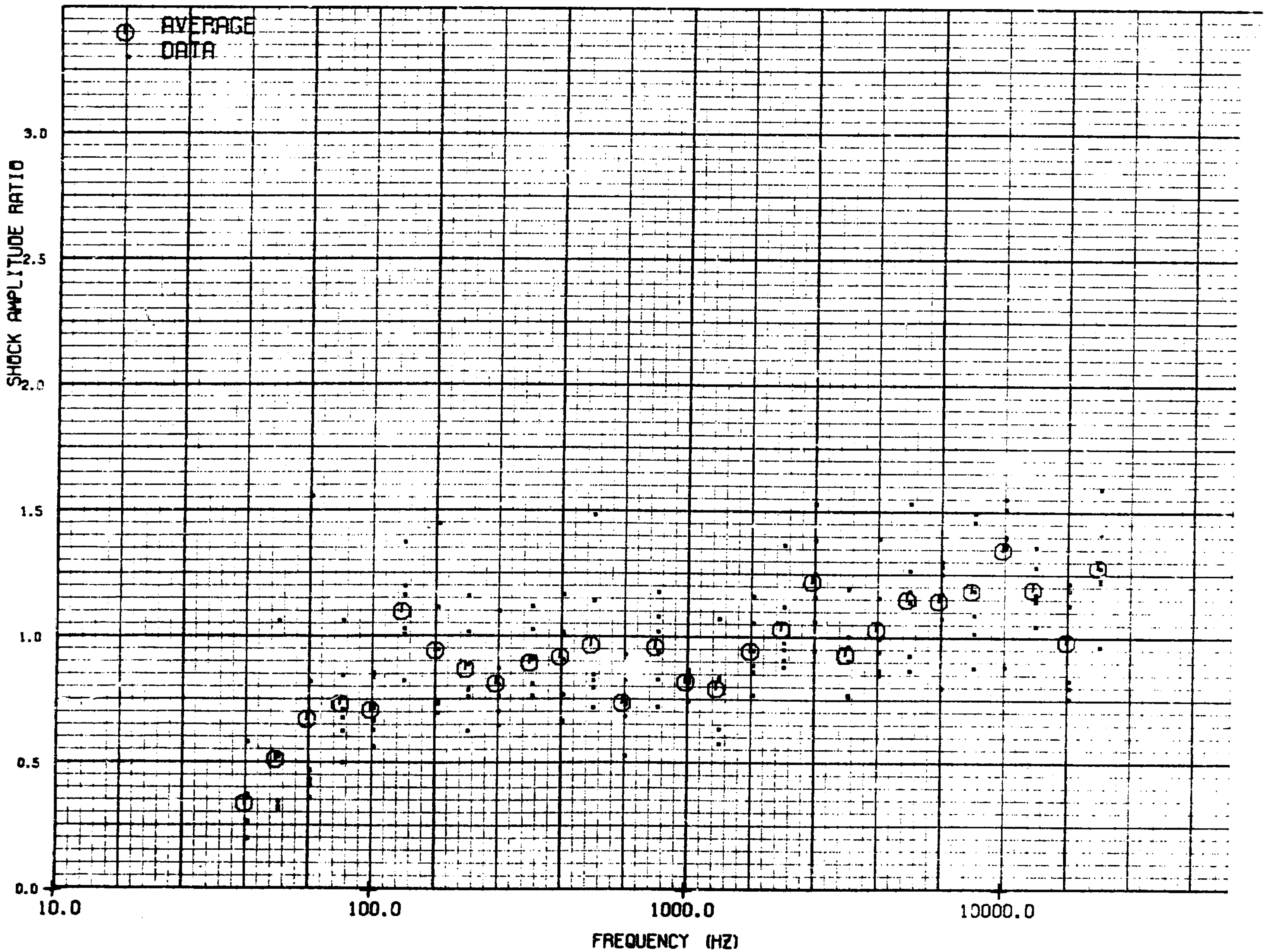


FIGURE 11. SHOCK AMPLITUDE RATIO (WEIGHT 3 / WEIGHT 1) - COMPONENT A (PHASE I)-


AVERAGE
DATA
SHOCK AMPLITUDE RATIO
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10.0
100.0
1000.0
10000.0
FREQUENCY (HZ)

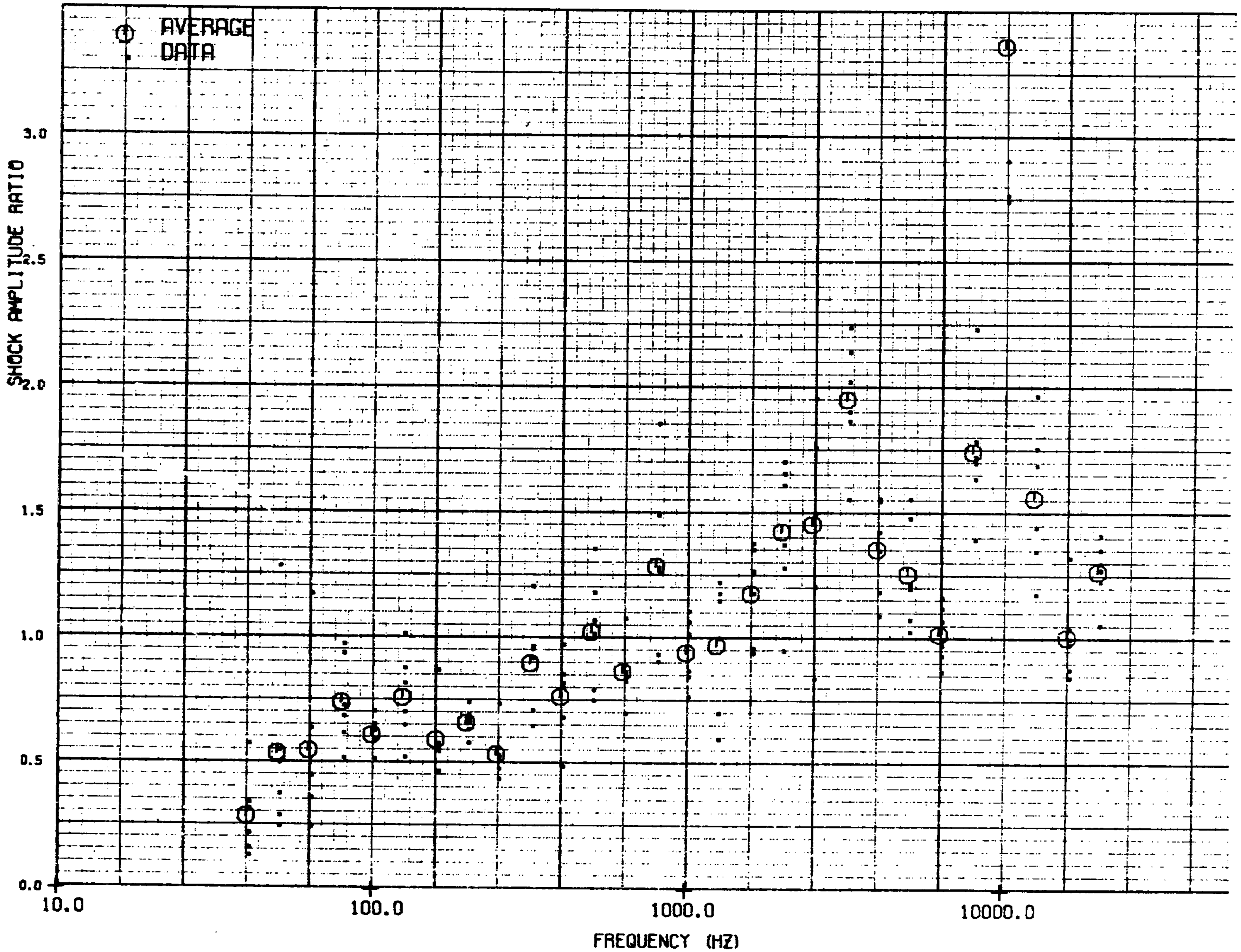


FIGURE 13. SHOCK AMPLITUDE RATIO (WEIGHT 3 / WEIGHT 1) - COMPONENT T (PHASE I)

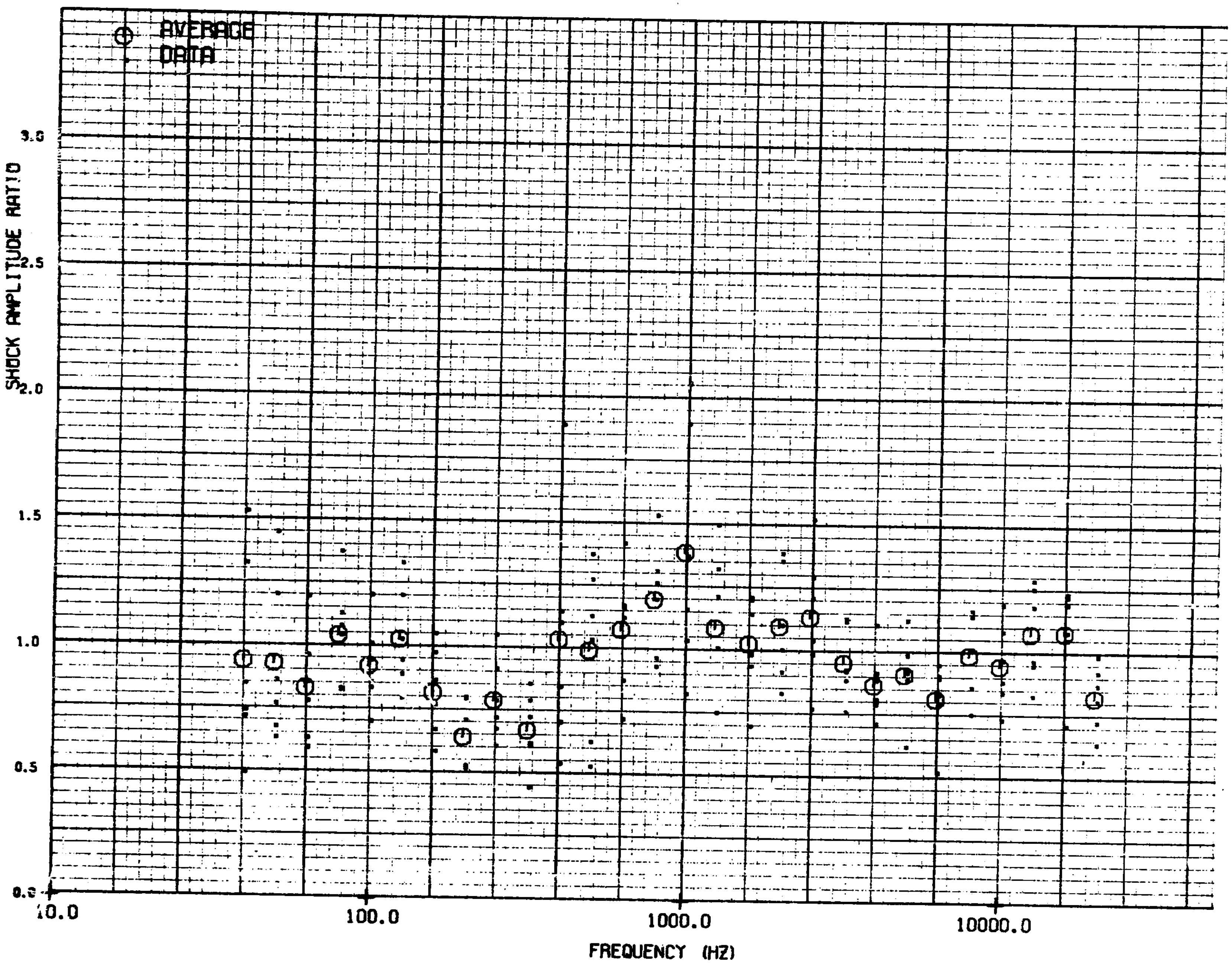


FIGURE 14. SHOCK AMPLITUDE RATIO (WEIGHT 2 / WEIGHT 1) - X MEMBER (PHASE IA)

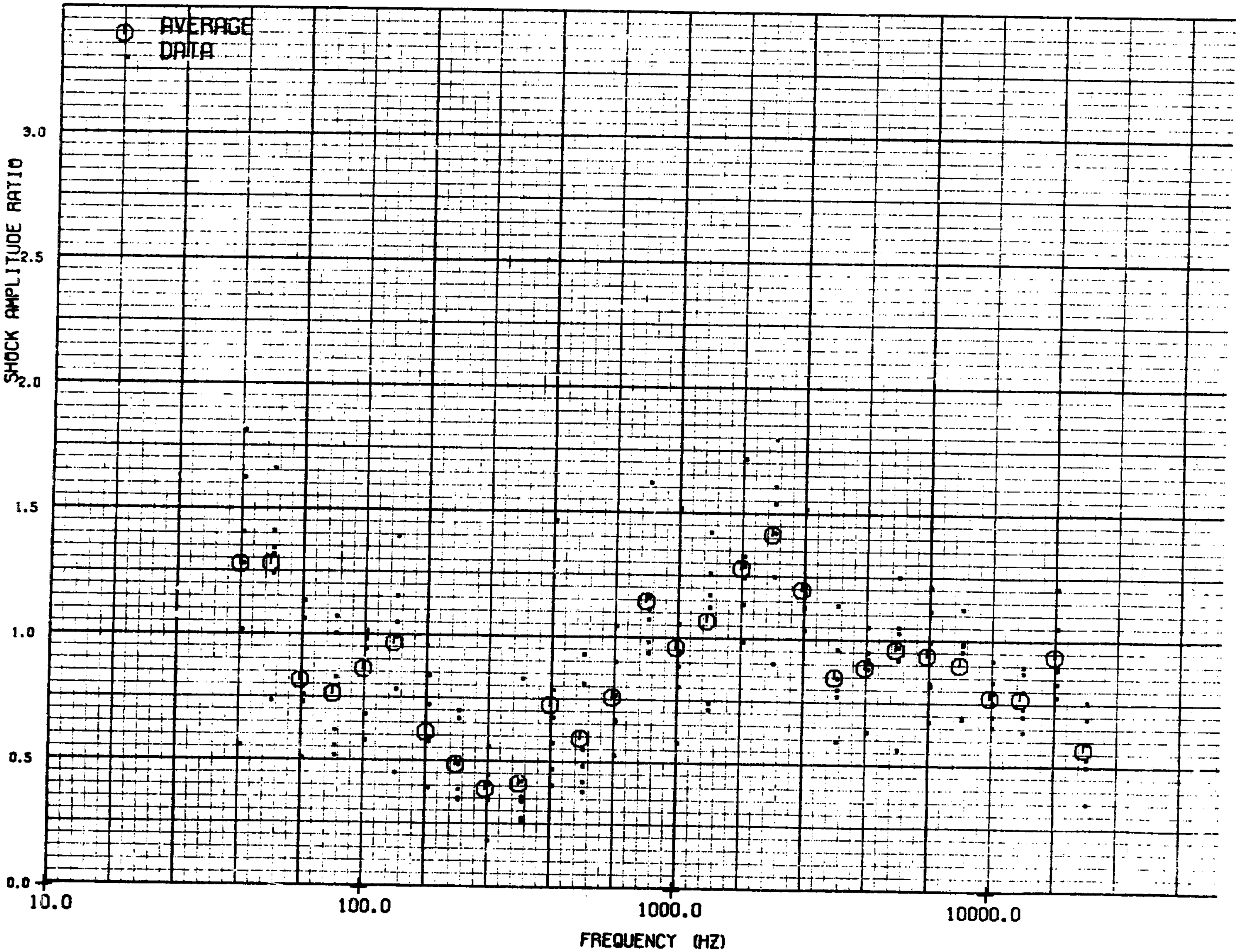


FIGURE 15. SHOCK AMPLITUDE RATIO (WEIGHT 3 / WEIGHT 1) - X MEMBER (PHASE IA)

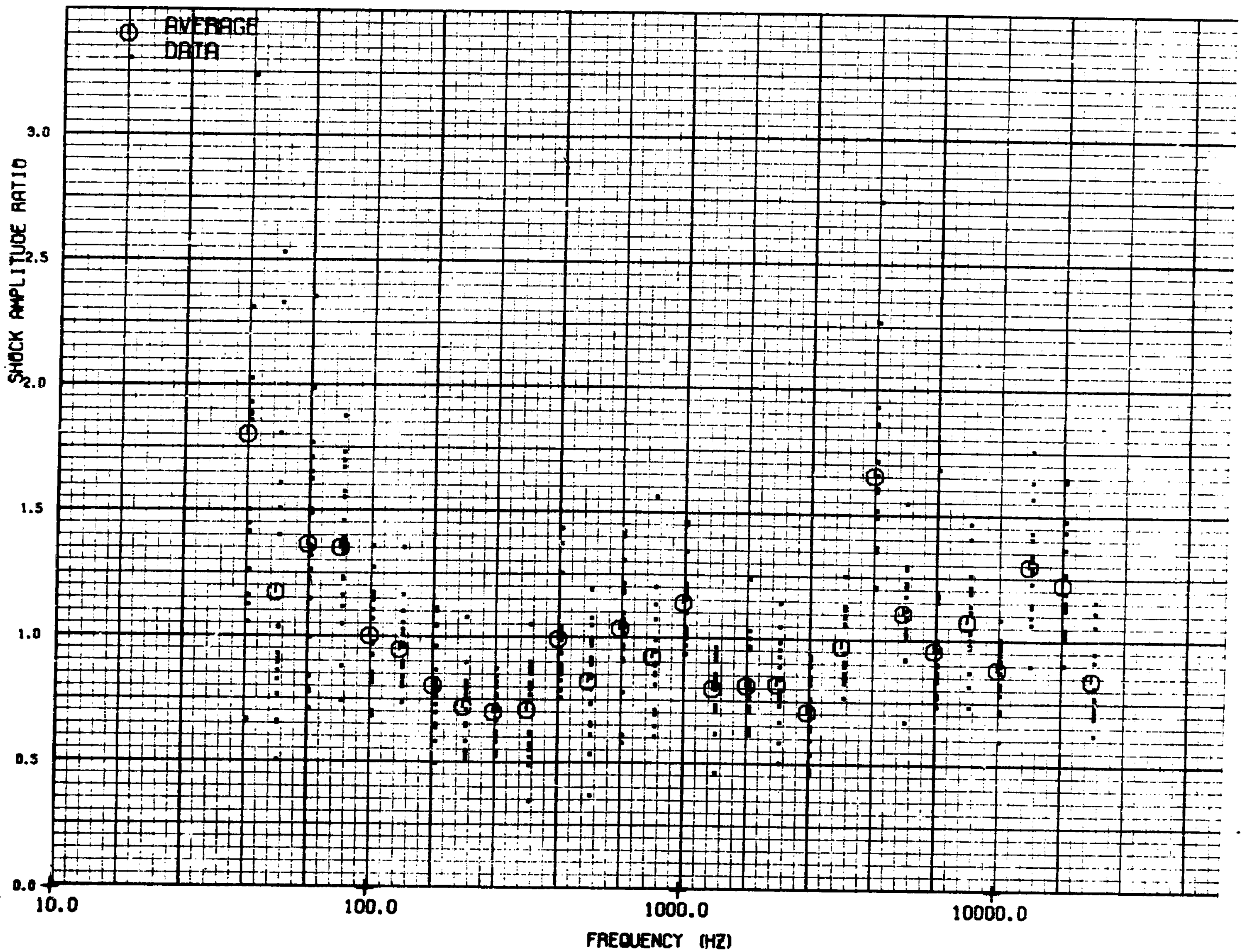


FIGURE 16. SHOCK AMPLITUDE RATIO (WEIGHT 2 / WEIGHT 1) - LOADED TRUSS (PHASE II)

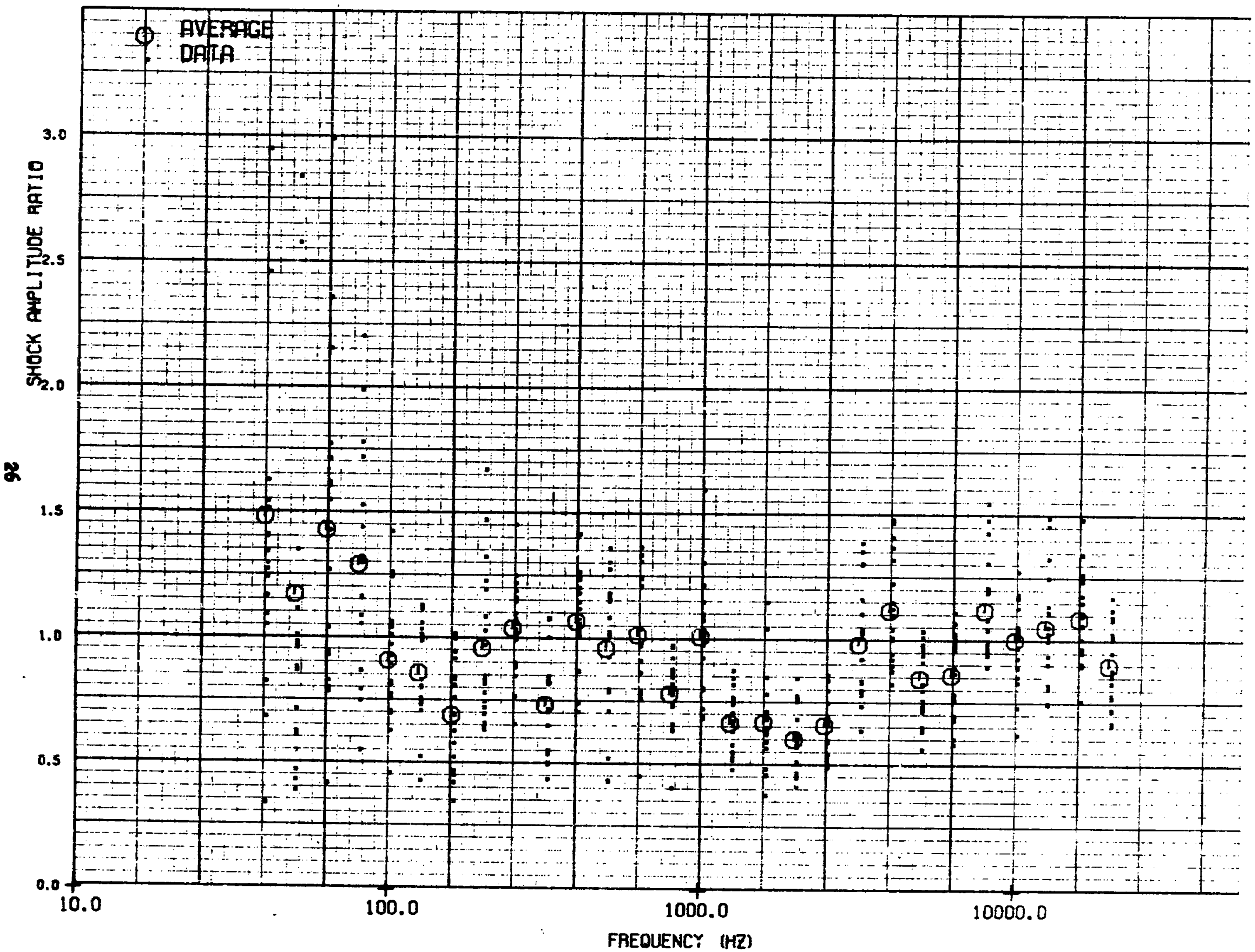


FIGURE 17. SHOCK AMPLITUDE RATIO (WEIGHT 3 / WEIGHT 1) - LOADED TRUSS (PHASE II)

