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VHg IMPACT TEST SET
(Design Task Report)

10 SEPTEMBER 1968

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 68-158

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VHg IMPACT TEST SET
(Design Task Report)

Prepared by:

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Environment Simulation Division

ABSTRACT: Described is a portable tester capable of producing steel-on-steel impacts in the range of 100,000g with durations of from 40 to 45 microseconds. The 6-foot tall, 1700-pound machine has a payload capacity of 10 pounds and is operated with low pressure (100 psi) air. The tester is intended primarily for testing ordnance components associated with arming, fuzing and safing functions; tests are limited to secondary explosives weighing 10 grams or less.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND 20910

 10 September 1968

VHg IMPACT TEST SET
(Design Task Report)

The VHg Impact Test Set is one of three testers authorized for development under Office of Naval Material Task MAT 03L 204/F099 02 01 Problem 010. The work was undertaken in support of the development of ordnance components associated with arming, fuzing, and safing functions. The task was funded over Fiscal Years 1966, 1967, and 1968. This report completes the work on the VHg tester development. A second report is in preparation describing the work on the other two testers, a setback-spin simulator and a setback-spin test set.

The opinions expressed are those of the Environmental Evaluation Department.

The author gratefully acknowledges the contributions of Mr. J. W. Simkins of the Product Design Division who conceived the basic air gun and stopping device designs.

The identification of commercial materials implies no criticism or endorsement by the U. S. Naval Ordnance Laboratory.

E. F. SCHREITER
Captain, USN
Commander

V. M. Korty

V. M. KORTY
By direction

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ILLUSTRATIONS

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REFERENCES

(a) NOLR 1056, 2nd Rev, NOL Shock-Testing Facilities, 1 Mar 1956
(b) NOLTR 63-263, Explosive Component Test Adaptor for Drop Shock Tester Mk 7 Mod 0, 6 Dec 1963
(c) NAVORD OD 37092, Tester, Drop Shock, Mark 7 Mod 0, 1 Sep 1966

SAFETY SUMMARY

Listed below is every "warning" contained in this publication and the page on which the "warning" is located. All personnel involved in the operation and maintenance of this equipment must fully understand the "warnings" and the procedures by which the hazard is to be reduced or eliminated.

WARNINGS

No explosive component containing more than 10 grams of secondary explosives may be tested on the machine. . . .Page 1

Exhaust air from the chamber and disconnect the supply air line before mounting components or dismantling tester parts. . . . . .Page 3

Never connect supply air line to a pressure source higher than 100 psi. . . . . Page 4

INTRODUCTION

1. The VHg Impact Test Set described will be used in the laboratory in lieu of the NOL 40-foot Guided Drop Tester to perform impact safety tests in the range of 100,000g, on components containing up to 10 grams of secondary explosives and on ordnance arming and fuzing devices weighing less than 10 pounds. The tester is also being considered for impact testing at reduced levels in the manufacturer's plant to screen inert components for manufacturing defects. The 40-foot tester will continue to be used for safety tests on items weighing over 10 pounds and for other high impact test requirements.

2. The 40-foot Guided Drop Tester, reference (a), has been in use at the Naval Ordnance Laboratory since 1949 in the safety testing of explosive components and other ordnance devices. The tester, one of a kind, is an outdoor drop tower capable of producing impacts in the range of 100,000g*. More recently, some explosive components have been tested on the Mk 7 Mod 0 Drop Shock Tester using a special adaptor to produce steel-on-steel impacts in the shock range of the 40-foot tester. The 40-foot and Mk 7 testers and some of the problems associated with their use as high impact testers are described in reference (b). The Mk 7 tester was also used for many of the feasibility studies performed during the development of the VHg test set. The studies are summarized in Appendix A.

WARNING

No explosive component containing more than 10 GRAMS of secondary explosive will be tested on the machine.

DESCRIPTION

GENERAL

3. The VHg Impact Test Set, figure 1, is portable, weighs 1700 pounds, occupies less than 12 square feet of floor space and is 6 feet high. The machine has a 32-inch diameter base and is 16 inches in diameter overall above its base. Its principal parts are a low pressure air chamber (main housing), a safety shield, an air gun, a test carriage, a carriage stopping mechanism, a control panel and a seismic

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*Accelerations produced during impacts in which the carriage is released from maximum height are too severe to be measured directly with any commercially available shock transducer (see paragraph 16).

base. A single low pressure air line supplies compressed air to operate the tester. The test carriage has mounting room for items 10 inches high and up to 12 inches in diameter and contains eight 3/8-16 mounting holes equally spaced on a 4-inch diameter bolt circle. General specifications for the machine are presented in Table 1. Tester components are described in the following paragraphs and are numerically keyed to figure 2.

PRINCIPAL COMPONENTS

4. Chamber (Item 1). A 12-inch I.D. by 13-inch O.D. by 28-inch long cylinder is the machine main housing and air chamber. The chamber holds one cubic foot of air and has a design burst safety factor of 10. The chamber supports or houses all other components of the machine and is isolated from the 500-pound floor plate with isomode pads and from the accelerating components with soft rubber rings.

5. Safety Shield (Item 2). A one-quarter inch thick steel safety shield (clamshell) protects the operator should test components fail. The shield is designed to withstand the blast of 10 grams of secondary explosives; however, when explosive components are tested the tester should be fired remotely. The shield must be closed before appreciable pressure can be built up in the chamber. Two handle latches are used to open, close and lock the shield.

6. Air Gun (Item 3). Contained in the air chamber is a 5-inch bore, 25-inch long air gun, figure 2. The gun has an integral ball release mechanism and contains a 30-pound, high impact steel piston. Both the air gun and release mechanism are operated with compressed air. The piston (impact hammer) assembly is stopped after impact with the carriage by a flange at the end of the barrel. The piston stopping force is reduced by compressing air between a sliding ring on the piston and the release link.

7. Test Carriage (Item 4). The test carriage rests 2 inches above the muzzle of the air gun. It consists of a high impact steel anvil housed within an aluminum yoke. Soft rubber rings isolate the yoke from the severe impact received by the anvil. The carriage and yoke are guided by a pair of steel rods that extend downward into the stopping mechanism.

8. Stopping Mechanism (Item 5). The carriage is stopped after impact by a pair of hydraulic pistons attached to the end of the carriage guide rods. Each piston has four orifices. The pistons and rods fit inside a closed cylinder filled with ASA 60 weight motor oil. In operation the devices are similar to gun recoil mechanisms; the stopping action is produced by forcing the oil through the orifices from one side of the piston to the other. The stopping device pistons travel approximately 13 inches.

9. Control Panel (Item 6). The tester operation is controlled by two hand-lever valves and a pressure gage in a panel mounted waist high on the front of the tester. The left-hand lever is used to fill

and exhaust the gun air chamber and the gage indicates the pressure in the chamber. The right-hand lever is used to lock and unlock the release mechanism.

10. Base (Item 7). The tester rests on a 1-inch thick steel plate that is seismically isolated from a 3-inch thick floor plate with isomode pads. The pads are used to prevent excessive floor loading during firing of the air gun and impact of the test carriage. To protect the floor from impact should the machine jump, the floor plate rests on a 1½-inch thick, 45 durometer rubber mat.

OPERATING PRINCIPLE

11. The VHg tester operates on low pressure air up to a maximum of 100 psi; it requires no other source of power. Impact is produced by firing a 30-pound steel piston upward in a vertical air gun toward a test carriage resting just above the gun muzzle. The sequence of operation of the tester is demonstrated in figure 3. Shown in figure 3A is the test carriage in position for firing. The piston (not visible) is locked in the release and pressure is being built up in the chamber. Figure 3B shows the impact action. At impact the piston transmits its energy to the test carriage, accelerating it upward — at this time the piston stops momentarily. Shown in figure 3C is the follow-through and stopping action of the test carriage and piston. The carriage is stopped by the hydraulic pistons (paragraph 8), and the piston is stopped by a cushion of air that is compressed between the piston guide ring and link as the guide ring rams into the muzzle retaining ring (see figure 2). Carriage reverse acceleration is less than 200g. The piston and carriage return to their firing position under their own weight. Air-gun setback and piston impact loads are mitigated through "Isomode" padding and rubber matting at the base of the machine, and through rubber rings between the air gun and chamber interfaces.

