BRL-MR

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MEMORANDUM REPORT BRL-MR-3952

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SHOCK TESTING OF A KULITE PRESSURE GAGE

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DECEMBER 1991

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U.S. ARMY LABORATORY COMMAND

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NOTICES

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
December 1991

3. REPORT TYPE AND DATES COVERED
Final. Jun-Sep 91.

4. TITLE AND SUBTITLE
Shock Testing of a Kulite Pressure Gage

5. FUNDING NUMBERS
PR: 1L162618AH80

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
BRL-MR-3952

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
A program designed to measure in-flight base pressure is presently underway at the Launch and Flight Division of the Ballistic Research Laboratory. The pressure gages used in the projectile must withstand projectile accelerations (from 10,000-20,000 g's) if they are to be effective. Shock tests were performed on Kulite pressure gages model No. XT-39-190-25A to determine its response to this type of acceleration level. This report details the workings of the Impac Shock Machine as well as the effect of acceleration on gage performance.

14. SUBJECT TERMS
Pressure Gage; Shock

15. NUMBER OF PAGES
13

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

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Acknowledgements

The author wishes to express his gratitude for their consultative assistance and suggestions to the following: David Hepner, Charles Mitchell and David Vazquez. Their experience in shock test machine operations was most beneficial.

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1. INTRODUCTION

Tests on Kulite pressure gages were conducted to determine what effect large accelerations loads have on gage performance. The need for this information was spawned by earlier M864 projectile tests performed at the Ballistic Research Laboratory's (BRL) Transonic Range facility.[1] These earlier tests measured projectile base pressure with great success at lower velocities (Mach (M) number=1.3), but, encountered difficulty at higher velocity (M=2.0) launches due to their associated higher accelerations. Typically, the base-pressure data are detected by the pressure gage, and then transmitted via projectile telemetry. Base-pressure data from some gage positions on several M864 rounds were not obtained. Typically gages used to measure external pressures in-flight are rated for a maximum of 2 atmospheres pressure. A successful pressure measurement requires: survival of in-bore accelerations, isolation from in-bore propellant temperature and pressure, isolation from centrifugal forces during flight, and reliable on-board electronics. Investigation of the pressure gage's response to acceleration was considered worthwhile.

A machine that subjects test specimens to large acceleration loads exists. The Impac shock machine, while not reproducing the same acceleration versus time history, does allow similar acceleration magnitudes to be placed on specimens. The gage performance after acceleration loading gives a measure of the ruggedness of the gage. The pressure gage shock tests were conducted at the BRL's Kent Building.

2. EQUIPMENT AND PROCEDURE

Figure 1 shows a sketch of the Impac shock test machine and some of the associated nomenclature. Essentially, in a shock loading cycle, the gages are mounted on the test cylinder fixture, clamped to the drop table, elevated to a prescribed height, and released. Gage pressure measurements were noted after each drop.

The gages used were Kulite model#XT-39-190-25A. Figure 2 shows a schematic view of the pressure gage. These diaphragm pressure gages used miniature, solid-state semiconductor strain-gage sensors to detect pressure variations, and a reinforcing stop to protect diaphragms against pressure extremes. The gages were approximately 25 mm long by 12 mm wide, and screwed into the test fixture. An O-ring seal is present at the bottom of the hexagonal portion of the gage to prevent gasses from leaking around the threads and altering the pressure measured (when pressures are being sensed). A fine screen is placed at the gage tip to protect the pressure gage membrane from damage. The gage weight was approximately 3.0 grams. The gage employed an internal resistor in its workings. There was some concern expressed that the resistor connections might not have been sturdy enough to support the weight of the resistor under acceleration loads above 10,000 g's.[2] But after weighing the resistor and determining the loads that the connection joints had to withstand, it was concluded that the connections offered adequate strength.

[1] Kayser, L., Kuzan, J. "IN-FLIGHT PRESSURE MEASUREMENTS ON SEVERAL 155MM, M864 BASE BURN PROJECTILES," Ballistic Research Laboratory Memorandum Report 3888, January 1991. (A232225)

[2] Note: "g" is the acceleration on Earth (9.8 meters per second squared) due to gravity.