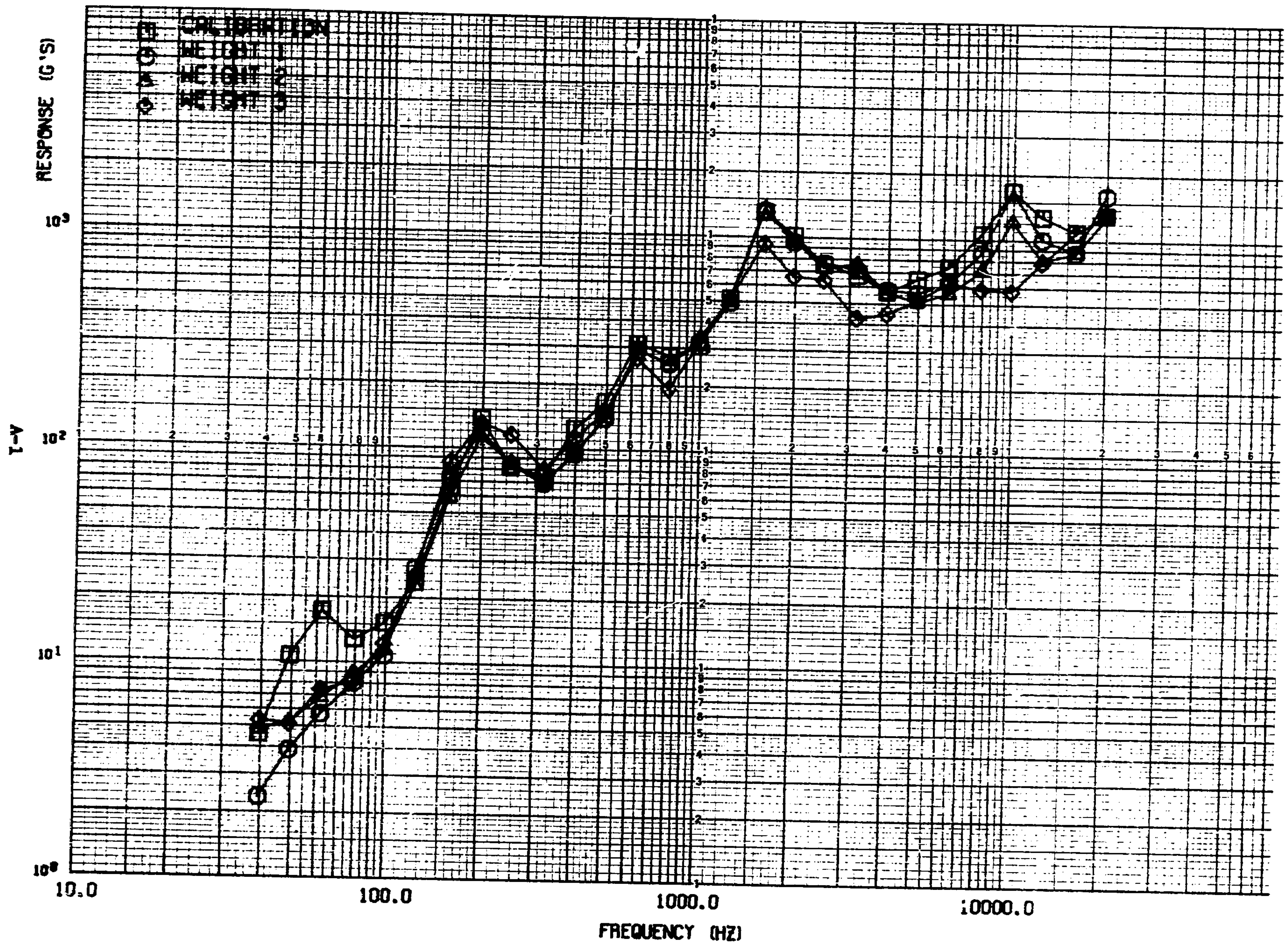


FIGURE 1A. COMPARISON OF SHOCK SPECTRA - ACCEL 01. PHASE I SINGLE MASS LOADING

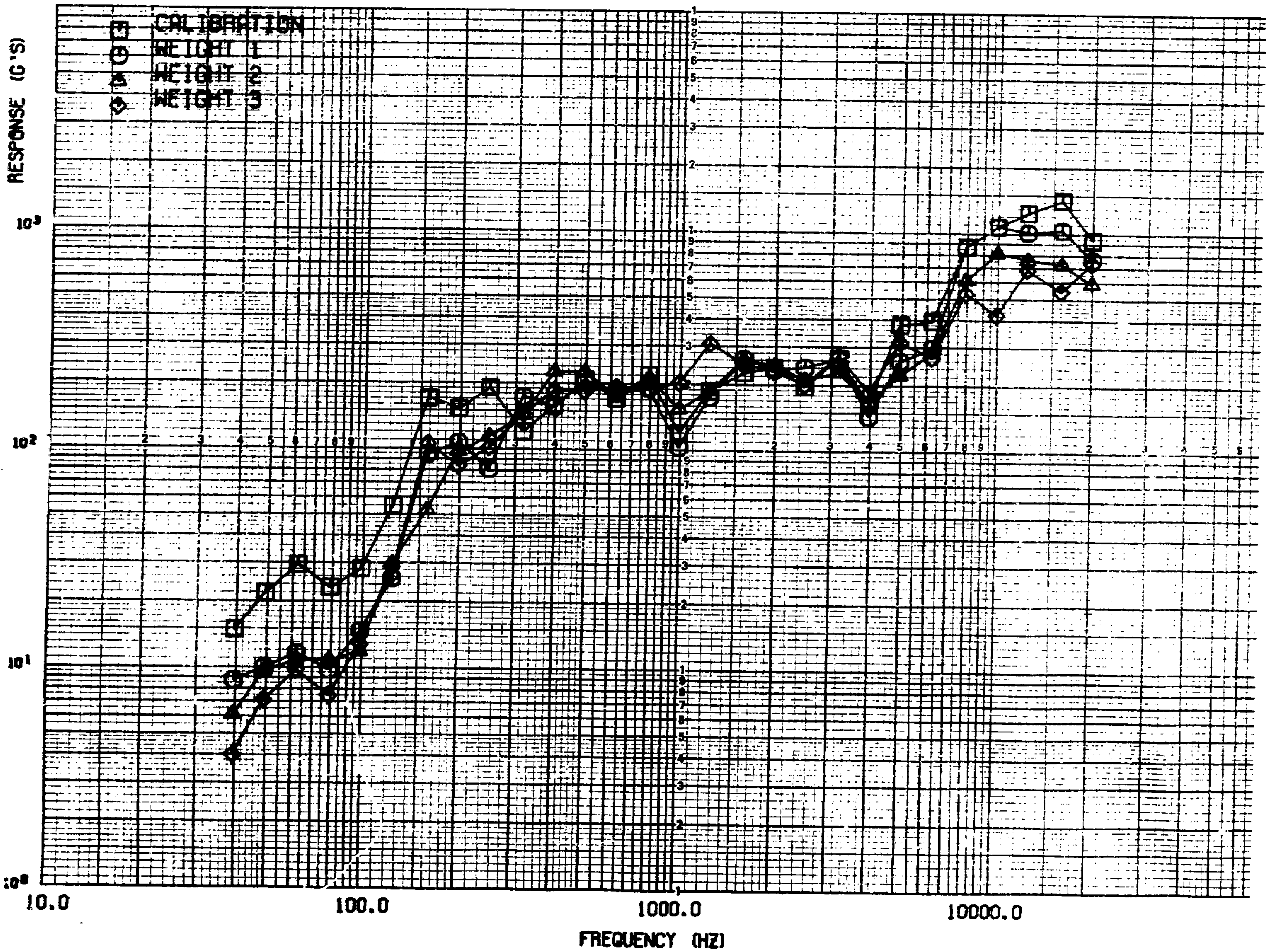


FIGURE 2A. COMPARISON OF SHOCK SPECTRA - ACCEL 02. PHASE I SINGLE MASS LOADING

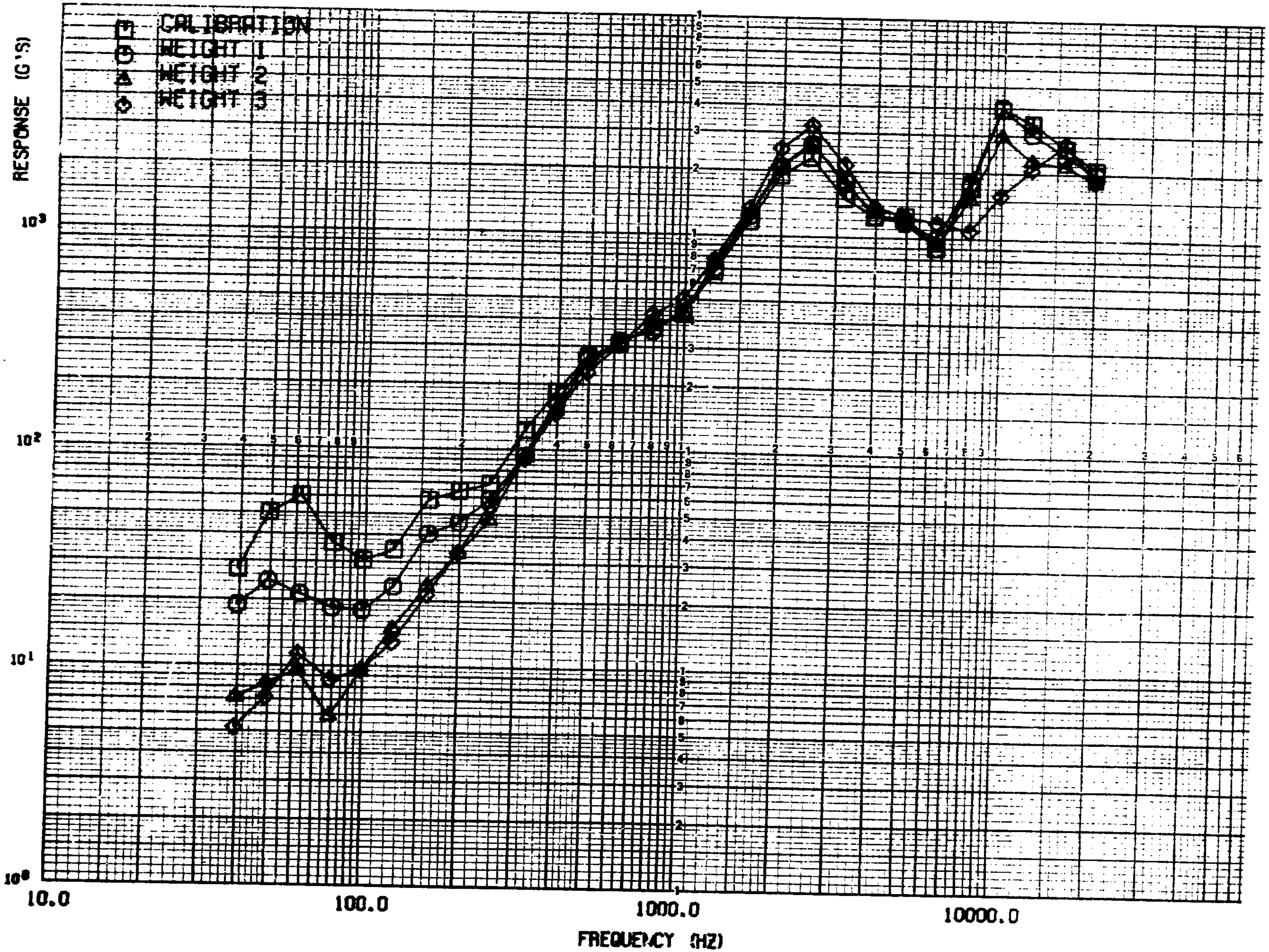


FIGURE 3A. COMPARISON OF SHOCK SPECTRA - ACCEL 03. PHASE I SINGLE MASS LOADING

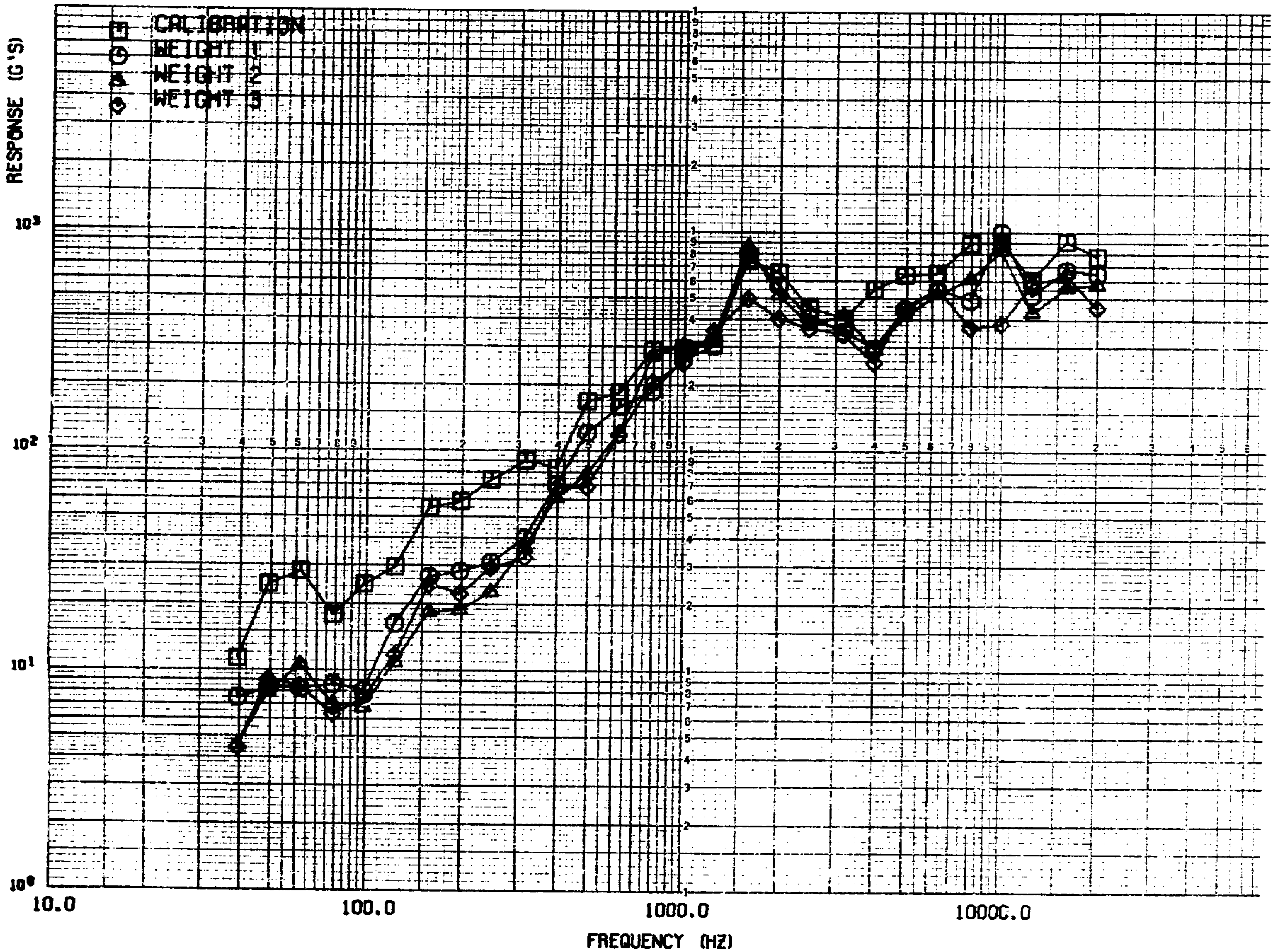


FIGURE 4A. COMPARISON OF SHOCK SPECTRA - ACCEL 04. PHASE I SINGLE MASS LOADING

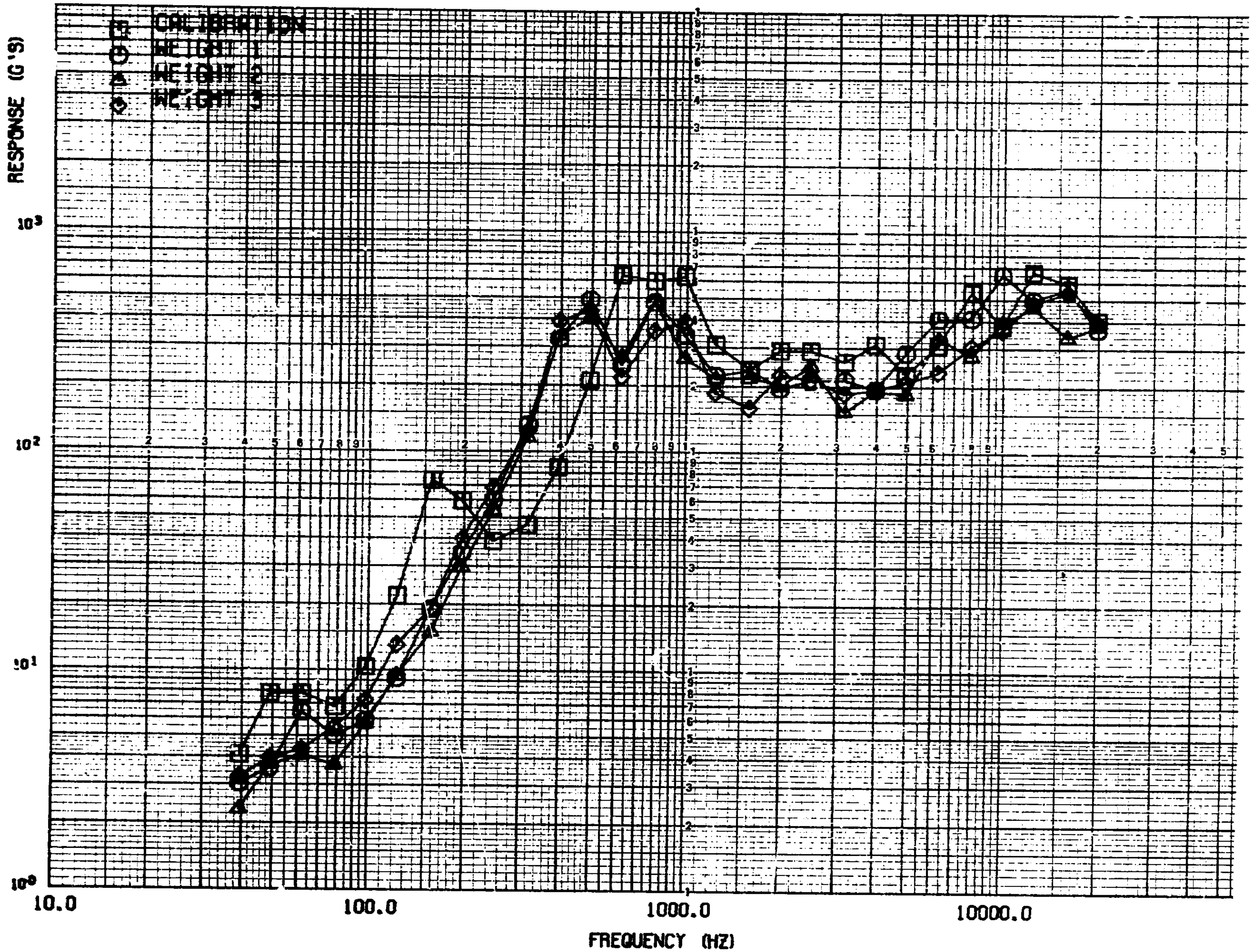


FIGURE 5A. COMPARISON OF SHOCK SPECTRA - ACCEL 05. PHASE I SINGLE MASS LOADING

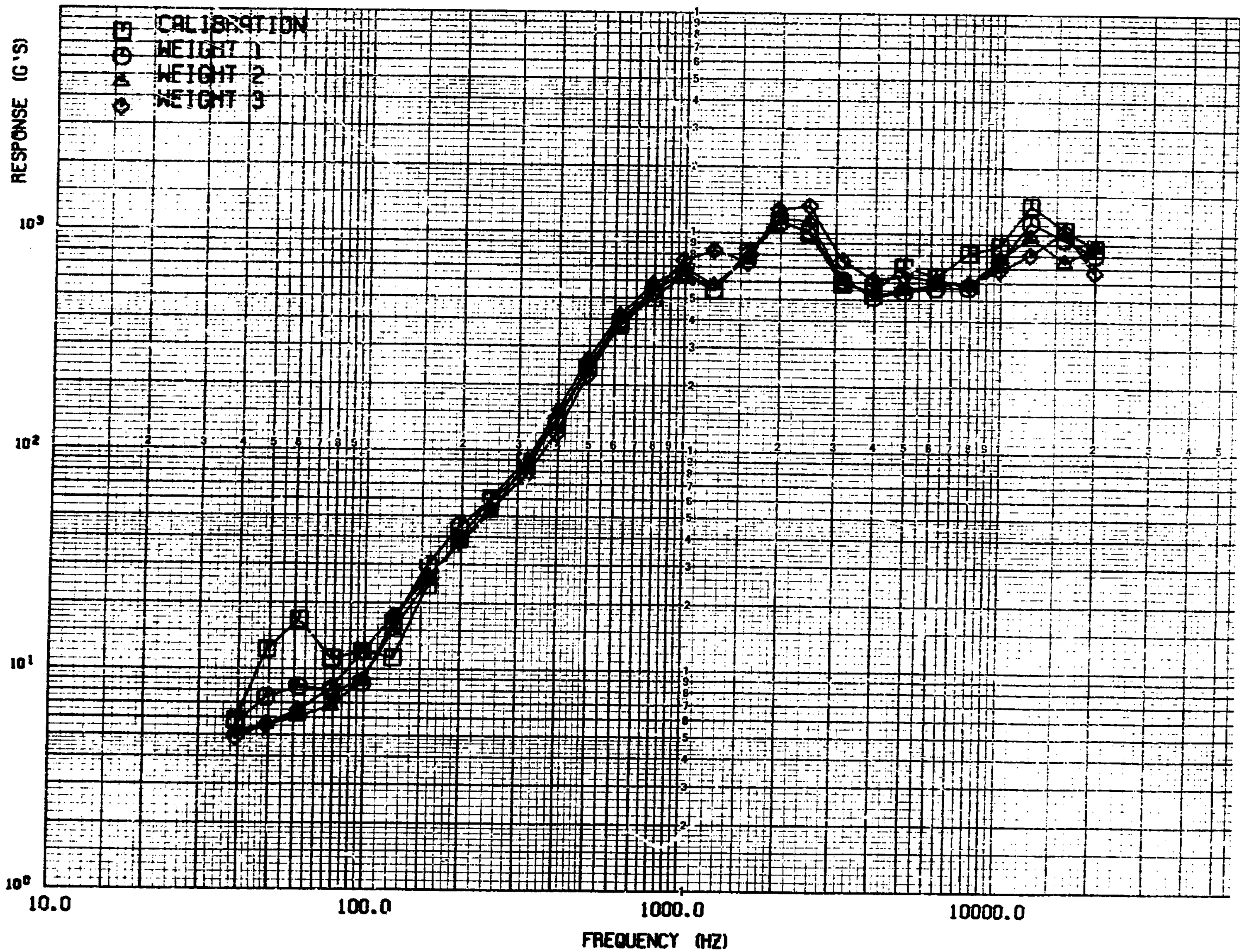


FIGURE 6A. COMPARISON OF SHOCK SPECTRA - ACCEL 06. PHASE I SINGLE MASS LOADING

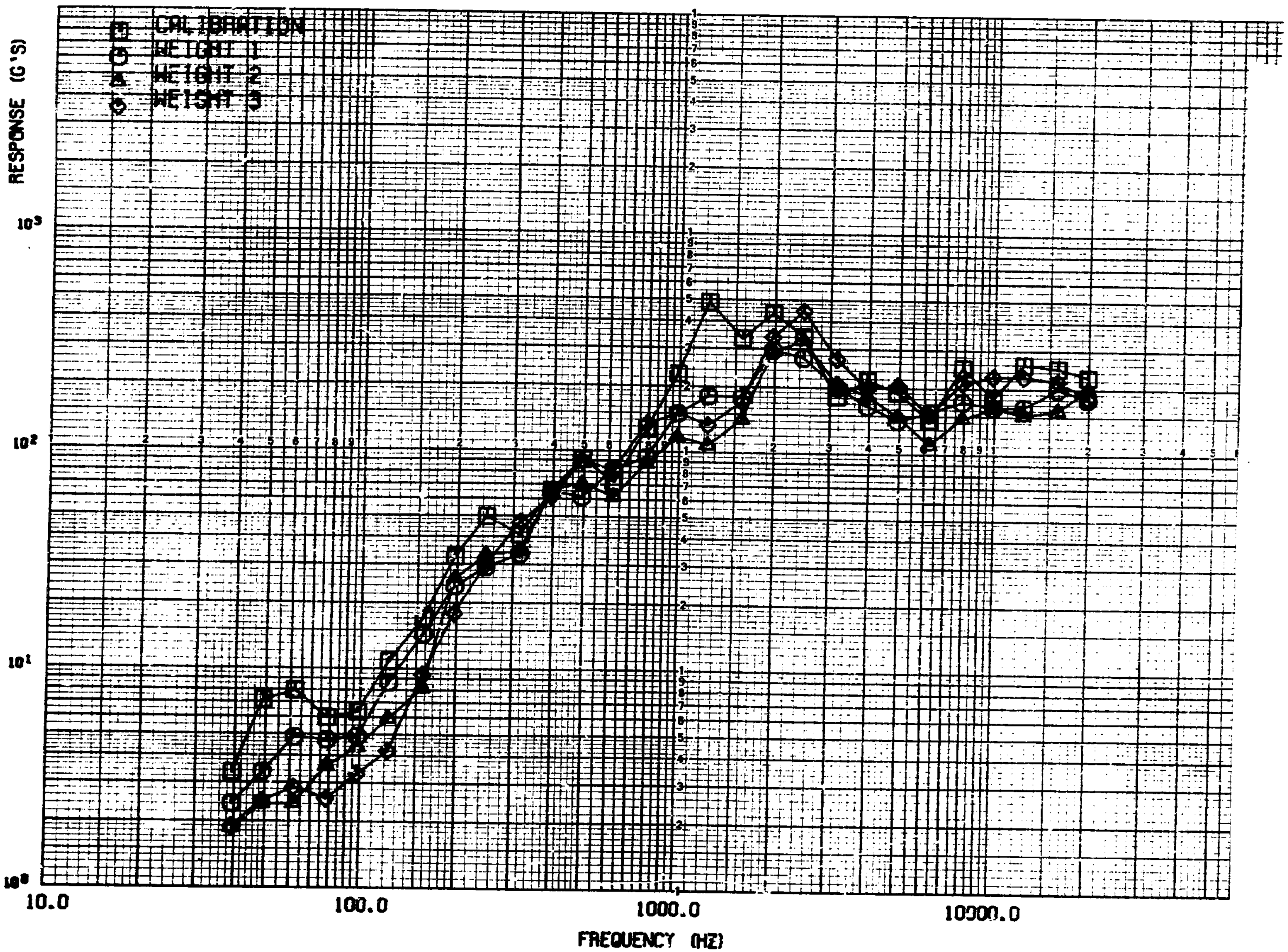


FIGURE 7A. COMPARISON OF SHOCK SPECTRA - ACCEL 07. PHASE I SINGLE MASS LOADING

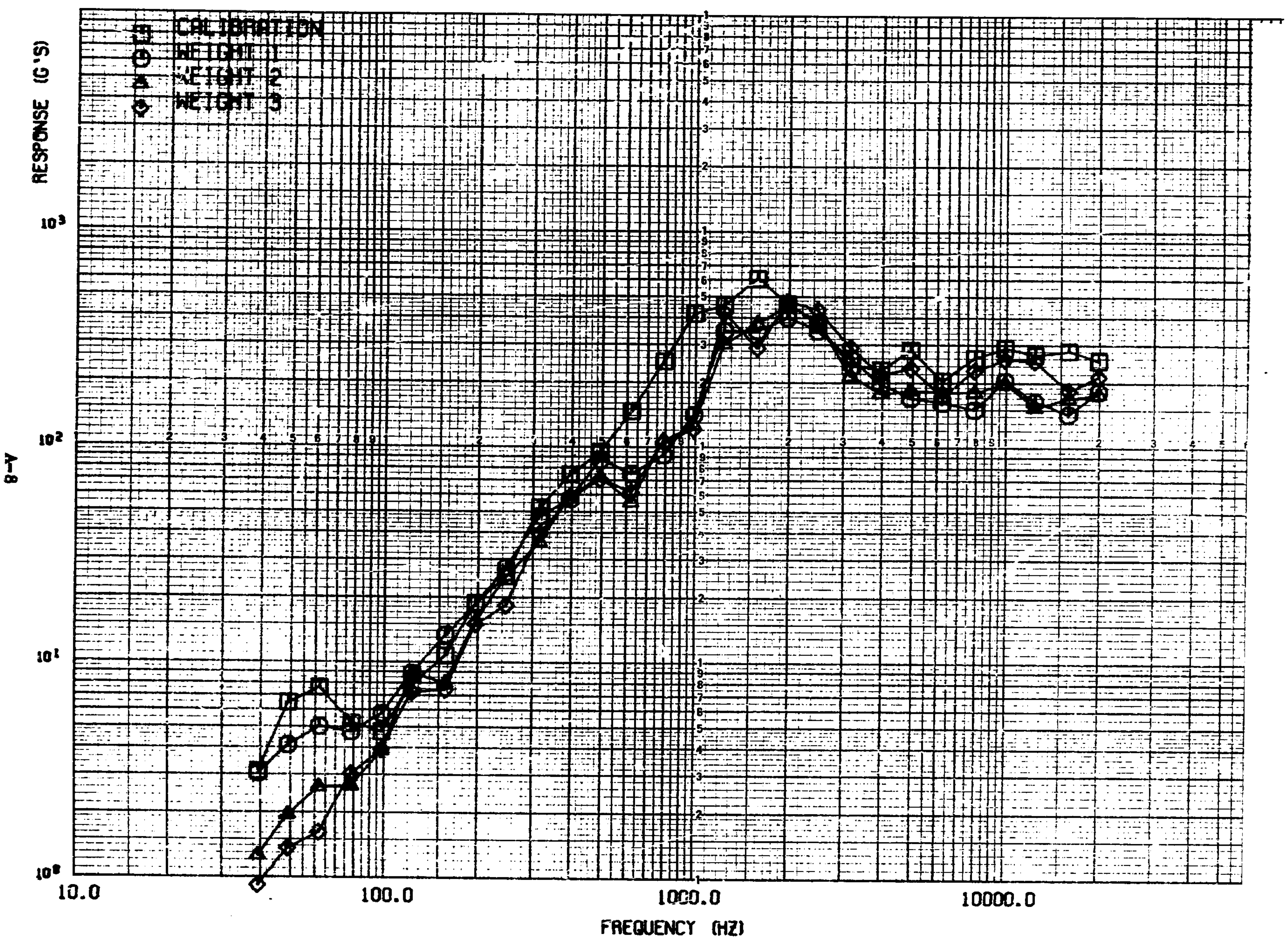


FIGURE 8A. COMPARISON OF SHOCK SPECTRA - ACCEL 08. PHASE I SINGLE MASS LOADING

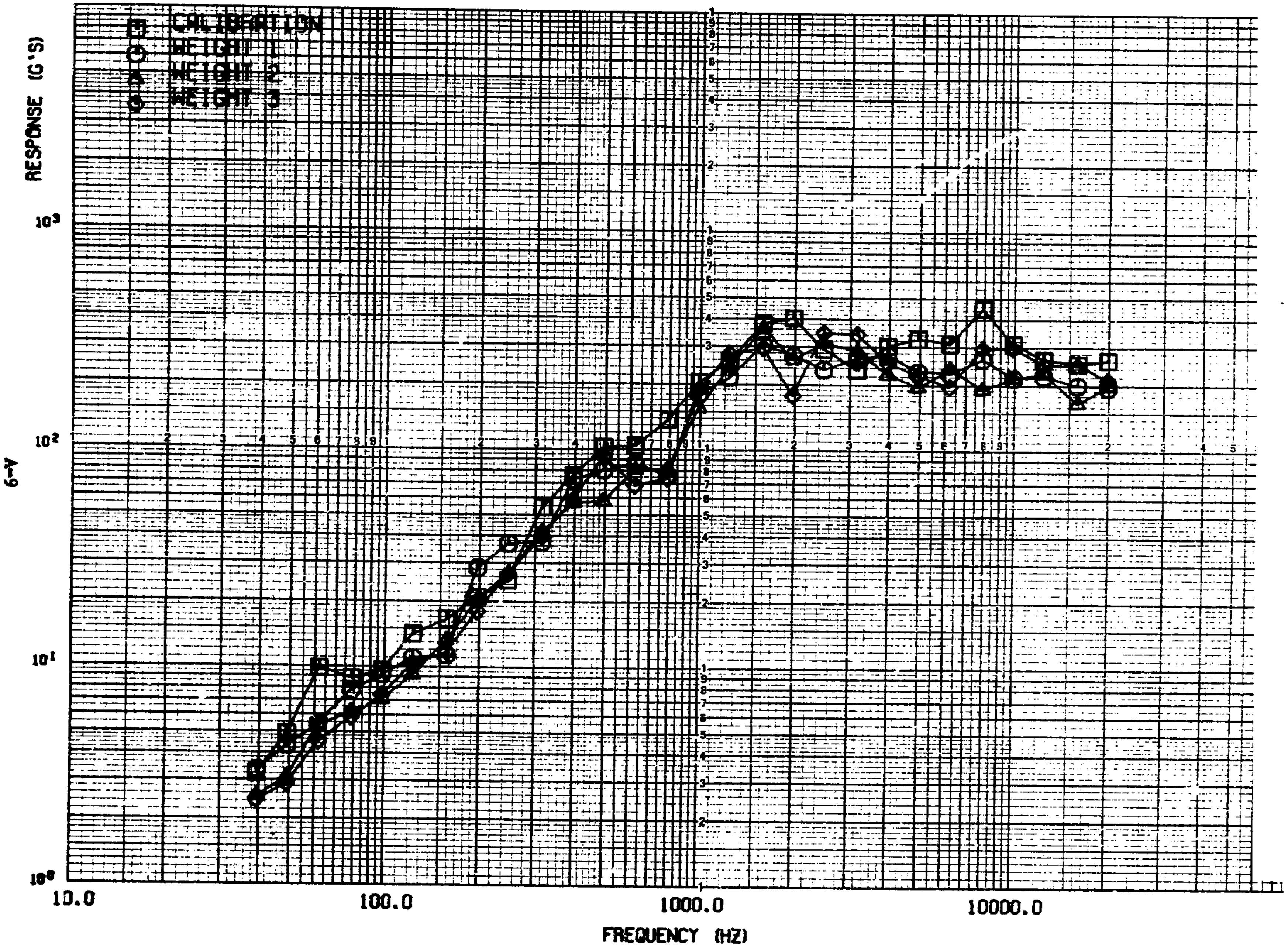


FIGURE 9A. COMPARISON OF SHOCK SPECTRA - ACCEL 09. PHASE I SINGLE MASS LOADING

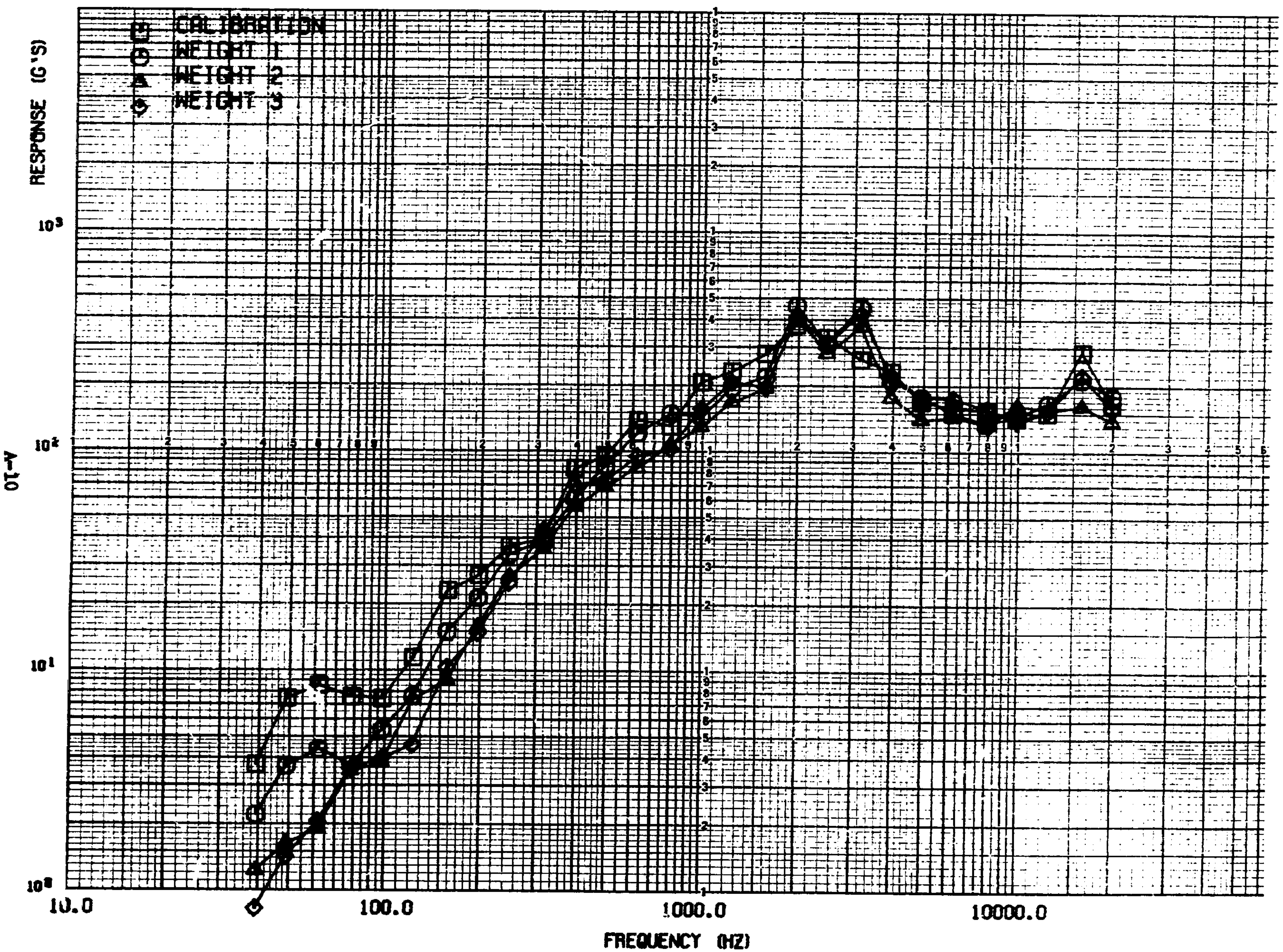


FIGURE 10A. COMPARISON OF SHOCK SPECTRA - ACCEL 10. PHASE I SINGLE MASS LOADING

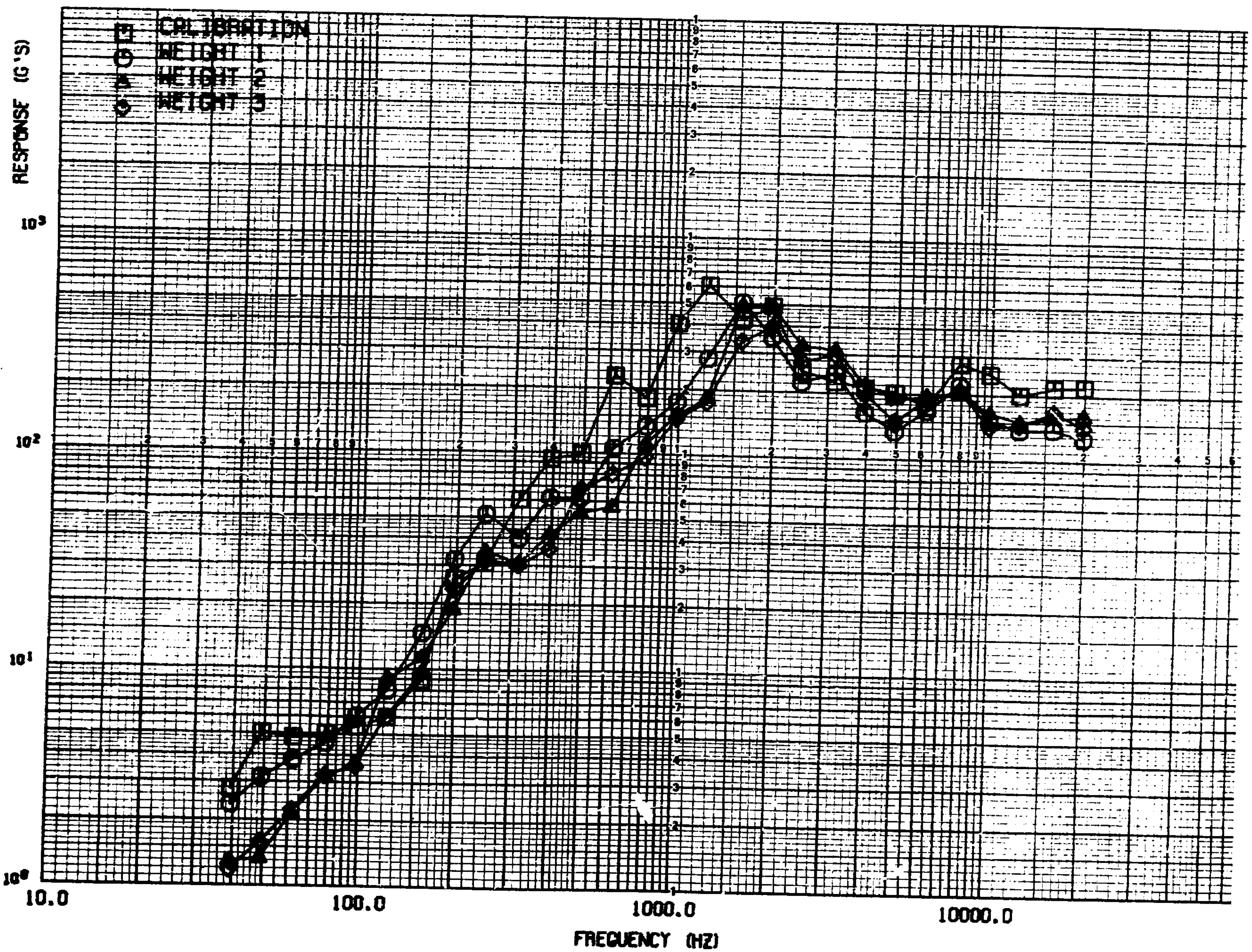


FIGURE 11A. COMPARISON OF SHOCK SPECTRA - ACCEL 11. PHASE I SINGLE MASS LOADING

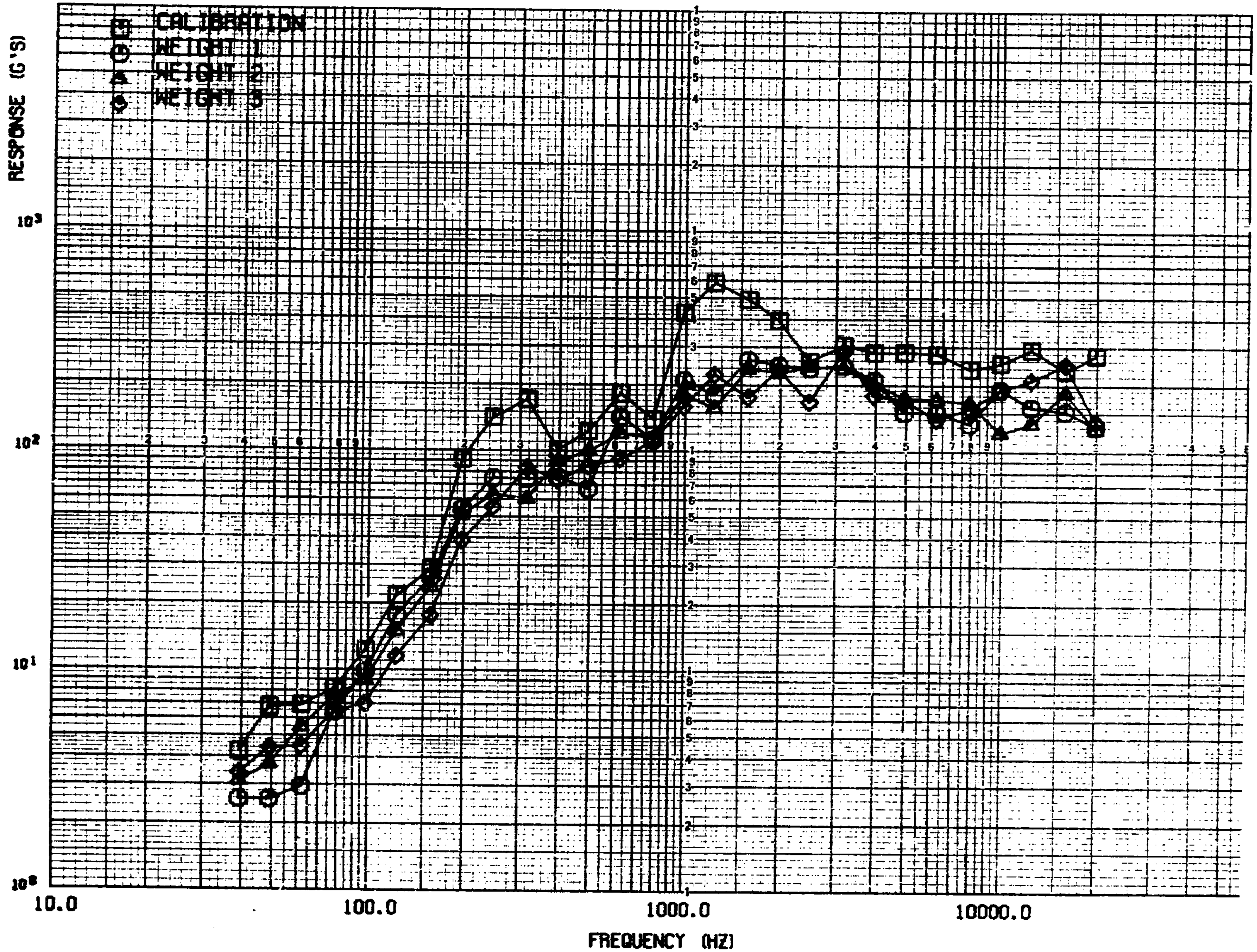


FIGURE 12A. COMPARISON OF SHOCK SPECTRA - ACCEL 12. PHASE I SINGLE MASS LOADING