OPERATING INSTRUCTIONS

MOUNTING TEST ITEM

WARNING

Exhaust the air from the tester chamber and disconnect the supply air line before mounting components or dismantling tester parts.

12. The tester is calibrated for payloads of 5 and 10 pounds. Test items, including fixtures, should be held to within one pound of these weights. One method suggested to maintain the calibrated weights is to use ballast rings with the same inside diameter and outside diameter as the carriage mounting rim (4.75 O.D. by 3.75 I.D.) and with 25/32-inch clearance holes on the same centers as those in the carriage (see paragraph 13). Steel ballast rings weigh approximately 2.4 pounds per inch of thickness.

13. Tester impacts are severe enough to fracture brittle or low strength bolts. Only bolts with high impact strength should be used to mount the test items. The rim of the carriage anvil contains eight 3/8-16 holes on a 4-inch diameter bolt circle. No less than eight bolts should be used to hold a test item. Stainless steel socket head bolts have proven the most durable for high impact testing. If the fixture is subjected to more than one impact, the bolts should be checked for tightness after each impact. Bolts should not be subjected to more than 10 impacts.

OPERATING PROCEDURE

14. The following procedure should be used to operate the tester:

a. Clean all surfaces around the test carriage to insure that no inflammable substances such as oil or grease are present, close and secure the safety shield, and connect the air line to the pressure source.

WARNING

Never connect the supply air line to a pressure source higher than 100 psi.

b. Push the right-hand lever from the "OFF" position to the "LOCK" position.

c. Pull the left-hand lever from the "OFF" position to the "PRESSURE" position until the desired pressure is built up (see fig. 3A) and return this lever to "OFF".

d. Pull the right-hand lever to the "RELEASE" position to fire the gun.

e. After the gun has been fired, push the left-hand lever to the exhaust position and allow the piston and carriage to return to their firing positions under their own weight — this takes approximately one minute.

SECURING THE TESTER

15. Even though the gun cannot be fired at operating pressure (80 psi) with the safety shield open, it is a good practice to disconnect the supply line to the gun after the chamber pressure has dropped to zero and before the shield is opened (the line has a quick-disconnect coupling at both ends). Also when the tester is secured, it is advisable to disconnect the supply line. Between tests, the chamber hand lever should be in the exhaust position and the release hand lever should be in the release position.

CALIBRATION

16. The term "calibration" as it applies to either the VHg Impact Test Set or the 40-foot Guided Drop Tester is used qualitatively.

Neither tester produces shocks that can be accurately or simply defined or that can be measured at the higher levels by conventional means. Both testers had to be calibrated using mechanical filters to protect the shock transducers from the lethal high frequency shocks produced and to achieve better definition of the fundamental parameters of shock. The acceleration calibration curves plotted are primarily intended to determine what degree of equivalence exists between the shocks produced by both the VHg and 40-foot testers; they are not intended to define accurately the forces acting on the items tested during impacts. Some shock measurements were made at low impact levels with unfiltered shock transducers to observe the complex high frequency content of the shocks produced.

17. The mechanical filter developed for use with shock transducers (see fig. B-1) has not been rigorously evaluated to check its response to a wide variety of shocks; however, it has been tested for response to relatively short impacts up to levels of 50,000g. In this shock range the filter performed satisfactorily (oscillograms of the impacts are shown in figure B-2). Further checks on mechanically filtered accelerometer accuracy were made by measuring impacts at lower levels with a velocity transducer and comparing the velocities with those obtained by graphically integrating the filtered accelerometer pulses. The measured velocities were also checked against computed values.

ACCELERATION

18. VHg accelerations were measured with Endevco 2225 M5 (100,000g) accelerometers. One accelerometer was mounted directly on the carriage; the other was potted in "Duxseal" in a separate housing (see Appendix B). Some risk was taken with the unfiltered accelerometer in the interest of obtaining as much information as possible about the characteristics of steel-on-steel impacts. Response oscillations in the accelerometer reached levels up to 160,000g before the accelerometer crystal fractured (see Table 2, item 1). Fracture occurred at a release pressure of 50 psi. Tester calibration curves plotted from the mechanically filtered accelerometer measurements are shown in figure 4. Oscillograms of the shocks are presented in figure B-3 and curves comparing filtered and unfiltered accelerometer measurements are presented in figure B-4. The 40-foot tester accelerations were measured with the same filtered accelerometer, but the unfiltered measurements were made with a Kistler 805A (100,000g) accelerometer. Calibration curves plotted from the filtered accelerometer measurements for both testers are compared in figure 5. Oscillograms of the 40-foot tester shocks are shown in figure B-5 and calibration measurements are plotted in figure B-6. Shock repeatability of the 40-foot tester was extremely poor; the curves plotted are of minimum and maximum accelerations measured.

VELOCITY

19. Velocity computations for the VHg tester are more complex than comparable computations for the free-fall, fixed-anvil, 40-foot tester. To check the computations, low pressure VHg impacts were

measured with a velocity transducer, and velocities at higher pressures were obtained by graphical integration of the filtered pulses (paragraph 17). Carriage impact velocity, or impact velocity change since the carriage is at rest before impact, was measured with a CEC transducer, type 4-102-001, 8 to 700 Hz. Measurements were made of impacts from 5- to 20-psi firing pressure or up to the dynamic limit of the transducer. To protect the transducer from the damaging high frequency shocks, it was mechanically filtered by mounting it in a special fixture between Duxseal pads — see figure B-1 for a description of the transducer filter. Sample oscillograms of the velocity measurements are presented in figure B-7. Calibration curves plotted from the measurements and from graphical integrations are presented in figure 6.

20. The velocity of the VHg tester air gun piston was computed using a computer program written for NOL air guns and air launchers. Corresponding test carriage velocities were computed using the conservation of momentum method. A sample calculation is presented in Appendix B. The velocities computed were within 11 percent of those obtained from shock measurements, figure 6.

21. The 40-foot Guided Drop Tester was not calibrated for velocity; shock repeatability was so poor that the effort seemed pointless. However, impact velocity change at the 40-foot drop height was obtained by graphically integrating the filtered accelerometer shock pulses. These ranged from about 60 to 70 fps.

PERFORMANCE

SHOCK

22. The design objectives of the VHg impact tester have been met. Impact velocity change for payloads of 5 and 10 pounds, and for operating pressures of 65 and 80 psi, respectively, is in the maximum range of that of the 40-foot Guided Drop Tester and fundamental pulse parameters of both testers are close enough considering the fact that the shock repeatability of the 40-foot tester is poor. Steel-on-steel impact shock repeatability has been significantly improved in the VHg tester because the impacting parts are more precisely guided.

23. It is not possible to determine whether there are any significant differences in the high frequency shocks produced by the 40-foot drop tester and the VHg tester. To maintain a test set (portable) configuration, a trade-off had to be made in the VHg carriage design; the weight and impacting surface area of the carriage had to be reduced to about one-half that of the lightest 40-foot Drop Tester carriage. Whether this compromise may make some difference from the standpoint of damage potential will have to be determined by comparing the results of tests on a wide variety of components. Damage equivalence tests are described in paragraph 25. The VHg tester has enough additional energy capability (see Table 1) to increase the impact levels should this prove necessary.

TESTER RUGGEDNESS AND OPERABILITY

24. Machine ruggedness has been considerably increased over the 40-foot Guided Drop Tester and the Mk 7 by isolating all but the piston and test carriage from the very high impacts and by providing better guidance for the moving parts. Despite the severe shock environment there have been no failures in any of the machine parts after more than 200 tests. The machine is safe and easy to operate. Its most significant advantage over drop testers is the ease with which instrumentation can be performed. The suitability of the VHg tester as a shock test set for laboratory and factory use is enhanced by the fact that it is portable, it consists of few moving parts, and requires no power except low pressure air for its operation.

