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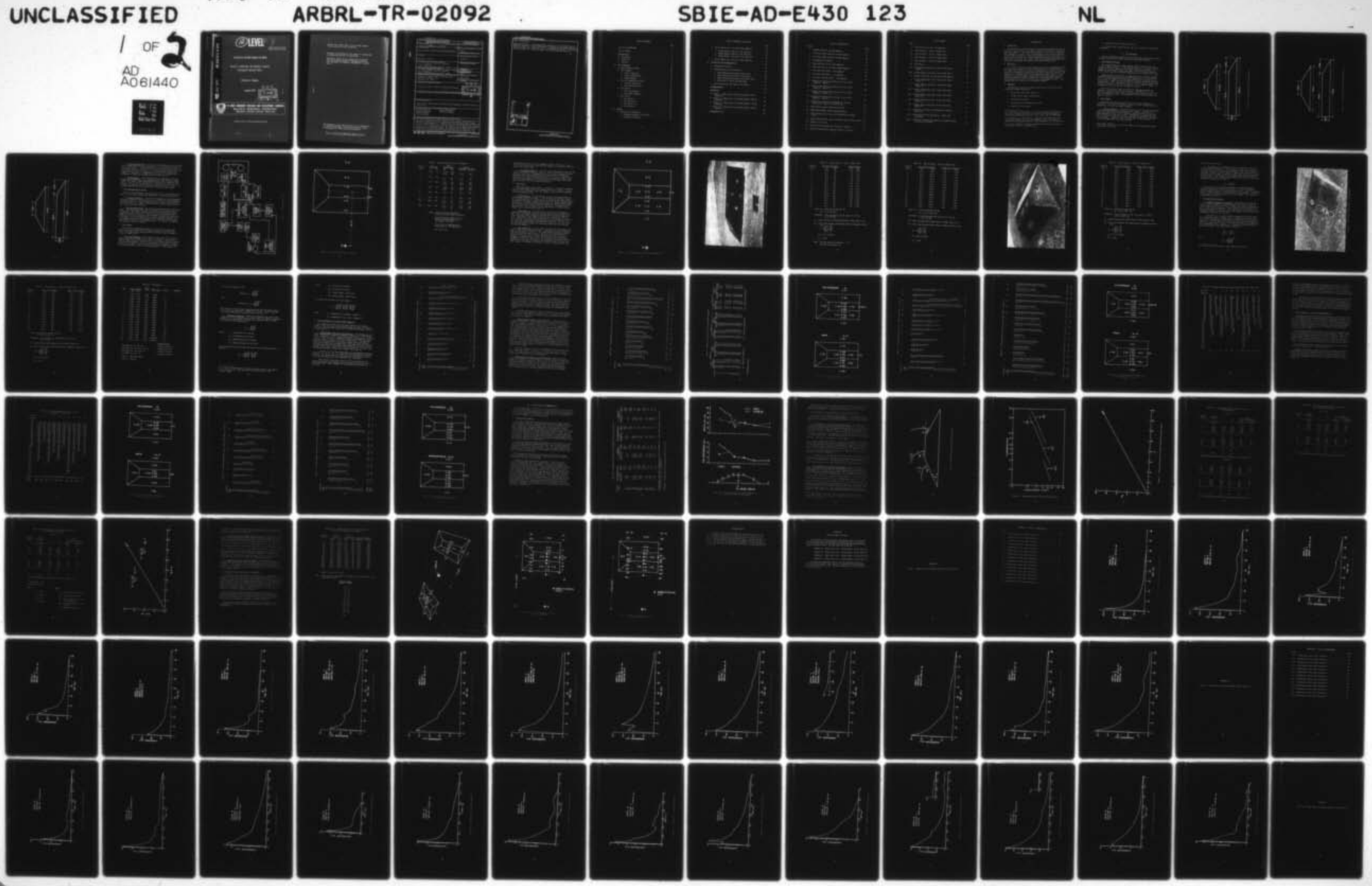

TECHNICAL REPORT ARBRL-TR-02092

# BLAST LOADING ON MODEL EARTH COVERED MAGAZINES

Charles N. Kingery

August 1978



US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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This report contains the results obtained from a series of high explosive tests designed to determine the blast loading on scaled models of earth covered munition storage magazines. A 1/30th scaled (non-responding) model was exposed to three charge weights (.454, .908 and 1.135 kg) and a 1/45th scaled model was exposed to a .454 kg charge weight. The objective was to determine the weight, configuration and stand-off distance for an uncovered TNT charge that would produce the pressure and impulse loading obtained from the explosion of a loaded earth covered munition magazine when placed at the side to side safe

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separation distance. A 1/30 scaled model exposed to a 1.135 kg hemispherical pentolite charge at a stand-off distance of 1.6m gave the best model simulation. This will scale, for a full-size test, to a hemispherical charge of TNT weighing 34,050 kg placed 47.2 m from the center line of the acceptor structures.

TABLE OF CONTENTS


| | | Page |
|---|---|---|
| | LIST OF ILLUSTRATIONS | 5 |
| | LIST OF TABLES | 7 |
| I. | INTRODUCTION | 9 |
| | A. Background | 9 |
| | B. Objectives | 9 |
| | C. Approach | 9 |
| II. | TEST PROCEDURE | 10 |
| | A. Model Magazine Design | 10 |
| | B. Test Charges | 10 |
| | 1. Type of Explosive | 10 |
| | 2. Charge Configuration | 14 |
| | 3. Charge Weights | 14 |
| | C. Test Instrumentation System | 14 |
| | 1. Pressure Transducer | 14 |
| | 2. Tape Recorder System | 14 |
| | D. Test Layout | 14 |
| | 1. Full Size Magazine | 14 |
| | 2. Scale Model Magazine | 18 |
| | E. Test Series | 18 |
| | 1. Test Series I | 18 |
| | 2. Test Series II | 18 |
| | 3. Test Series III | 18 |
| | 4. Test Series IV | 25 |
| III. | RESULTS | 25 |
| | A. Scaling Blast Parameters | 25 |
| | 1. Standard Atmospheric Conditions | 25 |
| | 2. Altitude Corrections | 29 |

TABLE OF CONTENTS (Continued)


Page

B. Blast Loading on a 1/30 Scale Model Magazine . . . . . . . . 30

1. Charge Weight 0.454 kg (1 lb) Pentolite . . . . . . . . 30
2. Charge Weight 0.908 kg (2 lb) Pentolite . . . . . . . . 32
3. Charge Weight 1.135 kg (2.5 lb) Pentolite . . . . . . . 32

C. Blast Loading on a 1/45 Scale Model Magazine . . . . . . . . 40

IV. DISCUSSION AND RECOMMENDATIONS . . . . . . . . . . . . . . . . . 46

A. Comparison of Results . . . . . . . . . . . . . . . . . . 46

B. Shock Reflection and Diffraction . . . . . . . . . . . . . . 48

1. Mach Reflection Pressure on Front Slope . . . . . . . . 49
2. Shock Diffraction Pressure on the Roof . . . . . . . . . 49
3. Shock Diffraction Pressure on the Rear Slope . . . . . . 57
4. Discussion of Theory and Experiment . . . . . . . . . . 57

C. Predicted Pressure and Impulse for Eskimo V . . . . . . . . 57

ACKNOWLEDGMENTS . . . . . . . . . . . . . . . . . . . . . . . . 62

APPENDIXES . . . . . . . . . . . . . . . . . . . . . . . . . . . 63

A. Series I - Model Scale 1/30 Charge Weight 0.454 kg Pentolite . . . . . . . . . . . . . . . . . . . . . . . . 65

B. Series II - Model Scale 1/30 Charge Weight 0.908 kg Pentolite . . . . . . . . . . . . . . . . . . . . . . . . 83

C. Series III - Model Scale 1/30 Charge Weight 1.135 kg Pentolite . . . . . . . . . . . . . . . . . . . . . . . . 99

D. Series VI - Model Scale 1/45 Charge Weight 0.454 kg Pentolite . . . . . . . . . . . . . . . . . . . . . . . . 111

DISTRIBUTION LIST . . . . . . . . . . . . . . . . . . . . . . . 125

## LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| 1. | Standard Munition Storage Magazine | 11 |
| 2. | 1/30 Scale Model Munition Storage Magazine | 12 |
| 3. | 1/45 Scale Model Munition Storage Magazine | 13 |
| 4. | Instrumentation System | 15 |
| 5. | Gage Locations on Full Size Magazine | 16 |
| 6. | Gage Locations on 1/30 Scale Model Magazine | 19 |
| 7. | 1/30 Scale Wood Model - Instrumented | 20 |
| 8. | 1/30 Scale Sand Model - Instrumented | 23 |
| 9. | 1/45 Scale Concrete Model - Instrumented | 26 |
| 10. | Pressure and Impulse Distribution on Full Scale Magazine - Series I | 35 |
| 11. | Pressure and Impulse Distribution on Full Scale Magazine - Series II | 38 |
| 12. | Pressure and Impulse Distribution on Full Scale Magazine - Series III | 42 |
| 13. | Pressure and Impulse Distribution on Full Scale Magazine - Series IV | 45 |
| 14. | Comparison of Results from ESKIMO III and Test Series III, Scaled to 34,050 kg TNT | 48 |
| 15. | Mach Reflection and Diffraction Pattern | 50 |
| 16. | Overpressure Ratio versus Scaled Distance | 51 |
| 17. | Input Pressure Ratio versus Mach Reflection Pressure Ratio | 52 |
| 18. | Input Pressure Ratio versus Diffracted Shock Pressure Ratio | 56 |
| 19. | ESKIMO V Test Layout | 59 |
| 20. | Predicted Peak Overpressure Contour for ESKIMO V | 60 |
| 21. | Predicted Overpressure Impulse Contour for ESKIMO V | 61 |

## LIST OF TABLES


| Table | | Page |
|---|---|---|
| I. | Gage Positions on Full Size Magazine | 17 |
| II. | Gage Distances - Series I Model Tests | 21 |
| III. | Gage Distances - Series II Model Tests | 22 |
| IV. | Gage Distances - Series III Model Tests | 24 |
| V. | Gage Distances - Series IV Model Tests | 27 |
| VI. | Test Matrix | 28 |
| VII. | Average Overpressure (psi) versus Time (msec) - Series I | 31 |
| VIII. | Average Impulse (psi-msec) versus Time (msec) | 33 |
| IX. | Summary of Results on 1/30 Scale Model Magazine | 34 |
| X. | Average Overpressure (psi) versus Time (msec) - Series II | 36 |
| XI. | Average Impulse (psi-msec) versus Time (msec) - Series II | 37 |
| XII. | Average Overpressure (psi) versus Time (msec) - Series III | 39 |
| XIII. | Average Impulse (psi-msec) versus Time (msec) - Series III | 41 |
| XIV. | Average Overpressure (psi) versus Time (msec) - Series IV | 43 |
| XV. | Average Impulse (psi-msec) versus Time (msec - Series IV | 44 |
| XVI. | Comparison of Results from ESKIMO III and Test Series III | 47 |
| XVII. | Mach Reflection and Diffraction - Theory and Experiment | 53 |
| XVIII. | Predicted Pressures and Impulses at Suggested Gauge Locations for ESKIMO V | 58 |

# I. INTRODUCTION

## A. Background

The Department of Defense Explosives Safety Board (DDESB) has for the past five years sponsored scale model studies at the Ballistic Research Laboratory (BRL)[1,2]. This work was sponsored in an effort to supplement and complement, as well as aid in the design of, full scale field tests. It was shown in Reference 2 that blast parameters from scaled models as small as 1/50 the full size storage magazines could be correlated directly with results from full scale tests. With this background knowledge and experience the present test program was planned and executed.

## B. Objectives

The primary objective of this project is to furnish information that will aid in the design of a large scale field test. The objectives of the large scale field test are (1) to demonstrate the safety of explosive storage in economically constructed non-circular steel and concrete arch magazines at a minimum side-to-side separation distance and (2) to use a smaller uncovered charge to produce the blast loads generated from a much larger explosive source contained in a standard earth-covered storage magazine similar to the one used in the ESKIMO III test[3]. The planned full-size field test is designated ESKIMO V.

## C. Approach

The approach to meet the primary objective was first to meet the following secondary objectives:

1. Design the scale model structure.

2. Establish the charge configuration.

3. Establish the charge.

4. Establish the instrumentation system.

5. Conduct the test series.

---

[1] *R. E. Reisler, L. Giglio-Tos, G. D. Teel, "Air Blast Parameters from Pentolite Cylinders Detonated on the Ground," Ballistic Research Laboratories Memorandum Report No. 2471, April 1975.* (AD #B003883L)

[2] *C. N. Kingery, G. A. Coulter, G. T. Watson, "Blast Parameters from Explosions in Model Earth Covered Magazines," Ballistic Research Laboratories Memorandum Report No. 2680, September 1976.* (AD #A031414)

[3] *F. H. Weals, "ESKIMO III Magazine Separative Tests," Naval Weapons Center Report TP-5771, February 1976.*

6. Recommend charge weight and location.

7. Predict blast loading on the full-size structures to be exposed on ESKIMO V.

## II. TEST PROCEDURE

The test procedures followed to meet the primary objective were those required to meet the secondary objectives noted under Approach.

### A. Model Magazine Design

The standard munition storage magazine being scaled for this test series is shown in Figure 1. The overall width is 27.43 metres (90 feet), length 35.05 metres (115 feet) and height 4.88 metres (16 feet). In ESKIMO III the distance between the center line of the donor magazine to the center line of the acceptor magazines was 34.75 metres (114 feet).

From preliminary calculations it appeared that a 13,620 kg (30,000) pound TNT charge would give the required pressure of 5.37 to 6.55 bars (78 - 95 psi) and impulse 44.83 bar-msec (650 psi-msec) over the top of the structure. Based on these preliminary estimates the model scale was established as 1/30. This implies that a .454 kg (1 pound) charge would simulate 12,259 kg (27,000 lb) of explosive. The 1/30 scale model, as designed for this test series, is shown in Figure 2.

In the later phase of the test series it appeared desirable to simulate a 41,370 kg (91,125 lb) TNT charge. Therefore a 1/45 scale model was designed so that blast loading could be simulated with a .454 kg (1 lb) pentolite charge. The dimensions of the 1/45 scale model are shown in Figure 3.

### B. Test Charges

Before the test charges could be cast it was first necessary to establish (1) the type of explosive required, (2) the configuration most appropriate, and (3) the weights required.

1. Type of Explosive. The BRL has over the past 25 years established a wealth of basic blast data from pentolite charges. Pentolite is relatively insensitive to shock, making it safe to handle and it gives good repeatability from shot to shot. Although TNT is planned for the full scale test it does not have the repeatability required of the small charge weights. Therefore, pentolite which has a TNT equivalency[4] of 1.17 was selected for use on this program.

[4] *T-M 5-1300, "Structure to Resist the Effects of Accidental Explosions," Army Manual, June 1969.*

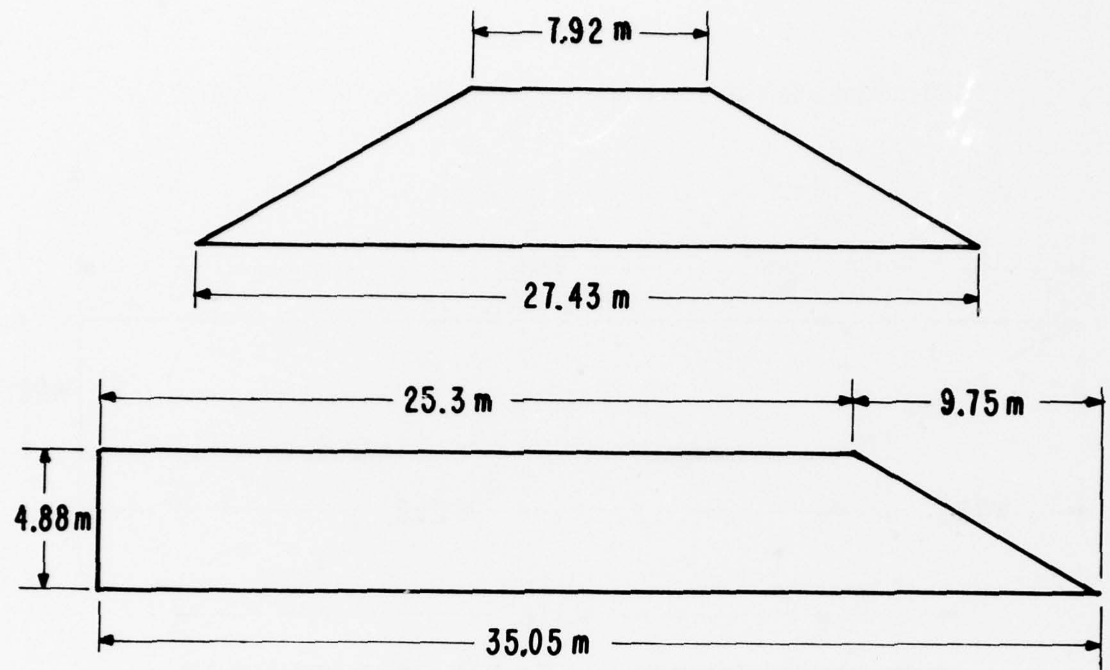


Figure 1. Standard Munition Storage Magazine

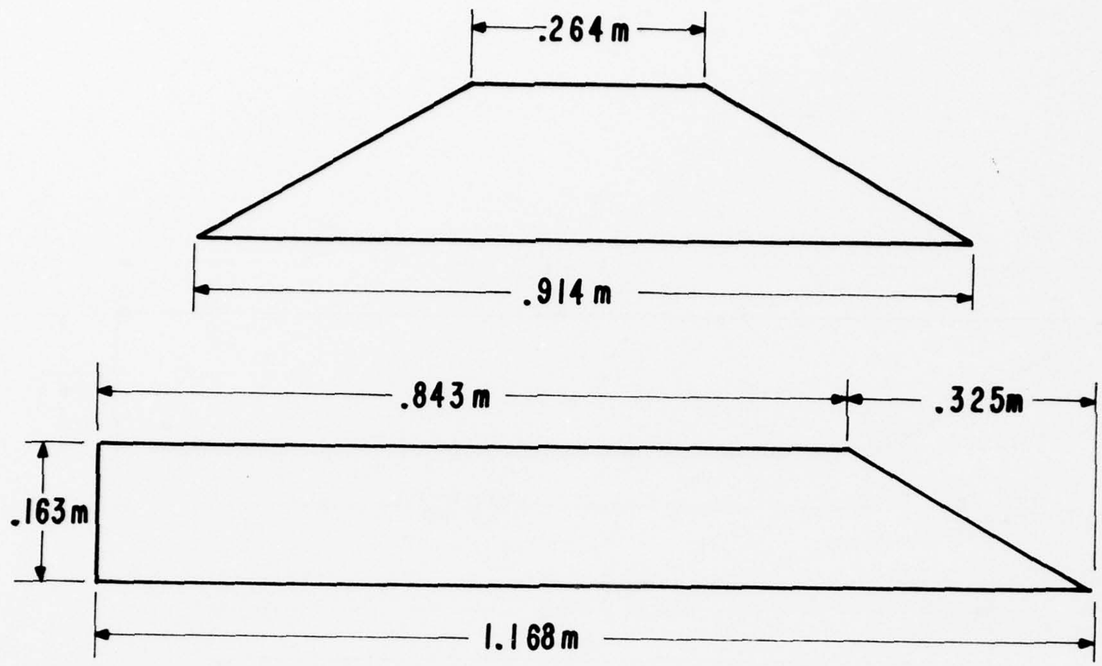


Figure 2. 1/30 Scale Model Munition Storage Magazine

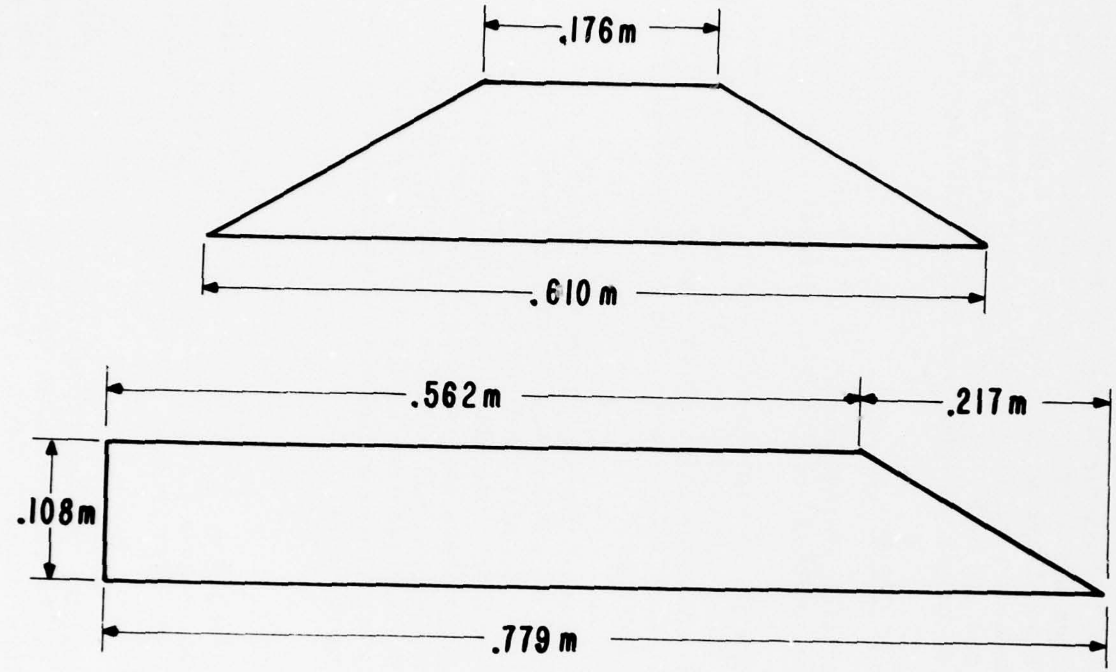


Figure 3. 1/45 Scale Model Munition Storage Magazine

2. Charge Configuration. The charge configurations first considered were a hemi-cylinder as used in Reference 2 or a cylindrical charge as used in Reference 1. After plotting the shock profile (iso-pressure and iso-impulse contours) along the 0, 45, 90, 135 and 180 degree lines it became apparent that the loading on a structure would be quite non-symmetric. Therefore, a recommendation was made to the DDESB that a hemispherical charge be considered for the full-size test.

3. Charge Weights. The recommendation for hemispherical charges as the donor configuration was accepted and an order for three charge weights was issued. These charge weights were 0.454, 0.908 and 1.135 kg or 1, 2 and 2.5 pounds of pentolite. The amount of explosive these charges will simulate and the location from the centerline of the acceptor magazine are discussed in later sections of this report.

C. Test Instrumentation System

The test instrumentation system consisted of (1) the pressure transducer, (2) the tape recorder with amplifiers, calibration and timing.

1. Pressure Transducer. Piezo-electric gauges were used throughout the series of tests. Two types were used. One type was the Susquehanna Instruments Model ST-4 with tourmaline sensors and the second type was a PCB Electronics Inc., Model 113A24 which has a quartz sensing element and a built-in source follower.

2. Tape Recorder System. The tape recorder consisted of three basic units - the power supply and voltage calibrator, the amplifier and the FM recorder. The FM tape recorder used was a Honeywell 7600 having a frequency response of 80 k Hz. Once the signal was recorded on the magnetic tape it was played back and recorded on a Honeywell Model 1858 Visrecorder. This oscillograph has excellent frequency response and the overpressure versus time recorder at the individual positions were read directly from the oscillograph playback. The overall instrumentation system is shown in Figure 4.

D. Test Layout

The test layout depended primarily on the selection of the model scale and charge weight because the gage locations on the model are fixed. The charge weight then governs the distance from the charge to a specific model scale.

1. Full Size Magazine. The locations of the gages on the full-size structure exposed on ESKIMO III are shown in Figure 5. The distances from the gauge locations listed in Table I are measured along the ground surface to the geometric center of the interior of the donor structure. Also listed in Table I are the peak overpressures and impulses recorded at similar positions on the two acceptor magazines. These values are

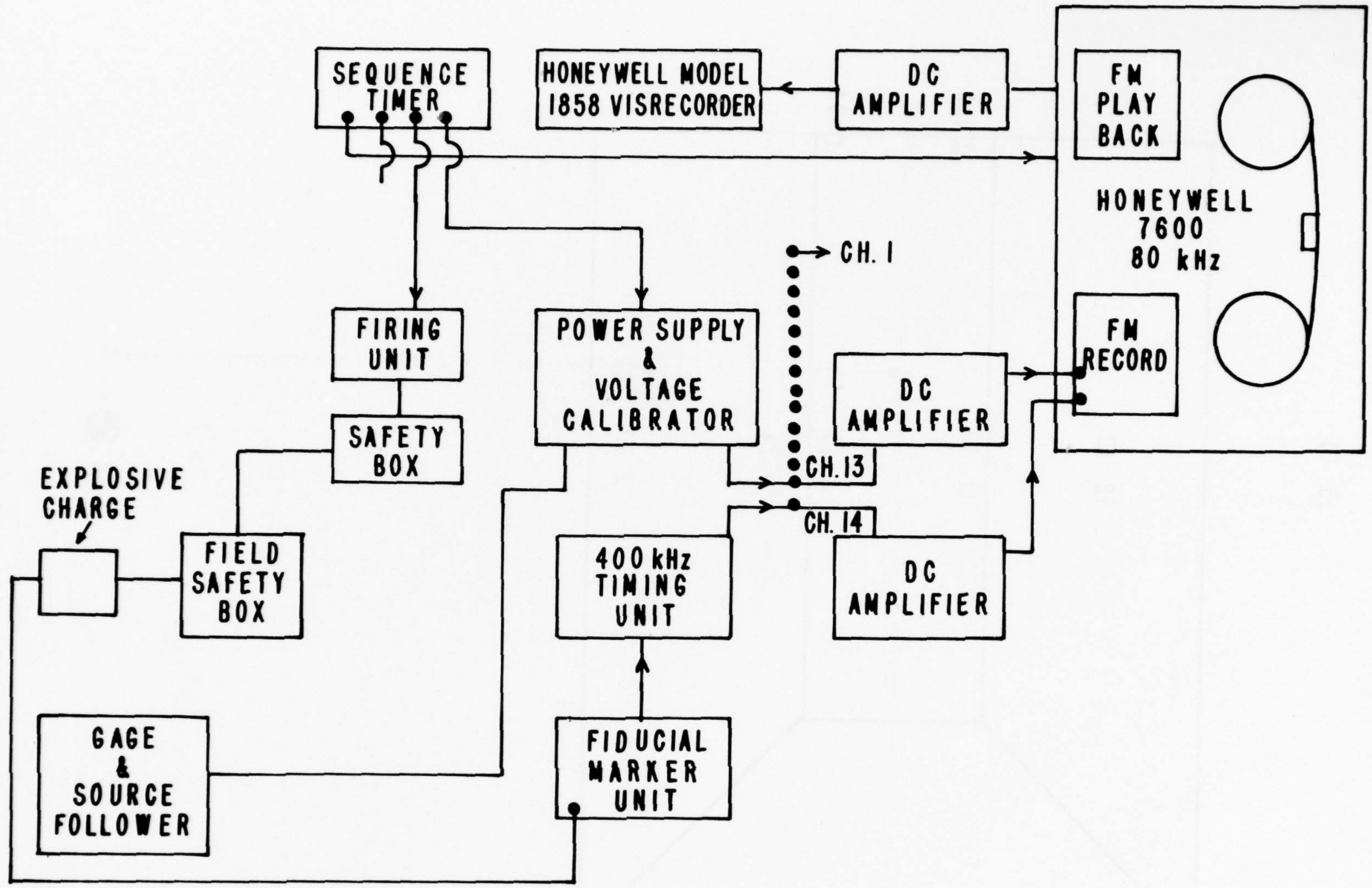


Figure 1. Instrumentation System

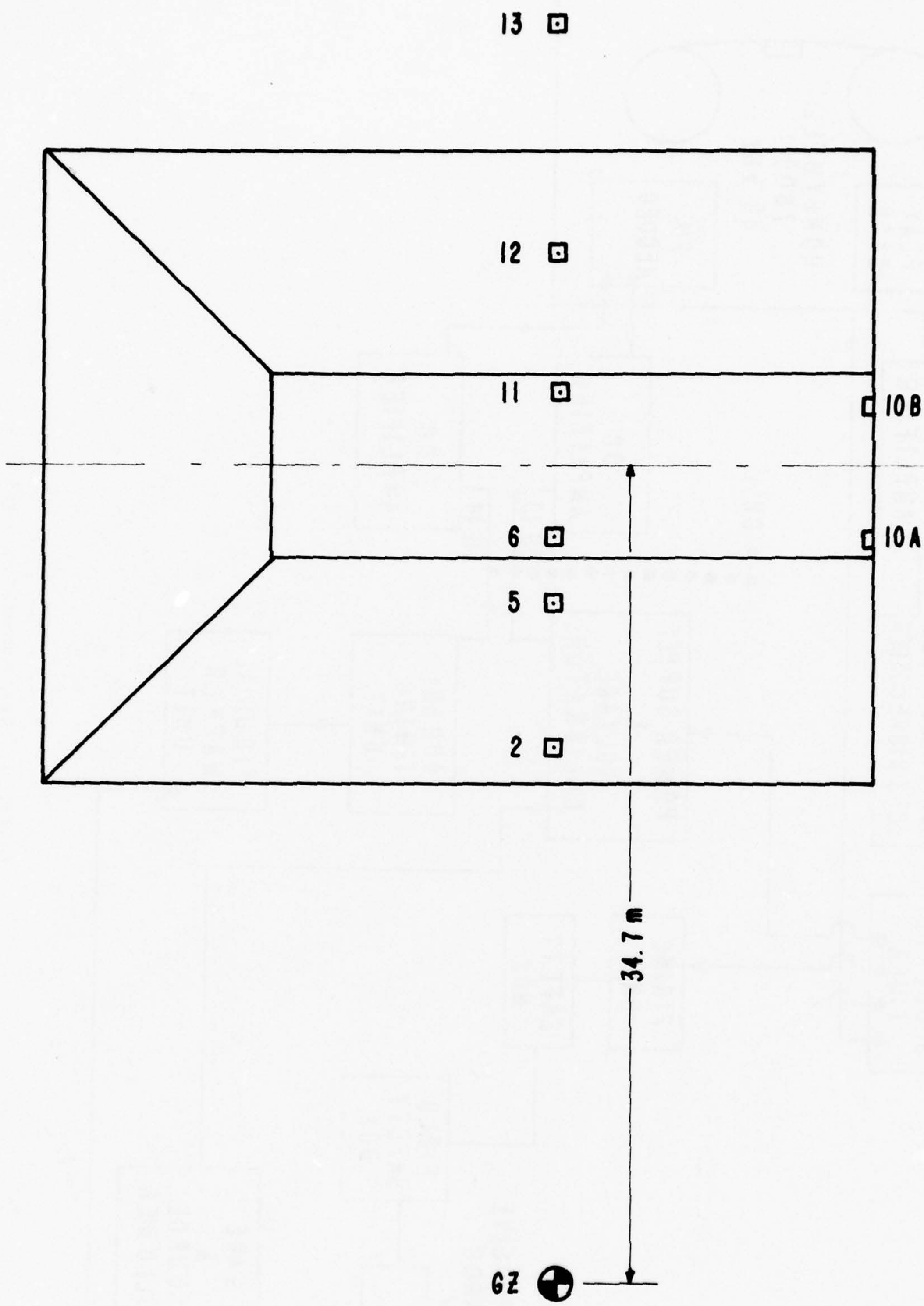


Figure 5. Gage Locations on Full Size Magazine

Table I. Gage Positions on Full Size Magazine

| Position No. | Distance m | Distance ft | Peak Overpressure bar | Peak Overpressure psi | Impulse bar-msec | Impulse psi-msec |
|---|---|---|---|---|---|---|
| 2 | 22.6 | 74 | 7.59 | 110 | - | - |
| | | | 8.28 | 120 | 55.4 | 804 |
| 5 | 28.7 | 94 | - | - | - | - |
| | | | 11.4 | 165 | 45.7 | 662 |
| 6 | 31.7 | 104 | 5.52 | 80 | 36.5 | 529 |
| | | | 6.55 | 95 | 55.6 | 806 |
| 11 | 37.8 | 124 | 5.38 | 78 | 42.9 | 622 |
| | | | 5.86 | 85 | 44.3 | 642 |
| 12 | 43.9 | 144 | 2.76 | 40 | 33.4 | 484 |
| | | | - | - | - | - |
| 13 | 53.0 | 174 | 3.45 | 50 | 45.0 | 652 |
| 10A | 33.8 | 111 | 5.17 | 75 | 42.5 | 616 |
| | | | 3.79 | 55 | 41.4 | 600 |
| 10B | 39.6 | 130 | 4.14 | 60 | 54.8 | 795 |
| | | | 2.76 | 40 | 40.9 | 593 |

NOTE: Position 10A and 10B bracket Position 10 on the Model Structure.

Distance between center lines of Donor and Acceptor Magazine is 34.7 metres (114 feet).

First value is from Magazine A
Second value is from Magazine B

bar x 100 = kPa

taken from the full scale test ESKIMO III report, Reference 3. The gage locations have been given position numbers to correspond with those used in the scaled model.

2. Scale Model Magazine. The locations of the gage positions on the 1/30 scale model are shown in Figure 6. Not all positions were instrumented on each shot. A maximum of 13 positions and a minimum of 7 positions were instrumented during the series of tests. The relative positions of the gages remained constant for a particular model scale but the distance between the charge center and the center line of the model was varied for each charge weight used.

E. Test Series

There were four series of tests. In series I, II, and III the model size was held constant while the charge weights were changed. In the series IV tests the model scale was changed. Each series is described in the following sections.

1. Test Series I. In test series I a 1/30 scale wooden model was instrumented as shown in Figure 7. The objective of this test series was, through the use of a scaled model, to determine the peak overpressure and impulse that might be expected on a full size storage magazine when subjected to a 13620 kg (30,000 lb) hemispherical charge of TNT placed at a distance of 34.7 metres from the centerline. The method used to determine the scaled distances of the gage positions relative to the charge center is presented in Table II.

2. Test Series II. In test series II the full size magazine is assumed to be subjected to the blast load from 27240 kg (60,000 lb) of TNT. Since the charge weight was doubled then the distance from the model centerline to the charge center must be increased by $2^{1/3}$ or 1.26. Therefore the 34.74 metres for series I must become 43.77 metres for series II. The method for calculating the scaled distances for the increased charge weight is presented in Table III. In test series II it was desirous to obtain the same peak overpressure but increase the positive impulse.

3. Test Series III. In test series III the same scaled model 1/30 was used but it was formed with sand. A photograph of the instrumented model is presented in Figure 8. The record quality improved considerably when the sand model was used. Based on the results from test series II there was still a need to increase the positive impulse. Therefore, a charge weight of 34050 kg (75,000 lb) was selected as a candidate for the full scale test. The procedure as noted in Tables II and III was used again to determine the scaled distance to place the small charge. The method is presented in Table IV along with the full

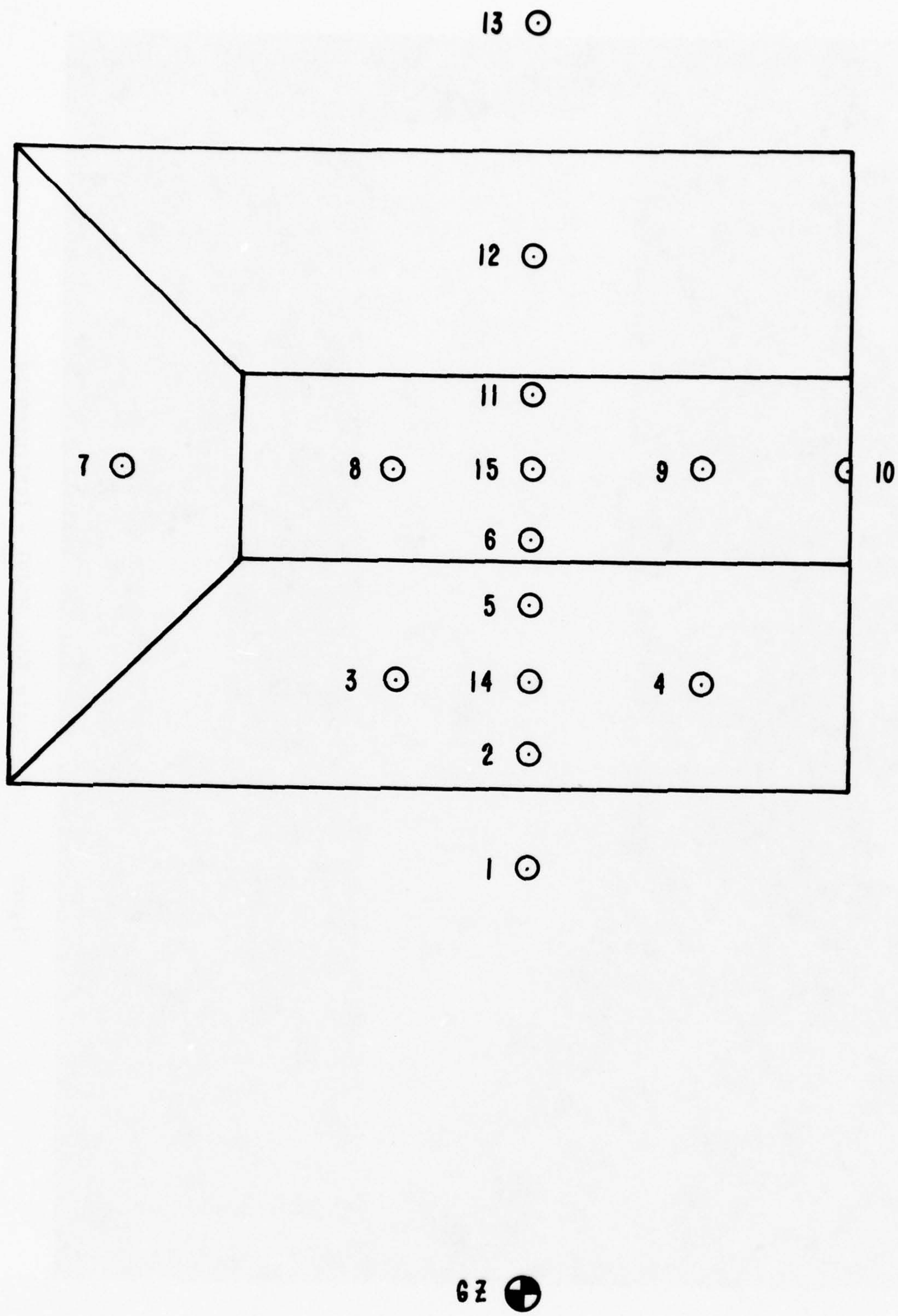


Figure 6. Gage Locations on 1/30 Scale Model Magazine

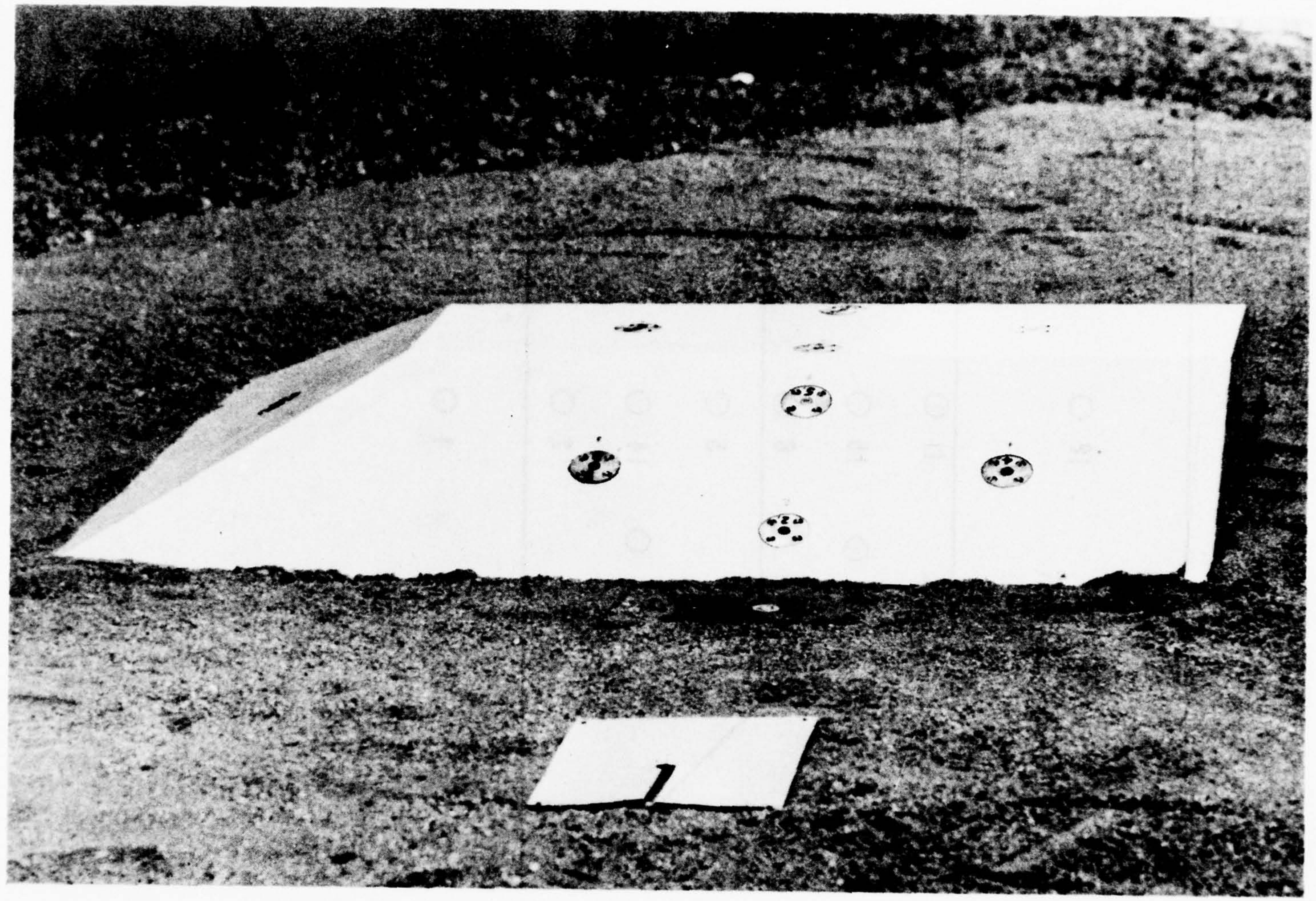

Figure 7. 1/30 Scale Wood Model - Instrumented

Table II. Gage Distances - Series I Model Tests

| Position No. | Full Scale Distance m | Full Scale Distance ft | Scale Distance m | Scale Distance ft |
|---|---|---|---|---|
| 1 | 18.3 | 60 | .62 | 2.03 |
| 2 | 22.6 | 74 | .77 | 2.51 |
| 3 | 26.2 | 86 | .89 | 2.92 |
| 4 | 26.2 | 86 | .89 | 2.92 |
| 5 | 28.7 | 94 | .97 | 3.19 |
| 6 | 31.7 | 104 | 1.08 | 3.53 |
| 7 | 38.7 | 127 | 1.31 | 4.31 |
| 8 | 35.4 | 116 | 1.20 | 3.93 |
| 9 | 35.4 | 116 | 1.20 | 3.93 |
| 10 | 36.9 | 121 | 1.25 | 4.10 |
| 11 | 37.8 | 124 | 1.28 | 4.20 |
| 12 | 43.9 | 144 | 1.49 | 4.88 |
| 13 | 53.0 | 174 | 1.80 | 5.90 |
| 14 | 25.6 | 84 | .87 | 2.85 |
| 15* | 34.7 | 114 | 1.18 | 3.87 |

Given: $W_2$ = 13620 kg (30,000 lb) TNT

$R_2$ = 34.7m (114 ft)

Determine: Scale distance $R_1$ for $W_1$ equal to .531 kg (1.17 lb) TNT.