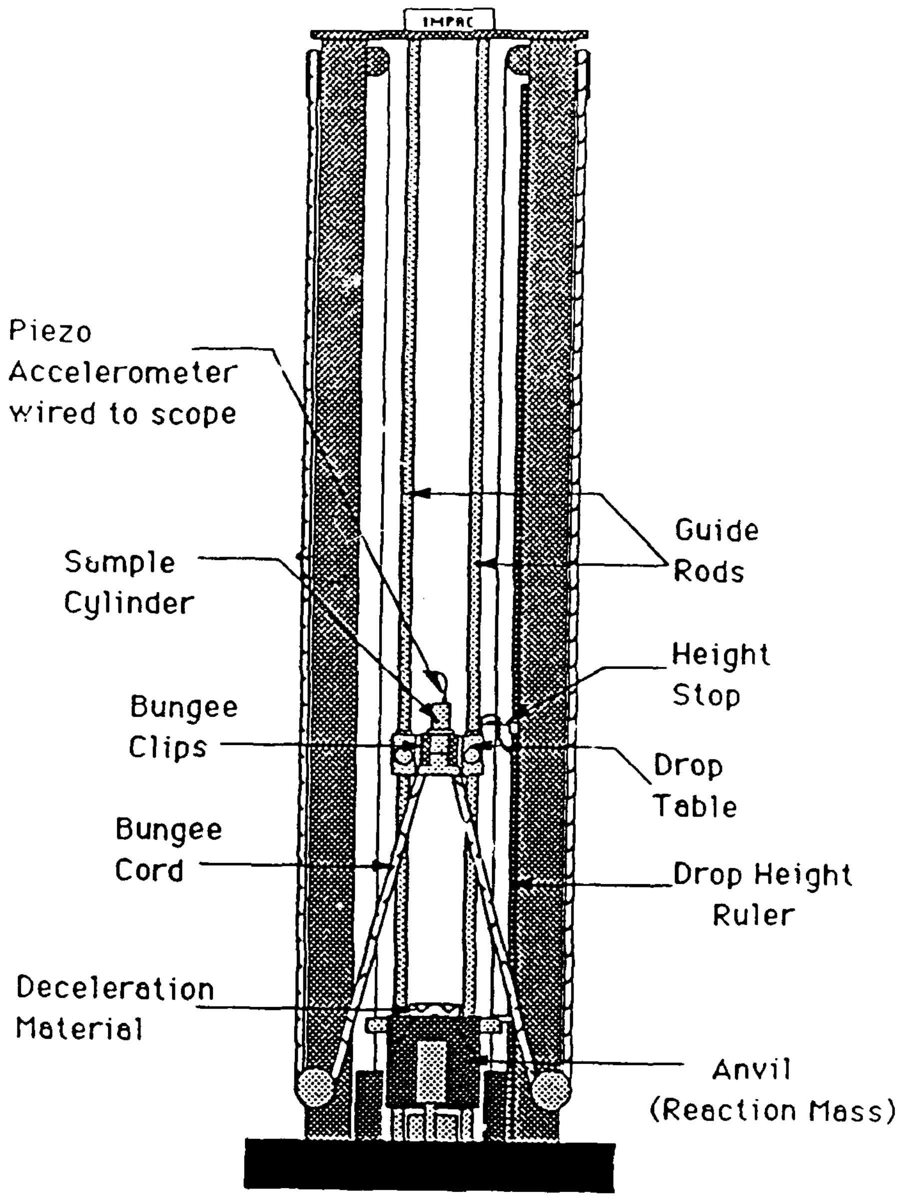

Figure 1. Impac Shock Test Machine and Accessories.

