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FIRING SHOCK MEASUREMENTS ON THE M16 RIFLE/M203 GRENADE LAUNCHER SYSTEM

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FRANKFORD ARSENAL
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Technical Support Directorate

U.S. ARMY ARMAMENT COMMAND
FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA 19137

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A firing program carried out on an M16 Rifle with an M203 Grenade Launcher attached is described during which shock measurements were obtained on a mock-up of a proposed Mini-Laser Rangefinder. Firing data obtained using 40 mm and 5.56 mm Ammunition.

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INTRODUCTION

The Frankford Arsenal has been engaged in the development of fire control instruments for most of the Army's weapon systems. These instruments range from complete integrated systems for major vehicles to small arms sighting devices. One of the major accomplishments has been the development of laser rangefinders which pinpoint target distances. In the past this type of fire control has been used almost exclusively in large weapon systems such as tanks, howitzers and even aircraft, such as helicopters. Consideration is now being given to adapting a minilaser rangefinder to a small arms system. Probably the most severe environment this fire control will be subjected to is the high intensity shock resulting from firing of the weapon. The instrument must not only structurally survive the firing shock but it must also maintain boresight within extremely close tolerances.

This report describes a data measurement program which was undertaken in order to gain information on the firing shock environment of a small arms fire control system. In these tests shock measurements were obtained on an M16 rifle with an M203 grenade launcher attached. While the program was primarily concerned with describing the shock environment at the mounting point of the range finder, the data obtained should also provide a useful guide in the design and testing of other M16 rifle mounted equipment.

WEAPON DESCRIPTION

The weapon used in this test program is shown in Figure 1. It consists of two systems, the M16 rifle and the M203 grenade launcher.

The M16 rifle is a 5.56mm, magazine-fed, gas operated, air cooled, shoulder fire weapon. It has semi-automatic and full automatic firing capability. The M203 grenade launcher incorporates a 40mm ammunition system with the M16A1 rifle. The launcher is a breech loaded, single shot, rifled weapon. The barrel slides forward on a dovetailed rail for loading or ejecting. The M203 is mounted directly below the barrel of the rifle and it has a separate trigger.

Figure 1. M16 Rifle/M203 Grenade Launcher System

AMMUNITION DESCRIPTION

The M16 fires a 5.56mm caliber round which has a total weight of 179 grains. The bullet head (projectile) alone weighs 55 grains. Standard ball propellant is used in this test. The M203 fires a 40mm caliber round which has a total weight of approximately 0.5 lb. ($0.23k_g$). An XM387E4 proof cartridge is used in this program. This cartridge is produced for use during weapon acceptance tests and contains no warhead or explosive.

DYNAMIC ANALYSIS

A simplified dynamic analysis of the weapon was made prior to the field test. This was done in order to gain some insight for estimating the maximum accelerations to be measured when the gun would be fired. A knowledge of the maximum accelerations is useful both for initial calibration of the instrumentation and also for checking the validity of the measured data.

From reference 1, the maximum accelerating force to the weapon from the firing of 5.56mm ammunition is estimated to be about 2090 lb. For a loaded test weapon which weighs about 11.5 lbs, the maximum acceleration imparted in the direction of the shock is given by

$$\text{Weapon Acceleration} = \frac{2090}{11.5} = 180 \text{ g's}$$

The maximum accelerating force to the weapon from the firing of the 40mm ammunition is estimated from the peak of the pressure-time history. Per conversation with Mr. Robert Smith of Picatinny Arsenal, the maximum theoretical chamber pressure for the grenade ammunition is approximately

[1] Firing Shock Measurements on the M16 Rifle, Memorandum Report M72-5-1, by James H. Wiland, Frankford Arsenal, Phila., Pa. April 1972

3000 lbs per square inch. For a diameter of 40mm (.787 in. radius) the maximum accelerating force is given by

$$F = \pi r^2 p = \pi \ (.787)^2 (3000) = 5840 \text{ lb.}$$

The corresponding acceleration to the weapon which weighs about 12 lbs when loaded is found as follows:

$$\text{Weapon Acceleration} = \frac{5840}{12} = 487 \text{ g's}$$

Therefore, the expected peak acceleration in the longitudinal axis during grenade firing should be approximately 487 g's. The corresponding pulse width should be less than a millisecond.

MOCK-UP OF THE MINI LASER RANGEFINDER

Since there were no prototypes of the laser rangefinder available for the field test, a mock-up box (weight = 1 lb, dimensions = 4" x 3" x 2") was made. The design considerations on the weight distribution necessitated the welding of a small aluminum block inside of the box onto the face mounted to the weapon. The mock-up is shown in Figures 2 and 3.

A reflex collimator sight mount was used to fasten the mock-up to the rifle. Although not intended for use with the laser rangefinder, it was the only mount available which would fixture the dummy sight in the approximate usage position. In order to permit fastening of the mount, it was necessary to machine off the front sight post and most of the rifle carrying handle. Sections of this handle were machined into two webs, one forward and one rearward. The mount straddled these webs and was secured by both torqued machine screws and pins. The mount, itself, consisted of three basic components; a baseplate which was fastened to the weapon, an elevation adjustment bar hinged on the forward end of the base plate, and an azimuth adjustment bar hinged vertically on the elevation adjustment bar. All adjustments were locked with jam screws and setscrews.