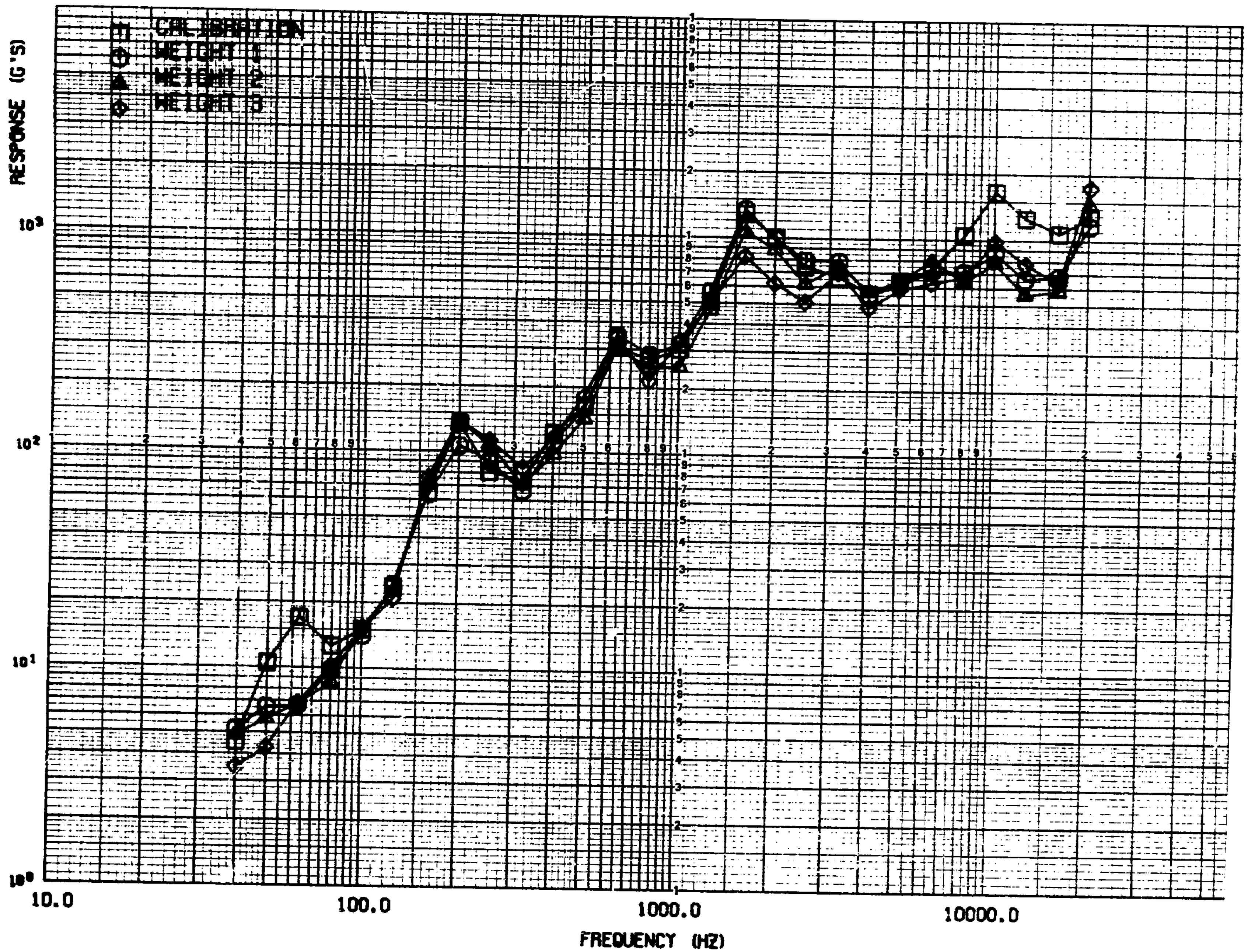


FIGURE 13A. COMPARISON OF SHOCK SPECTRA - ACCEL 01. PHASE IA SINGLE MASS LOADING

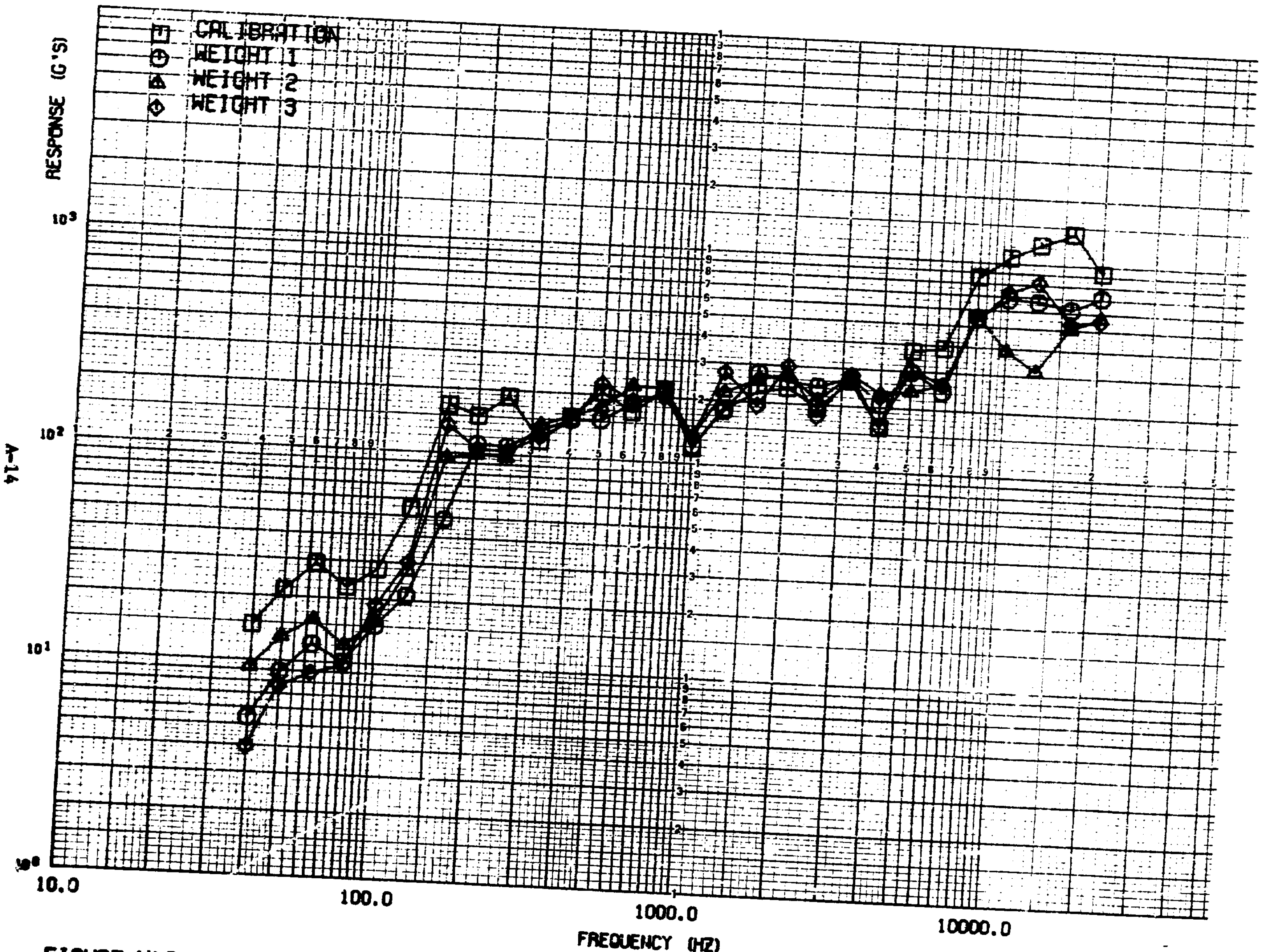


FIGURE 14A. COMPARISON OF SHOCK SPECTRA - ACCEL 02. PHASE IA SINGLE MASS LOADING

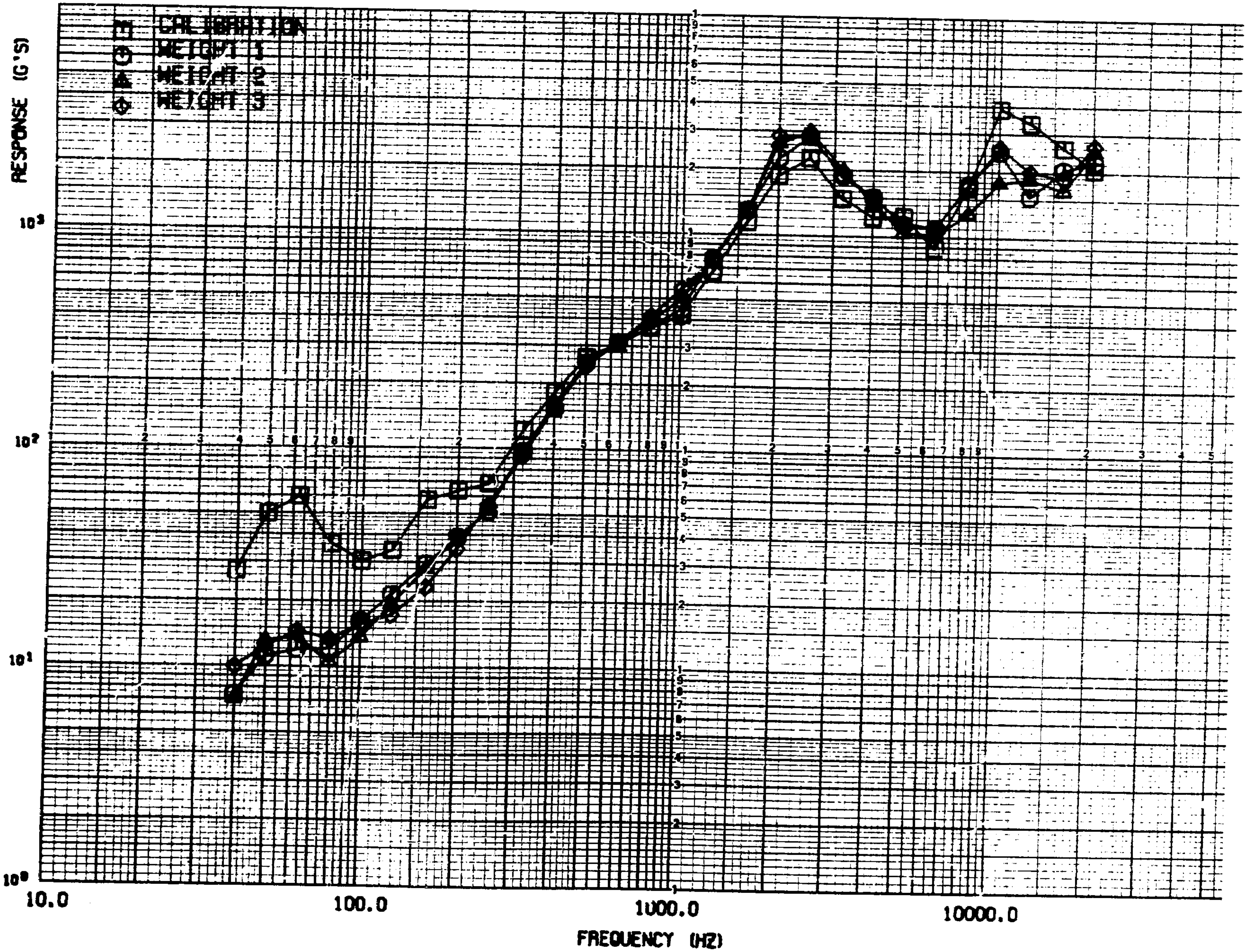


FIGURE 15A. COMPARISON OF SHOCK SPECTRA - ACCEL 03. PHASE IA SINGLE MASS LOADING

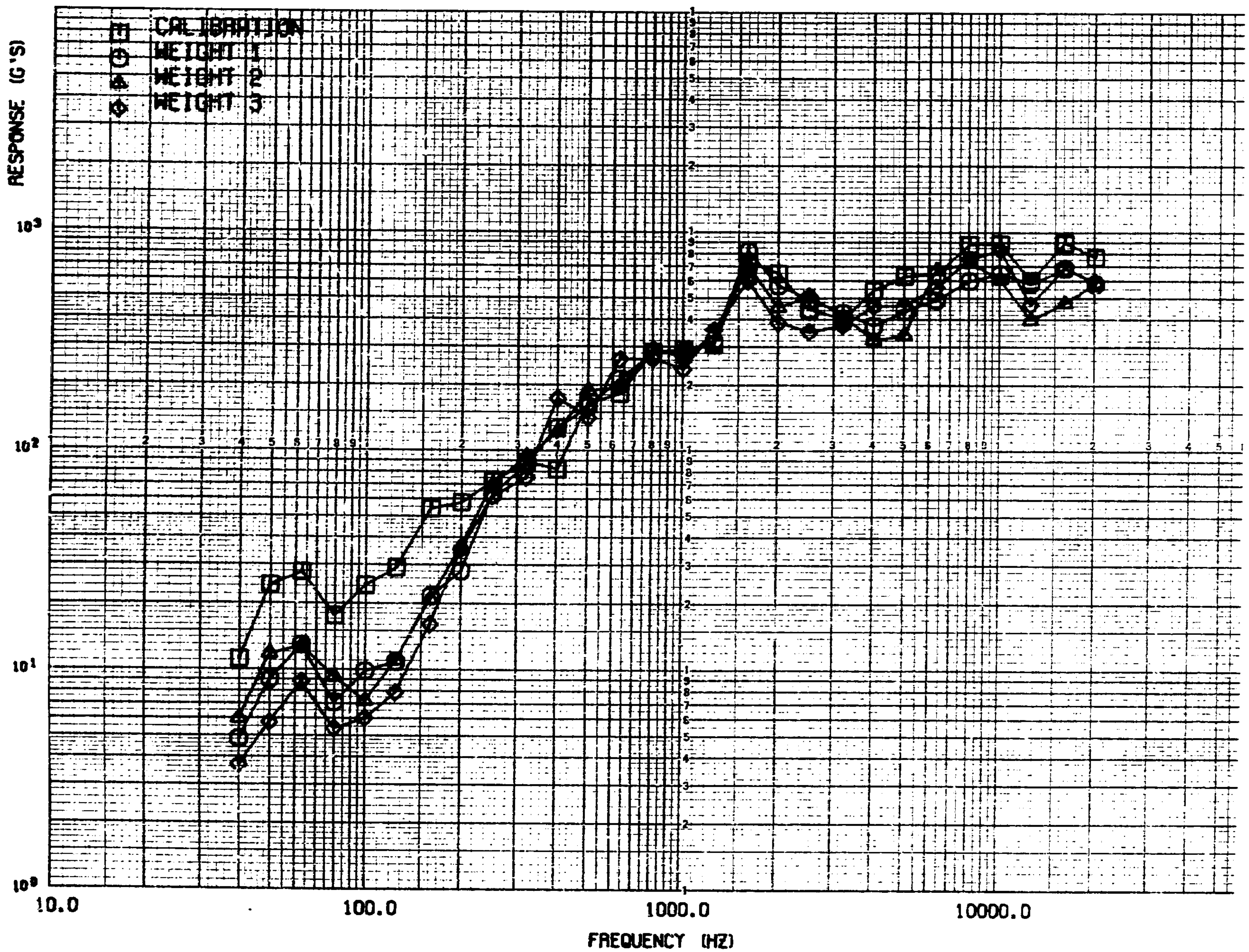


FIGURE 16A. COMPARISON OF SHOCK SPECTRA - ACCEL 04. PHASE IA SINGLE MASS LOADING

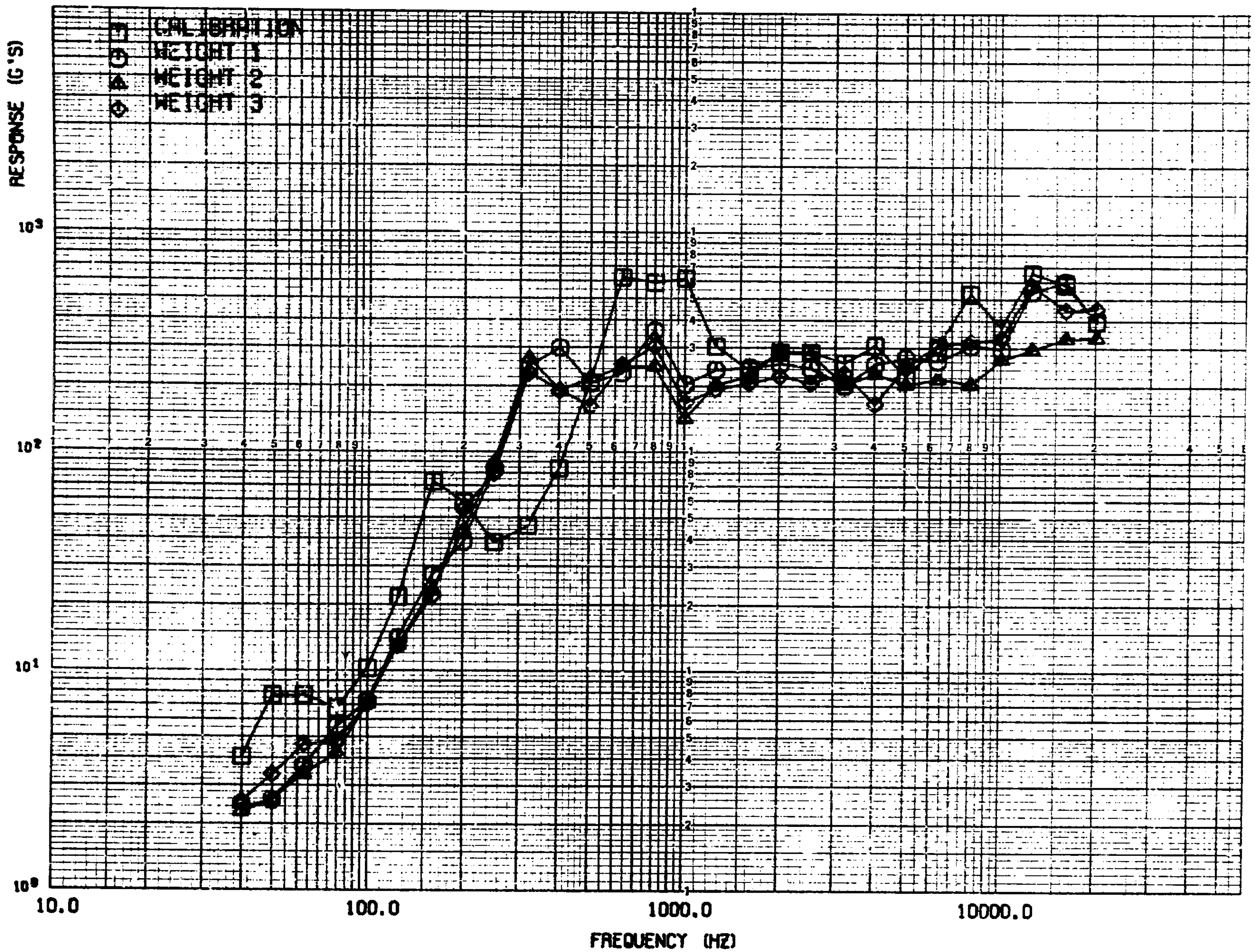


FIGURE 17A. COMPARISON OF SHOCK SPECTRA - ACCEL 05. PHASE IA SINGLE MASS LOADING

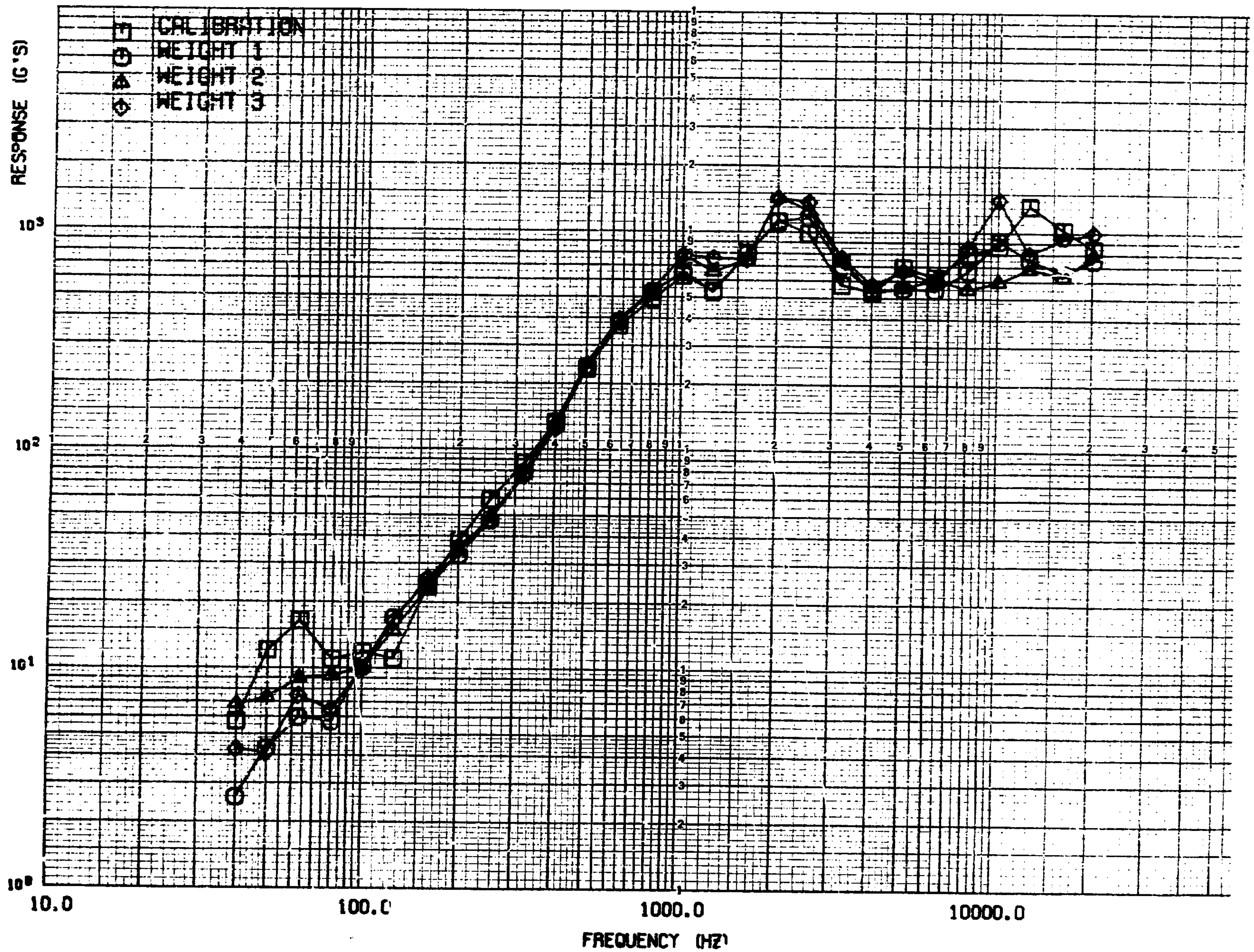


FIGURE 18A. COMPARISON OF SHOCK SPECTRA - ACCEL 06. PHASE IA SINGLE MASS LOADING

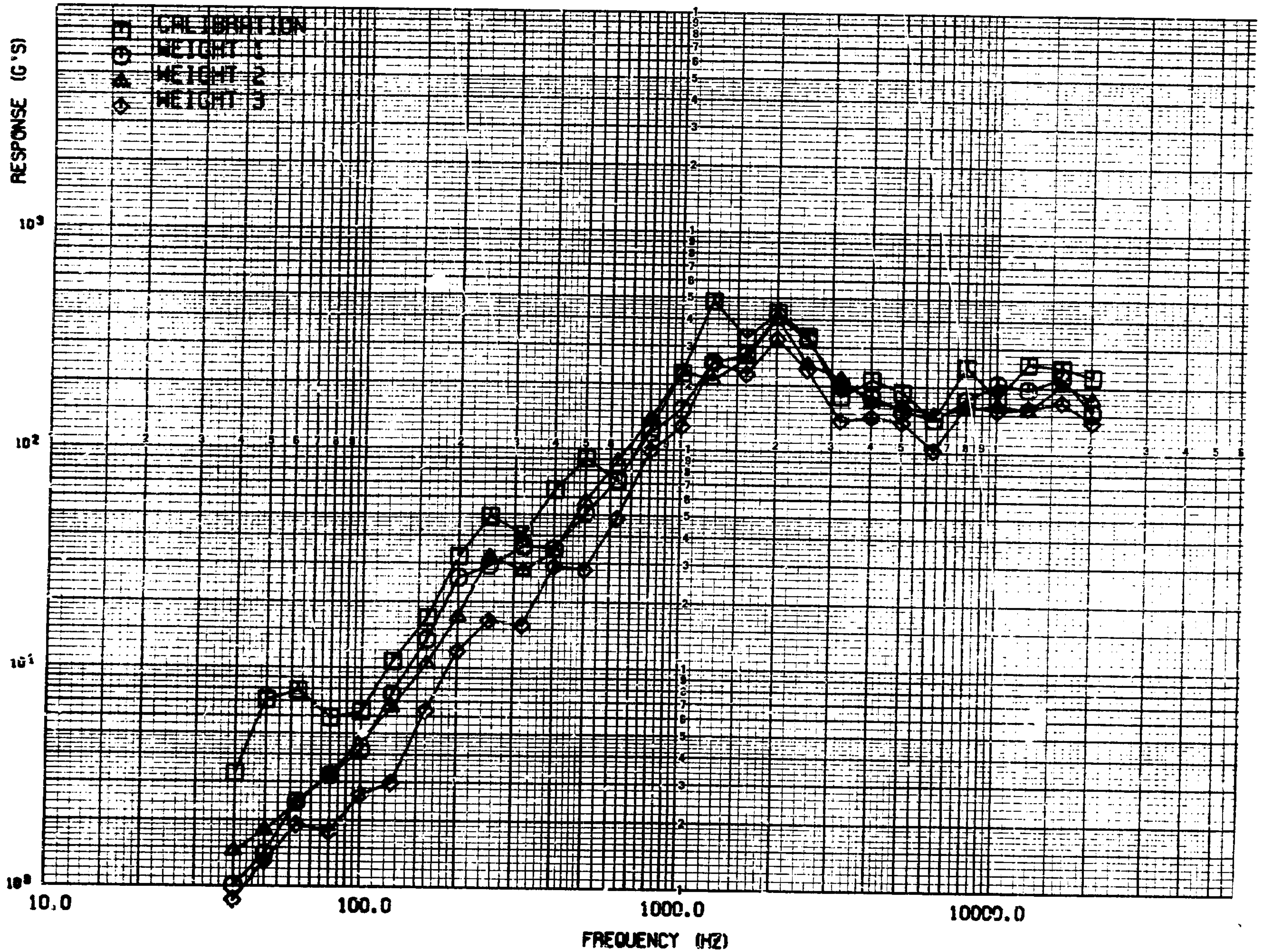


FIGURE 19A. COMPARISON OF SHOCK SPECTRA - ACCEL 07. PHASE IA SINGLE MASS LOADING

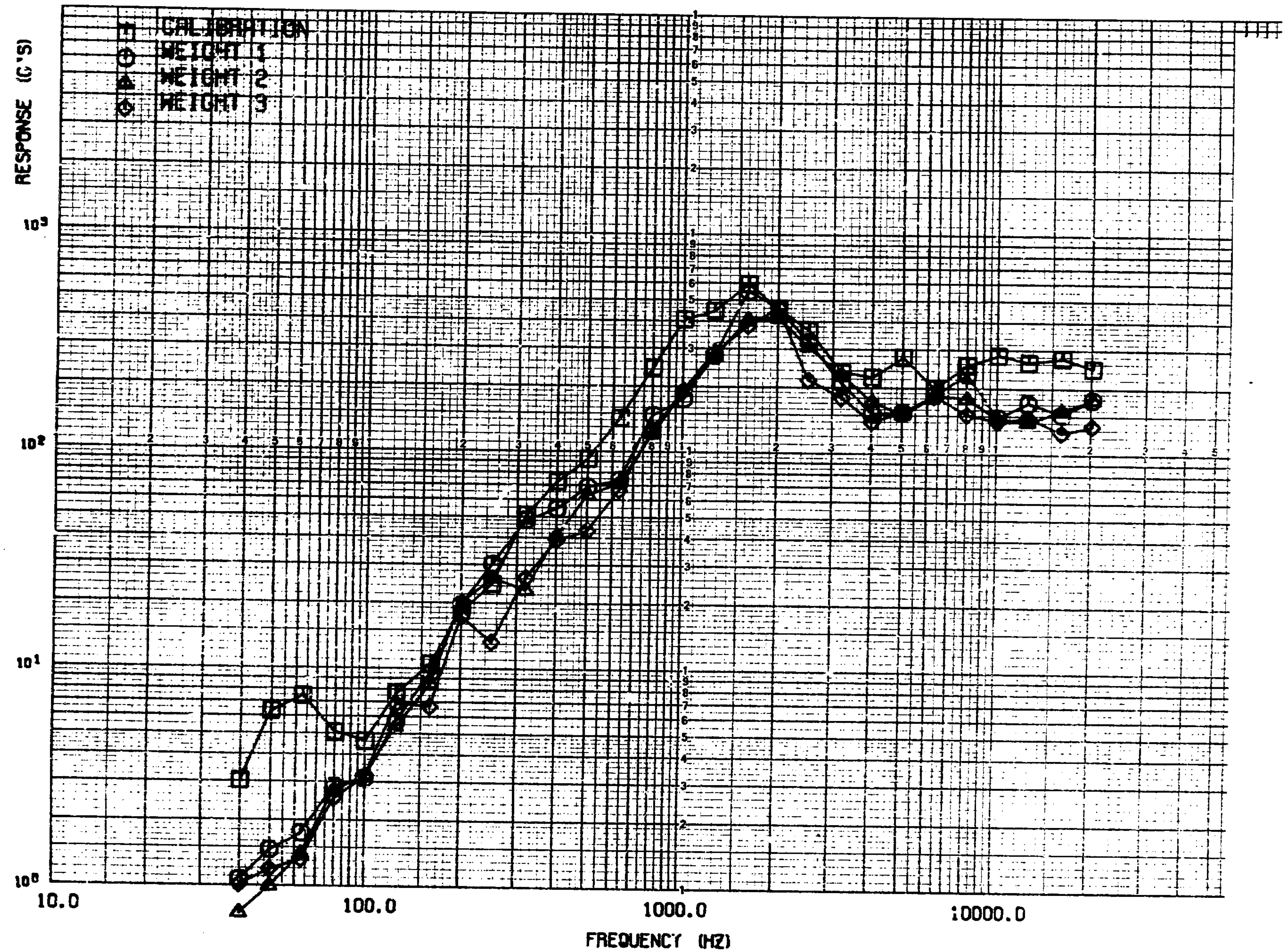


FIGURE 20H. COMPARISON OF SHOCK SPECTRA - ACCEL 08. PHASE IA SINGLE MASS LOADING

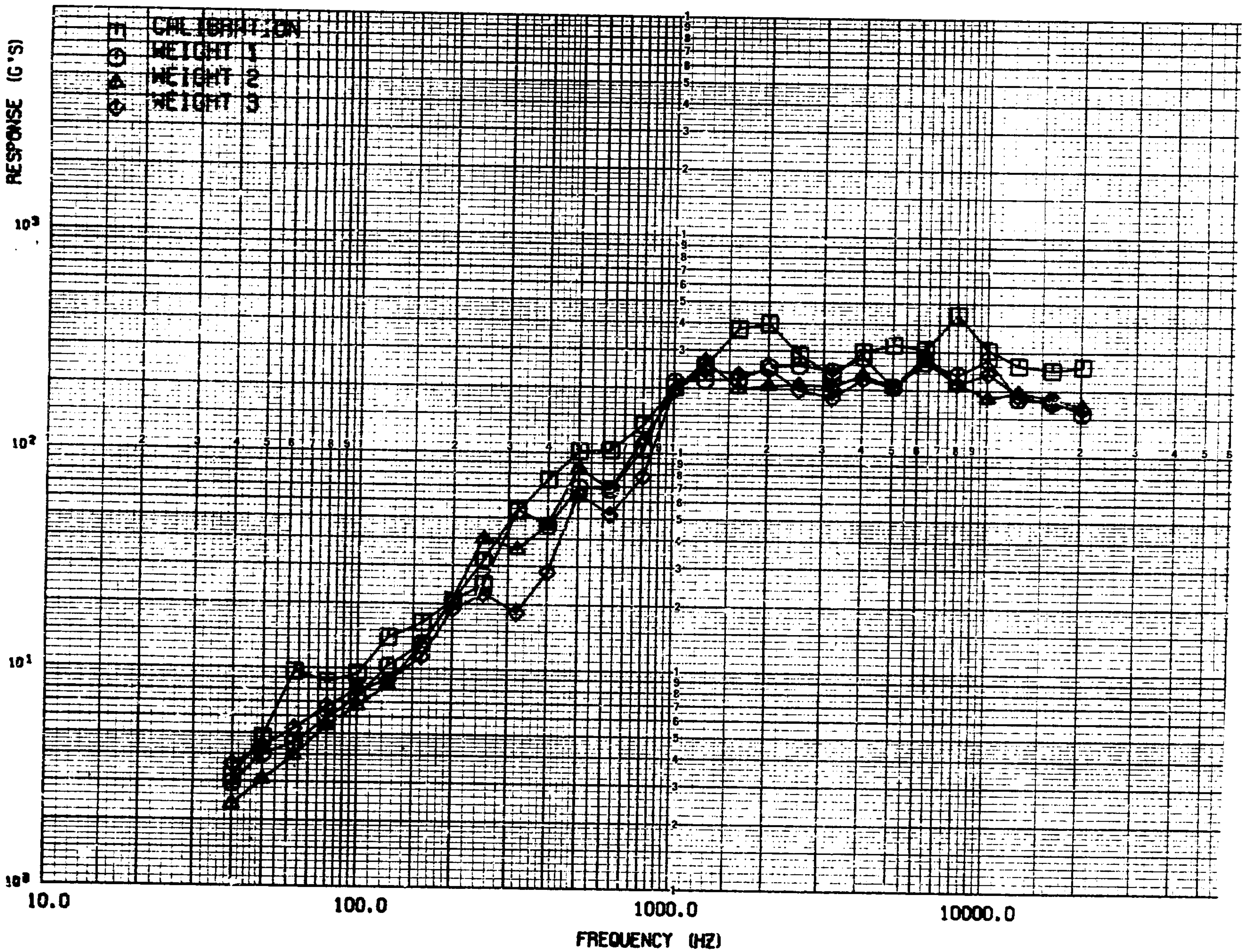


FIGURE 21A. COMPARISON OF SHOCK SPECTRA - ACCEL 09. PHASE IA SINGLE MASS LOADING

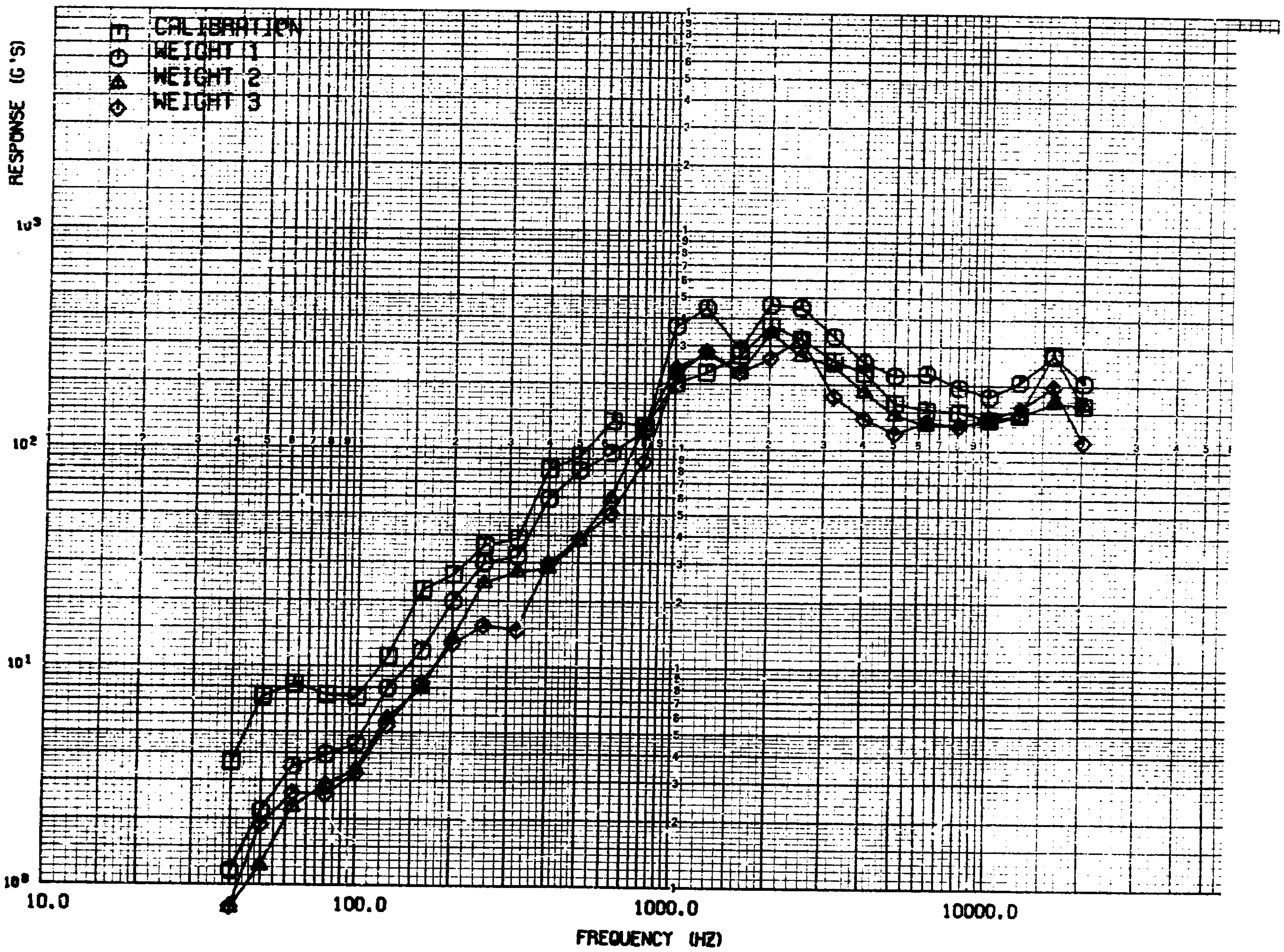
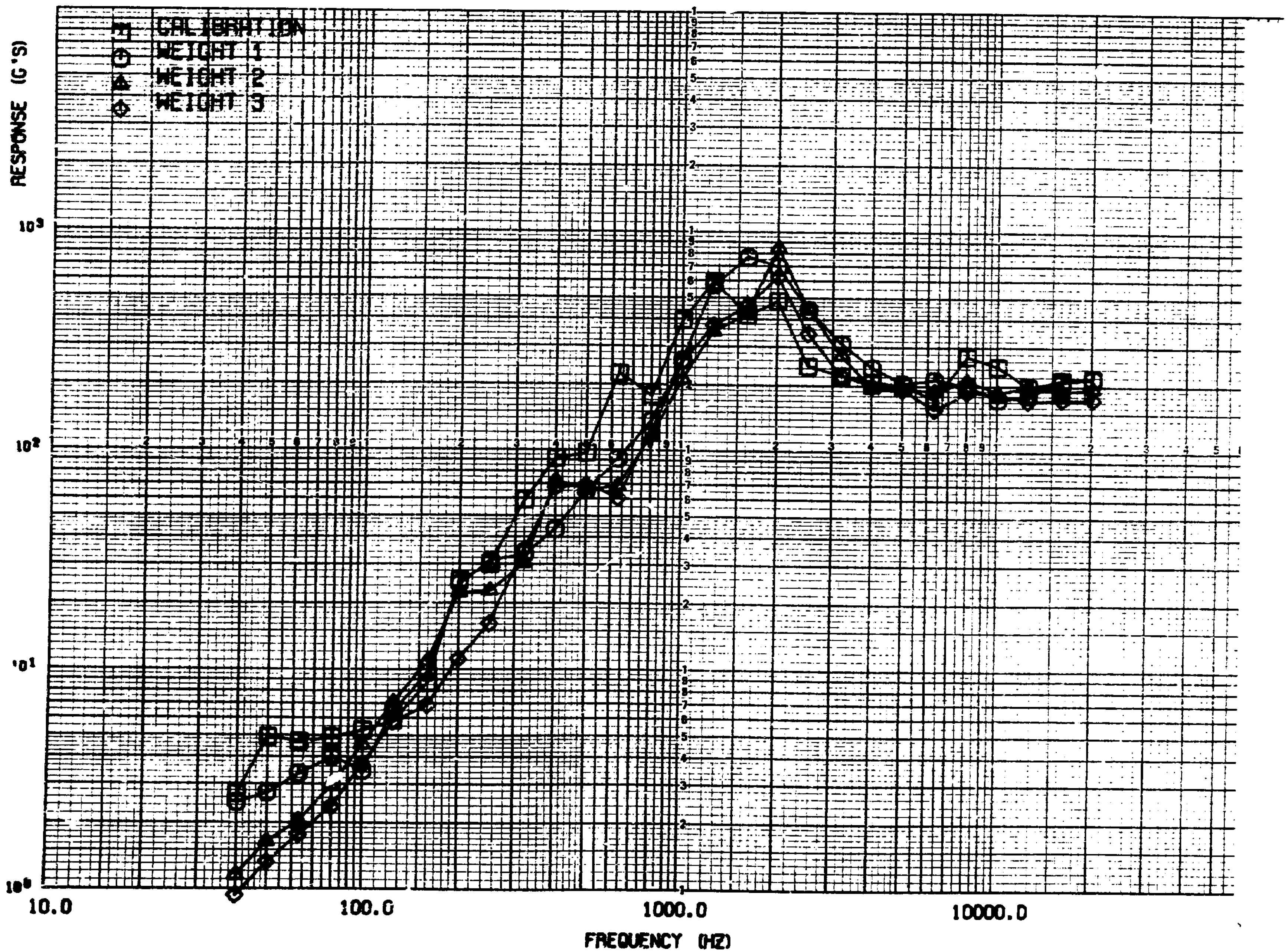


FIGURE 22A. COMPARISON OF SHOCK SPECTRA - ACCEL 10. PHASE IA SINGLE MASS LOADING

A-22


CALIBRATION
WEIGHT 1
WEIGHT 2
WEIGHT 3
RESPONSE (G'S)
10³
10²
10¹
10⁰
10.0
100.0
1000.0
10000.0
FREQUENCY (HZ)