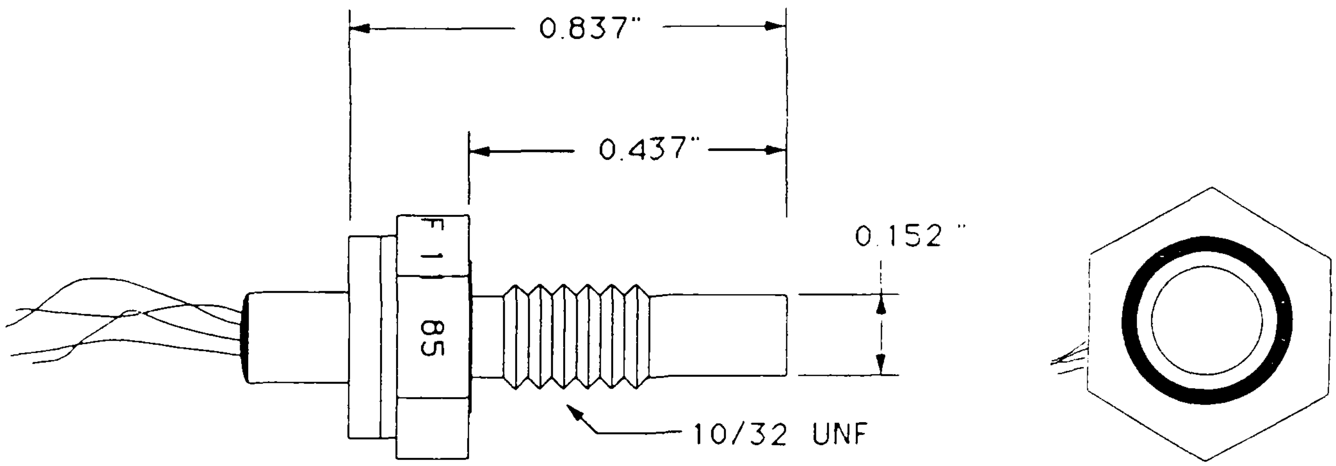

Figure 2. Pressure Gage Schematic.

The pressure gages were tested in a series of steps. The first step in the tests was to use a pressure gage and an amplifier to develop a voltage output versus applied-pressure curve: a calibration curve. This curve was used as a baseline for all measurements made with this gage. The gage was then used to measure the same applied pressures to determine if there was any hysteresis that might influence later measurements. None was detected. These measurements were performed using a vacuum pump, voltmeter, vacuum gage, and of course the pressure gages tested. Each gage output voltage was recorded for pressures ranging from near atmospheric to near 600 Pa (1.013×10^5 Pa $\approx$ 1 atmosphere). Output from a well-documented Statham gage was simultaneously recorded to provide a known reference output. Next the gage was subjected to an acceleration load, after which, the same pressure measurements were taken with the gage. This was done to assess the effect of the acceleration loading on the gage response. The gages (mounted axially and transversely) were shock-loaded simultaneously. Figure 3 shows a sketch of the gages mounted on the cylindrical test fixture.

3. DISCUSSION

Shock machine decelerations were measured by a piezo-electric accelerometer. The accelerometer was mounted adjacent to a mechanical accelerometer and nearby the Kulite gages, and was subjected to the same accelerations. The piezo-electric accelerometer was pre-calibrated, and its functional range was 0-50,000 g's. The upper bound for the accelerom-