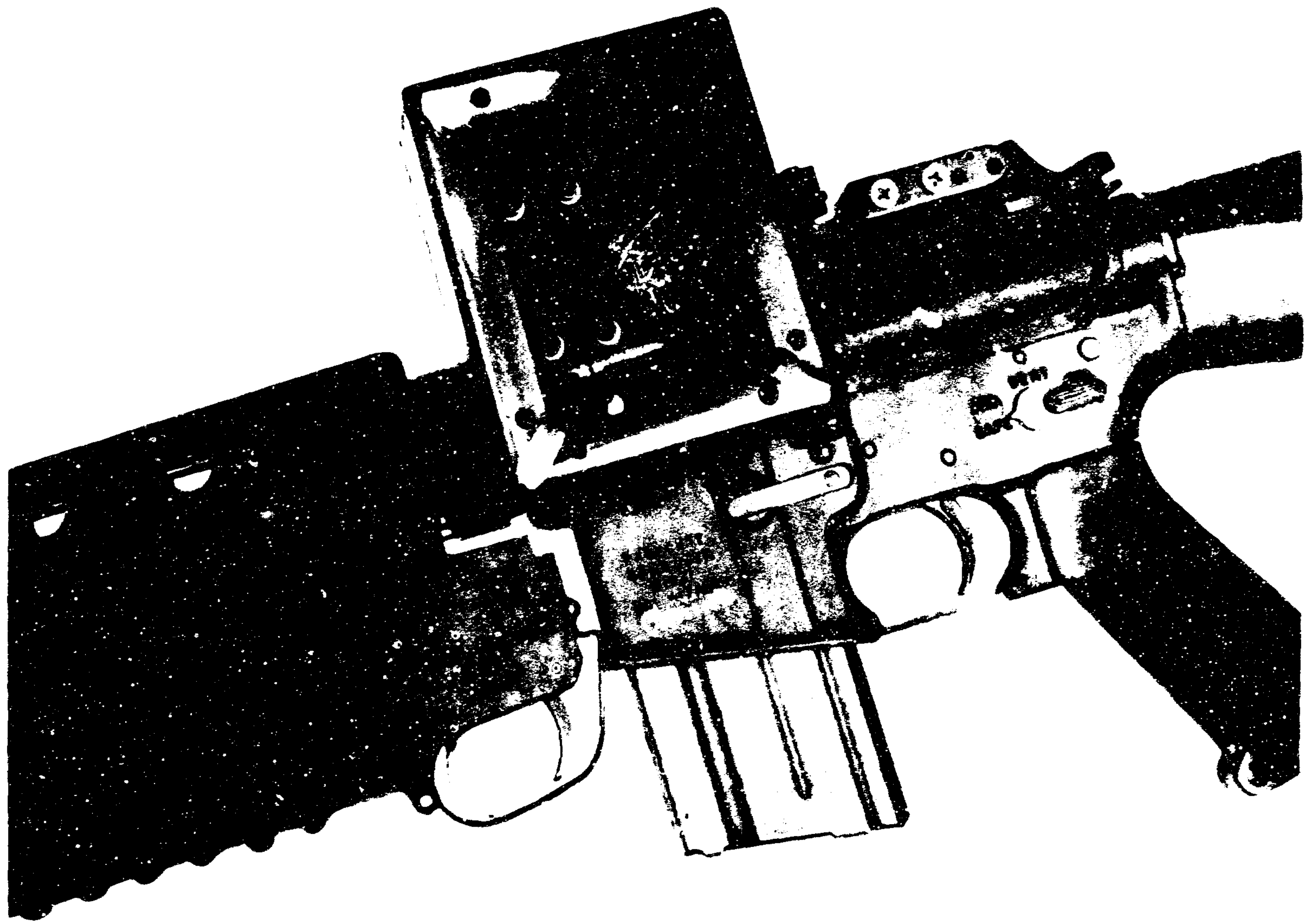

Figure 2. Close-Up of the Mock-Up Box With Cover Removed

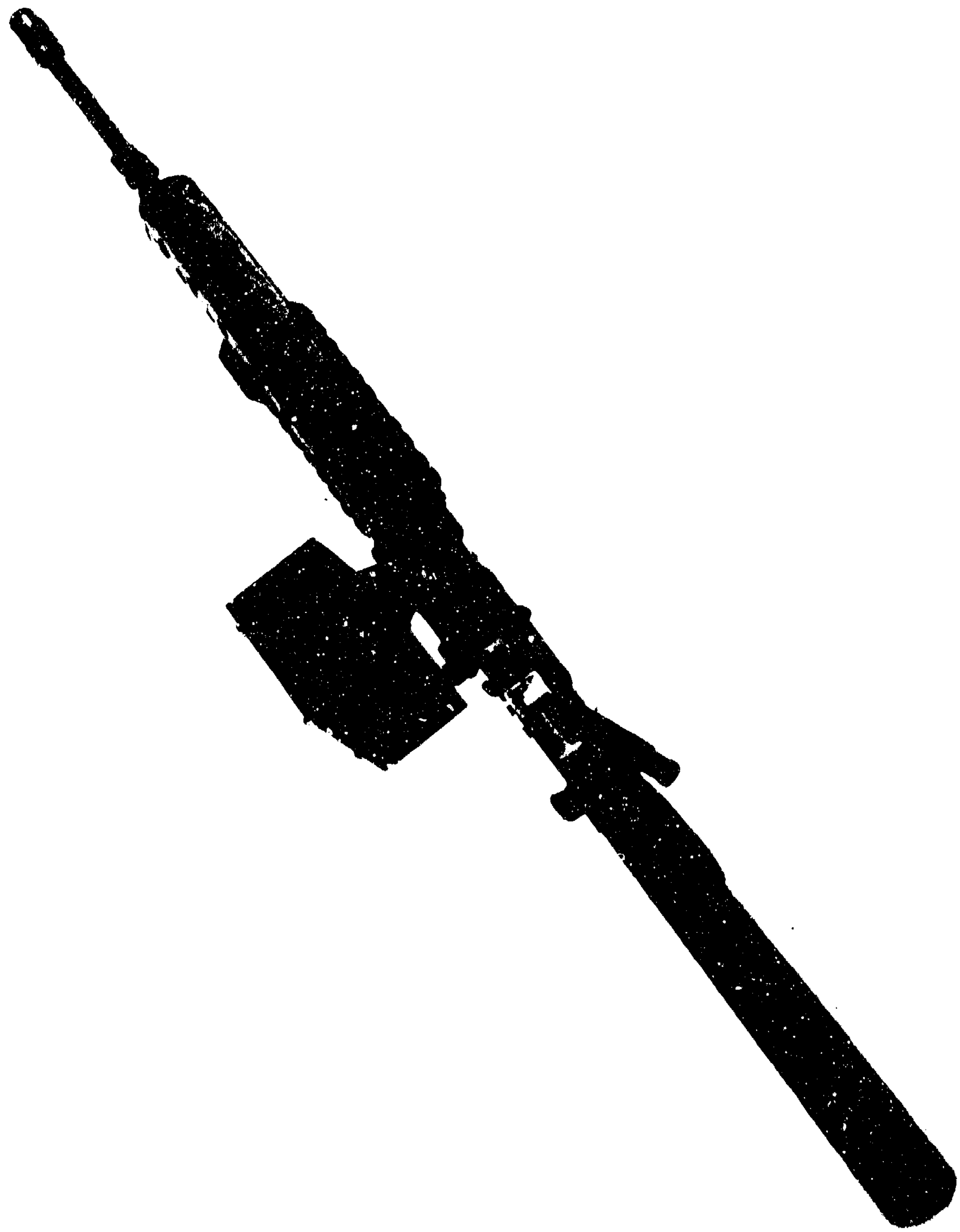

Figure 3. Top View of Weapon Depicting Mock-Up Mounting Technique

TEST PROGRAM AND INSTRUMENTATION

The firings and data acquisition were made at the Frankford Arsenal test ranges located at Fort Dix, New Jersey, on 23 July 1975. The F. A. Mobile Instrumentation Laboratory was driven to the test site, and used for signal conditioning and tape recording the data. The test instrumentation consisted of the following:

1. Three piezoelectric shock accelerometers, Endevco model 2225.

2. Three "zero drive" signal conditioning systems, MB model N400 amplifiers and line drivers.

3. One 14-channel Sangamo model 3562 FM tape recorder operated at 30 ips.

The accelerometers were bonded to the aluminum block inside the mock-up using Grip commercial dental cement. They were oriented so that measurements along three mutually perpendicular axes could be obtained. The positioning is described in Table 1 and shown in Figure 4.

Table 1. Accelerometer Positions

Tape Channel	Acc. Serial No.	Direction
1	HB79	Transverse (left - right)
2	HB31	Vertical (relative to the barrel axis)
3	CH07	Longitudinal (barrel axis)

Firing shock data was desired for various combinations of gun elevation, gun positioning, rifle firing rate and type of ammunition. A listing of the test firing conditions is presented in Table 2.