$R_1$ = Scale distances from Charge Center to Model Center Line

$R_2$ = Full scale distance from Charge Center to Magazine Center Line

$$R_1 = R_2 \left( \frac{W_1^{1/3}}{W_2^{1/3}} \right)$$

$$R_1 = 34.7\ (0.03391)$$

$$R_1 = 1.18\text{m}$$

NOTE: TNT Equivalency of Pentolite = 1.17

*Center line distance, $R_2$

Table III. Gage Distances - Series II Model Tests

| Position No. | Full Scale Distances m | Full Scale Distances ft | Model Scale Distances m | Model Scale Distances ft |
|---|---|---|---|---|
| 1 | 27.3 | 89.6 | .93 | 3.04 |
| 2 | 31.6 | 103.6 | 1.07 | 3.51 |
| 3 | 35.1 | 115.3 | 1.19 | 3.91 |
| 4 | 35.1 | 115.3 | 1.19 | 3.91 |
| 5 | 37.7 | 123.6 | 1.28 | 4.19 |
| 6 | 40.7 | 133.6 | 1.38 | 4.53 |
| 7 | 47.0 | 154.1 | 1.59 | 5.21 |
| 8 | 44.2 | 145.0 | 1.50 | 4.92 |
| 9 | 44.2 | 145.0 | 1.50 | 4.92 |
| 10 | 45.4 | 149.0 | 1.54 | 5.05 |
| 11 | 46.8 | 153.6 | 1.59 | 5.21 |
| 12 | 52.9 | 173.6 | 1.79 | 5.89 |
| 13 | 62.1 | 203.6 | 2.10 | 6.90 |
| 14 | 34.6 | 113.6 | 1.17 | 3.85 |
| 15* | 43.8 | 143.6 | 1.48 | 4.87 |

Given: $W_2$ = 27240 kg (60,000 lb) TNT

$R_2$ = 43.8 m (143.6 ft)

Determine: $R_1$, Scale distance for $W_1$ equal to 1.062 kg (2.34 lb) TNT

$R_1$ = Scale distance from Charge Center to Model Center Line

$R_2$ = Full scale distance Charge Center to Magazine Center Line

$$R_1 = R_2 \left( \frac{W_1^{1/3}}{W_2^{1/3}} \right)$$

$$R_1 = 43.8\ (0.03391)$$

$$R_1 = 1.48\text{m}$$

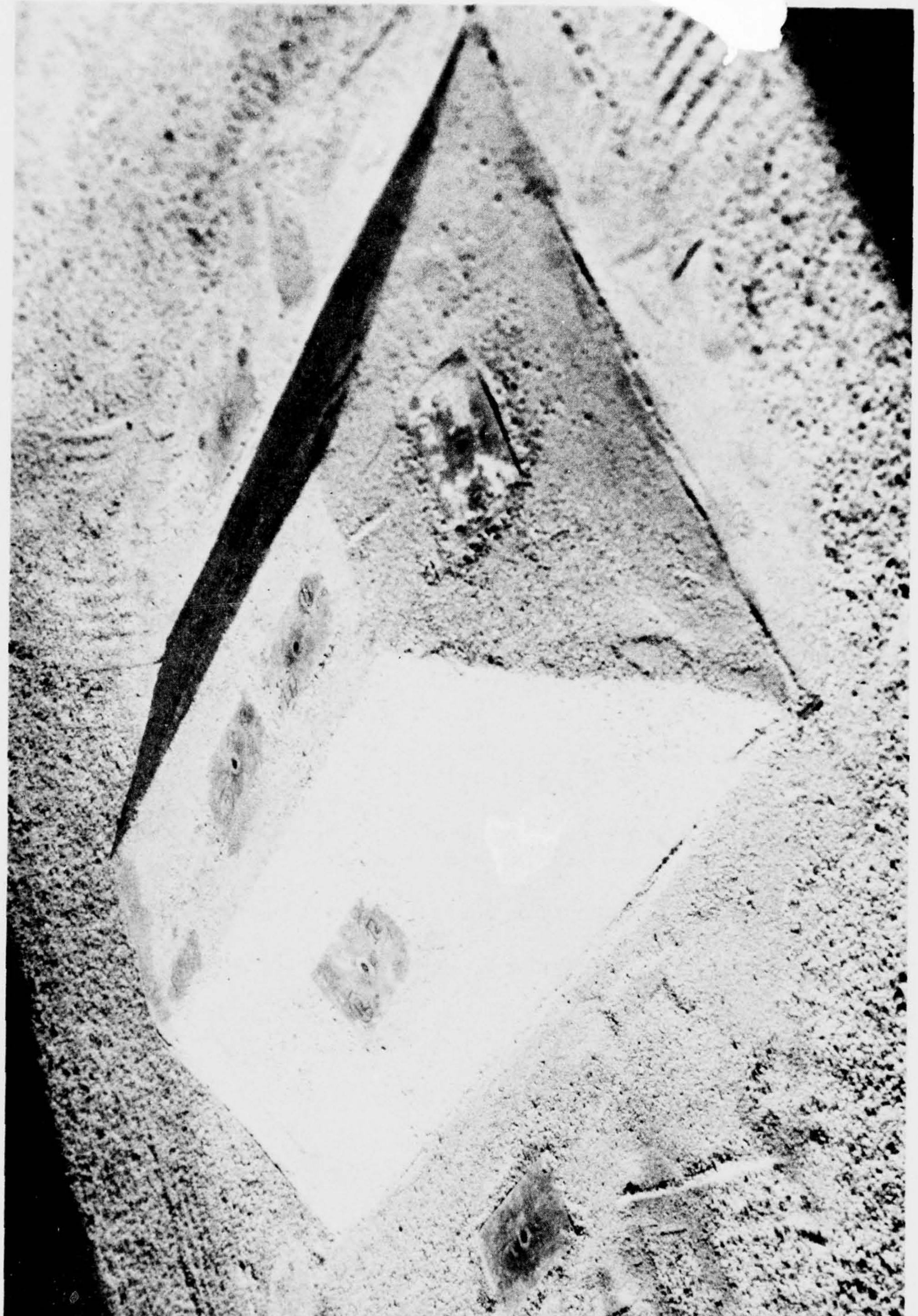

Figure 8. 1/30 Scale Sand Model - Instrumented

Table IV. Gage Distances - Series III Model Tests

| Position No. | Full Scale Distances | | Model Scale Distances | |
|---|---|---|---|---|
| | m | ft | m | ft |
| 1 | 30.7 | 100.7 | 1.04 | 3.41 |
| 2 | 35.0 | 114.7 | 1.19 | 3.89 |
| 3 | 38.5 | 126.3 | 1.31 | 4.28 |
| 4 | 38.5 | 126.3 | 1.31 | 4.28 |
| 5 | 41.1 | 134.7 | 1.39 | 4.57 |
| 6 | 44.1 | 144.7 | 1.50 | 4.91 |
| 7 | 50.1 | 164.5 | 1.70 | 5.58 |
| 8 | 47.5 | 156.0 | 1.61 | 5.29 |
| 9 | 47.5 | 156.0 | 1.61 | 5.29 |
| 10 | 48.8 | 160.0 | 1.65 | 5.43 |
| 11 | 50.2 | 164.7 | 1.70 | 5.59 |
| 12 | 56.3 | 184.7 | 1.91 | 6.26 |
| 13 | 65.4 | 214.7 | 2.22 | 7.28 |
| 14 | 38.0 | 124.7 | 1.29 | 4.23 |
| 15 | 47.2 | 154.7 | 1.60 | 5.25 |

Given: $W_2$ = 34050 kg (75,000 lb) TNT
$R_2$ = 47.2m (154.7 ft)

Determine: Scale distance $R_1$, for a $W_1$ equal to 1.328 kg (2.925 lb) TNT = $W_1$

$R_1$ = Scale distance from Charge Center to Model Center Line

$R_2$ = Full scale distance from Charge Center to Magazine Center Line

$$R_1 = R_2 \left( \frac{W_1^{1/3}}{W_2^{1/3}} \right)$$

$$R_1 = 47.2\ (0.03391)$$

$$R_1 = 1.60\text{m}$$

and model scale distances.

4. Test Series IV. Although test series III gave the desired pressure and scaled impulse it was decided to conduct one series with a smaller model 1/45 and one of the previously used charge weights. A sand model similar to the one shown in Figure 8 was used on the first shot and a concrete model as shown in Figure 9 was used for the second and third shots. The method for calculating the distances from the charge center to the structure center line of the full scale and model structure is presented in Table V.

## III. RESULTS

The results will be presented primarily in tabular form with selected overpressure versus time histories to show the loading at pertinent gauge locations. The major portion of the tests was conducted using a 1/30 scale model and three different charge weights. Only one charge weight was fired against the 1/45 scale model. The shot matrix is presented in Table VI.

### A. Scaling Blast Parameters

1. Standard Atmospheric Conditions. The Hopkinson scaling law[5] was used in this report to design the model test layout, select the charge weights and predict the blast loading that might be expected on a full-scale munition magazine. Scaling laws allow the prediction of blast wave properties from small scale experiments to any other scale, provided the type of explosive source, the geometry of the source, and atmospheric conditions are identical.

Theoretically, a target located a distance $R_1$ from the center of an explosive source of weight $W_1$ will be subjected to a blast wave with a peak overpressure of amplitude P, a duration $t_{+1}$ and a positive impulse $I_1$. Now the Hopkinson scaling law states that the distance $R_2$ at which a target must be placed to receive the same peak overpressure, from a different charge weight $W_2$, is a function of the cube roots of the charge weights. The relationship is given by

$$\frac{R_1}{W_1^{1/3}} = \frac{R_2}{W_2^{1/3}}$$

and

$$R_2 = R_1 \left(\frac{W_2}{W_1}\right)^{1/3}$$

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[5] *B. Hopkinson, British Ordnance Board Minutes 13565, 1915.*

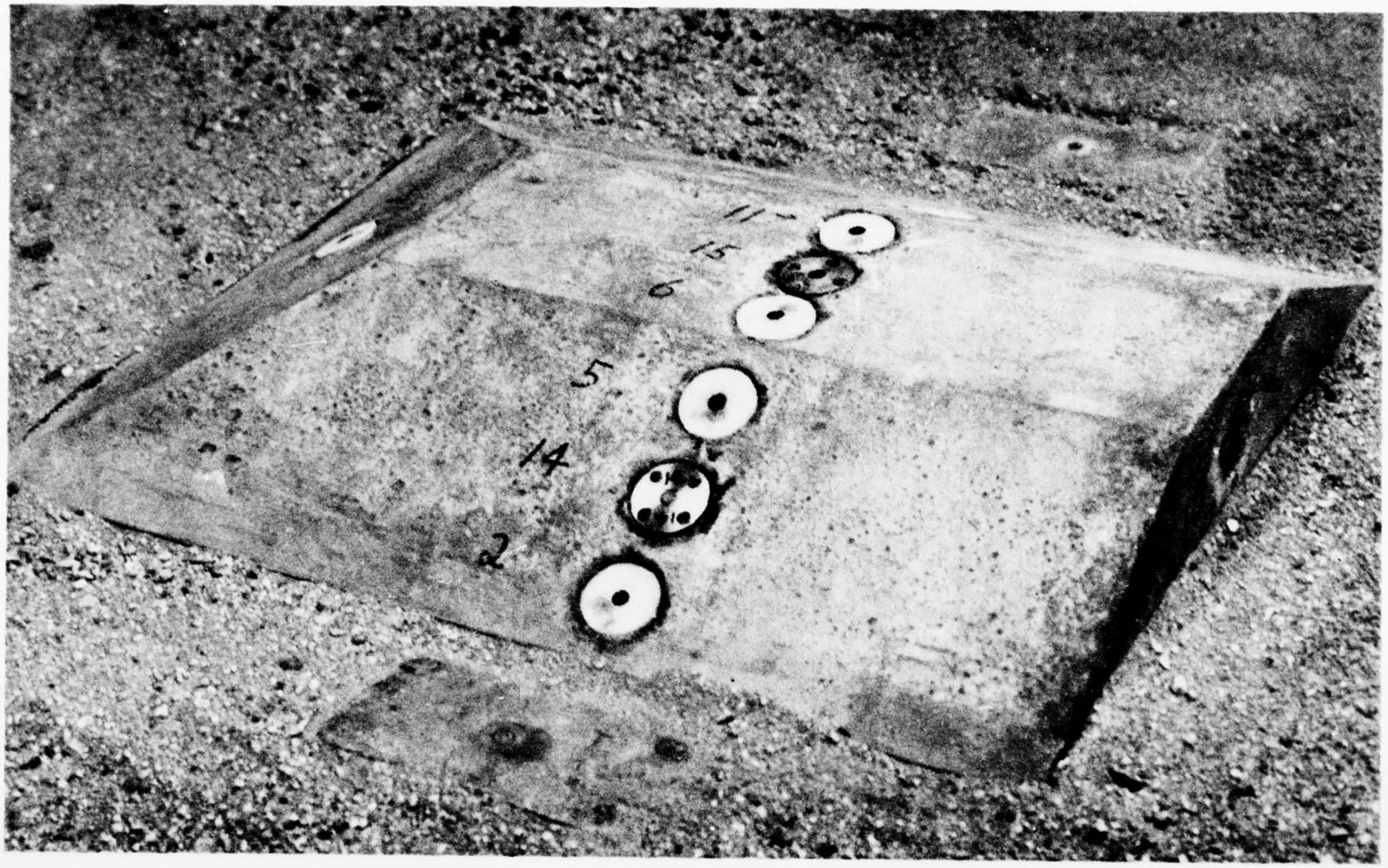


Figure 9. 1/45 Scale Concrete Model - Instrumented

Table V. Gage Distances - Series IV Model Tests

| Position No. | Full Scale Distance m | Full Scale Distance ft | Model Scale Distance m | Model Scale Distance ft |
|---|---|---|---|---|
| 1 | 33.8 | 111 | .79 | 2.60 |
| 2 | 38.1 | 125 | .89 | 2.93 |
| 3 | 41.5 | 136 | .97 | 3.18 |
| 4 | 41.5 | 136 | .97 | 3.18 |
| 5 | 44.2 | 145 | 1.03 | 3.39 |
| 6 | 47.2 | 155 | 1.11 | 3.63 |
| 7 | 53.1 | 174 | 1.24 | 4.07 |
| 8 | 50.6 | 166 | 1.18 | 3.89 |
| 9 | 50.6 | 166 | 1.18 | 3.89 |
| 10 | 51.8 | 170 | 1.21 | 3.98 |
| 11 | 53.3 | 175 | 1.25 | 4.10 |
| 12 | 59.4 | 195 | 1.39 | 4.56 |
| 13 | 68.6 | 225 | 1.61 | 5.27 |
| 14 | 41.1 | 135 | .96 | 3.16 |
| 15 | 50.3 | 165 | 1.18 | 3.86 |

Given: 41370 kg (91,125 lb) TNT = $W_2$
$R_2$ = 50.3 m (165 ft)

Determine: Scale distance $R_1$ for $W^1$ equal to 0.531 kg (1.17 lb) TNT

$R_1$ = Scale distance from Charge Center to Model Center Line

$R_2$ = Full scale distance from Charge Center to Magazine Center Line

$$R_1 = R_2 \left( \frac{W_1^{1/3}}{W_2^{1/3}} \right)$$

$$R_1 = 50.3\ (.02341)$$

$$R_1 = 1.18 \text{ m}$$

Table VI. Test Matrix

| Shot | Charge Weights kg | Charge Weights lb | Model Scale | Model Type | Series | Remarks |
|---|---|---|---|---|---|---|
| 1 | 0.449 | 0.99 | 1/30 | Wood | I | * |
| 2 | 0.451 | 0.99 | 1/30 | Wood | I | |
| 3 | 0.897 | 1.98 | 1/30 | Wood | II | |
| 4 | 0.897 | 1.98 | 1/30 | Wood | II | |
| 5 | 0.903 | 1.99 | 1/30 | Wood | II | ** |
| 6 | 0.898 | 1.98 | 1/30 | Wood | II | |
| 7 | 0.451 | 0.99 | 1/30 | Wood | I | |
| 8 | 0.901 | 1.98 | 1/30 | Wood | II | |
| 9 | 0.896 | 1.97 | 1/30 | Wood | II | |
| 10 | 0.449 | 0.99 | 1/30 | Wood | I | |
| 11 | 0.902 | 1.99 | 1/30 | Sand | II | |
| 12 | 0.451 | 0.99 | 1/30 | Sand | I | |
| 13 | 0.452 | 0.99 | 1/45 | Sand | IV | |
| 14 | 1.135 | 2.50 | 1/30 | Sand | III | |
| 15 | 1.134 | 2.50 | 1/30 | Sand | III | |
| 16 | 1.125 | 2.48 | 1/30 | Sand | III | |
| 17 | 1.136 | 2.50 | 1/30 | Sand | III | |
| 18 | 0.447 | 0.98 | 1/45 | Concrete | IV | |
| 19 | 0.448 | 0.99 | 1/45 | Concrete | IV | |

| | AVERAGE WEIGHTS |
|---|---|
| 1/30 Model 2w, 7w, 10w, 125 | - 0.451 kg (0.99 lb) |
| 1/30 Model 3w, 4w, 6w, 8w, 9w, 11 | - 0.899 kg (1.98 lb) |
| 1/30 Model 14s, 15s, 16s, 17s | - 1.133 kg (2.50 lb) |
| 1/45 Model 13s, 18c, 19c | - 0.449 kg (0.99 lb) |

*Shot 1 - Data not usable

**Shot 5 - Misfire

For similar conditions then

$$\text{Impulse } I_2 = I_1 \left(\frac{W_2}{W_1}\right)^{1/3}$$

and

$$\text{Duration } t_{+2} = t_{+1} \left(\frac{W_2}{W_1}\right)^{1/3} .$$

Note that the scaling factor required to scale the 1/30 model results to the full size structure is $(W_2/W_1)^{1/3}$ or 29.49. Results from the 1/45 scale model must be scaled by a factor of 42.72.

2. Altitude Corrections. When blast parameters are scaled from standard sea level conditions to altitudes where the ambient atmospheric conditions are appreciably different then corrections must be made[6]. The correction for overpressure is

$$p_a = p_o \left(\frac{P_a}{P_o}\right)$$

where $p_a$ = overpressure at altitude

$p_o$ = overpressure at sea level

$P_a$ = ambient pressure at altitude

$P_o$ = ambient pressure at sea level.

The corrected value for distance (R) for the new overpressure level is given by

$$R_a = R_o \left(\frac{W_2}{W_1}\right)^{1/3} \left(\frac{P_o}{P_a}\right)^{1/3}$$

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[6] *R. G. Sachs, "The Dependence of Blast on Ambient Pressure and Temperature," BRL Report No. 466, Aberdeen Proving Ground, Md. 1944.* (AD #ATI 39393)

where $R_a$ = distance at altitude

$R_o$ = distance at sea level

$W_2$ = charge weight - full scale

$W_1$ = charge weight - model scale.

For impulse at altitude, the relationship is

$$I_a = I_o \left(\frac{W_2}{W_1}\right)^{1/3} \left(\frac{P_a}{P_o}\right)^{2/3} \left(\frac{T_o}{T_a}\right)^{1/2}$$

where $T_a$ = temperature at altitude - degrees K

$T_o$ = temperature at sea level - degrees K.

B. Blast Loading on a 1/30 Scale Model Magazine

The dimensions of the 1/30 scale model magazine are shown in Figure 2. The locations of the airblast gages are shown in Figure 6 with their distances from ground zero or charge center given in Tables II, III, and IV.

1. Charge Weight 0.454 kg (1 lb) Pentolite. In planning the test layout the pentolite charge was assumed to represent 1.17 that amount of TNT. Therefore, in the scaling relationship $W_1$ was equal to 0.531 kg (1.17 lb ) TNT. The tests conducted with this scale model and charge weight are noted in Table II as Series I Model Tests. Although the model was constructed with 1-inch thick plywood and heavy internal bracing the results were dissappointing. Some gage positions received excessive accelerations which were superimposed on the record of overpressure versus time. During this series Positions 3, 4, 8 and 9 were removed and Positions 14 and 15 were added. (See Figure 6).

On shot 12 a 1/30 scale sand model was instrumented and tested. Positions 1, 7, 8, 10, 12, 13, 14, and 15 were instrumented as shown in Figure 8. The results from the sand model were excellent and all but two of the following shots were conducted with sand models.

The records of pressure versus time for each position were tabulated at equal time increments and an average overpressure versus time established. These averages for each position are listed in Table VII.

Table VII. Average Overpressure (psi) versus Time (msec) - Series I

| Position / Time msec | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .00 | 284 | 335 | 248 | 216 | 177 | 97 | 44 | 63 | 63 | 37 | 59 | 24 | 29 | 245 | 76 |
| .05 | 121 | 215 | 160 | 170 | 124 | 45 | 30 | 55 | 57 | 27/46 | 48 | 20 | 23 | 215 | 54 |
| .10 | 68 | 121 | 140 | 70 | 87 | 28 | 25 | 45 | 40 | 36 | 38 | 18 | 20 | 130 | 43 |
| .15 | 43 | 84 | 80 | 50 | 62 | 27 | 26 | 33 | 30 | 30 | 32 | 15 | 17 | 85 | 34 |
| .20 | 31 | 73 | 60 | 35 | 41 | 9 | 16 | 30 | 25 | 22 | 28 | 13 | 15 | 55 | 26 |
| .25 | 22 | 52 | 50 | 25 | 42 | 7 | 14 | 24 | 20 | 19 | 23 | 12 | 13 | 35 | 17 |
| .30 | 18 | 46 | 40 | 20 | 38 | 5 | 13 | 18 | 15 | 16 | 20 | 10 | 12 | 25 | 14 |
| .35 | 12 | 39 | 40 | 15 | 31 | 5 | 10 | 15 | 12 | 14 | 16 | 9 | 9.4 | 20 | 13 |
| .40 | 9 | 30 | 25 | 10 | 26 | 6 | 10 | 11 | 10 | 11 | 13 | 9 | 8.0 | 20 | 8.9 |
| .45 | 10 | 34 | 15 | 8 | 24 | 3 | 9 | 8 | 9 | 10 | 10 | 8 | 7.1 | 17 | 9.0 |
| .50 | 5 | 38 | 5 | 5 | 22 | 4 | 8 | 6 | 7 | 8 | 7 | 7 | 6.1 | 12 | 10 |
| .60 | 0 | 20 | 0 | 0 | 21 | 0 | 5 | 3 | 5 | 5 | 5 | 5 | 4.5 | 8 | 6.6 |
| .70 | | 2 | | | 14 | | 4 | 2 | 4 | 3 | 3 | 4 | 3.8 | 5 | 3.0 |
| .80 | | 0 | | | 12 | | 3 | 0 | 4 | 2 | 2 | 3 | 3.3 | 0 | 3.0 |
| .90 | | | | | 7 | | 2 | | 3 | 2 | 0 | 1 | 3.6 | | 2.0 |
| 1.0 | | | | | 0 | | 1 | | 0 | 0 | | 1 | 2.9 | | 1.0 |
| 1.1 | | | | | | | 0 | | | | | 1 | 2.3 | | 0 |
| 1.2 | | | | | | | | | | | | 0 | 1.4 | | |
| 1.3 | | | | | | | | | | | | | 1.1 | | |
| 1.4 | | | | | | | | | | | | | .6 | | |
| 1.5 | | | | | | | | | | | | | .4 | | |
| 1.6 | | | | | | | | | | | | | .2 | | |
| 1.7 | | | | | | | | | | | | | 0 | | |
| 1.8 | | | | | | | | | | | | | | | |
| | *** | *** | * | * | *** | ** | ** | ** | * | ** | *** | * | *** | * | *** |

The * indicates the number of acceptable records used in the averaging process.

From the average overpressure versus time tabulations, impulse versus time was calculated and these calculations are listed in Table VIII. At the bottom of each column the total impulse is noted. The total impulse values from the model were scaled up to full size and are also listed in Table VIII. The gage calibrations are for pounds per square inch (psi) and therefore the listings in Table VII and VIII are overpressure in psi and impulse in psi - msec.

The results from the Series I tests are summarized in Table IX where the pressure and impulse values are listed in both psi, bar and psi-msec, bar-msec. The values listed in Table IX are presented in Figure 10 to show the peak overpressure (bars) and impulse (bar-msec) distribution of the various positions over the full scale munition storage magazine exposed to a 13620 kg (30,000 lb) hemispherical TNT charge.

The peak overpressure recorded at Position 15 was satisfactory but the overpressure impulse was too low, 30.9 bar-msec vs the required 44.8 bar-msec. Therefore, the charge weight was doubled and another test series was conducted.

2. Charge Weight 0.908 kg (2 lb) Pentolite. These tests are designated as Series II and in Table III it is noted that the pentolite charge is assumed to represent 1.062 kg (2.34 lb) TNT. A 1/30 scale model was instrumented and as noted in Series I not all gage positions were instrumented on all shots. Average values of the overpressure versus time recorded at the various positions are listed in Table X. The average values of overpressure versus time were used to calculate the impulse versus time at each gage position. The impulse versus time calculations are listed in Table XI and the total impulse is listed at the bottom of each column for the scale model with a second value for the impulse to be expected on the full size magazine. The peak overpressure and total positive impulse values from Series II are listed in Table IX. The values listed in Table IX are presented in Figure 11 to show the pressure and impulse distribution to be expected over a full scale munition storage magazine exposed to a 27240 kg (60,000 lb) hemispherical TNT charge.

The peak overpressure meets the established criterion but again the overpressure impulse is too low - 41.2 bar-msec versus 44.8 bar-msec. The charge weight was increased 2.5 times the series 1 charge weight and a third test series was conducted.

3. Charge Weight 1.135 kg (2.5 lb) Pentolite. These tests were designated as Series III and in Table IV it is noted that the pentolite charge is assumed to represent 1.328 kg (2.927 lb) of TNT. A 1/30 scale sand model was used for Shots 14, 15, 16, and 17. The instrumented positions are given in Table XII where the average values of overpressure versus time are listed. The average values of overpressure versus time were used to calculate impulse versus time at each gage

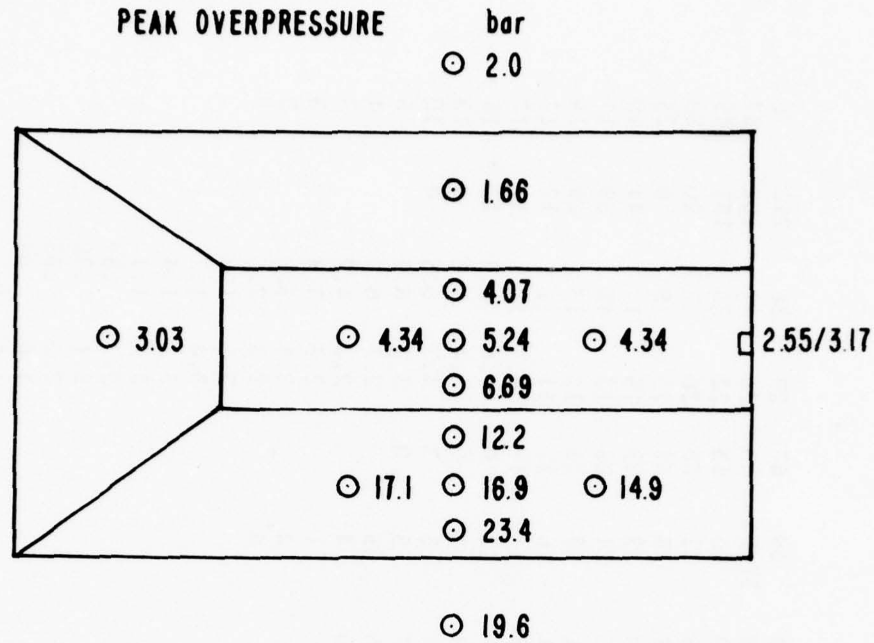
Table VIII. Average Impulse (psi-msec) versus Time (msec) - Series I

| Position | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time msec | | | | | | | | | | | | | | | |
| .00 | | | | | | | | | | | | | | | |
| .05 | 10.1 | 12.1 | 8.70 | 9.65 | 7.53 | 3.55 | 1.85 | 2.95 | 2.43 | 1.41 | 2.68 | 1.10 | 1.30 | 11.5 | 3.25 |
| .10 | 4.73 | 8.40 | 7.50 | 6.00 | 5.28 | 1.83 | 1.38 | 2.50 | 2.43 | 1.78 | 2.15 | .95 | 1.08 | 6.63 | 2.43 |
| .15 | 2.78 | 5.13 | 5.50 | 3.00 | 3.73 | 1.38 | 1.28 | 1.95 | 1.75 | 1.65 | 1.75 | .83 | .93 | 5.38 | 1.93 |
| .20 | 1.85 | 3.93 | 3.50 | 2.13 | 2.60 | .90 | 1.05 | 1.58 | 1.38 | 1.30 | 1.50 | .70 | .80 | 3.50 | 1.50 |
| .25 | 1.33 | 3.13 | 2.75 | 1.50 | 2.10 | .40 | .75 | 1.35 | 1.13 | 1.03 | 1.28 | .63 | .70 | 2.25 | 1.08 |
| .30 | 1.00 | 2.45 | 2.25 | 1.13 | 2.00 | .30 | .68 | 1.05 | .88 | .88 | 1.08 | .55 | .63 | 1.50 | .78 |
| .35 | .75 | 1.80 | 2.00 | .88 | 1.73 | .25 | .58 | .83 | .68 | .75 | .90 | .48 | .54 | 1.13 | .68 |
| .40 | .35 | 1.40 | 1.63 | .63 | 1.43 | .28 | .50 | .65 | .55 | .63 | .73 | .46 | .44 | 1.00 | .55 |
| .45 | .48 | 1.60 | 1.00 | .45 | 1.25 | .23 | .48 | .48 | .48 | .53 | .58 | .43 | .38 | .93 | .45 |
| .50 | .38 | 1.80 | .50 | .33 | 1.15 | .18 | .40 | .35 | .40 | .45 | .43 | .37 | .33 | .73 | .48 |
| .60 | .25 | 2.90 | .13 | 00 | 1.05 | .20 | .60 | .45 | .60 | .65 | .60 | .58 | .53 | 1.00 | .83 |
| .70 | 00 | 1.10 | | | 1.75 | 00 | .45 | .25 | .45 | .40 | .40 | .45 | .42 | .65 | .48 |
| .80 | | .10 | | | 1.30 | | .35 | .10 | .40 | .27 | .25 | .35 | .36 | .25 | .30 |
| .90 | | 00 | | | .95 | | .25 | 00 | .30 | .22 | .10 | .21 | .33 | 00 | .25 |
| 1.0 | | | | | .55 | | .15 | | .15 | .10 | 00 | .14 | .26 | | .15 |
| 1.1 | | | | | 00 | | 00 | | | 00 | | .11 | .19 | | .05 |
| 1.2 | | | | | | | | | | | | .04 | .13 | | 00 |
| 1.3 | | | | | | | | | | | | 00 | .09 | | |
| 1.4 | | | | | | | | | | | | | .05 | | |
| 1.5 | | | | | | | | | | | | | .03 | | |
| 1.6 | | | | | | | | | | | | | .01 | | |
| 1.7 | | | | | | | | | | | | | | | |
| 1.8 | | | | | | | | | | | | | | | |
| Model | 24.18 | 45.84 | 35.46 | 25.70 | 34.40 | 9.50 | 10.75 | 14.49 | 14.01 | 12.05 | 14.43 | 8.38 | 9.88 | 36.45 | 15.19 |
| Full Scale | 713 | 1352 | 1046 | 758 | 1014 | 280 | 317 | 427 | 413 | 355 | 426 | 247 | 291 | 1074 | 448 |

Table IX. Summary of Results on 1/30 Scale Model Magazine

| Position | Series I | | | | Series II | | | | Series III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Peak Overpressure | | Total Impulse | | Peak Overpressure | | Total Impulse | | Peak Overpressure | | Total Impulse | |
| | psi | bar | psi-msec | bar-msec | psi | bar | psi-msec | bar-msec | psi | bar | psi-msec | bar-msec |
| 1 | 284 | 19.6 | 713 | 49.2 | 214 | 14.8 | 1158 | 79.9 | 181 | 12.5 | 962 | 66.3 |
| 2 | 335 | 23.3 | 1352 | 93.2 | 293 | 20.2 | 1864 | 128.5 | 260* | 17.9* | 1450* | 100* |
| 3 | 248 | 17.1 | 1046 | 72.1 | 224 | 15.4 | 1053 | 72.6 | - | - | - | - |
| 4 | 216 | 14.9 | 758 | 52.3 | 211 | 14.6 | 944 | 65.1 | - | - | - | - |
| 5 | 177 | 12.2 | 1014 | 69.9 | 167 | 11.5 | 1205 | 83.1 | 160* | 11.0* | 1088* | 75.0* |
| 6 | 97 | 6.69 | 280 | 19.3 | 101 | 6.97 | 241 | 16.6 | 92 | 6.34 | 360 | 24.8 |
| 7 | 44 | 3.03 | 317 | 21.9 | 58 | 4.00 | 447 | 30.8 | 62 | 4.28 | 601 | 41.4 |
| 8 | 63 | 4.34 | 427 | 29.5 | 69 | 4.76 | 447 | 30.8 | 78 | 5.38 | 624 | 43.0 |
| 9 | 63 | 4.34 | 413 | 28.5 | 80 | 5.52 | 546 | 37.7 | - | - | - | - |
| 10 | 46 | 3.17 | 355 | 24.5 | 39 | 2.69 | 494 | 34.1 | 60 | 4.14 | 585 | 40.3 |
| 11 | 59 | 4.07 | 426 | 29.4 | 67 | 4.62 | 474 | 32.7 | 67 | 4.62 | 587 | 40.1 |
| 12 | 24 | 1.66 | 247 | 17.0 | 29 | 2.00 | 402 | 27.7 | 34 | 2.34 | 522 | 36.0 |
| 13 | 29 | 2.00 | 291 | 20.1 | 36 | 2.48 | 428 | 29.5 | 37 | 2.55 | 386 | 26.6 |
| 14 | 245 | 16.9 | 1074 | 74.1 | 212 | 14.6 | 1119 | 77.2 | 211 | 14.6 | 1233 | 85.0 |
| 15 | 76 | 5.24 | 448 | 30.9 | 76 | 5.24 | 598 | 41.2 | 87 | 6.00 | 661 | 45.6 |
| | $W_2$ = 13620 kg (30,000 lbs) | | | | $W_2$ = 27240 kg (60,000 lbs) | | | | $W_2$ = 34050 kg (75,000 lbs) | | | |

*Extrapolated values.