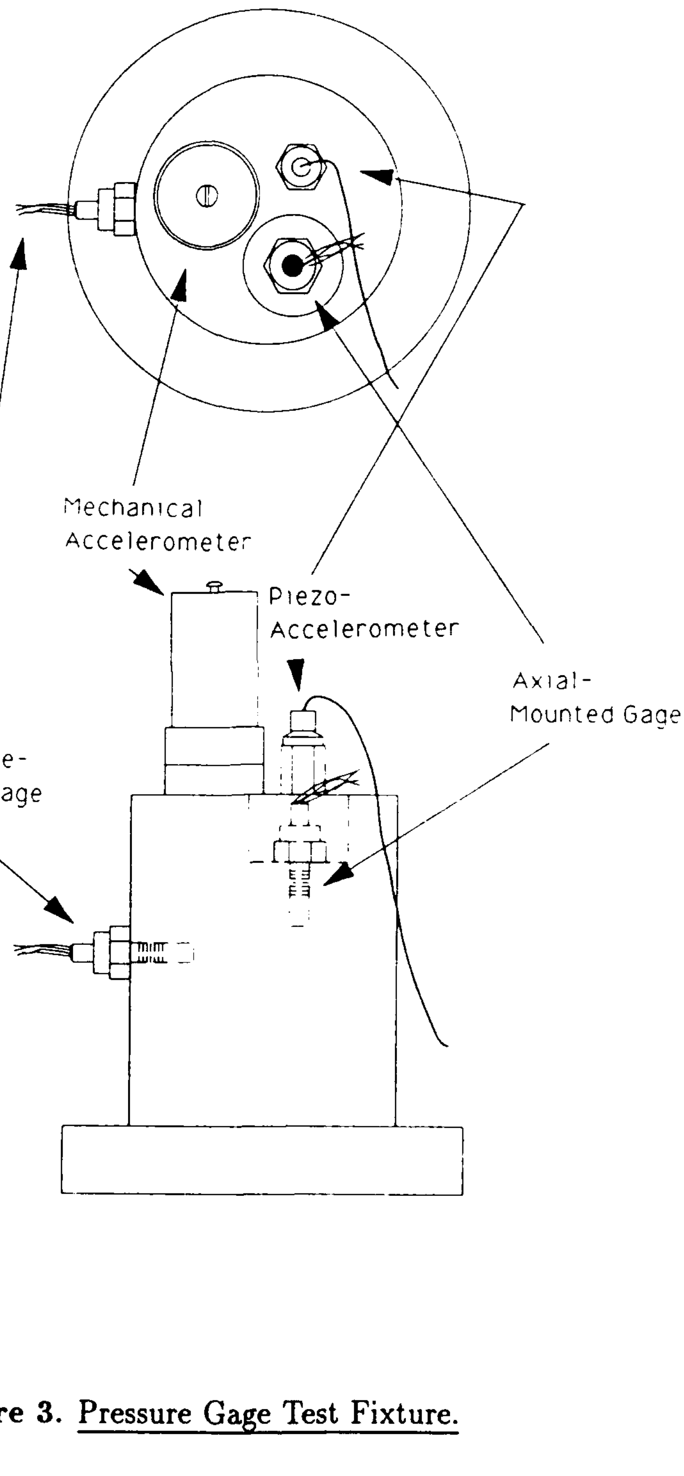

Figure 3. Pressure Gage Test Fixture.

eter was much higher than the maximum 15,000 g's planned for the gage test; therefore, the accelerometer was considered suitable. The mechanical accelerometer is basically a copper-crusher device. The amount of deformation measured on the copper sphere can be correlated to the maximum acceleration load. The correlation is based on empirical acceleration measurements. Since electronic measurements can sometimes suffer due to stray voltages and other maladies, it was important to have a second measure of the acceleration. The difference between the mechanical and the piezo-electric accelerometer readings was on the order of 10-15%. The gages and accelerometers were mounted on an aluminum cylinder, which was clamped to the drop table.

Some drop test data required more extensive examination than others. The expected data trace is a pulse. Unfortunately when the drop table was released from greater and greater heights, the accelerometer registered very large secondary pulses and spikes. Apparently these pulses represent the resonance of the fixture or the drop table. A felt pad was placed at the bottom of the fixture to reduce the resonance effects. This was moderately successful at the lower drop heights, but resonance effects again arose as the drop height increased. Attempts were made to increase the height above where the resonance occurred, but the anomalous secondary pulses and spikes continued. In general, drops that exhibited secondary accelerometer spikes that were of equal magnitude to the initial pulse were repeated.

4. RESULTS

The overall effect of the shock machine accelerations placed on the pressure gages seems to be nonexistent. As stated before, the acceleration versus time profile is not the same as that experienced by the gage in the gun, but the magnitudes are similar. The primary difference between the acceleration loadings is that pulse duration for the shock machine is much shorter (.5 ms as compared to 6.5 ms). Figures 4 - 5 are pressure gage output versus applied pressures taken after various shock loads. They indicate that there seems to be no effect on gage sensitivity for shock acceleration loadings to 15,000 g's. The pressure measurement results obtained after each drop were essentially the same, hence only one post-shock graph is displayed for each orientation. The gages seemed to hold up equally reliably whether loaded transversely or axially.

Only two gages were tested. The gages seemed to be insensitive to the shock loadings selected, and their calibration outputs were similar. It was felt the other Kulite gages would likely produce the same response, and hence, they were not tested. Figures 4 and 5 include Statham gage outputs as a reference.