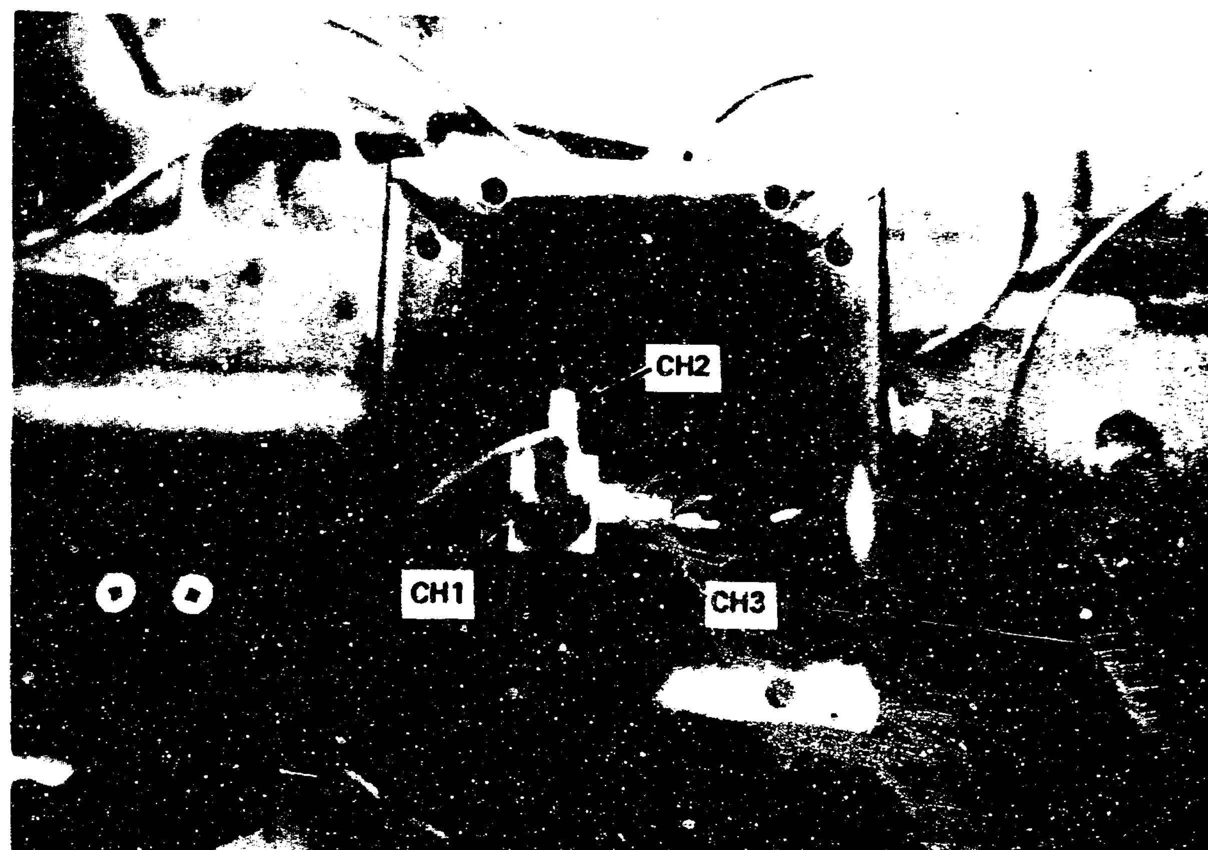

Figure 4. Accelerometer Mounting Locations

Table 2. Test Firing Conditions

Ammunition	Description	# Rounds
1. 40mm	Shoulder fire, high elevation	3
2. "	" " , med elevation	3
3. "	" " , low elevation	3
4. "	Hip fire, high elevation	3
5. "	" " , med elevation	3
6. "	" " , low elevation	3
7. "	Arm pit fire, high elevation	3
8. "	" " " , med elevation	3
9. "	" " " , low elevation	3
10. 5.56mm	Low, semi-auto	5
11. "	Rapid, semi-auto	5
12. "	Burst, automatic	10
13. "	Burst, automatic	7

During the grenade firing, high elevation was approximately 45°. Medium and low elevations were about 30° and 15° respectively.

DATA PROCESSING

The data was returned to Frankford Arsenal where it was processed for data analysis. Oscillograms and shock spectra were made for each test condition. The oscillograms contain information in the form of acceleration-time histories and are used to describe the shock in terms of peak G-level, pulse width and pulse shape. Shock spectra, which are plots of acceleration vs. frequency, can be used to evaluate the damage potential of the shock environment. Each frequency represents the natural frequency of a single degree of freedom system and the accelerations are the maximum accelerations each single degree of freedom would experience when subjected to the given shock. For the example of the mock-up of the laser rangefinder, a shock spectrum obtained near the mount can be used to determine the input acceleration to the fire control if it were considered as a one degree of freedom system and subjected to the gun-fire shock.

RESULTS

A sampling of oscillograph records are presented in figures A-1, A-2, and A-3 and selected shock sprectra are shown in figures B-1 thru B-6.

DISCUSSION OF RESULTS

After reviewing all the time histories and shock spectra for the grenade firing, it was apparent that the shock was independent of the gun orientation. The results of high elevation firing were identical to medium or low elevation firing. There was also no significant difference between records when the weapon was supported against the shoulder and records with the weapon supported under the gunner's arm pit or against the hip. Therefore, the oscillograms and shock spectra shown in this report represent the typical grenade launched gunfire environment for the M203 system.

Examining the time history response for the grenade launched gunfire condition (Figure A-1), the longitudinal axis shows an initial high frequency shock of about 480 g's and 0.5 ms. This is followed by a short duration of high frequency and a damped vibration with a period of about 11 ms. The initial peak is representative of the mock-up response to the shock from the combustion pressure-time history. The short duration of high frequency is probably due to the response of the aluminum block welded inside the mock-up vibrating at its resonance. The damped vibration, when taking into consideration the result along the transverse axis, is indicative of the mock-up behaving as a torsional mass-spring system with a natural frequency of about 90 Hz. The oscillogram along the vertical (relative to the barrel) axis indicates that the mock-up is much stiffer in this direction and the measured acceleration-time history is the high frequency response of the aluminum block. The oscillogram in the transverse axis shows the 90 Hz. damped residual vibration. Two axes, longitudinal and transverse, both showing residual motion at an identical frequency indicated a rotational (torsional mode) vibration about the vertical axis.

The shock spectra (figures B-1, B-2 and B-3) clearly show the large responses at about 90 Hz. in the longitudinal and transverse axes. A significant result in comparing the three shock spectra is that the curve from the longitudinal axis is the highest throughout most of the frequency range. This indicates that most severe damage potential is in this axis. (In stating "most severe damage potential", the failure mode is considered to be bending). The relatively large responses in all three spectra in the region from 3000 to 4000 Hz. are not considered as critical as the lower frequency responses. The mount for the mini-laser range finder, which has yet to be determined, will probably have a resonance well below a few thousand hertz and hence, it will provide structural filtering which will attenuate the high frequency components of the gunfire shock.

A comparison of the longitudinal shock spectrum to theoretical spectra of simple shock pulses reveals that a 400 g, 0.5 ms half-sine pulse would produce about the same effect on the weapon as the gunfire shock. Using a similar procedure, the effect of the transverse and vertical shocks could be approximated by 100 g's, 1.0 ms. and 250 g's, 0.5 ms. half-sine pulses, respectively.

Examining the acceleration-time history from the firing of 5.56mm ammunition (figure A-2), the largest shock, as expected, occurs in the longitudinal axis. This shock has a peak of about 250 g's and is 1.0 ms. in duration. The responses in the other two axes are much lower. The rifle gunfire shock is seen to contain a second large transient about 70 ms. after the initial shock. In considering the mechanics of the rifle, this phenomena is attributable to the bolt going into battery. In the vertical and transverse axes, this shock is greater than the one produced by ammunition ignition. In looking at the record of burst firing (figure A-3) it is seen that this shock does not occur after the last round in a group has been fired. This is because the bolt is prevented from going into battery if no round is present.