DAMAGE EQUIVALENCE

25. Some correlative studies to establish damage equivalence between the VHg and the 40-foot testers have been run on a limited number of samples and show very encouraging results. Table 2 describes the test items and lists the damage which duplicates that of similar items tested on the 40-foot Guided Drop Tester. More correlative tests are planned to broaden the investigation and will be reported when sufficient data have been obtained. The improved shock repeatability of the VHg tester is considered an important factor in maintaining damage equivalence from test to test.

CONCLUDING COMMENTS

26. The VHg tester, like the 40-foot Guided Drop Tester, is intended to produce a shock severe enough to qualify ordnance arming, fuzing and safing components — the shock is considered more severe than any shock which may occur in ordnance accidentally dropped 40 feet onto any hard surface. It is important to note that both testers produce shocks too severe to be monitored accurately with existing accelerometers and too complex for the stresses to be determined accurately in the test components during impact. Neither tester duplicates or simulates the shock effects or any particular accidental drop situation.

27. Despite the difficulties encountered in controlling very high impact shocks and the unorthodox means employed to measure and compare the shocks produced by both testers, enough information has been obtained to demonstrate that the VHg adequately meets NOL requirements for qualification tests on the above-mentioned components. Accordingly, the tester is recommended for use in NOL programs. It is also recommended that the feasibility of specifying the VHg tester for use in screening components for manufacturing defects be studied in the interest of releasing the tester for general use by other laboratories and by contractors.

28. This design task report constitutes a disclosure of the VHg prototype tester only. Authorization of the tester for general use will require authenticated drawings and a formal manual on tester operation, maintenance and safety. No changes in the VHg prototype

design are contemplated at this time; however, if the tester is authorized for general use, it is recommended that the design be updated in accordance with Navy test set requirements.