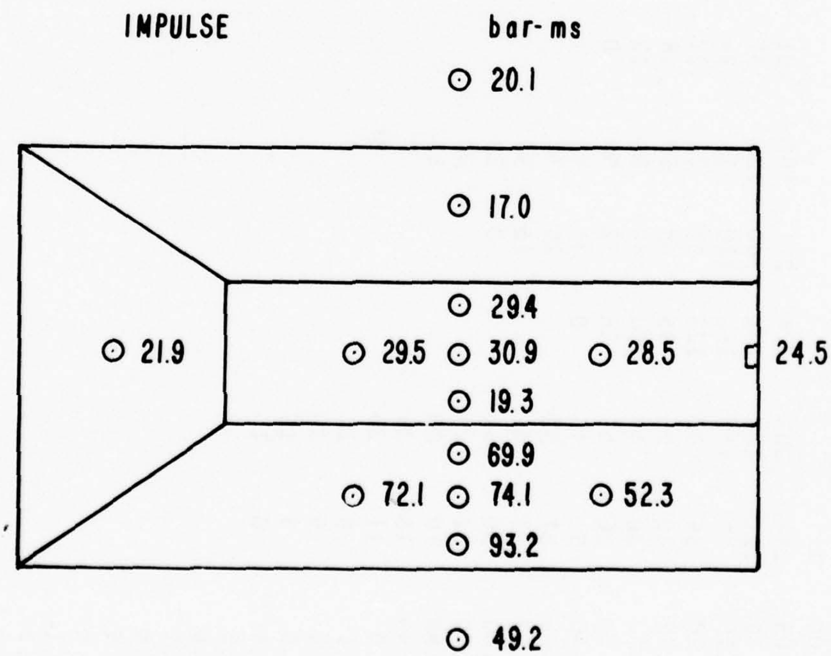



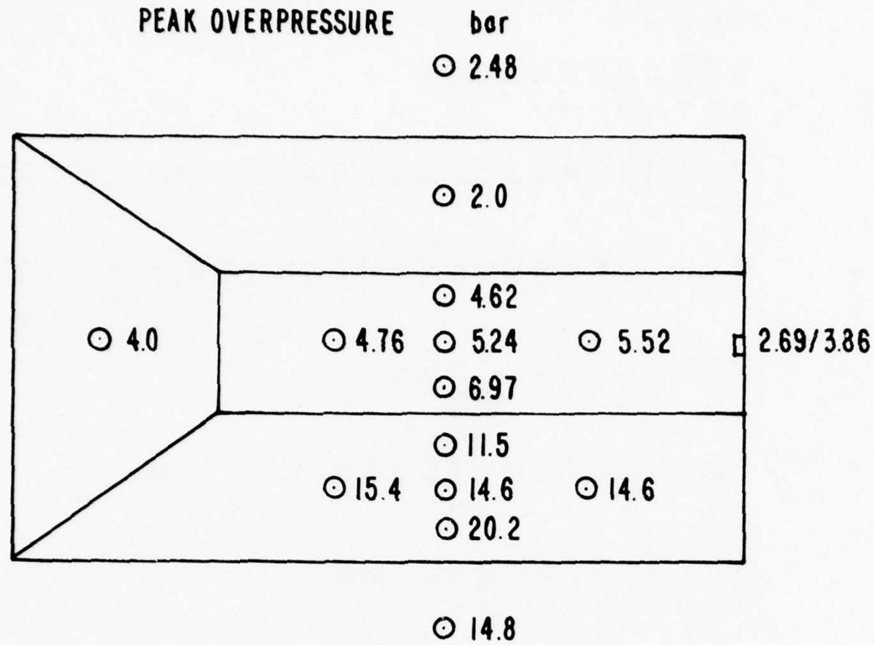

Figure 10. Pressure and Impulse Distribution on Full Scale Magazine - Series I

Table X. Average Overpressure (psi) versus Time (msec) - Series II

| Position | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time Msec | | | | | | | | | | | | | | | |
| .00 | | | | | | | | | | | | | | | |
| .05 | 214 | 293 | 224 | 211 | 167 | 101 | 58 | 69 | 80 | 39 | 67 | 29 | 36 | 212 | 76 |
| .10 | 121 | 187 | 139 | 160 | 135 | 37 | 40 | 52 | 59 | 37/56 | 53 | 26 | 29 | 182 | 57 |
| .15 | 77 | 117 | 155 | 110 | 111 | 24 | 28 | 39 | 50 | 36 | 43 | 22 | 25 | 132 | 49 |
| .20 | 55 | 92 | 123 | 61 | 75 | 22 | 23 | 31 | 38 | 31 | 36 | 20 | 22 | 96 | 39 |
| .25 | 40 | 93 | 95 | 58 | 58 | 18 | 21 | 24 | 23 | 25 | 32 | 17 | 19 | 70 | 25 |
| .30 | 30 | 49 | 64 | 42 | 55 | 12 | 19 | 17 | 19 | 23 | 29 | 15 | 17 | 41 | 19 |
| .35 | 26 | 63 | 26 | 32 | 50 | 0 | 17 | 13 | 13 | 21 | 25 | 12 | 15 | 39 | 17 |
| .40 | 31 | 45 | 0 | 31 | 42 | | 15 | 8 | 11 | 17 | 21 | 13 | 13 | 29 | 19 |
| .45 | 31 | 52 | | 24 | 37 | | 15 | 11 | 11 | 16 | 17 | 11 | 11 | 17 | 17 |
| .50 | 34 | 41 | | 16 | 33 | | 13 | 10 | 18 | 14 | 12 | 9.0 | 10 | 13 | 17 |
| .60 | 36 | 31 | | 0 | 28 | | 10 | 10 | 14 | 12 | 9 | 7.8 | 9.2 | 12 | 15 |
| .70 | 22 | 24 | | | 20 | | 9 | 5 | 13 | 9 | 6 | 6.4 | 7.3 | 8 | 13 |
| .80 | 19 | 30 | | | 13 | | 8 | 4 | 8 | 8 | 3 | 4.7 | 6.8 | 0 | 10 |
| .90 | 13 | 25 | | | 7 | | 7 | 6 | 7 | 5 | 0 | 3.3 | 6.2 | | 5 |
| 1.0 | 11 | 20 | | | 8 | | 5 | 6 | 6 | 5 | | 2.3 | 6.0 | | 4 |
| 1.1 | 6 | 24 | | | 0 | | 3 | 3 | 0 | 4 | | 2.2 | 4.7 | | 3 |
| 1.2 | 5 | 19 | | | | | 2 | 0 | | 1 | | 2.3 | 3.8 | | 3 |
| 1.3 | 3 | 15 | | | | | 0 | | | 2 | | 2.4 | 3.0 | | 5 |
| 1.4 | 0 | 10 | | | | | | | | 0 | | 2.3 | 2.3 | | 0 |
| 1.5 | | 0 | | | | | | | | | | 3.5 | 1.8 | | |
| 1.6 | | | | | | | | | | | | 3.4 | 1.7 | | |
| 1.7 | | | | | | | | | | | | 3.2 | 1.4 | | |
| 1.8 | | | | | | | | | | | | 3.4 | 1.1 | | |
| 1.9 | | | | | | | | | | | | 2.3 | .82 | | |
| 2.0 | | | | | | | | | | | | 2.1 | .70 | | |
| 2.1 | | | | | | | | | | | | 2.0 | .35 | | |
| 2.2 | | | | | | | | | | | | 1.8 | .65 | | |
| | | | | | | | | | | | | 1.5 | 0 | | |
| | | | | | | | | | | | | 1.0 | | | |
| | | | | | | | | | | | | 0 | | | |
| | ***** | ***** | ** | ** | ***** | ***** | ***** | *** | ** | * | ***** | * | ***** | * | * |

Table XI. Average Impulse (psi-msec) versus Time (msec) - Series II

| Position / Time Msec | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .00 | | | | | | | | | | | | | | | |
| .05 | 8.38 | 12.0 | 9.08 | 9.28 | 7.55 | 3.45 | 2.45 | 3.03 | 3.48 | 1.90 | 3.00 | 1.38 | 1.63 | 9.85 | 3.33 |
| .10 | 4.95 | 7.50 | 7.35 | 6.75 | 6.15 | 1.53 | 1.70 | 2.28 | 2.73 | 2.30 | 2.40 | 1.20 | 1.35 | 7.85 | 2.65 |
| .15 | 3.30 | 5.23 | 6.95 | 4.28 | 4.65 | 1.15 | 1.28 | 1.75 | 2.20 | 1.68 | 1.98 | 1.05 | 1.18 | 5.70 | 2.20 |
| .20 | 2.38 | 4.63 | 5.45 | 2.98 | 3.34 | 1.00 | 1.10 | 1.38 | 1.53 | 1.40 | 1.70 | .93 | 1.03 | 4.15 | 1.60 |
| .25 | 1.75 | 3.55 | 3.98 | 2.50 | 2.84 | .75 | 1.00 | 1.03 | 1.05 | 1.20 | 1.53 | .80 | .90 | 2.78 | 1.10 |
| .30 | 1.40 | 2.80 | 2.25 | 1.85 | 2.63 | .30 | .90 | .75 | .80 | 1.10 | 1.35 | .68 | .80 | 2.00 | .90 |
| .35 | 1.43 | 2.70 | .65 | 1.58 | 2.30 | 0 | .80 | .53 | .60 | .95 | 1.15 | .63 | .70 | 1.70 | .90 |
| .40 | 1.55 | 2.43 | 0 | 1.38 | 1.98 | | .75 | .48 | .55 | .83 | .95 | .60 | .60 | 1.15 | .90 |
| .45 | 1.63 | 2.33 | | 1.00 | 1.75 | | .70 | .53 | .73 | .75 | .73 | .50 | .53 | .75 | .85 |
| .50 | 1.75 | 1.80 | | .40 | 1.53 | | .58 | .50 | .80 | .65 | .43 | .42 | .48 | .63 | .80 |
| .60 | 3.40 | 2.75 | | 0 | 2.40 | | .95 | .75 | 1.35 | 1.05 | .45 | .71 | .83 | 1.00 | 1.40 |
| .70 | 2.55 | 2.70 | | | 1.65 | | .85 | .45 | 1.03 | .85 | .30 | .56 | .66 | .40 | 1.15 |
| .80 | 1.60 | 2.75 | | | .95 | | .75 | .50 | .73 | .65 | .10 | .40 | .65 | 0 | .75 |
| .90 | 1.20 | 2.25 | | | .74 | | .60 | .60 | .65 | .50 | 0 | .28 | .61 | | .45 |
| 1.0 | .87 | 2.20 | | | .40 | | .40 | .45 | .30 | .46 | | .23 | .54 | | .35 |
| 1.1 | .58 | 2.15 | | | | | .25 | .15 | 0 | .25 | | .23 | .43 | | .30 |
| 1.2 | .42 | 1.70 | | | | | .10 | 0 | | .15 | | .24 | .34 | | .40 |
| 1.3 | .15 | 1.25 | | | | | 0 | | | .10 | | .24 | .27 | | .25 |
| 1.4 | 0 | .50 | | | | | | | | 0 | | .29 | .21 | | 0 |
| 1.5 | | 0 | | | | | | | | | | .35 | .18 | | |
| 1.6 | | | | | | | | | | | | .33 | .16 | | |
| 1.7 | | | | | | | | | | | | .33 | .13 | | |
| 1.8 | | | | | | | | | | | | .29 | .10 | | |
| 2.0 | | | | | | | | | | | | .22 | .08 | | |
| 2.1 | | | | | | | | | | | | .21 | .05 | | |
| 2.2 | | | | | | | | | | | | .19 | .05 | | |
| | | | | | | | | | | | | .17 | .03 | | |
| | | | | | | | | | | | | .13 | 0 | | |
| | | | | | | | | | | | | .05 | | | |
| | | | | | | | | | | | | 0 | | | |
| Model | 39.29 | 63.22 | 35.71 | 32.00 | 40.86 | 8.18 | 15.16 | 15.16 | 18.53 | 16.76 | 16.07 | 13.64 | 14.52 | 37.96 | 20.28 |
| Full Scale | 1158 | 1864 | 1053 | 944 | 1205 | 241 | 447 | 447 | 546 | 494 | 474 | 402 | 428 | 1119 | 598 |



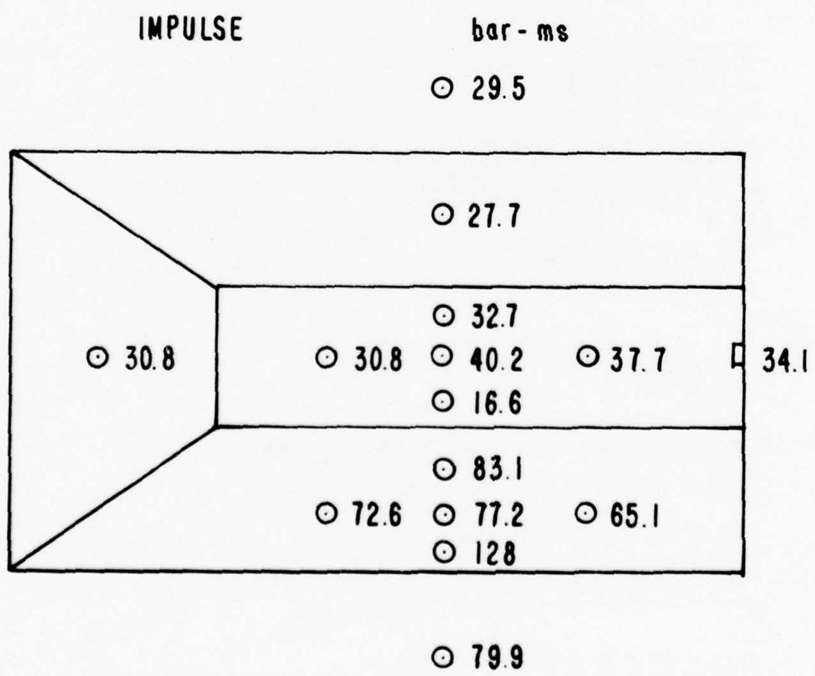




Figure 11. Pressure and Impulse Distribution on Full Scale Magazine - Series II

Table XII. Average Overpressure (psi) versus Time (msec) Series III

| Position<br>Time msec | 1 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|
| .00 | 181 | 71 | 62 | 78 | 42 | 67 | 34 | 37 | 211 | 87 |
| .05 | 118 | 53/92 | 45 | 62 | 38/60 | 55 | 28 | 31 | 165 | 70 |
| .10 | 78 | 31 | 36 | 53 | 43 | 44 | 25 | 26 | 132 | 53 |
| .15 | 60 | 26 | 32 | 47 | 33 | 43 | 23 | 23 | 100 | 43 |
| .20 | 42 | 19 | 28 | 35 | 29 | 31 | 19 | 20 | 73 | 32 |
| .25 | 33 | 17 | 22 | 27 | 27 | 33 | 18 | 18 | 51 | 27 |
| .30 | 32 | 14 | 22 | 23 | 22 | 29 | 16 | 16 | 38 | 22 |
| .35 | 28 | 9.5 | 19 | 20 | 20 | 23 | 15 | 13 | 28 | 18 |
| .40 | 20 | 4.7 | 16 | 18 | 19 | 22 | 13 | 11 | 23 | 16 |
| .45 | 22 | 5.0 | 16 | 15 | 16 | 20 | 12 | 8.7 | 20 | 15 |
| .50 | 17 | 3.6 | 12 | 13 | 14 | 17 | 11 | 7.7 | 16 | 13 |
| .60 | 12 | 2.6 | 11 | 10 | 13 | 11 | 8.8 | 6.5 | 13 | 10 |
| .70 | 9.0 | 0 | 9.6 | 8.4 | 8.7 | 5.5 | 7.1 | 5.0 | 11 | 8.9 |
| .80 | 8.0 | | 7.8 | 6.6 | 6.3 | 2.8 | 5.5 | 3.6 | 7.3 | 8.4 |
| .90 | 6.3 | | 6.4 | 3.3 | 5,5 | 0 | 5.0 | 4.8 | 4.5 | 6.4 |
| 1.0 | 4.5 | | 4.4 | 2.1 | 4.1 | | 3.2 | 3.5 | 3.3 | 4.7 |
| 1.1 | 3.8 | | 2.9 | 1.0 | 3.6 | | 3.6 | 2.5 | .50 | 3.2 |
| 1.2 | 2.0 | | 2.7 | .5 | 3.3 | | 5.1 | 1.7 | 0 | 1.5 |
| 1.3 | 1.8 | | 2.7 | 0 | 2.2 | | 4.8 | 1.1 | | .80 |
| 1.4 | 2.0 | | 4.9 | | 1.0 | | 4.9 | .80 | | 0 |
| 1.5 | 1.0 | | 3.3 | | .10 | | 4.7 | .58 | | |
| 1.6 | .75 | | 1.4 | | .50 | | 4.3 | .87 | | |
| 1.7 | .25 | | 1.5 | | 0 | | 3.8 | .87 | | |
| 1.8 | .13 | | 2.2 | | | | 3.5 | .25 | | |
| 1.9 | 0 | | 0 | | | | 3.2 | 0 | | |
| 2.0 | | | | | | | 2.6 | | | |
| 2.1 | | | | | | | 1.9 | | | |
| 2.2 | | | | | | | 1.3 | | | |
| 2.3 | | | | | | | 1.1 | | | |
| 2.4 | | | | | | | .5 | | | |
| 2.5 | | | | | | | .5 | | | |
| 2.6 | | | | | | | 0 | | | |
| | **** | * | *** | *** | **** | * | **** | **** | **** | *** |

position. The impulse versus time calculation are listed in Table XIII with the total impulse noted at the bottom of each column. The peak overpressure and total positive impulse values from Series III are listed in Table IX. They are presented in Figure 12 to show the pressure and impulse distribution to be expected over a full scale munition storage magazine exposed to a 34,050 kg (75,000 lb) hemispherical charge of TNT.

On test series III the peak overpressure criterion was satisfied at Position 15 with 6.0 bars (87.0 psi). The requirement was from 5.37 to 6.55 bars (78 - 95 psi). The overpressure impulse requirement was 44.8 bars (650 psi-msec) and at Position 15 an overpressure impulse of 45.6 bars (661 psi-msec) was obtained. Therefore, a recommendation for the full scale test was a 34,050 kg (74,000 lb) hemispherical charge of TNT placed 47.2 m (155 ft) from the center line of the acceptor magazines.

C. Blast Loading on a 1/45 Scale Model Magazine

The dimensions of the 1/45 scale model magazine are shown in Figure 3. A photograph of the instrumented model is presented in Figure 9. This test series (Series IV) was conducted to determine the blast loading to be expected from a 41,370 kg (91,125 lb) TNT charge placed 50.3 m (165 ft) from the centerline of the full size munition storage magazine. As noted in Table VI, on Shot 13 a sand model was used while on Shots 18 and 19 a concrete model was used. The gage position and charge weight are given in Table V.

Values of the average overpressure versus time for the three shots are listed in Table XIV for all positions instrumented. These average values of overpressure versus time were used to calculate values of average impulse versus time which are listed in Table XV. The total positive impulse for each position is listed at the bottom of each column. The second value in the column is the scaled up value of total impulse to be expected at the same location on a full size structure.

The distribution of peak overpressure and impulse to be expected over a full size magazine is shown in Figure 13.

Although the full-scale charge weight for Test Series IV would be approximately 22 percent greater than the 34050 kg (75,000 lb) considered for Test Series III, there was very little difference in the scaled up overpressure impulse values on the top of the structure. Compare the overpressure impulse values presented in Figure 12 versus Figure 13.

Table XIII. Average Impulse (psi-msec) versus Time (msec) - Series III

| Position | 1 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|
| Time-msec | | | | | | | | | | |
| .00 | | | | | | | | | | |
| .05 | 7.48 | 3.10 | 2.68 | 3.50 | 2.00 | 3.05 | 1.55 | 1.70 | 9.40 | 3.93 |
| .10 | 4.91 | 3.08 | 2.03 | 2.88 | 2.58 | 2.48 | 1.33 | 1.43 | 7.43 | 3.08 |
| .15 | 3.44 | 1.42 | 1.70 | 2.50 | 1.90 | 2.18 | 1.20 | 1.23 | 5.80 | 2.40 |
| .20 | 2.54 | 1.11 | 1.50 | 2.05 | 1.55 | 1.85 | 1.05 | 1.08 | 4.33 | 1.88 |
| .25 | 1.88 | .91 | 1.25 | 1.55 | 1.40 | 1.60 | .93 | .95 | 3.10 | 1.48 |
| .30 | 1.64 | .78 | 1.10 | 1.25 | 1.23 | 1.55 | .85 | .85 | 2.23 | 1.23 |
| .35 | 1.49 | .56 | 1.03 | 1.08 | 1.05 | 1.30 | .78 | .73 | 1.65 | 1.00 |
| .40 | 1.19 | .36 | .88 | .95 | .98 | 1.13 | .70 | .60 | 1.28 | .85 |
| .45 | 1.04 | .24 | .80 | .83 | .88 | 1.05 | .63 | .49 | 1.08 | .78 |
| .50 | .98 | .22 | .70 | .70 | .75 | .93 | .58 | .41 | .90 | .70 |
| .60 | 1.48 | .31 | 1.15 | 1.15 | 1.35 | 1.40 | .99 | .71 | 1.45 | 1.15 |
| .70 | 1.06 | .13 | 1.03 | .92 | 1.09 | .83 | .80 | .58 | 1.20 | .95 |
| .80 | .85 | 0 | .87 | .75 | .75 | .42 | .63 | .43 | .92 | .87 |
| .90 | .71 | | .71 | .50 | .55 | .14 | .53 | .42 | .59 | .74 |
| 1.00 | .54 | | .54 | .27 | .48 | 0 | .41 | .42 | .39 | .56 |
| 1.1 | .41 | | .37 | .16 | .39 | | .34 | .30 | .04 | .40 |
| 1.2 | .30 | | .28 | .08 | .35 | | .44 | .21 | .03 | .24 |
| 1.3 | .20 | | .27 | .03 | .28 | | .50 | .14 | 0 | .12 |
| 1.4 | .19 | | .38 | 0 | .16 | | .49 | .10 | | .04 |
| 1.5 | .15 | | .41 | | .06 | | .48 | .07 | | 0 |
| 1.6 | .09 | | .24 | | .03 | | .45 | .07 | | |
| 1.7 | .05 | | .15 | | .03 | | .41 | .09 | | |
| 1.8 | .02 | | .19 | | 0 | | .37 | .06 | | |
| 1.9 | 0 | | .11 | | | | .34 | .02 | | |
| 2.0 | | | 0 | | | | .29 | 0 | | |
| 2.1 | | | | | | | .23 | | | |
| 2.2 | | | | | | | .16 | | | |
| 2.3 | | | | | | | .12 | | | |
| 2.4 | | | | | | | .08 | | | |
| 2.5 | | | | | | | .05 | | | |
| 2.6 | | | | | | | 0 | | | |
| Model | 32.64 | 12.22 | 20.37 | 21.15 | 19.84 | 19.91 | 17.71 | 13.09 | 41.82 | 22.4 |
| Full Scale | 962 | 360 | 601 | 624 | 585 | 587 | 522 | 386 | 1233 | 661 |

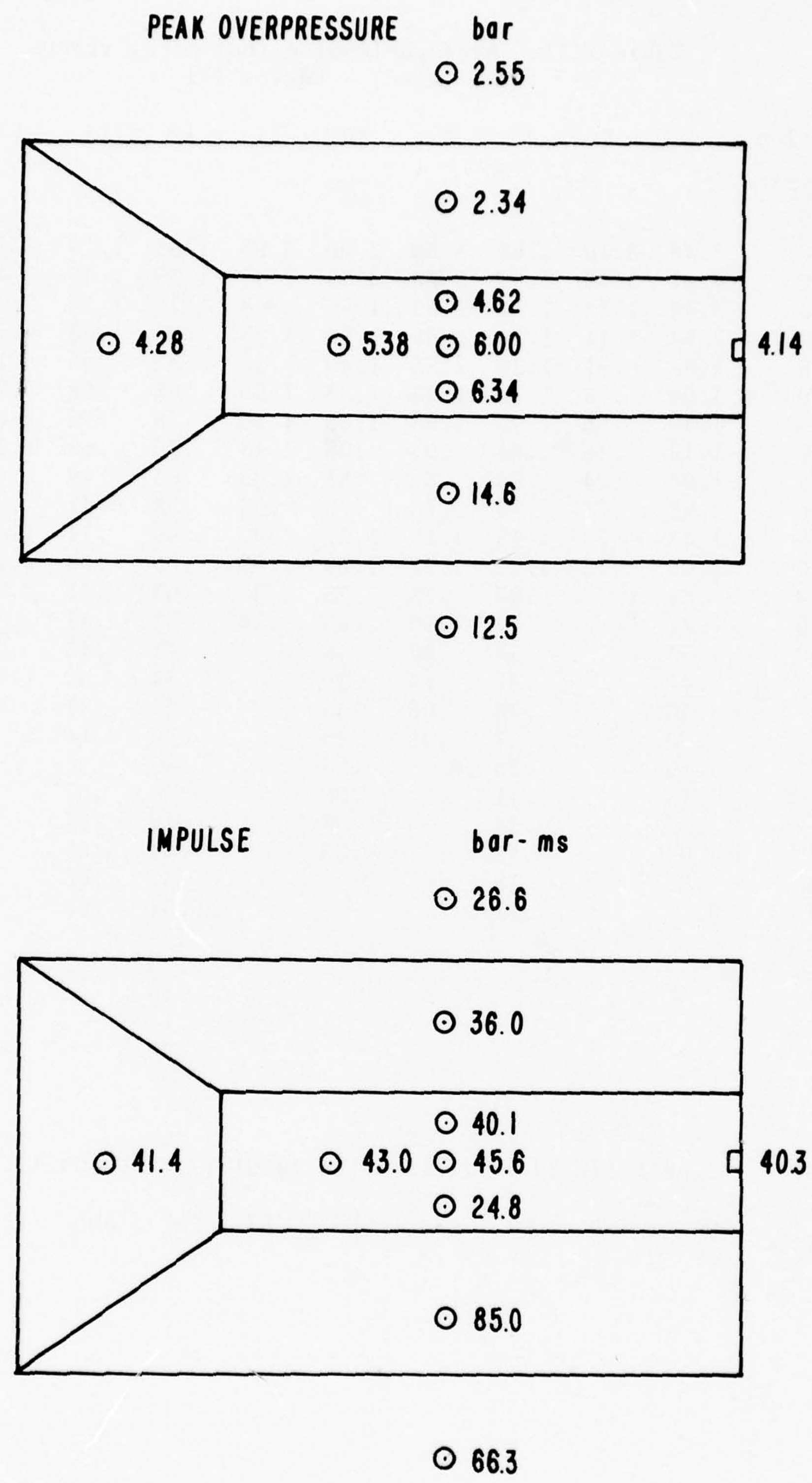



Figure 12. Pressure and Impulse Distribution on Full Scale Magazine - Series III

Table XIV. Average Overpressure (psi) versus Time (msec) - Series IV

| Position<br>Time msec | 1 | 2 | 5 | 6 | 7 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| .00 | 172 | 347 | 147 | 96 | 57 | 55 | 70 | 31 | 36 | 156 | 81 |
| .05 | 96 | 150 | 103 | 39 | 45 | 48 | 45 | 28 | 29 | 126 | 50 |
| .10 | 61 | 113 | 74 | 25 | 29 | 36 | 42 | 25 | 23 | 96 | 45 |
| .15 | 43 | 72 | 68 | 15 | 24 | 31 | 38 | 20 | 18 | 63 | 36 |
| .20 | 31 | 41 | 50 | 14 | 22 | 26 | 30 | 16 | 15 | 43 | 30 |
| .25 | 24 | 30 | 31 | 9.3 | 20 | 21 | 21 | 15 | 12 | 32 | 18 |
| .30 | 23 | 21 | 21 | 3.8 | 17 | 18 | 16 | 12 | 11 | 25 | 15 |
| .35 | 26 | 15 | 14 | 4.3 | 15 | 18 | 9.7 | 9.2 | 9.4 | 19 | 12 |
| .40 | 16 | 10 | 11 | 3.6 | 13 | 14 | 7.0 | 7.8 | 8.6 | 14 | 9.5 |
| .45 | 13 | 5 | 11 | 3.6 | 11 | 12 | 5.3 | 8.4 | 8.3 | 10 | 7.8 |
| .50 | 12 | 3 | 10 | 2.8 | 8.9 | 8.7 | 2.9 | 6.5 | 8.0 | 7.3 | 6.5 |
| .60 | 8.0 | 0 | 8 | 0 | 6.5 | 7.3 | 2.0 | 5.3 | 5.2 | 6.3 | 3.7 |
| .70 | 5.3 | | 0 | | 4.4 | 4.4 | 0 | 5.0 | 4.2 | 4.0 | 6.0 |
| .80 | 4.0 | | | | 3.7 | 3.8 | | 4.0 | 2.8 | 2.0 | 3.5 |
| .90 | 3.0 | | | | 3.2 | 4.1 | | 5.5 | 2.2 | 0 | 3.0 |
| 1.0 | 2.3 | | | | 1.2 | 1.3 | | 4.6 | 1.2 | | 1.5 |
| 1.1 | 0 | | | | 1.0 | 1.8 | | 4.2 | .6 | | 0 |
| 1.2 | | | | | 0 | 1.8 | | 3.6 | .4 | | |
| 1.3 | | | | | | 1.0 | | 3.4 | 0 | | |
| 1.4 | | | | | | 0 | | 3.0 | | | |
| 1.5 | | | | | | | | 1.8 | | | |
| 1.6 | | | | | | | | .9 | | | |
| | *** | ** | * | * | *** | *** | * | * | *** | ** | ** |

Table XV. Average Impulse (psi-msec) versus Time (msec) - Series IV

| Position | 1 | 2 | 5 | 6 | 7 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time msec | | | | | | | | | | | |
| .00 | | | | | | | | | | | |
| .05 | 6.70 | 12.4 | 6.25 | 3.38 | 2.55 | 2.58 | 2.88 | 1.48 | 1.63 | 7.05 | 3.28 |
| .10 | 3.93 | 6.58 | 4.43 | 1.60 | 1.85 | 2.10 | 2.18 | 1.33 | 1.30 | 5.55 | 2.38 |
| .15 | 2.60 | 4.63 | 3.55 | 1.00 | 1.33 | 1.68 | 2.00 | 1.13 | 1.03 | 3.98 | 2.03 |
| .20 | 1.85 | 2.83 | 2.95 | .73 | 1.15 | 1.43 | 1.70 | .90 | .83 | 2.65 | 1.65 |
| .25 | 1.38 | 1.78 | 2.03 | .58 | 1.05 | 1.18 | 1.28 | .78 | .68 | 1.88 | 1.20 |
| .30 | 1.17 | 1.28 | 1.30 | .33 | .93 | .98 | .93 | .68 | .58 | 1.43 | .83 |
| .35 | 1.23 | .90 | .88 | .20 | .80 | .90 | .64 | .53 | .51 | 1.10 | .68 |
| .40 | 1.05 | .63 | .63 | .20 | .70 | .80 | .42 | .43 | .45 | .83 | .54 |
| .45 | .73 | .38 | .55 | .18 | .60 | .65 | .31 | .41 | .42 | .60 | .43 |
| .50 | .63 | .20 | .53 | .16 | .50 | .52 | .21 | .37 | .41 | .43 | .36 |
| .60 | 1.00 | .15 | .90 | .14 | .77 | .80 | .24 | .59 | .66 | .68 | .52 |
| .70 | .67 | 0 | .40 | 0 | .49 | .59 | .10 | .45 | .47 | .52 | .49 |
| .80 | .47 | | 0 | | .41 | .41 | 0 | .48 | .35 | .30 | .48 |
| .90 | .35 | | | | .35 | .40 | | .51 | .25 | .10 | .33 |
| 1.0 | .27 | | | | .22 | .27 | | .44 | .17 | 0 | .23 |
| 1.1 | .12 | | | | .11 | .16 | | .39 | .09 | | .08 |
| 1.2 | 0 | | | | .05 | .18 | | .35 | .05 | | 0 |
| 1.3 | | | | | 0 | .14 | | .32 | .02 | | |
| 1.4 | | | | | | .05 | | .24 | 0 | | |
| 1.5 | | | | | | 0 | | .14 | | | |
| 1.6 | | | | | | | | .05 | | | |
| | | | | | | | | 0 | | | |
| Model | 24.15 | 31.76 | 24.40 | 8.50 | 13.86 | 15.82 | 12.89 | 12.52 | 9.90 | 27.1 | 15.51 |
| Full Scale | 1032 | 1357 | 1042 | 363 | 592 | 676 | 551 | 535 | 423 | 1157 | 663 |

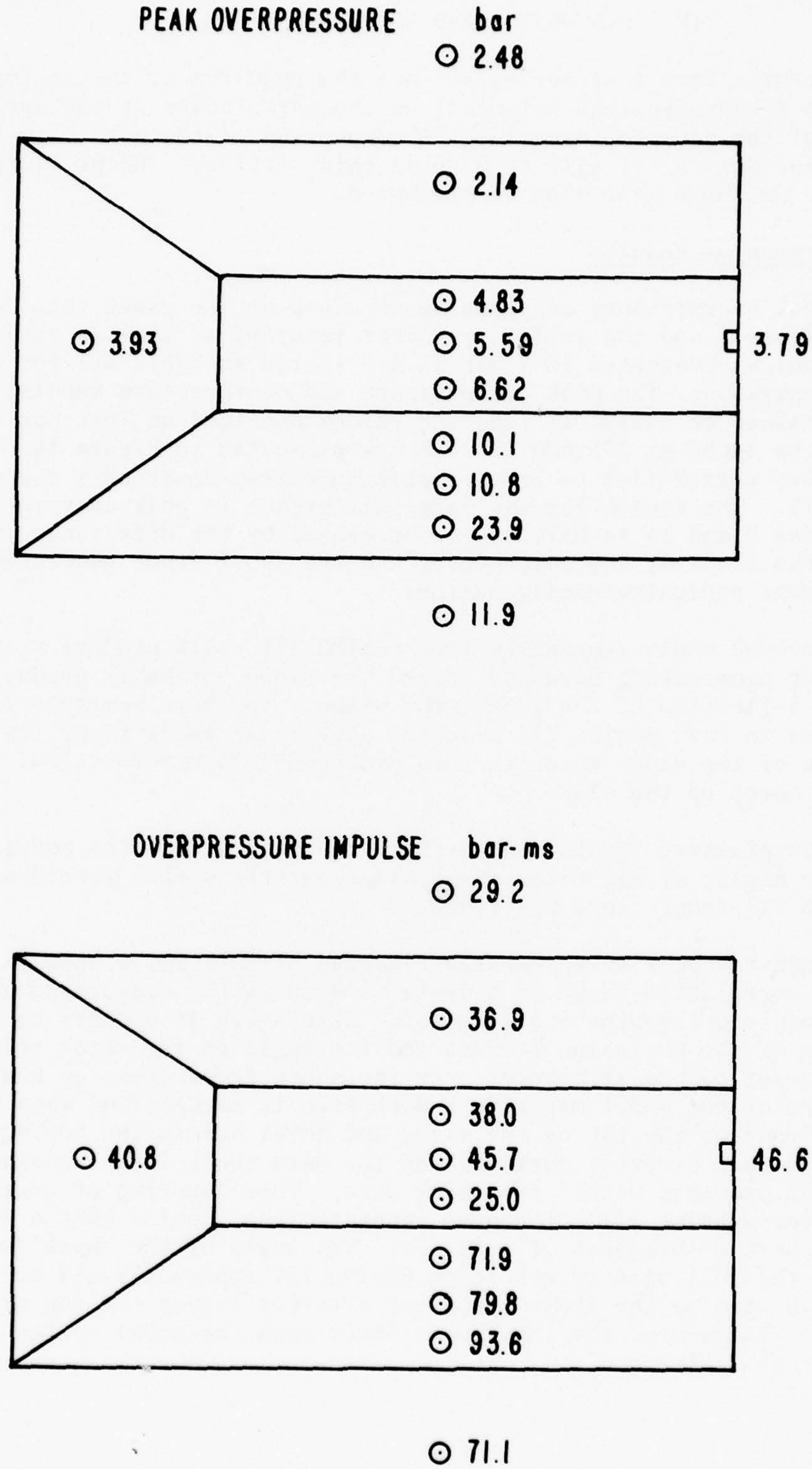



Figure 13. Pressure and Impulse Distribution on Full Scale Magazine - Series IV

## IV. DISCUSSION AND RECOMMENDATIONS

The results from test Series III met the requirement for an impulse load of 44.8 bar-msec (650 psi-msec) on the earth cover at the apex of the arch of the acceptor magazine. A comparison of the data from ESKIMO III and Test Series III will be made in this section. The predicted values for ESKIMO V will also be presented.

### A. Comparison of Results

The peak overpressure and impulse obtained at the gauge location shown in Table I and the scaled-up values recorded at similar positions on the model, as presented in Table IX, are listed in Table XVI for a direct comparison. The peak overpressure and overpressure impulse values obtained on ESKIMO III and the values obtained on Test Series III scaled up to 34050 kg (75,000 lb) TNT are presented in Figure 14. There is very good correlation of peak overpressure from Position 5 through Position 13. The reason for the large difference in peak overpressure at Positions 2 and 14 is believed to be caused by the difference in the angle of the slope of the earth cover and the shock front generated from two different explosive configurations.

The covered explosive charge from ESKIMO III would produce a curved shock front propagating downward toward the slope, probably producing a regular reflection at the toe of the slope. The bare hemispherical charge used in Test Series III produces a vertical shock front starting up the toe of the slope which in turn produces a Mach reflection, and a Mach stem moves up the slope.

The overpressure impulse shows the same trend except the model values are higher at all three front slope positions than recorded on the ESKIMO III front slope positions.

Although the peak overpressures recorded at Position 6 show excellent correlation there is a dramatic drop in the overpressure impulse obtained from the scaled model. Here again it appears to be a function of the explosion sources and the angle of the shock relative to earth cover on the structures. As the shock front moves up the front slope of the model magazine a Mach stem is formed; and when the Mach stem reaches the top of the slope and moves across the top surface of the structure a vortex forms behind the Mach shock front causing a lowering of pressure within the shock wave. This lowering of overpressure versus time will of course generate less impulse than a shock wave without the influence of a vortex. The angle of the shock front impinging the full size structure on ESKIMO III apparently did not form a Mach stem up the front slope nor a vortex across the top of the structure. Therefore, the impulse is lower than the model up the slope and higher at Position 6.

Table XVI. Comparison of Results from ESKIMO III and Test Series III

| Position No. | Peak Overpressure bar | | Impulse bar-msec | | Peak Overpressure psi | | Impulse psi msec | |
|---|---|---|---|---|---|---|---|---|
| | ESKIMO III | Model | ESKIMO III | Model | ESKIMO III | Model | ESKIMO III | Model |
| 1 | - | 12.5 | - | 66.3 | - | 181 | - | 962 |
| 2a | 7.59 | 17.9* | - | 100* | 110 | 260* | - | 1450* |
| 2b | 8.28 | - | 55.4 | - | 120 | - | 804 | - |
| 14 | - | 14.6 | - | 85.0 | - | 211 | - | 1233 |
| 5a | - | 11.0* | - | 75.0* | - | 160* | - | 1088* |
| 5b | 11.4 | - | 45.7 | - | 165 | - | 662 | - |
| 6a | 5.52 | 6.34 | 36.5 | 24.8 | 80 | 92 | 529 | 360 |
| 6b | 6.55 | - | 55.6 | - | 95 | - | 806 | - |
| 15 | - | 6.00 | - | 45.6 | - | 87 | - | 661 |
| 11a | 5.38 | 4.62 | 42.9 | 40.1 | 78 | 67 | 622 | 587 |
| 11b | 5.86 | - | 44.3 | - | 85 | - | 642 | - |
| 8 | - | 5.38 | - | 43.0 | - | 78 | - | 624 |
| 7 | - | 4.28 | - | 41.4 | - | 62 | - | 601 |
| 10a | 4.48 | - | 41.9 | - | 65 | - | 608 | - |
| 10 | - | 4.14 | - | 40.3 | - | 60 | - | 585 |
| 10b | 3.45 | - | 47.8 | - | 50 | - | 694 | - |
| 12a | 2.76 | 2.34 | 33.4 | 36.0 | 40 | 34 | 484 | 552 |
| 12b | - | - | - | - | - | - | - | - |
| 13 | 3.45 | 2.55 | 45.0 | 26.6 | 50 | 37 | 652 | 386 |

Designation a and b are for Magazine A and B on ESKIMO III. Values from the model test series III are listed with the a designation.

*Indicates extrapolated values based on other test series.

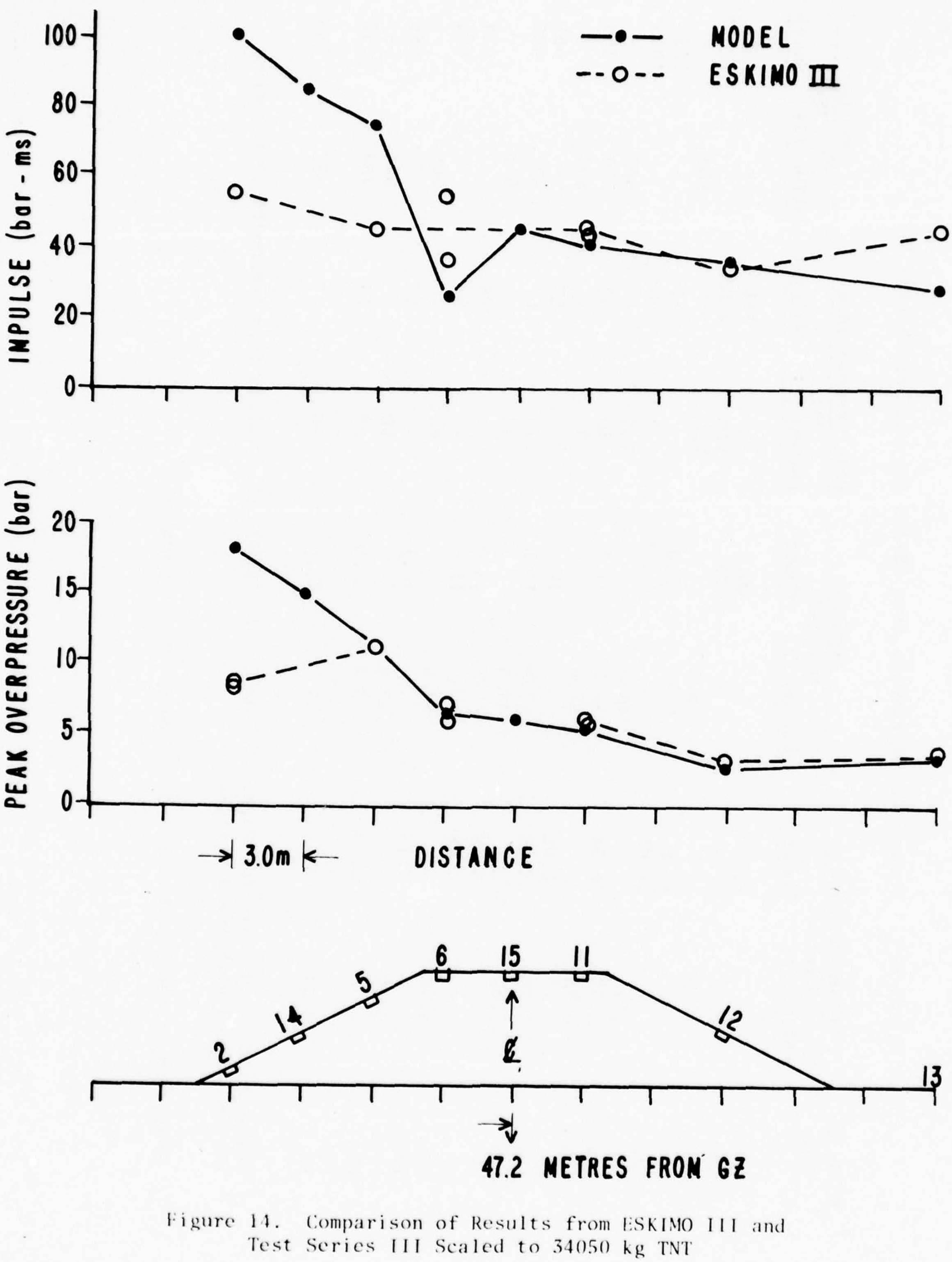



Figure 14. Comparison of Results from ESKIMO III and Test Series III Scaled to 34050 kg TNT

Other positions show very good correlation of both peak overpressure and overpressure impulse with the exception of position 13 where the impulse from ESKIMO III is higher than recorded on test Series III.

B. Shock Reflection and Diffraction - Theory and Experiment

The theoretical treatment of shock reflection and diffraction presented in this section was taken from Reference 7. It contains a summary of methods for predicting the effects of terrain on blast wave propagation.

1. Mach Reflection Pressure on the Front Slope. The peak Mach reflection overpressure up the center of the front slope of the model structure can be determined from two-dimensional theory. A typical Mach reflection pattern is shown in Figure 15. Here the incident shock pressure ratio Z is $P_s/P_o$, where $P_s$ is the peak incident overpressure and $P_o$ is atmospheric pressure. The pressure ratio for the Mach reflected shock $Z_m$ is $P_M/P_o$, where $P_m$ is the peak Mach overpressure and $P_o$ is atmospheric pressure. The angle $\Theta$ in Figure 15 is 26.6 degrees.

The incident shock pressure ratio Z for a hemispherical pentolite surface burst is plotted versus scaled distance in Figure 16. This curve was developed from data presented in Reference 1. When Z is determined for a selected scaled distance up the front slope then the Mach reflection ratio $Z_m$ can be determined from Figure 17 where $Z_m$ is plotted as a function of Z for a slope angle of 26.6 degrees. This curve was developed from data presented in Reference 7.

The values of $Z_m$ determined up the front slope for selected scaled distances have been plotted in Figure 16 and listed for the gauge positions 2, 14, and 6 in Table XVII. The Mach pressure ratio $Z_m$ values were converted to $P_m$ values for a direct comparison with experimental values of $P_m$.