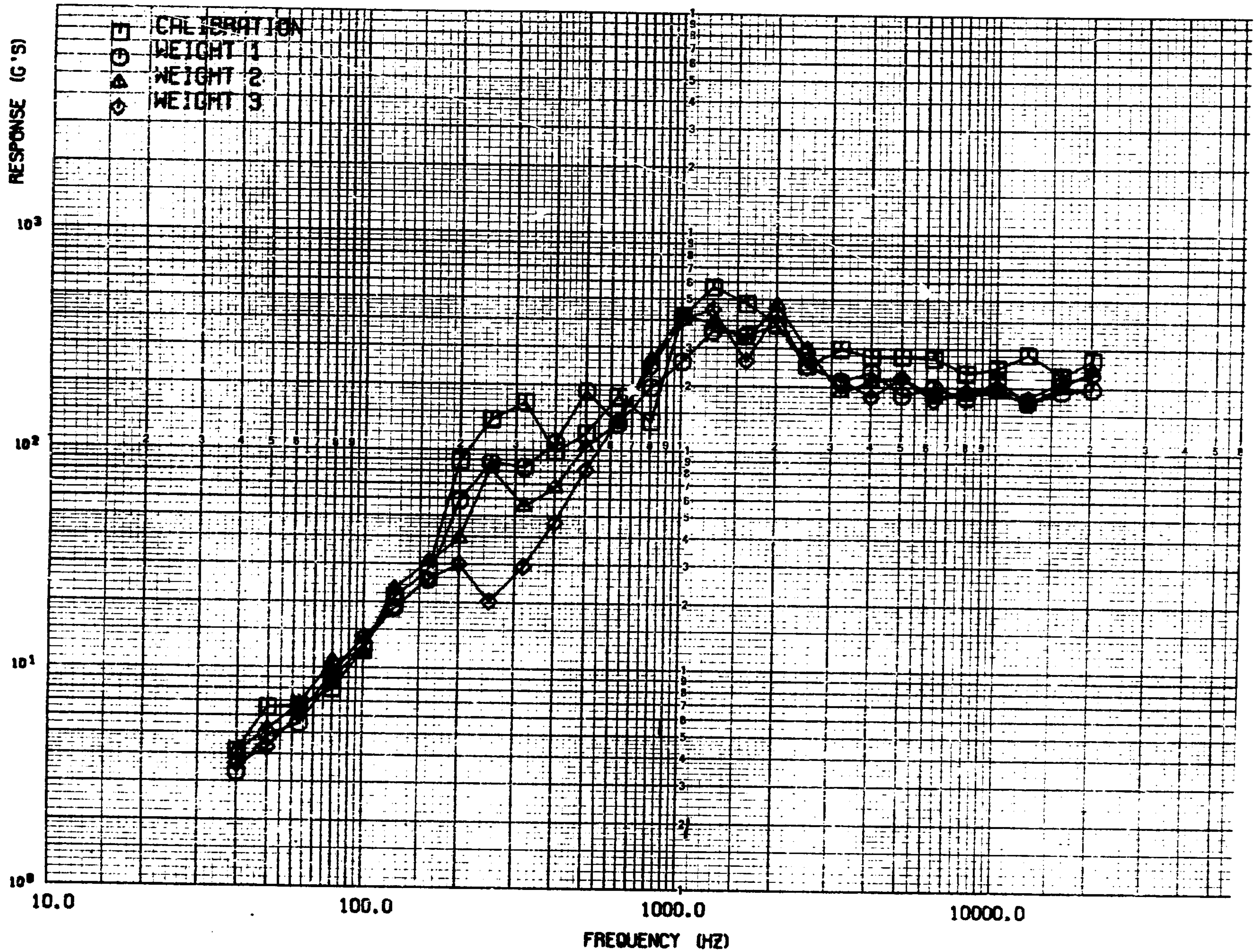


FIGURE 24A. COMPARISON OF SHOCK SPECTRA - ACCEL 12. PHASE IA SINGLE MASS LOADING

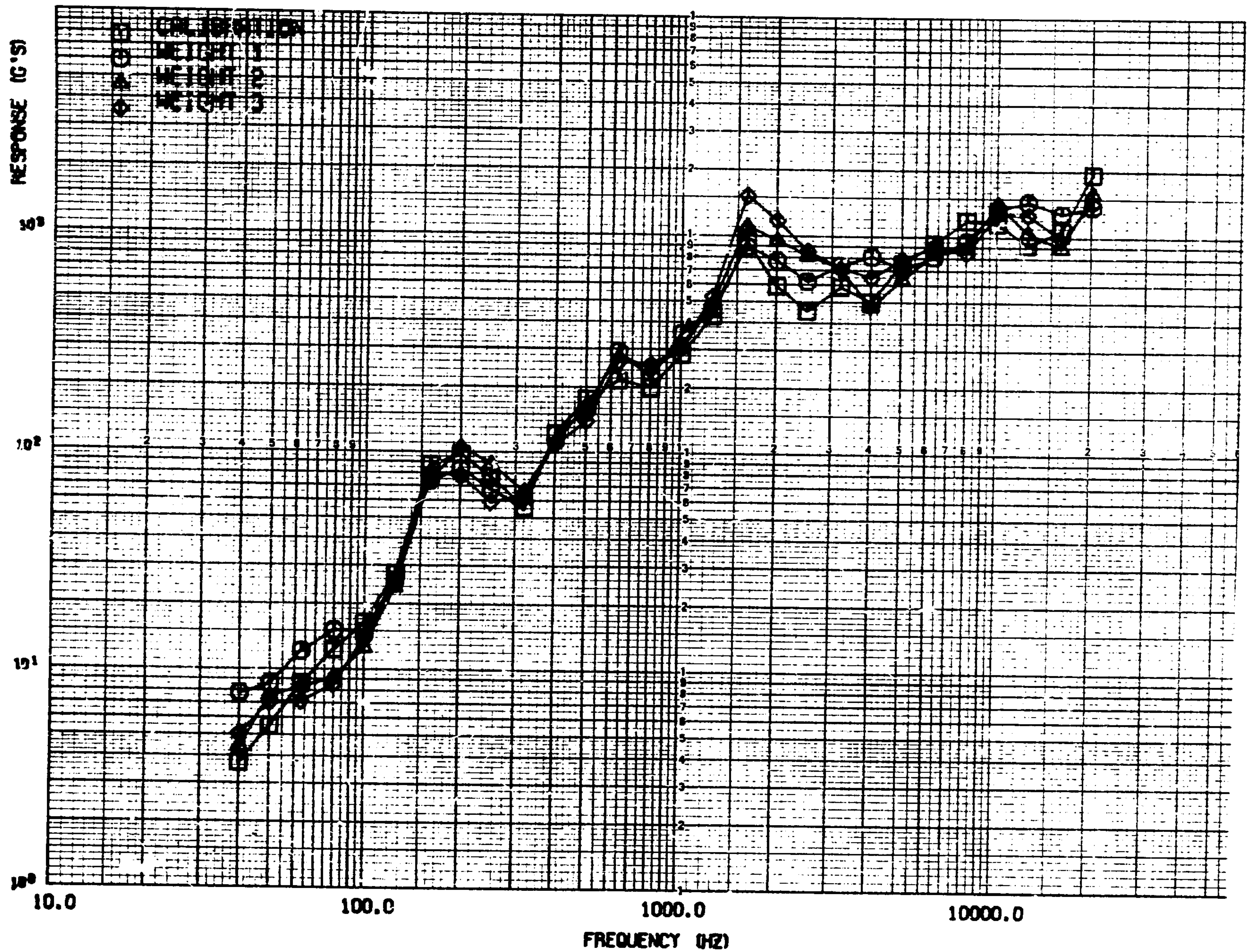


FIGURE 25A. COMPARISON OF SHOCK SPECTRA - ACCEL 01. PHASE II DISTRIBUTED MASS

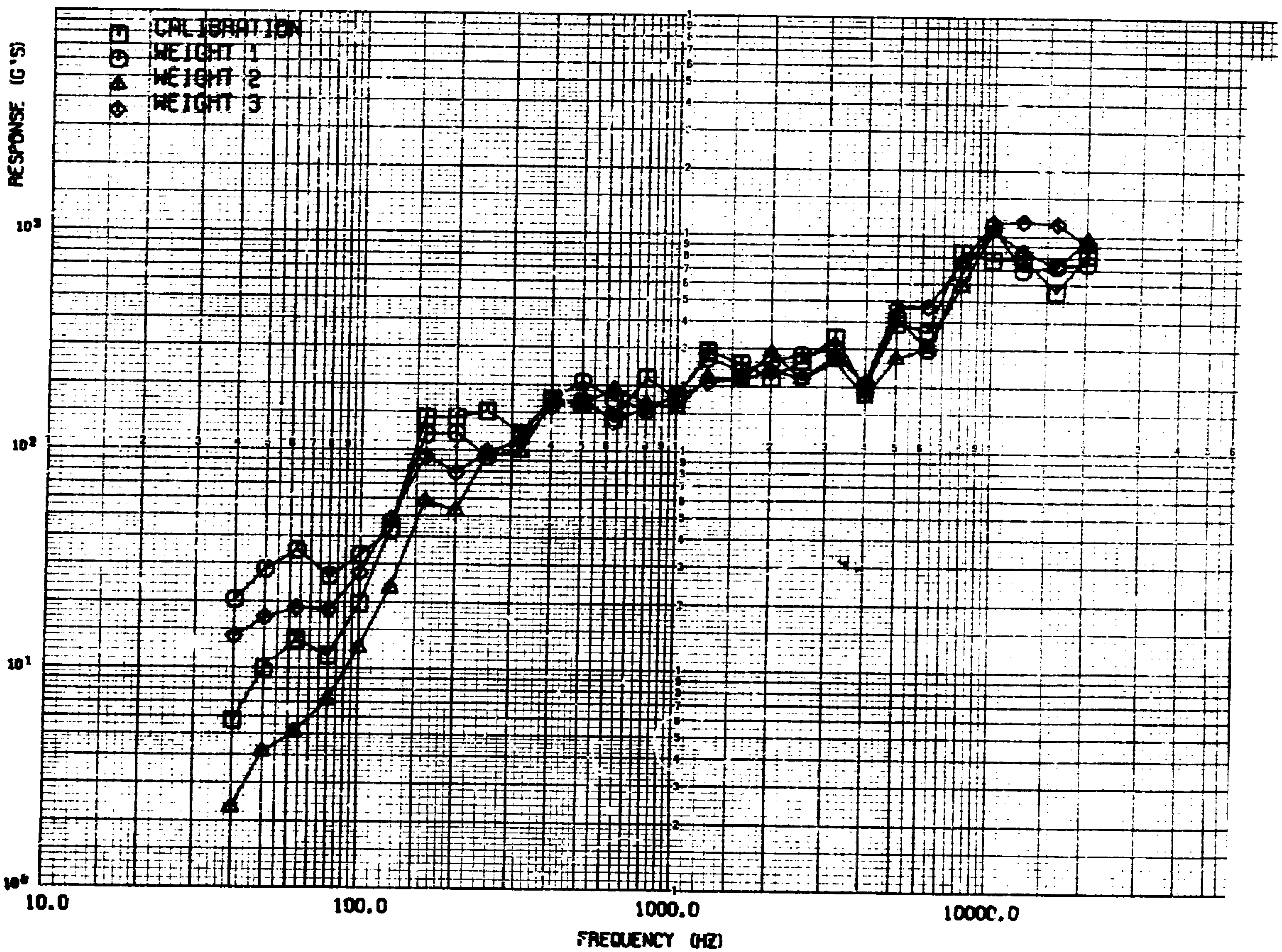


FIGURE 26A. COMPARISON OF SHOCK SPECTRA - ACCEL 02. PHASE II DISTRIBUTED MASS

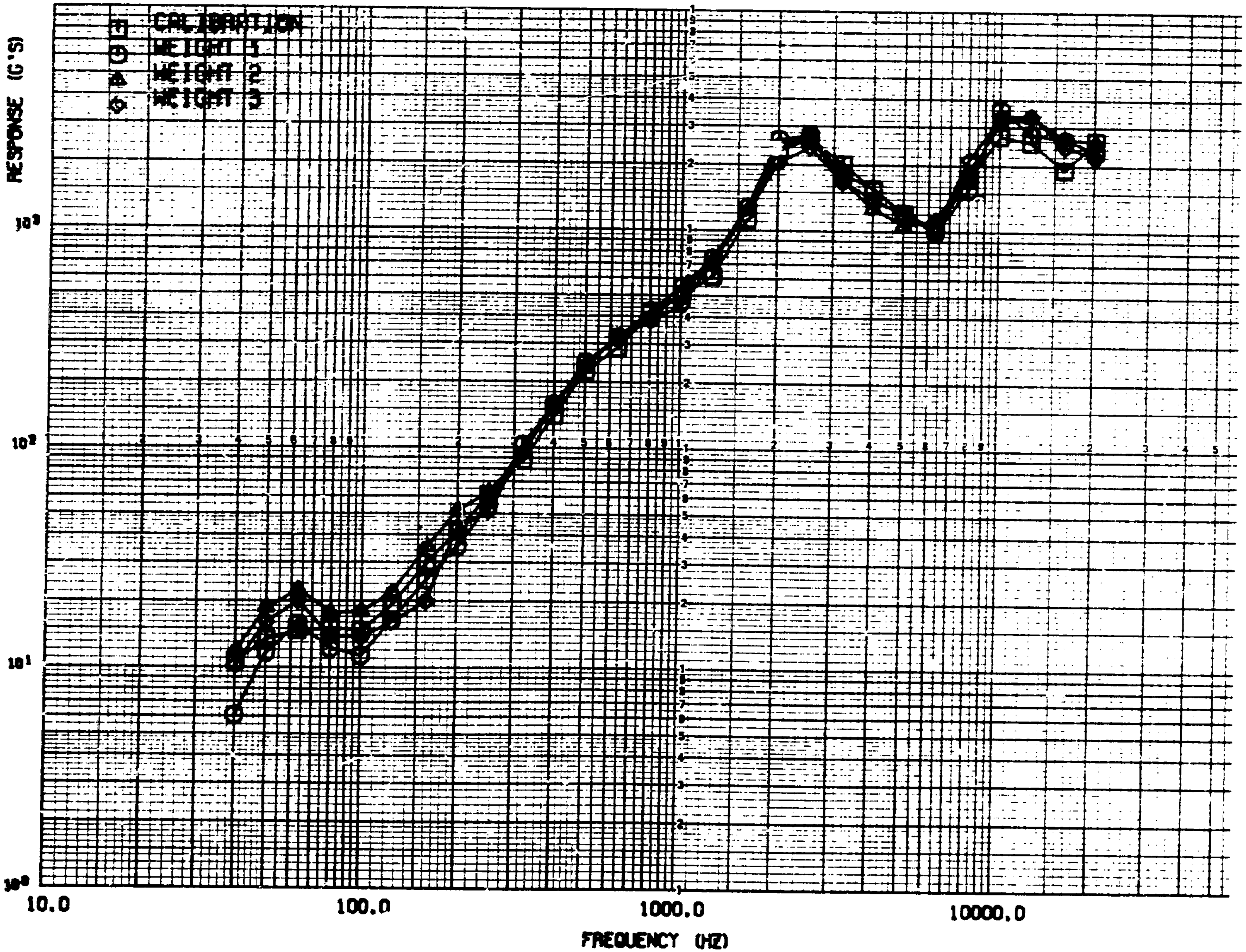


FIGURE 27A. COMPARISON OF SHOCK SPECTRA - ACCEL 03. PHASE II DISTRIBUTED MASS

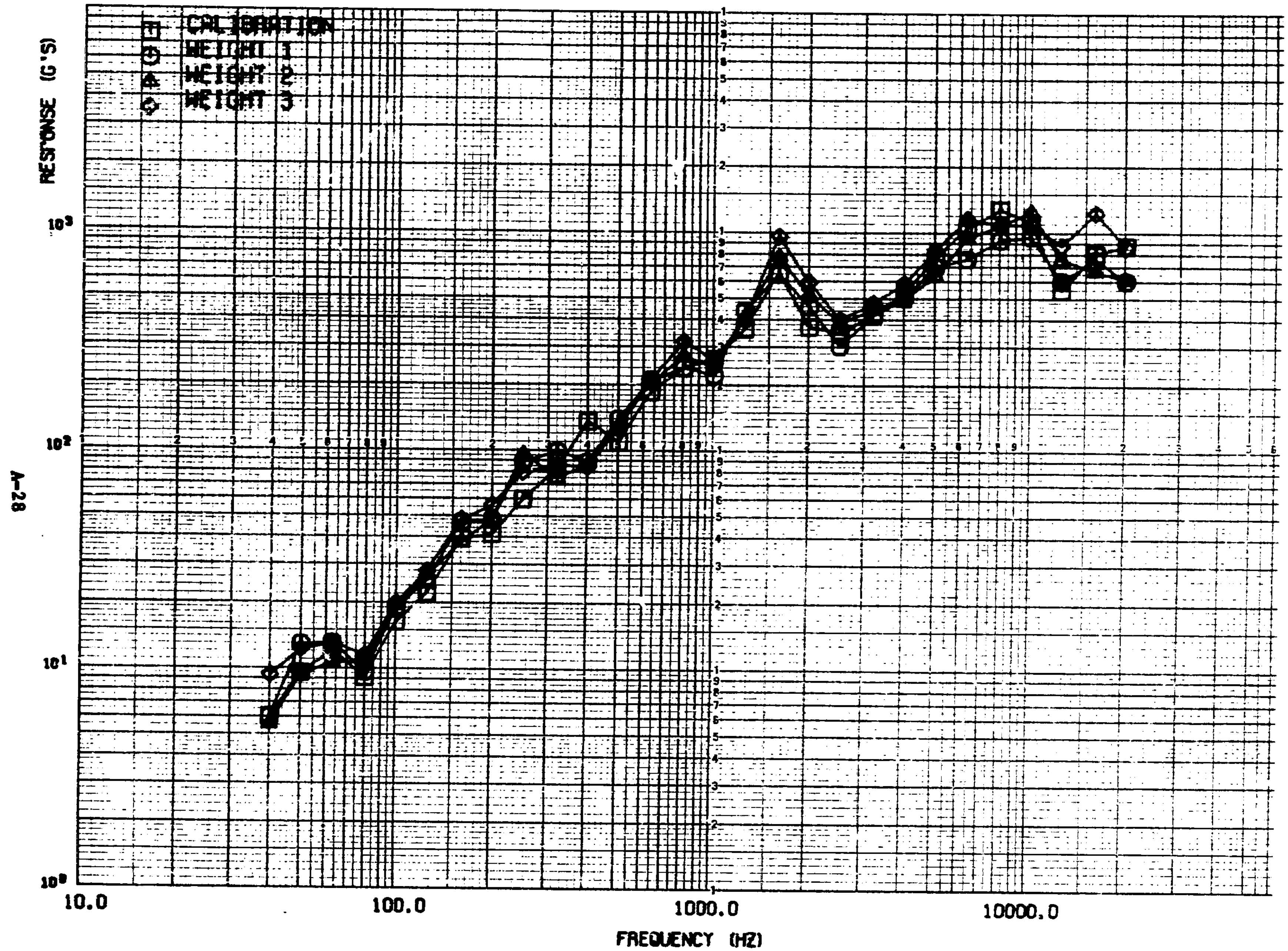


FIGURE 28A. COMPARISON OF SHOCK SPECTRA - ACCEL 04. PHASE II DISTRIBUTED MASS

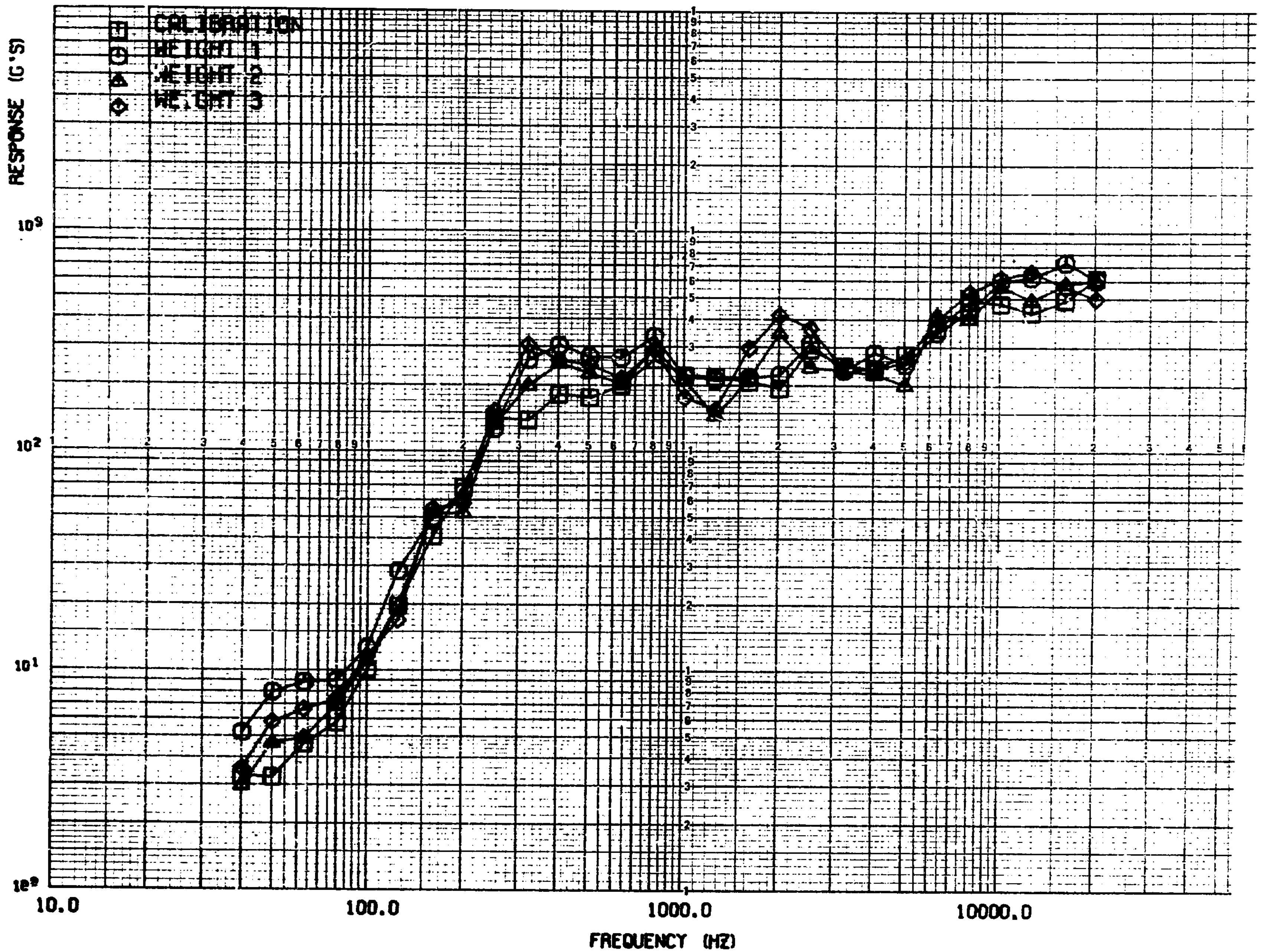


FIGURE 29A. COMPARISON OF SHOCK SPECTRA - ACCEL 05. PHASE II DISTRIBUTED MASS

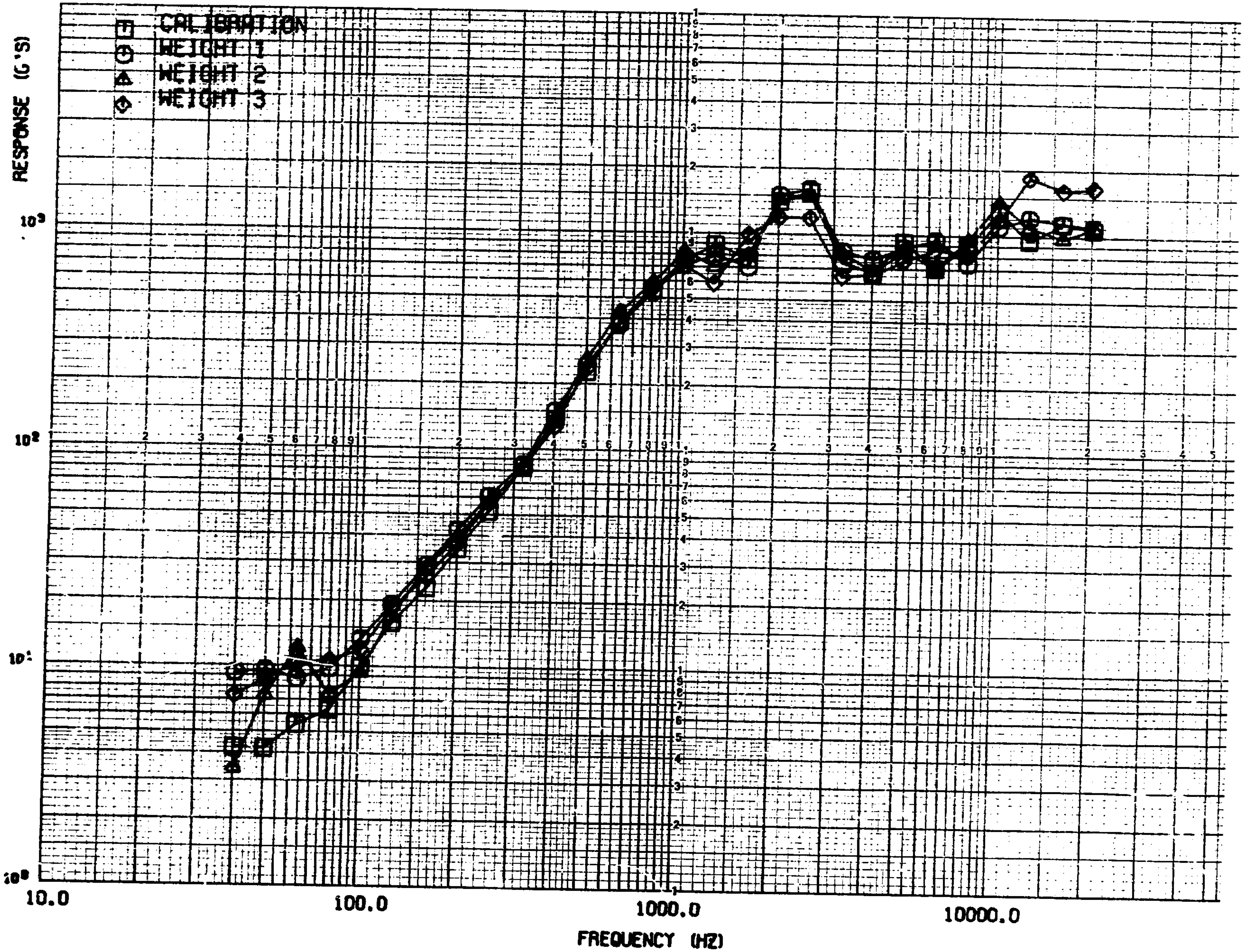


FIGURE 30A. COMPARISON OF SHOCK SPECTRA - ACCEL 06. PHASE II DISTRIBUTED MASS

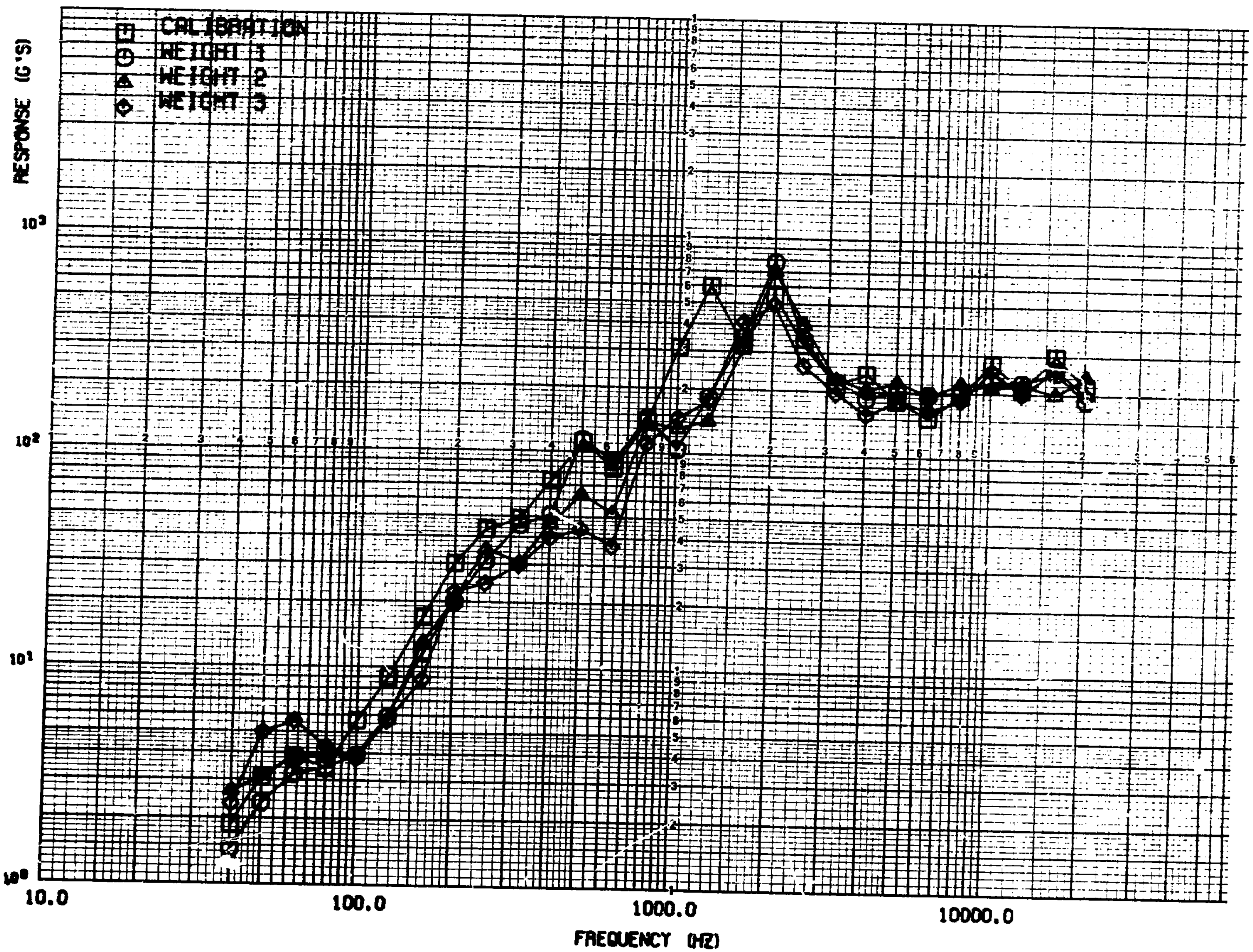


FIGURE 31 A. COMPARISON OF SHOCK SPECTRA - ACCEL 07. PHASE II DISTRIBUTED MASS

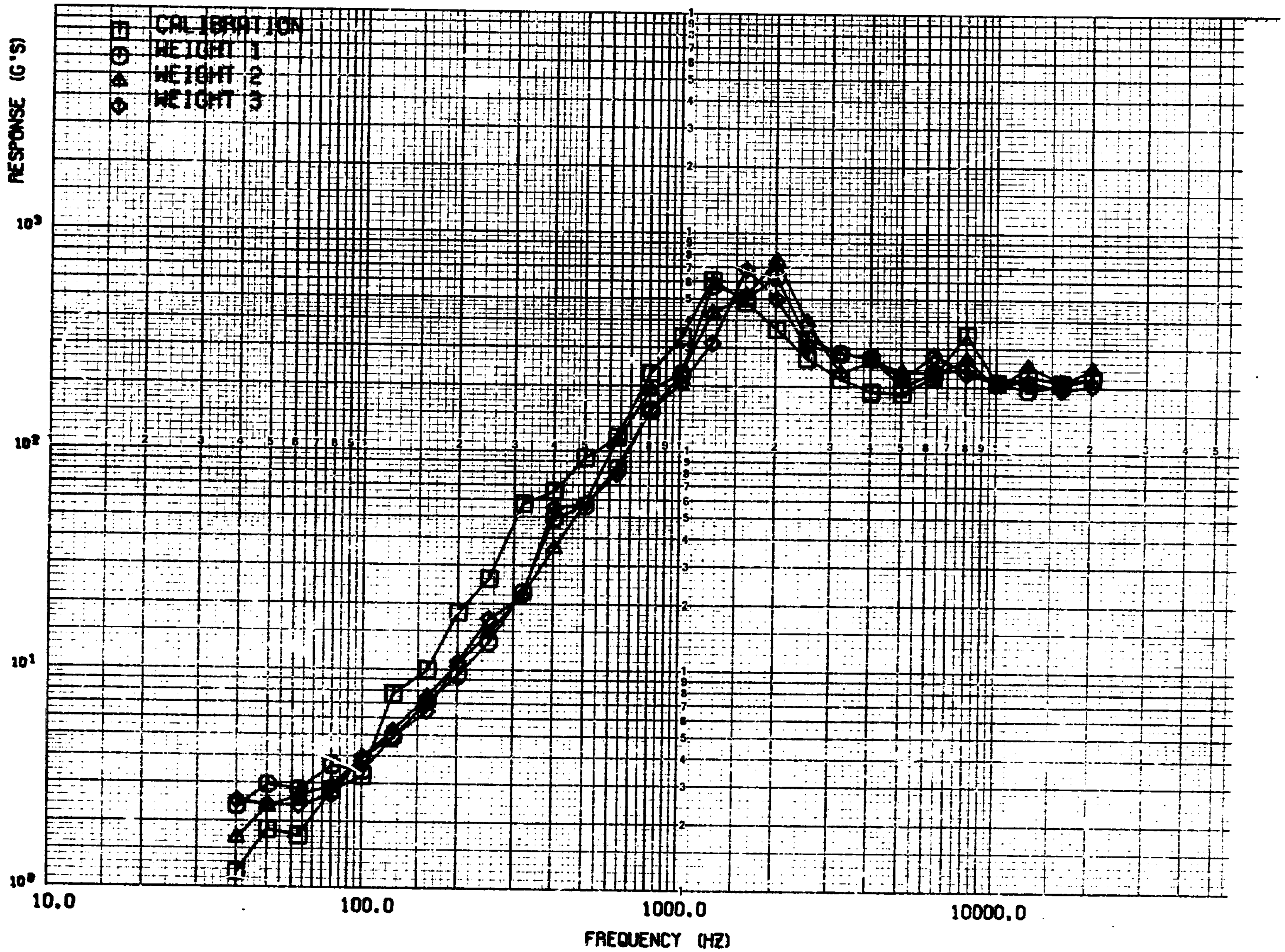


FIGURE 32A. COMPARISON OF SHOCK SPECTRA - ACCEL C8. PHASE II DISTRIBUTED MASS

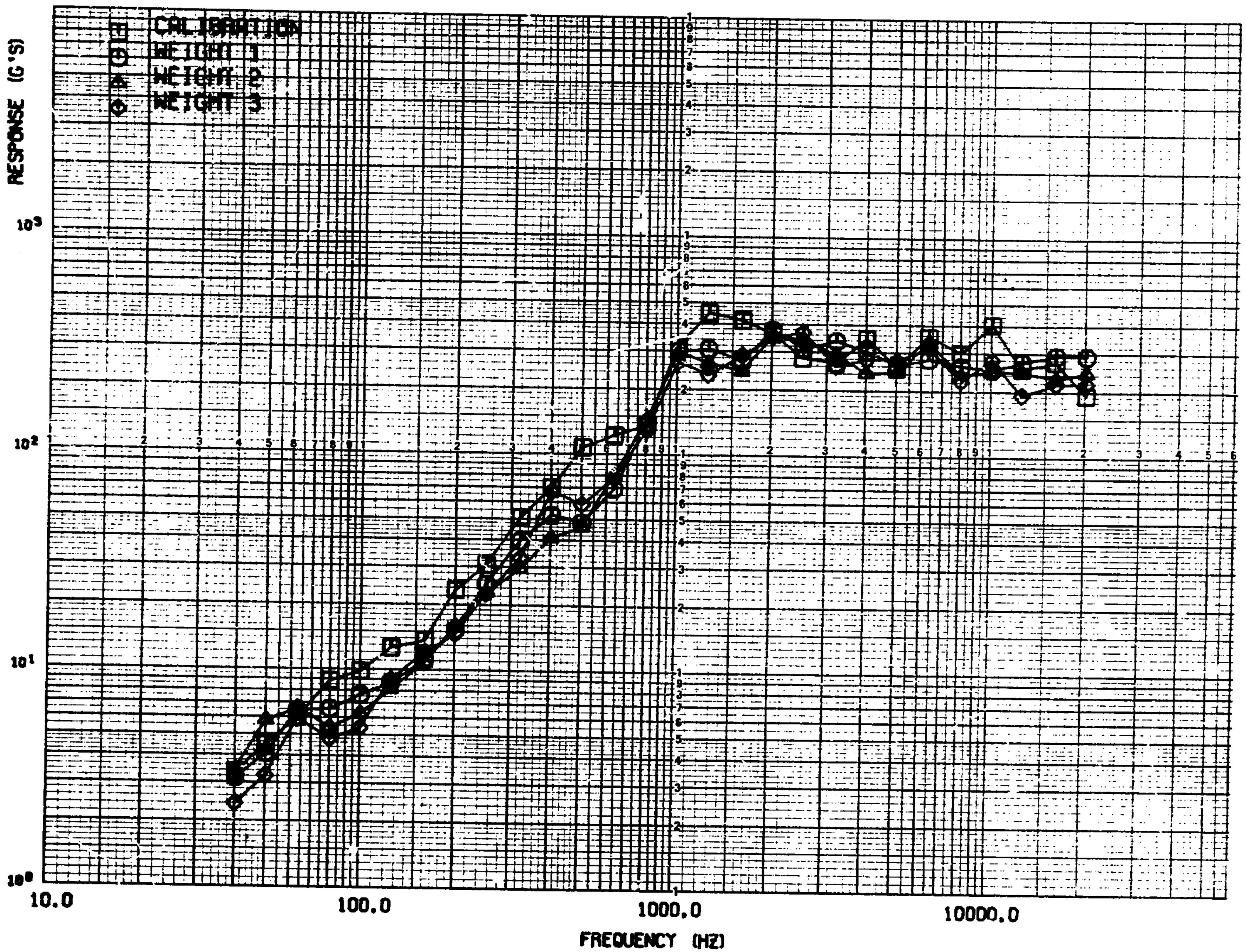


FIGURE 33A. COMPARISON OF SHOCK SPECTRA - ACCEL 09. PHASE II DISTRIBUTED MASS

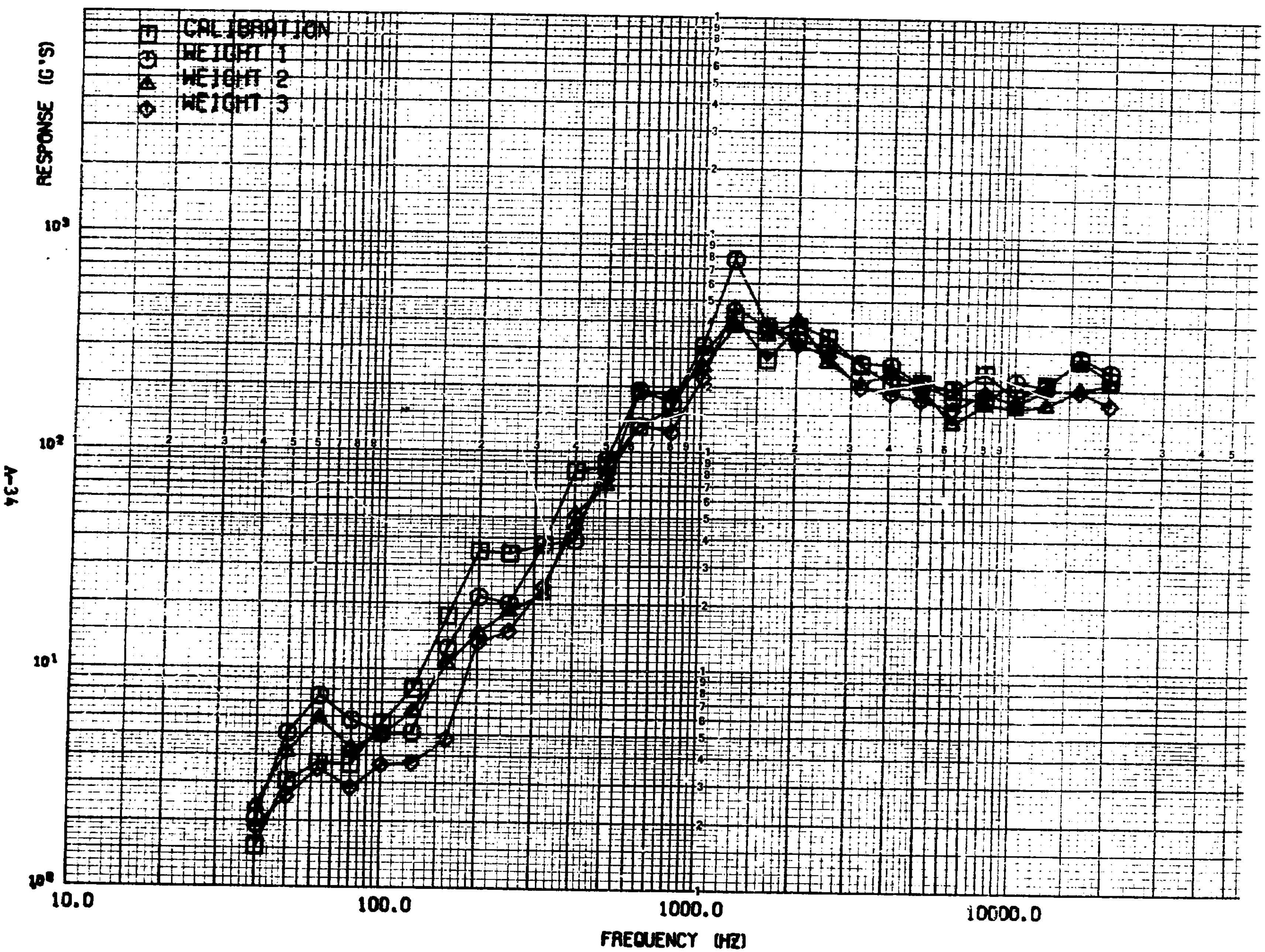


FIGURE 34A. COMPARISON OF SHOCK SPECTRA - ACCEL 10. PHASE II DISTRIBUTED MASS

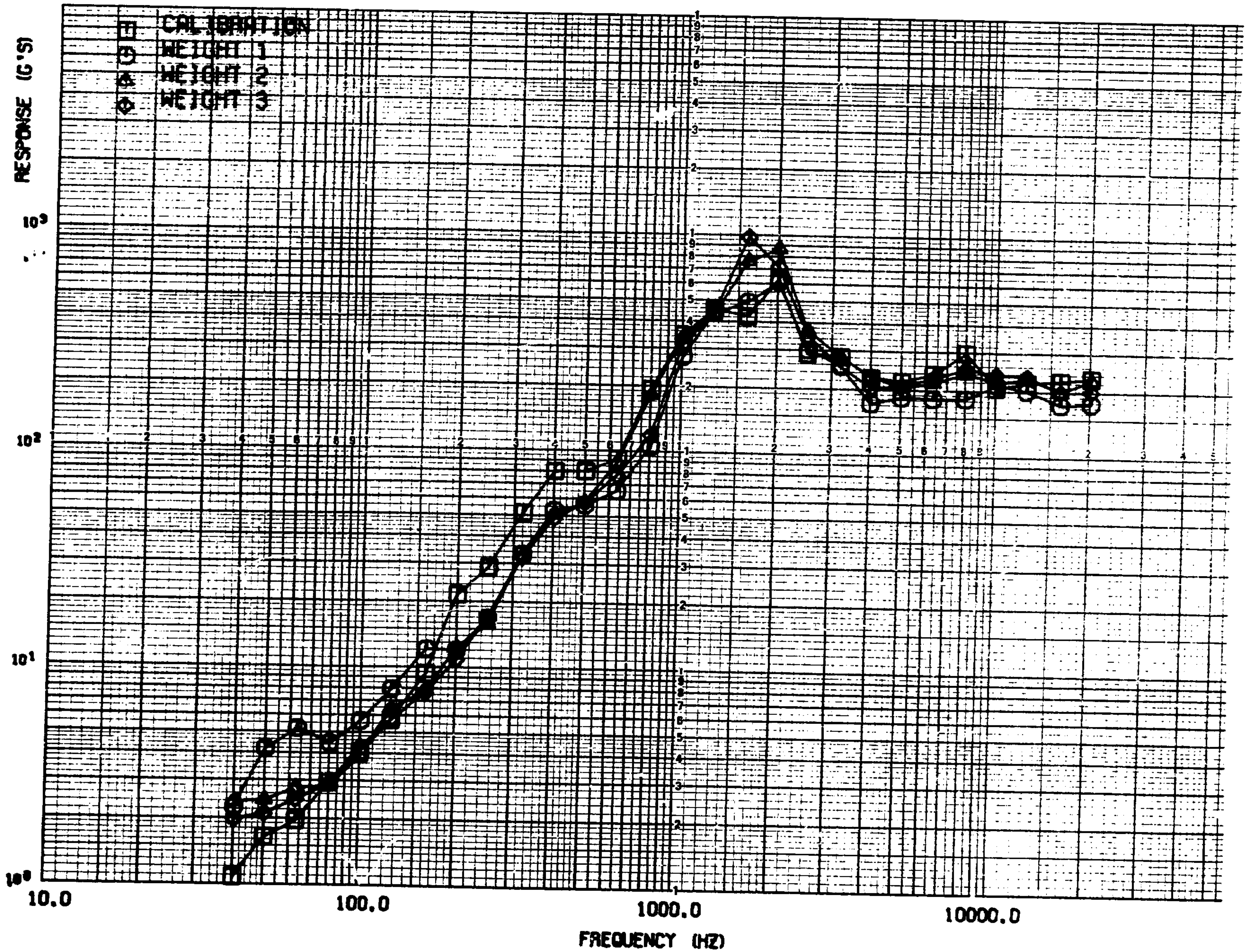


FIGURE 35A. COMPARISON OF SHOCK SPECTRA - ACCEL 11. PHASE II DISTRIBUTED MASS

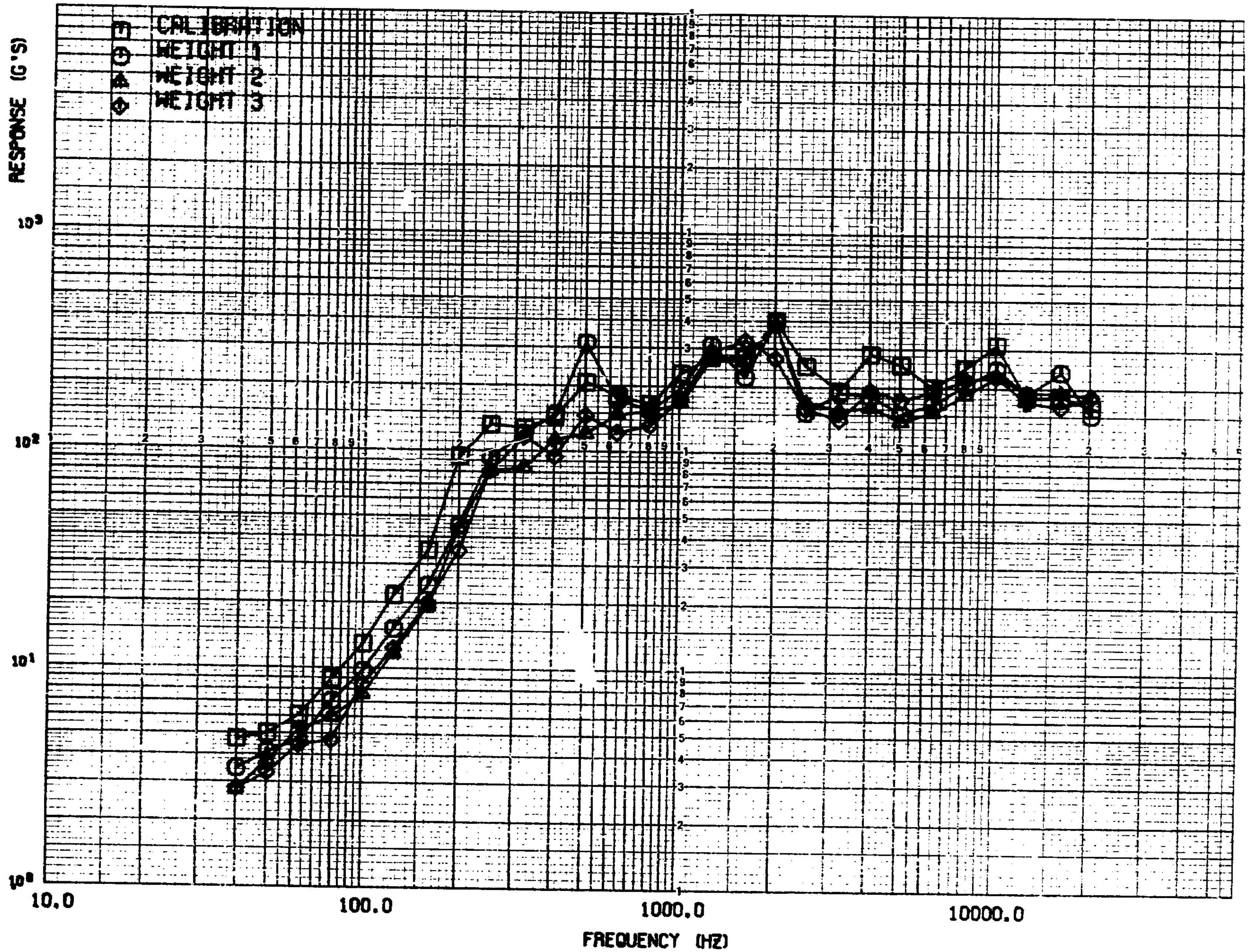


FIGURE 36A. COMPARISON OF SHOCK SPECTRA - ACCEL 12. PHASE II DISTRIBUTED MASS

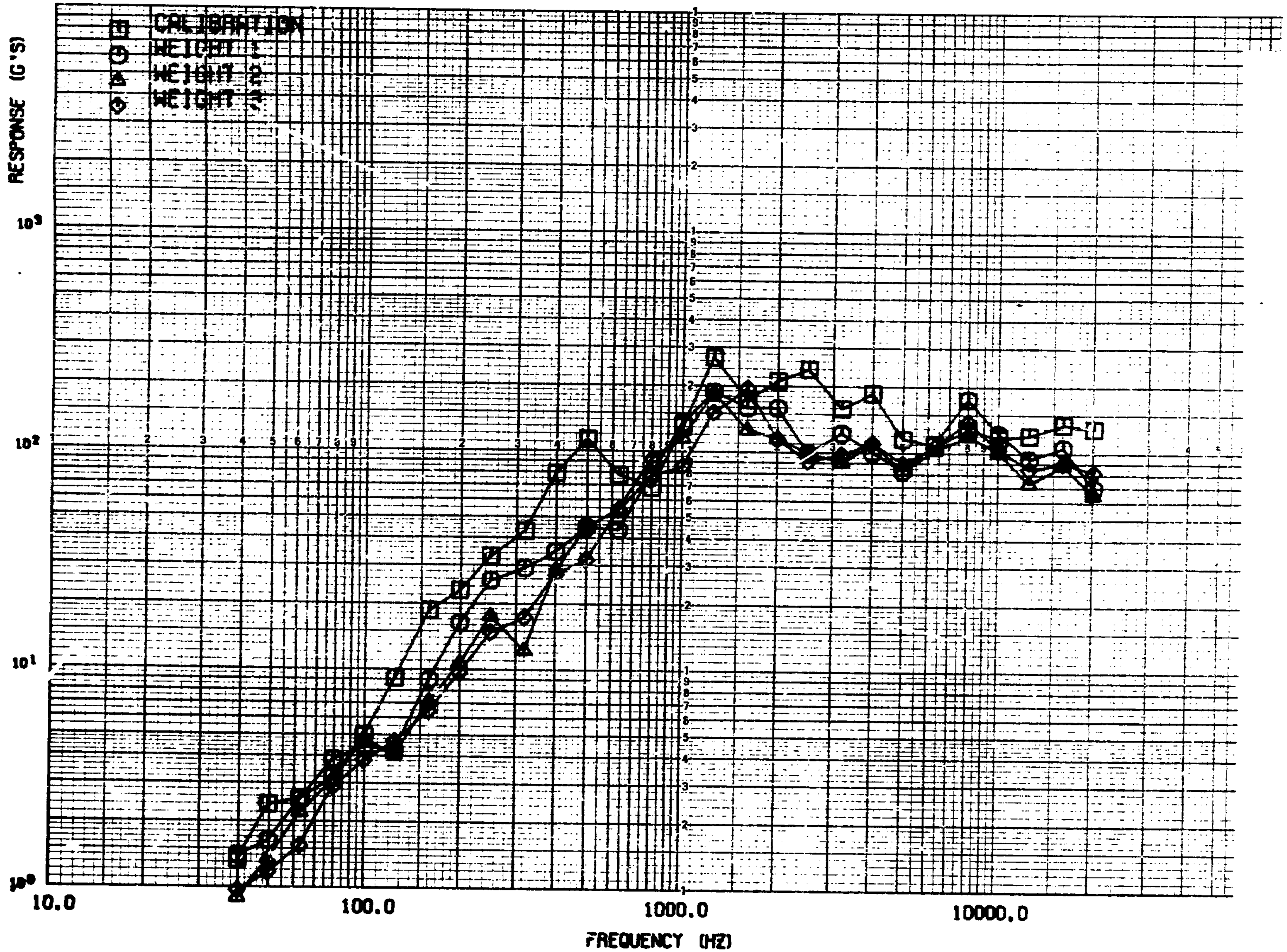


FIGURE 37A. COMPARISON OF SHOCK SPECTRA - ACCEL 13. PHASE II DISTRIBUTED MASS

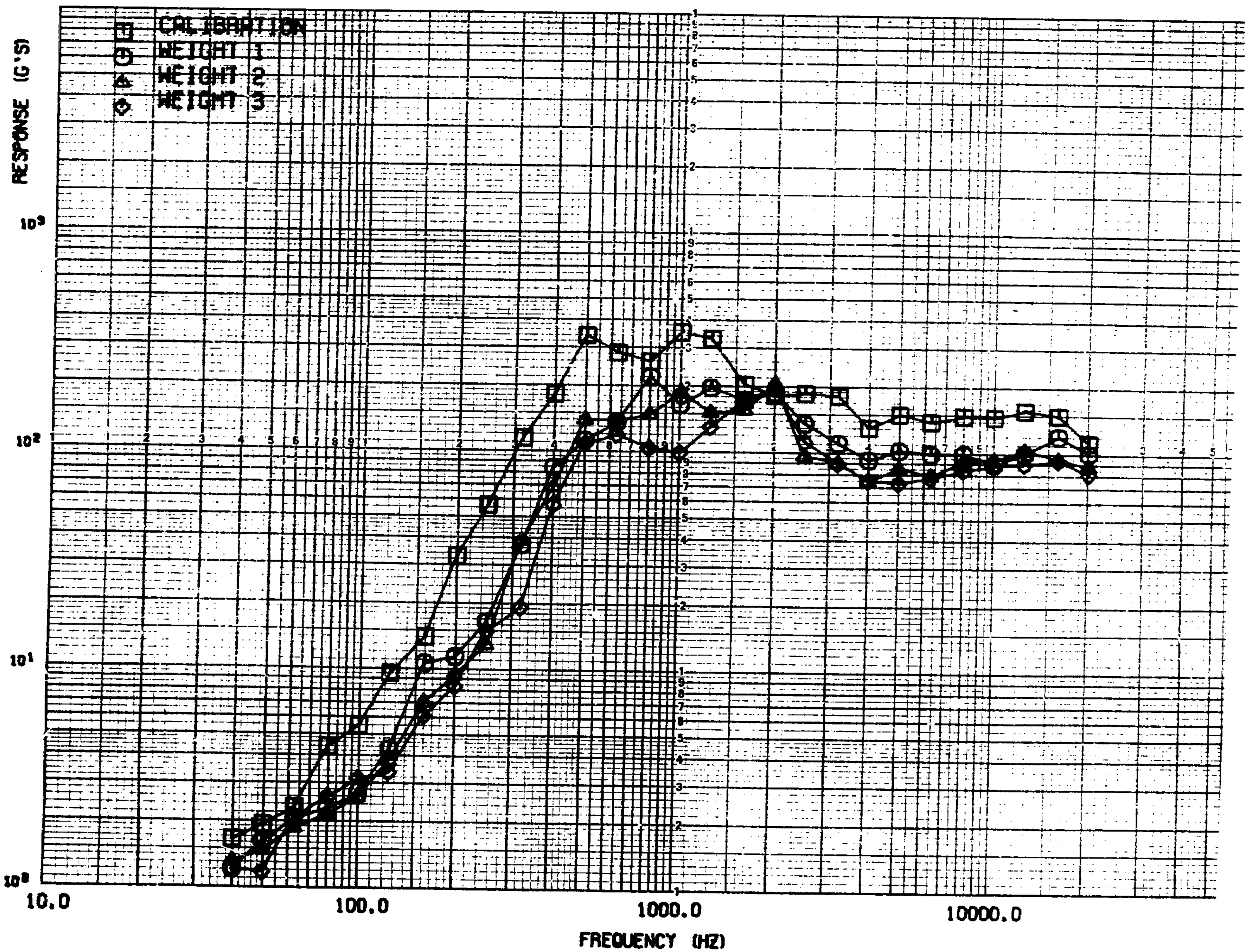