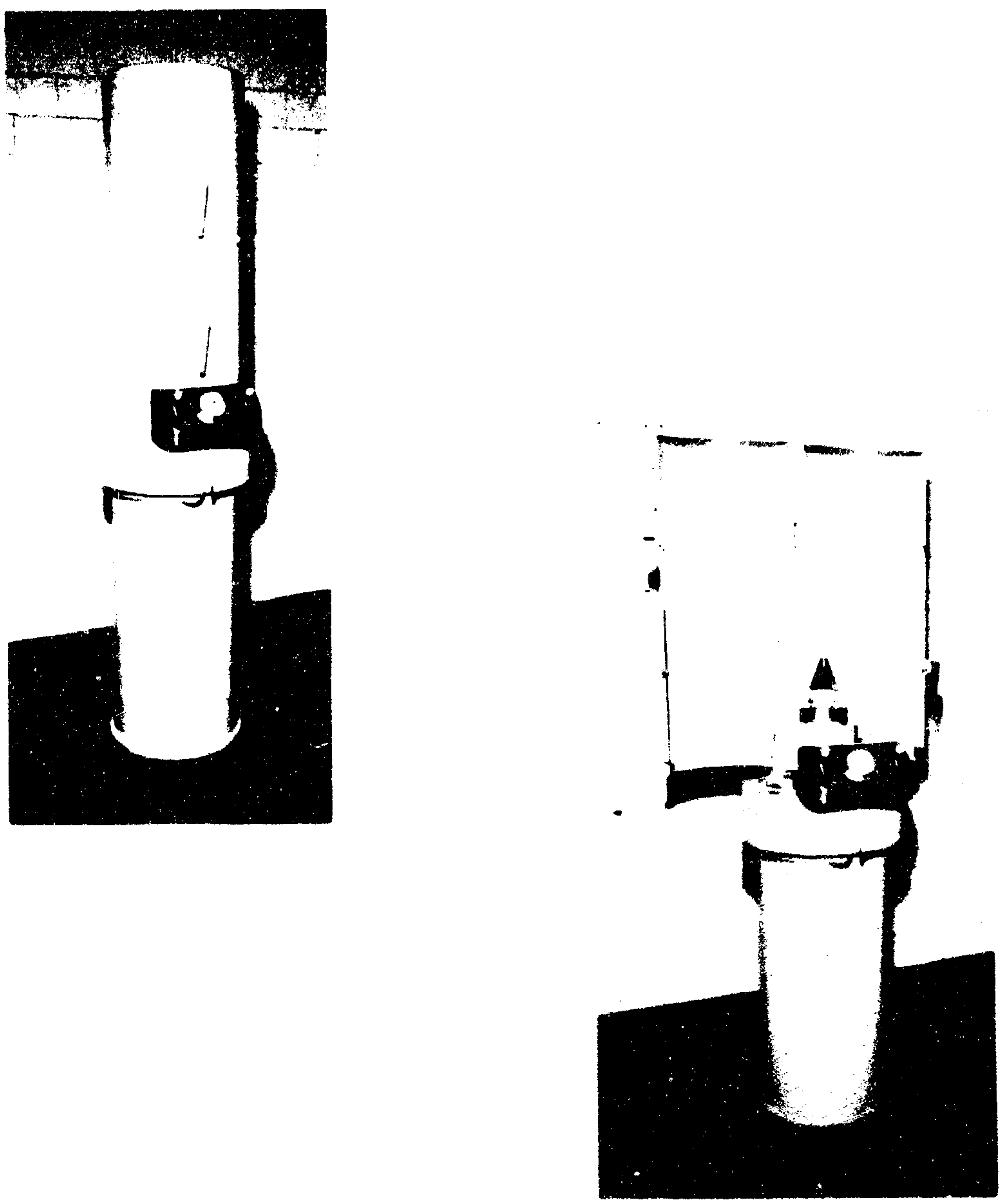


FIG. 1. VHq IMPACT TEST SET

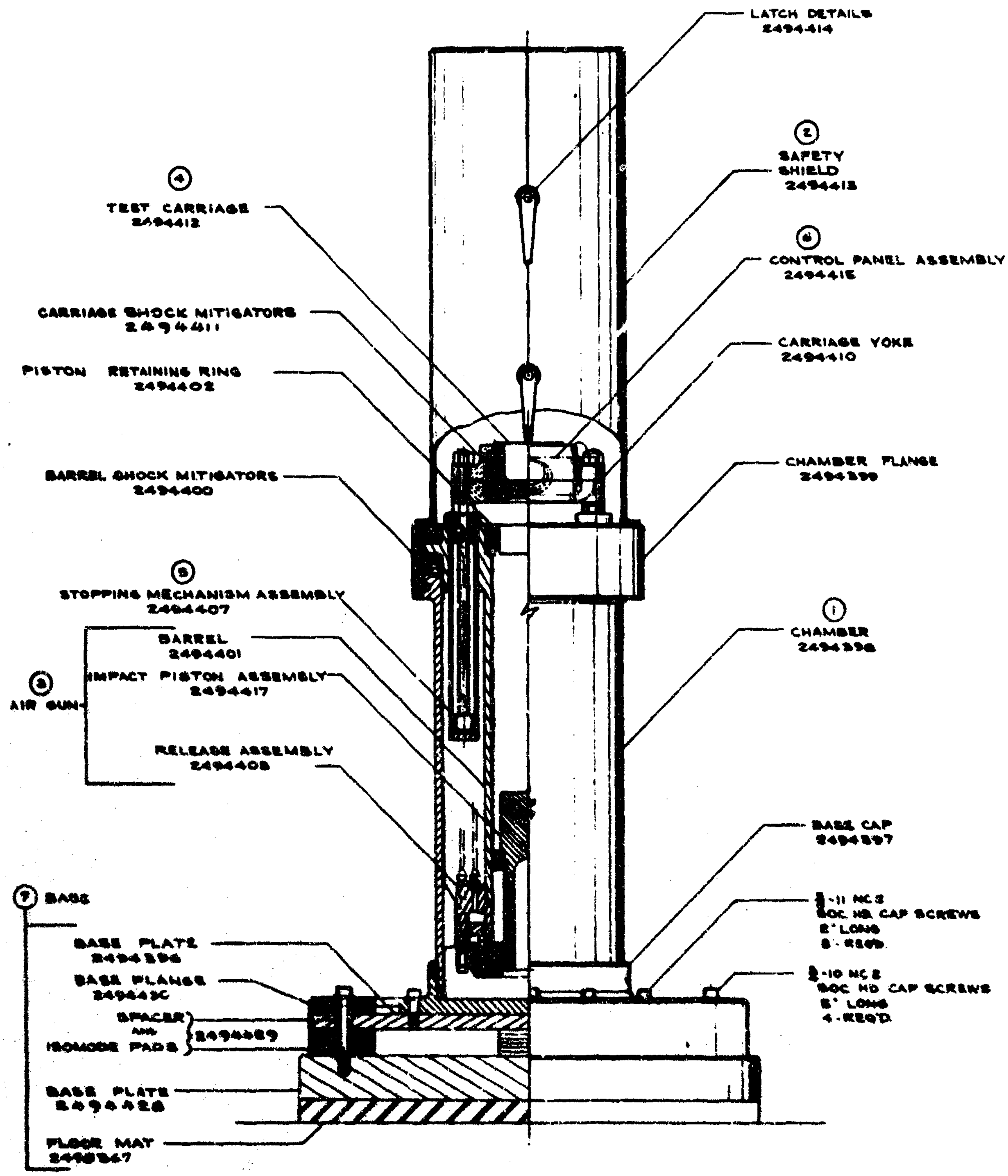
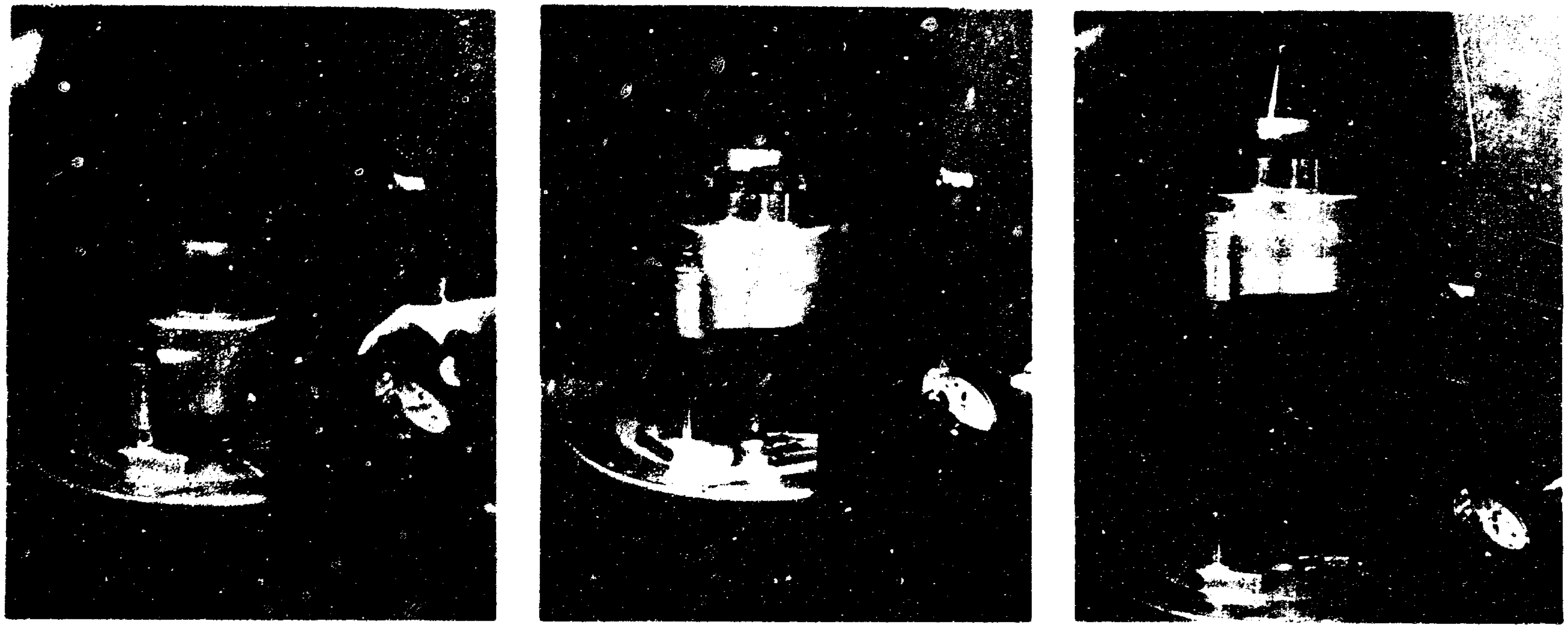