2. Shock Diffraction Pressures on the Roof. When a rising slope changes to a falling slope then the Mach reflection process changes to a shock diffraction. The process is reversed and the pressure on the surface becomes less than the input pressure. This condition is shown in Figure 15 where $Z_m$ becomes the input shock ratio and the diffracted shock pressure ratio is noted as $Z_T$ which is $P_T/P_o$ where $P_T$ is the overpressure on the top of the structure and $P_o$ is the atmospheric pressure. A plot of $Z_T$ as a function of $Z_m$ for $\Theta$ equal to 26.6° is presented in Figure 18. Based on the assumption that the diffraction process is a reversal of the reflection process the overpressure ratio $Z_T$ across the top of the model structure becomes equal to Z, the incident overpressure ratio shown in Figure 16. The values of $Z_T$, determined from Figure 18 have been plotted

[7] *R. J. Arave and N. R. Wallace, "Dynamic Pressure from Blast Waves: Methods for Predicting the Effects of Terrain," URS Corporation, URS 649-6, February 1966.*

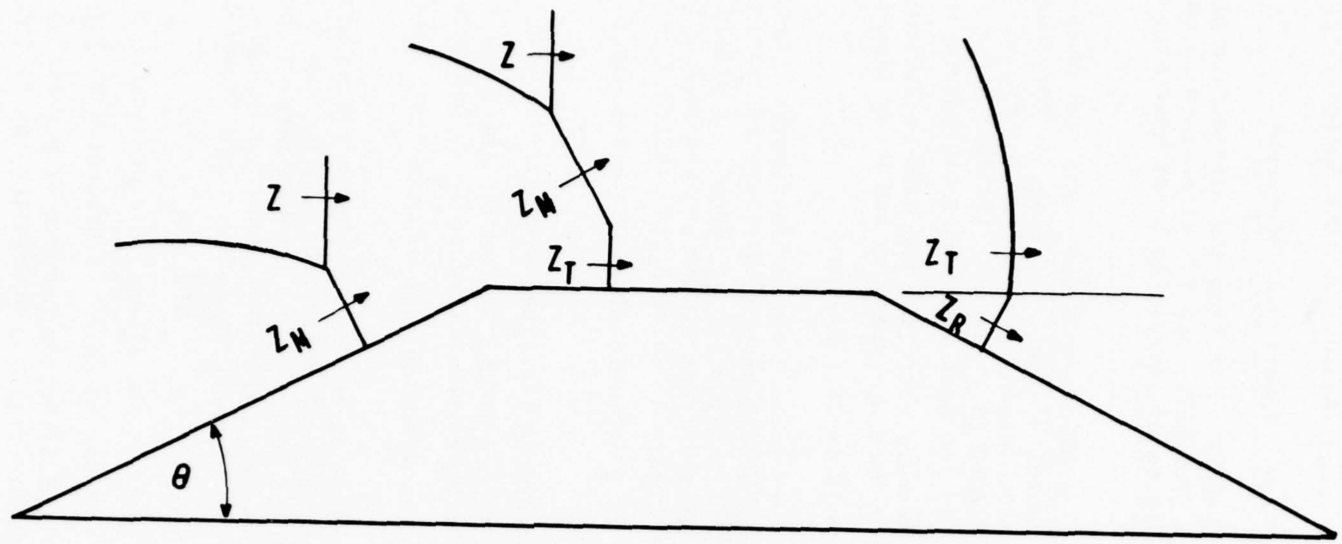



Figure 15. Mach Reflection and Diffraction Pattern

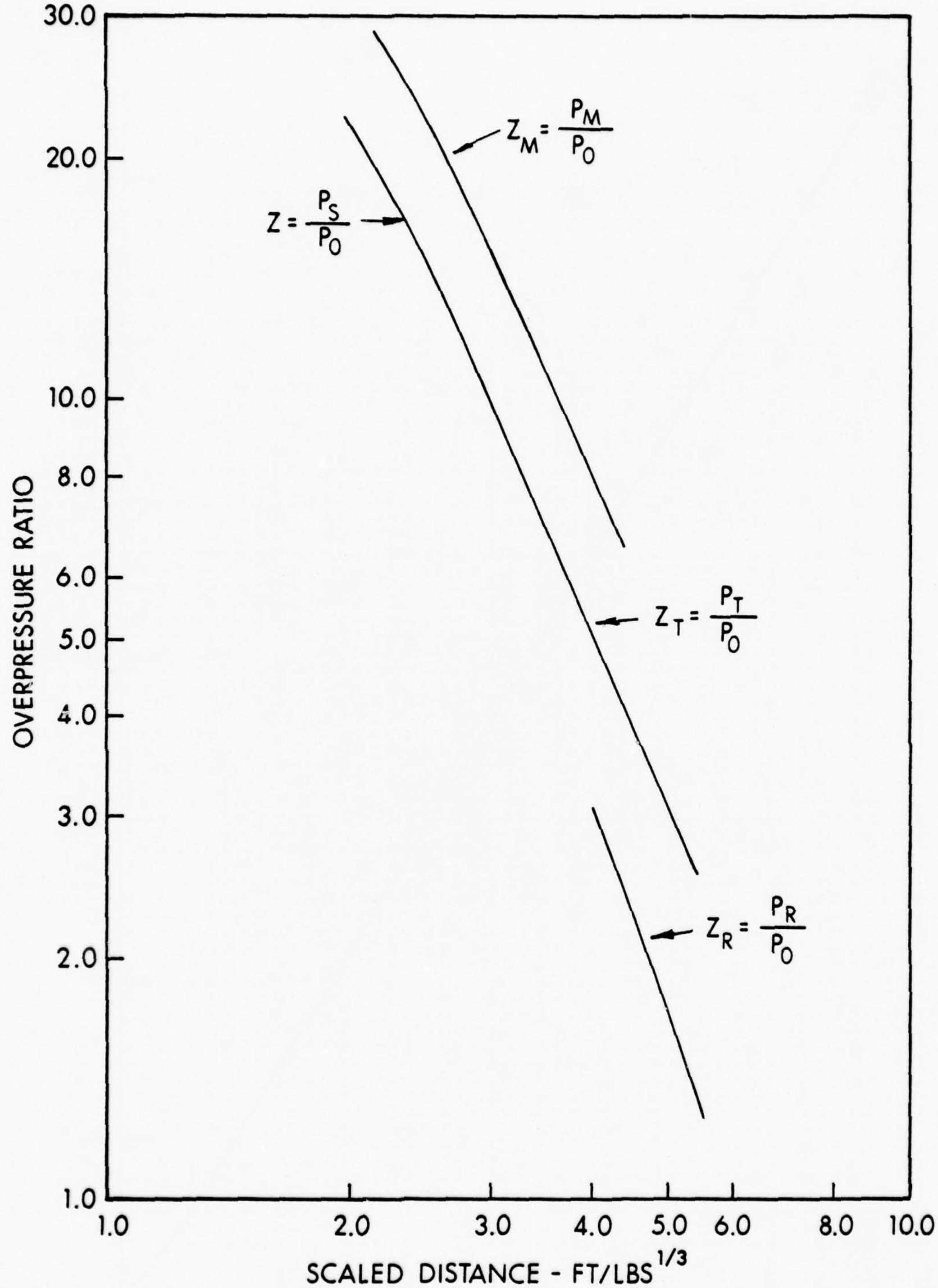



Figure 16. Overpressure Ratio versus Scaled Distance

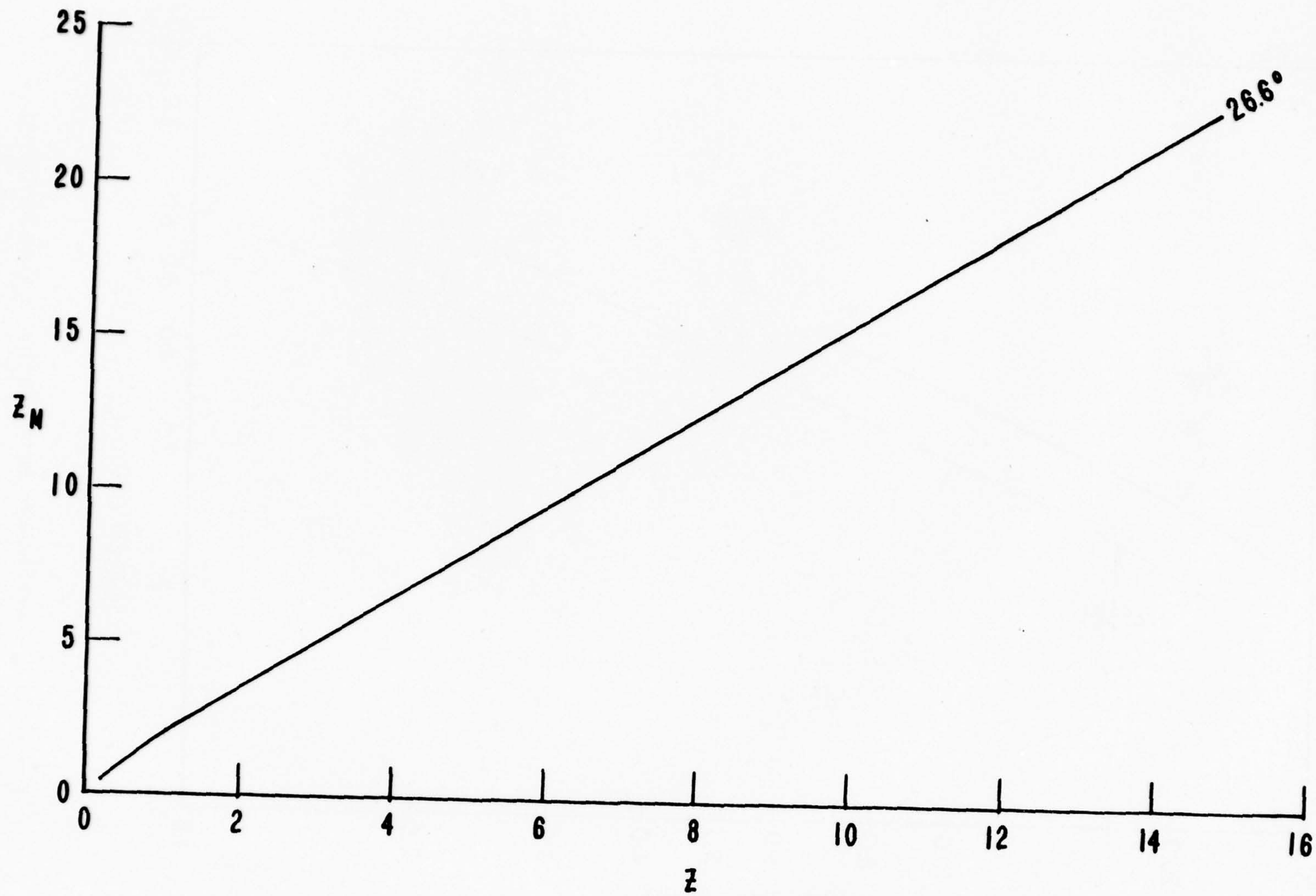



Figure 17. Input Pressure Ratio versus Mach Reflection Pressure Ratio

Table XVII. Mach Reflection and Diffraction-Theory and Experiment

Series I

| Position Number | Scaled Distance $\lambda$ ft/lbs$^{1/3}$ | $Z$ | $Z_m$ | Peak Mach Overpressure Theory psi | Peak Mach Overpressure Experiment psi |
|---|---|---|---|---|---|
| 2 | 2.51 | 15.0 | 23.0 | 338 | 338 |
| 14 | 2.85 | 11.4 | 17.6 | 259 | 245 |
| 5 | 3.19 | 8.7 | 13.6 | 199 | 177 |
| * | 3.43 | 7.3 | 11.4 | 168 | - |
| | | $Z_m$ | $Z_T$ | | |
| 6 | 3.53 | 10.8 | 6.9 | 100 | 97 |
| 15 | 3.87 | 8.9 | 5.6 | 82 | 76 |
| 11 | 4.20 | 7.4 | 4.6 | 67 | 59 |
| ** | 4.31 | 7.0 | 4.3 | 63 | - |
| | | $Z_T$ | $Z_R$ | | |
| 12 | 4.88 | 3.2 | 1.8 | 27 | 24 |

Series II

| Position Number | Scaled Distance $\lambda$ ft/lbs$^{1/3}$ | $Z$ | $Z_m$ | Peak Mach Overpressure Theory psi | Peak Mach Overpressure Experiment psi |
|---|---|---|---|---|---|
| 2 | 2.79 | 12.0 | 18.5 | 272 | 293 |
| 14 | 3.06 | 9.6 | 14.9 | 219 | 212 |
| 5 | 3.33 | 7.8 | 12.2 | 179 | 167 |
| * | 3.52 | 7.0 | 11.0 | 162 | - |
| | | $Z_m$ | $Z_T$ | | |
| 6 | 3.60 | 10.4 | 6.6 | 97 | 101 |
| 15 | 3.87 | 8.9 | 5.6 | 82 | 76 |
| 11 | 4.14 | 7.6 | 4.7 | 69 | 67 |
| ** | 4.22 | 7.3 | 4.5 | 66 | |
| | | $Z_T$ | $Z_R$ | | |
| 12 | 4.67 | 3.6 | 2.1 | 30 | 29 |

Table XVII. Mach Reflection and Diffraction-Theory and Experiment (Continued)

Series III

| Position Number | Scaled Distance $\lambda$ ft/lbs$^{1/3}$ | Z | $Z_m$ | Peak Mach Overpressure Theory psi | Peak Mach Overpressure Experiment psi |
|---|---|---|---|---|---|
| 2 | 2.87 | 11.0 | 17.0 | 250 | 260 |
| 14 | 3.12 | 9.0 | 14.0 | 206 | 211 |
| 5 | 3.37 | 7.8 | 12.2 | 179 | 160 |
| * | 3.55 | 6.8 | 10.7 | 157 | - |
| | | $Z_m$ | $Z_T$ | | |
| 6 | 3.62 | 10.3 | 6.5 | 96 | 92 |
| 15 | 3.87 | 8.9 | 5.6 | 82 | 87 |
| 11 | 4.12 | 7.7 | 4.8 | 70 | 67 |
| ** | 4.19 | 7.4 | 4.6 | 68 | - |
| | | $Z_T$ | $Z_R$ | | |
| 12 | 4.61 | 3.7 | 2.1 | 31 | 34 |

Table XVII. Mach Reflection and Diffraction-Theory and Experiment (Continued)

Series IV

| Position Number | Scaled Distance λ ft/lbs$^{1/3}$ | Z | $Z_m$ | Peak Mach Overpressure Theory psi | Peak Mach Overpressure Experiment psi |
|---|---|---|---|---|---|
| 2 | 2.93 | 10.6 | 16.4 | 241 | 347 |
| 14 | 3.16 | 8.9 | 13.9 | 203 | 156 |
| 5 | 3.39 | 7.6 | 11.9 | 175 | 147 |
| * | 3.43 | 7.3 | 11.4 | 168 | - |
| | | $Z_m$ | $Z_T$ | | |
| 6 | 3.63 | 10.0 | 6.3 | 93 | 96 |
| 15 | 3.87 | 8.9 | 5.6 | 82 | 81 |
| 11 | 4.10 | 7.8 | 4.9 | 71 | 70 |
| ** | 4.31 | 7.0 | 4.3 | 63 | - |
| | | $Z_T$ | $Z_R$ | | |
| 13 | 4.56 | 3.9 | 2.3 | 33 | 31 |

*Top of front slope.

**Rear edge of roof.

NOTE:

$Z = P_s/P_o$

$Z_m = P_m/P_o$

$Z_T = P_T/P_o$

$Z_R = P_R/P_o$.

WHERE:

$P_s$ = Peak incident overpressure

$P_m$ = Peak mach overpressure

$P_T$ = Peak overpressure on top of structure

$P_R$ = Peak overpressure on rear slope

$P_o$ = Atmospheric pressure.

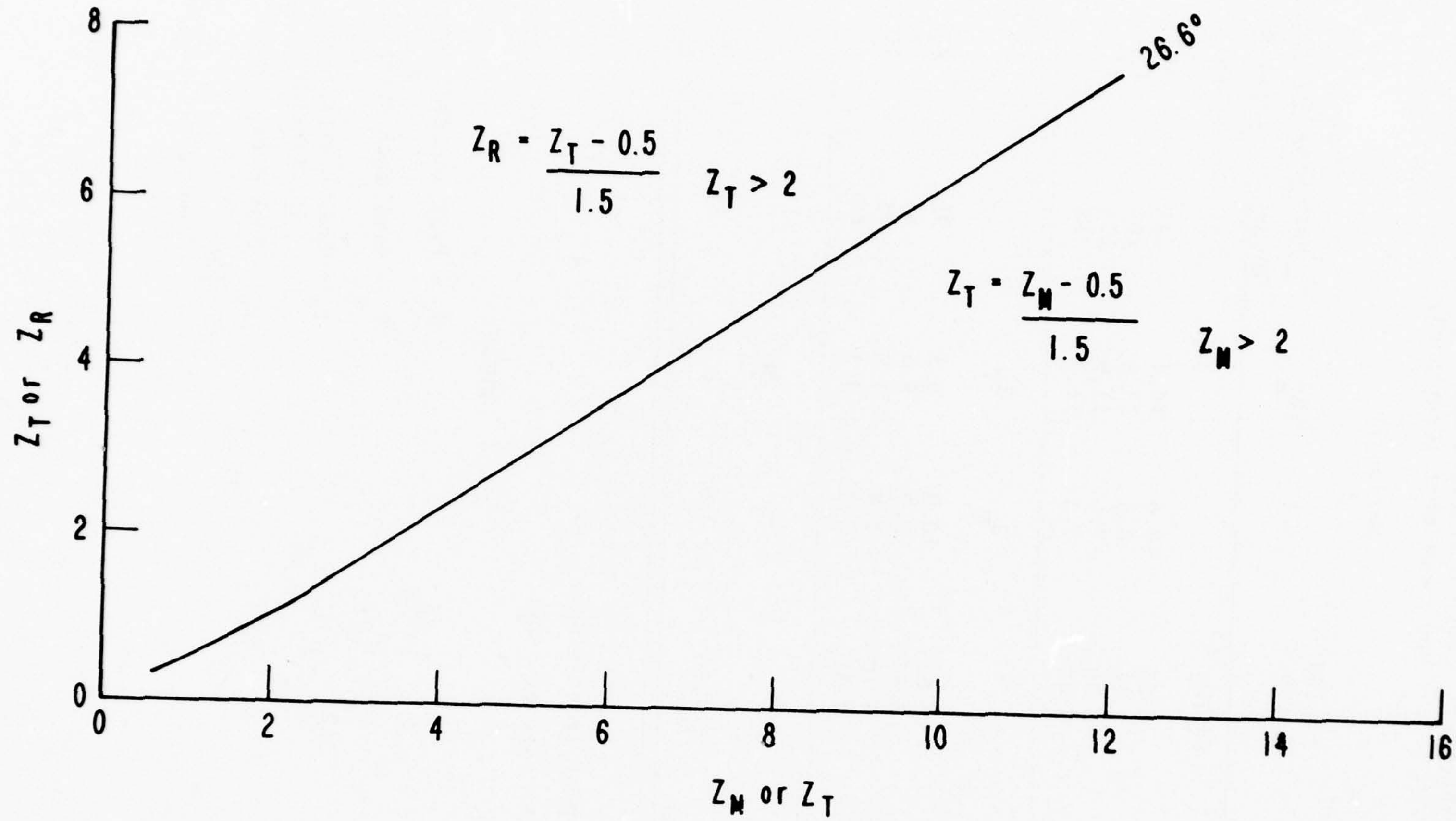



Figure 18. Input Pressure Ratio versus Diffracted Shock Pressure Ratio

in Figure 16. The values determined at scaled distances for gauge positions 6, 15, and 11 are listed in Table XVII for direct comparison with measured values of peak overpressure.

3. Shock Diffraction Pressure on the Rear Slope. When the shock wave passes over the top surface of the structure and starts down the rear surface, a second shock diffraction occurs as shown in Figure 15. The diffracted shock ratio $Z_T$ now becomes the input pressure ratio and the pressure ratio down the rear slope becomes $Z_R$ which is $P_R/P_o$, where $P_R$ is the peak overpressure on the rear slope and $P_o$ is the atmospheric pressure. A plot of $Z_R$ versus $Z_T$ is presented in Figure 18. Values of $Z_T$ for scaled distances down the rear slope were determined from Figure 18 to determine values of $Z_R$ which are plotted in Figure 16. A value of $Z_R$ determined for Position 12 on the rear slope is listed in Table XVII and converted to $P_R$ for a direct comparison with measured values.

4. Discussion of Theory and Experiment. The determination of peak overpressures on the front slope, top and rear of the model structure was made for the complete series of tests using the theory developed in Reference 7. The comparisons of the theoretical values with measured values is quite good. The overall variation of theory versus experiment is less than ±5 percent.

C. Predicted Pressure and Impulse for ESKIMO V

Two munition storage magazines will be exposed to a hemispherical TNT charge consisting of 9,376, 8-pound demolition blocks making a total weight of 34,054 kg (75,008 lbs). The structure will be placed equidistant 47.2 metres (155 feet) from ground zero (see Figure 19). The suggested gauge locations, distances, predicted peak overpressure, and impulses are listed in Table XVIII. The peak overpressures to be expected on structures A and B are presented as iso-pressure contours in Figure 20. The predicted overpressure impulse values for the full scale test are presented as iso-impulse contours in Figure 21.

The distances and impulse predictions have been scaled for charge weight only and not for the atmospheric pressure or temperature that might be expected at the test site because the test date for ESKIMO V has not been established at this time. The values are noted in both bars and psi for planning convenience and gauge calibration.

Note that the gauge locations on the full size structure do not correspond directly with the gauge locations on the 1/30th or 1/45th scaled models.

Table XVIII. Suggested Gauge Locations, Predicted Pressures and Impulses for ESKIMO V

| Position Number | Distance from GZ | | Peak Overpressure | | Positive Impulse | |
|---|---|---|---|---|---|---|
| | Metres | Feet | bar | Psi | bar-Msec | Psi-Msec |
| *1 | 30.5 | 100.0 | 15.2 | 220 | 66.3 | 962 |
| A2 | 35.1 | 115.0 | 17.9 | 260 | 100.0 | 1450 |
| B3 | 38.5 | 126.3 | 14.1 | 205 | 83.0 | 1204 |
| B4 | 38.1 | 125.0 | 14.6 | 211 | 85.0 | 1233 |
| A5 | 38.5 | 126.3 | 14.1 | 205 | 83.0 | 1204 |
| *6 | 41.1 | 135.0 | 11.0 | 160 | 75.0 | 1088 |
| *7 | 44.2 | 145.0 | 6.34 | 92 | 24.8 | 360 |
| A8 | 50.1 | 164.5 | 4.28 | 62 | 41.4 | 601 |
| A9 | 47.5 | 156.0 | 5.52 | 80 | 43.0 | 624 |
| *10 | 47.2 | 155.0 | 6.00 | 87 | 45.6 | 661 |
| B11 | 48.5 | 156.0 | 5.52 | 80 | 43.0 | 624 |
| B12 | 48.8 | 160.0 | 4.14 | 60 | 40.3 | 585 |
| *13 | 50.3 | 165.0 | 4.62 | 67 | 40.4 | 587 |
| B14 | 53.3 | 175.0 | 3.45 | 50 | 36.6 | 530 |
| A15 | 56.4 | 185.0 | 2.34 | 34 | 36.0 | 522 |
| A16 | 65.5 | 215.0 | 2.55 | 37 | 26.6 | 386 |

*Common to Structures A and B

NOTE: Gauge positions on ESKIMO V structure not all equivalent to gauge positions on Models.

| Gauge Positions | | |
|---|---|---|
| ESKIMO V | = | MODEL |
| 1 | = | 1 |
| 2 | = | 2 |
| 3 | = | 3 |
| 4 | = | 14 |
| 5 | = | 4 |
| 6 | = | 5 |
| 7 | = | 6 |
| 8 | = | 7 |
| 9 | = | 8 |
| 10 | = | 15 |
| 11 | = | 9 |
| 12 | = | 10 |
| 13 | = | 11 |
| 14 | = | - |
| 15 | = | 12 |
| 16 | = | 13 |

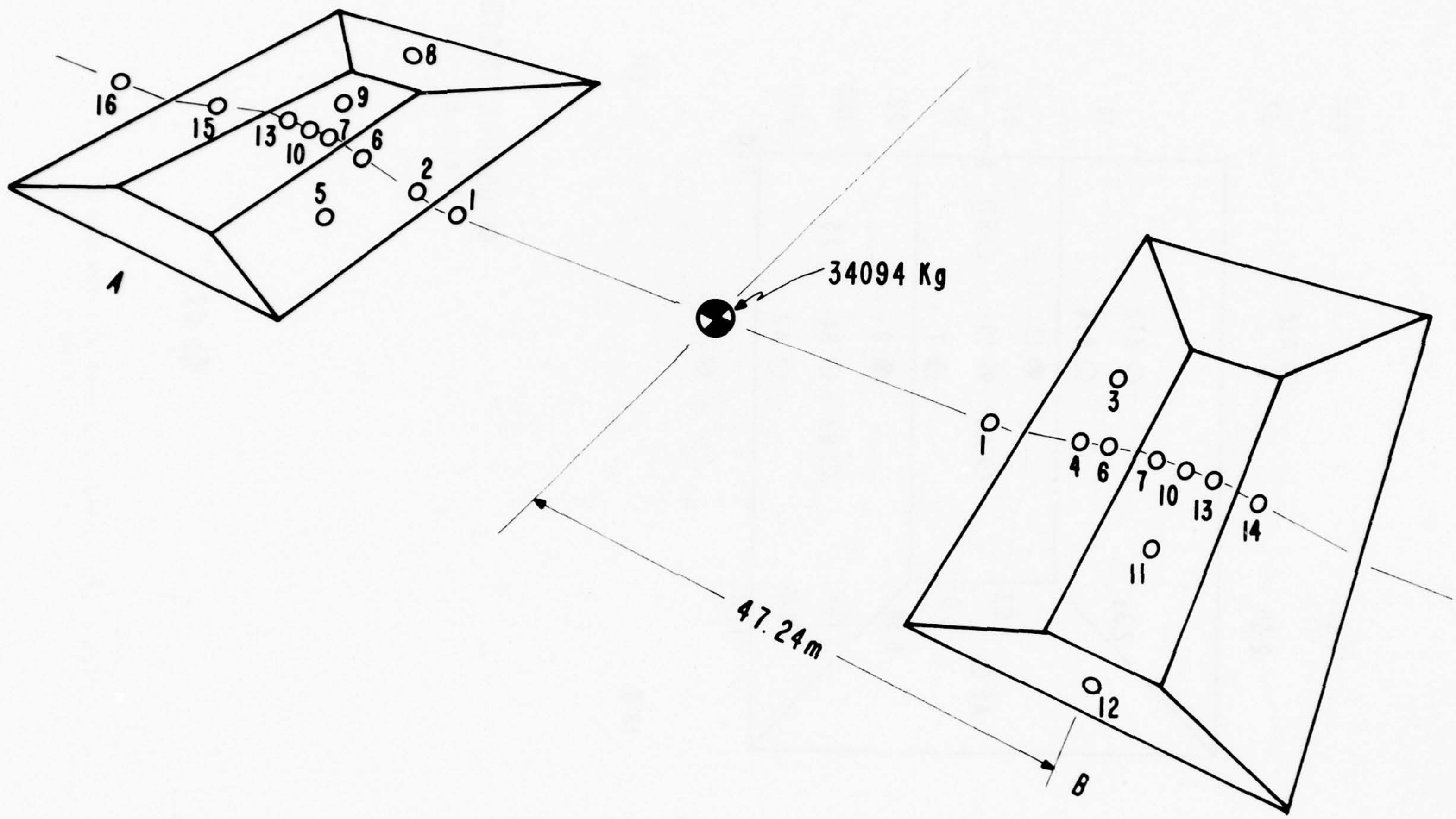



Figure 19. ESKIMO V Test Layout

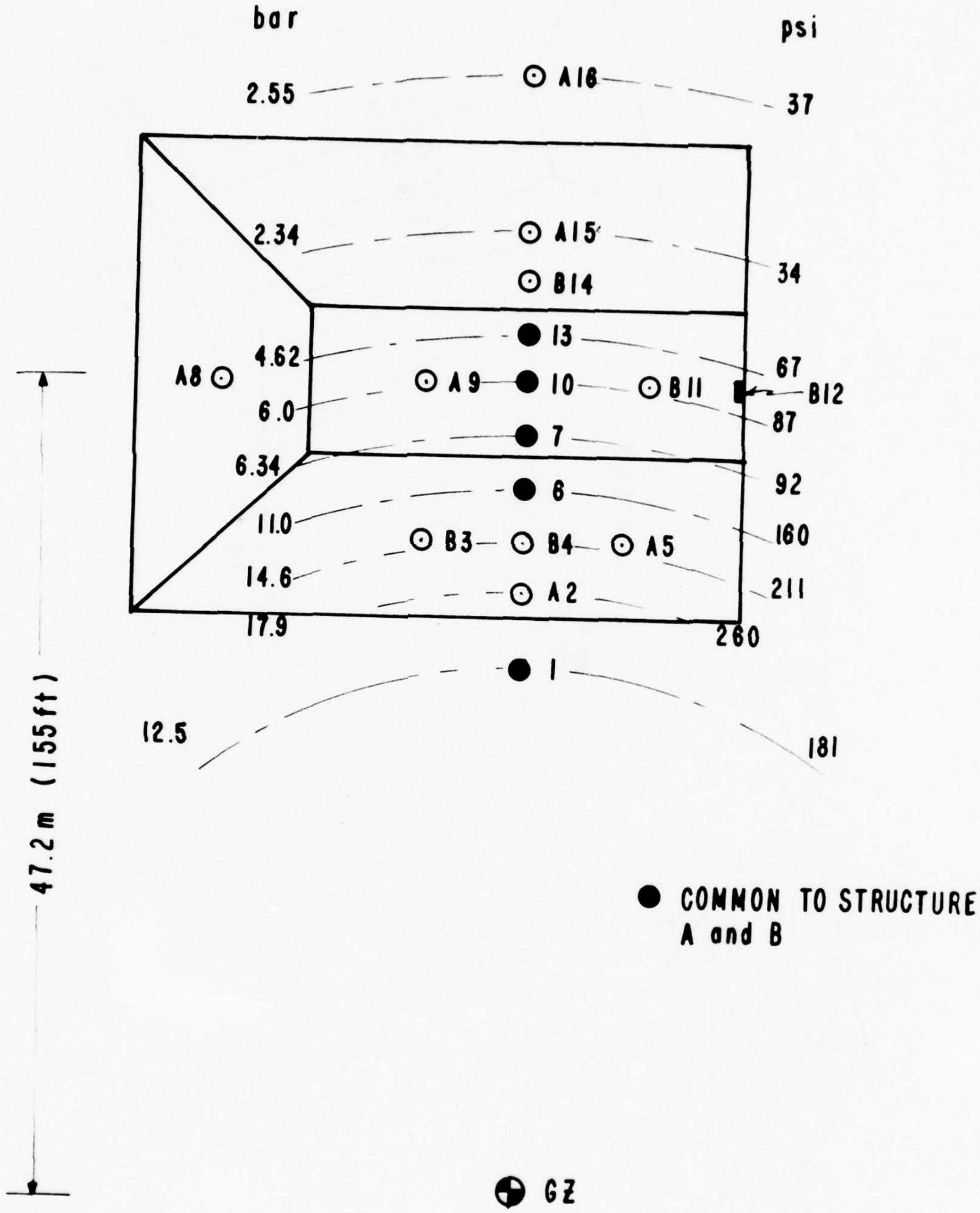



Figure 20. Predicted Peak Overpressure Contours for ESKIMO V

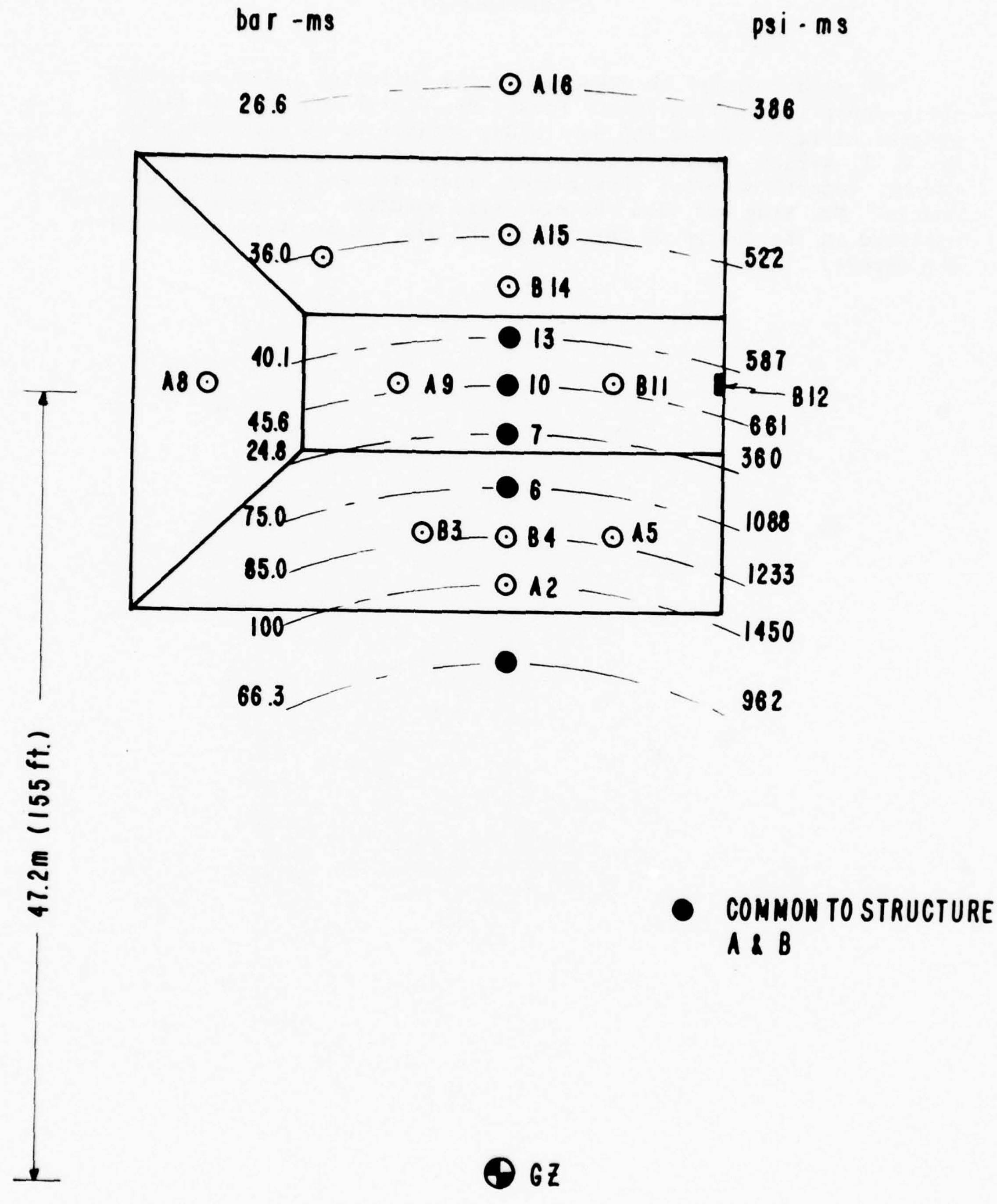



Figure 21. Predicted Overpressure Impulse Contours for ESKIMO V

## ACKNOWLEDGMENTS

The author wishes to acknowledge the following individuals and their specific contributions. First, Mr. George Coulter, as field project officer, guided the day to day activities on the test site. Mr. G. T. Watson operated the recording trailer and Mr. Vincent King and Mr. Kenneth Holbrook constructed, instrumented, and placed the models. Mr. King was also the explosive handler. Mr. William Matthews assisted in the design of the models and did the art work presented in the report.

# APPENDIXES

## PRESSURE VERSUS TIME DATA

The Appendixes show the average overpressure versus time recorded at the gage positions instrumented on the 1/30 and 1/45 scale models. They are divided into four sections for presenting the different charge weights and model scales. The divisions are as follows:

Appendix A - Model Scale 1/30 - Charge Weight .454 kg Pentolite

Appendix B - Model Scale 1/30 - Charge Weight .908 kg Pentolite

Appendix C - Model Scale 1/30 - Charge Weight 1.135 kg Pentolite

Appendix D - Model Scale 1/45 - Charge Weight .454 kg Pentolite.

All plots of overpressure versus time are presented in units of bars versus milliseconds, where the bar is obtained by dividing pounds per square inch (psi) by 14.5. The bar multiplied by 100 is equivalent to one kilopascal.