5. CONCLUSIONS

The Kulite gages (model #XT-39-190-25A) demonstrated no loss in performance for short duration shock impulses with magnitudes near 15,000 g's. The gage appears insensitive to orientation (axial or transverse) under these loadings as well. Given the gages' performance, it is possible a seal failure caused the lack of data in the M864 tests.

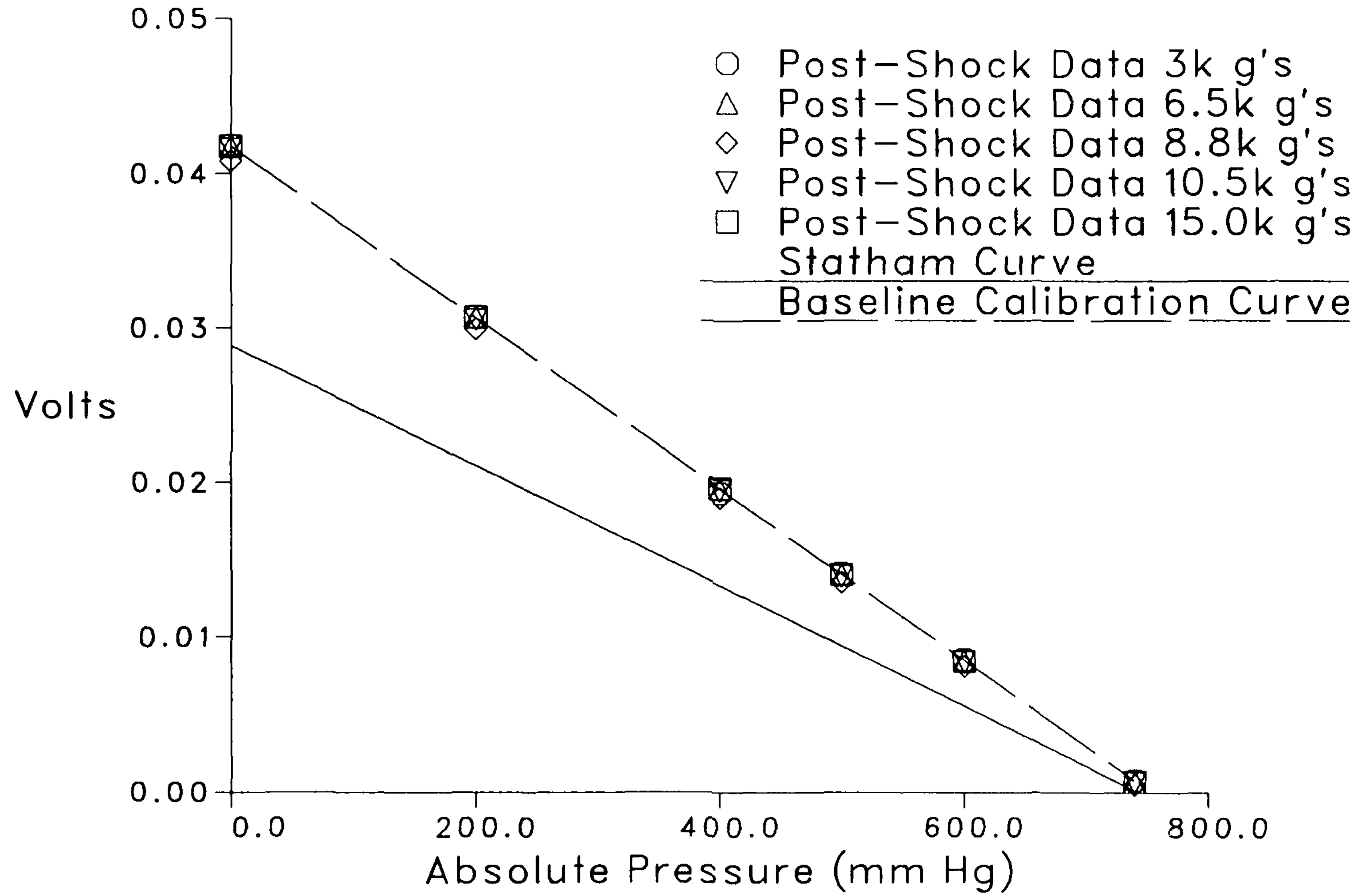

Figure 4. Pressure Gage F-11-85 Axial Post-Shock Calibration Data.