FIG. 2. VHg IMPACT TEST SET COMPONENTS



A. Carriage in Ready-to-Fire Position

B. Carriage and Piston Shortly After Impact

C. Carriage and Piston Decelerating

FIG. 3. SEQUENCE OF OPERATION

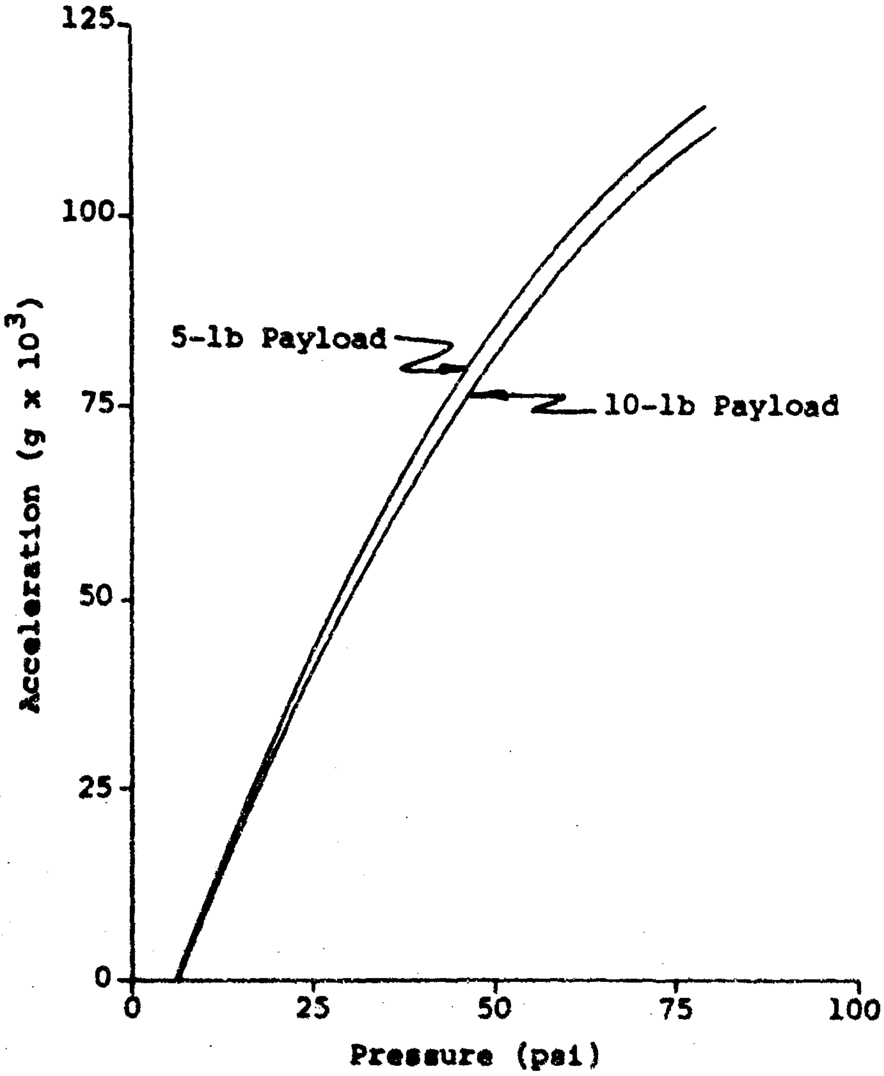


FIG. 4. ACCELERATION CALIBRATION CURVES

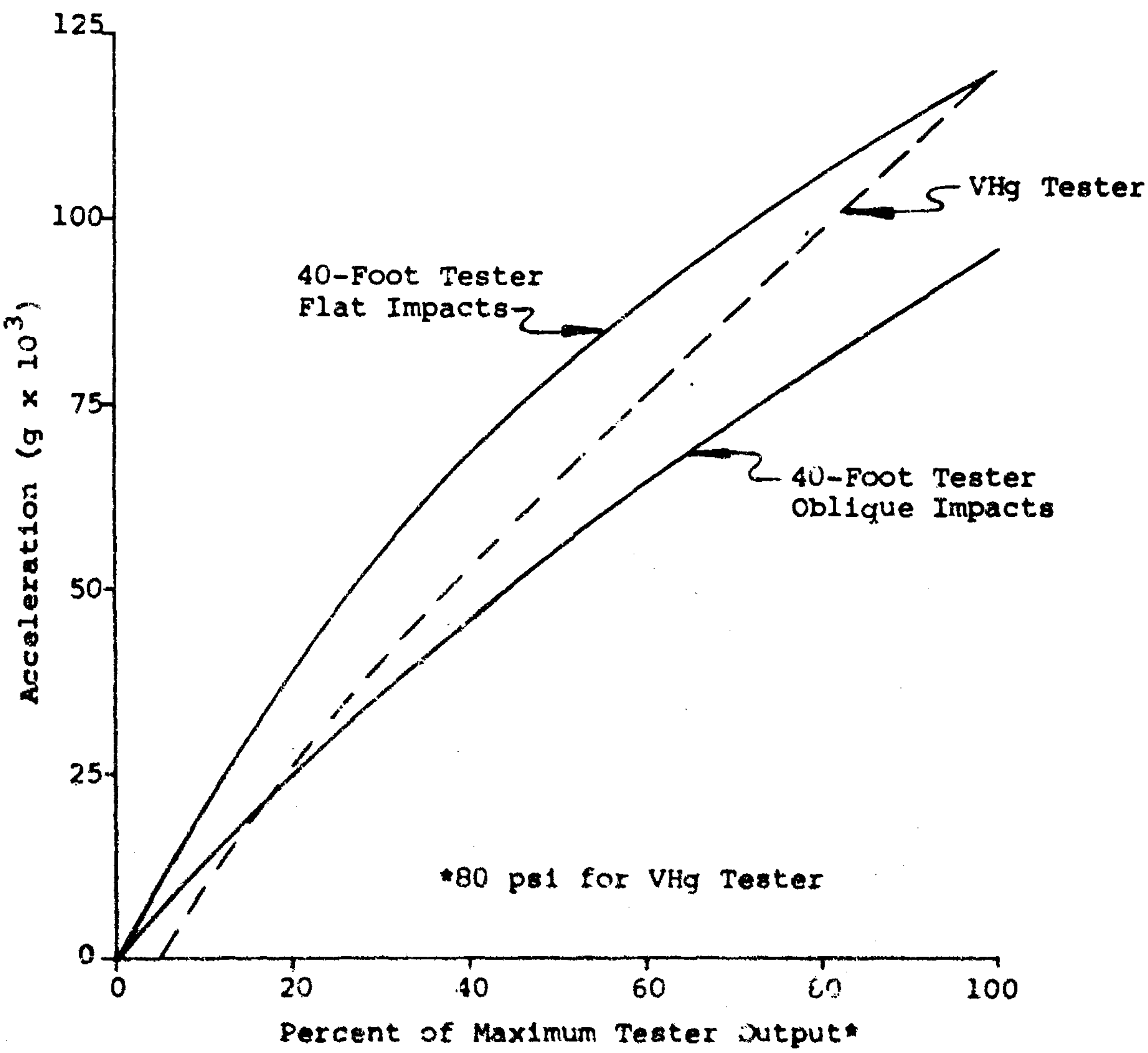


FIG. 5. COMPARISON OF VHg AND 40-FOOT TESTER CALIBRATIONS

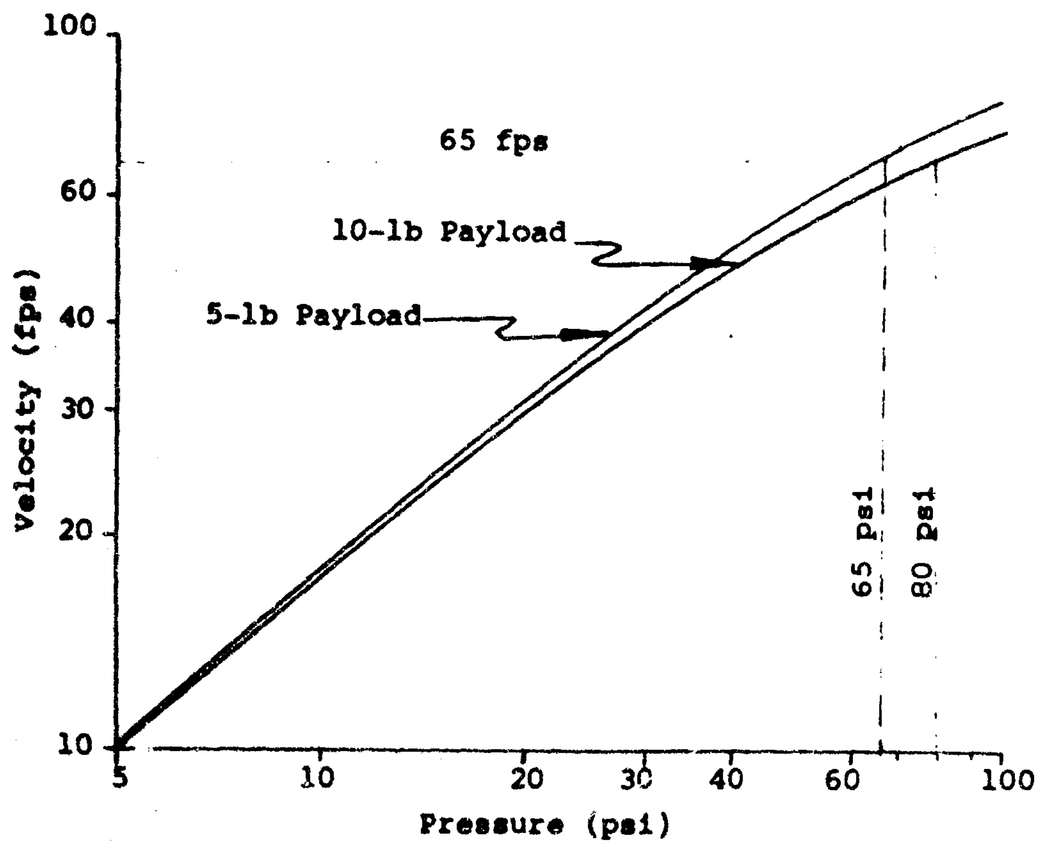


FIG. 6. VHg VELOCITY CALIBRATION CURVES

Table 1

GENERAL SPECIFICATIONS

Overall Height	6 feet
Upper Structure Diameter	13 inches
Base Diameter	32 inches
Power (Low Pressure Air)	100 psi
Operating Pressure	80 psi
Air Gun Chamber Volume	1 cu ft
Air Gun Piston Stroke (Nominal)	2 feet
Maximum Output Energy (100 psi)	3500 ft-lb
Operating Output Energy (80 psi)	3000 ft-lb
Test Carriage Tare Weight	17 lb
Payload Capacity	10 lb
Nominal Shock Characteristics (80 psi and 10-lb payload)	
Peak Acceleration	100,000g
Impact Duration	40 to 45 μsec
Impact Velocity Change	65 fps
Carriage Reverse Acceleration (Peak)	200g