# APPENDIX A

Series I - Model Scale 1/30 Charge Weight 0.454 kg Pentolite

## APPENDIX A - LIST OF ILLUSTRATIONS


Figure | Page

A-1 Overpressure versus Time, Position 1 . . . . . . . . . . . . 67

A-2 Overpressure versus Time, Position 2 . . . . . . . . . . . . 68

A-3 Overpressure versus Time, Position 3 . . . . . . . . . . . . 69

A-4 Overpressure versus Time, Position 4 . . . . . . . . . . . . 70

A-5 Overpressure versus Time, Position 5 . . . . . . . . . . . . 71

A-6 Overpressure versus Time, Position 6 . . . . . . . . . . . . 72

A-7 Overpressure versus Time, Position 7 . . . . . . . . . . . . 73

A-8 Overpressure versus Time, Position 8 . . . . . . . . . . . . 74

A-9 Overpressure versus Time, Position 9 . . . . . . . . . . . . 75

A-10 Overpressure versus Time, Position 10 . . . . . . . . . . . 76

A-11 Overpressure versus Time, Position 11 . . . . . . . . . . . 77

A-12 Overpressure versus Time, Position 12 . . . . . . . . . . . 78

A-13 Overpressure versus Time, Position 13 . . . . . . . . . . . 79

A-14 Overpressure versus Time, Position 14 . . . . . . . . . . . 80

A-15 Overpressure versus Time, Position 15 . . . . . . . . . . . 81

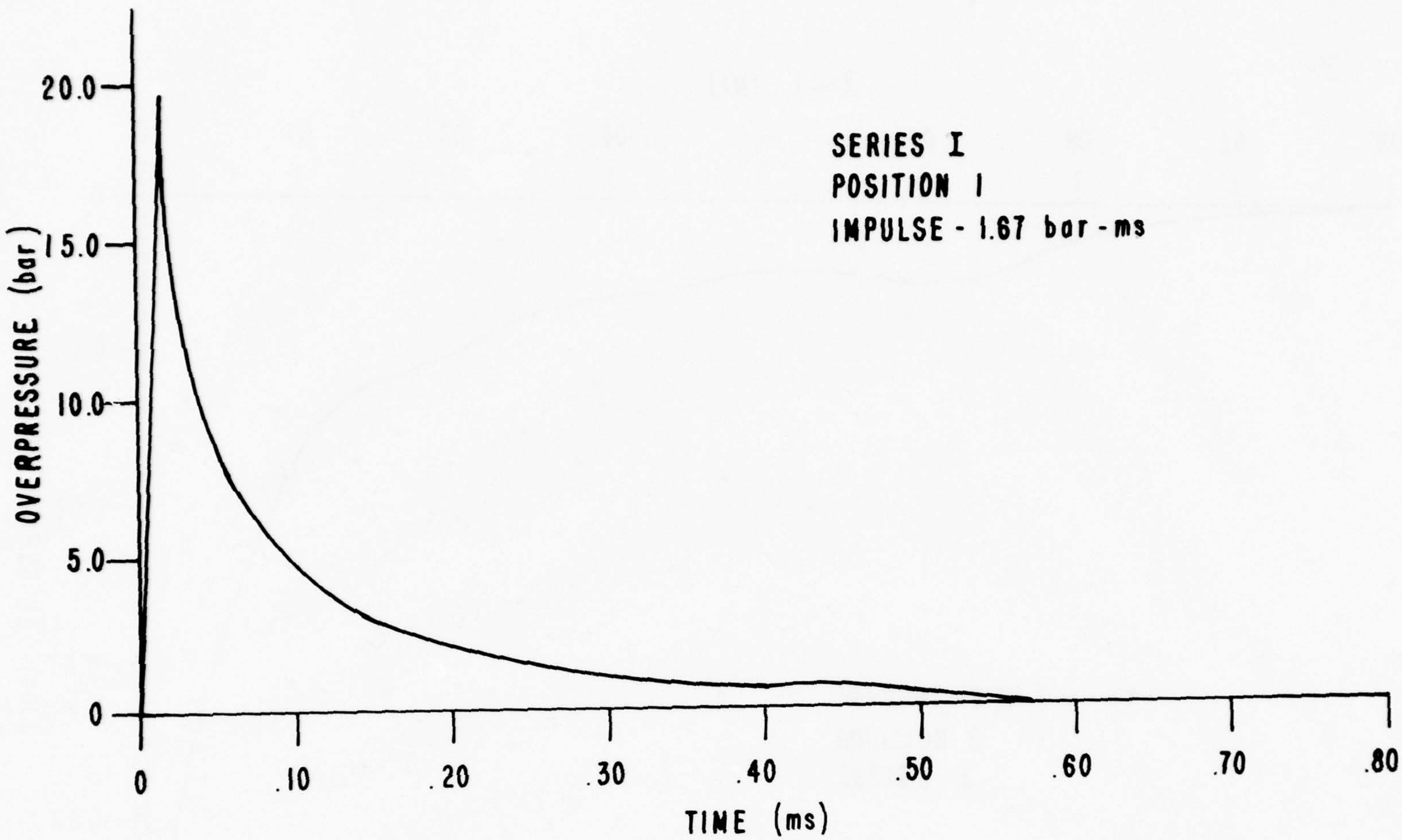



Figure A-1. Overpressure versus Time, Position 1

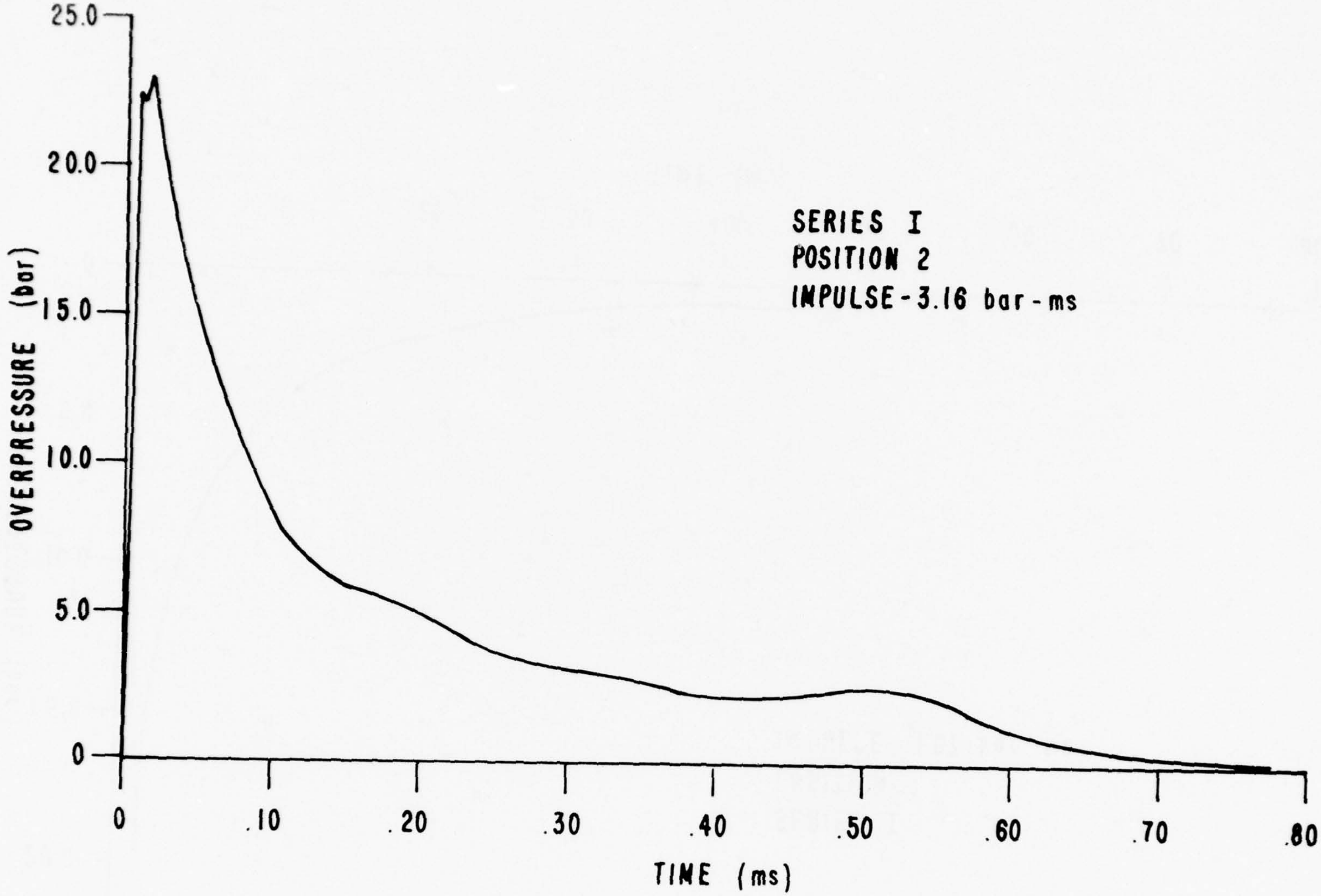



Figure V-2. Overpressure versus Time, Position 2

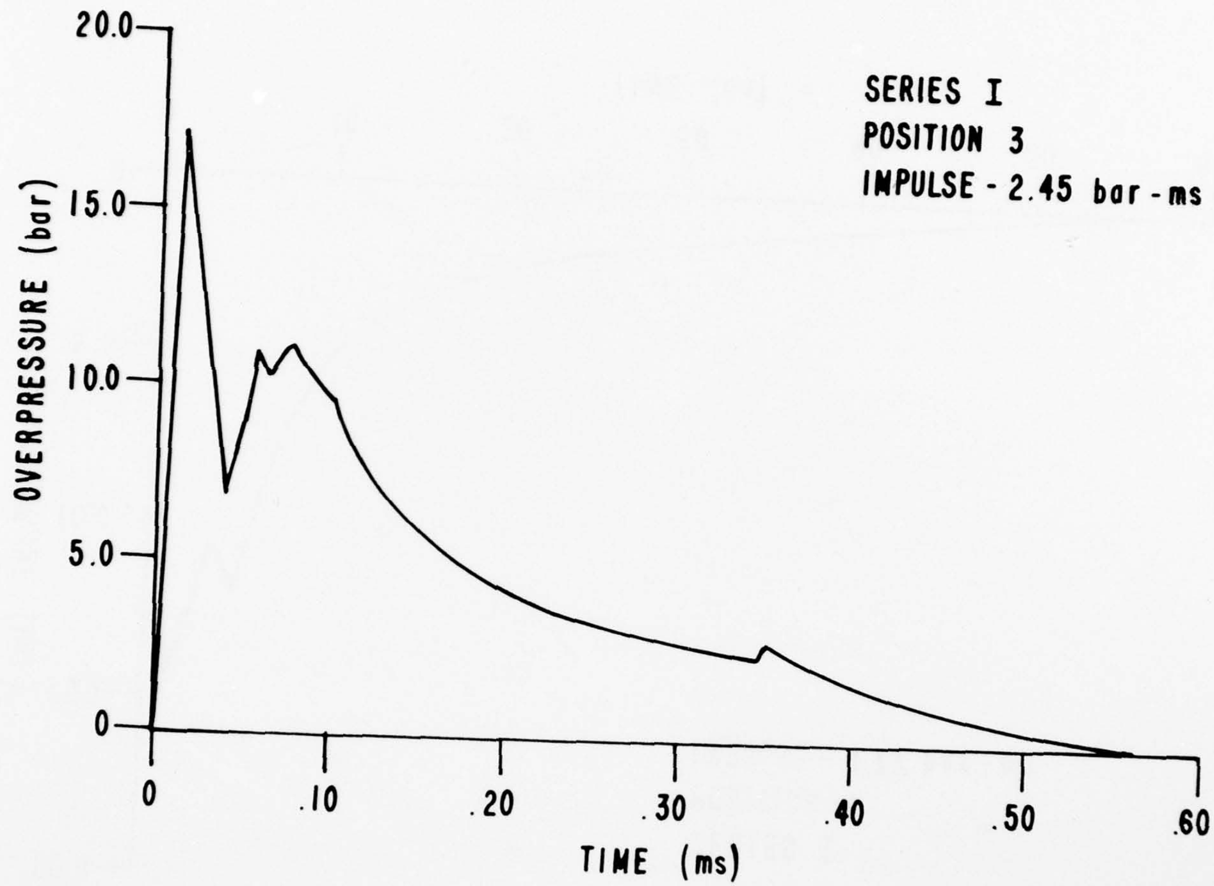



Figure A-3. Overpressure versus Time, Position 3

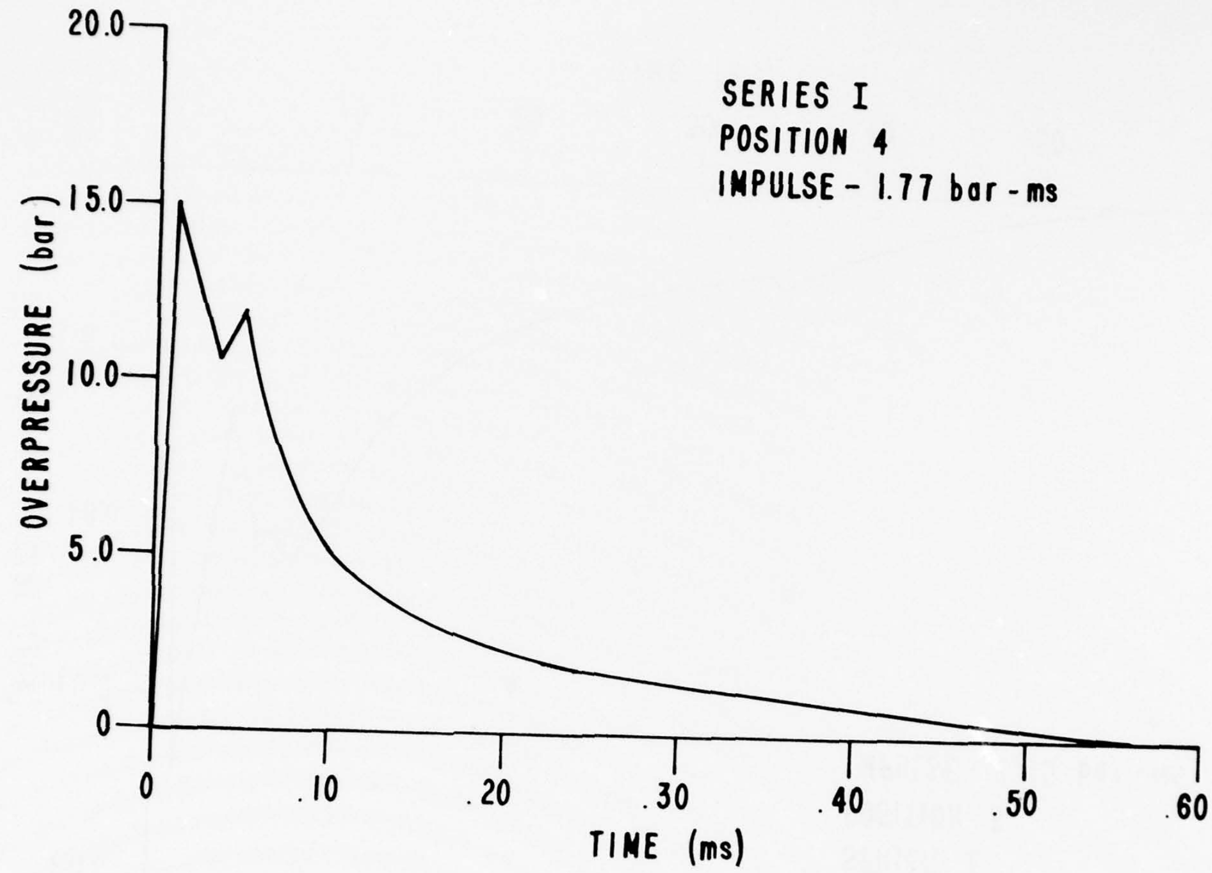



Figure A-4. Overpressure versus Time, Position 4

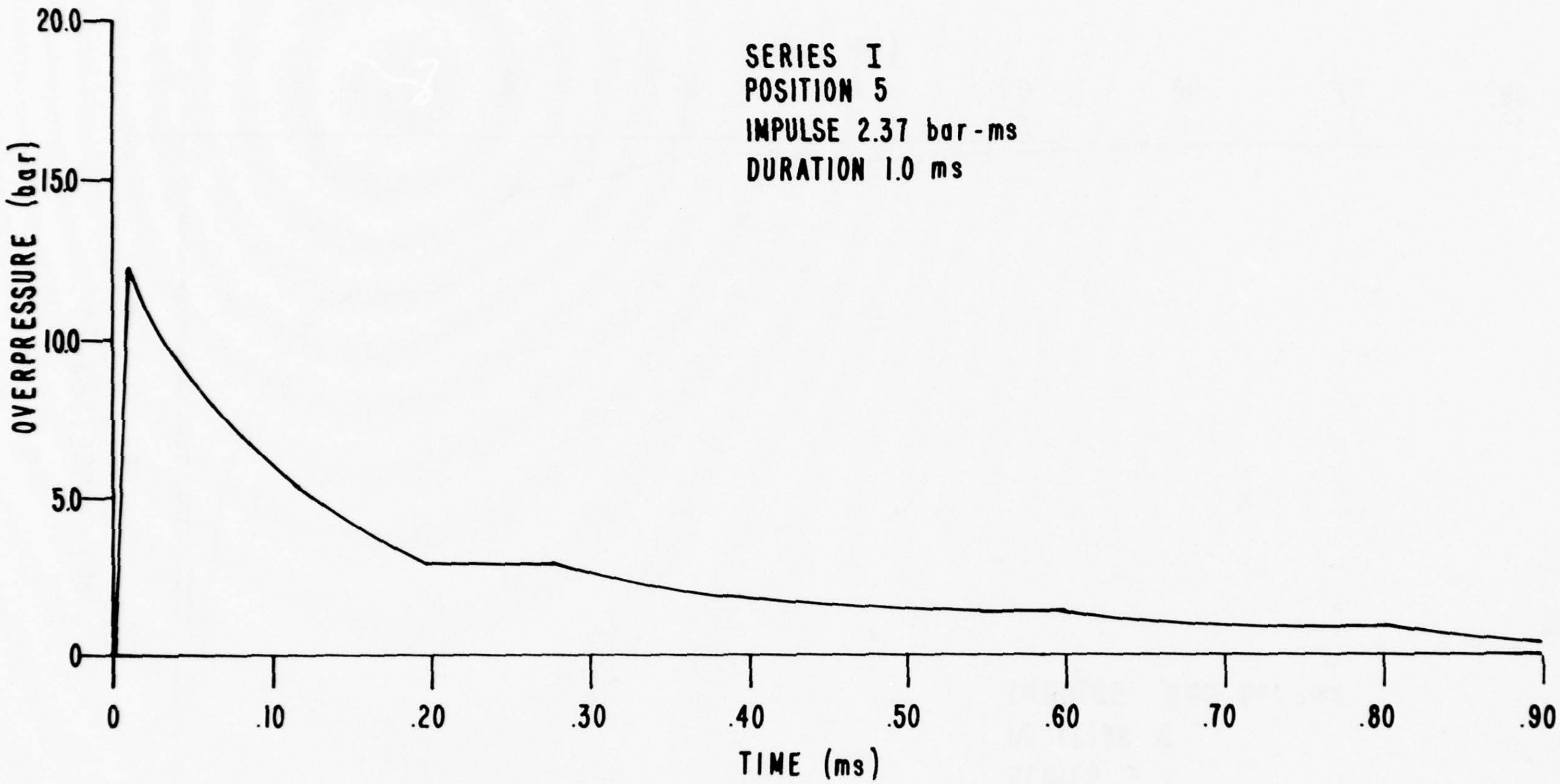



Figure A-5. Overpressure versus Time, Position 5

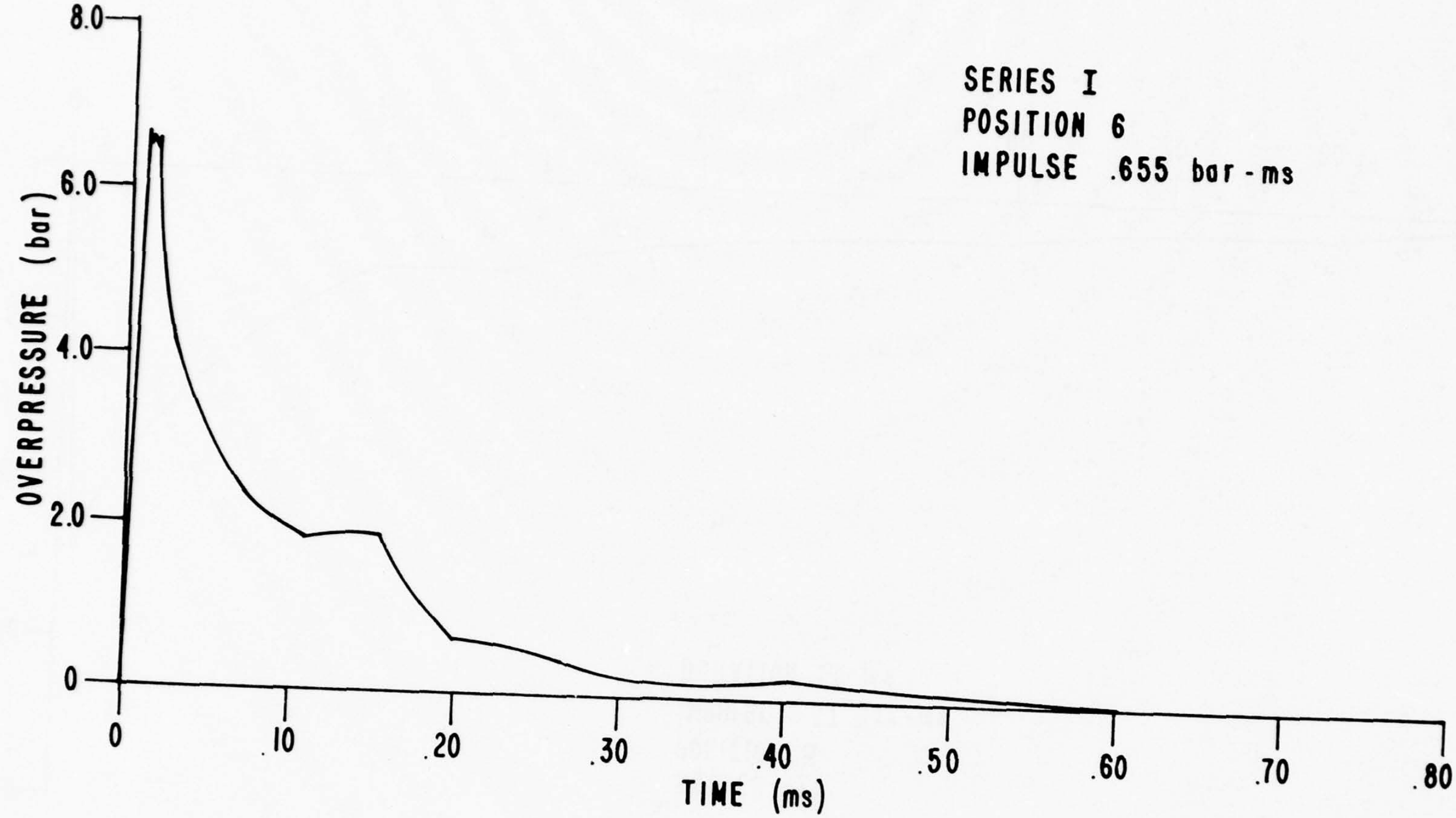



Figure A-6. Overpressure versus Time, Position 6

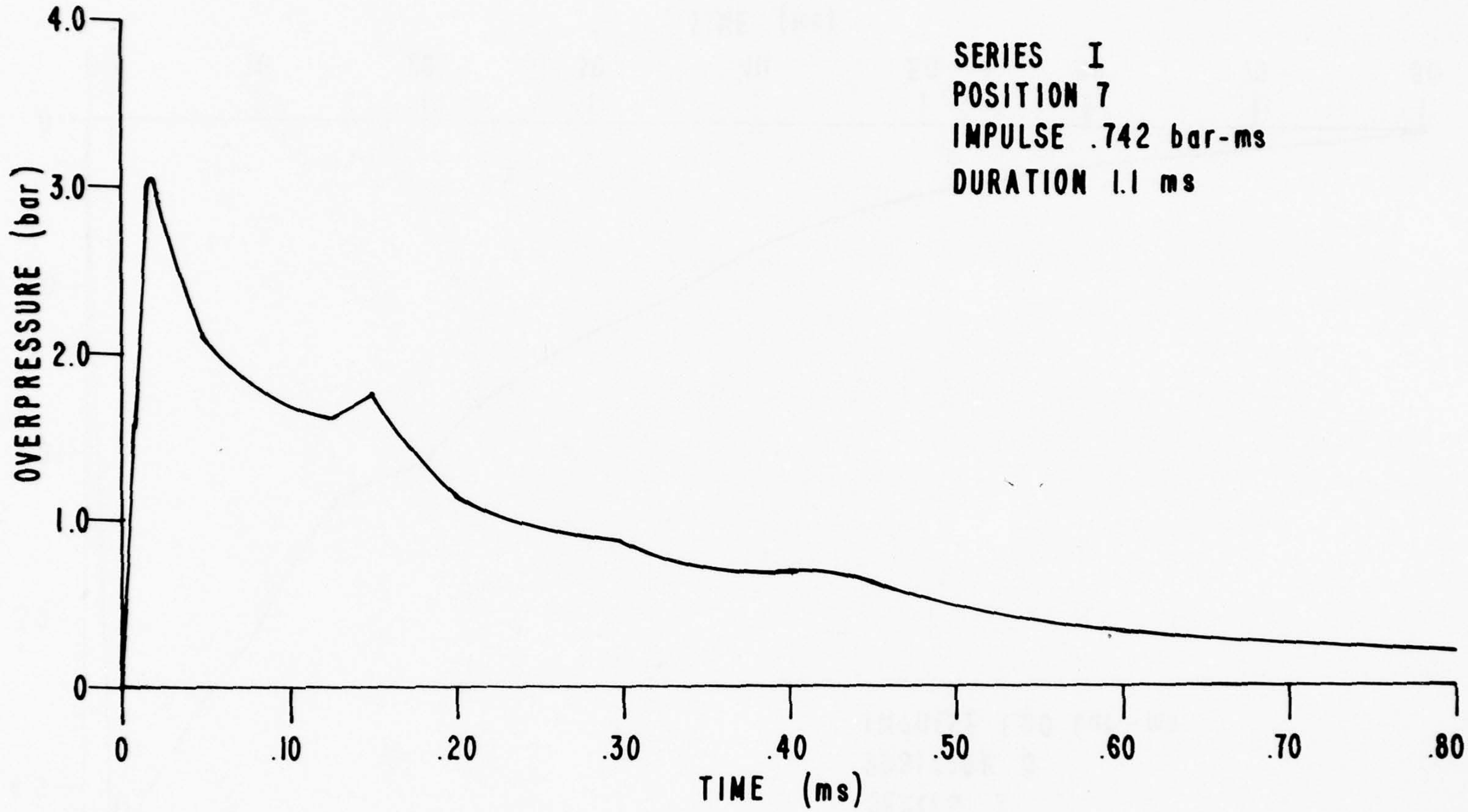



Figure A-7. Overpressure versus Time, Position 7

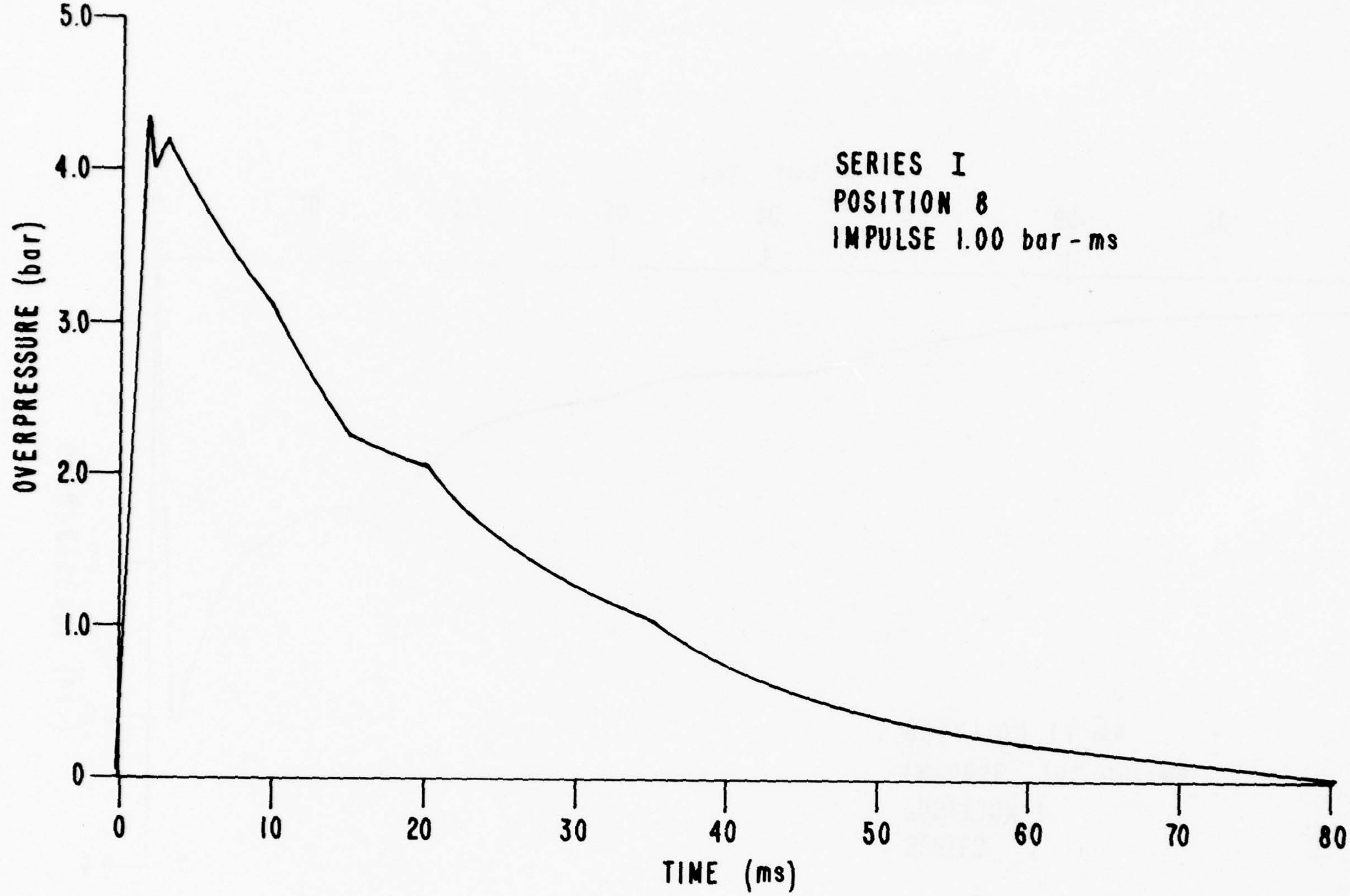



Figure A-8. Overpressure versus Time, Position 8

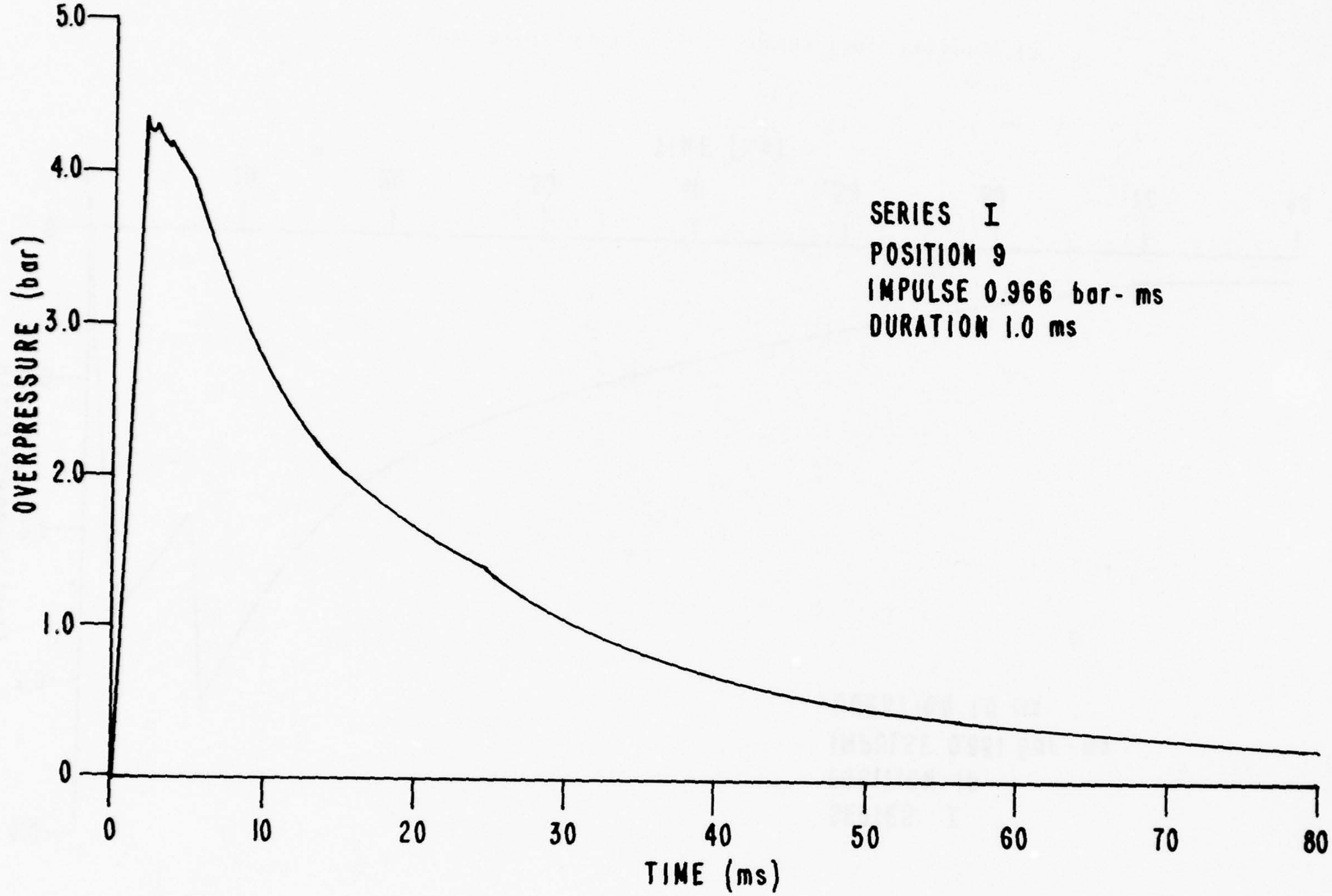



Figure A-9. Overpressure versus Time, Position 9

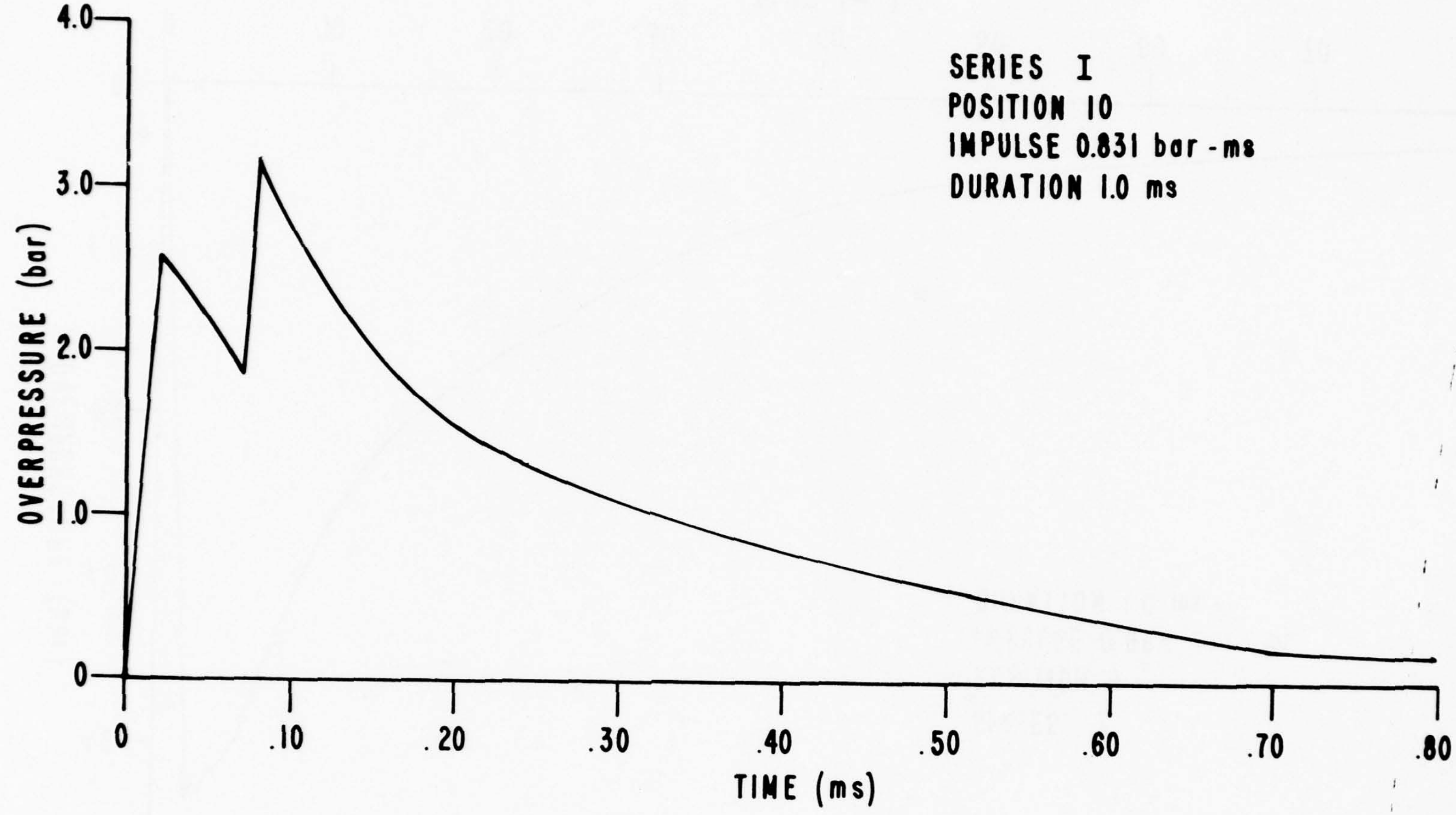



Figure A-10. Overpressure versus Time, Position 10

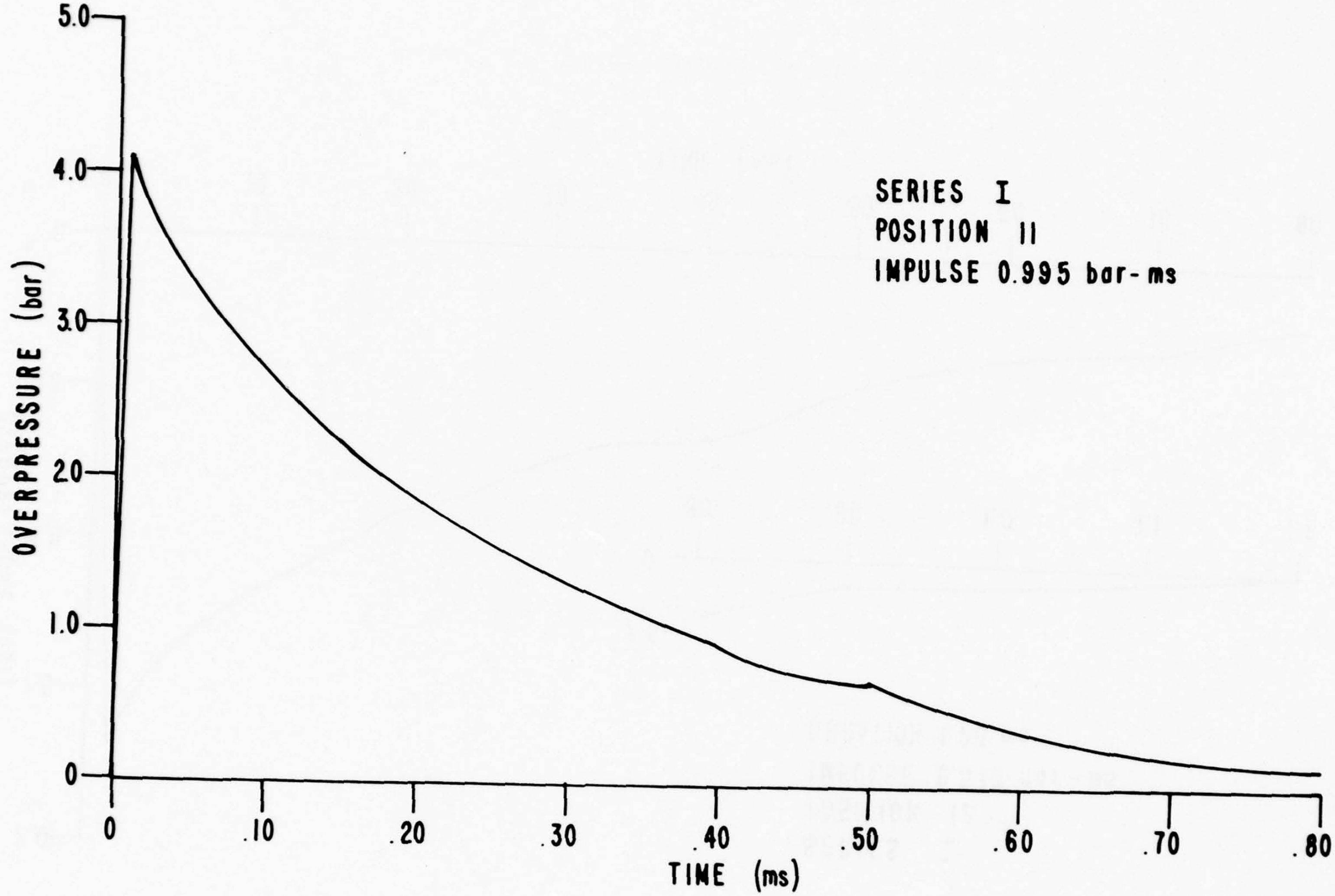



Figure A-11. Overpressure versus Time, Position 11

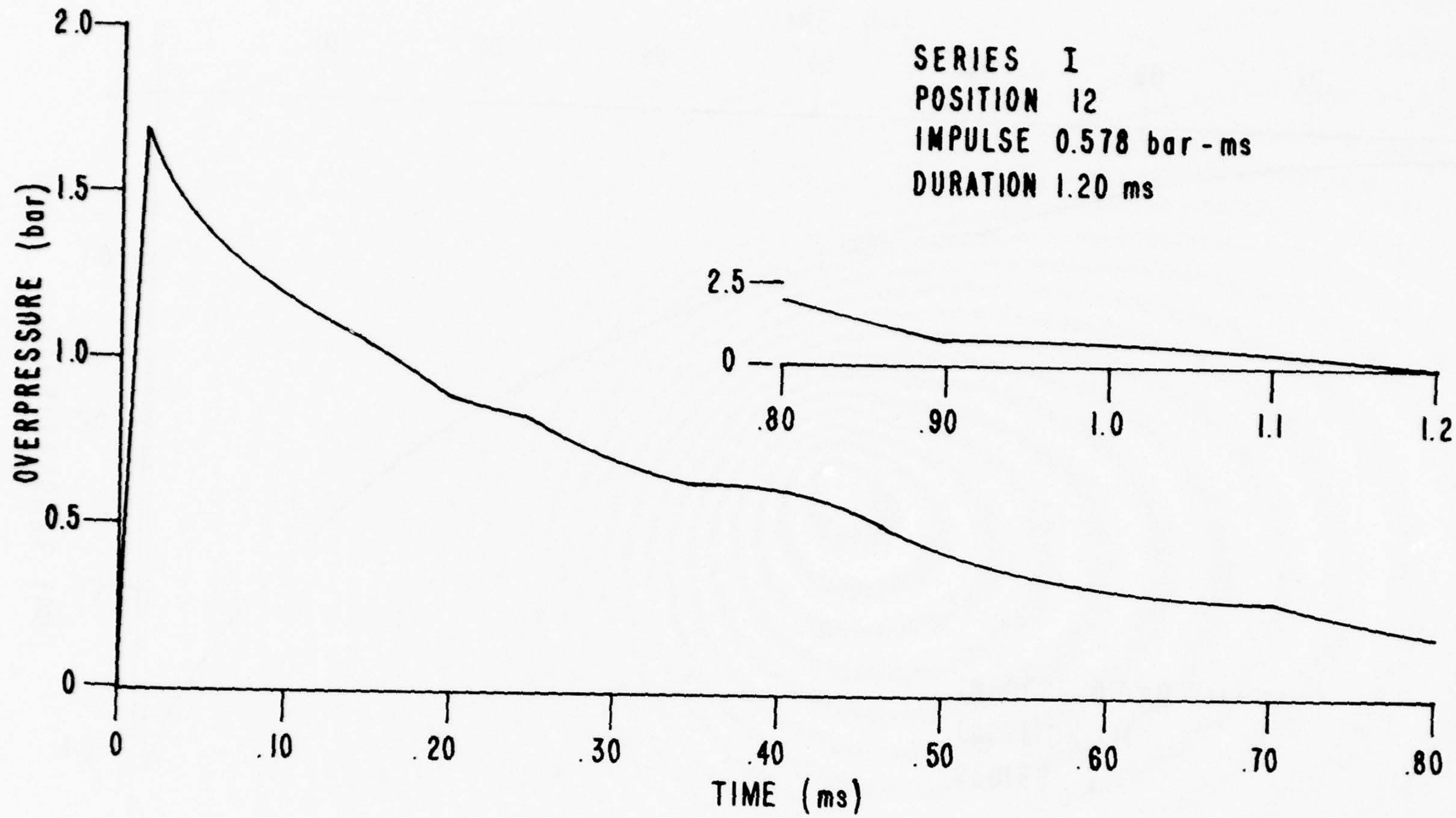



Figure A-12. Overpressure versus Time, Position 12

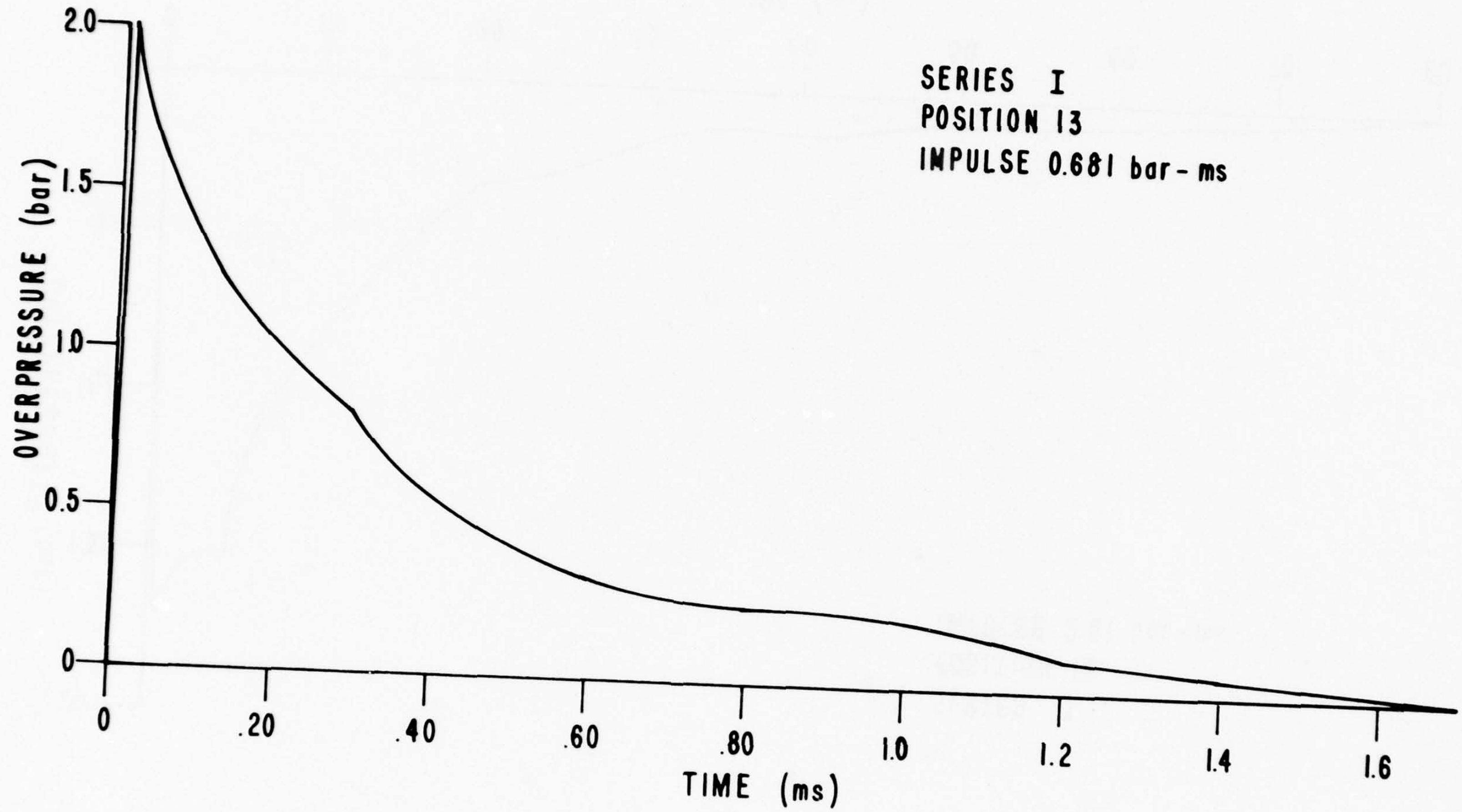



Figure A-13. Overpressure versus Time, Position 13

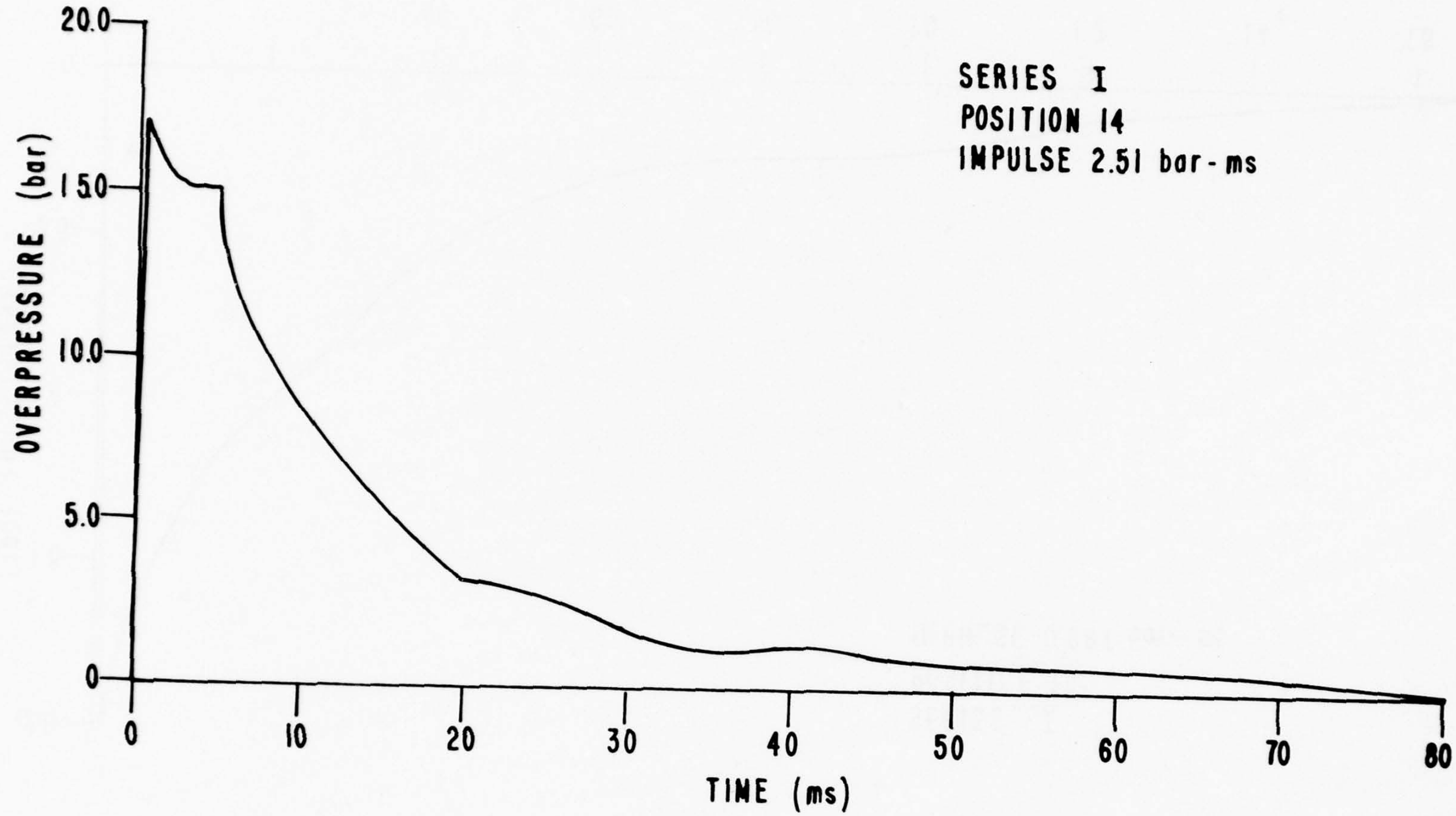



Figure A-14. Overpressure versus Time, Position 14

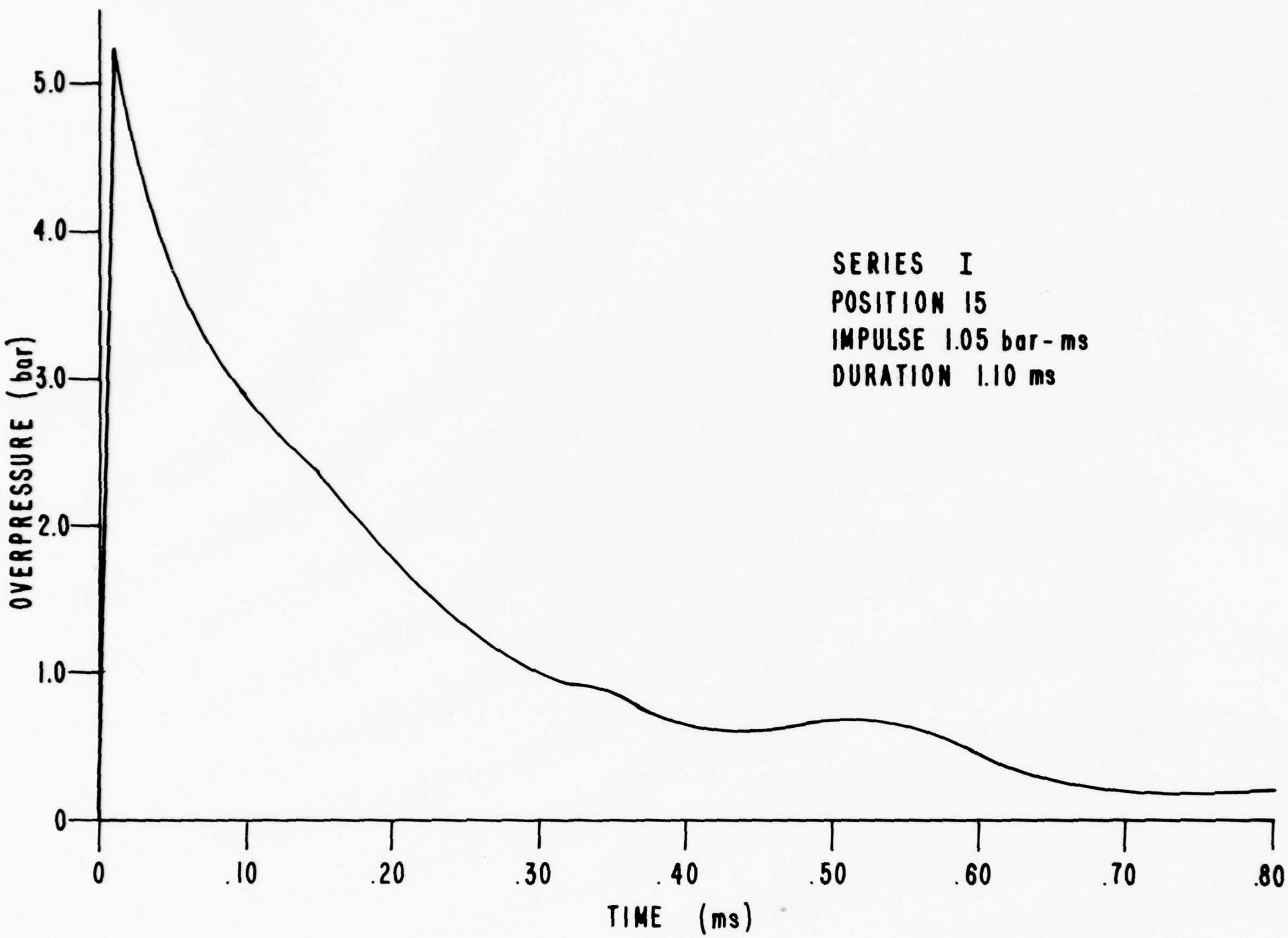



Figure A-15. Overpressure versus Time, Position 15

# APPENDIX B

Series II - Model Scale 1/30 Charge Weight 0.908 kg Pentolite

APPENDIX B - LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| B-1 | Overpressure versus Time, Position 1 . . . . . . . . . . . . | 85 |
| B-2 | Overpressure versus Time, Position 2 . . . . . . . . . . . . | 86 |
| B-3 | Overpressure versus Time, Position 5 . . . . . . . . . . . . | 87 |
| B-4 | Overpressure versus Time, Position 6 . . . . . . . . . . . . | 88 |
| B-5 | Overpressure versus Time, Position 7 . . . . . . . . . . . . | 89 |
| B-6 | Overpressure versus Time, Position 8 . . . . . . . . . . . . | 90 |
| B-7 | Overpressure versus Time, Position 9 . . . . . . . . . . . . | 91 |
| B-8 | Overpressure versus Time, Position 10 . . . . . . . . . . . | 92 |
| B-9 | Overpressure versus Time, Position 11 . . . . . . . . . . . | 93 |
| B-10 | Overpressure versus Time, Position 12 . . . . . . . . . . . | 94 |
| B-11 | Overpressure versus Time, Position 13 . . . . . . . . . . . | 95 |
| B-12 | Overpressure versus Time, Position 14 . . . . . . . . . . . | 96 |
| B-13 | Overpressure versus Time, Position 15 . . . . . . . . . . . | 97 |