In comparing the shock spectra of the rifle firing to those spectra from grenade firing, it is apparent that the grenade produces a higher level shock. The 90 Hz. resonance response is much less pronounced in the rifle gunfire shock and yet there is not much difference between the spectra in the high frequency range (greater than 2000 Hz). In comparing the rifle firing shock spectra to spectra of simple pulses, the effect on the weapon in the longitudinal axis can be approximated by a 250 g, 1.0 ms. half-sine pulse. Similarly, the effect on the weapon in the transverse and vertical axes are approximated by 100 g's, 1.0 ms. and 10[illegible] g's, 0.5 ms. half-sine pulses, respectively.

CONCLUSIONS

1. The shock produced from firing the 40mm grenade is of greater intensity than the shock from the 5.56mm bullet.

2. The maximum shock produced from grenade firing is about 480 g's, 0.5 ms. in the longitudinal axis.

3. Due to the mock-up mounting technique, there is a 90 Hz. torsional resonance about the vertical axis.

4. The shock produced from 5.56mm firing is of lower intensity than what was found in previous measurements with the M16 rifle. This is a result of the added weight on the rifle due to the attachment of the M203 system. An increase in weight results in a lower accelerating force to the weapon.

5. The dynamic analysis of the weapon resulted in an expected g-level which was very close to the measured g-level. Hence, this technique can and should be used prior to field testing.

RECOMMENDATIONS

1. Consideration should be given for the design of a special mount to be used with the laser rangefinder. The tested configuration, using a reflex collimator sight mount appears to be unacceptable because of the relatively low frequency resonance response to the high intensity shock produced by the grenade.

2. Based on shock spectrum analysis, the following laboratory shock pulse levels can be used to approximate the effect of the grenade firing on the weapon:

Longitudinal Axis	- 400 g's, 0.5 ms., half sine
Transverse Axis	- 100 g's, 1.0 ms., half sine
Vertical Axis	- 250 g's, 0.5 ms., half sine

APPENDIX A

Selected acceleration-time Histories of M16 Rifle With M203. Grenade Launcher Attached.

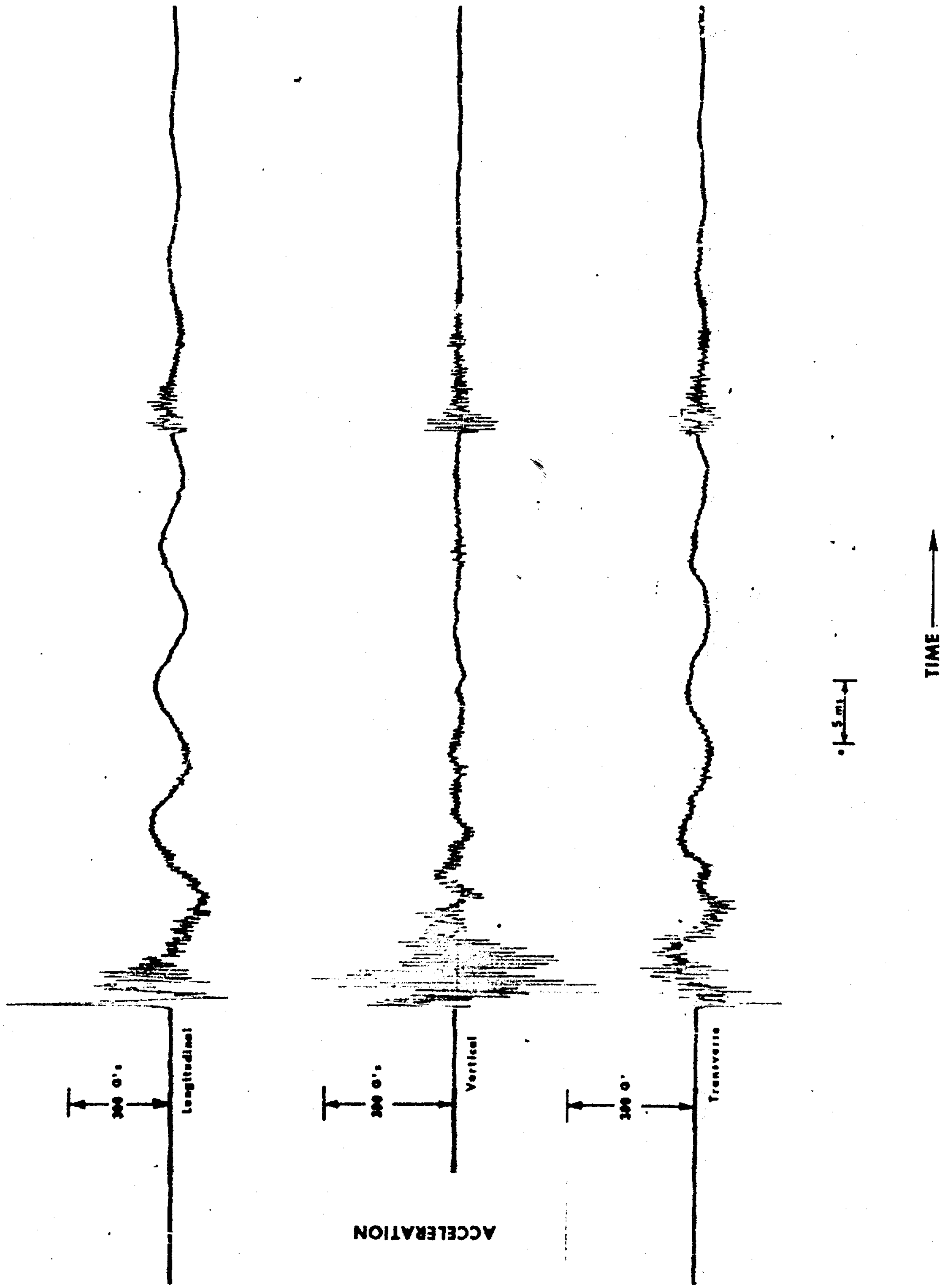

Figure A-1. Acceleration-Time History of a Typical M203 Grenade Launched Gunfire Shock