Table 2

DAMAGE EQUIVALENCE DATA
(VHg, 65 psi, 5-lb ±1 lb Payload vs 40-foot Tester, 40-ft Drop)

Test Item	VHg Tester		40-foot Tester	
	No. of Items	Damage or Actuation	No. of Items	Damage or Actuation
Endevco 2225M5 100,000g Transducer 4-1-68	1	Crystal fractured	1	Same
Mk 51 Mod 0 Primers 5-6-68	12	One out of 12 fired	20	One out of 20 fired
Mk 87 Mod 0 Battery 5-20-68	1	a. Bottom of case bulged 1/16". b. Connector potting pulverized. c. Both gear trains jammed, making system inoperative. d. Case compressed about 1/8" and bulged near the bottom about 1/32". The device failed safe. e. All fixture bolts were loose after impact.	3	Same
Mod 3 Copper-Ball Accelerometer 5-24-68	2	a. Take-up wedge guide pins bent. b. Accelerometers were loose after impact.	2	Same
NOL Zero-g Device 6-7-68	1	a. Two connectors and two ball sockets (cones) separated; one of the sockets fractured into 3 pieces. b. Housing slipped 0".020 on its 6-32 bolts at the connector end and 0".060 at the timer end. c. Housing bowed about 0".010 over its 4".0 unsupported length. d. The device was inoperable and failed safe.	1	Same, except only one socket separated.
Mod 10 Copper-Ball Accelerometer 7-22-68	1	Glass inertia weight (0.2-gram) fractured	1	Same

Appendix A

SUMMARY OF FEASIBILITY STUDIES

A-1. Feasibility studies relating to the design of the VHg Impact Test Set were run on a Mk 7 Mod 0 Drop Shock Tester, reference (c). The Mk 7 Mod 0 is a portable shock test set used for Class A tests of mine components weighing less than 25 pounds. Its maximum shock range is 800g. Several modifications to the tester were necessary to safely conduct high impact tests and to evaluate critical component designs such as the tester anvil, carriage and propulsion system. Figure A-1 shows the Mk 7 tester and identifies the items modified.

A-2. The significant positive results of the study were as follows:

a. Shock repeatability was considerably improved over an earlier version of the Mk 7 high impact tester from ±35 percent to less than ±15 percent. This was done by replacing the wire-rope cable guides with rigid guide rods, by directly attaching the shock cord propulsion system to the carriage (in lieu of using tow cables) and by extending the length of the carriage frame. True alignment of the carriage frame structure still remained a problem because of the severe impacts. This problem in particular led to the adoption of the present VHg Impact Test Set design — the VHg has no overhead carriage frame.

b. Use of soft rubber isolators between the carriage frame and the carriage anvil nearly doubled the life of most of the carriage parts.

c. Attaching the shock cord directly between the carriage and base of the tester (see paragraph A-2a) eliminated propulsion system failures; tow cable failures in the Mk 7 occurred at between 50 and 75 drops.

d. Use of a dynamically balanced electrical release greatly reduced transverse kickback of the carriage and produced flatter impacts. The release also eliminated the hangfire problem associated with the Mk 7 hydraulic release mechanism.

A-3. The first design which evolved from the Mk 7 studies was in principle a ruggedized version of the Mk 7 Mod 0 Drop Shock Tester described in reference (b). The salient design features, illustrated in figure A-2, were a hydraulic lift, a clamshell safety shield, an open-face test carriage (no over-carriage frame) and direct shock-cord propulsion. Even though the Mk 7 design was superseded by that of the VHg tester, it is considered a feasible alternate design for high impact testing and for tests at lower levels and where shock pads are used to tailor the shock parameters.

A-4. The Mk 7 tester used in the feasibility studies continues to be used for high impact testing, but at lower shock levels to reduce attrition on carriage components. Its shock range is limited to impacts no higher than 50,000g; this is more than six times the design level for the original Mk 7 tester. The test carriage impacting surface has a 100-inch radius and impacts are against deformable and expendable shock pads placed on the seismic anvil.

No.	Item
1.	Electrical Release
2.	Rigid Guide Rods
3.	Scale and Cut-off Switch
4.	High-Impact Test Carriage
5.	3/4-Dia. Shock Cord
6.	Anvil Extension
7.	Vacuum Chuck
8.	Safety Shield (open)
9.	Safety Shield (closed)