FIGURE 38A. COMPARISON OF SHOCK SPECTRA - ACCEL 14. PHASE II DISTRIBUTED MASS

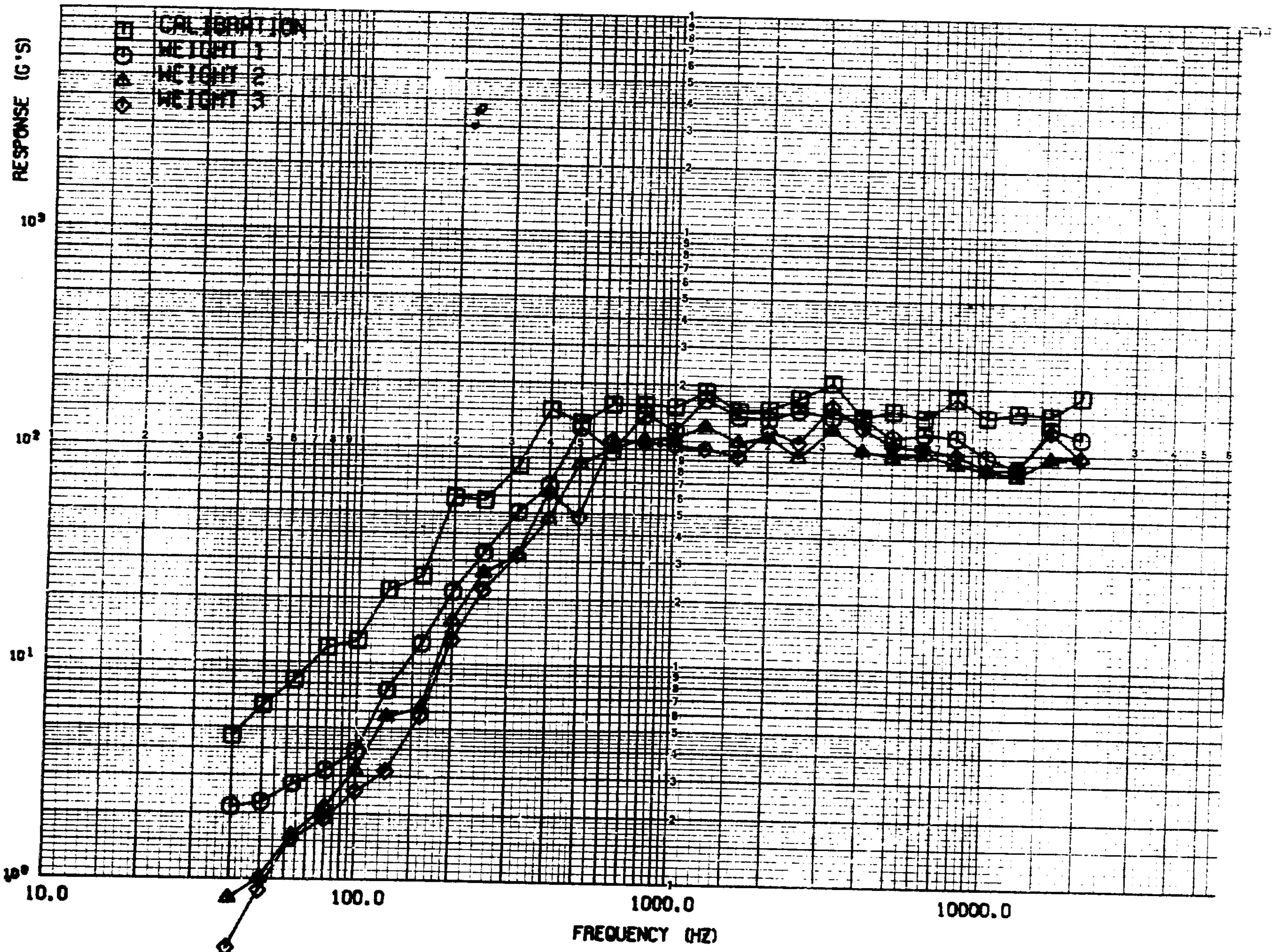


FIGURE 39A. COMPARISON OF SHOCK SPECTRA - ACCEL 15. PHASE II DISTRIBUTED MASS

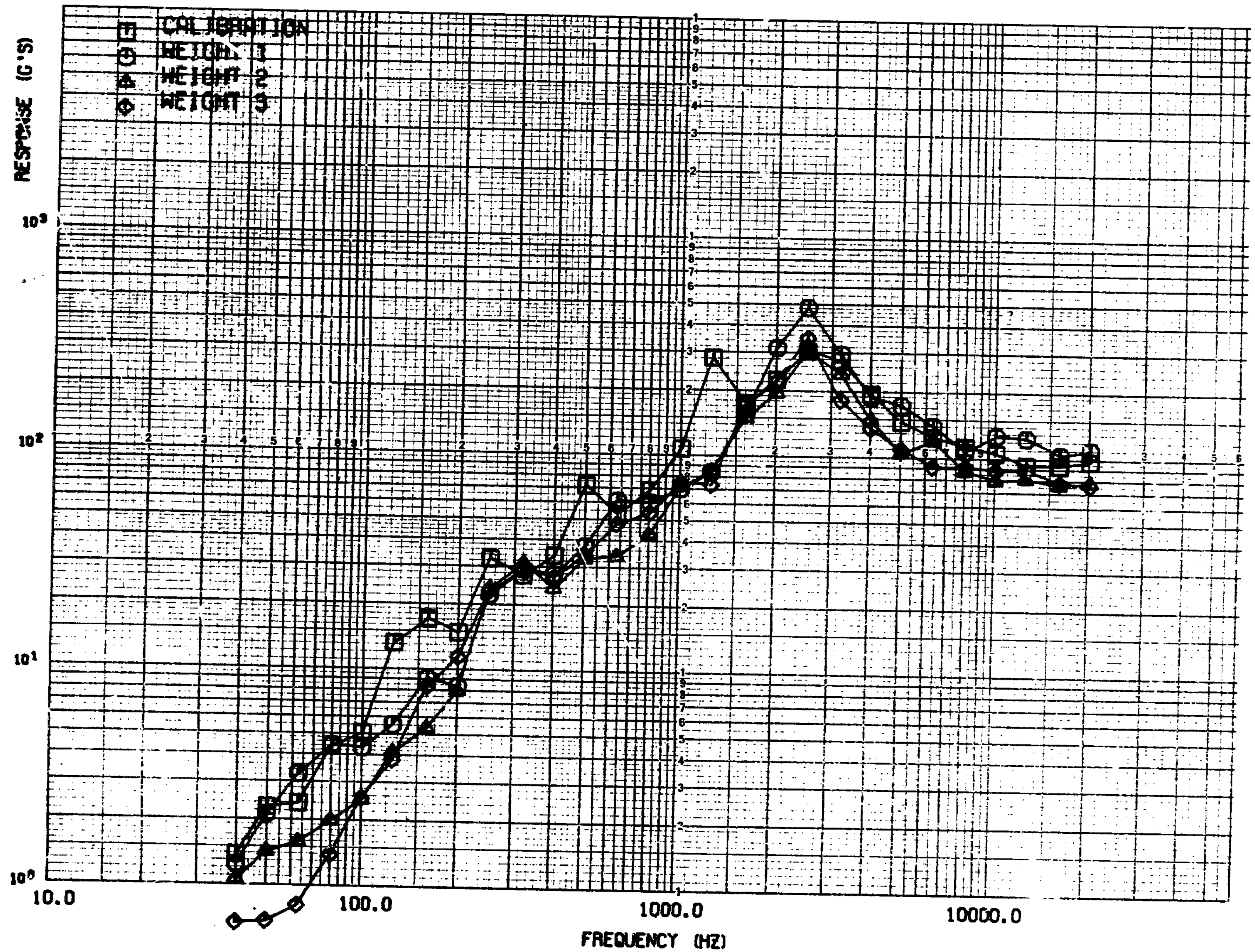


FIGURE 40A. COMPARISON OF SHOCK SPECTRA - ACCEL 16. PHASE II DISTRIBUTED MASS

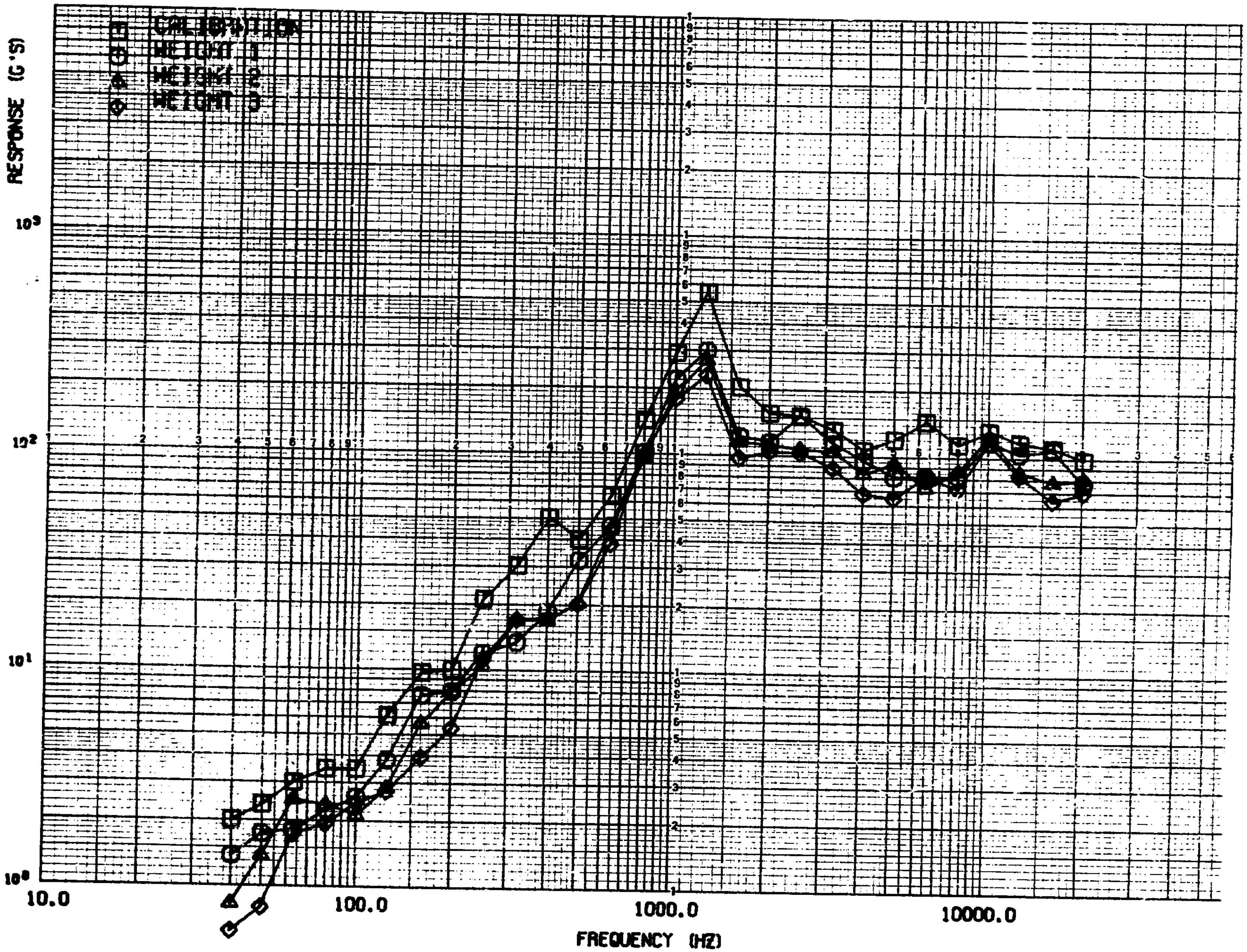


FIGURE 41 A. COMPARISON OF SHOCK SPECTRA - ACCEL 17. PHASE II DISTRIBUTED MASS

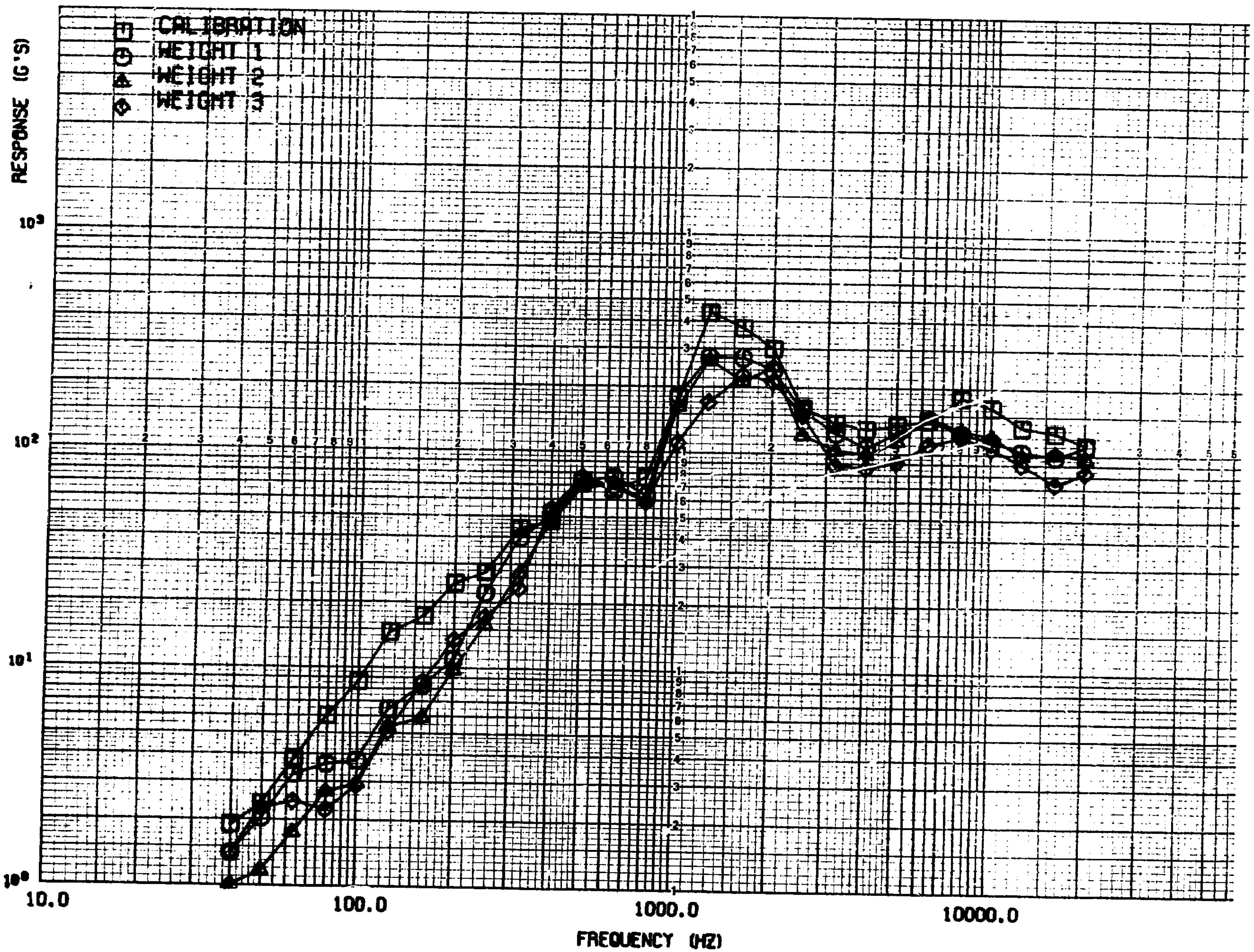


FIGURE 42A. COMPARISON OF SHOCK SPECTRA - ACCEL 18. PHASE II DISTRIBUTED MASS

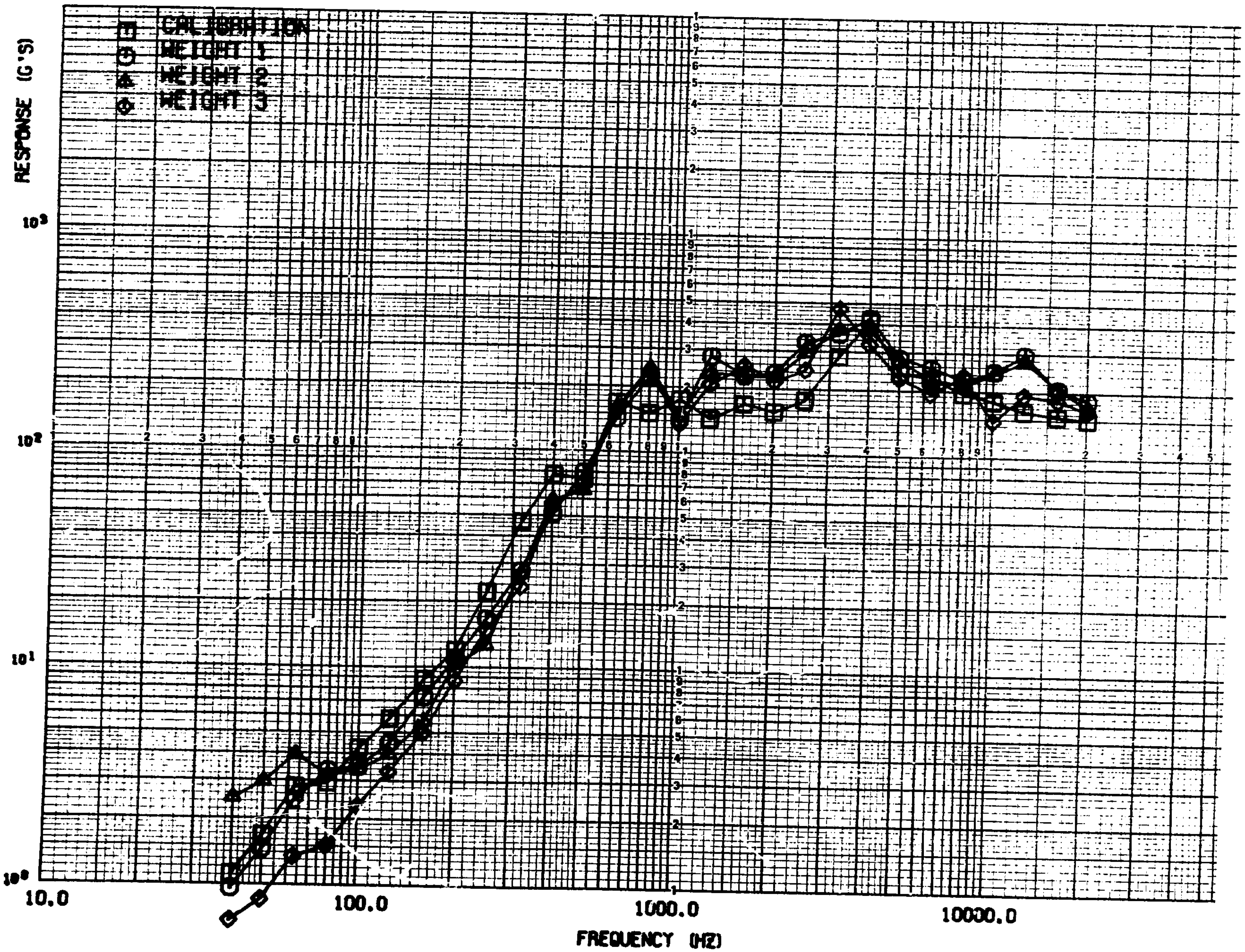


FIGURE 43A. COMPARISON OF SHOCK SPECTRA - ACCEL 19. PHASE II DISTRIBUTED MASS

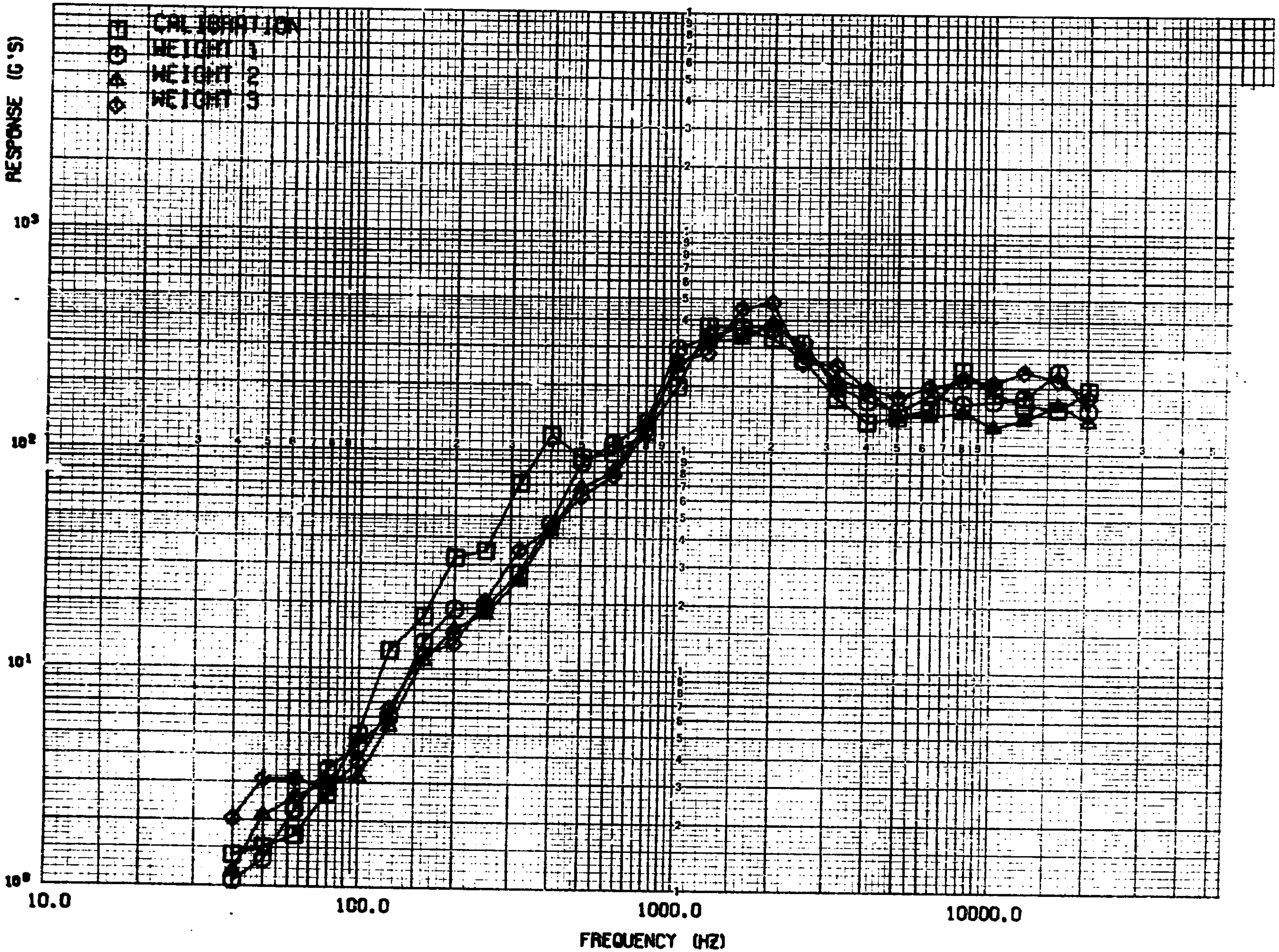


FIGURE 44A. COMPARISON OF SHOCK SPECTRA - ACCEL 20. PHASE II DISTRIBUTED MASS

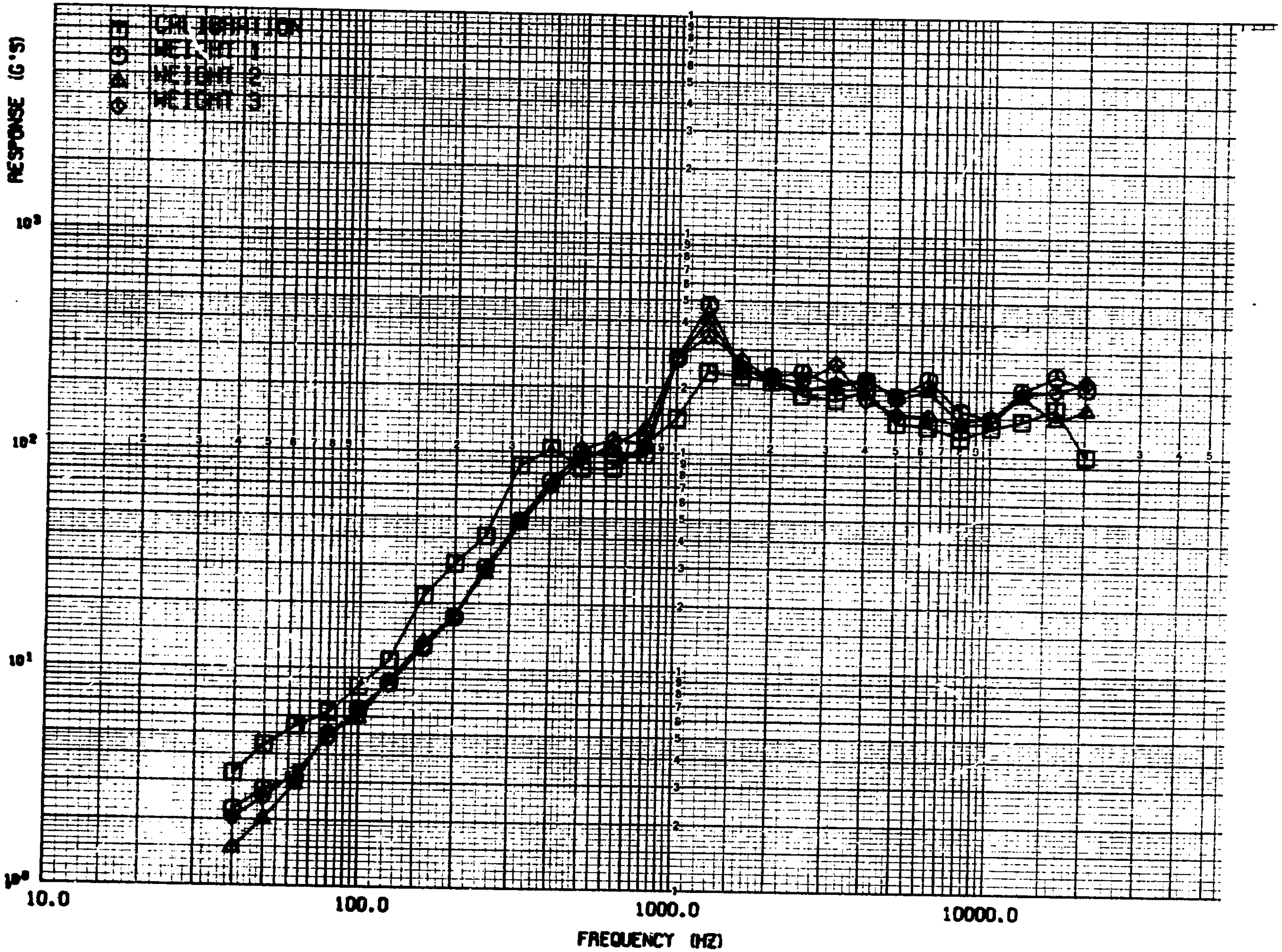


FIGURE 45A. COMPARISON OF SHOCK SPECTRA - ACCEL 21. PHASE II DISTRIBUTED MASS

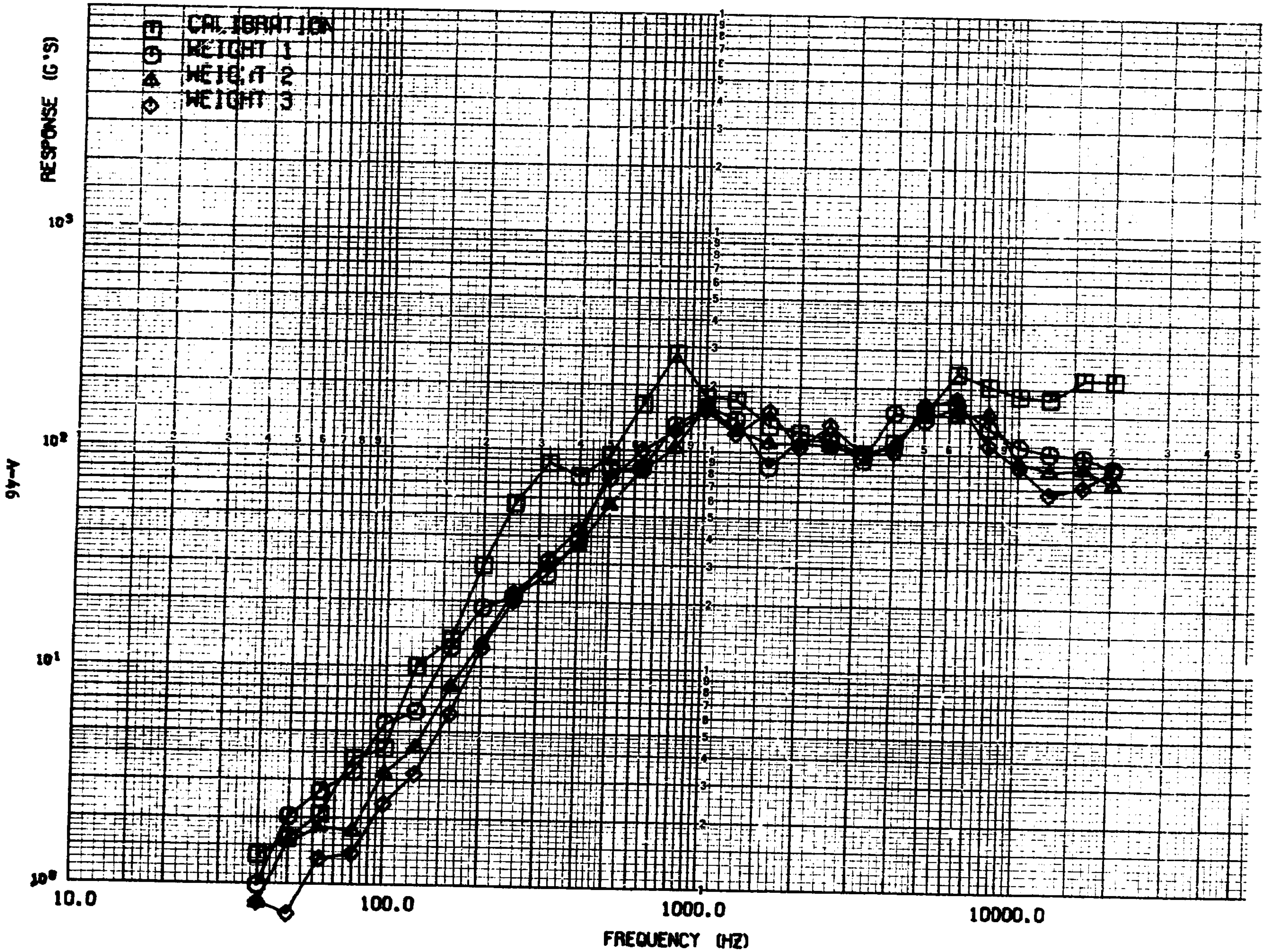


FIGURE 46A. COMPARISON OF SHOCK SPECTRA - ACCEL 22. PHASE II DISTRIBUTED MASS

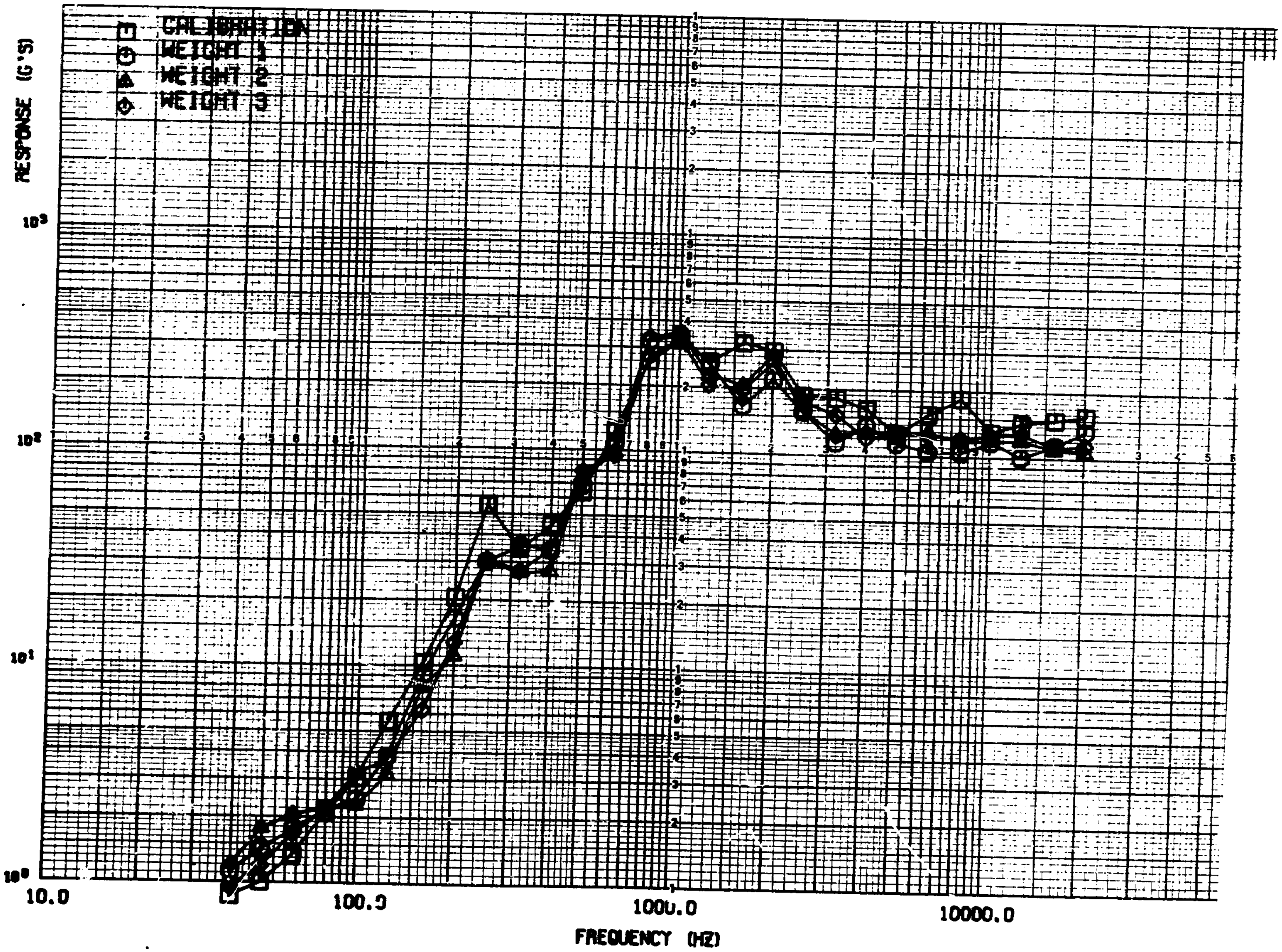


FIGURE 47A. COMPARISON OF SHOCK SPECTRA - ACCEL 23. PHASE II DISTRIBUTED MASS

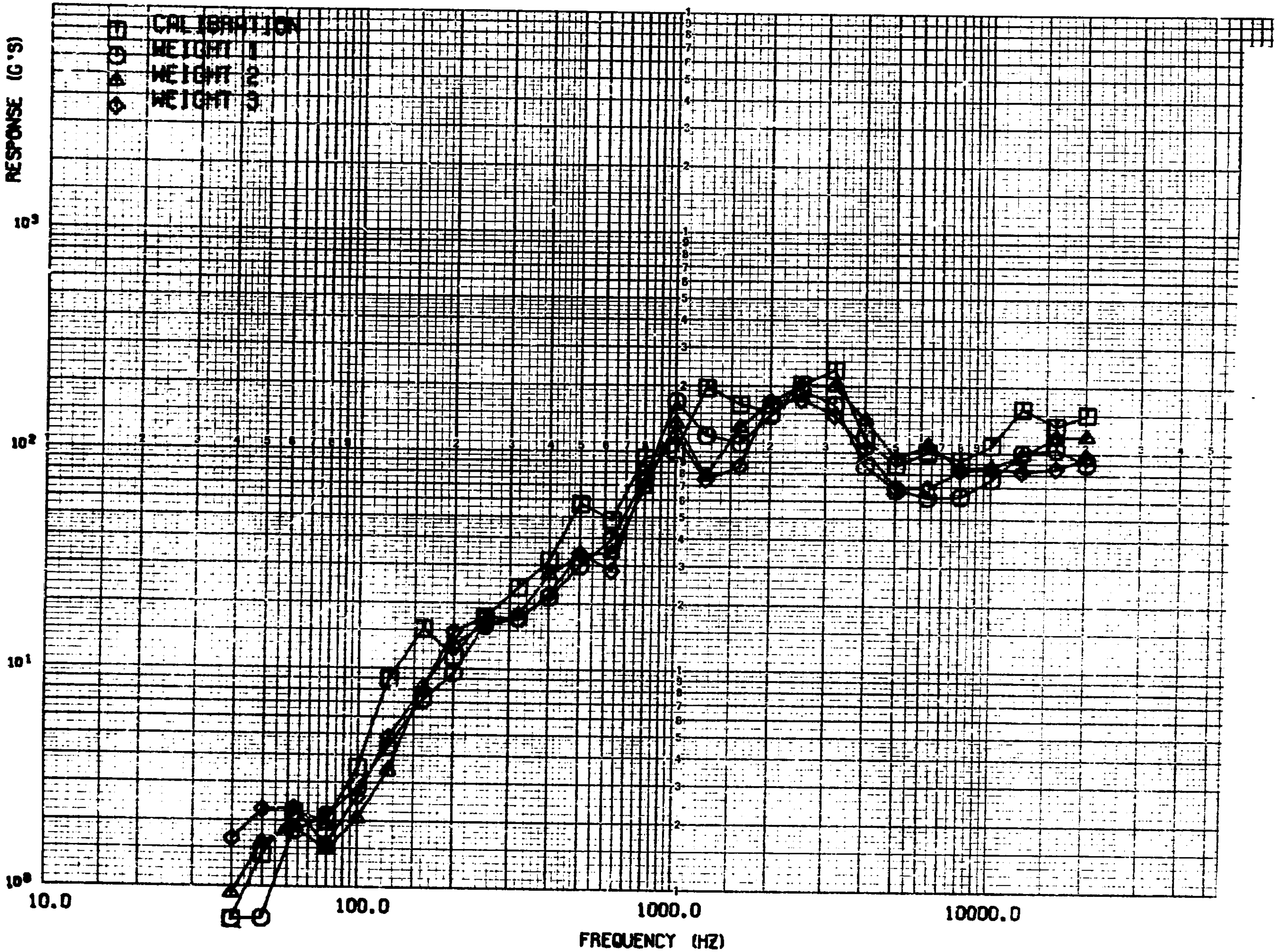


FIGURE 48A. COMPARISON OF SHOCK SPECTRA - ACCEL 24. PHASE II DISTRIBUTED MASS

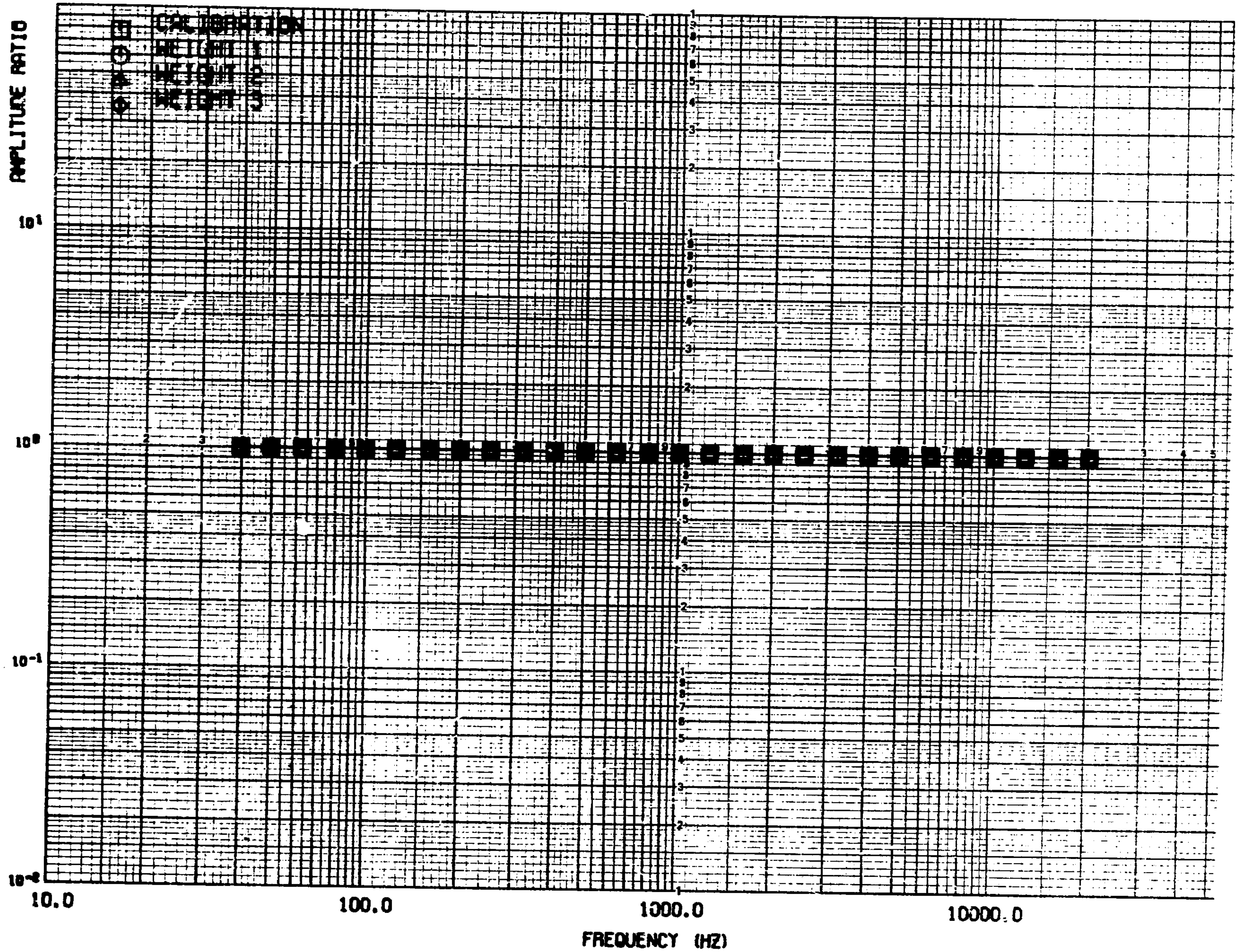


FIGURE 49A. NORMALIZED SHOCK SPECTRA - ACCEL 01. PHASE I SINGLE MASS LOADING

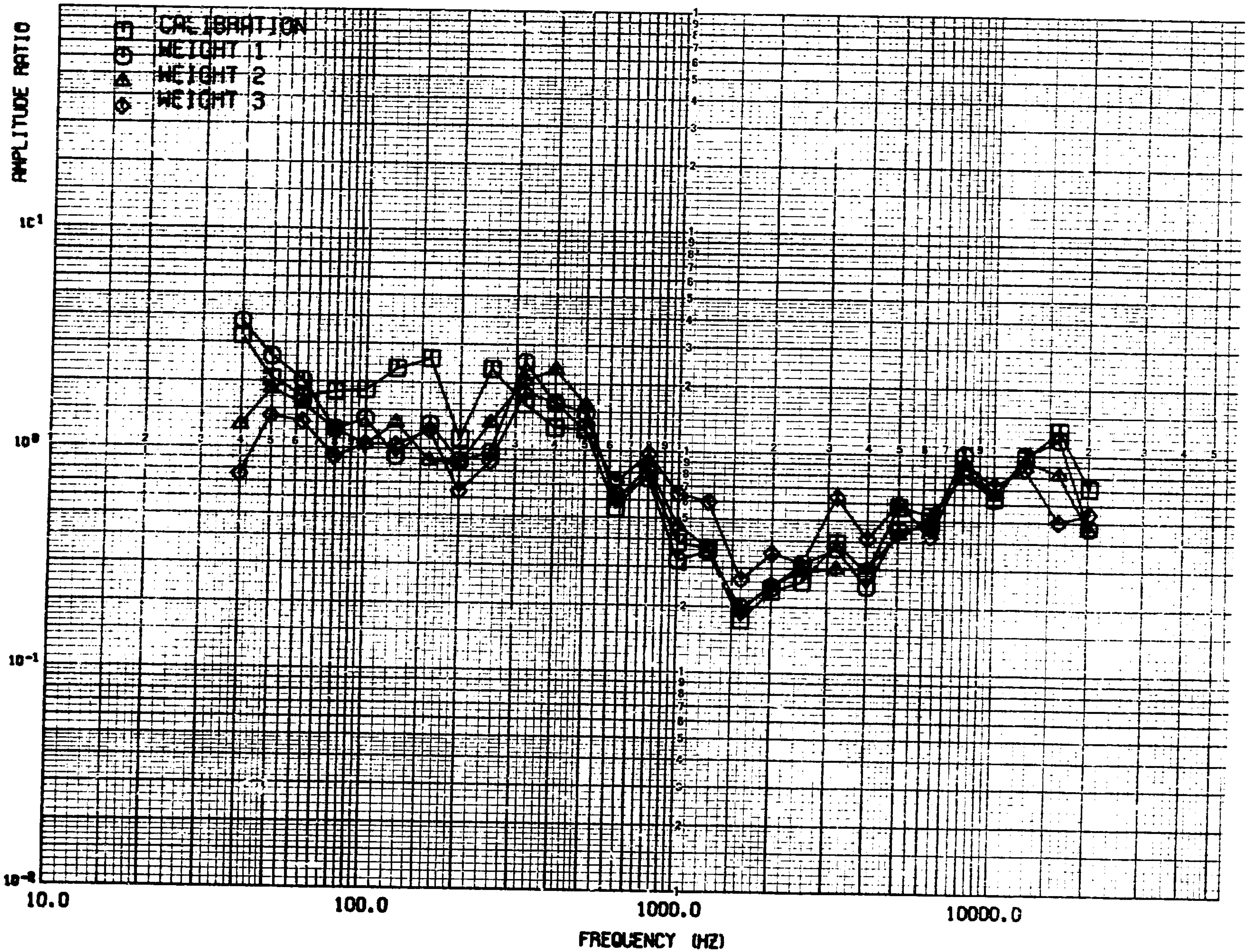


FIGURE 50A. NORMALIZED SHOCK SPECTRA - ACCEL 02. PHASE I SINGLE MASS LOADING

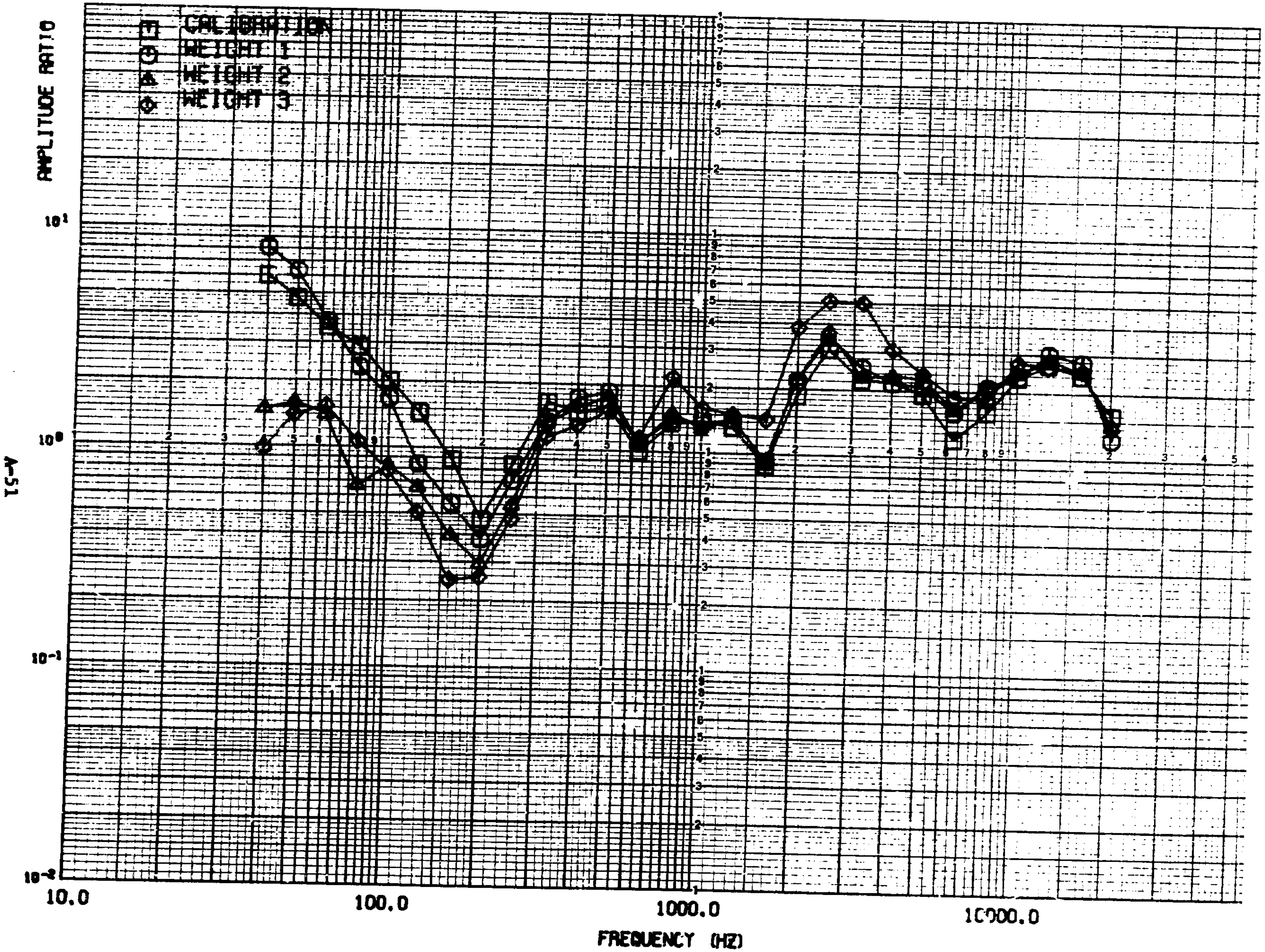


FIGURE 51A. NORMALIZED SHOCK SPECTRA - ACCEL 03. PHASE I SINGLE MASS LOADING

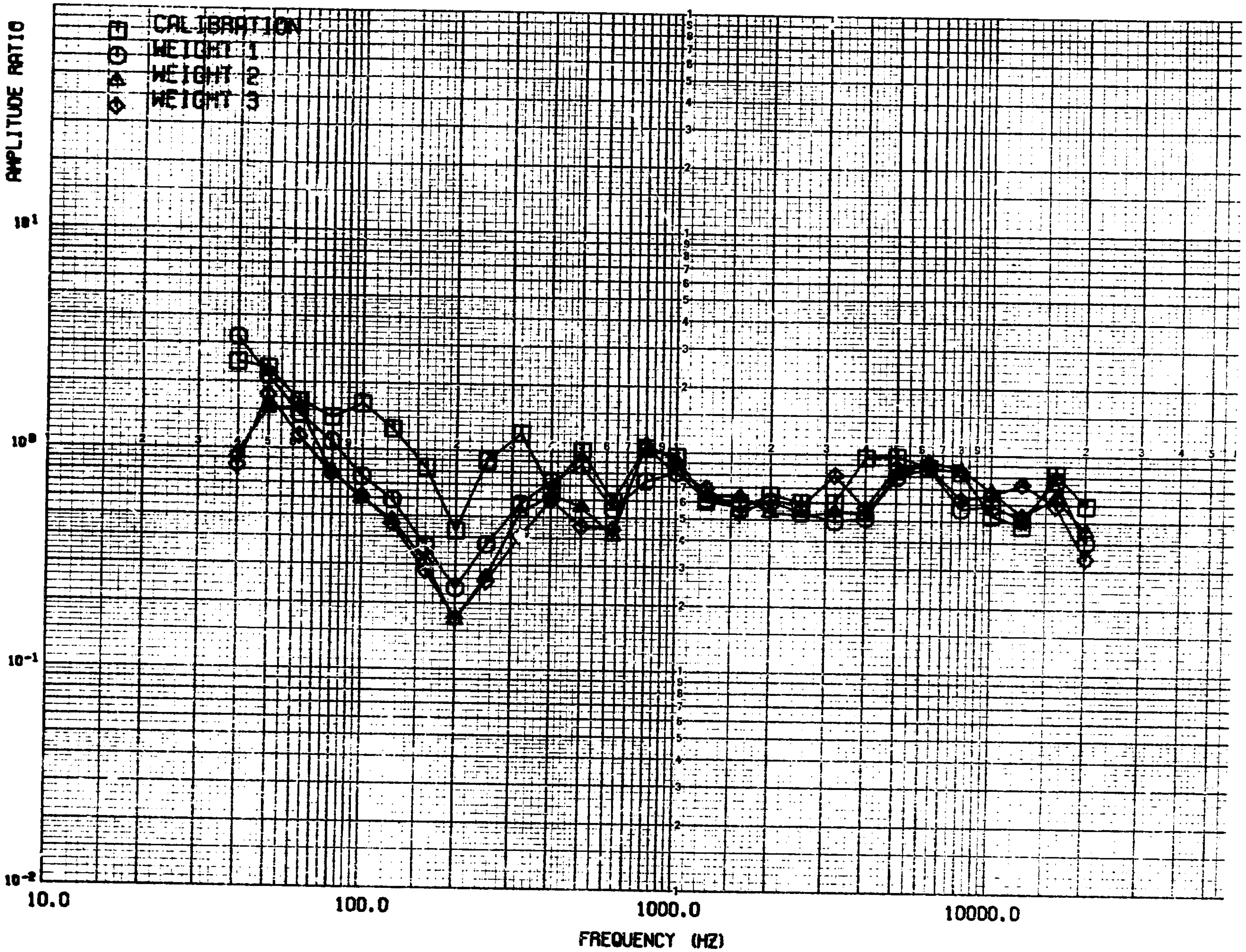


FIGURE 52A. NORMALIZED SHOCK SPECTRA - ACCEL 04. PHASE I SINGLE MASS LOADING