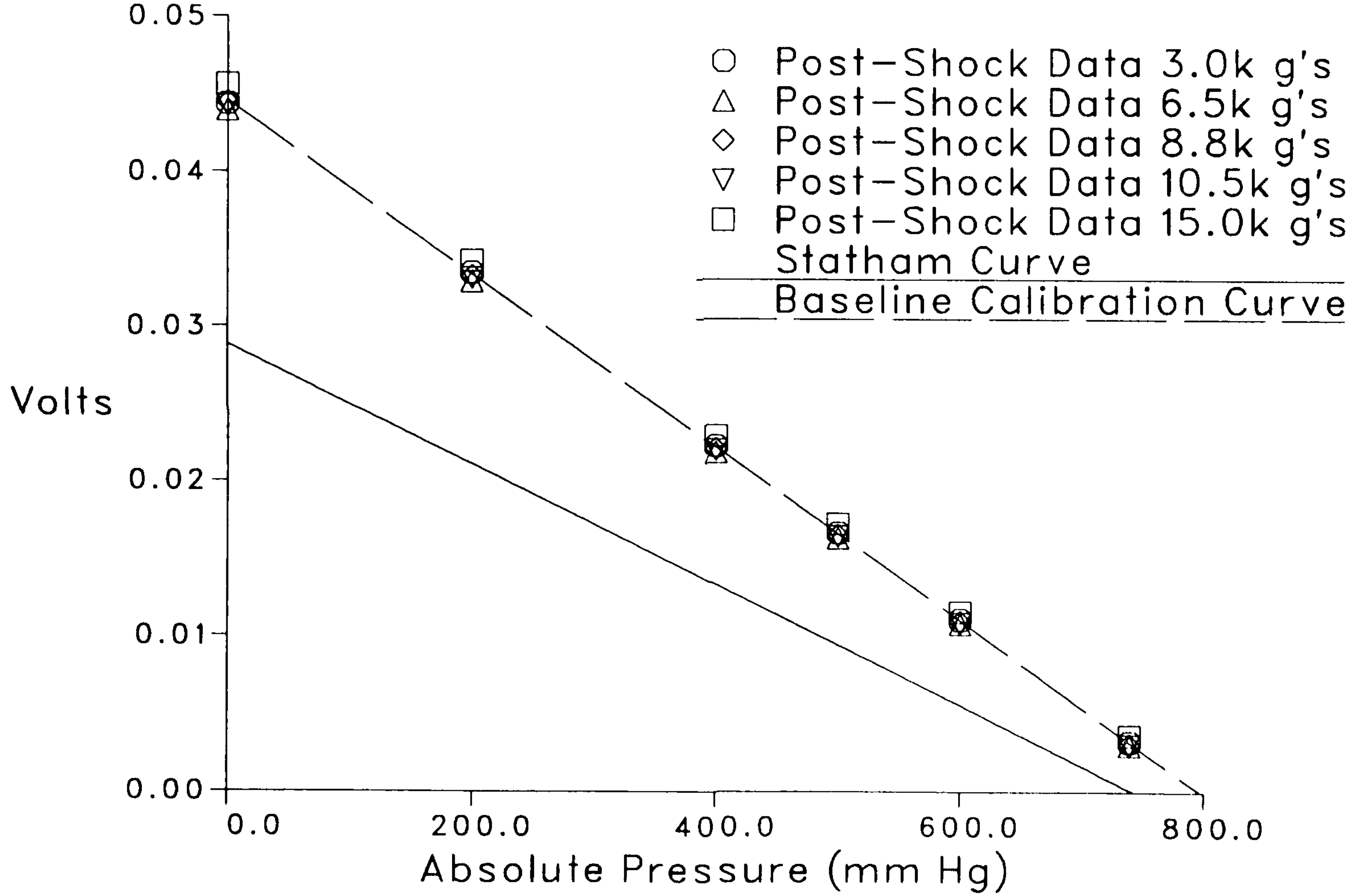

Figure 5. Pressure Gage F-11-81 Transverse Post-Shock Calibration Data.

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