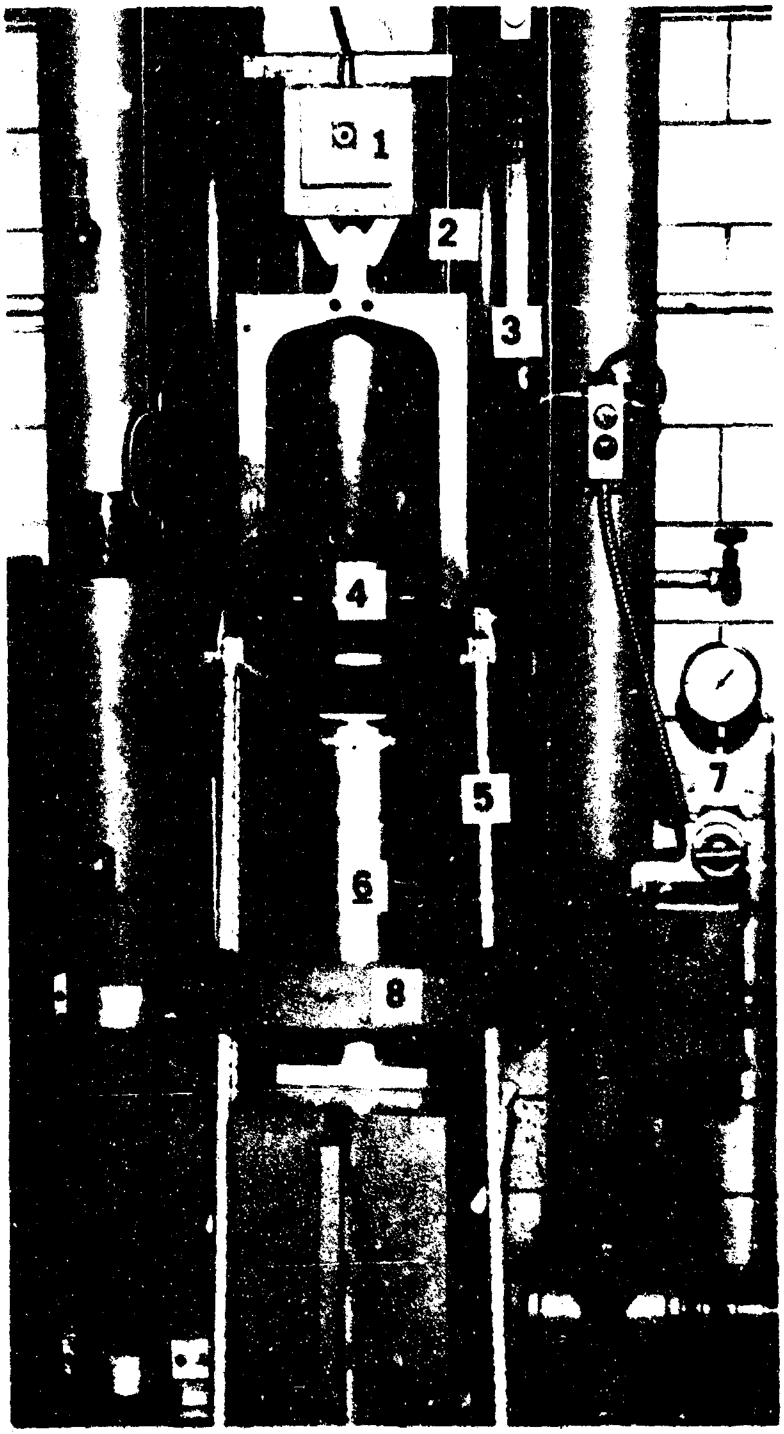


FIG. A-1. MK 7 MODIFICATIONS FOR FEASIBILITY STUDIES

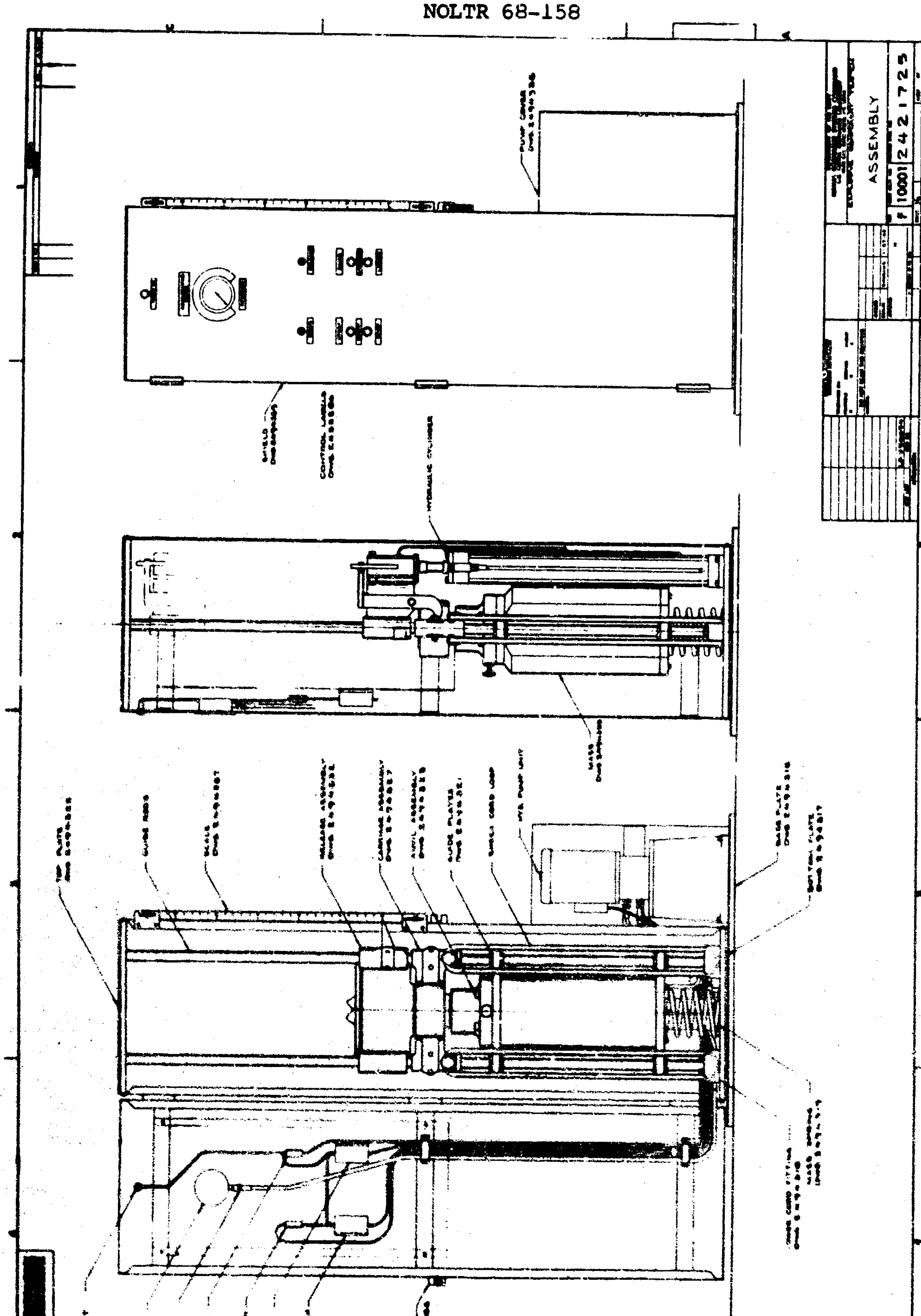


FIG. A-2. ALTERNATE VHg IMPACT TEST SET DESIGN

Appendix B

CALIBRATION SHOCK DATA AND COMPUTATIONS

MECHANICAL FILTERS

B-1. VHg tester impacts at levels of over 50-psi firing pressure are lethal to mechanically unfiltered shock transducers and impacts at levels over 20 psi are lethal to commercially available velocity transducers. NOL 40-foot Drop Tester impacts at levels of over 20 feet are similarly lethal to unfiltered shock transducers. The high frequency components of shock are the source of transducer damage. To protect against these shocks mechanical filters were used with the calibrating transducers; figure B-1 shows schematics of the two types of filters. Because of the damage risk involved, use of the unfiltered transducer in the 40-foot tester calibration was limited to drops below 10 feet. The response of the mechanically filtered accelerometer to short duration impacts was checked by subjecting it to shocks ranging from 3000g and 0.6 ms duration to 50,000g and 50 μsec duration. Oscillograms of the shocks are shown in figure B-2. For the purpose of comparing the fundamental parameters of the shocks produced by the two testers, the filter performed satisfactorily.

CALIBRATION MEASUREMENTS

B-2. Continuous measurements of VHg impact accelerations were made at pressures from 15 psi to 70 psi. Up to levels of 50 psi both filtered and unfiltered accelerometers were used to monitor the shocks; above 50 psi only the filtered accelerometer was used. Sample oscillograms of the VHg tester shocks are presented in figure B-3 and measurements are plotted in figure B-4. Similar measurements were made of 40-foot Guided Drop Tester impacts to establish the degree of correlation between shocks produced by both testers; sample oscillographs of the shocks are shown in figure B-5 and filtered accelerometer measurements are plotted in figure B-6. Calibrations of both testers are compared in figure 5 of the report and discussed in paragraph 18.

B-3. Impact velocity of the VHg tester carriage was also measured continuously with a 0.3 critically damped velocity transducer at firing pressures from 5 psi to 20 psi -- impacts above this level were beyond the dynamic range of the transducer. Pulses at pressures of 10 psi and higher had to be faired; high frequency oscillation obscured the fundamental pulse. Sample velocity oscillograms are shown in figure B-7. Curves plotted from the velocity measured and velocities obtained by pulse integration and computation are compared in figure B-8. Computed velocities are discussed in paragraph B-4.

COMPUTATIONS

B-4. Using a computer program written for NOL air guns and launchers, an empirical relationship for the air gun piston was derived. This equation is

$$v_p = \sqrt{61.1\ P}$$

A sample computation of test carriage velocity (impact velocity change) for a release pressure of 70 psi and a payload of 10 pounds is presented below.