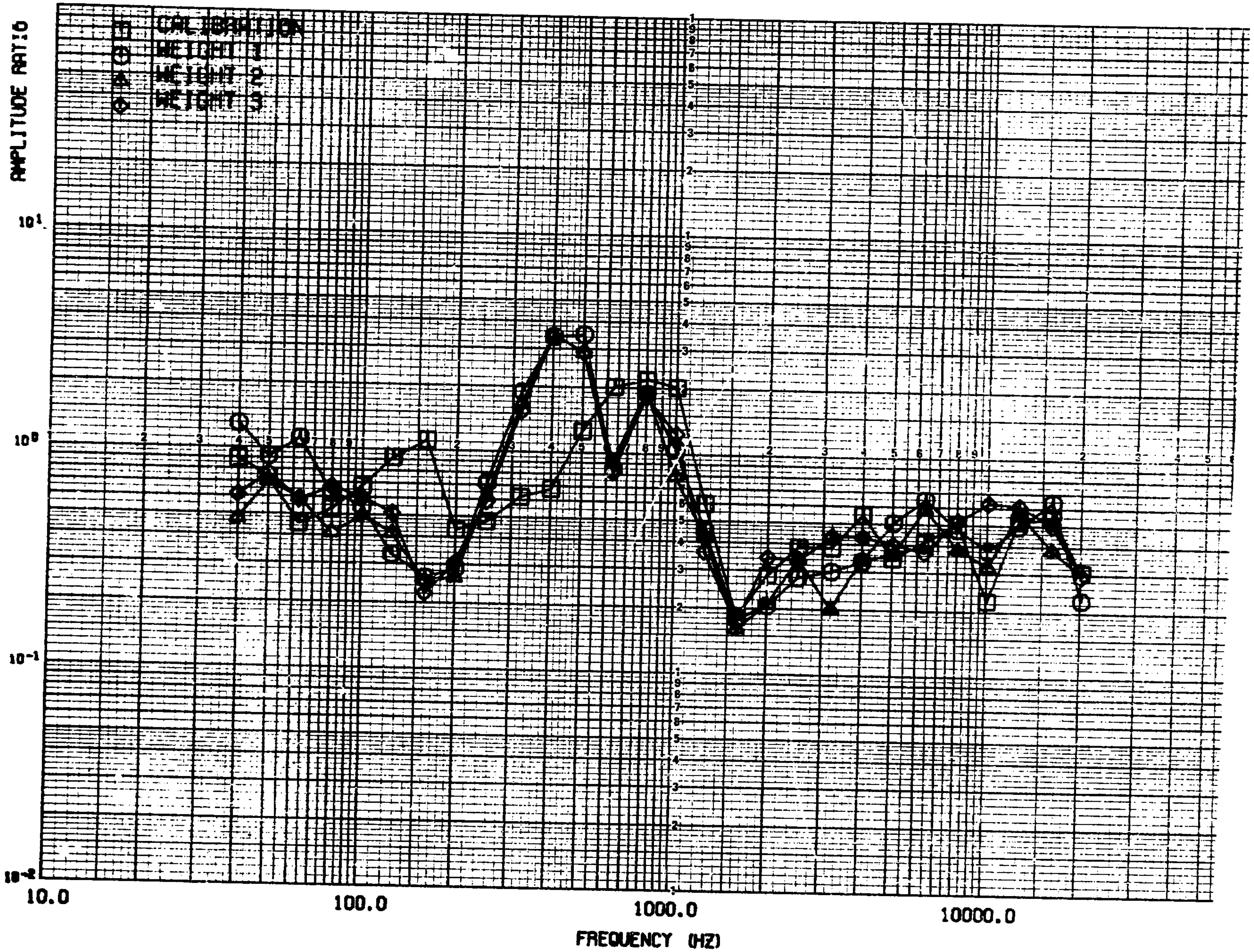


FIGURE 53A. NORMALIZED SHOCK SPECTRA - ACCEL 05. PHASE I SINGLE MASS LOADING

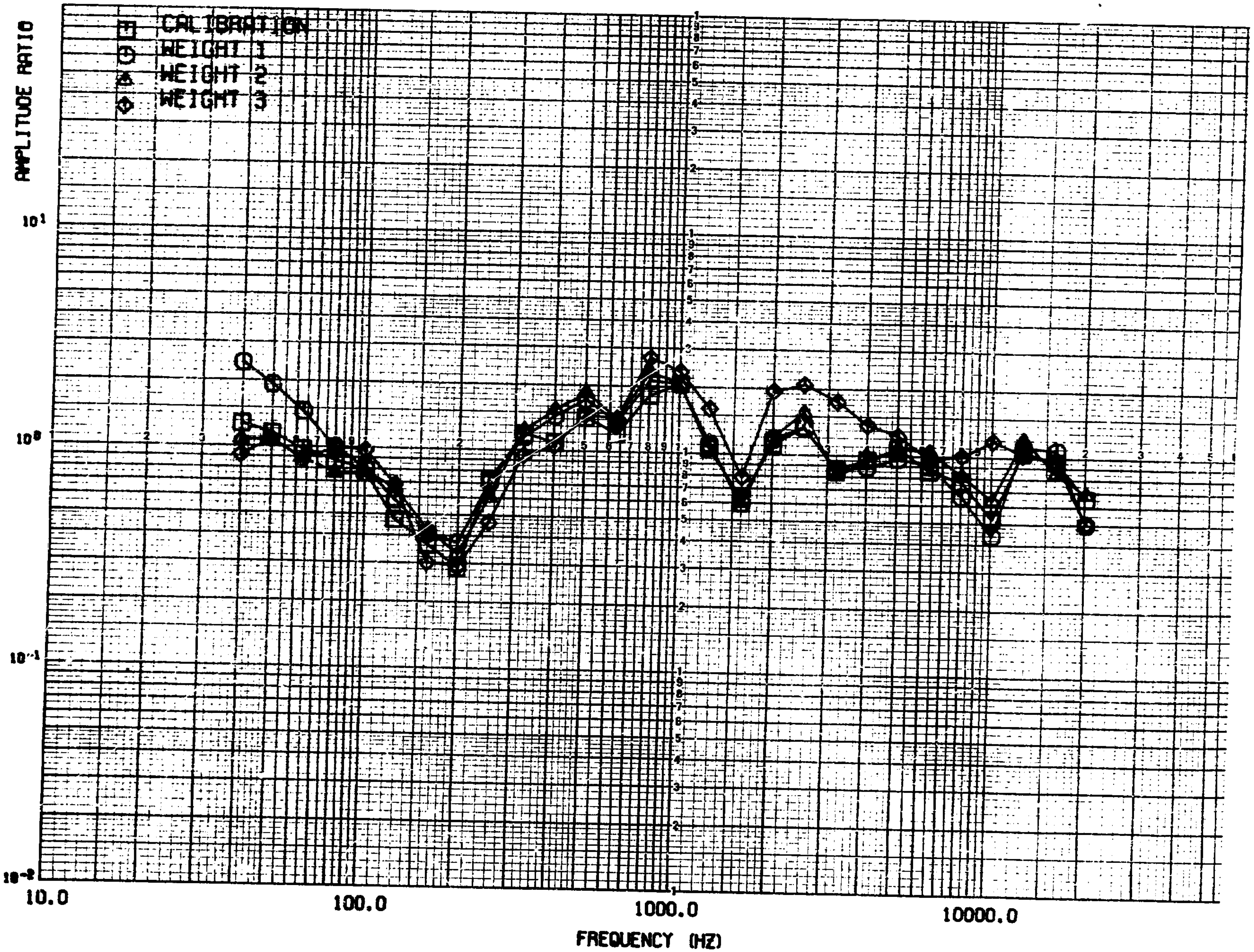


FIGURE 54 A. NORMALIZED SHOCK SPECTRA - ACCEL 06. PHASE I SINGLE MASS LOADING

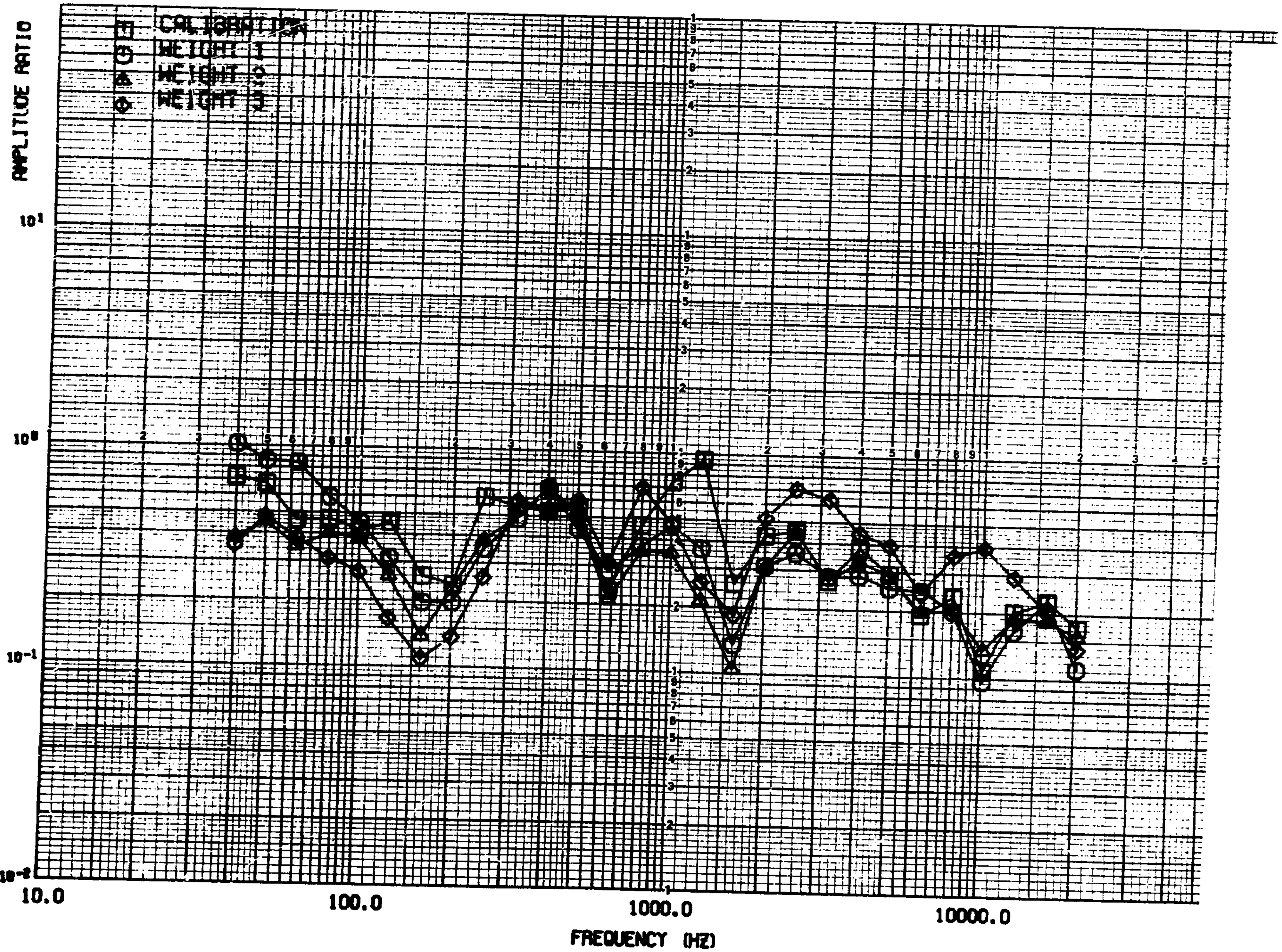


FIGURE 55A. NORMALIZED SHOCK SPECTRA - ACCEL 07. PHASE I SINGLE MASS LOADING

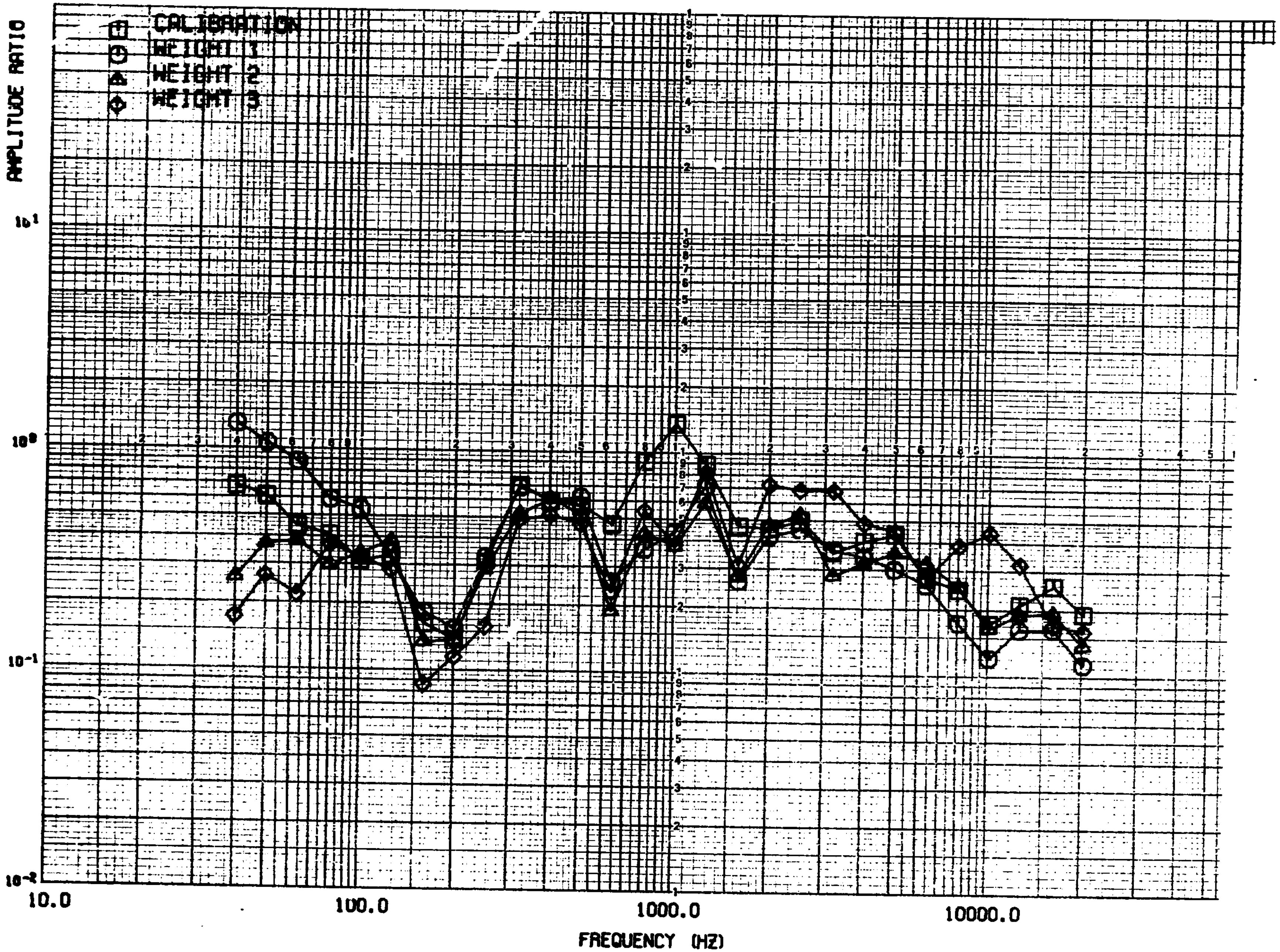


FIGURE 56A. NORMALIZED SHOCK SPECTRA - ACCEL 08. PHASE I SINGLE MASS LOADING

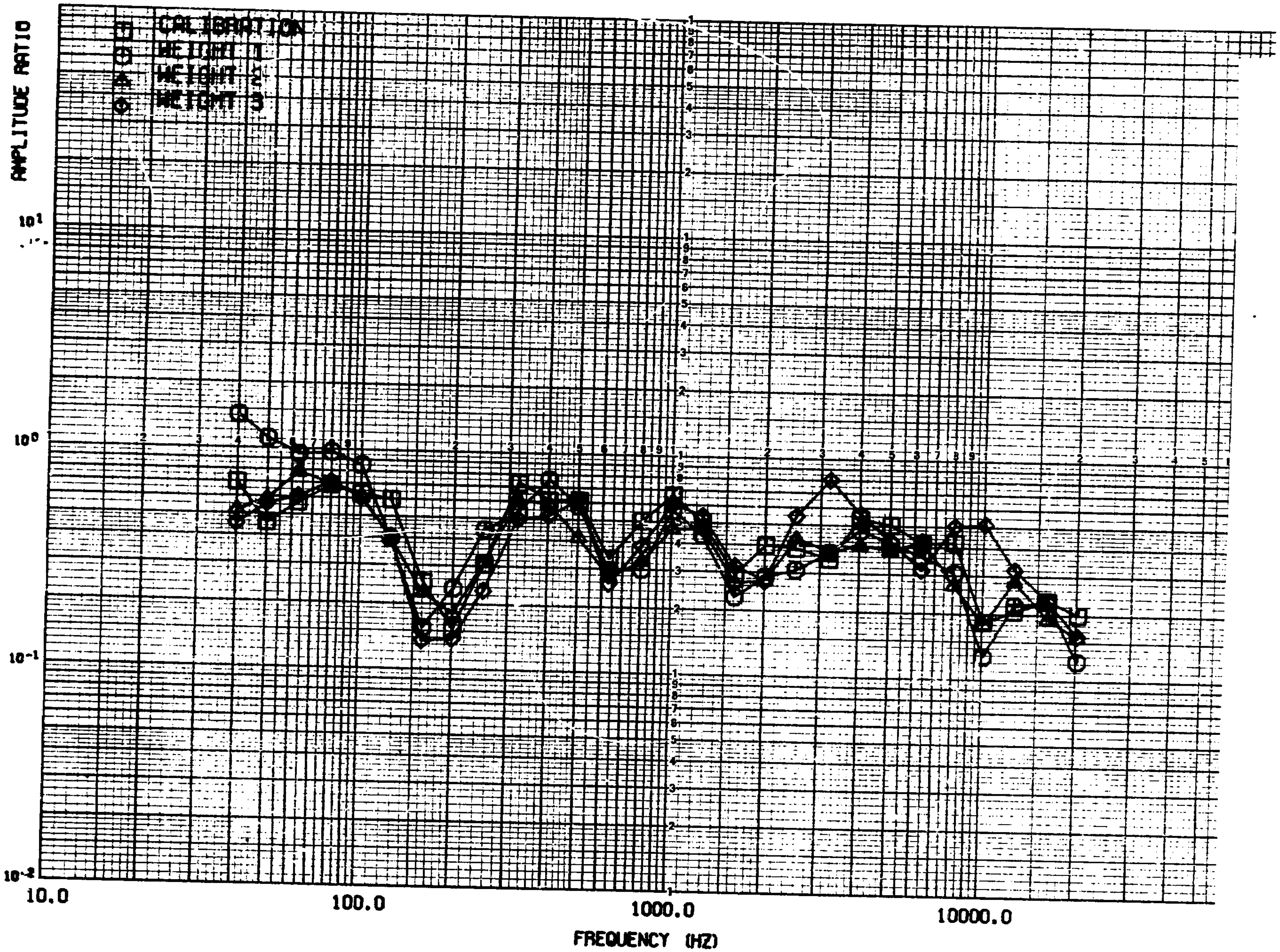


FIGURE 57A. NORMALIZED SHOCK SPECTRA - ACCEL 09. PHASE I SINGLE MASS LOADING

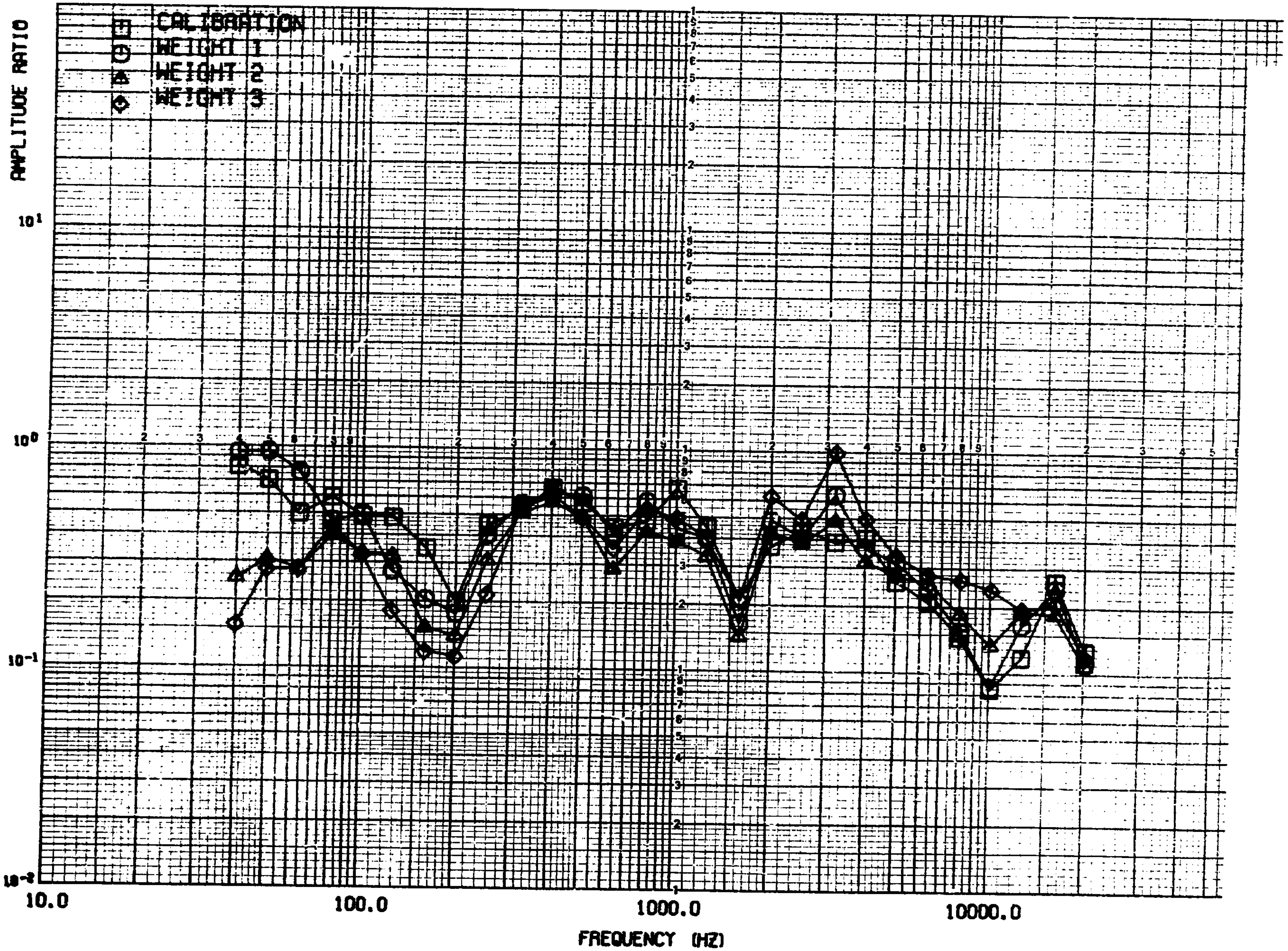


FIGURE 58A. NORMALIZED SHOCK SPECTRA - ACCEL 10. PHASE I SINGLE MASS LOADING

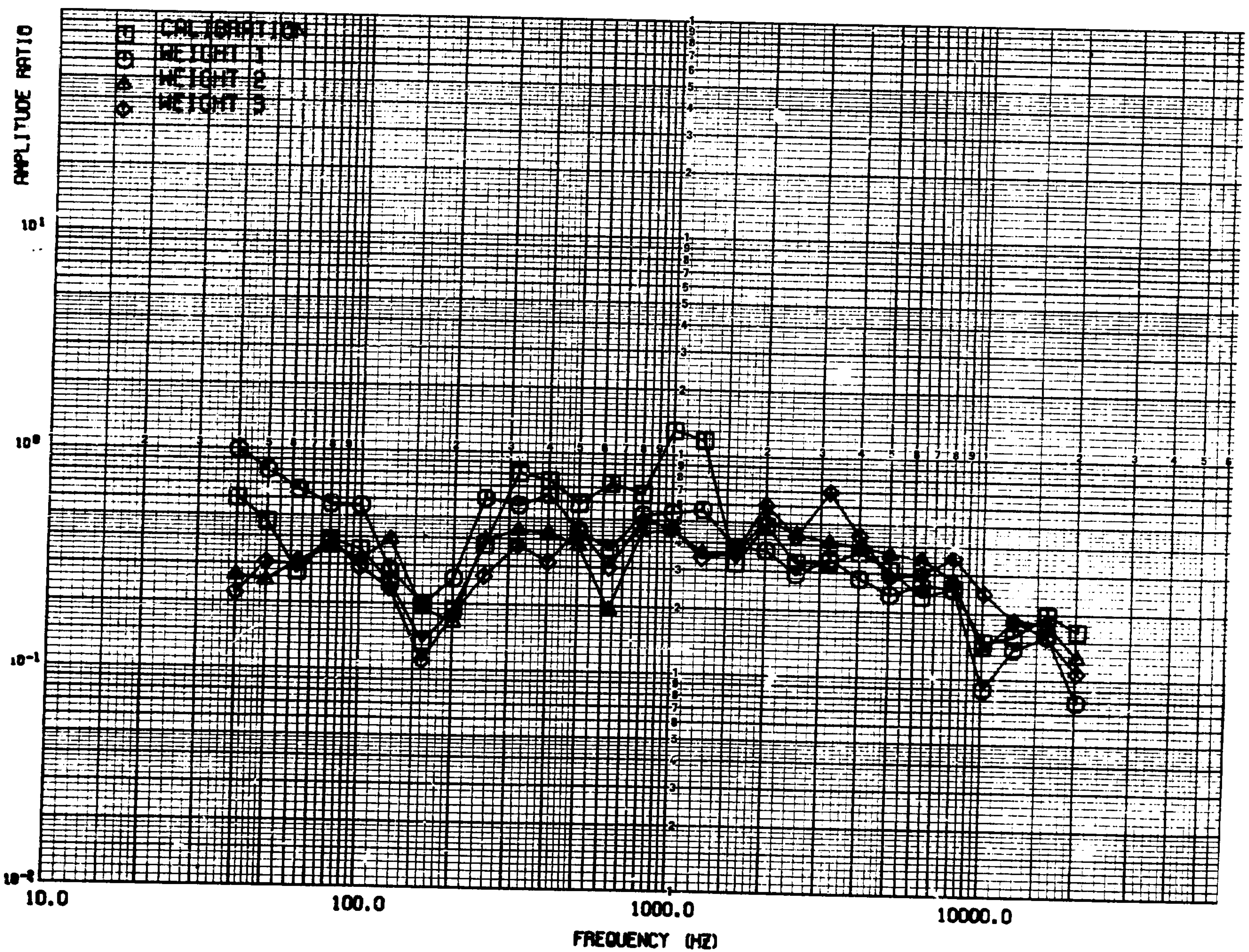


FIGURE 59A. NORMALIZED SHOCK SPECTRA - ACCEL 11. PHASE I SINGLE MASS LOADING

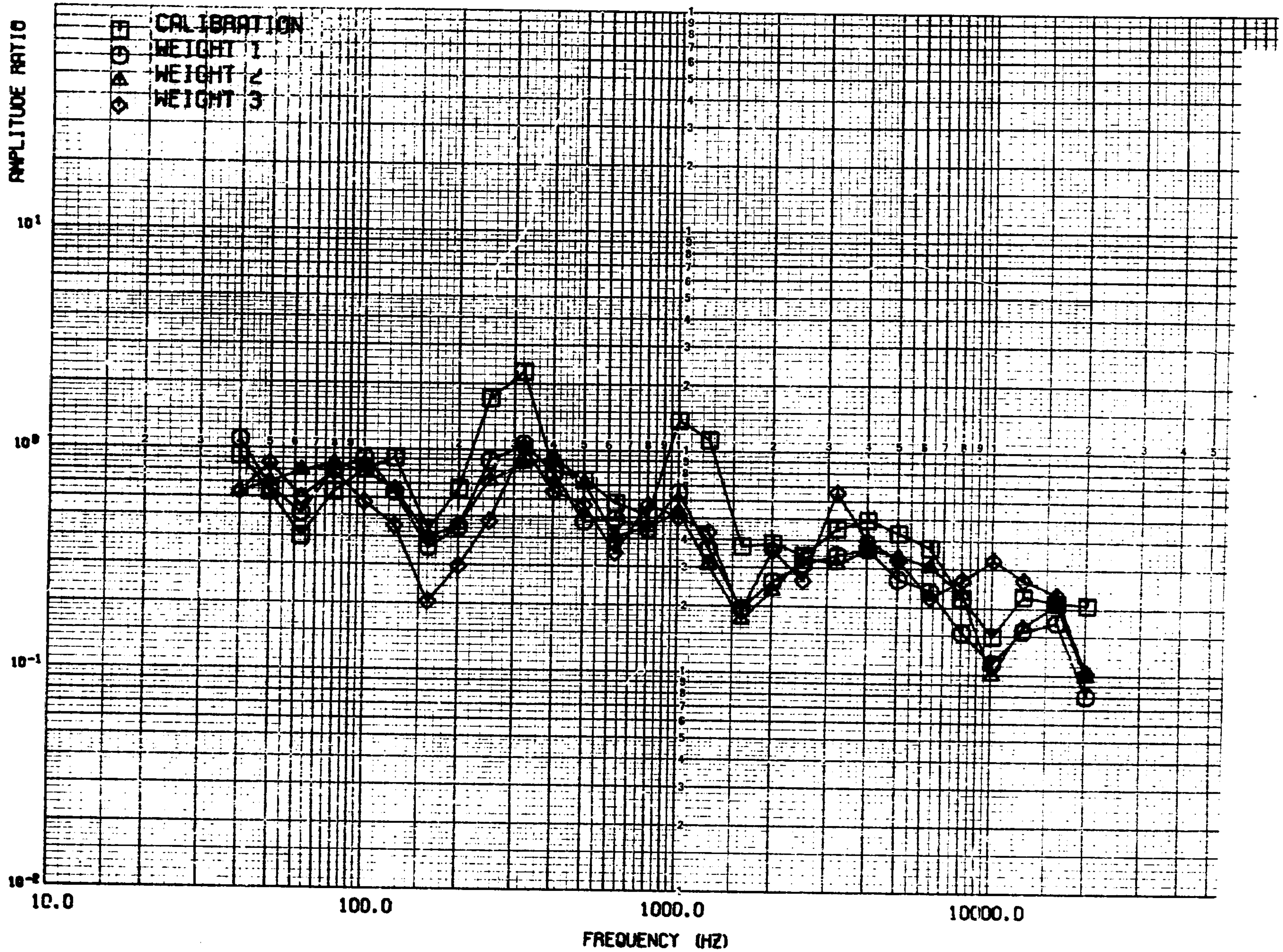


FIGURE 60A. NORMALIZED SHOCK SPECTRA - ACCEL 12. PHASE I SINGLE MASS LOADING

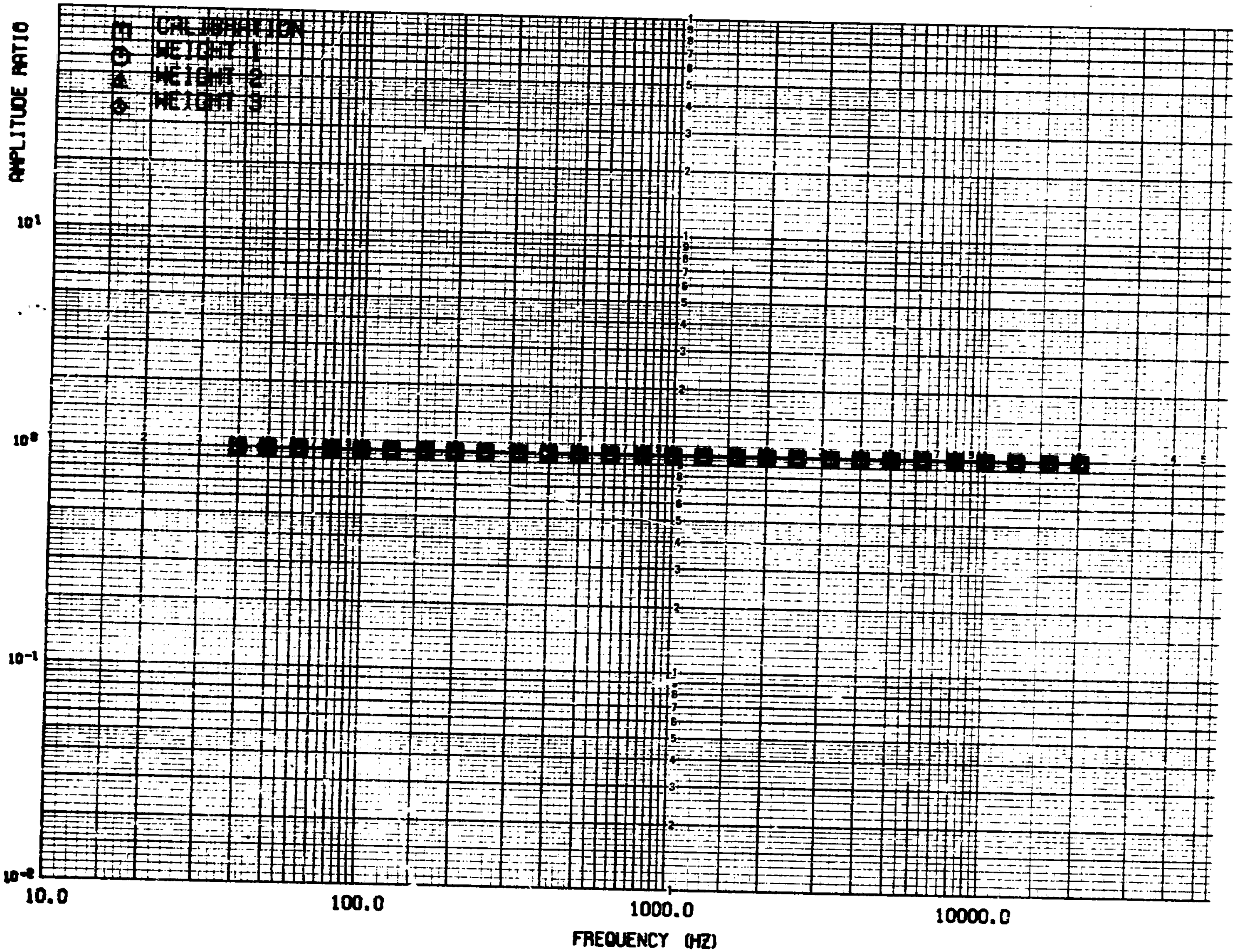


FIGURE 61A. NORMALIZED SHOCK SPECTRA - ACCEL 01. PHASE IA SINGLE MASS LOADING

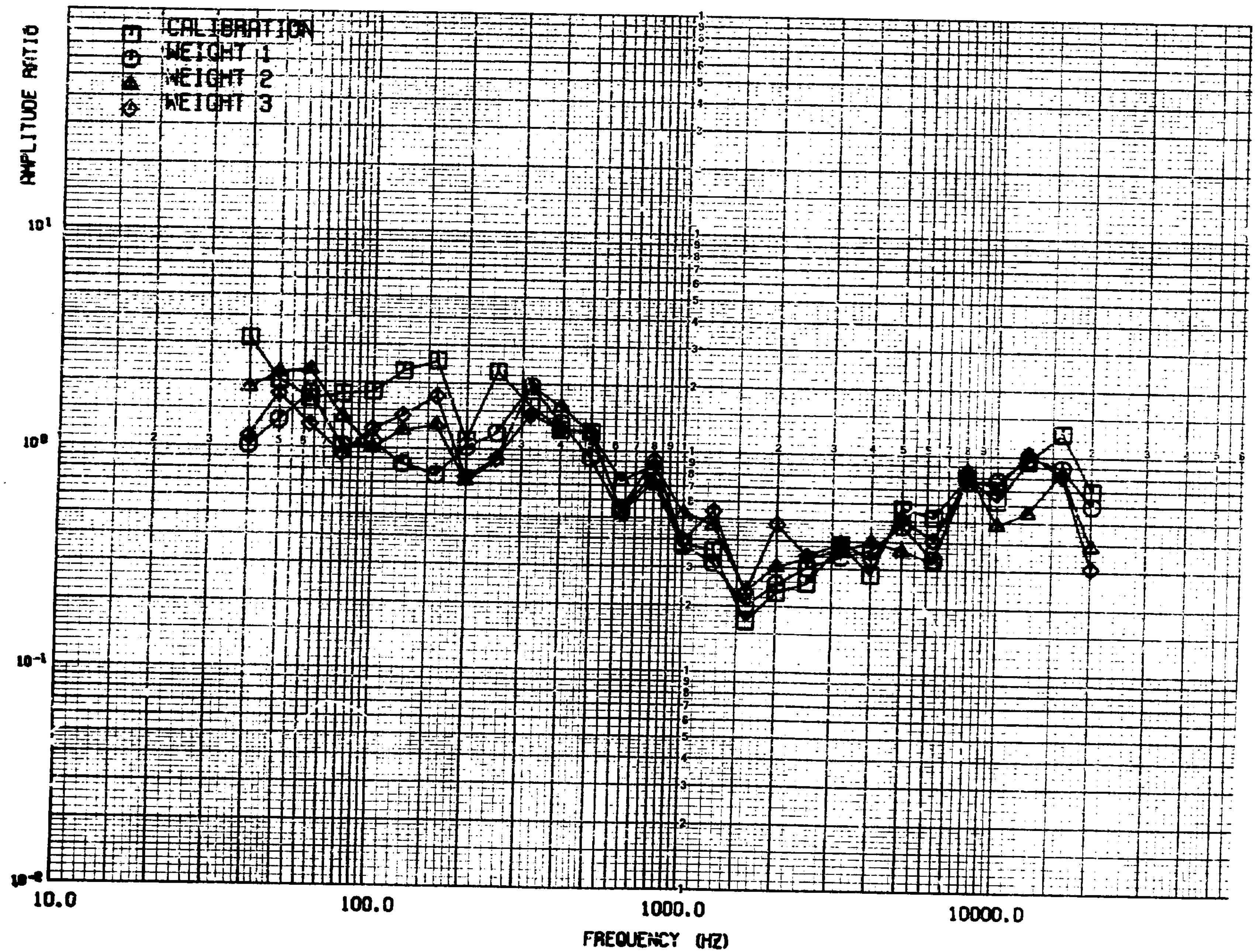


FIGURE 62A. NORMALIZED SHOCK SPECTRA - ACCEL 02. PHASE IA SINGLE MASS LOADING

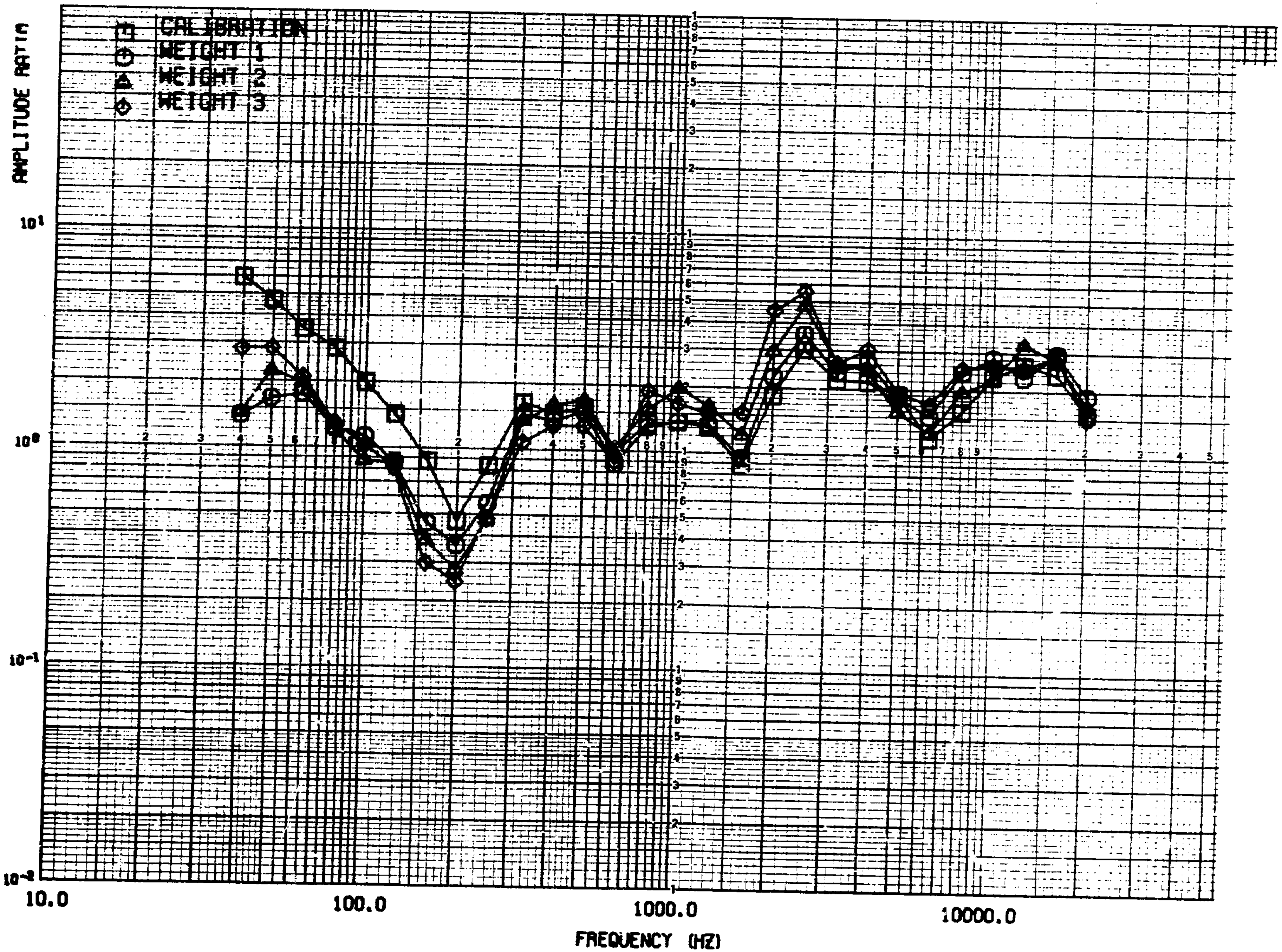


FIGURE 63A. NORMALIZED SHOCK SPECTRA - ACCEL 03. PHASE IA SINGLE MASS LOADING

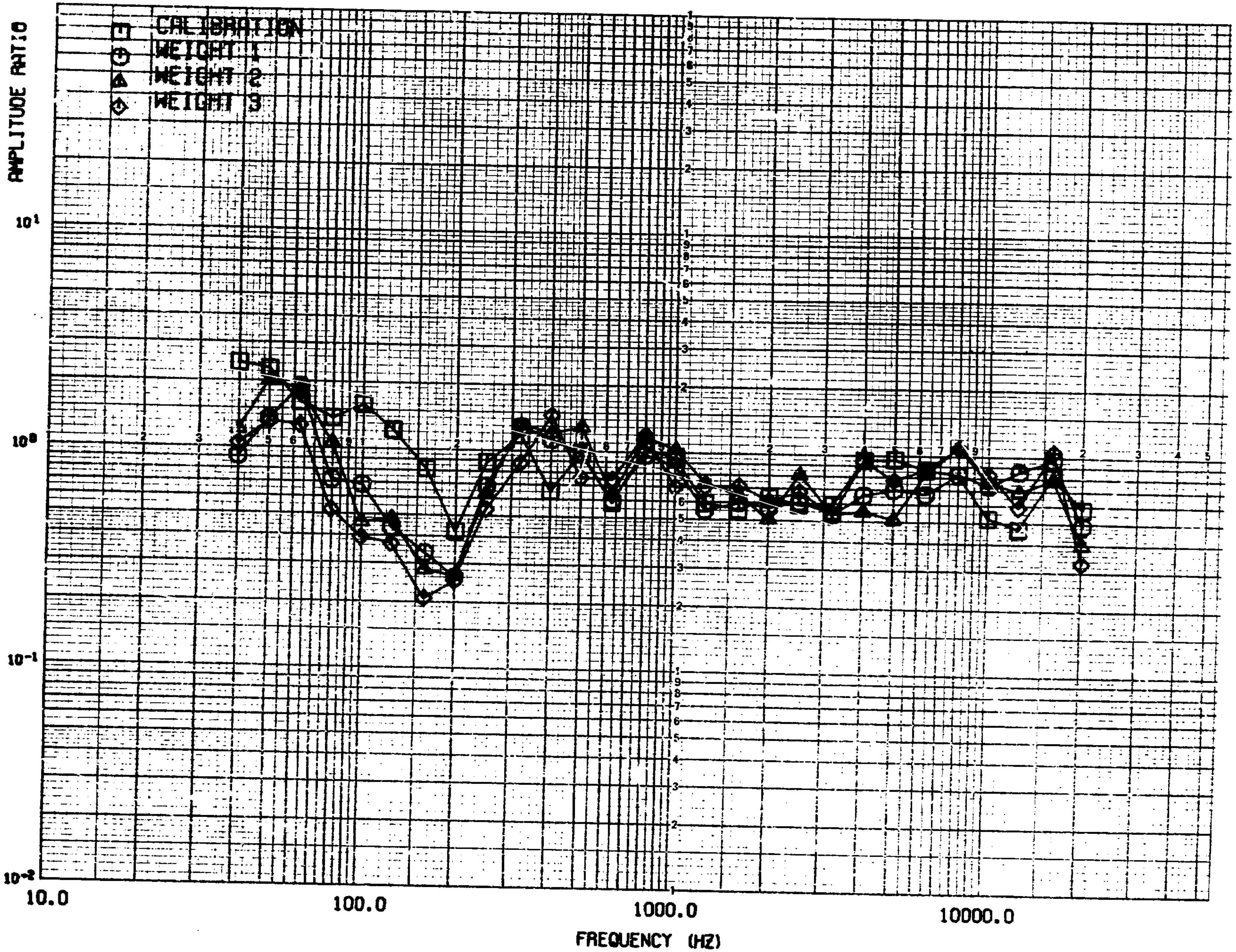


FIGURE 64A. NORMALIZED SHOCK SPECTRA - ACCEL 04. PHASE IA SINGLE MASS LOADING

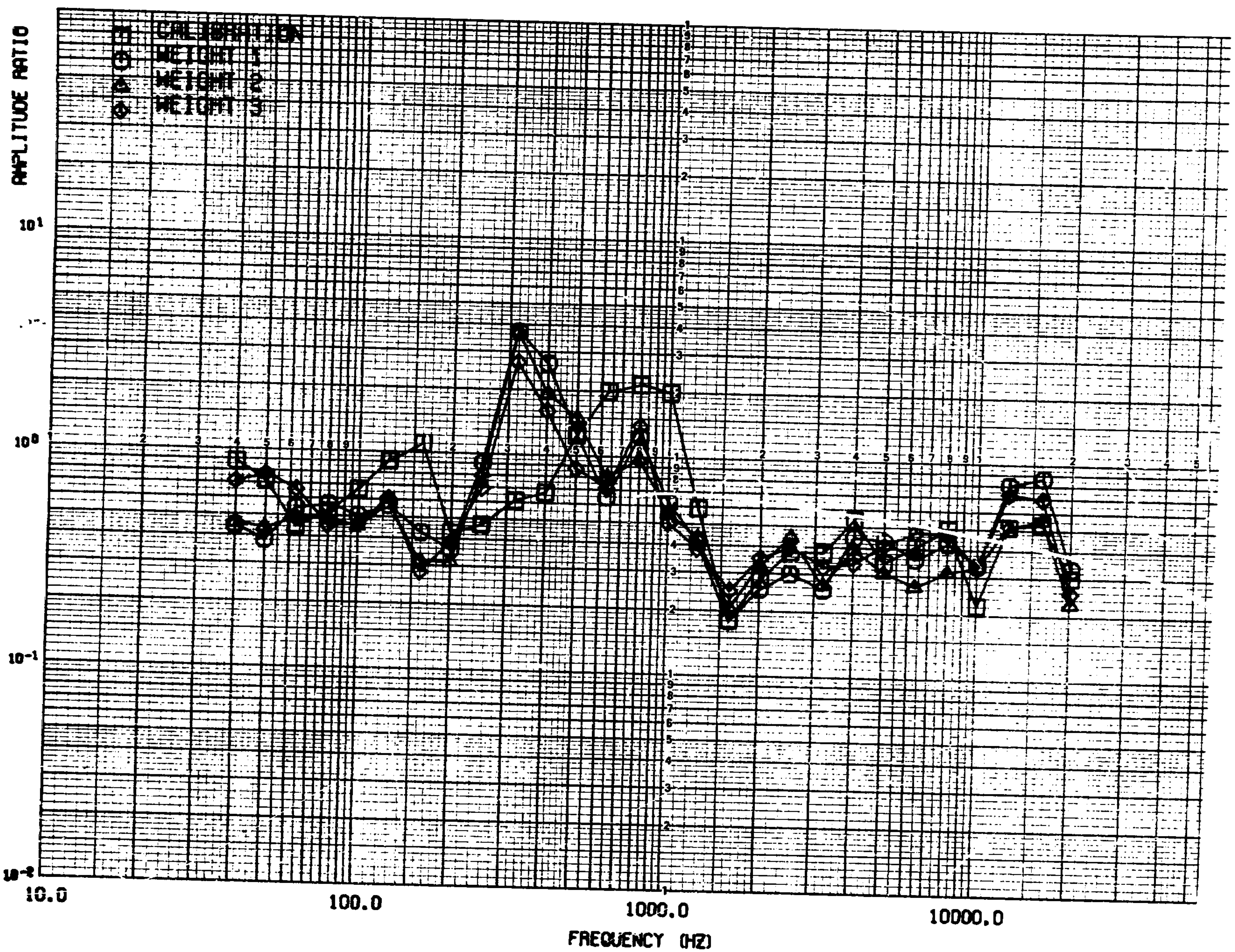


FIGURE 65A. NORMALIZED SHOCK SPECTRA - ACCEL 05. PHASE IA SINGLE MASS LOADING

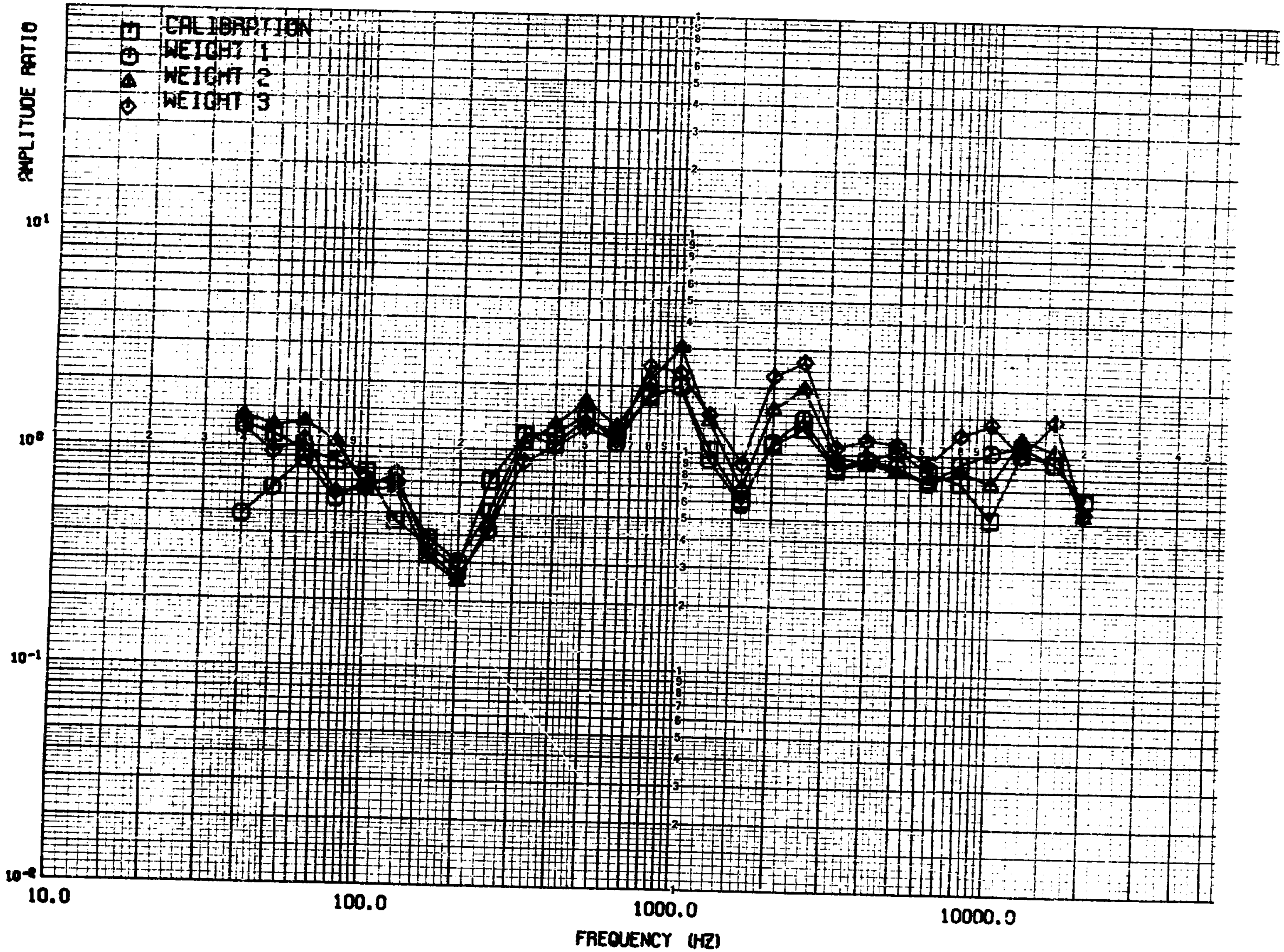


FIGURE 66A. NORMALIZED SHOCK SPECTRA - ACCEL 06. PHASE IA SINGLE MASS LOADING

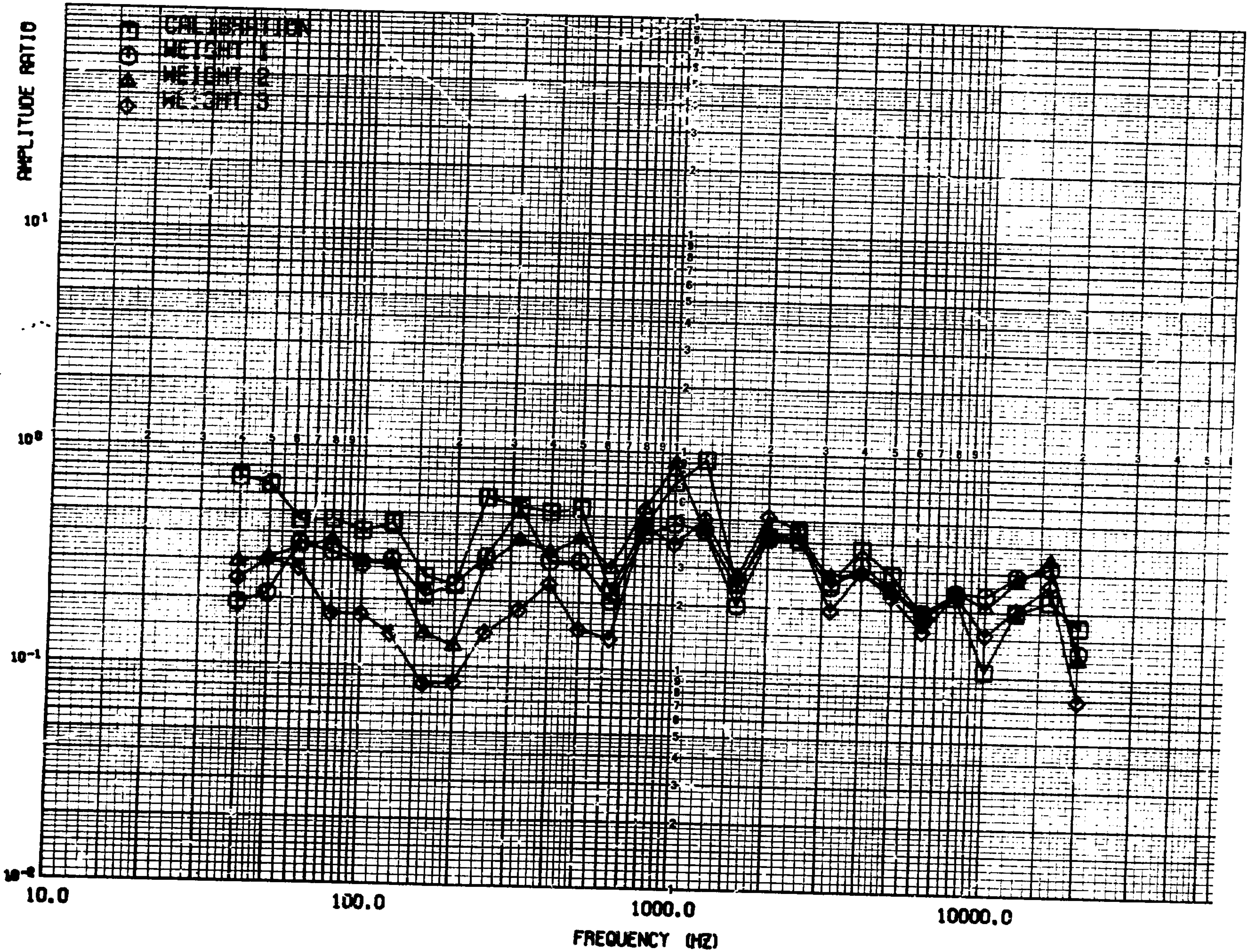