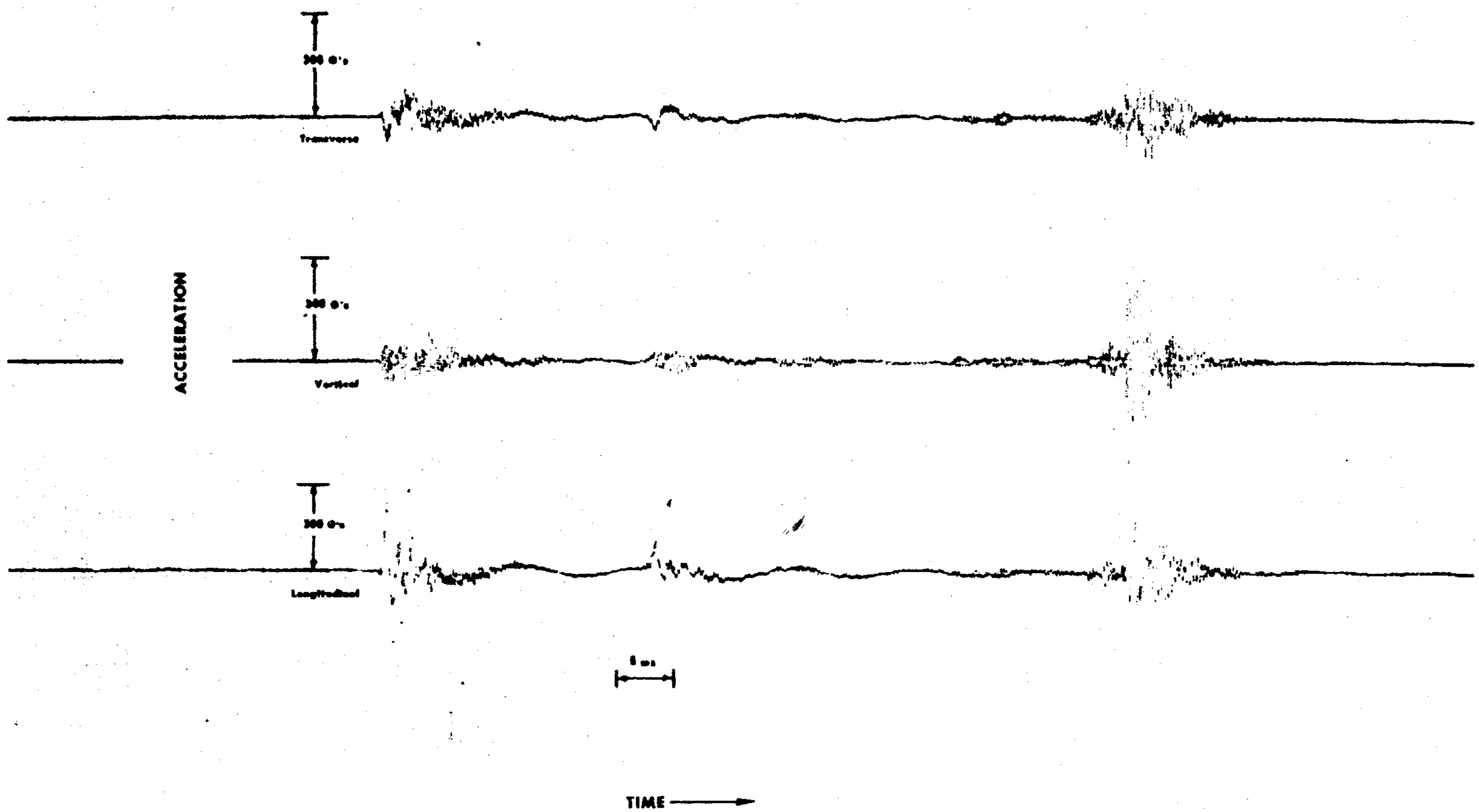

Figure A-2. Acceleration-Time History of a Typical M16 Rifle Gunfire Shock (Semi-Automatic)

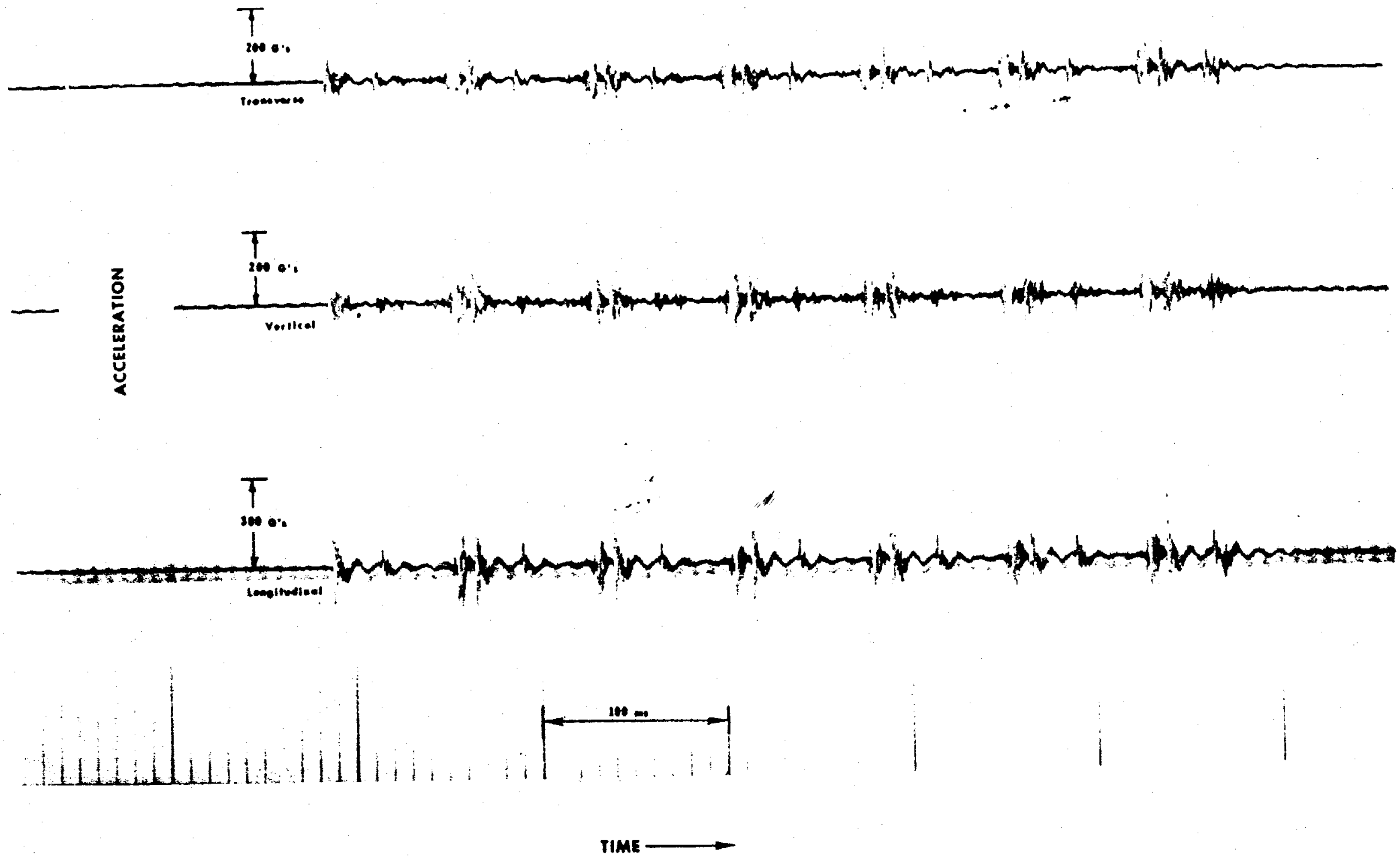

Figure A-3. Acceleration-Time History of a Typical M16 Rifle Gunfire Shock (Automatic Burst)

APPENDIX B

Selected Shock Response Spectra For M16 Rifle With M203 Grenade Launcher Attached.