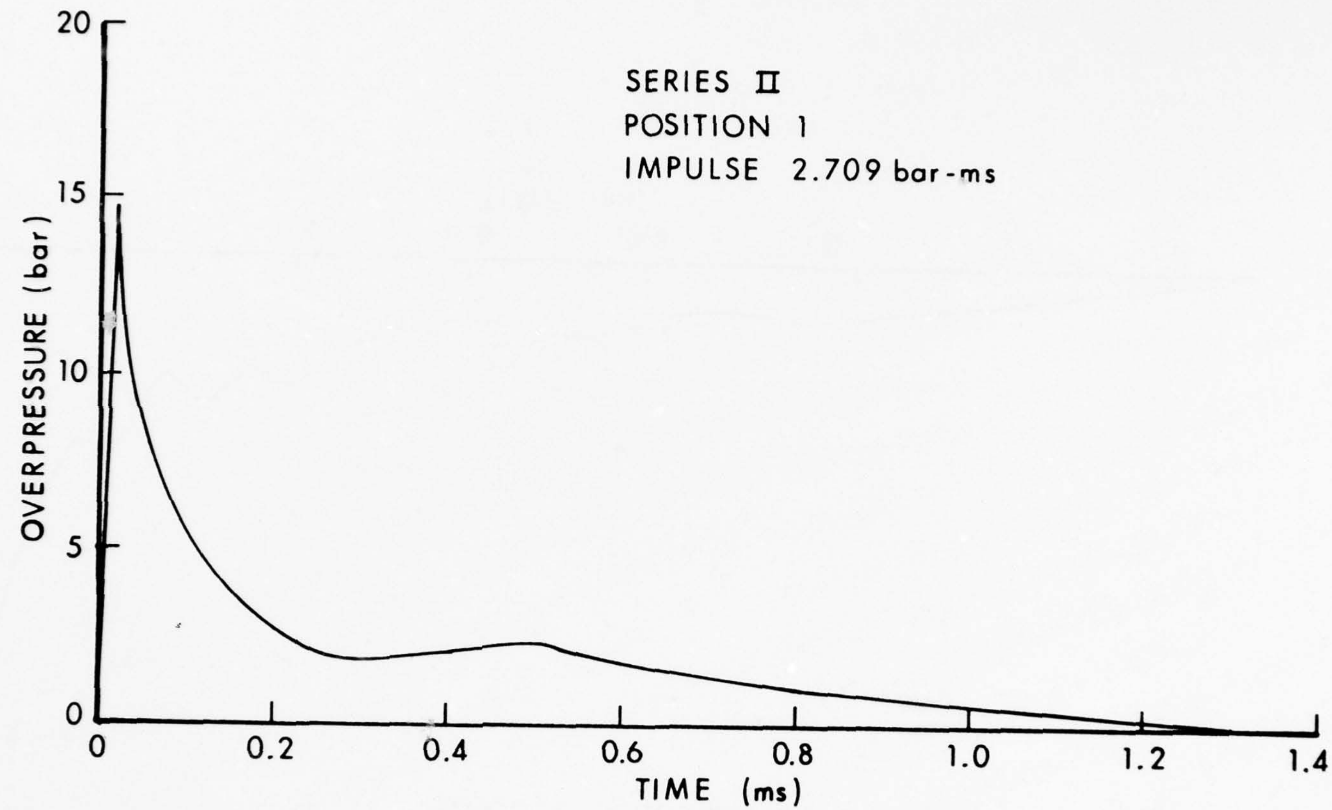



Figure B-1. Overpressure versus Time Position 1

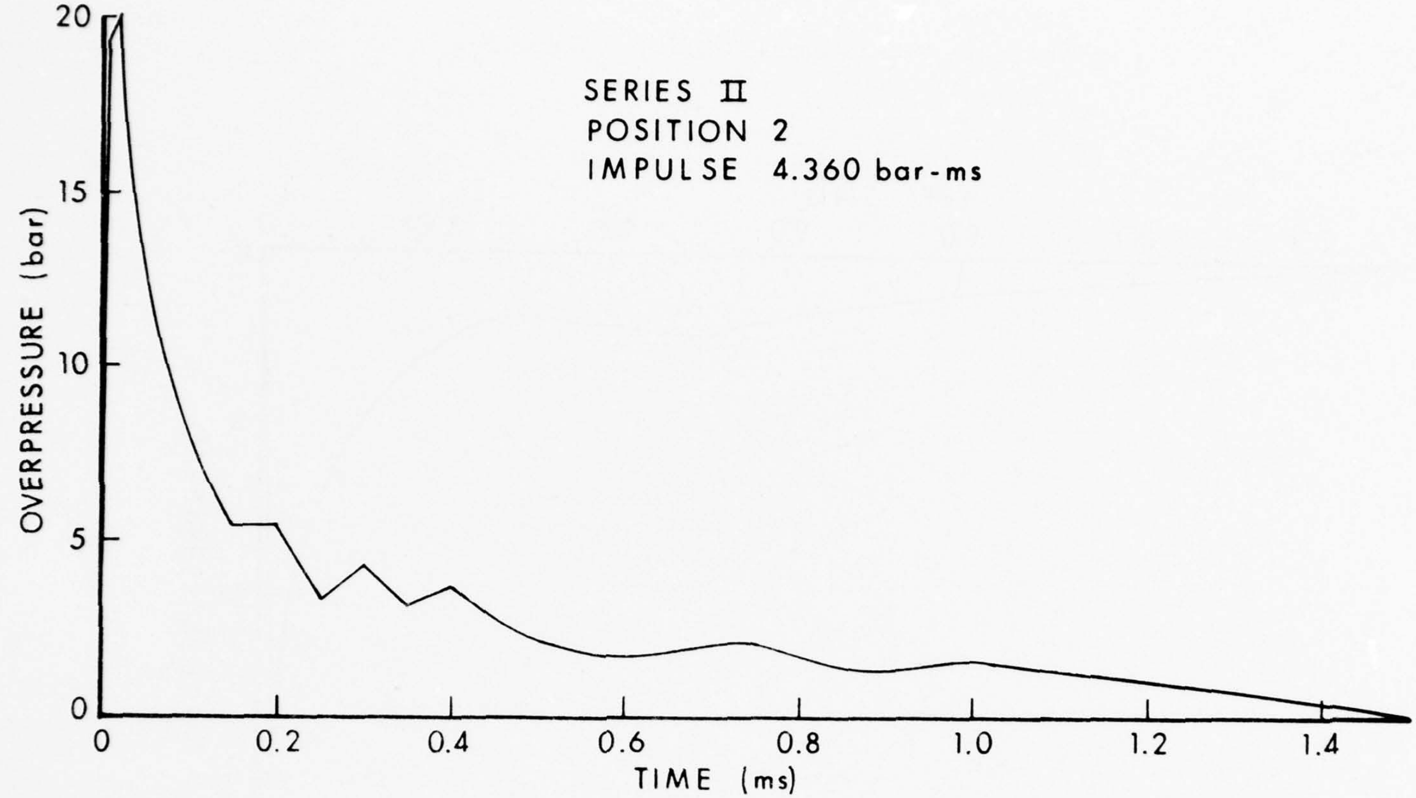



Figure B-2. Overpressure versus Time, Position 2

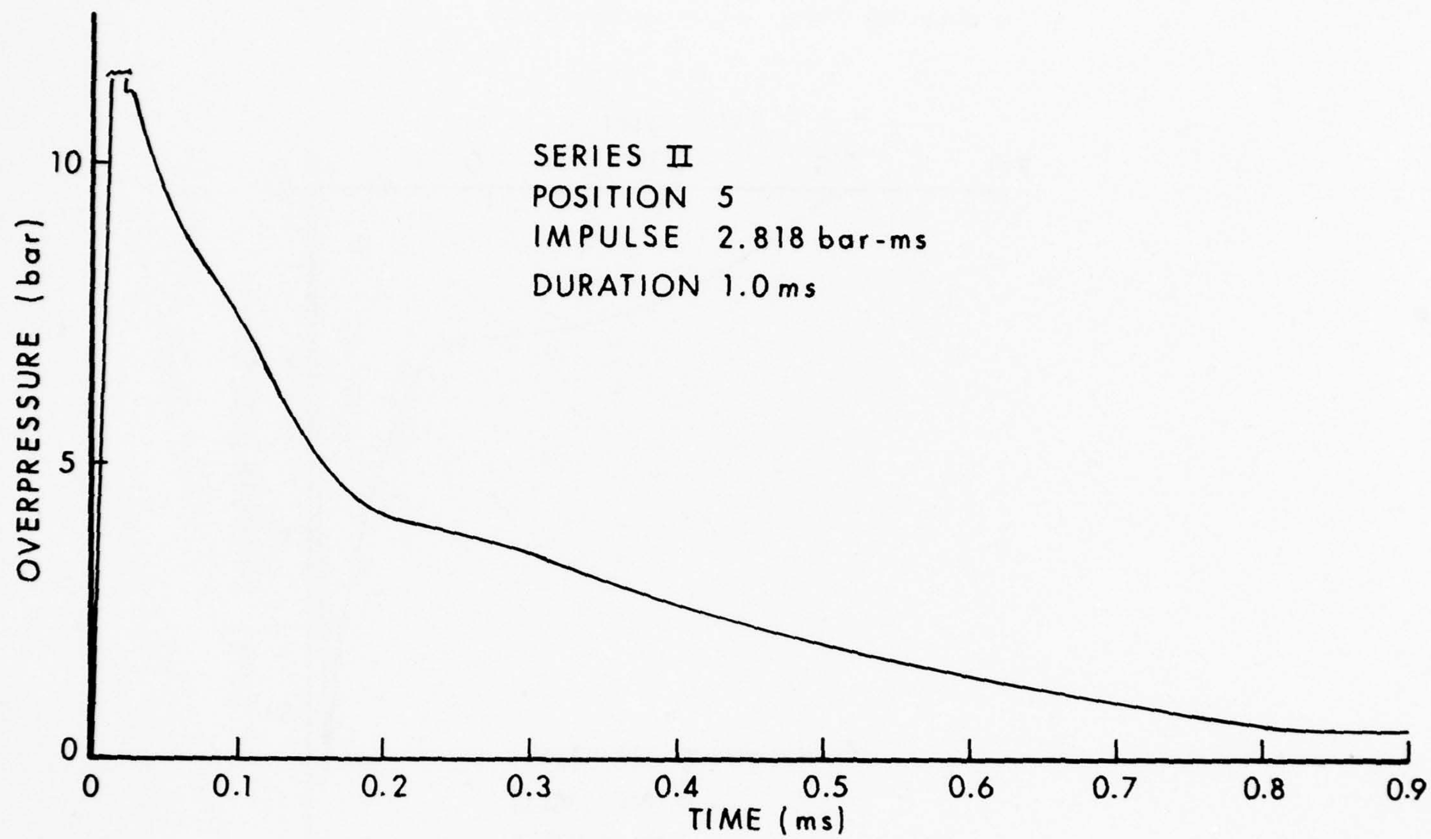



Figure B-3. Overpressure versus Time, Position 5

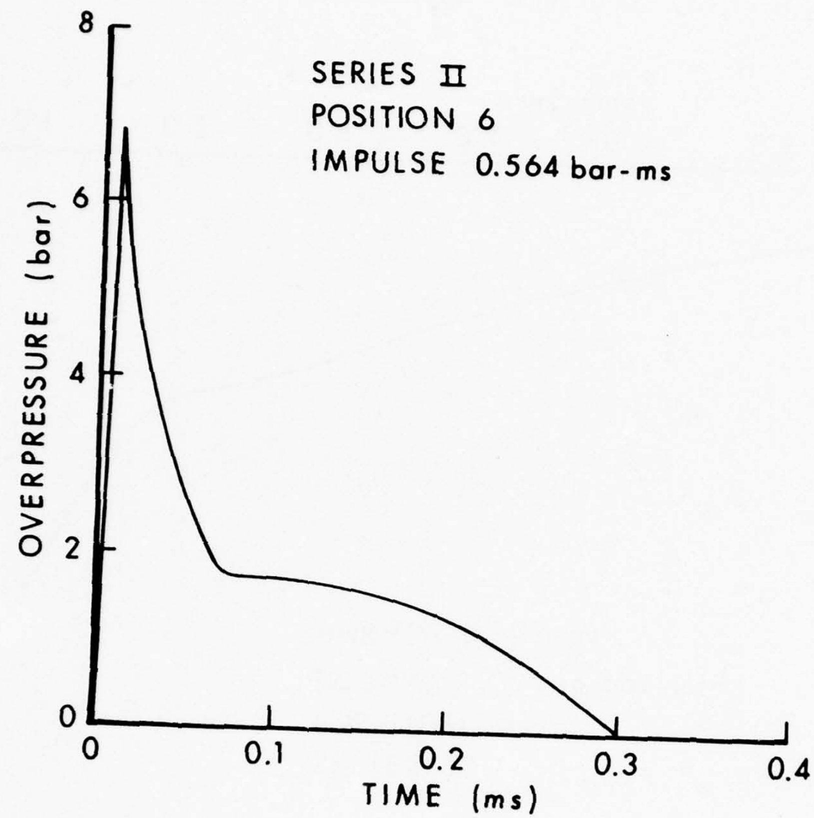



Figure B-4. Overpressure versus Time, Position 6

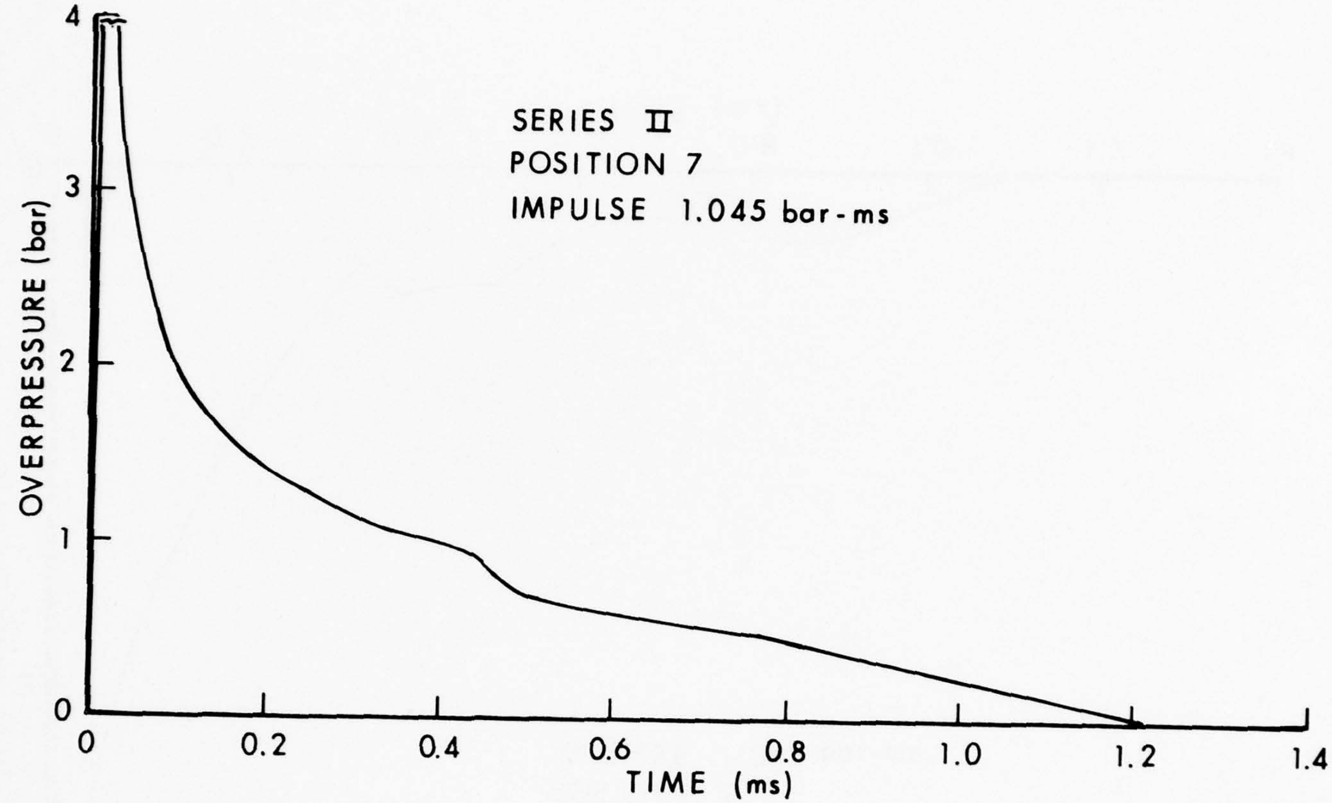



Figure B-5. Overpressure versus Time, Position 7

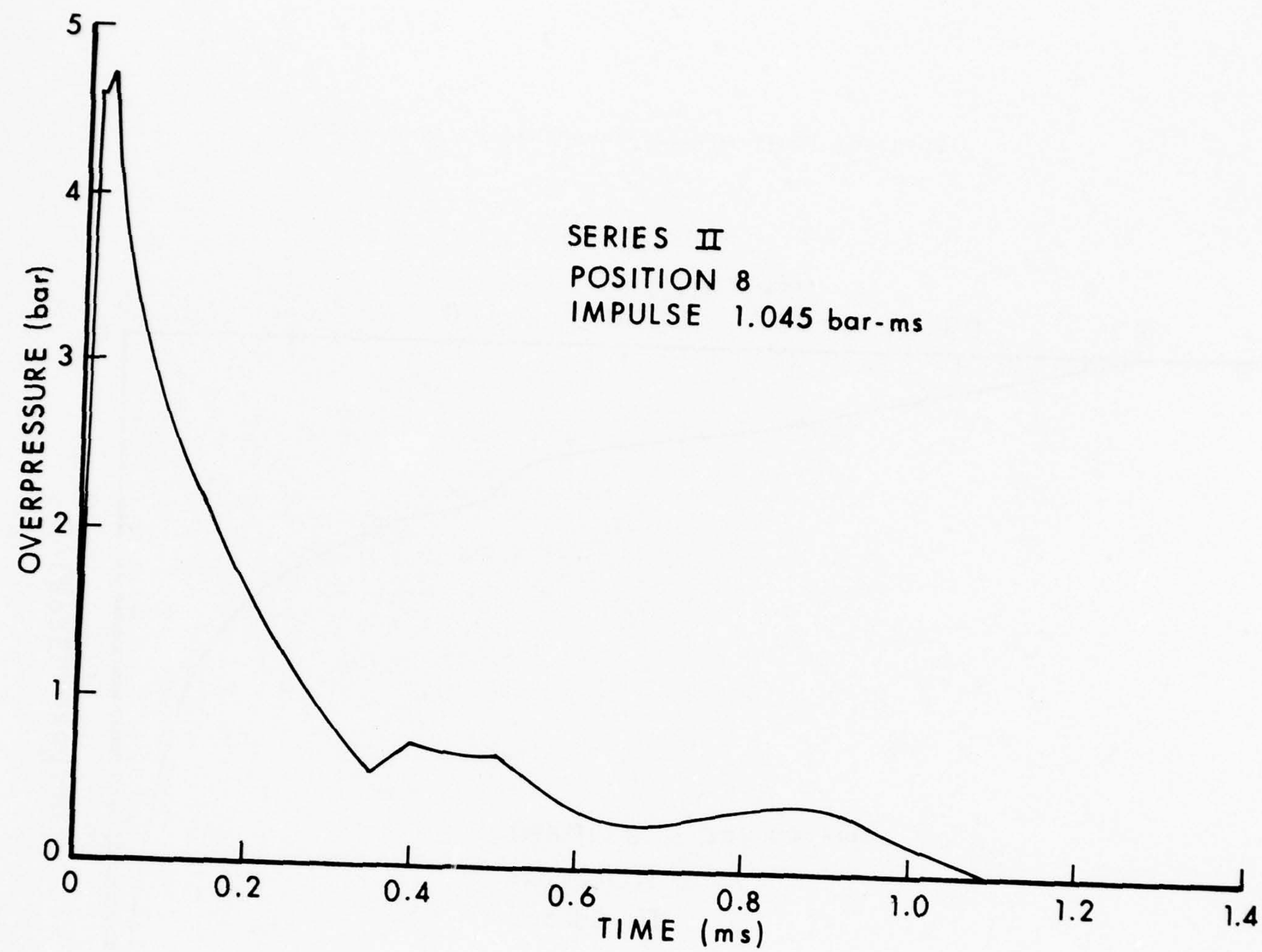



Figure B-6. Overpressure versus Time, Position 8

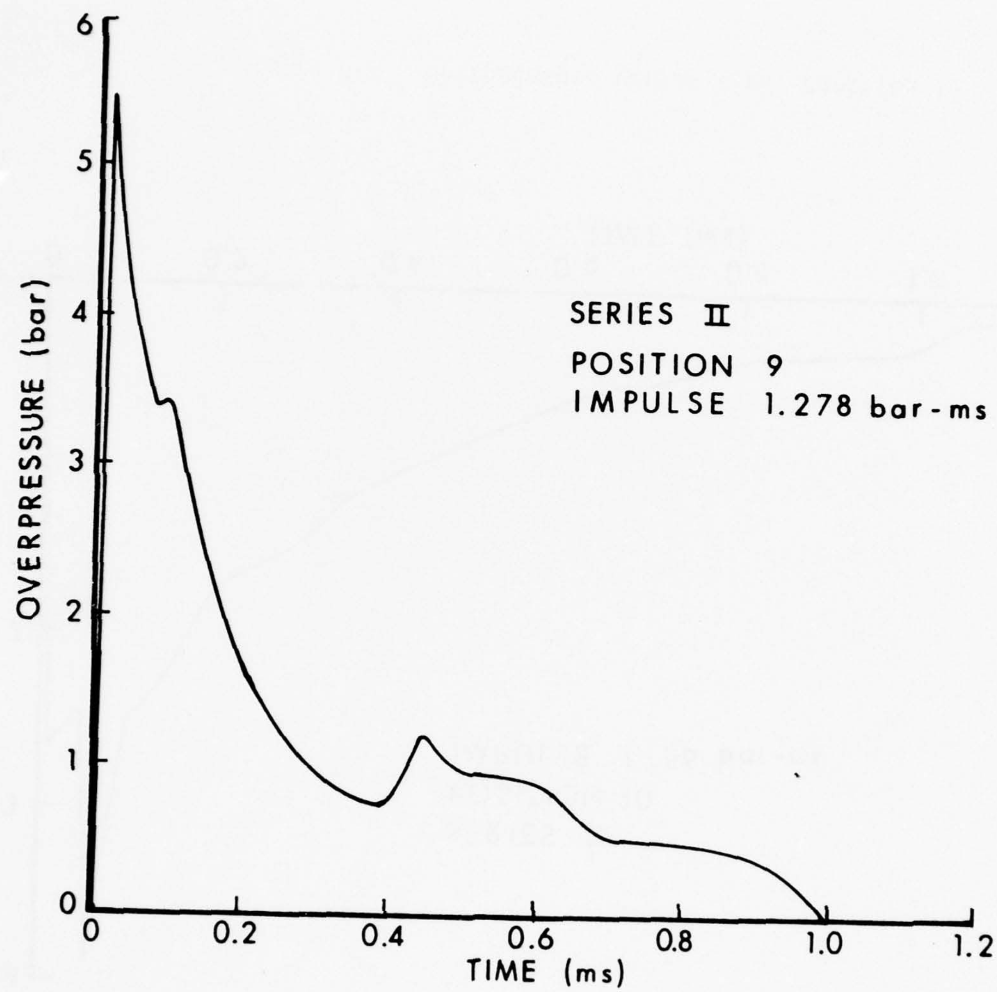



Figure B-7. Overpressure versus Time, Position 9

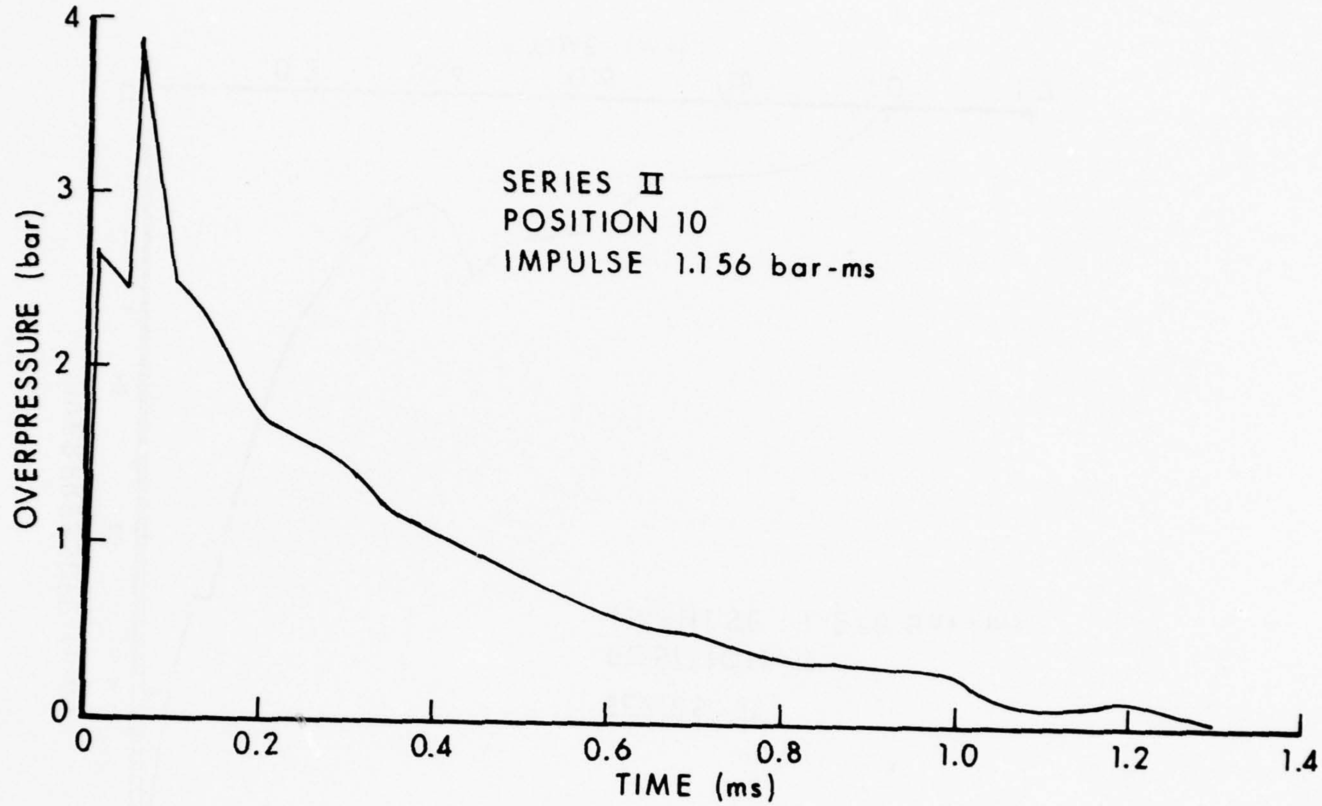



Figure B-8. Overpressure versus Time, Position 10

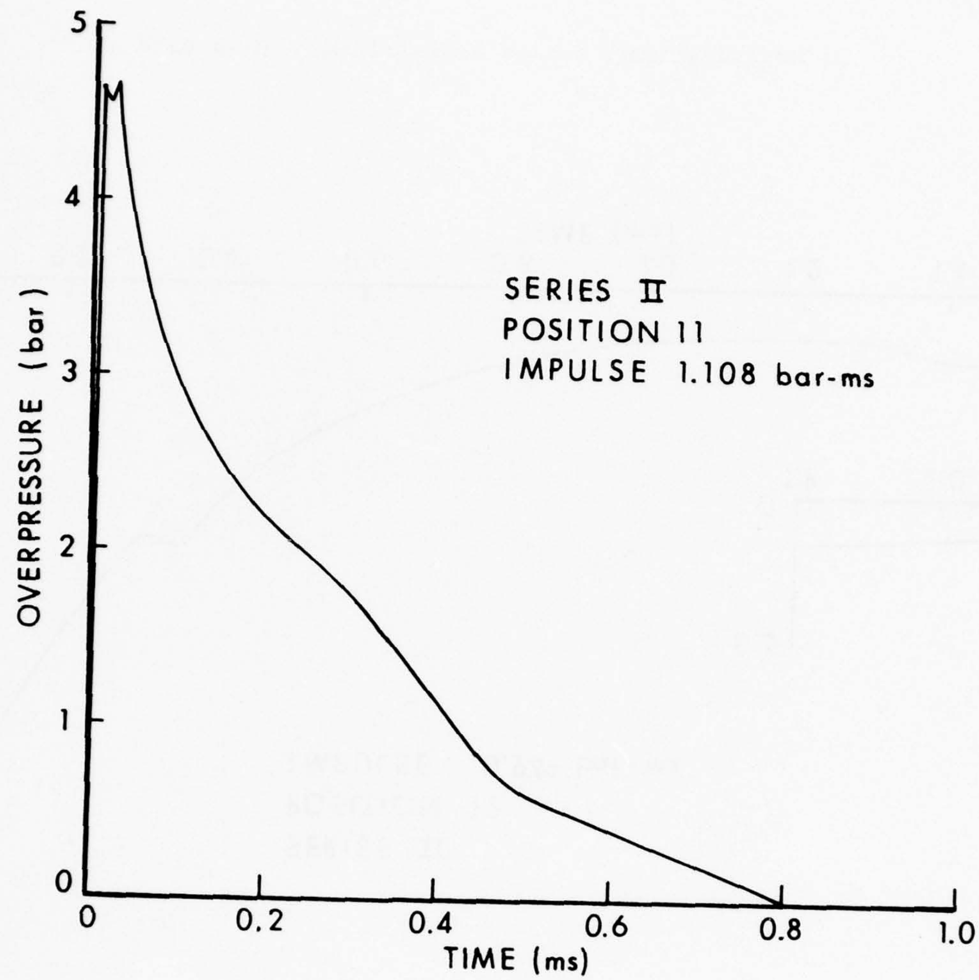



Figure B-9. Overpressure versus Time, Position 11

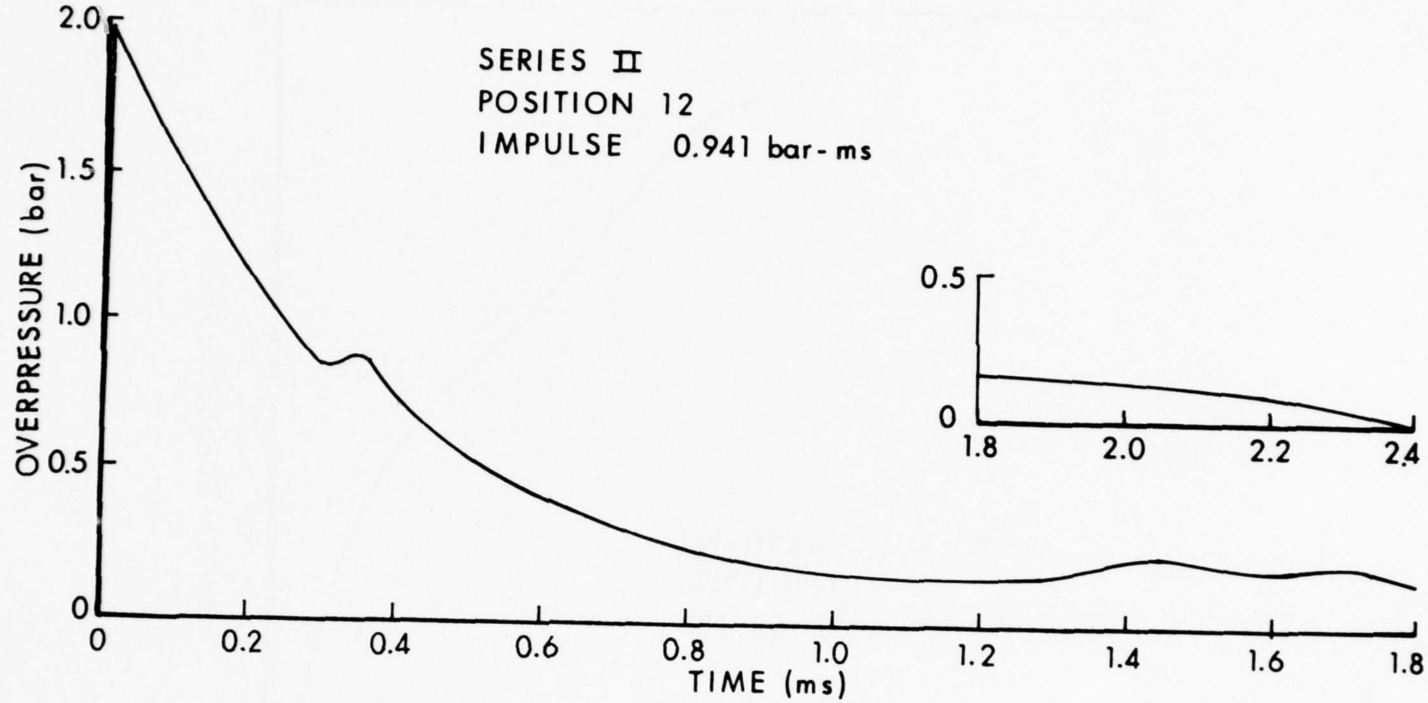



Figure B-10. Overpressure versus Time, Position 12

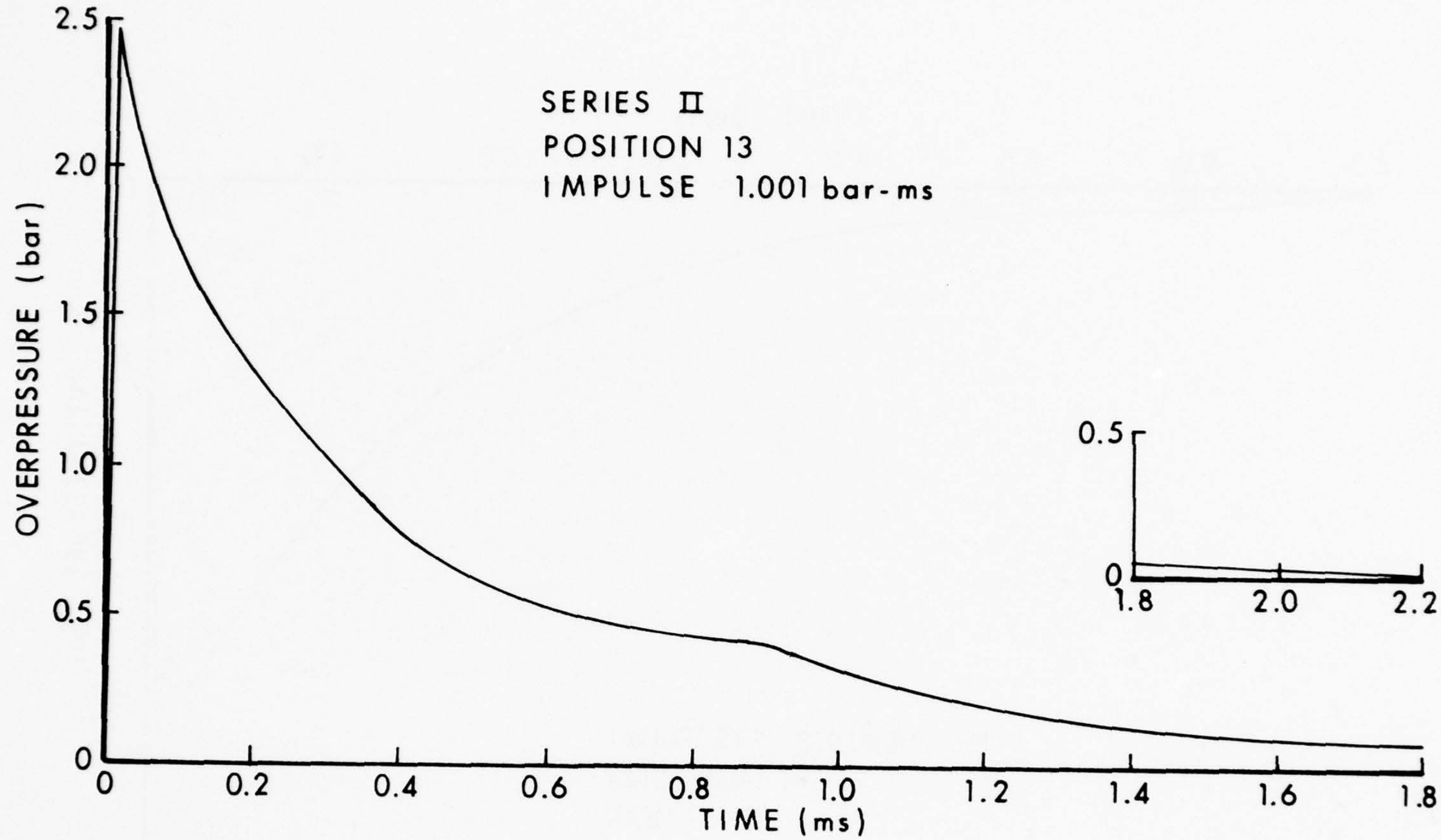



Figure B-11. Overpressure versus Time, Position 13

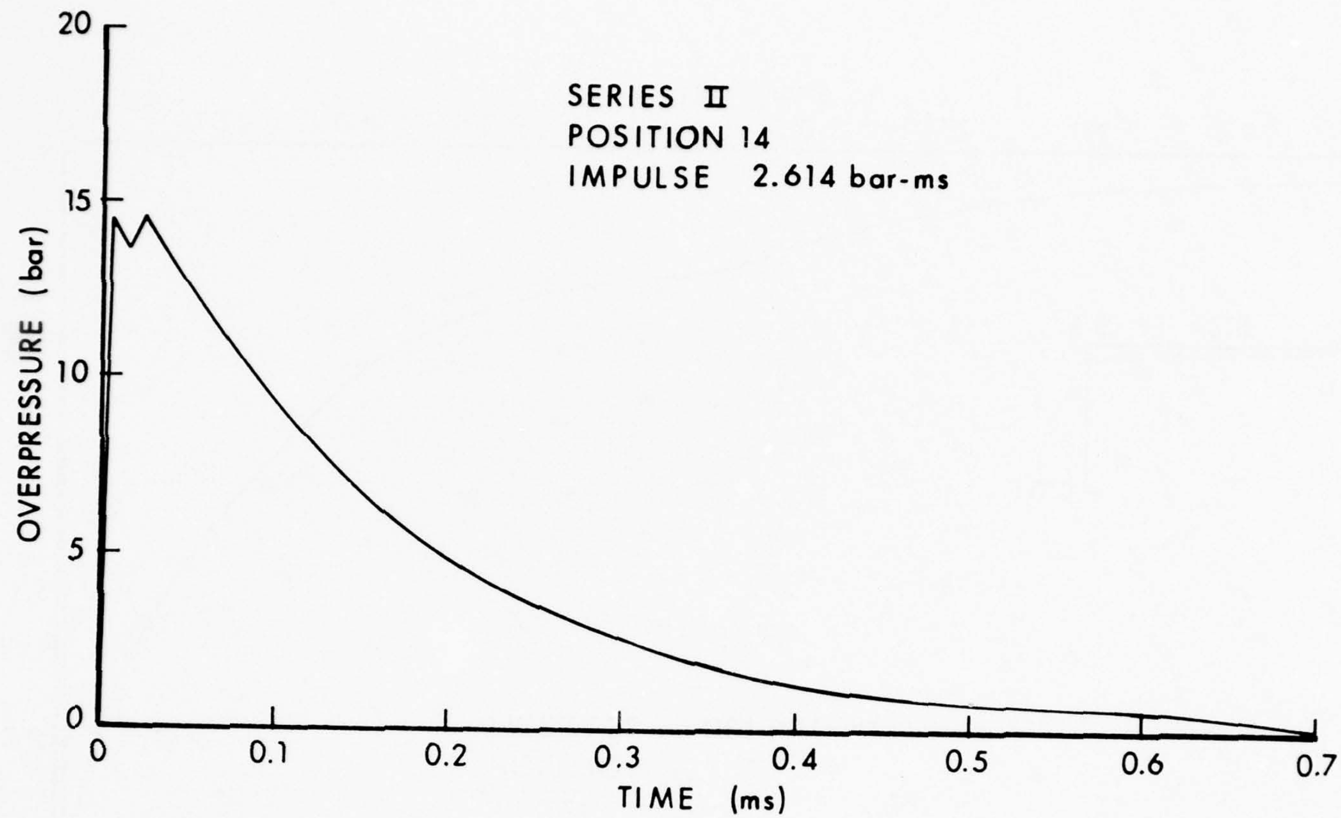



Figure B-12. Overpressure versus Time, Position 14

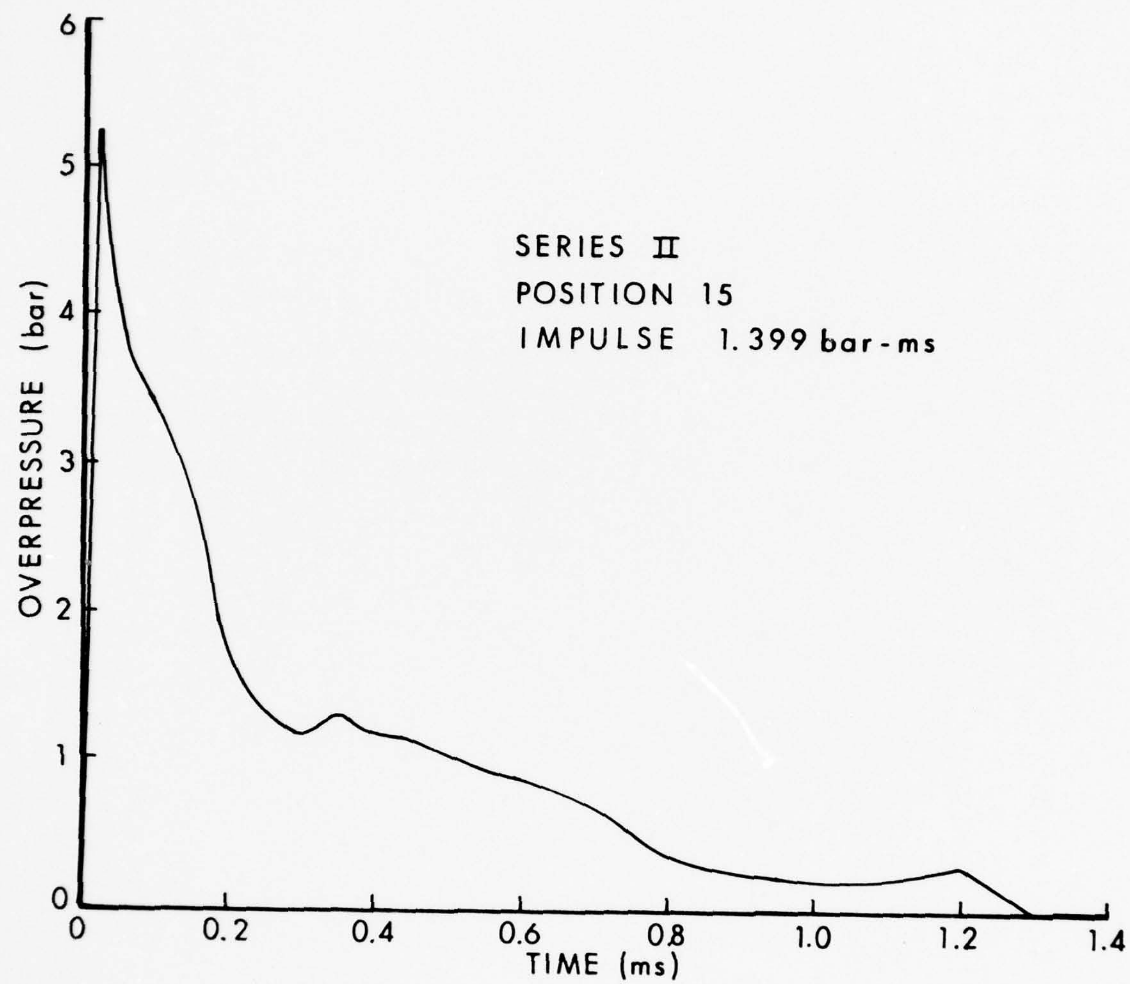



Figure B-13. Overpressure versus Time, Position 15

# APPENDIX C

Series III - Model Scale 1/30 Charge Weight 1.135 kg Pentolite

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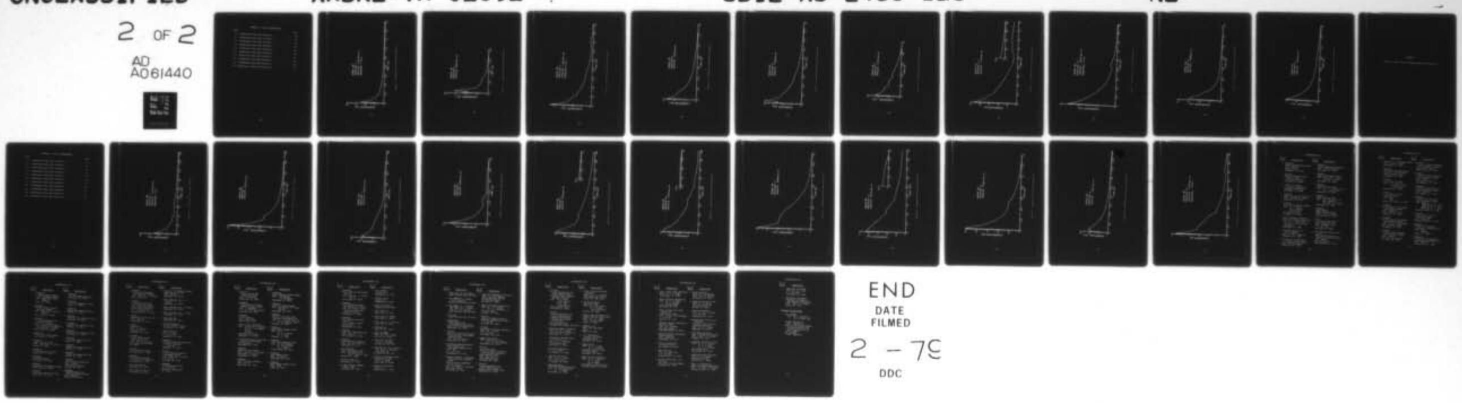

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## APPENDIX C - LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| C-1 | Overpressure versus Time, Position 1 | 101 |
| C-2 | Overpressure versus Time, Position 6 | 102 |
| C-3 | Overpressure versus Time, Position 7 | 103 |
| C-4 | Overpressure versus Time, Position 8 | 104 |
| C-5 | Overpressure versus Time, Position 10 | 105 |
| C-6 | Overpressure versus Time, Position 11 | 106 |
| C-7 | Overpressure versus Time, Position 12 | 107 |