FIGURE 67A. NORMALIZED SHOCK SPECTRA - ACCEL 07. PHASE IA SINGLE MASS LOADING

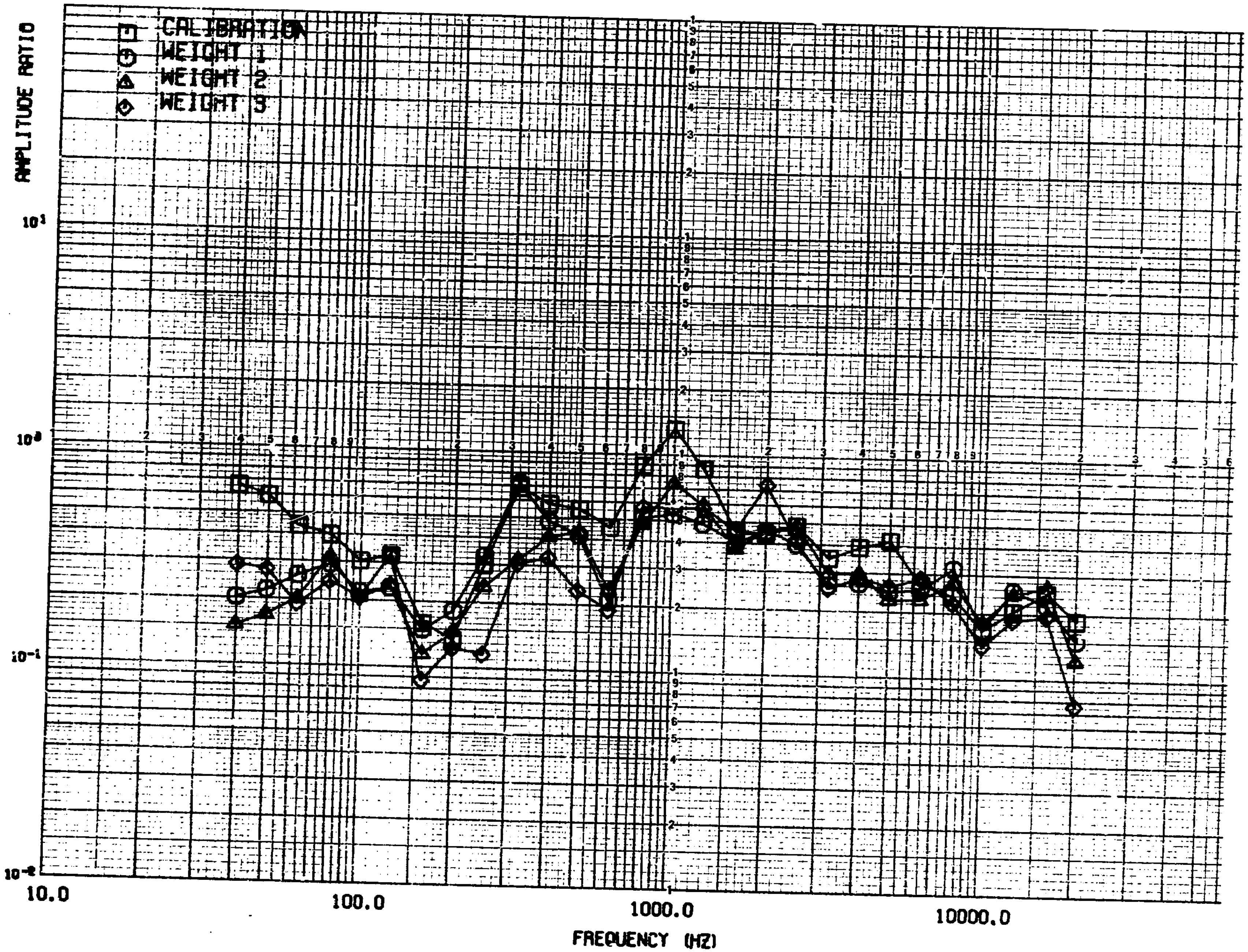


FIGURE 68A. NORMALIZED SHOCK SPECTRA - ACCEL 08. PHASE IA SINGLE MASS LOADING

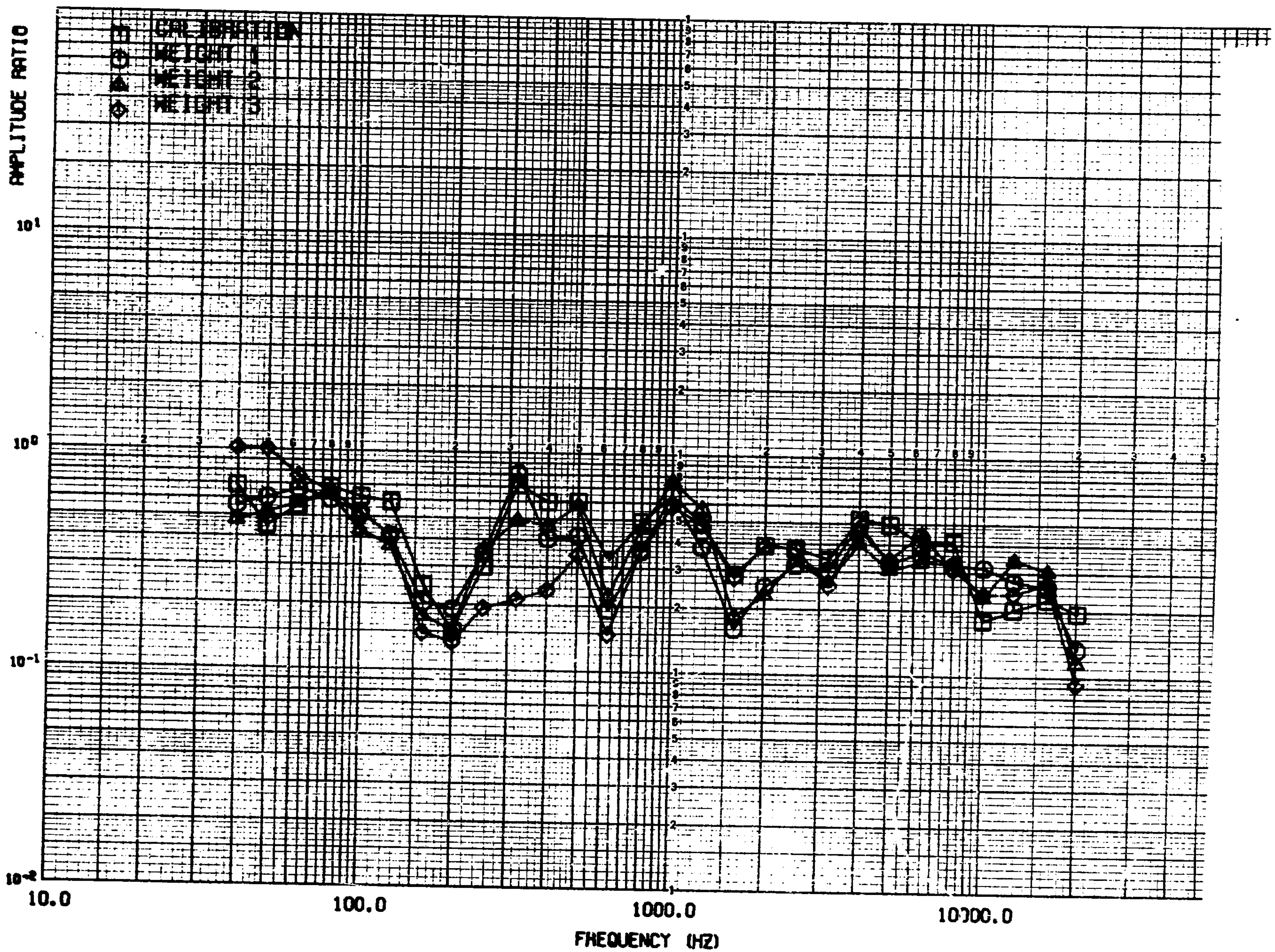


FIGURE 69A. NORMALIZED SHOCK SPECTRA - ACCEL 09. PHASE IA SINGLE MASS LOADING

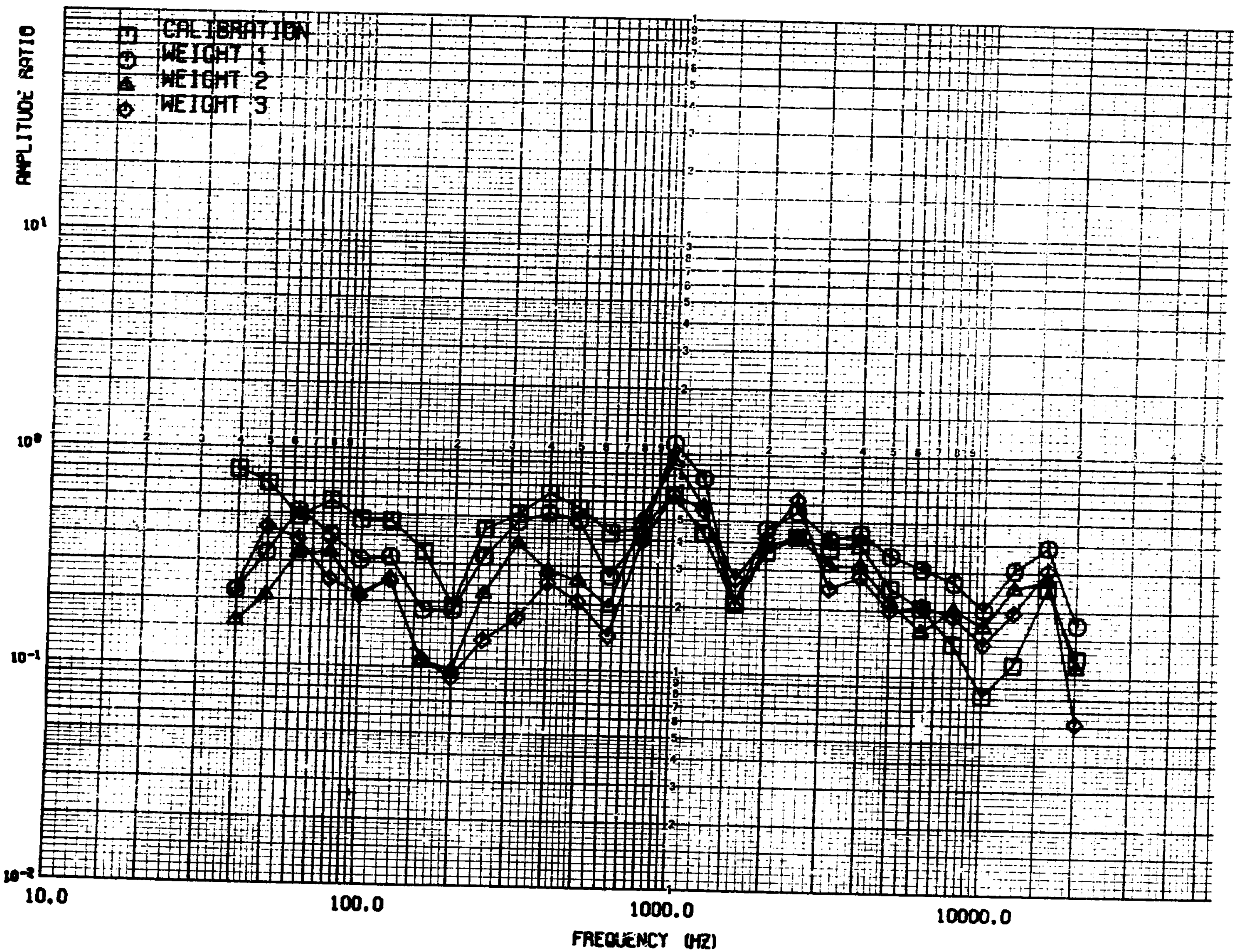


FIGURE 70A. NORMALIZED SHOCK SPECTRA - ACCEL 10. PHASE IA SINGLE MASS LOADING

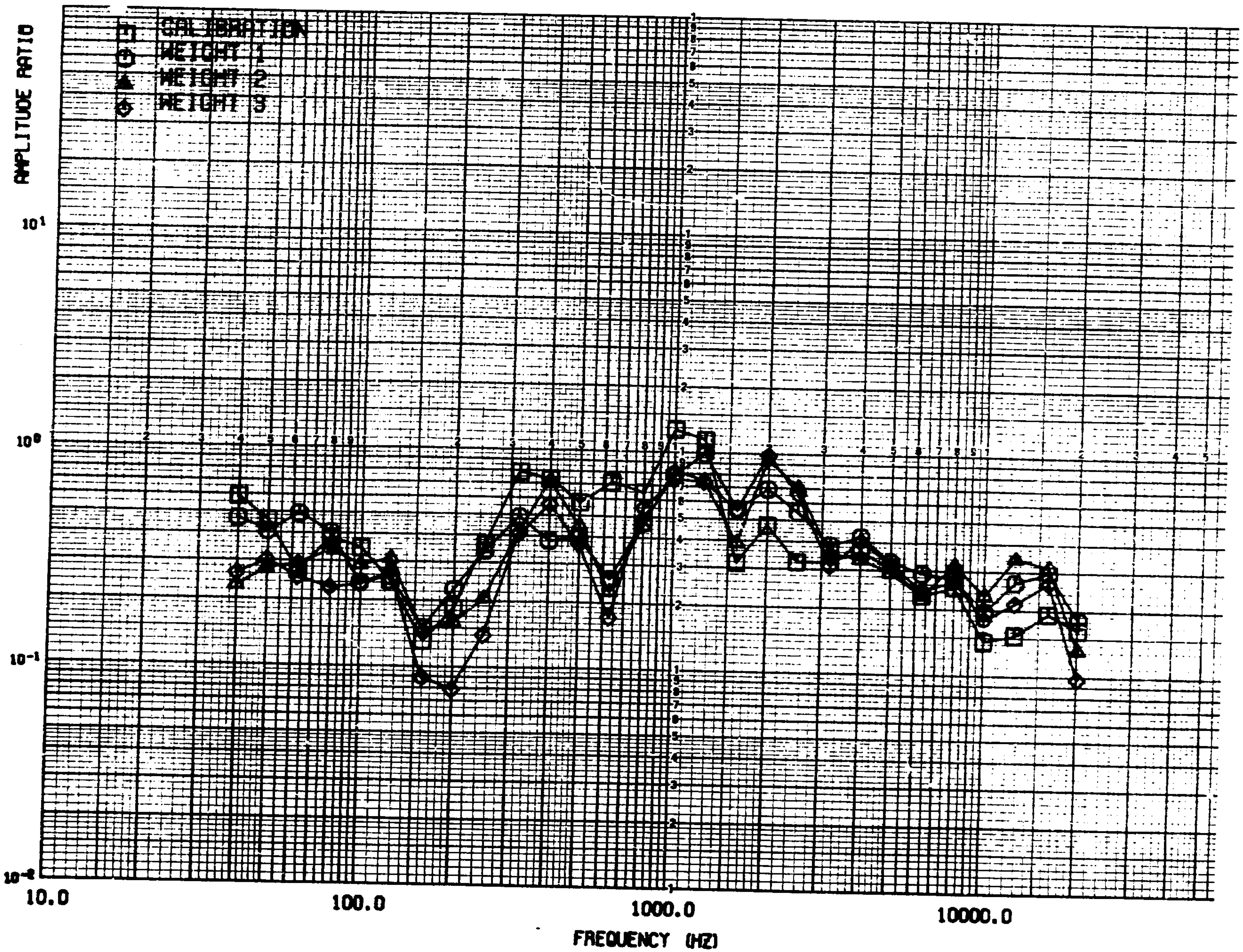


FIGURE 71A. NORMALIZED SHOCK SPECTRA - ACCEL 11. PHASE IA SINGLE MASS LOADING

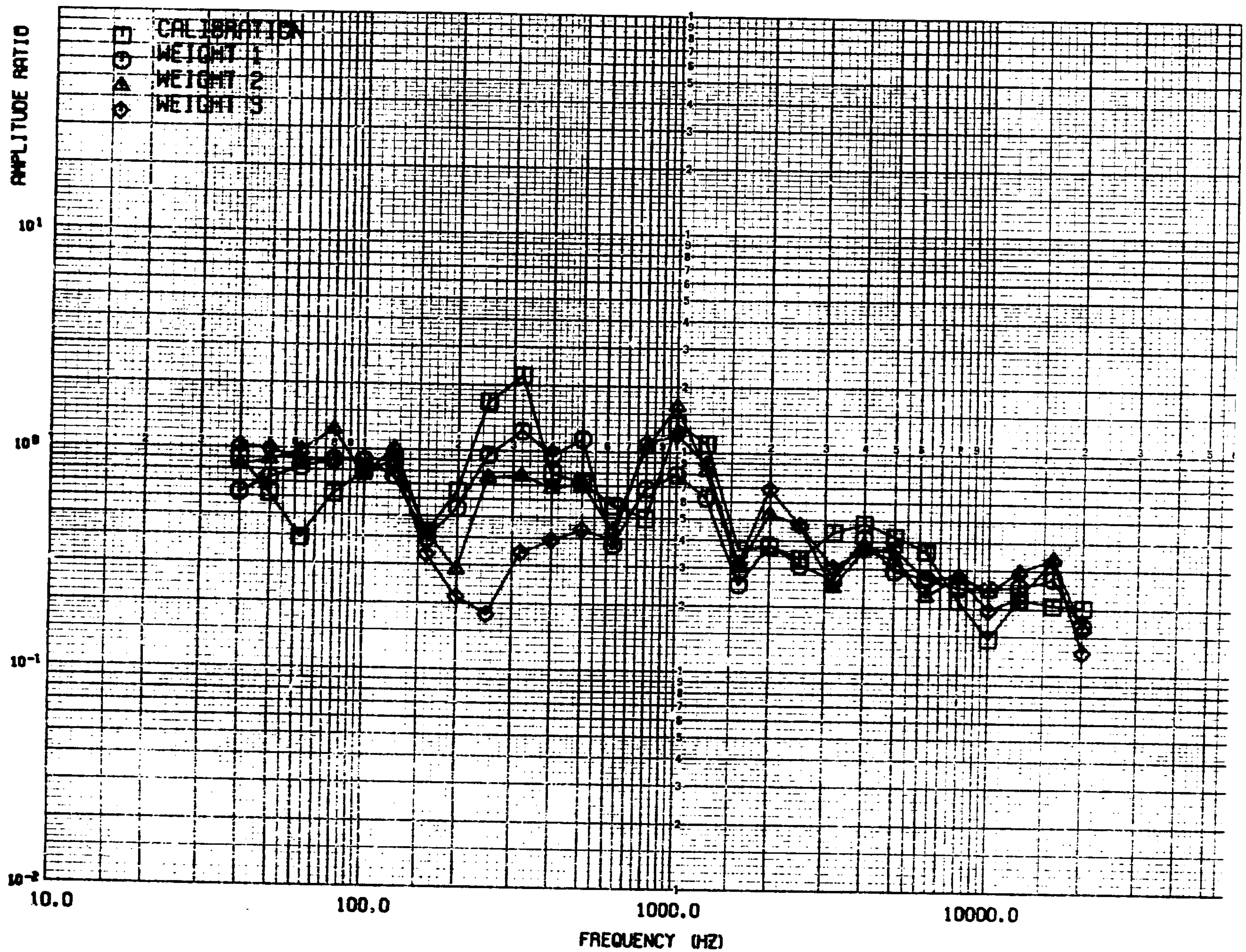


FIGURE 72A. NORMALIZED SHOCK SPECTRA - ACCEL 12. PHASE IA SINGLE MASS LOADING

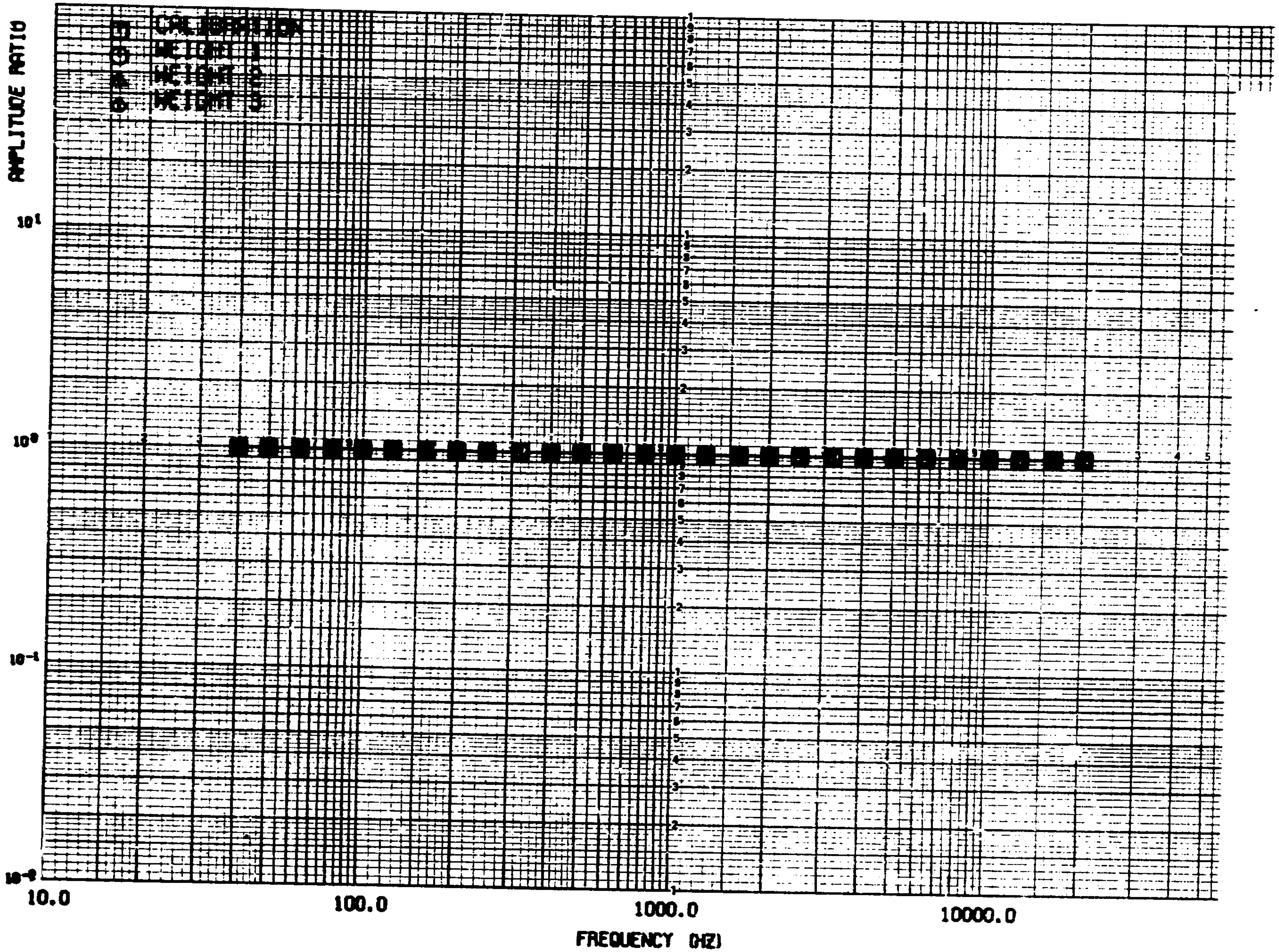


FIGURE 73A. NORMALIZED SHOCK SPECTRA - ACCEL 01. PHASE II DISTRIBUTED MASS

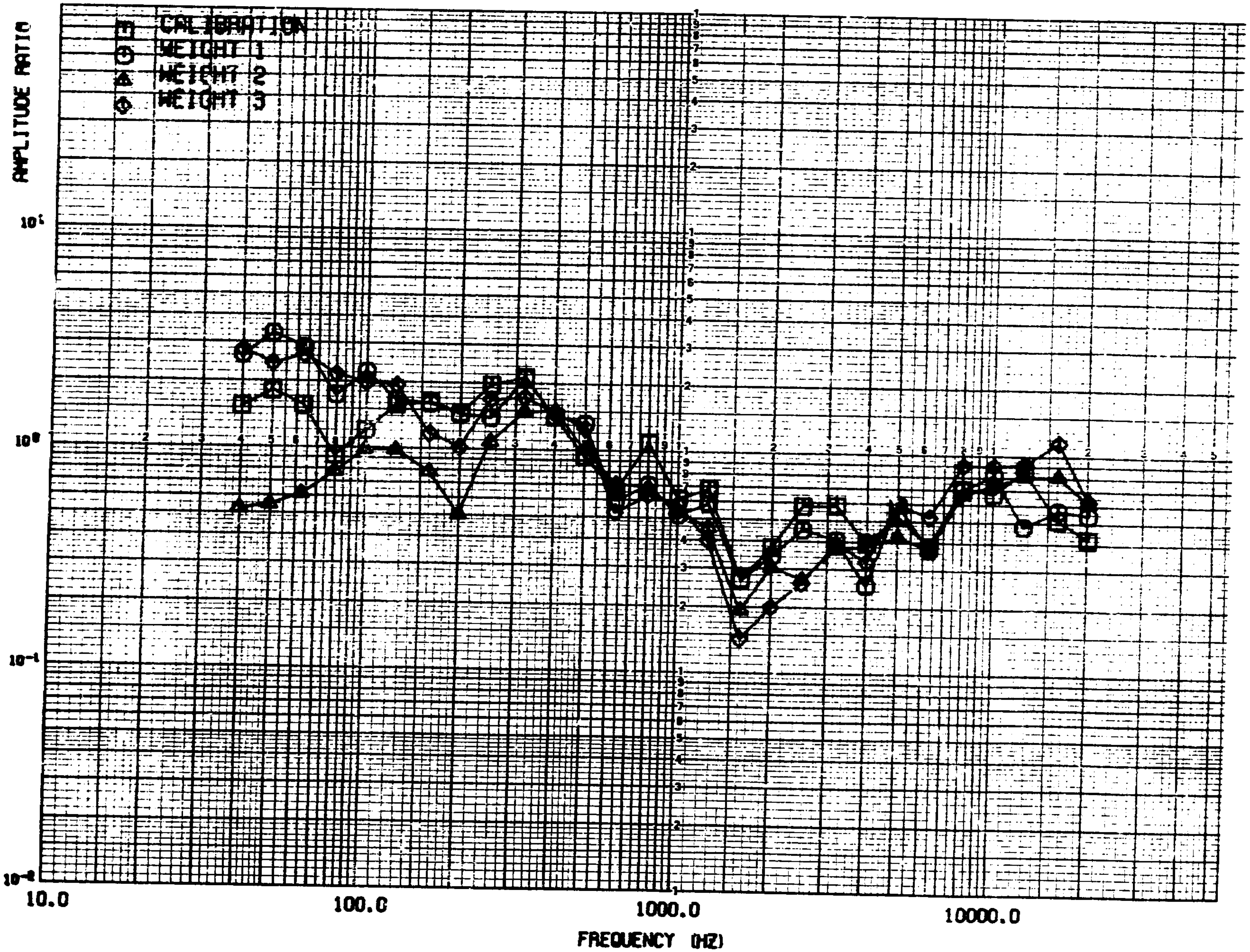


FIGURE 74A. NORMALIZED SHOCK SPECTRA - ACCEL 02. PHASE II DISTRIBUTED MASS

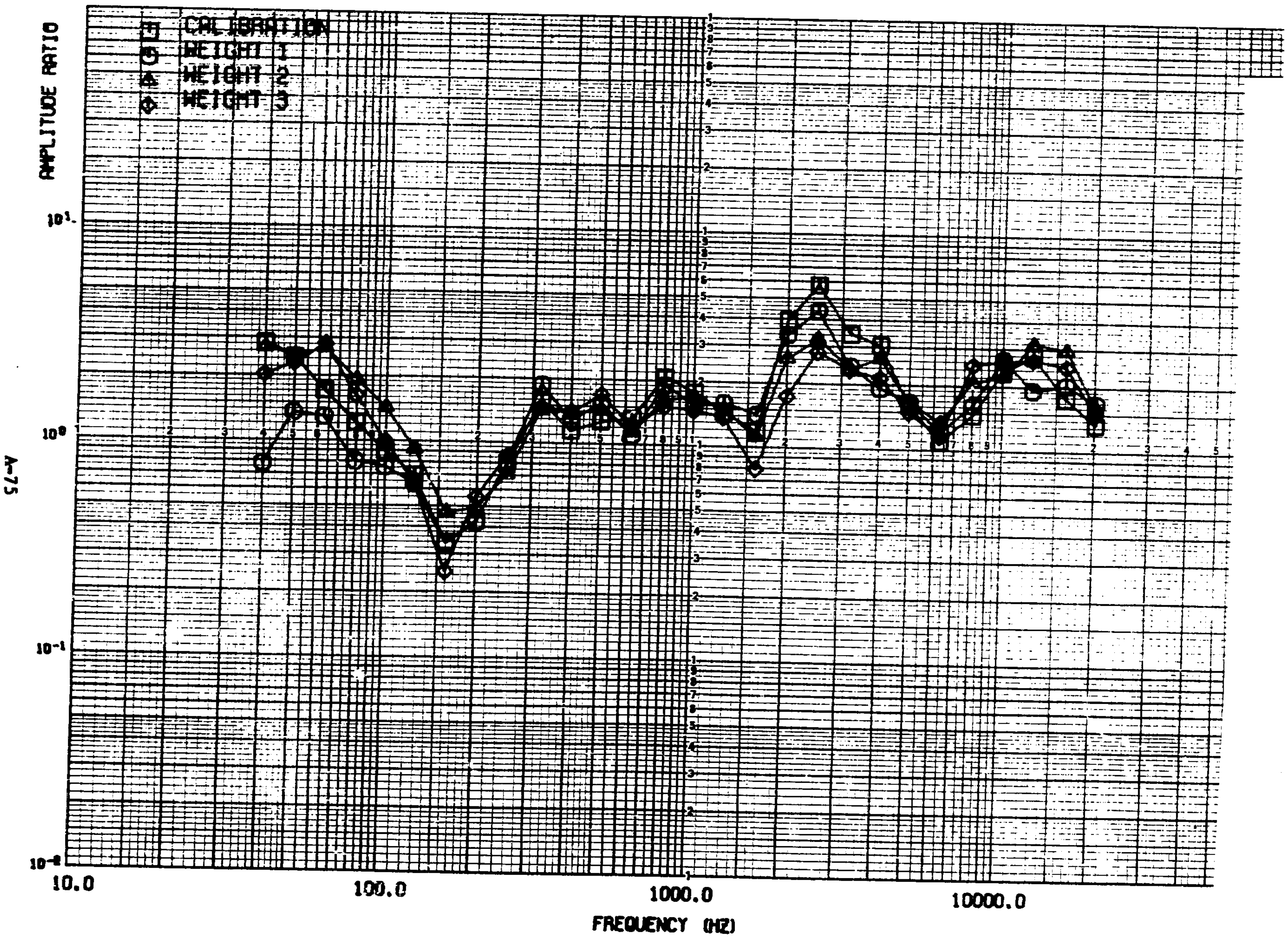


FIGURE 75A. NORMALIZED SHOCK SPECTRA - ACCEL 03. PHASE II DISTRIBUTED MASS

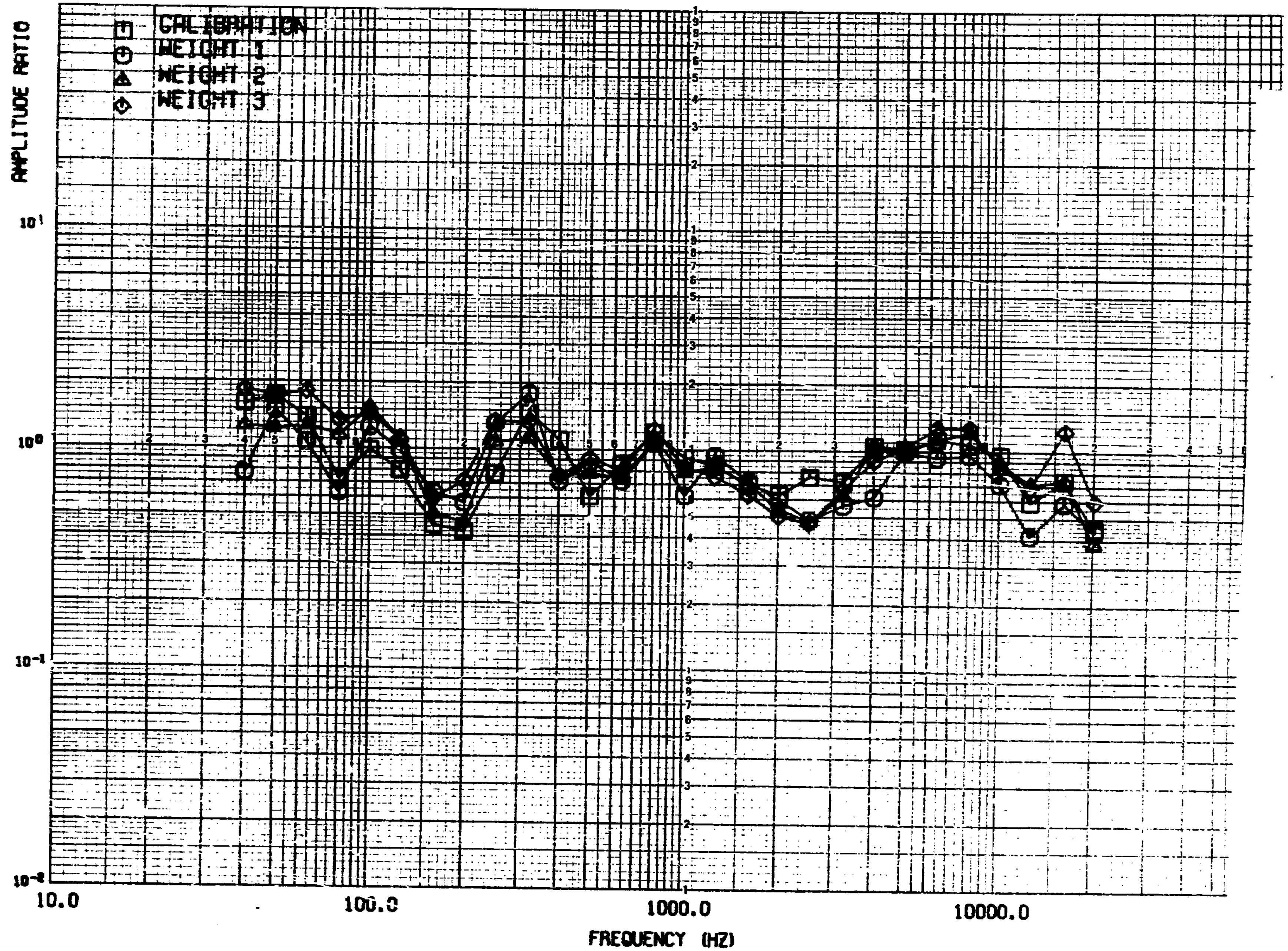


FIGURE 76A. NORMALIZED SHOCK SPECTRA - ACCEL 04. PHASE II DISTRIBUTED MASS

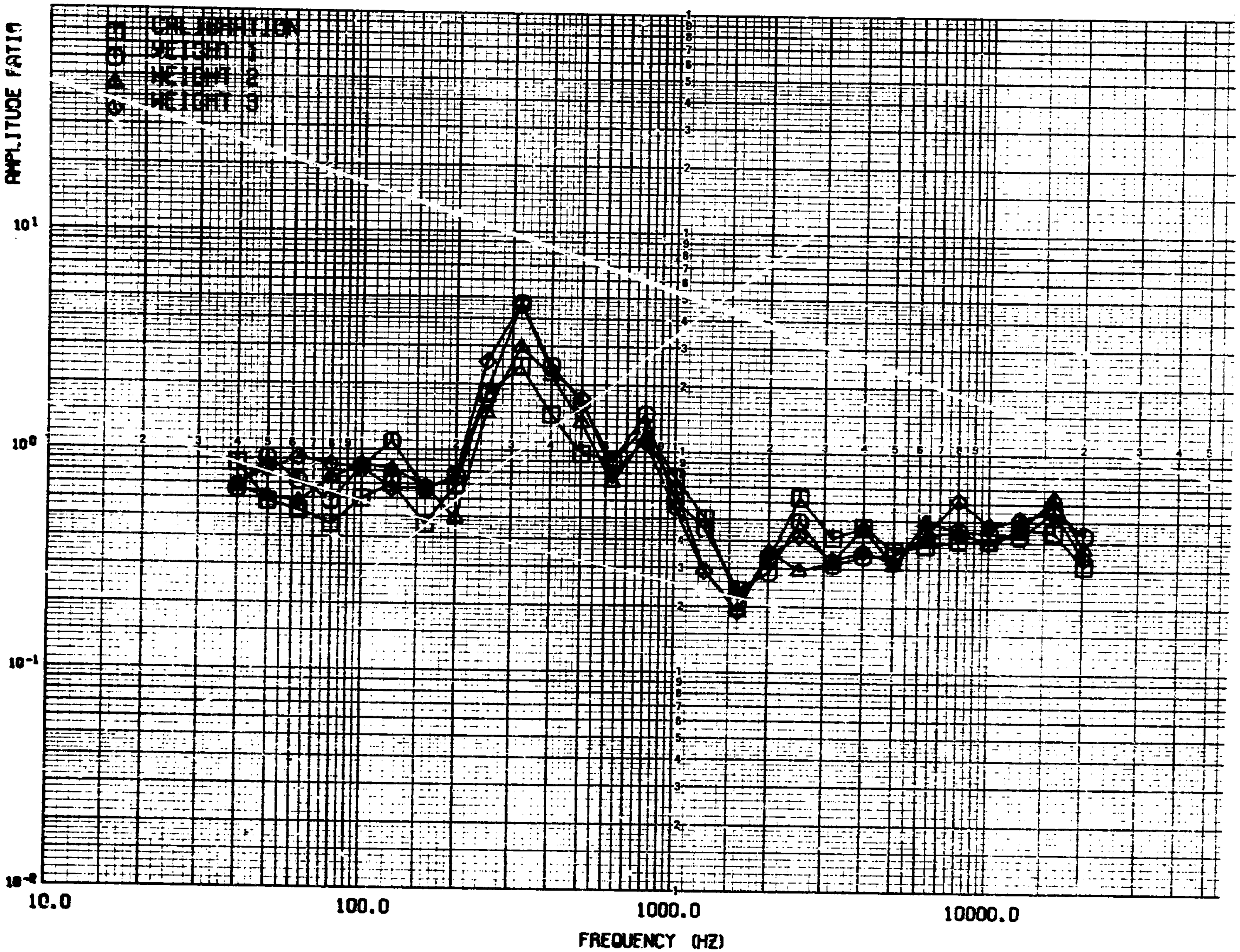


FIGURE 77A. NORMALIZED SHOCK SPECTRA - ACCEL 05. PHASE II DISTRIBUTED MASS

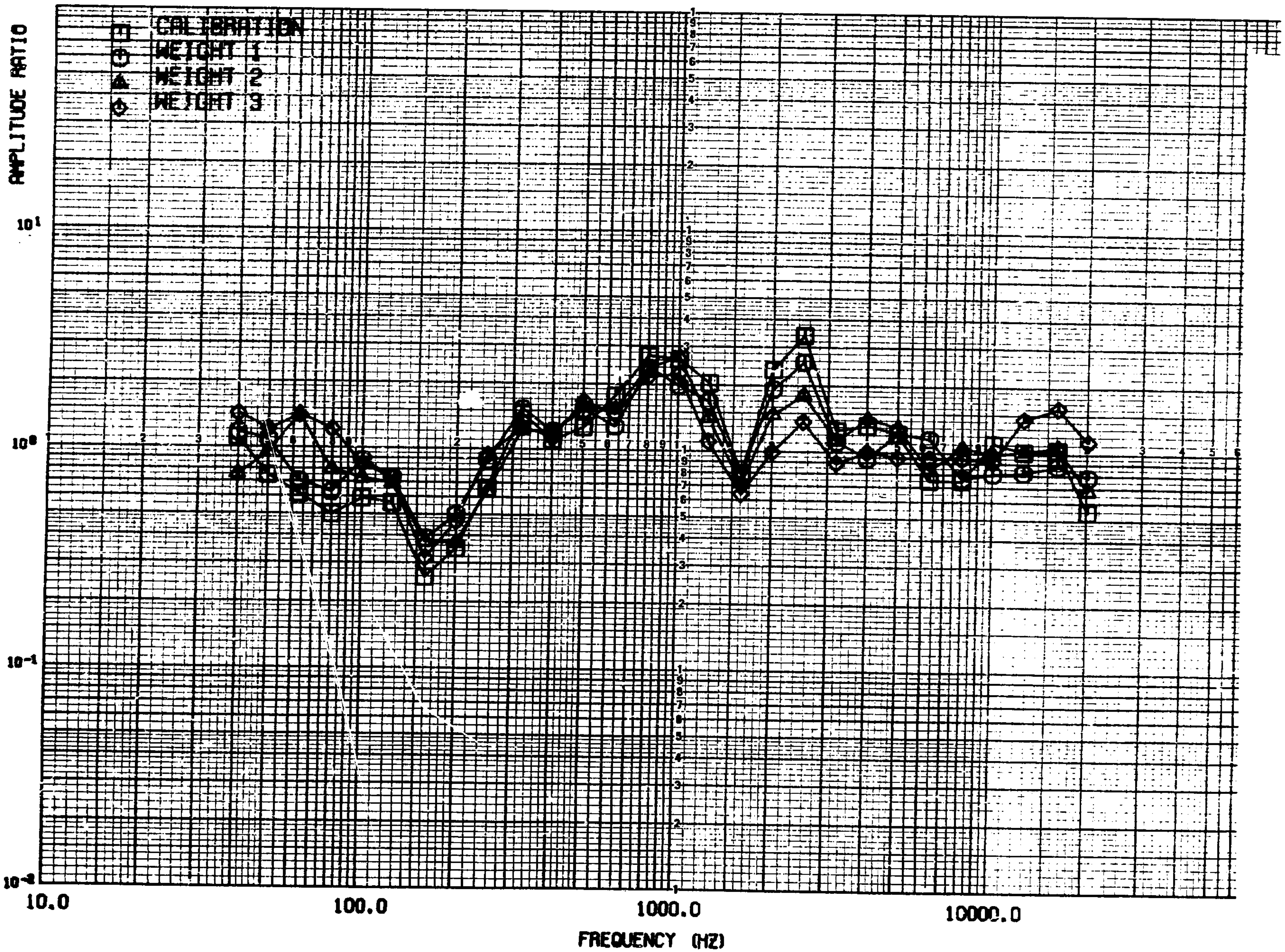


FIGURE 78A. NORMALIZED SHOCK SPECTRA - ACCEL 06. PHASE II DISTRIBUTED MASS

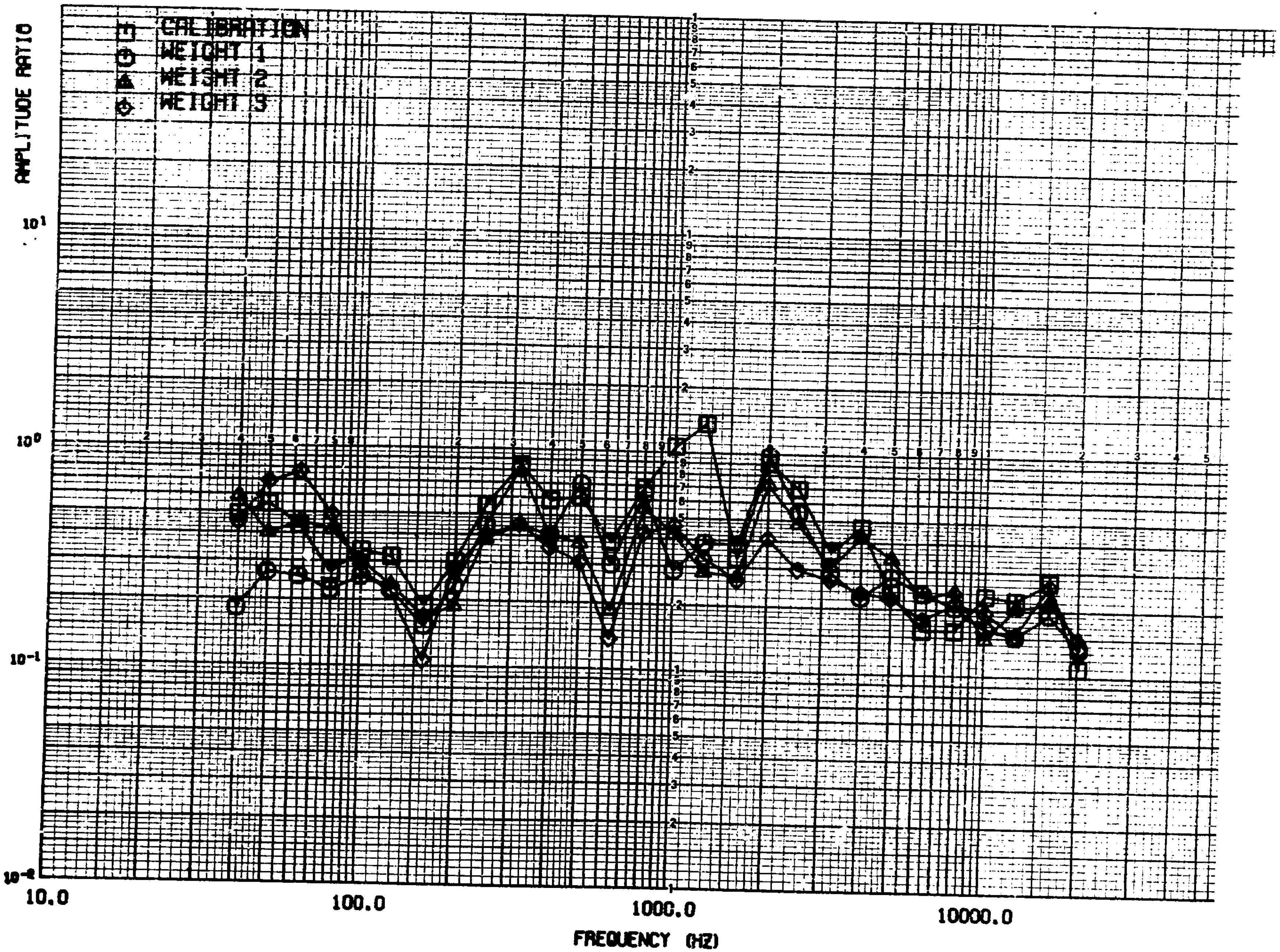


FIGURE 79A. NORMALIZED SHOCK SPECTRA - ACCEL 07. PHASE II DISTRIBUTED MASS

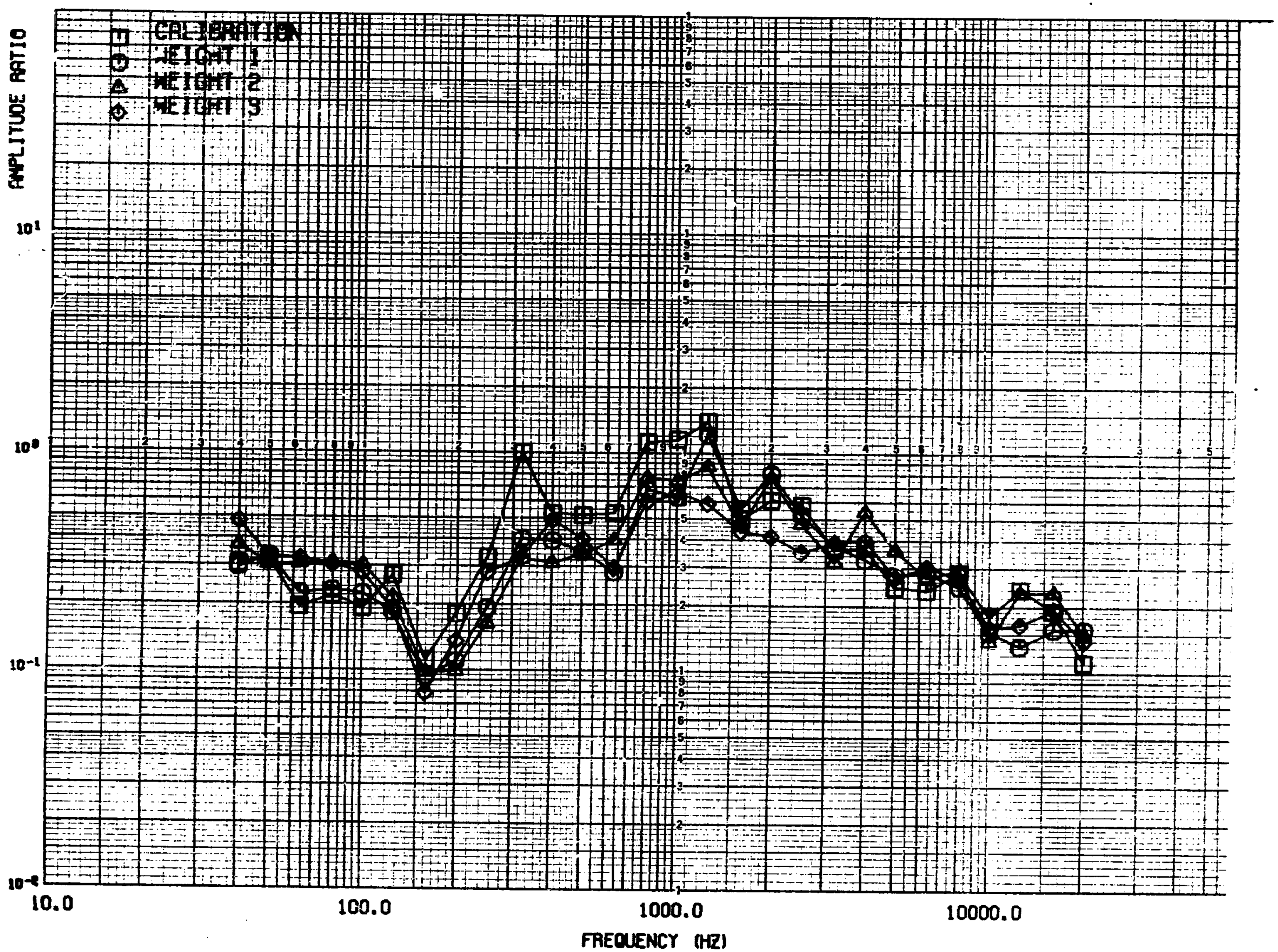


FIGURE 80A. NORMALIZED SHOCK SPECTRA - ACCEL 08. PHASE II DISTRIBUTED MASS

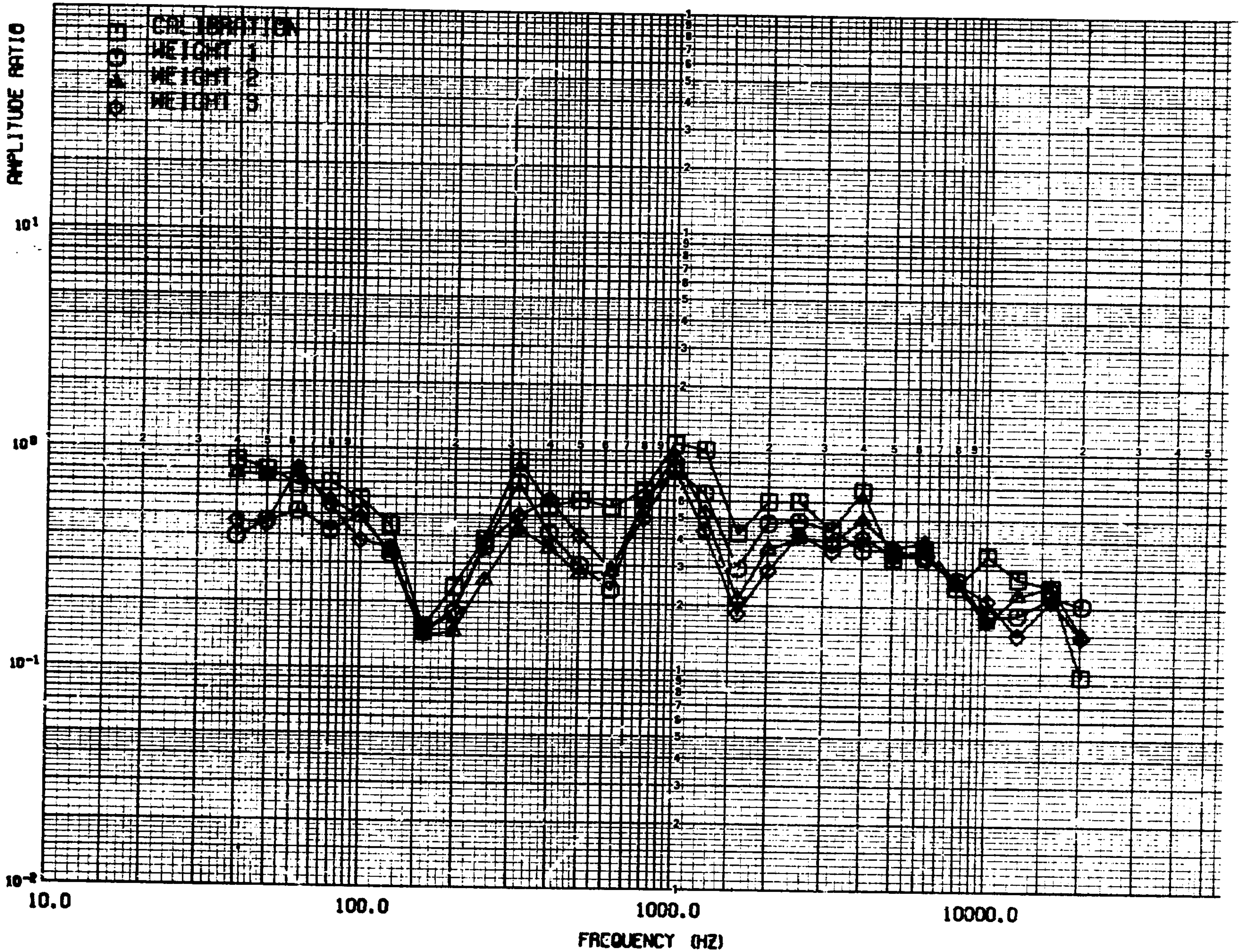


FIGURE 81A. NORMALIZED SHOCK SPECTRA - ACCEL 09. PHASE II DISTRIBUTED MASS