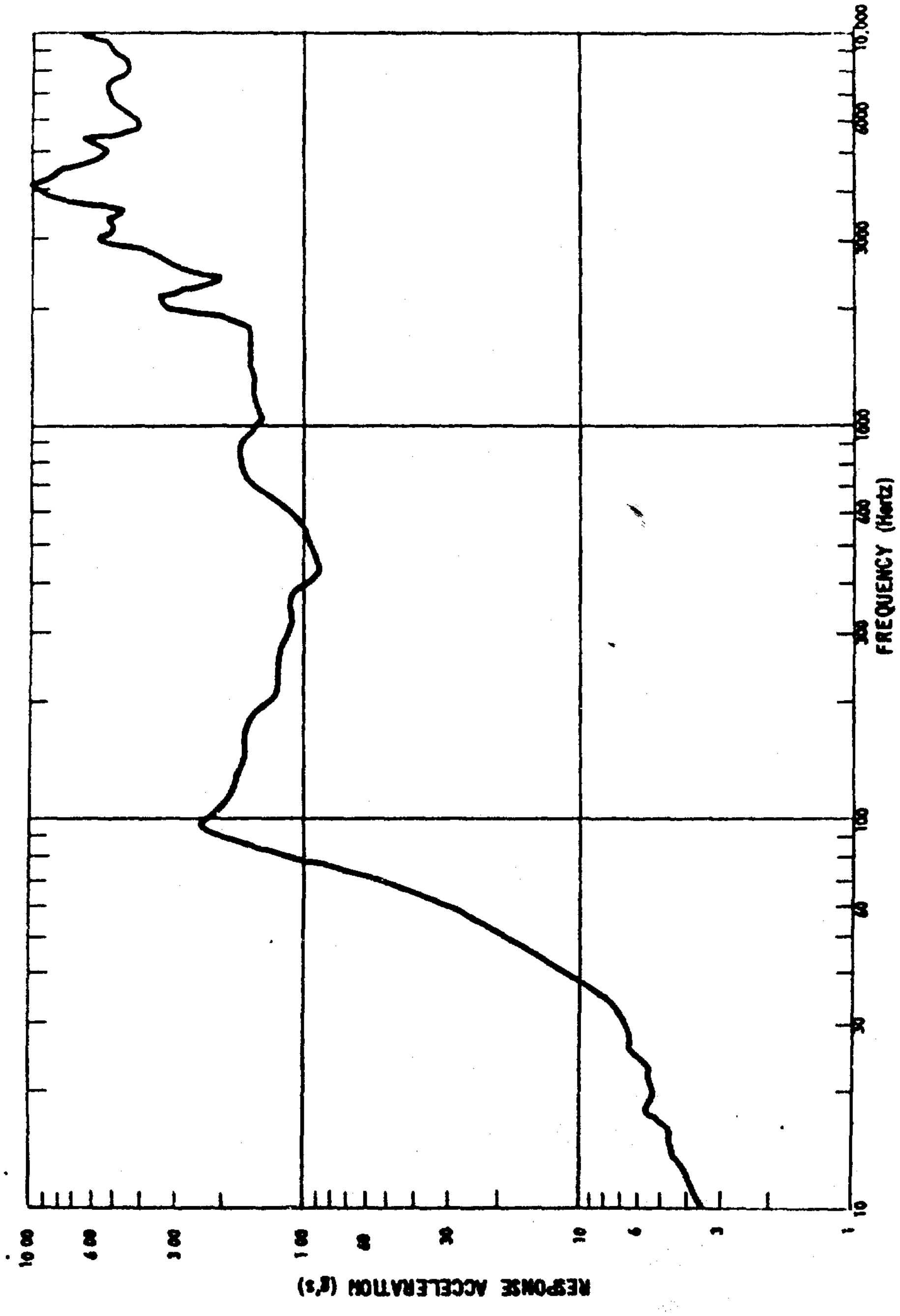

Figure B-1. Shock Spectrum of a Typical Grenade Launched Gunfire Shock-Transverse Axis

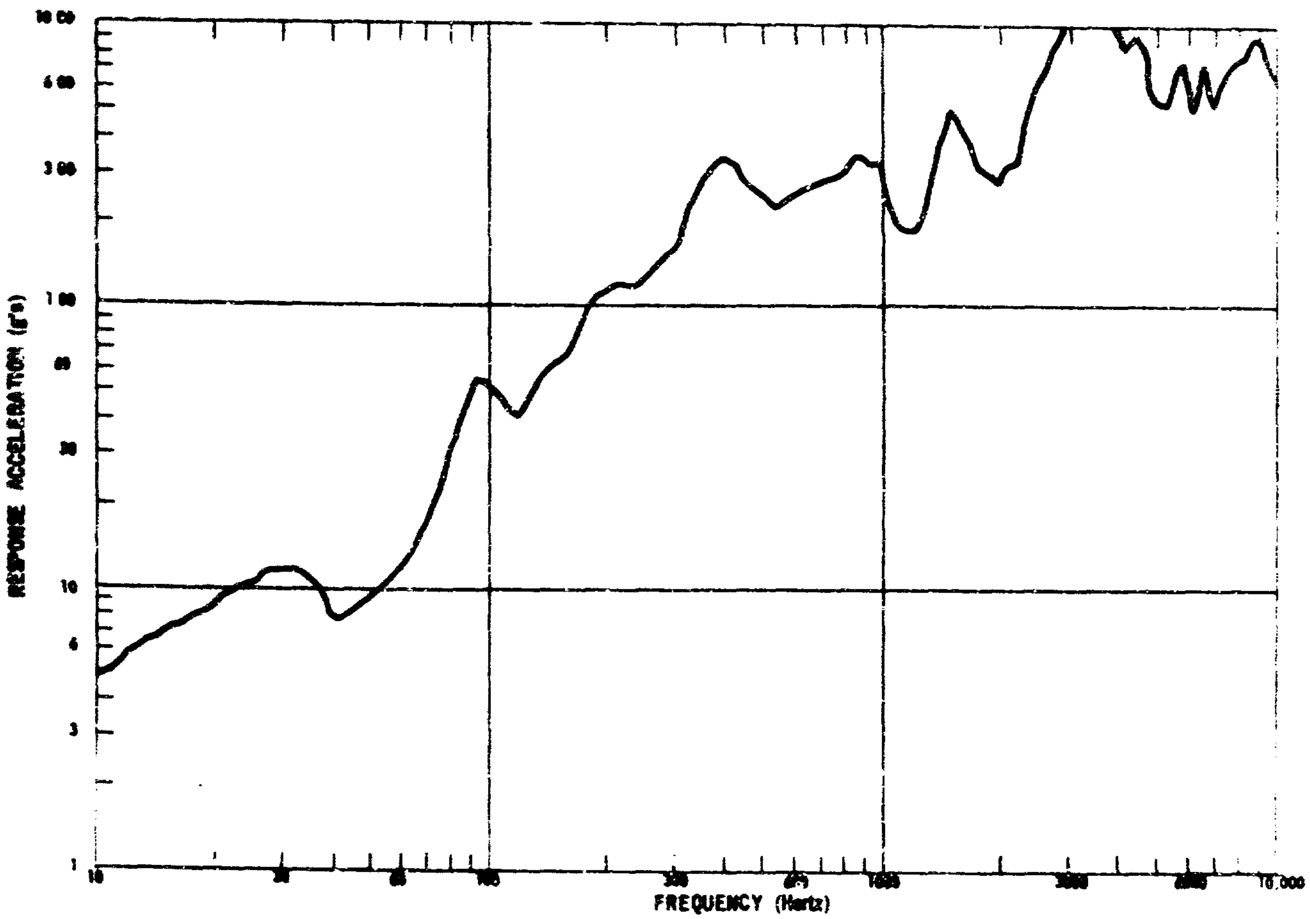

Figure B-2. Shock Spectrum of a Typical Grenade Launched Gunfire Shock-Vertical Axis