| C-8 | Overpressure versus Time, Position 13 | 108 |
| C-9 | Overpressure versus Time, Position 14 | 109 |
| C-10 | Overpressure versus Time, Position 15 | 110 |

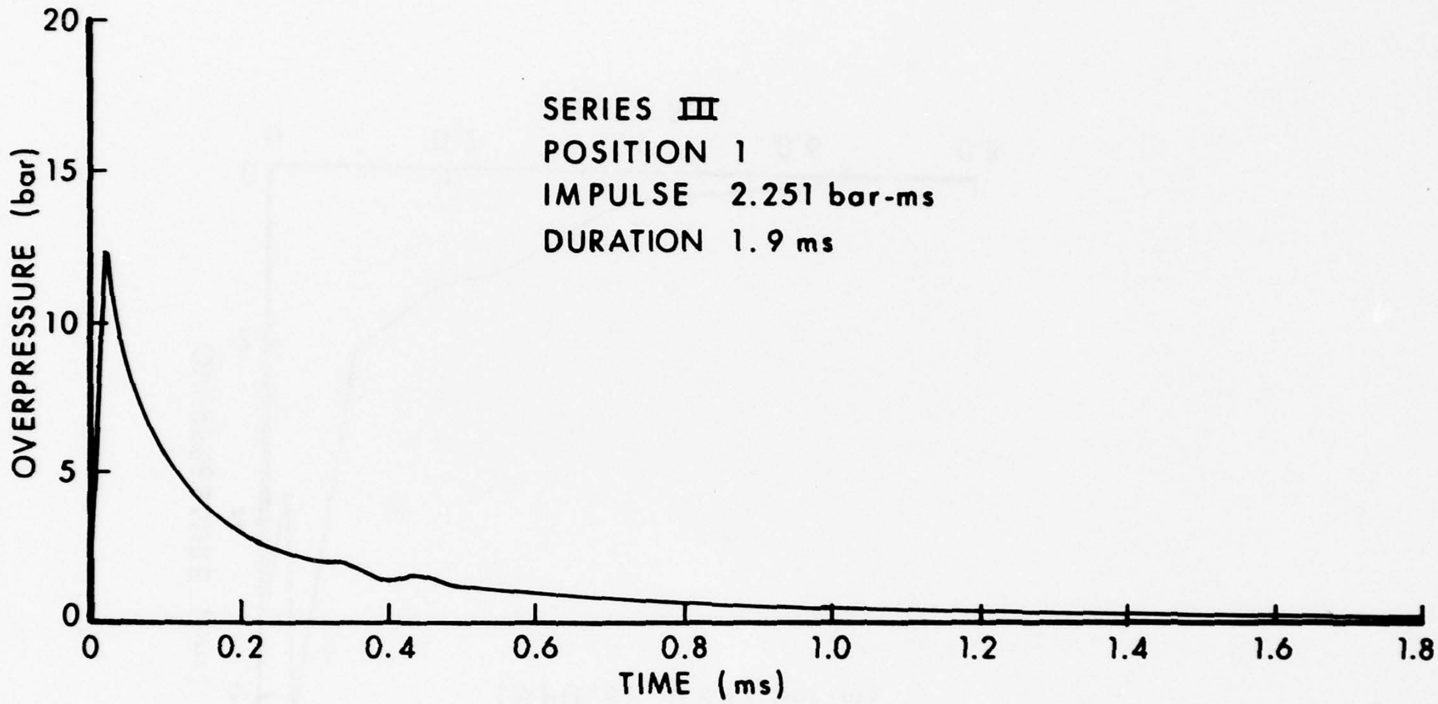



Figure C-1. Overpressure versus Time, Position 1

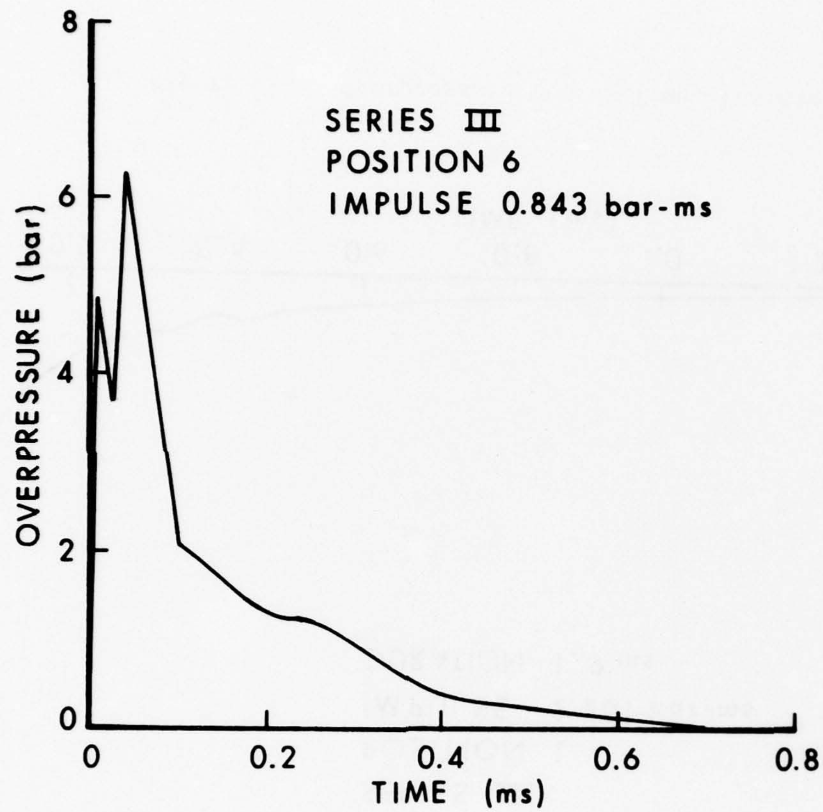



Figure C-2. Overpressure versus Time, Position 6

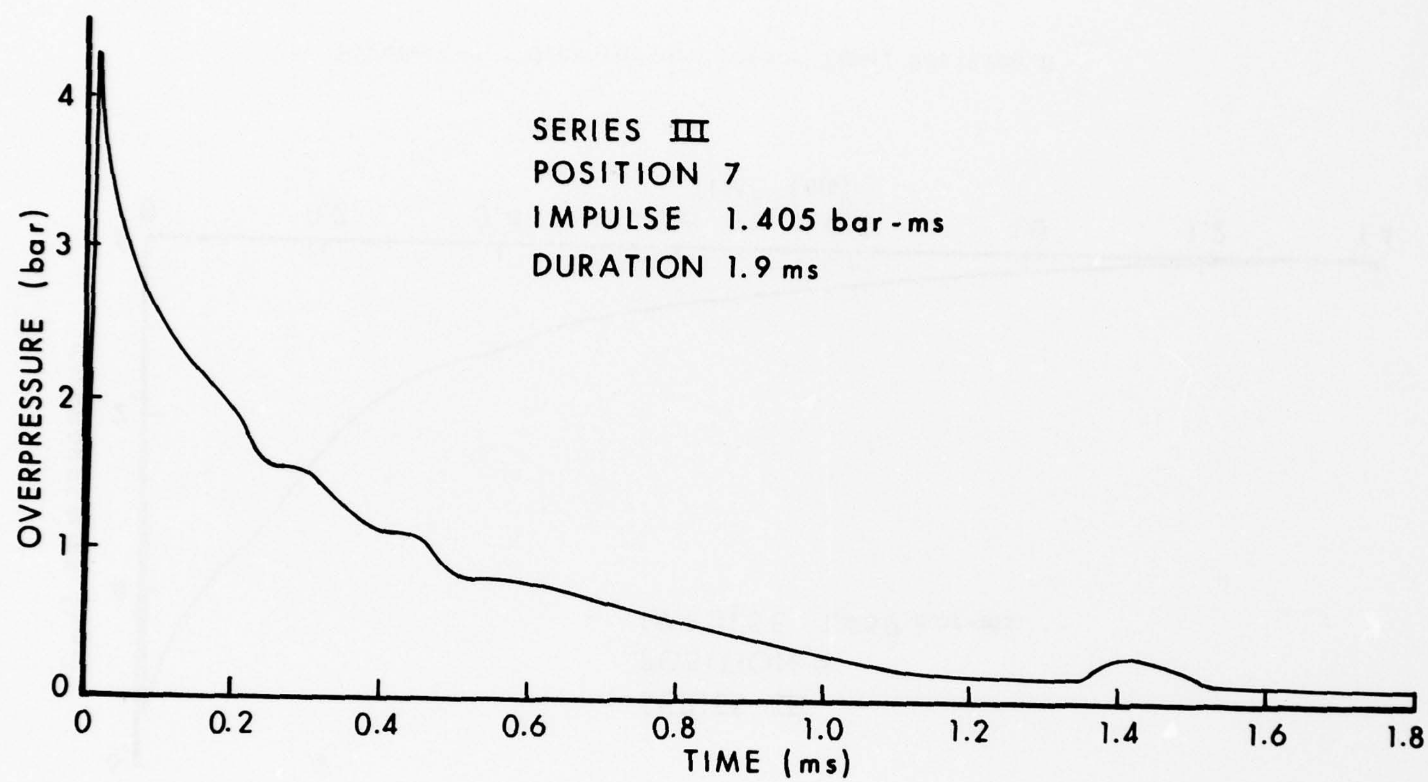



Figure C-3. Overpressure versus Time, Position 7

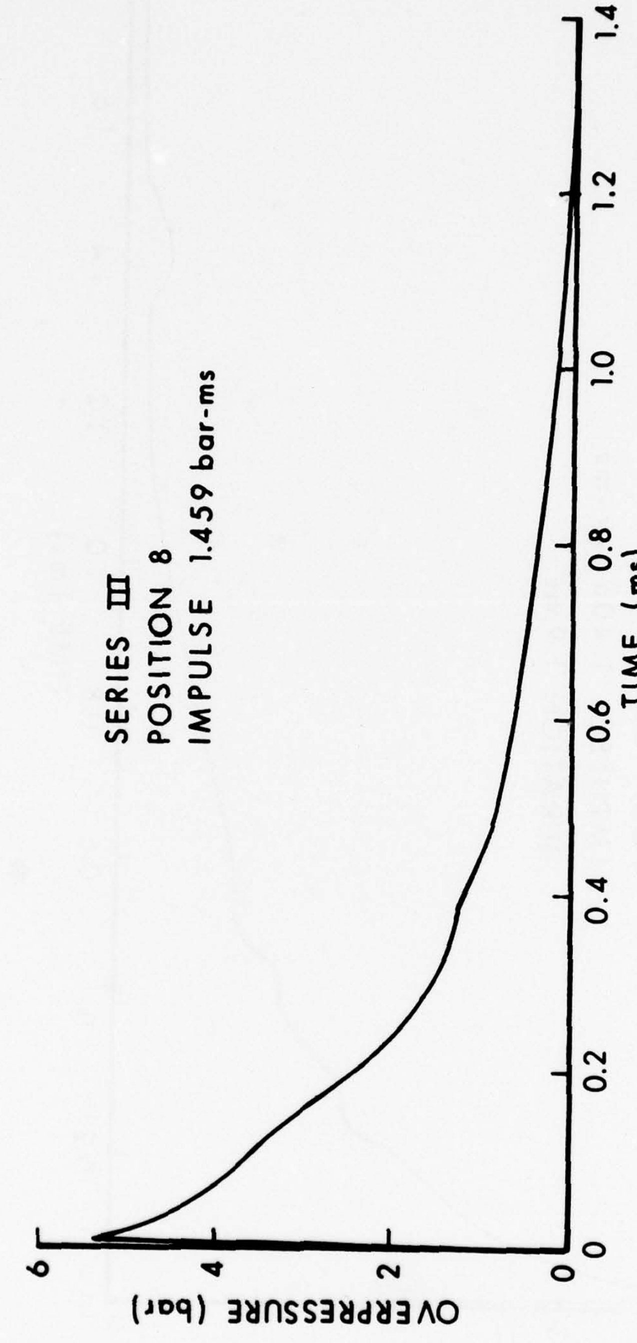



Figure C-4. Overpressure versus Time, Position 8

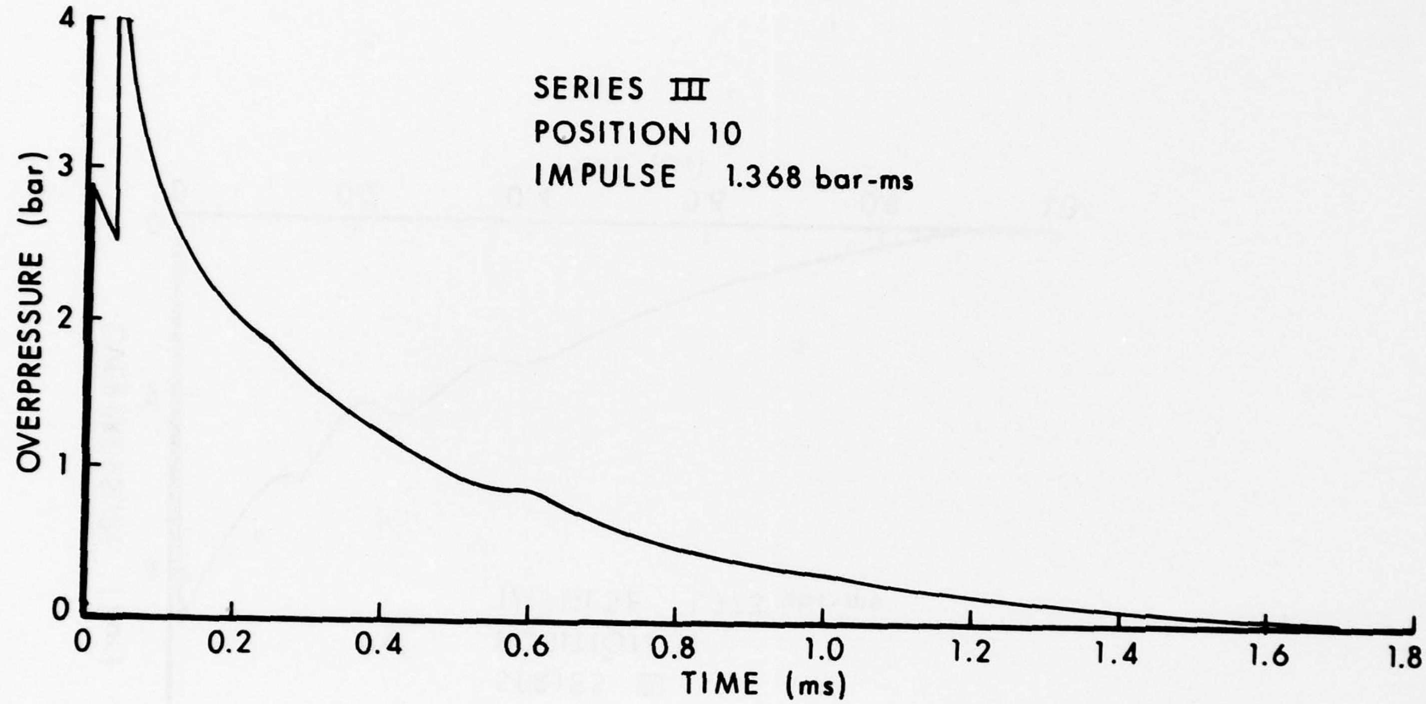



Figure C-5. Overpressure versus Time, Position 10

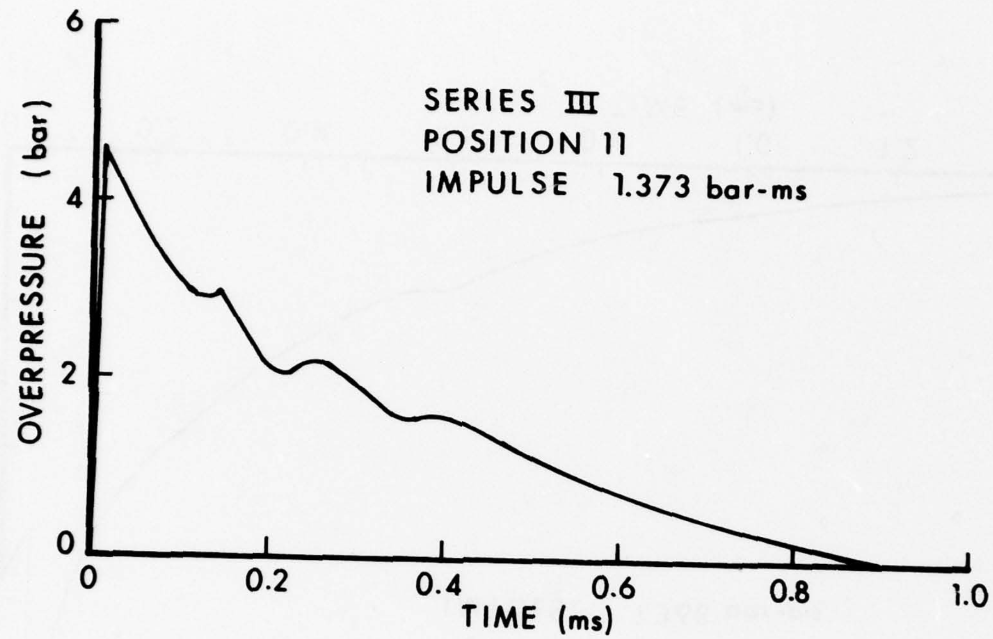



Figure C-6. Overpressure versus Time, Position 11

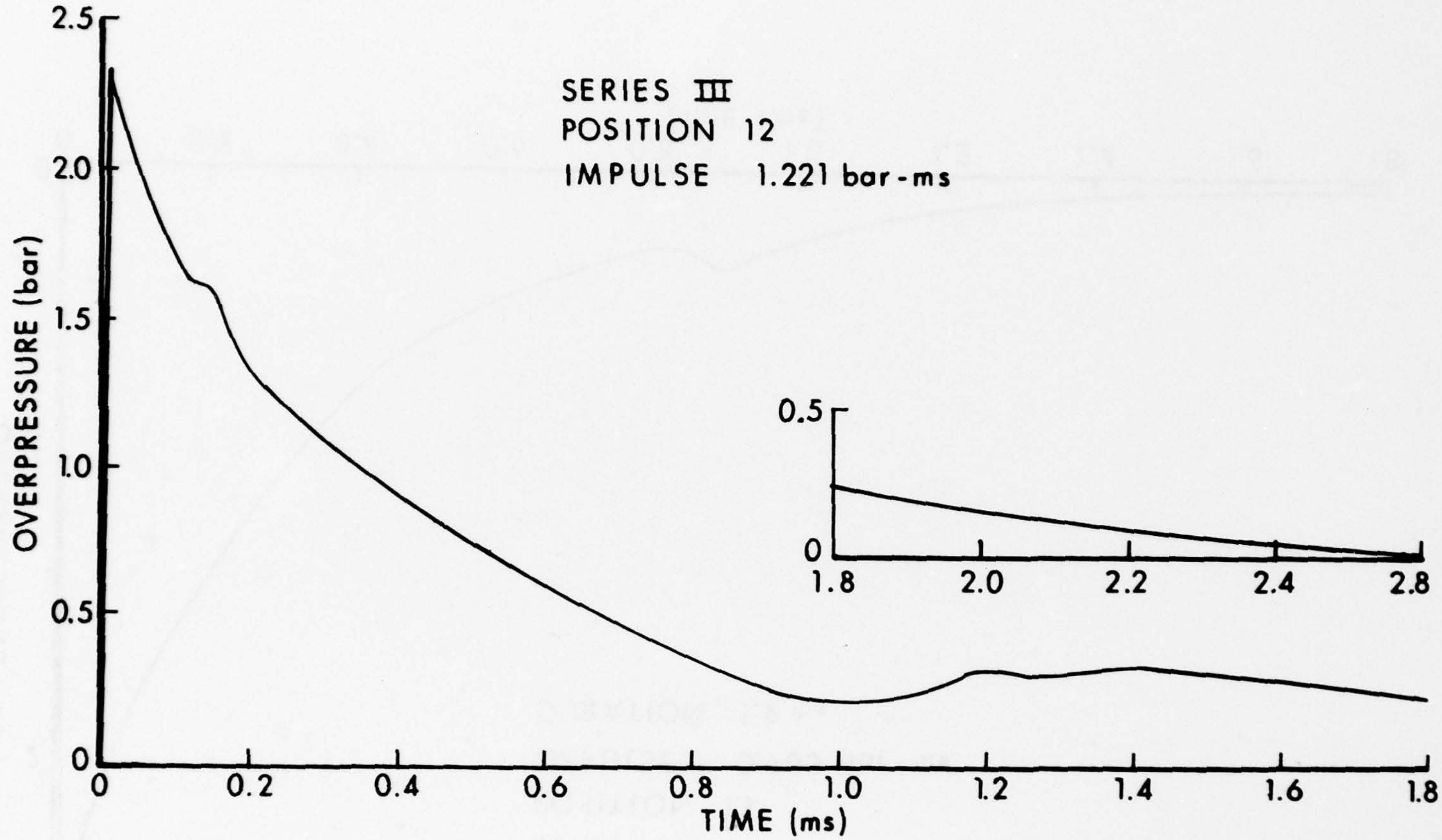



Figure C-7. Overpressure versus Time, Position 12

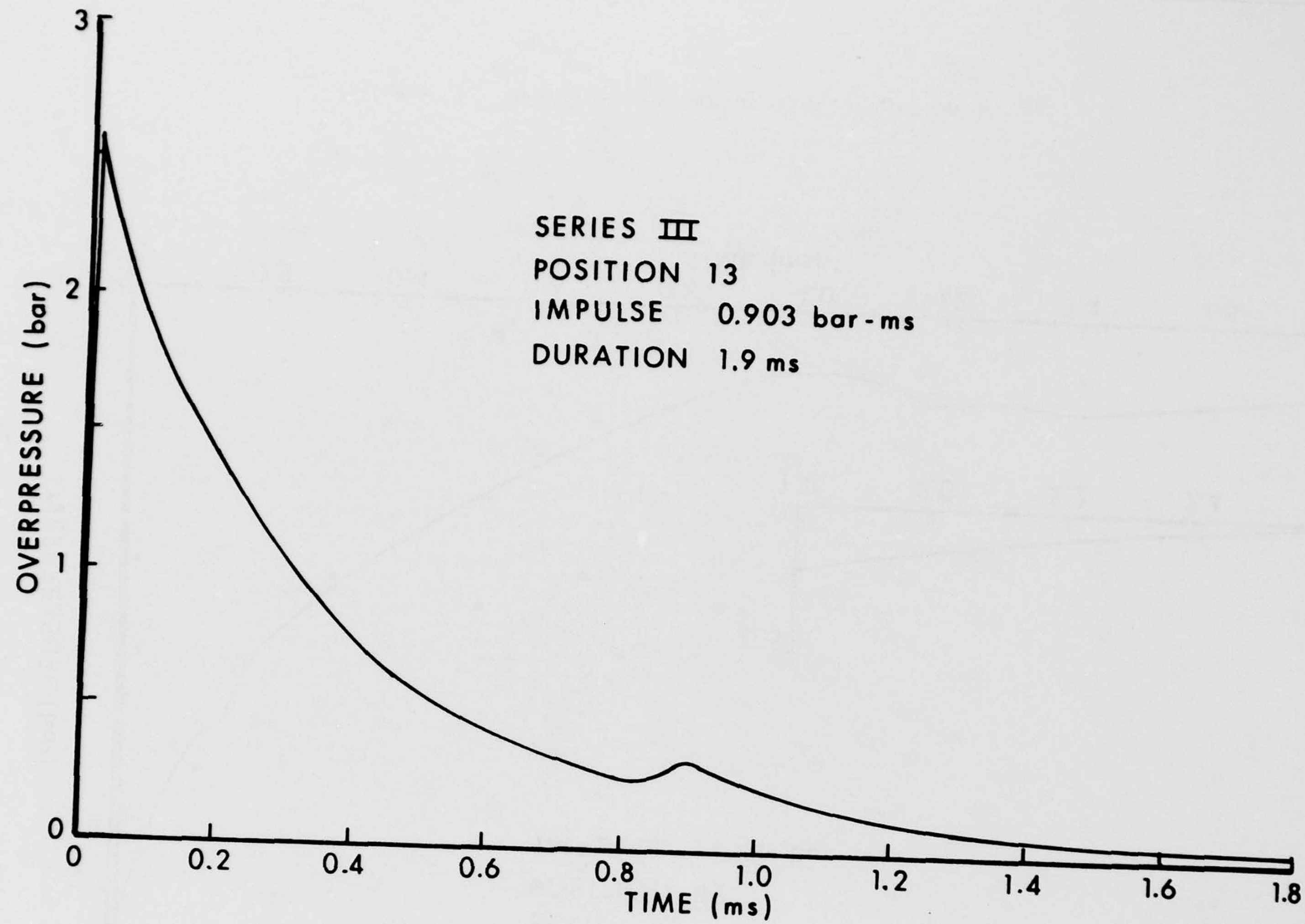



Figure C-8. Overpressure versus Time, Position 13

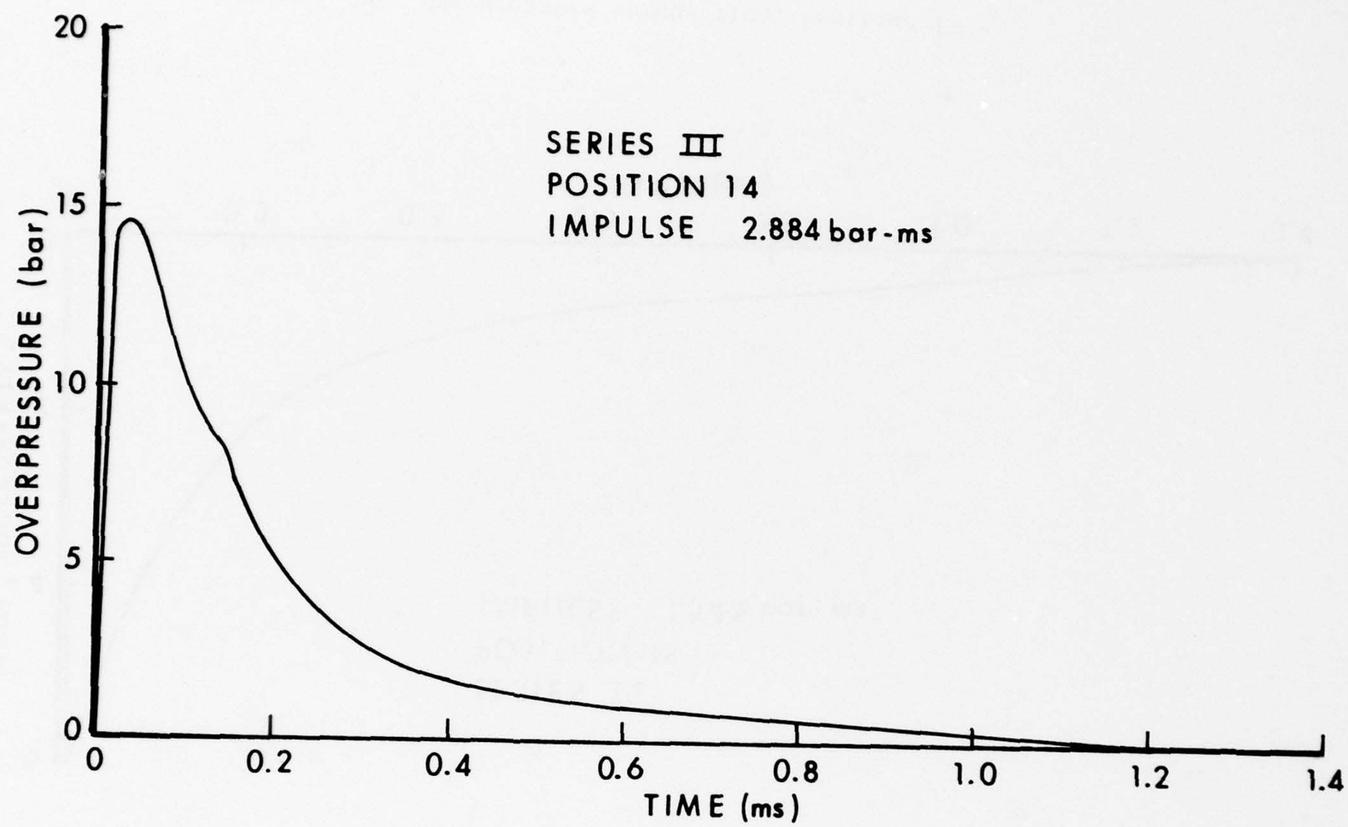



Figure C-9. Overpressure versus Time, Position 14

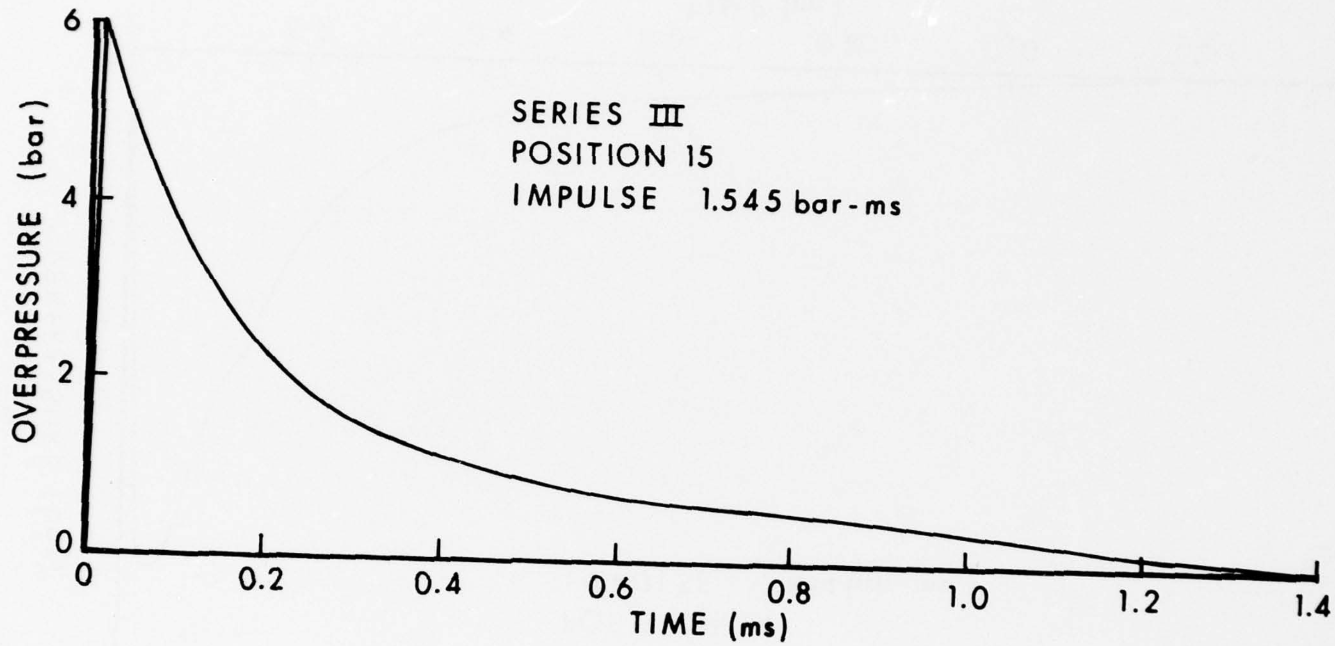



Figure C-10. Overpressure versus Time, Position 15

# APPENDIX D

Series VI - Model Scale 1/45 Charge Weight 0.454 kg Pentolite

## APPENDIX D - LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| D-1 | Overpressure versus Time, Position 1 | 113 |
| D-2 | Overpressure versus Time, Position 2 | 114 |
| D-3 | Overpressure versus Time, Position 5 | 115 |
| D-4 | Overpressure versus Time, Position 6 | 116 |
| D-5 | Overpressure versus Time, Position 7 | 117 |
| D-6 | Overpressure versus Time, Position 10 | 118 |
| D-7 | Overpressure versus Time, Position 11 | 119 |
| D-8 | Overpressure versus Time, Position 12 | 120 |
| D-9 | Overpressure versus Time, Position 13 | 121 |
| D-10 | Overpressure versus Time, Position 14 | 122 |
| D-11 | Overpressure versus Time, Position 15 | 123 |