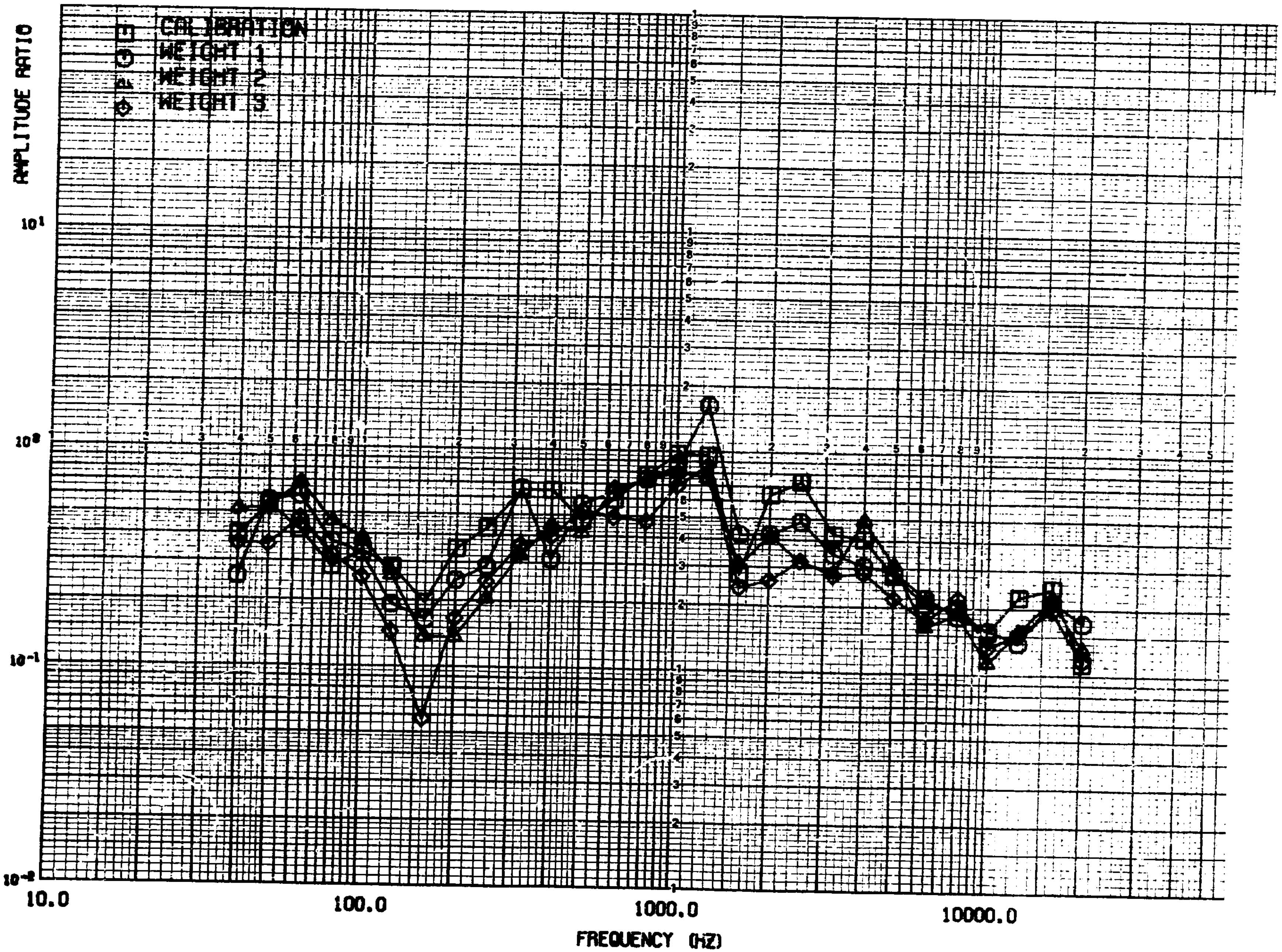


FIGURE 82A. NORMALIZED SHOCK SPECTRA - ACCEL 10. PHASE II DISTRIBUTED MASS

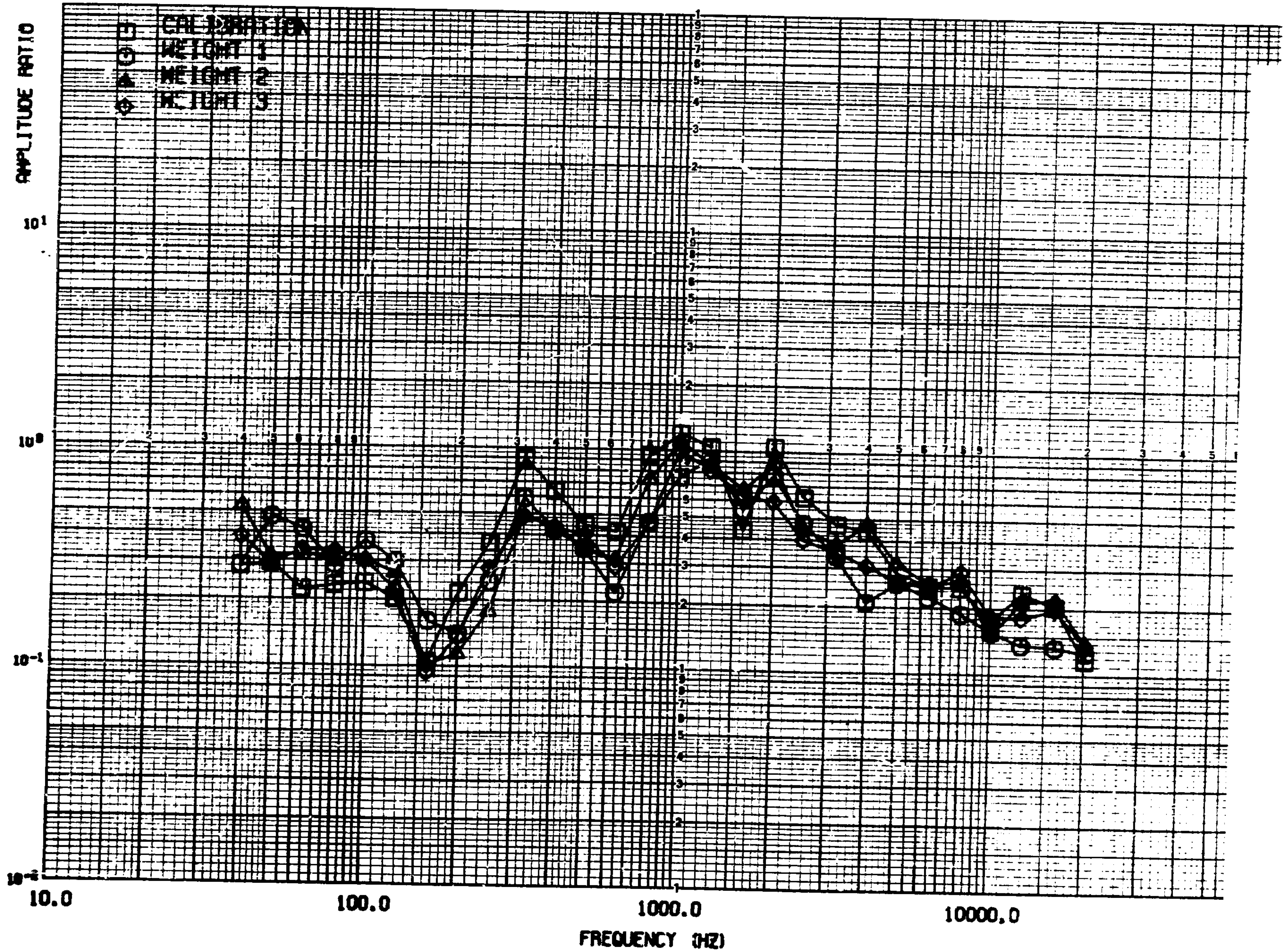


FIGURE 83A. NORMALIZED SHOCK SPECTRA - ACCEL 11. PHASE II DISTRIBUTED MASS

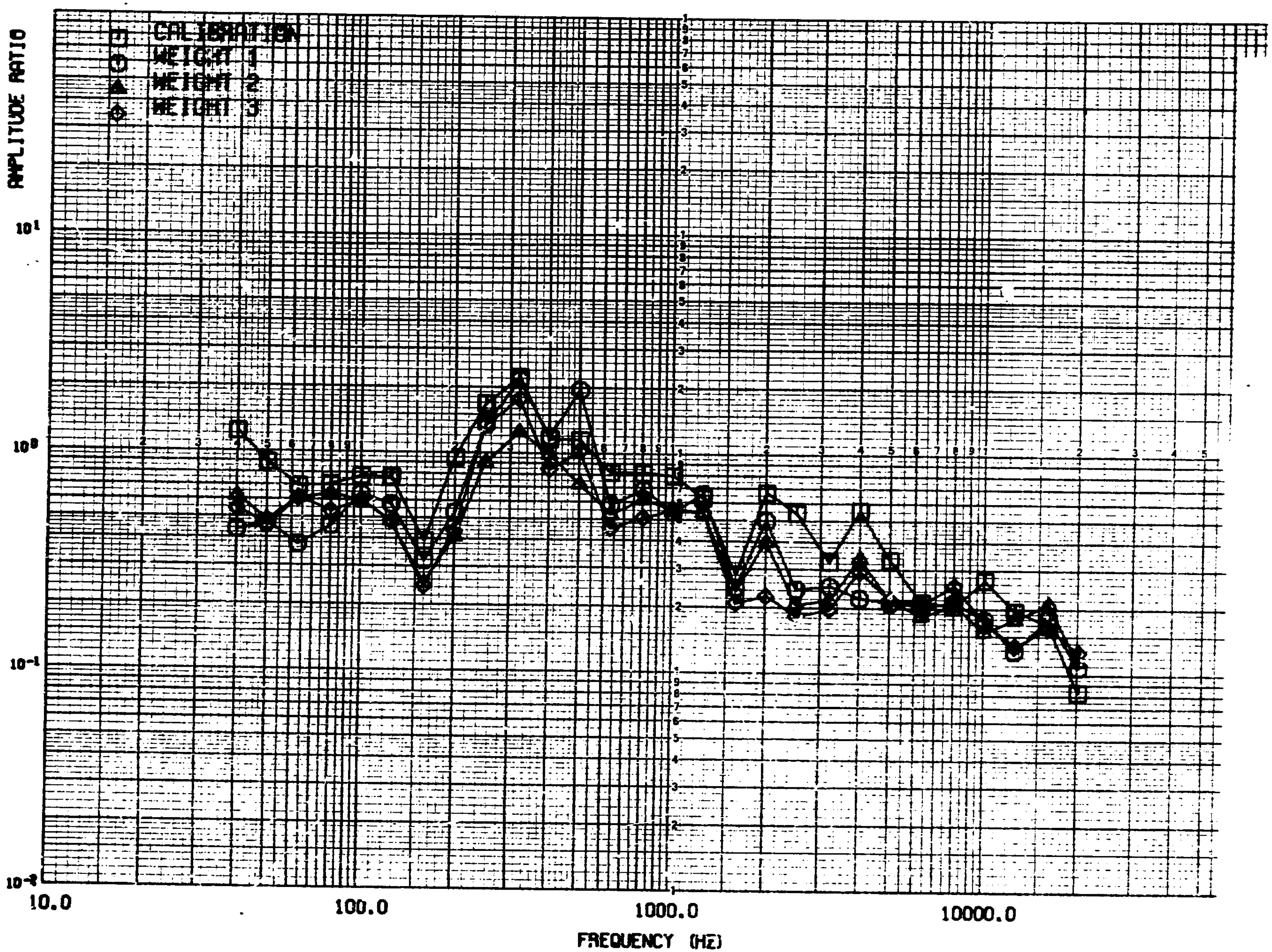


FIGURE 84A. NORMALIZED SHOCK SPECTRA - ACCEL 12. PHASE II DISTRIBUTED MASS

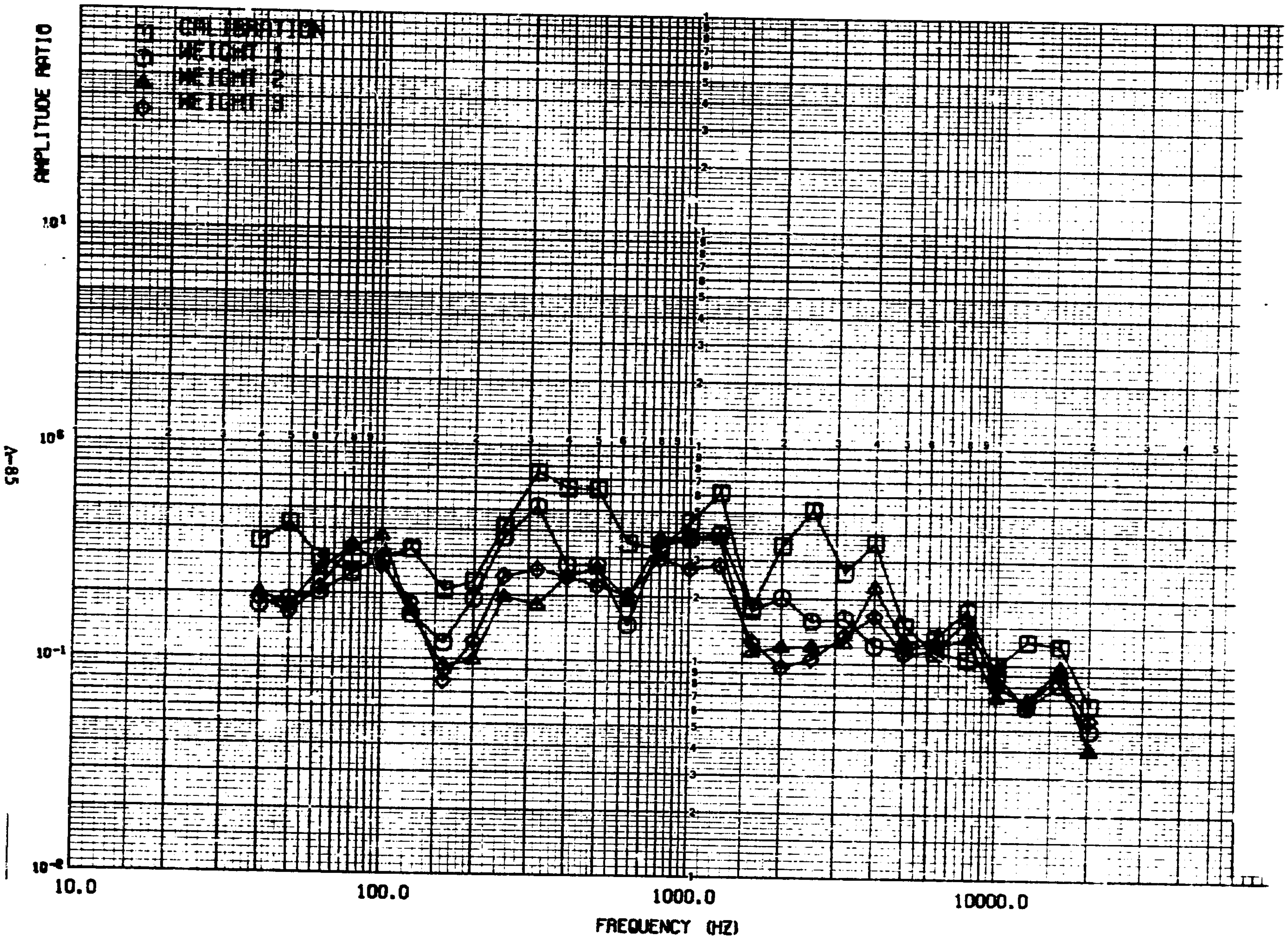


FIGURE 85A. NORMALIZED SHOCK SPECTRA - ACCEL 13. PHASE II DISTRIBUTED MASS

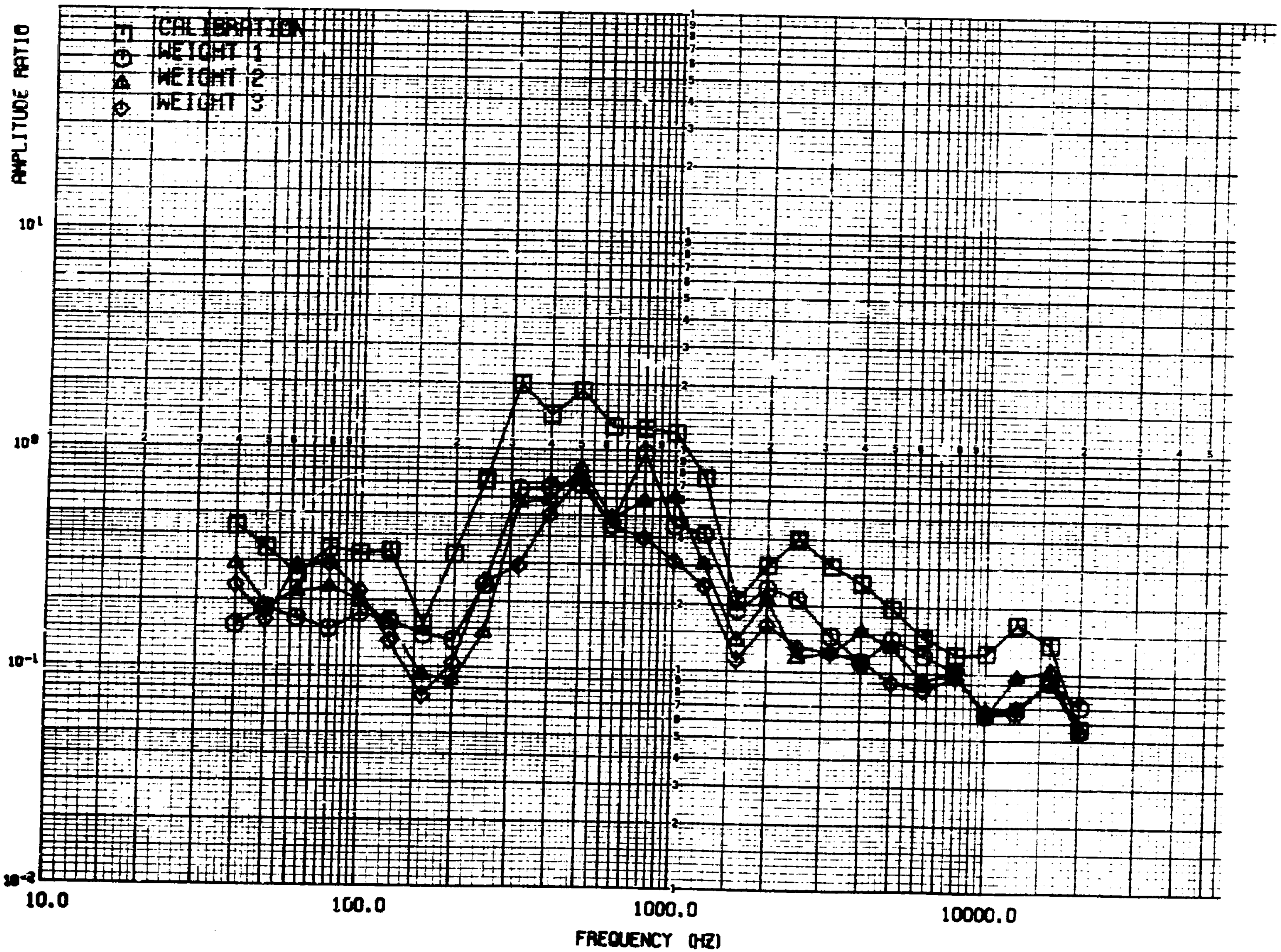


FIGURE 86A. NORMALIZED SHOCK SPECTRA - ACCEL 14. PHASE II DISTRIBUTED MASS

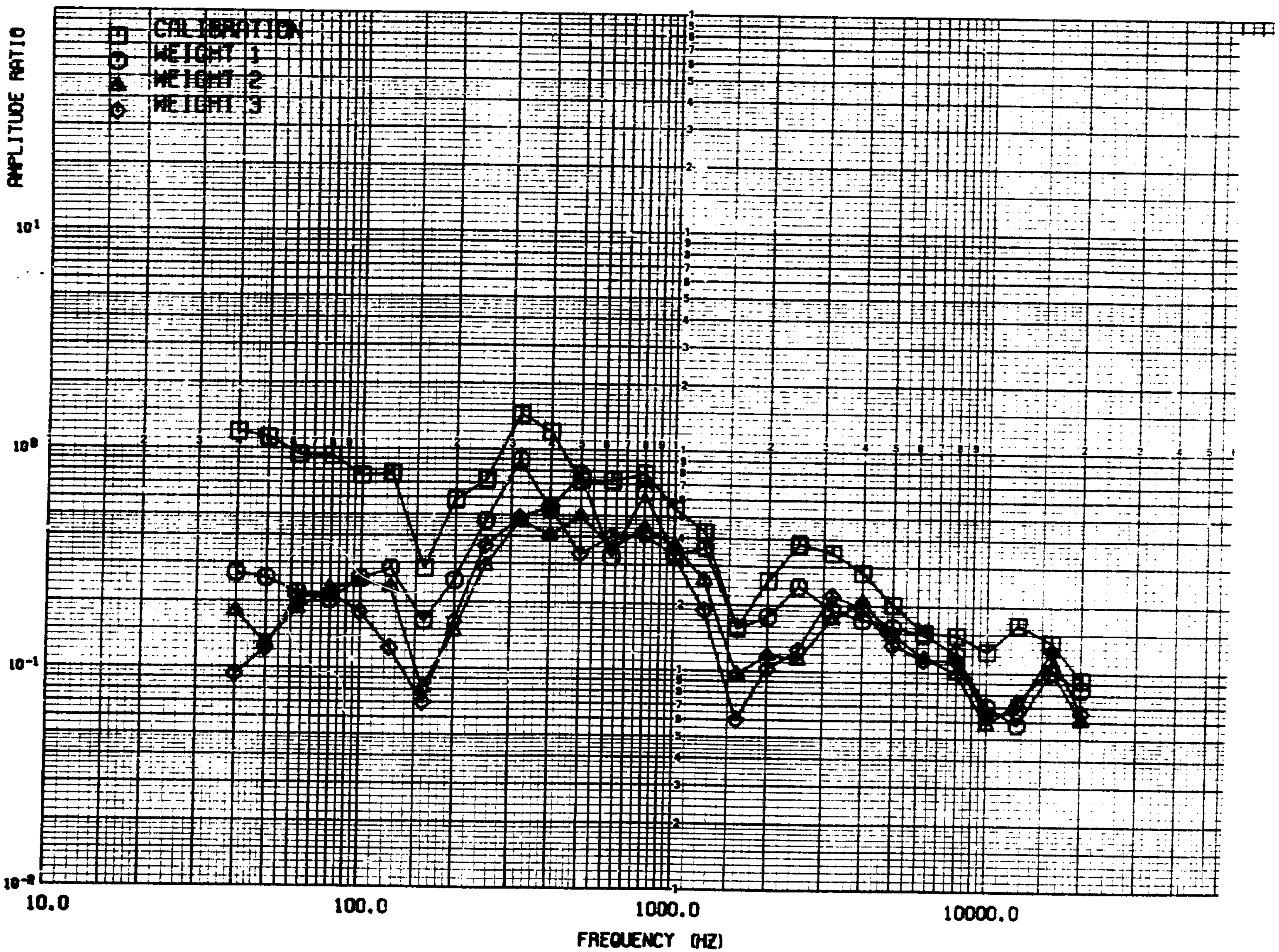


FIGURE 87A. NORMALIZED SHOCK SPECTRA - ACCEL 15. PHASE II DISTRIBUTED MASS

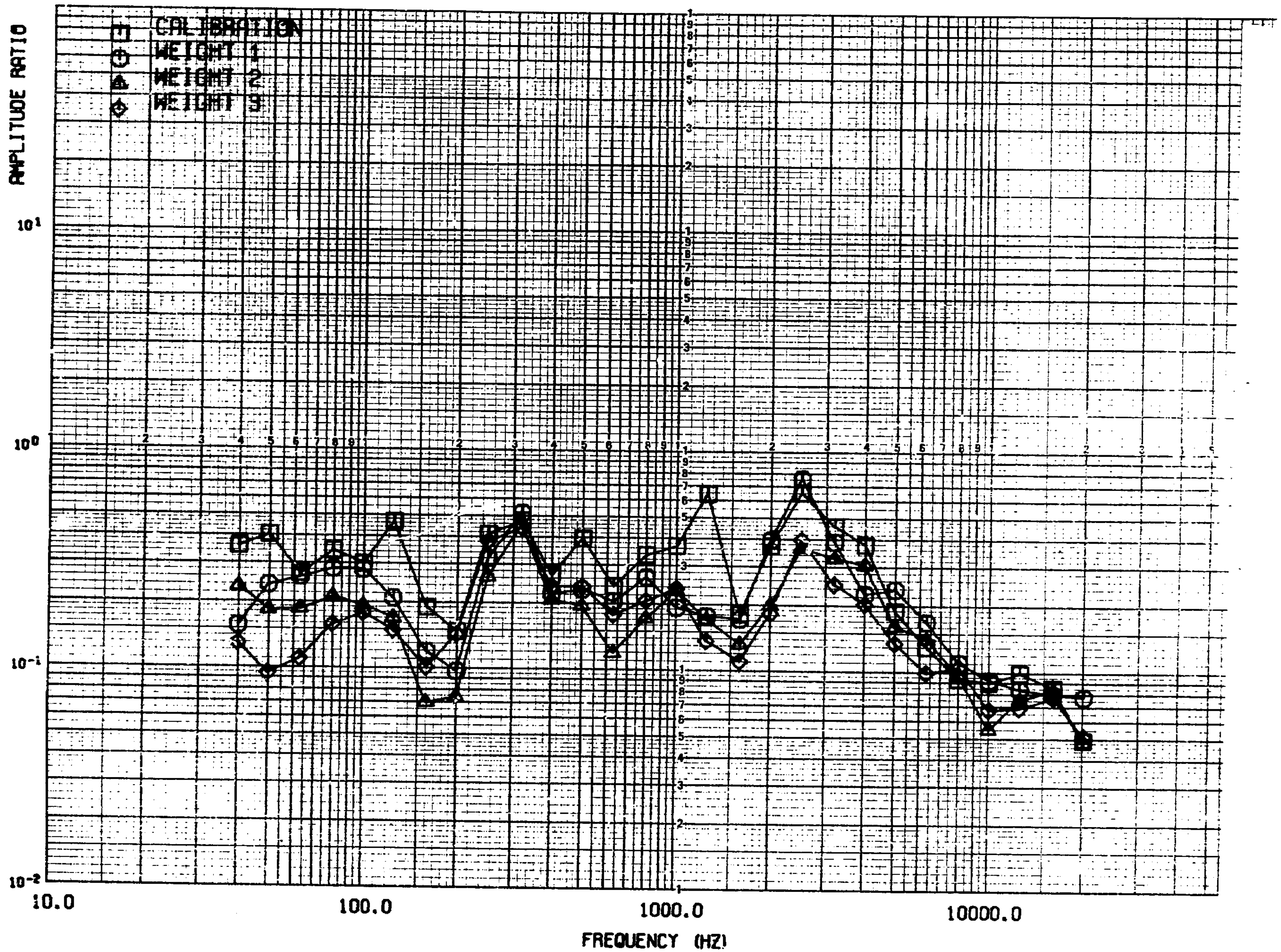


FIGURE 88A. NORMALIZED SHOCK SPECTRA - ACCEL 16. PHASE II DISTRIBUTED MASS

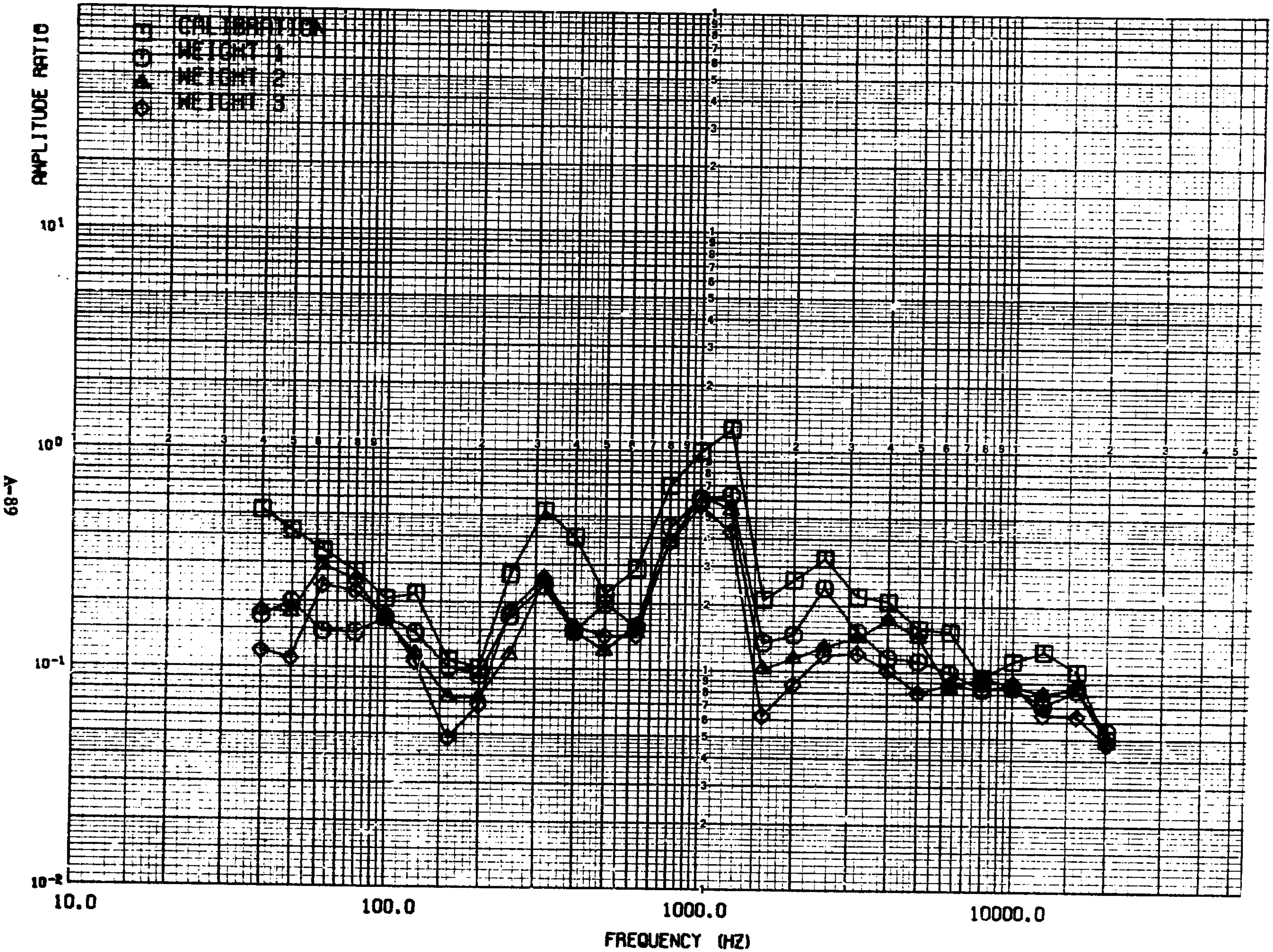


FIGURE 89A. NORMALIZED SHOCK SPECTRA - ACCEL 17. PHASE II DISTRIBUTED MASS

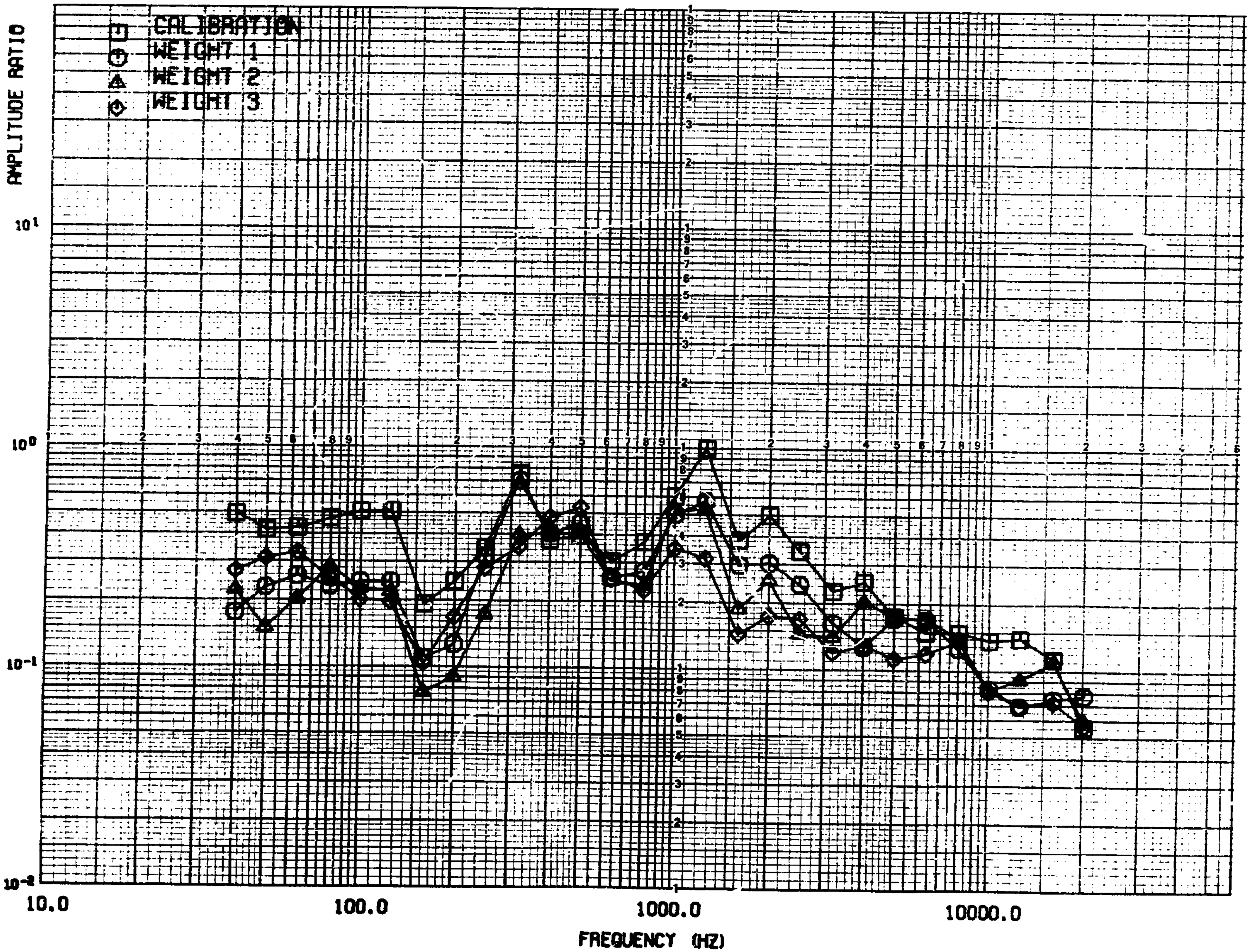


FIGURE 30A. NORMALIZED SHOCK SPECTRA - ACCEL 18. PHASE II DISTRIBUTED MASS

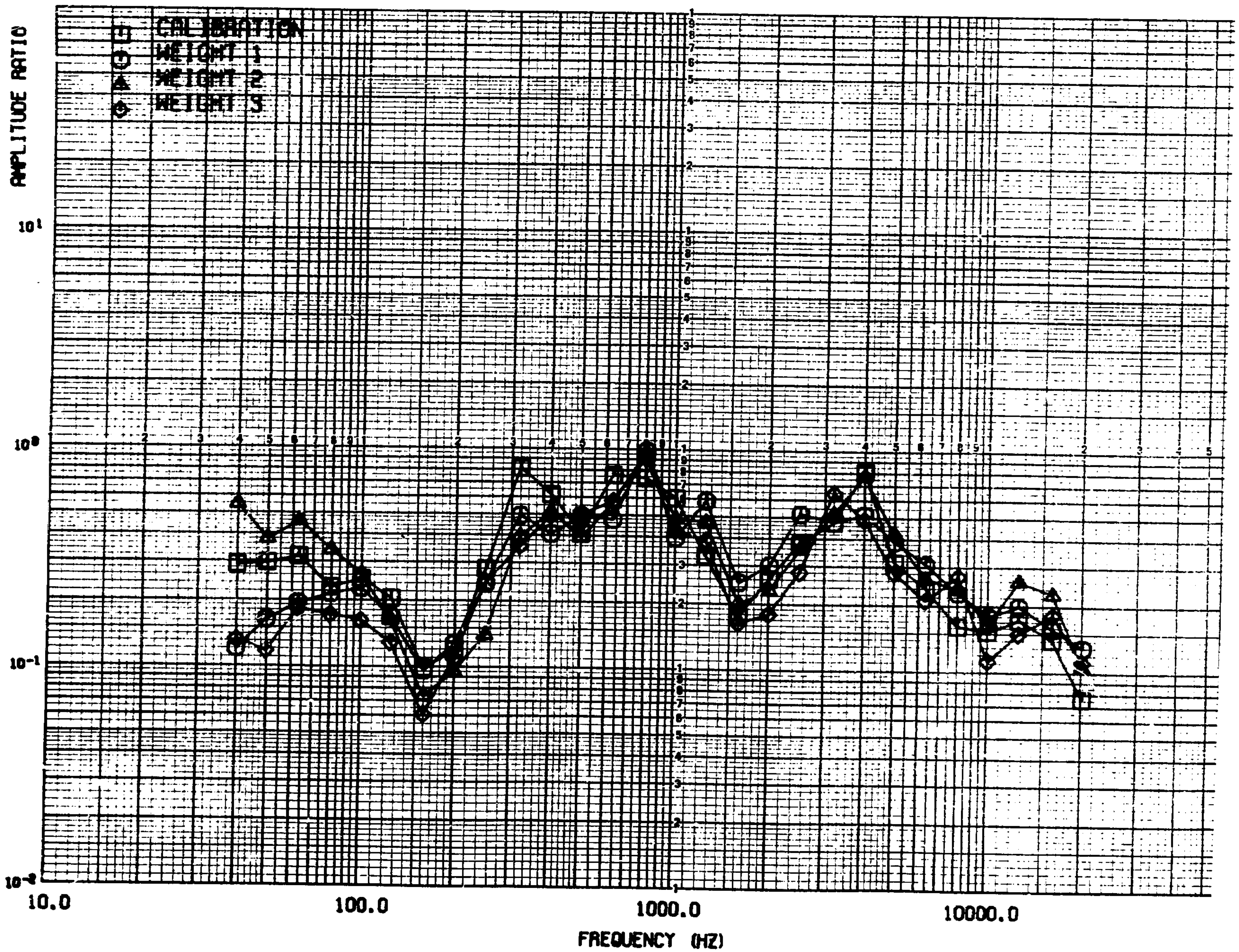


FIGURE 91A. NORMALIZED SHOCK SPECTRA - ACCEL 19. PHASE II DISTRIBUTED MASS

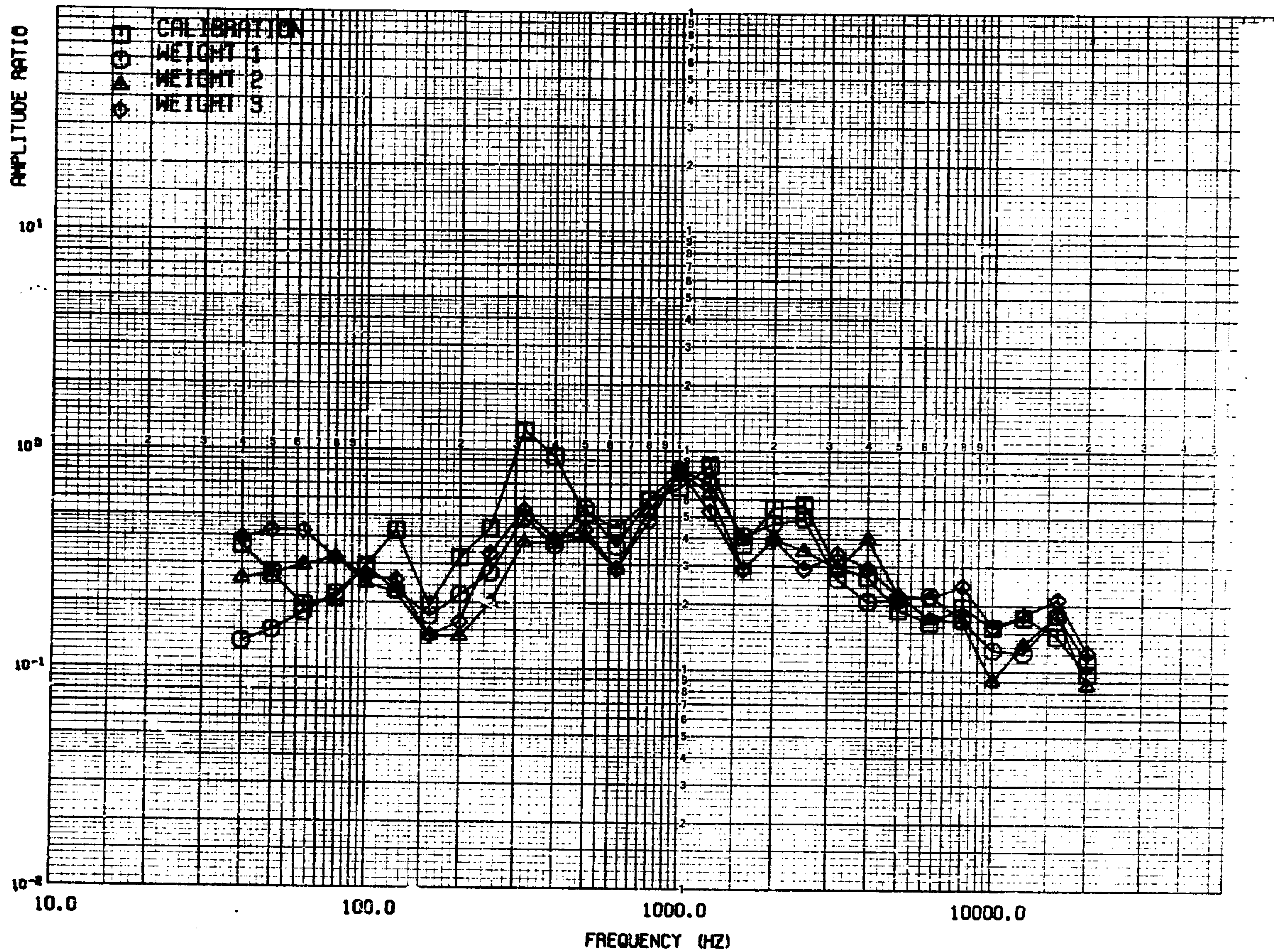


FIGURE 92A. NORMALIZED SHOCK SPECTRA - ACCEL 20. PHASE II DISTRIBUTED MASS

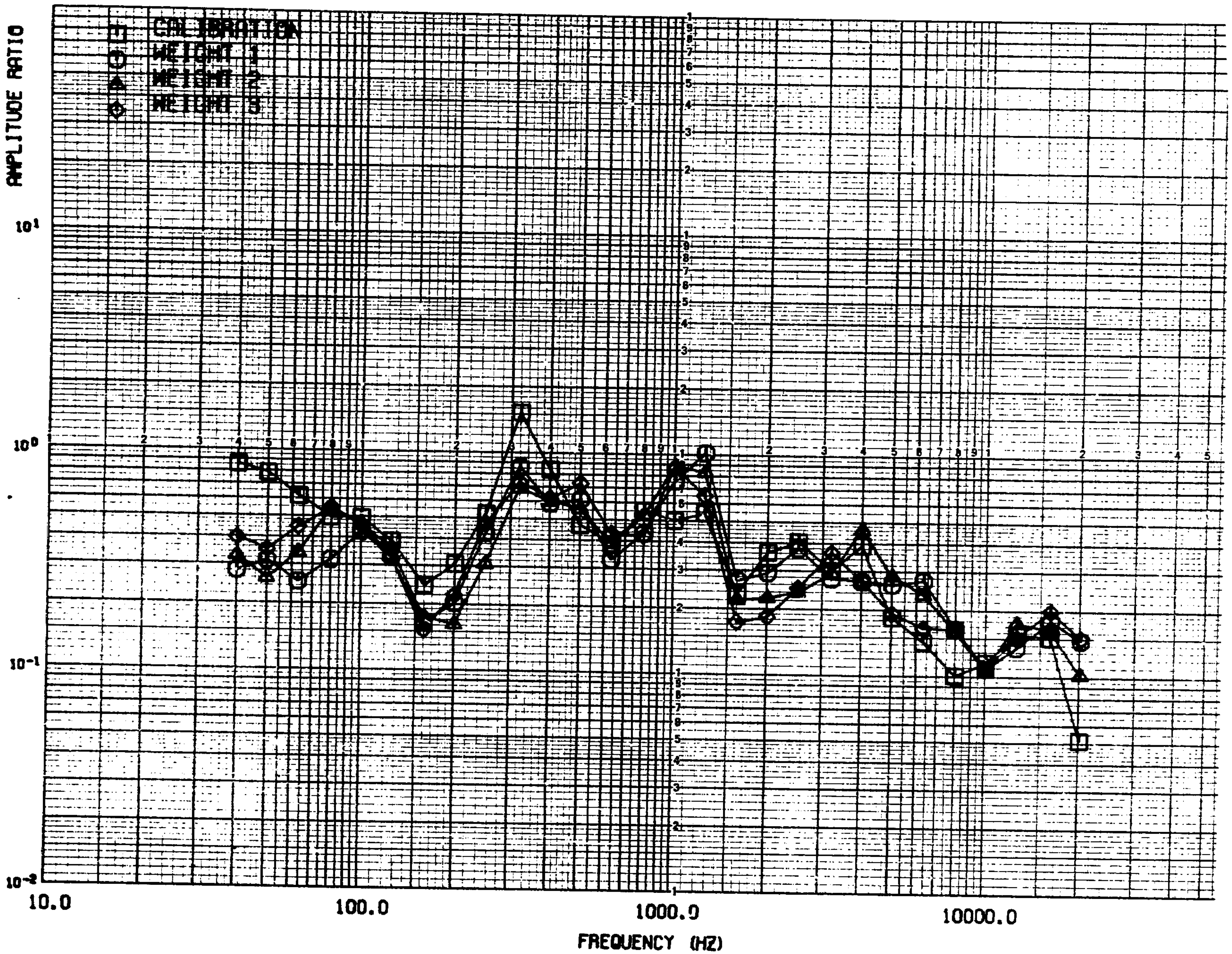


FIGURE 93A. NORMALIZED SHOCK SPECTRA - ACCEL 21. PHASE II DISTRIBUTED MASS

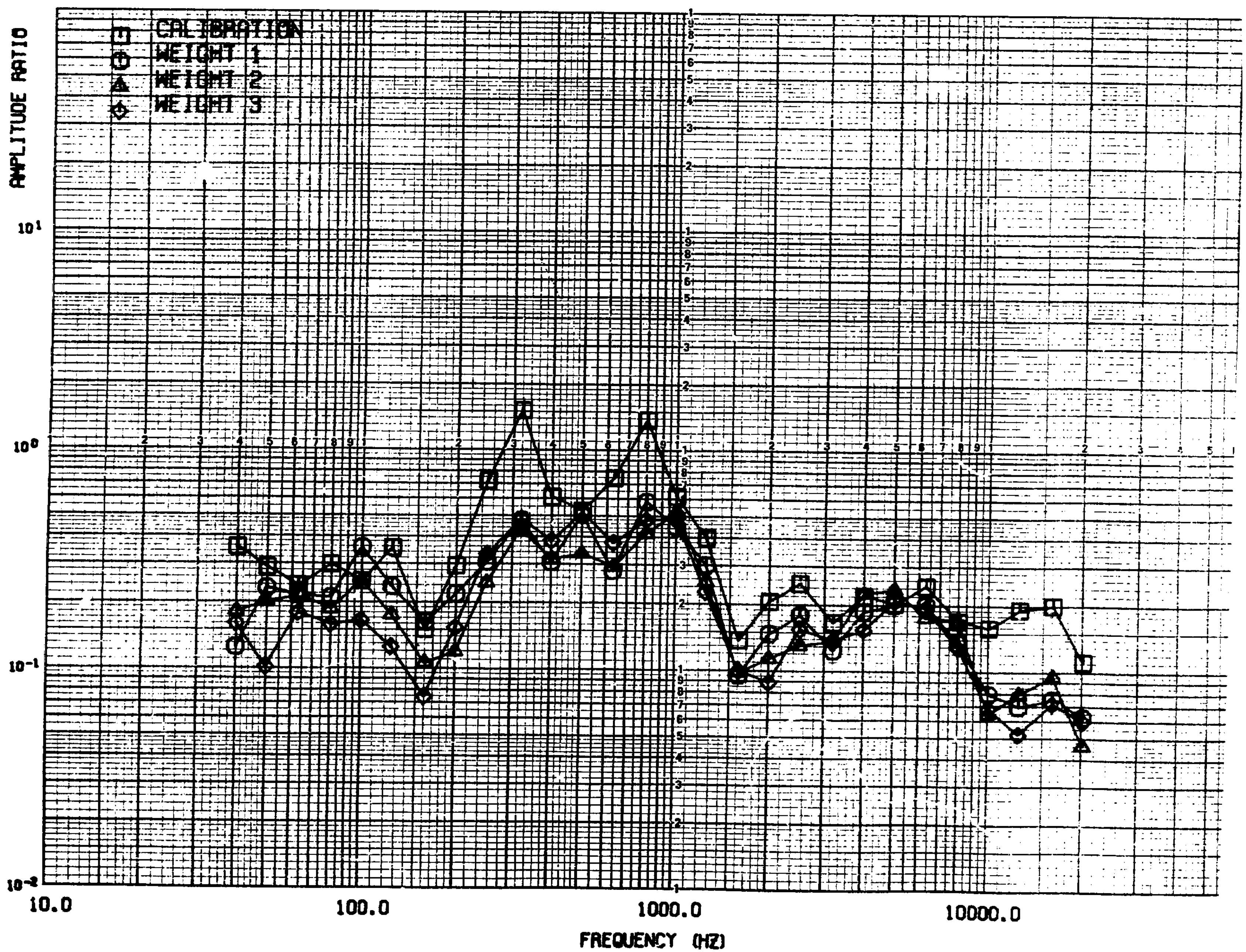


FIGURE 94A. NORMALIZED SHOCK SPECTRA - ACCEL 22. PHASE II DISTRIBUTED MASS

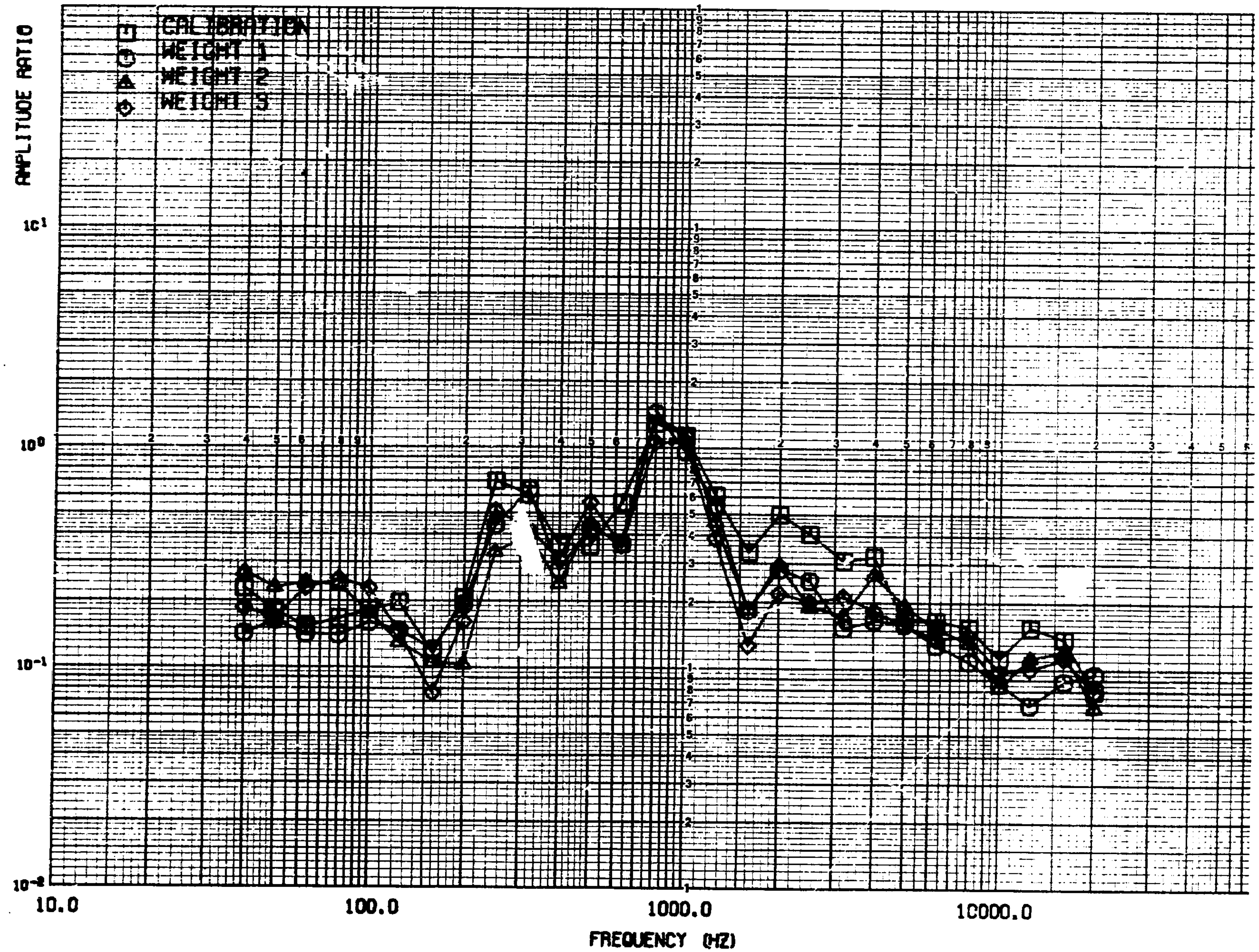


FIGURE 95A. NORMALIZED SHOCK SPECTRA - ACCEL 23. PHASE II DISTRIBUTED MASS

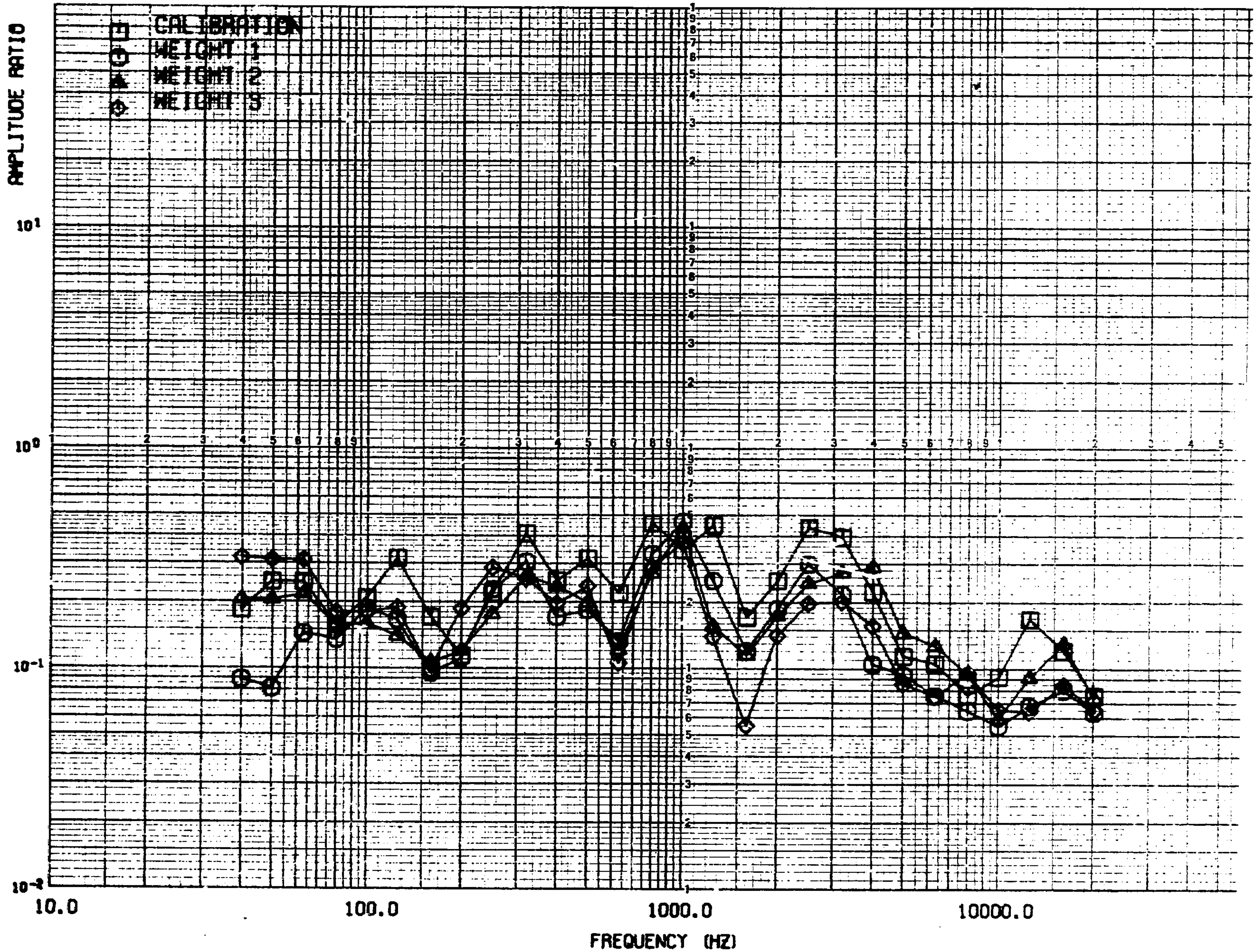


FIGURE 96A. NORMALIZED SHOCK SPECTRA - ACCEL 24. PHASE II DISTRIBUTED MASS