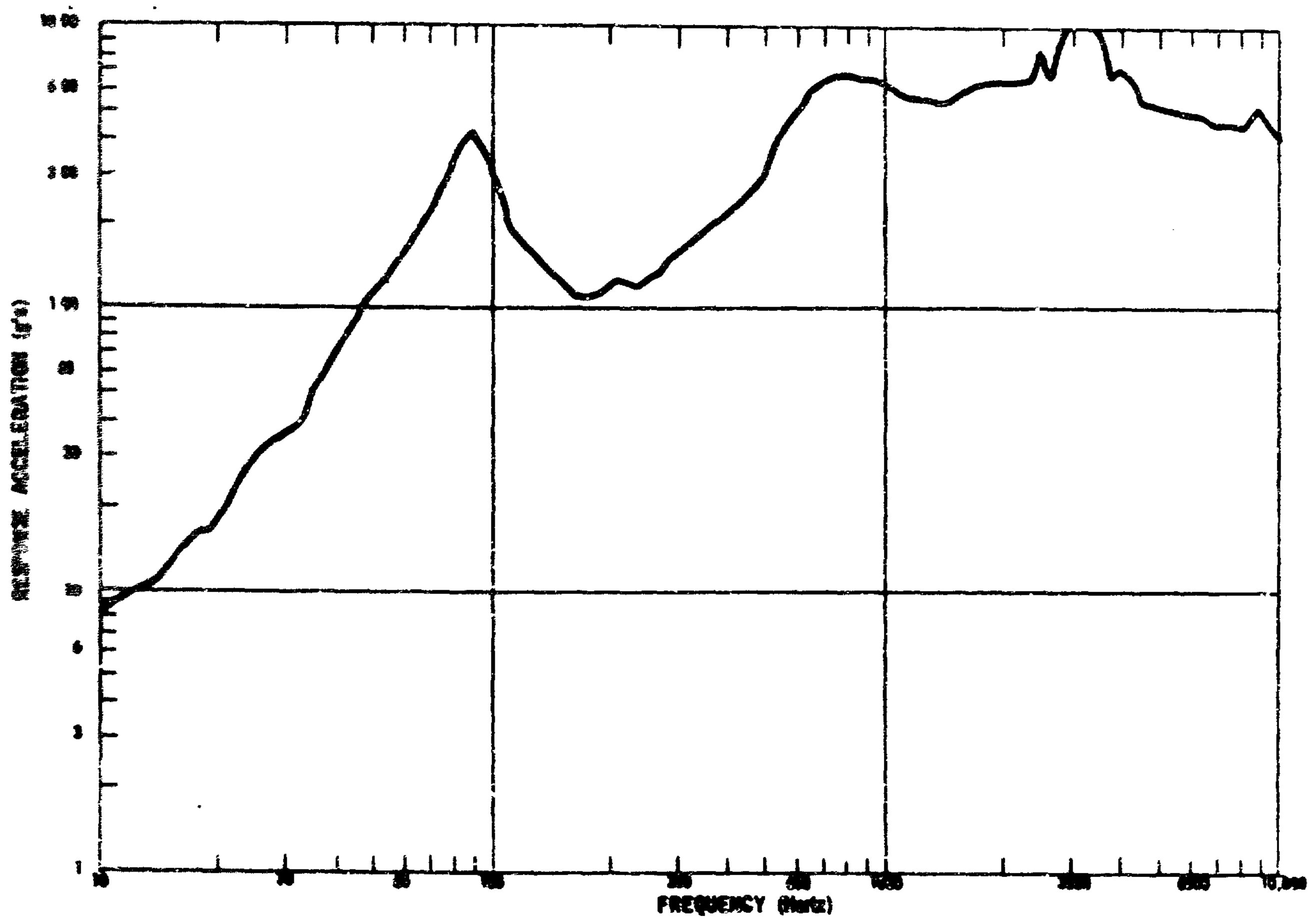

Figure B-3. Shock Spectrum of a Typical Grenade Launched Gunfire Shock-Longitudinal Axis