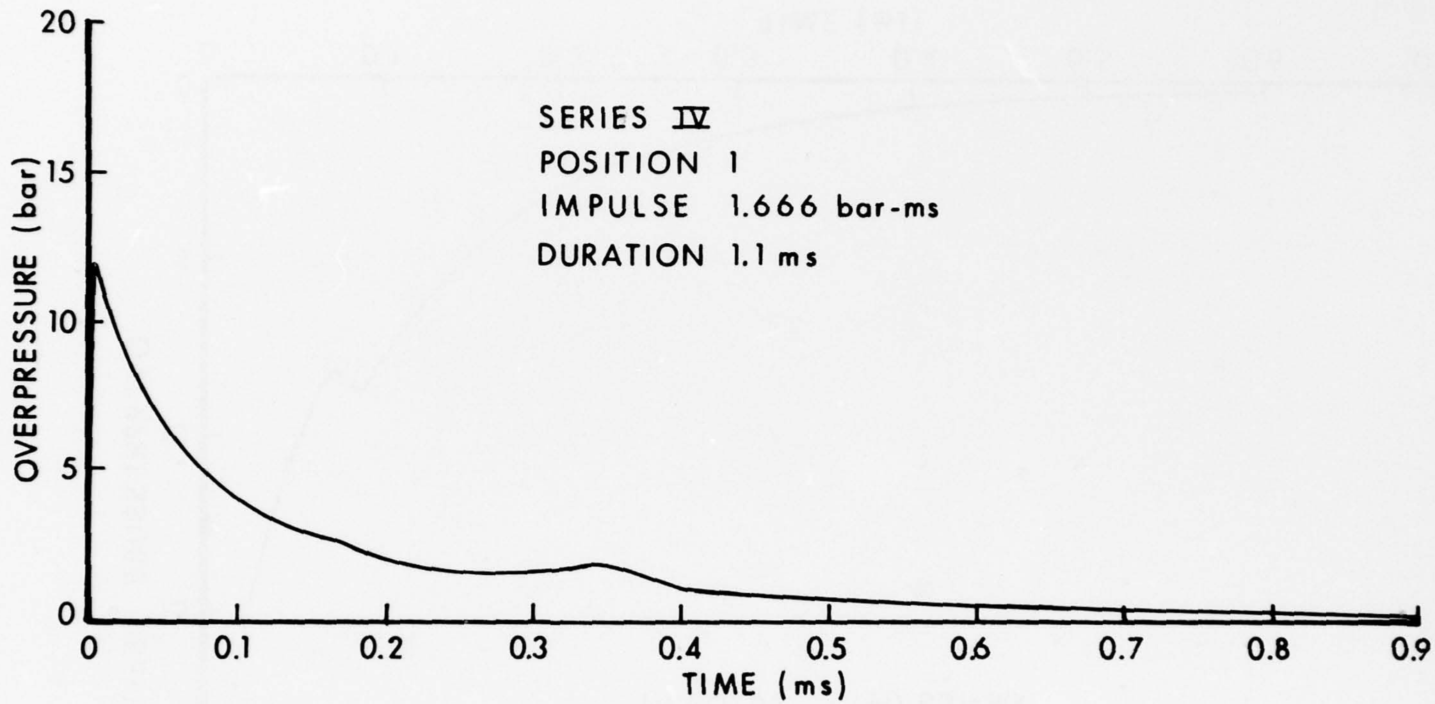



Figure D-1. Overpressure versus Time, Position 1

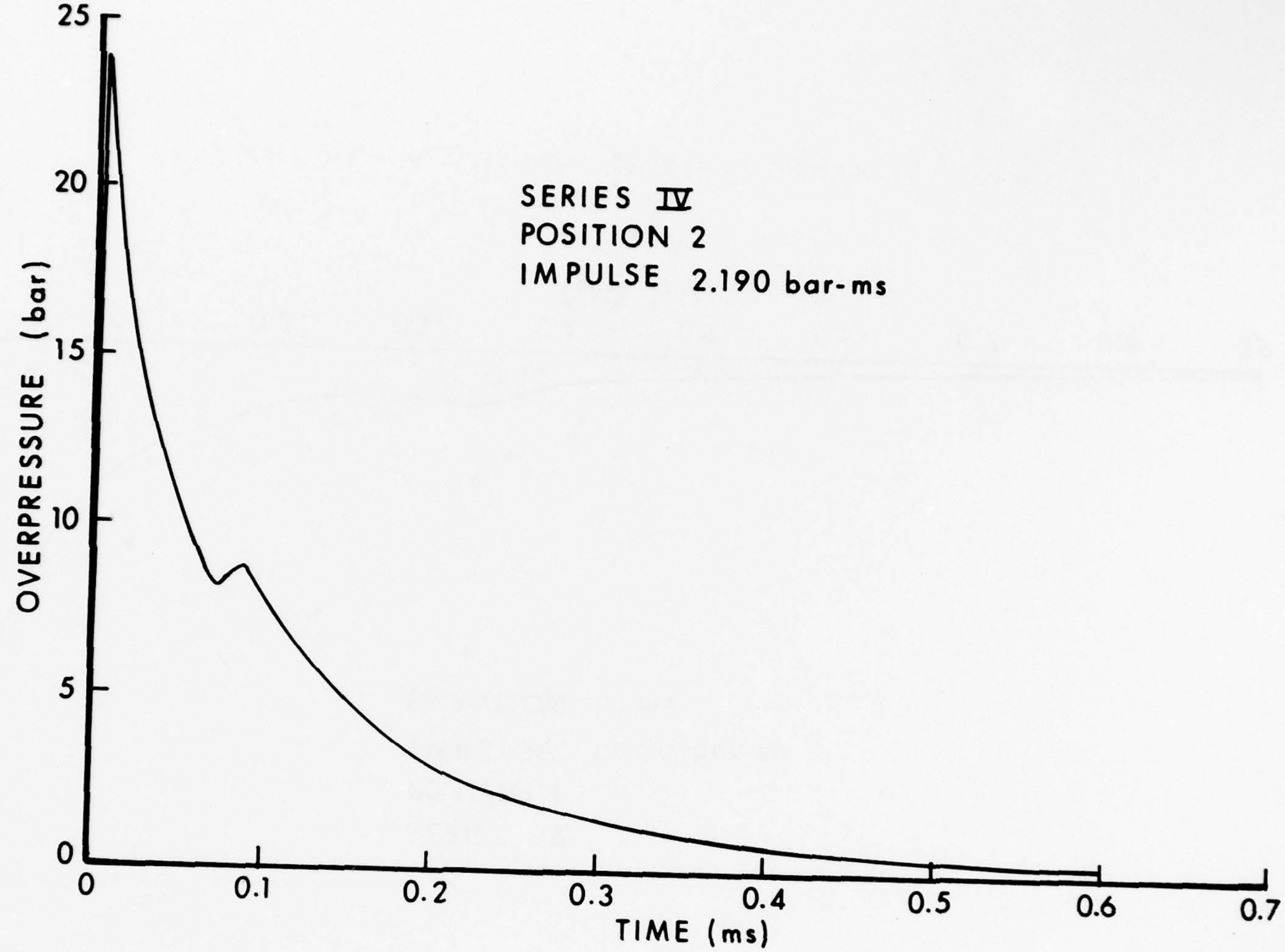



Figure D-2. Overpressure versus Time, Position 2

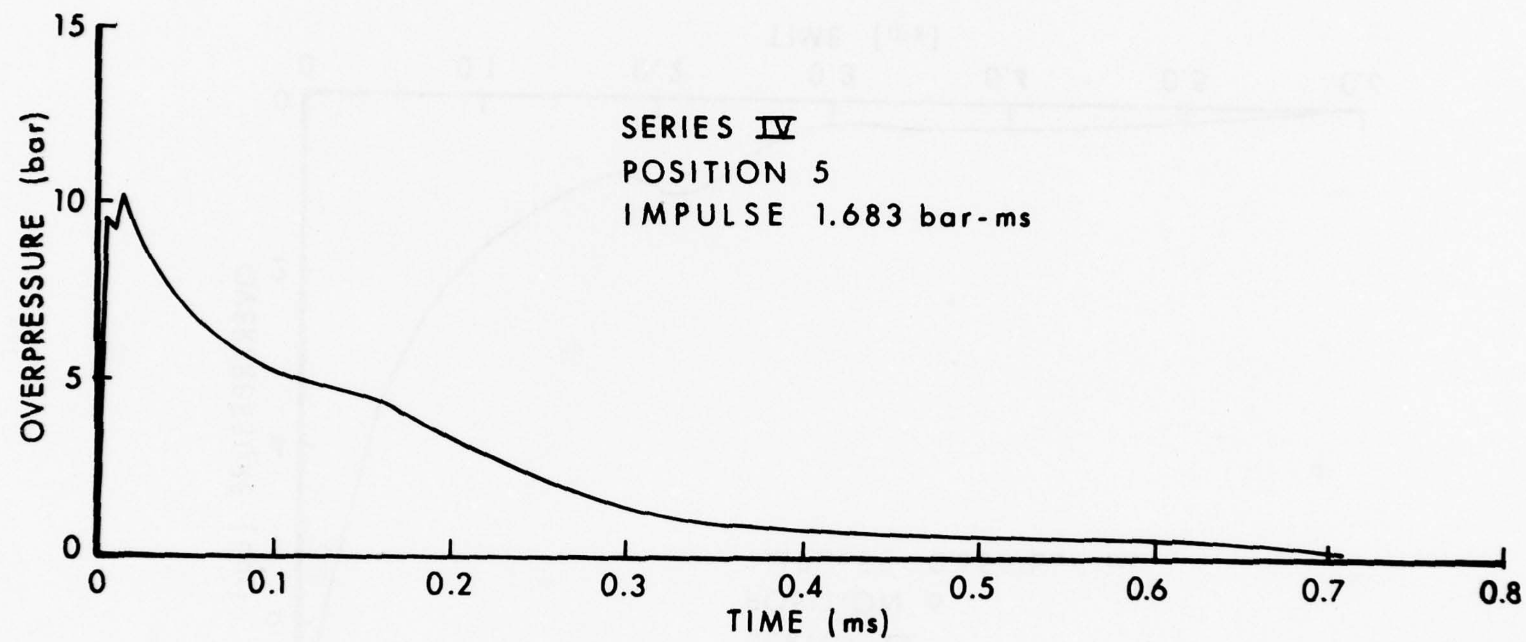



Figure D-3. Overpressure versus Time, Position 5

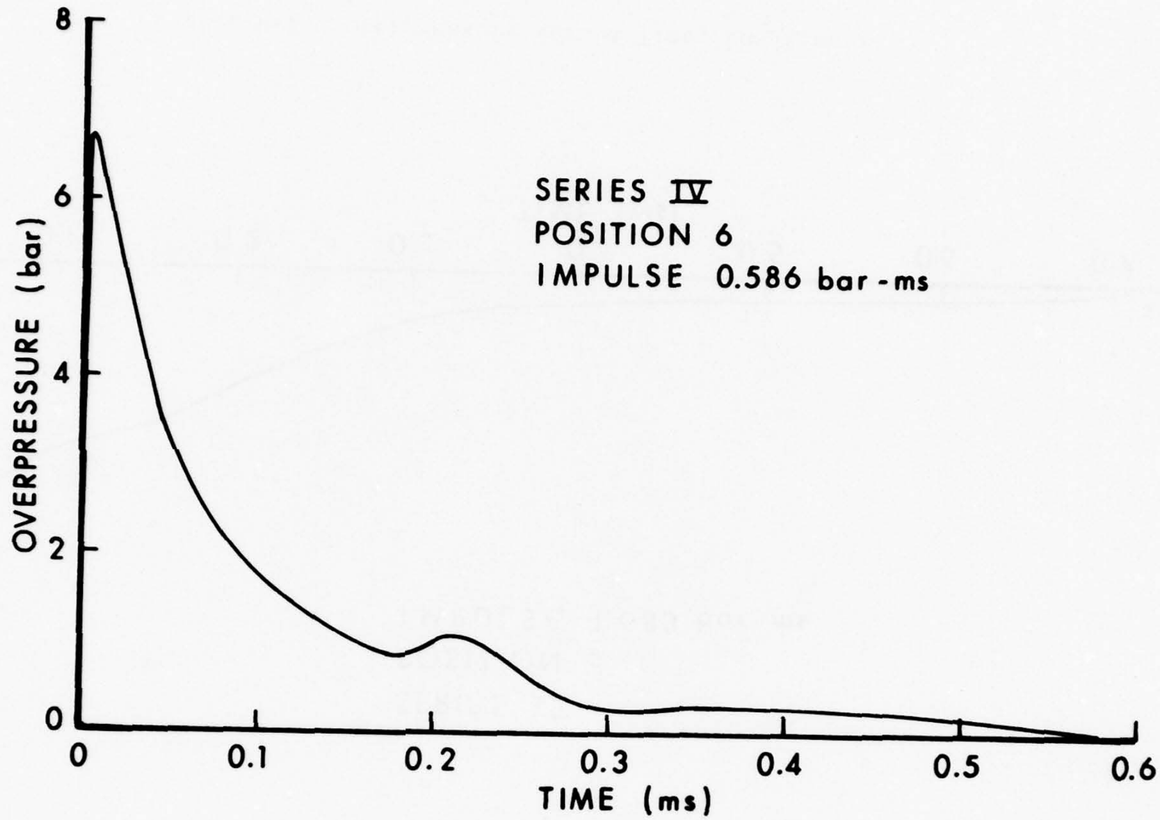



Figure D-4. Overpressure versus Time, Position 6

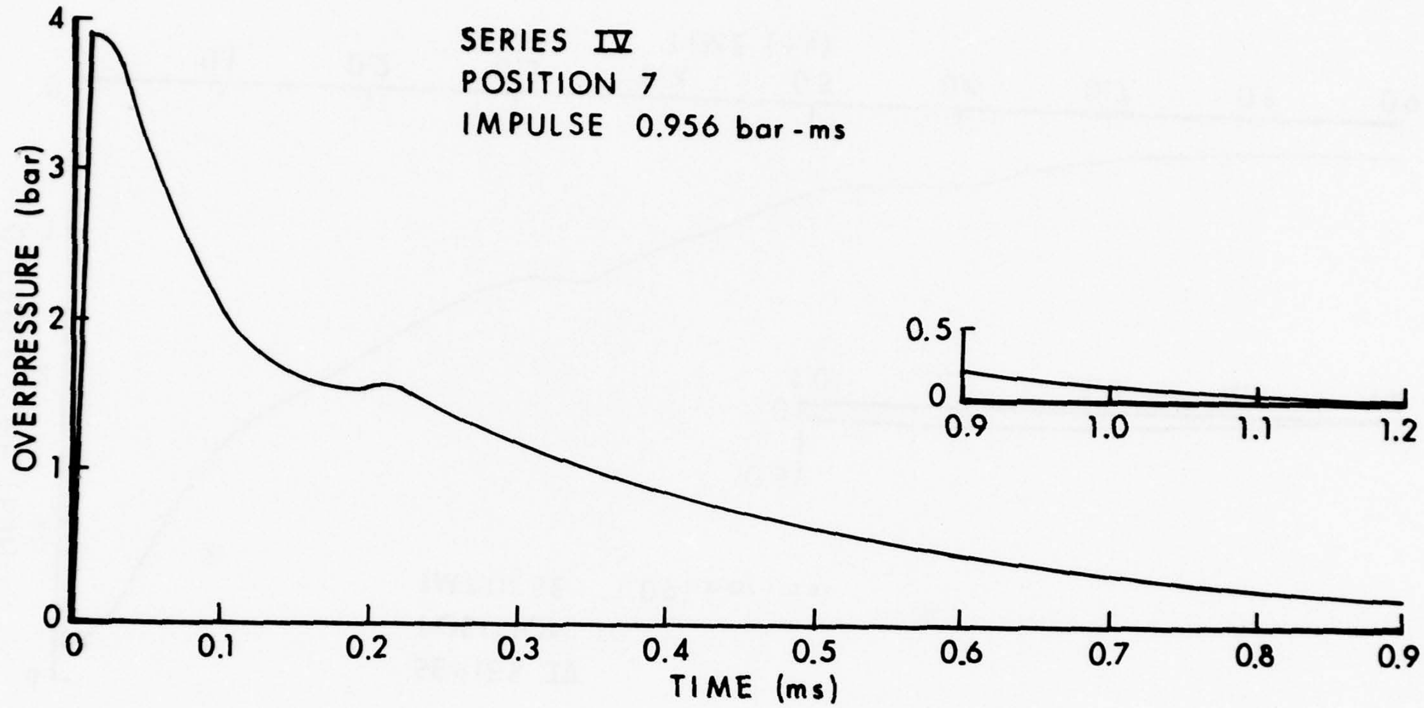



Figure D-5. Overpressure versus Time, Position 7

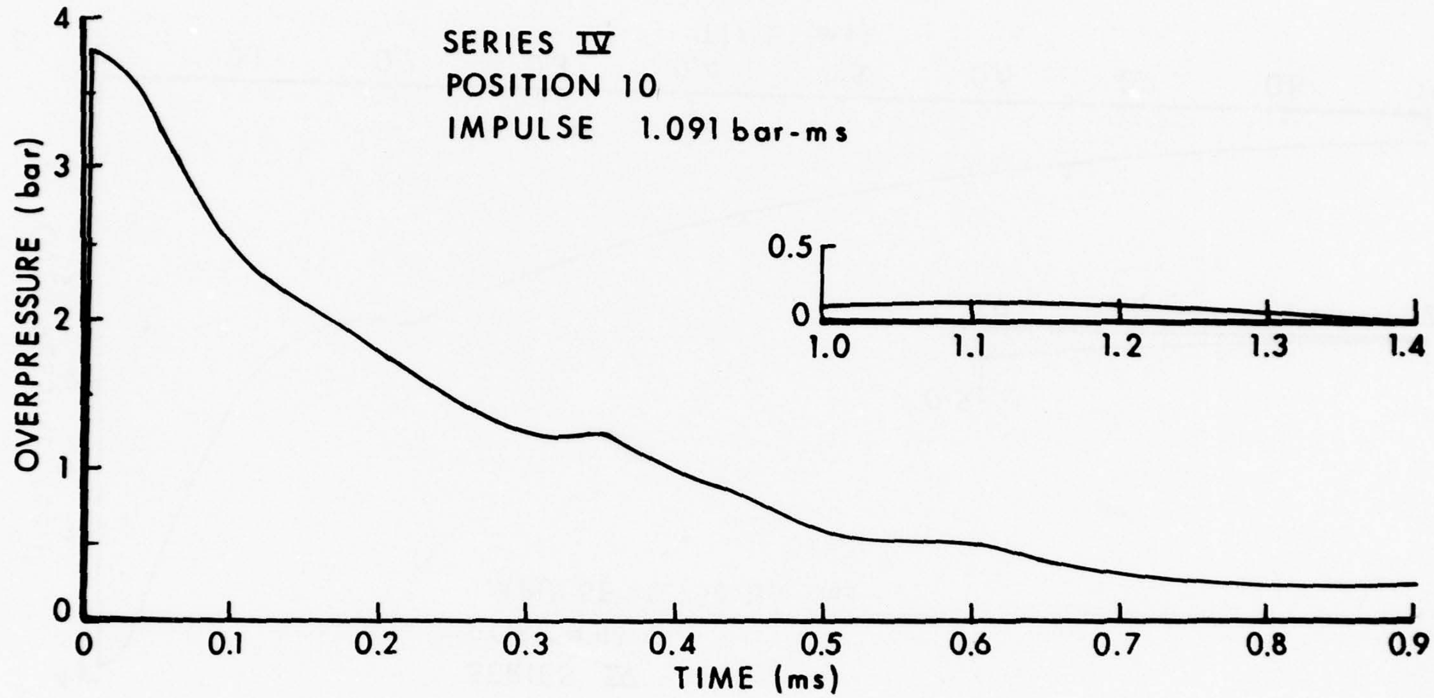



Figure D-6. Overpressure versus Time, Position 10

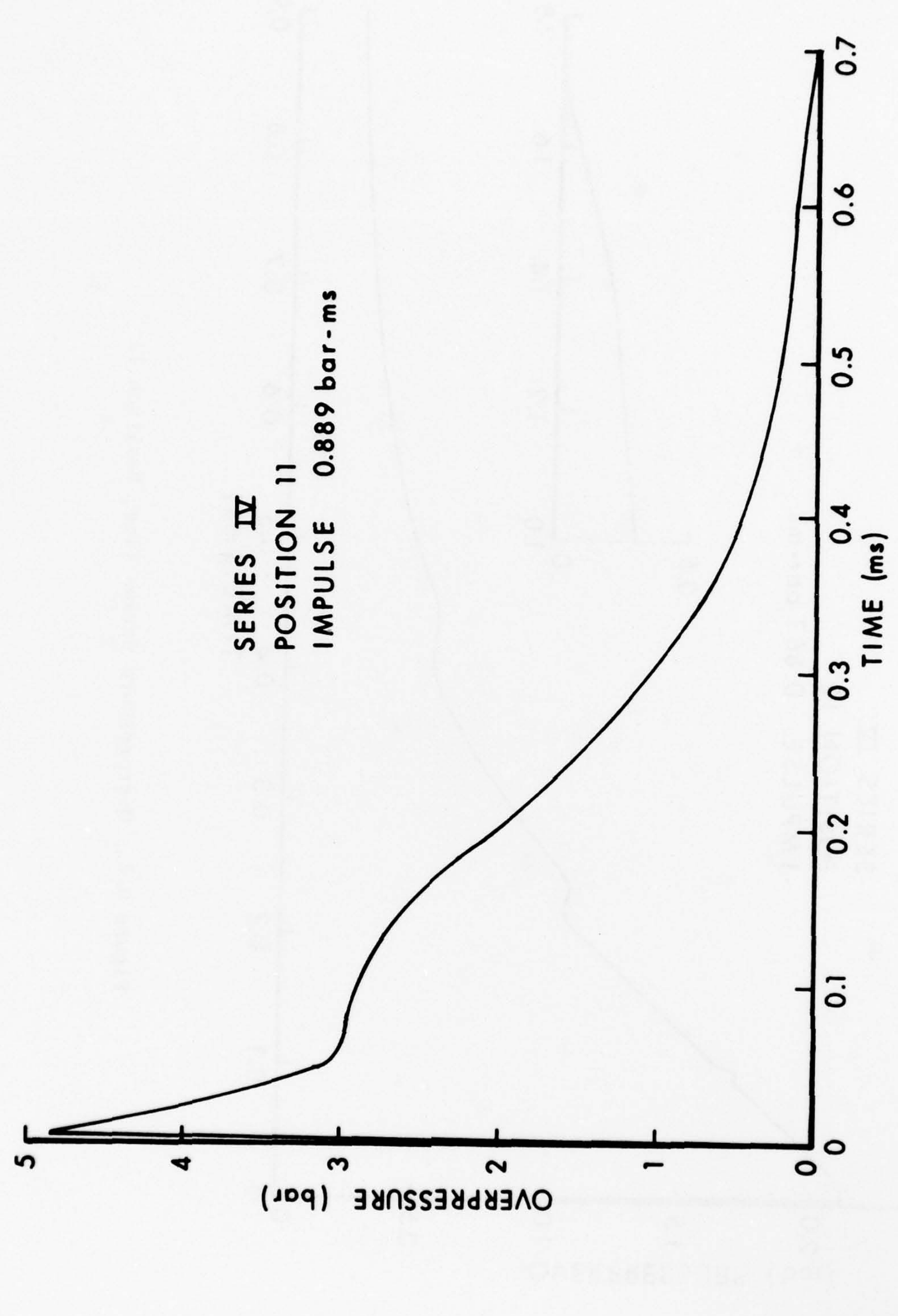



Figure D-7. Overpressure versus Time, Position 11

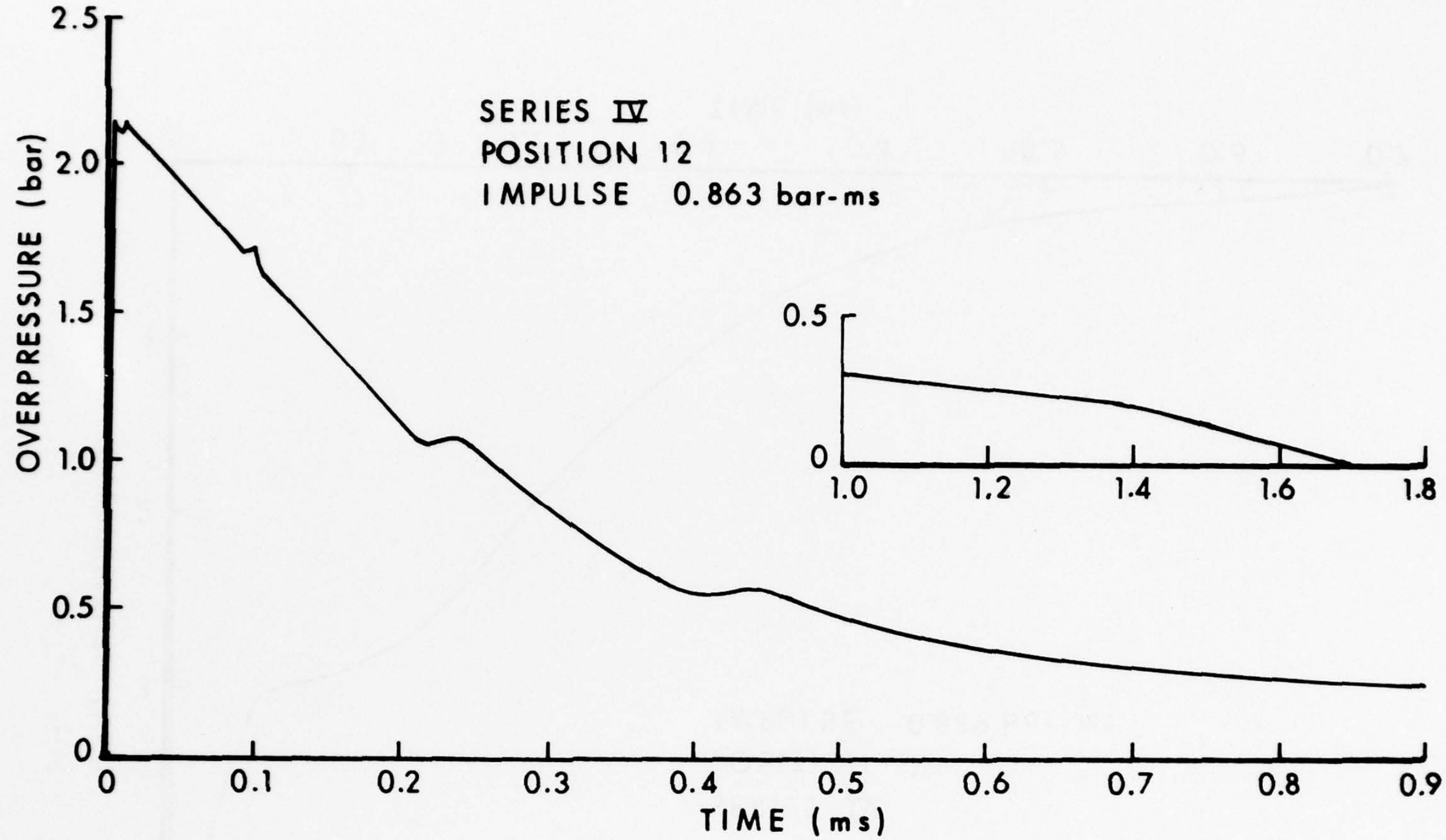



Figure D-8. Overpressure versus Time, Position 12

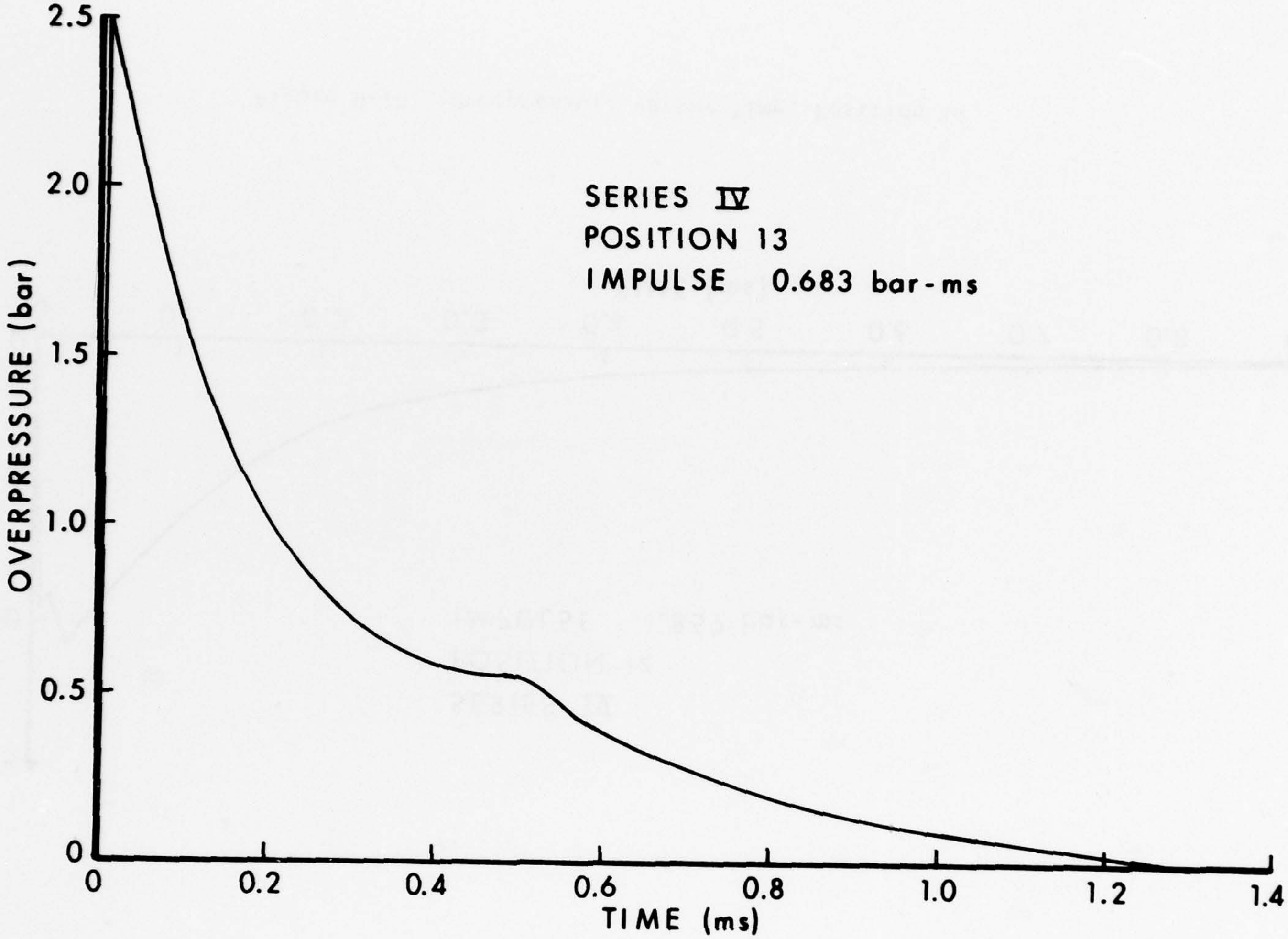



Figure D-9. Overpressure versus Time, Position 13

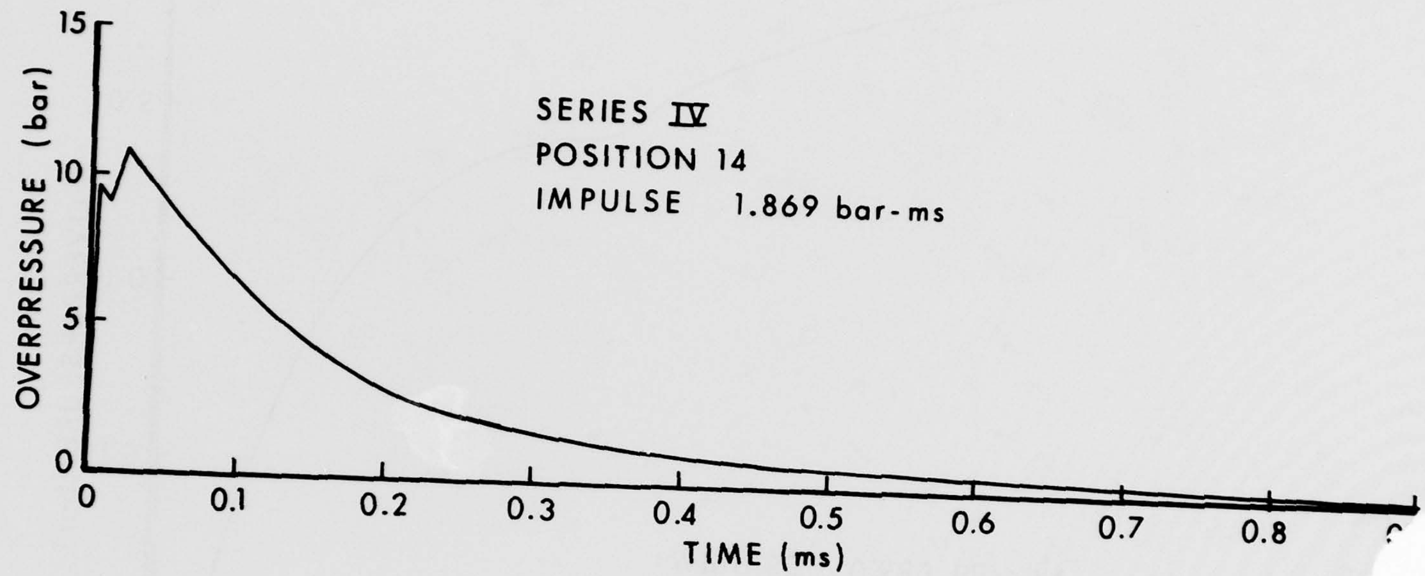
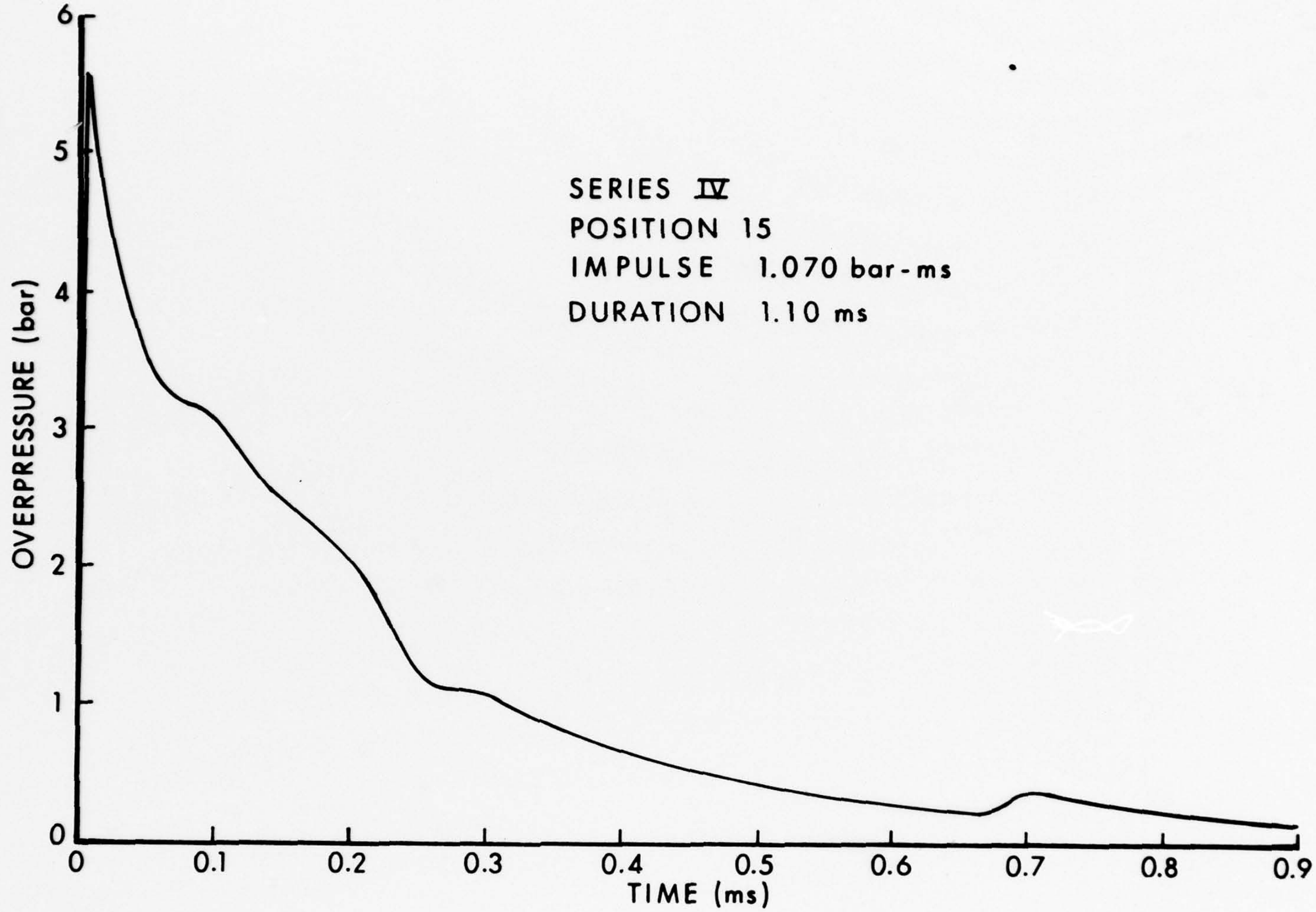



Figure D-10. Overpressure versus Time, Position 14

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