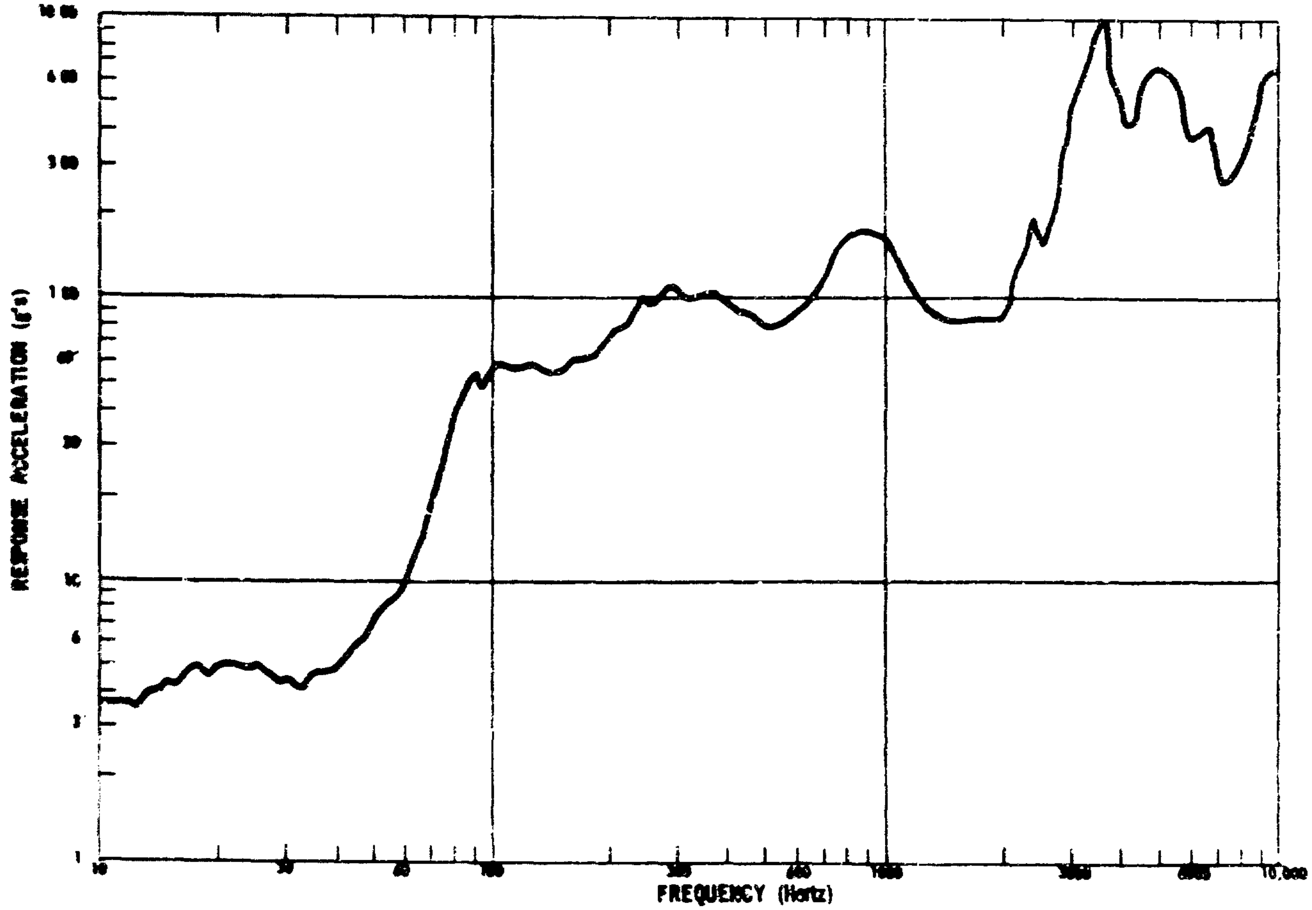

Figure B-4. Shock Spectrum of a Typical Rifle Gunfire Shock-Transverse Axis

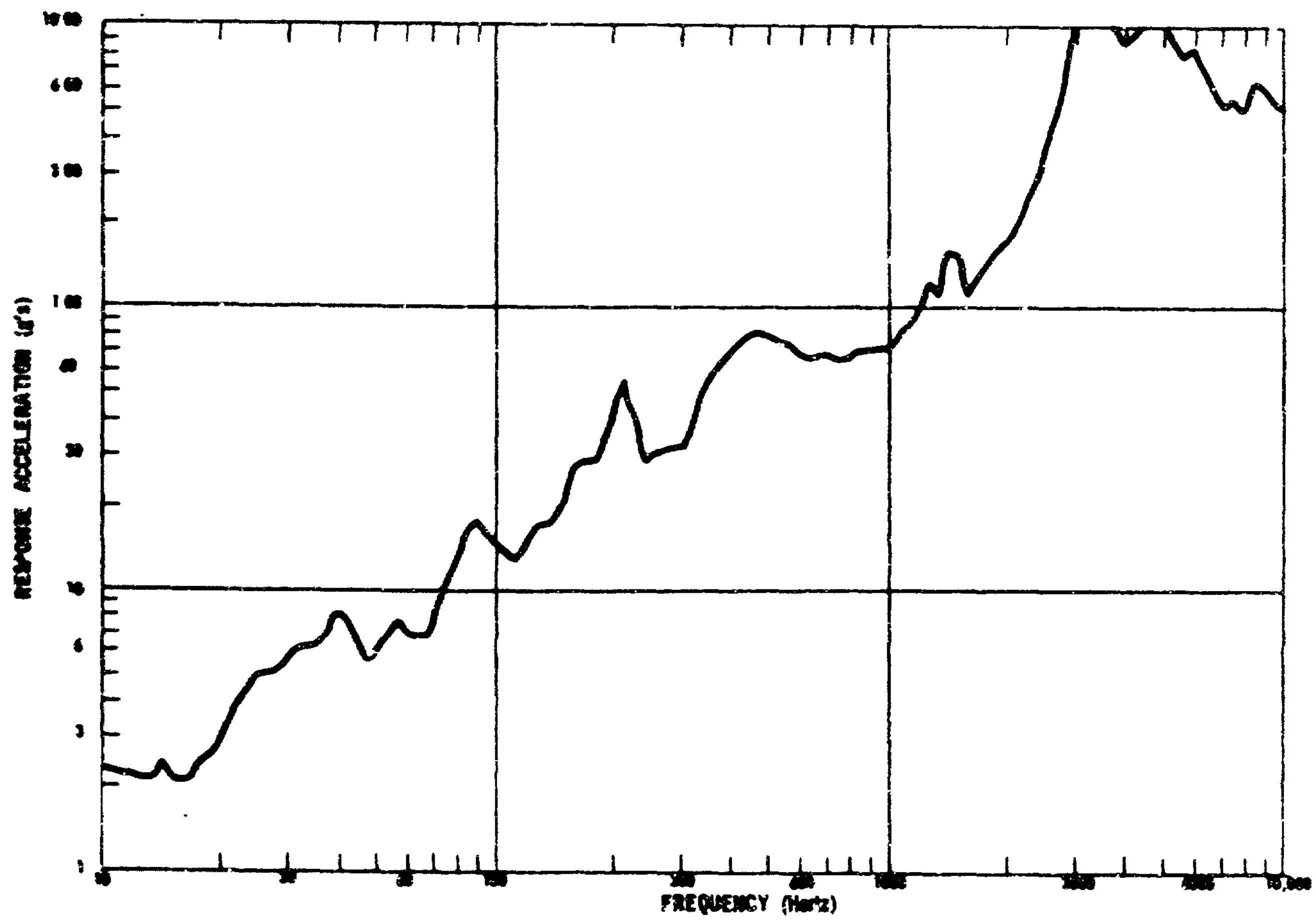

Figure B-5. Shock Spectrum of a Typical Rifle Gunfire Shock-Transverse

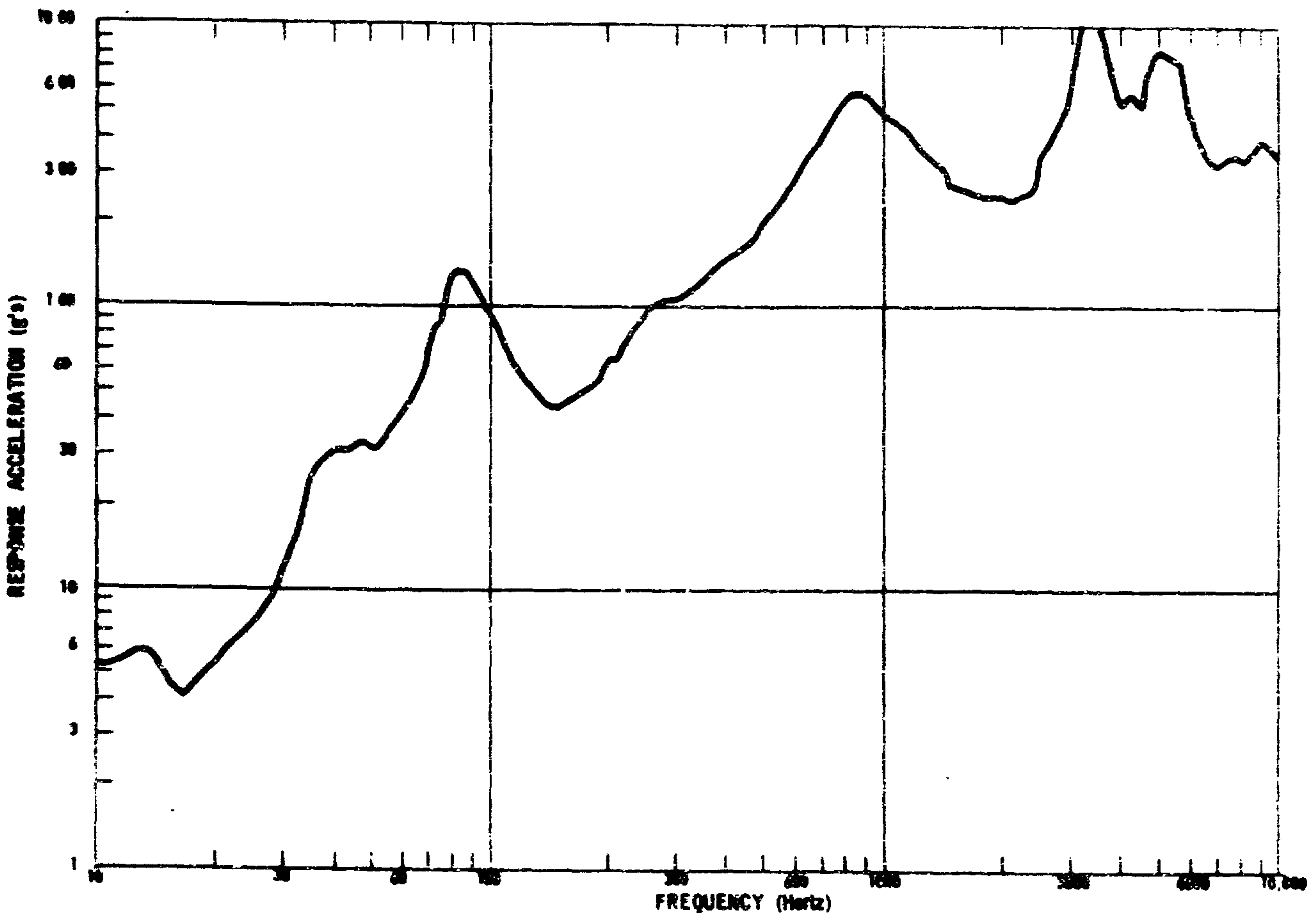

Figure B-6. Shock Spectrum of a Typical Rifle Gunfire Shock-Longitudinal Axis

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