NOMENCLATURE

P - Pressure in pounds per square inch

W_c - Weight of carriage anvil (plus payload) in pounds

W_p - Weight of impact piston in pounds

v_c - Initial carriage velocity in feet per second

v_p - Initial piston velocity in feet per second

v_c' - Carriage velocity after impact in feet per second

v_p' - Piston velocity after impact in feet per second

e - Impact coefficient (0.7 for Elastuf 44)

Using the conservation of momentum and elastic impact method

$$W_p\ v_p + W_c\ v_c = W_p\ v_p' + W_c\ v_c' \qquad (1)$$

and

$$e = \frac{v_c' - v_p'}{v_p - v_c} \qquad (2)$$

Since the initial carriage velocity is zero, equations (1) and (2) reduce to

$$W_p\ v_p = W_p\ v_p' + W_c\ v_c' \qquad (3)$$

$$e\ v_p = -v_p' + v_c' \qquad (4)$$

$$v_p = \sqrt{61.1 \times 70} = 65.5 \text{ fps}$$

Solving (3) and (4) simultaneously

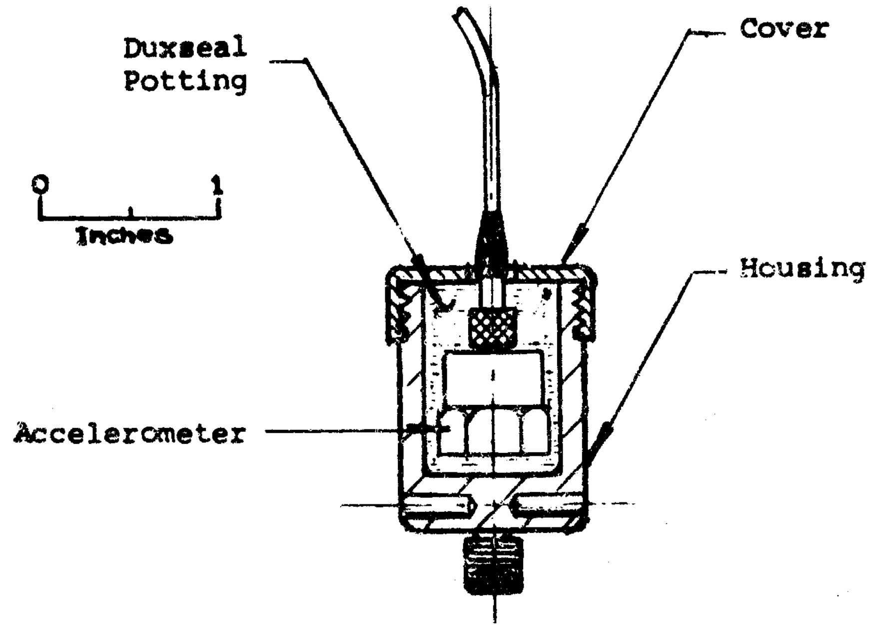
$$30 \times 65.5 = 30\, v_p' + 27\, v_c'$$

$$30 \times .7 \times 65.5 = -30\, v_p' + 30\, v_c'$$

$$3341 = 57\, v_c'$$

$$v_c' = 58.7 \text{ fps}$$

B-5. The computed values of velocity are compared with velocities obtained by measurements and by shock pulse integration in figure B-8. The computed values are about 11 percent low. Considering the unconventional methods used to measure the VHg tester shock and to some extent the errors expected in the computations, the calibrations are closer than expected.



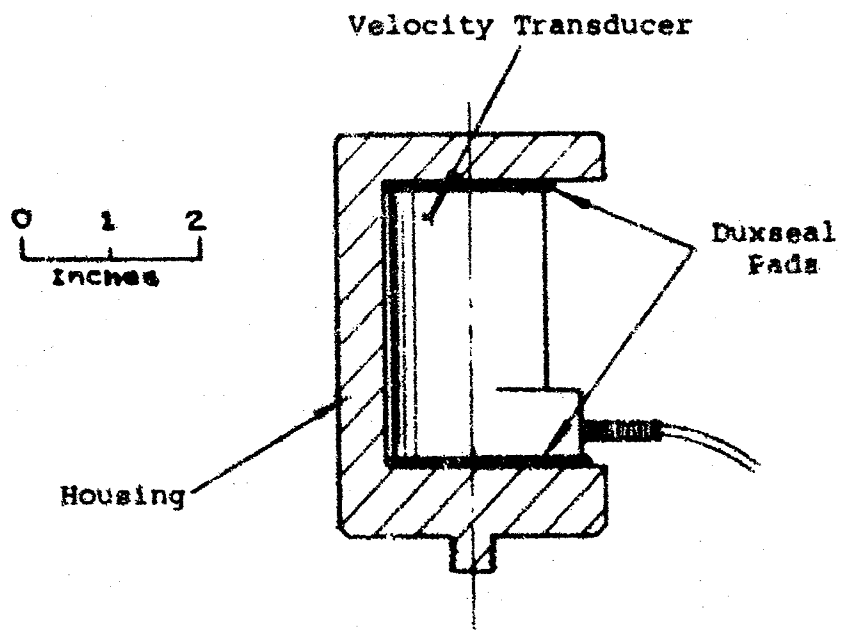
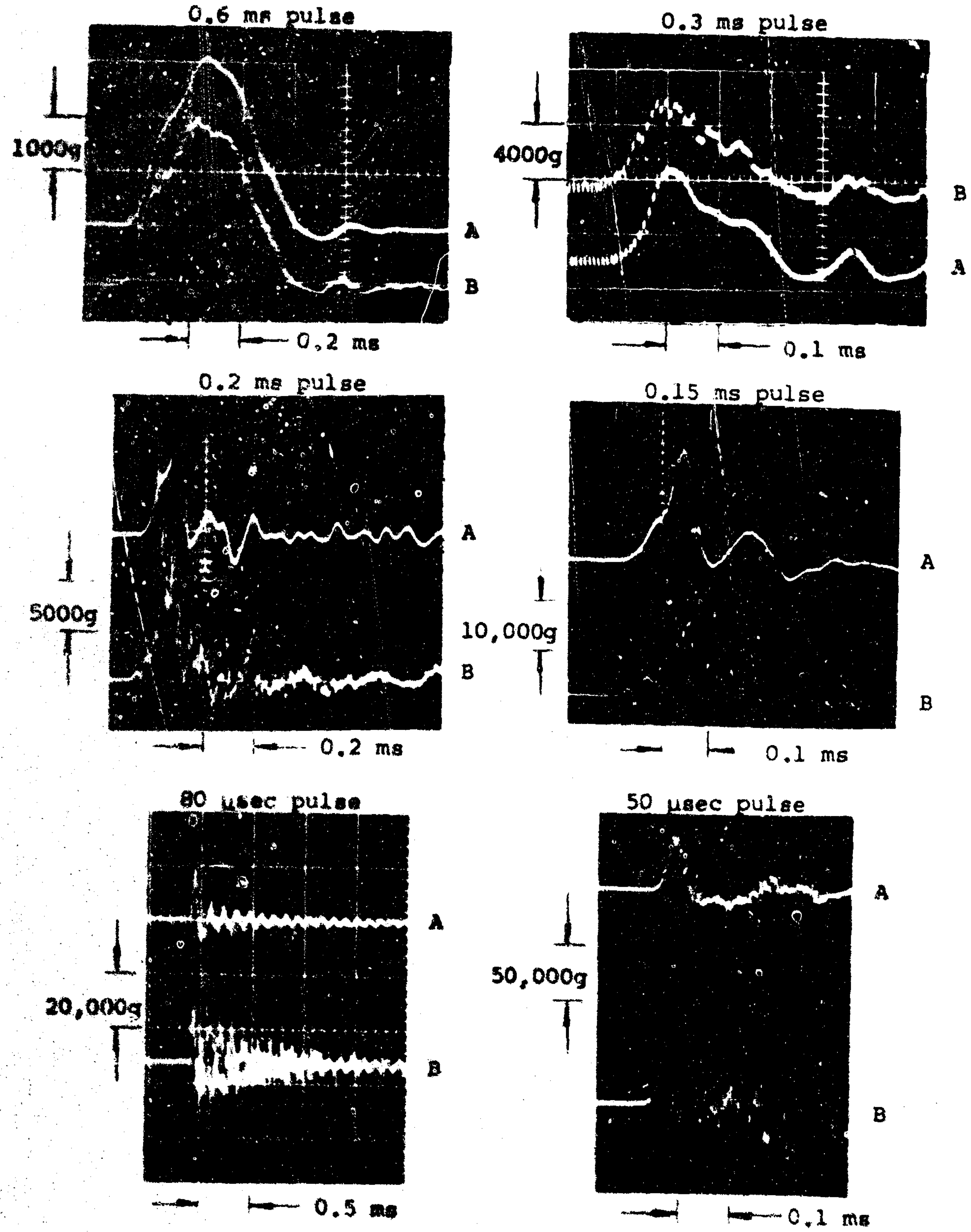
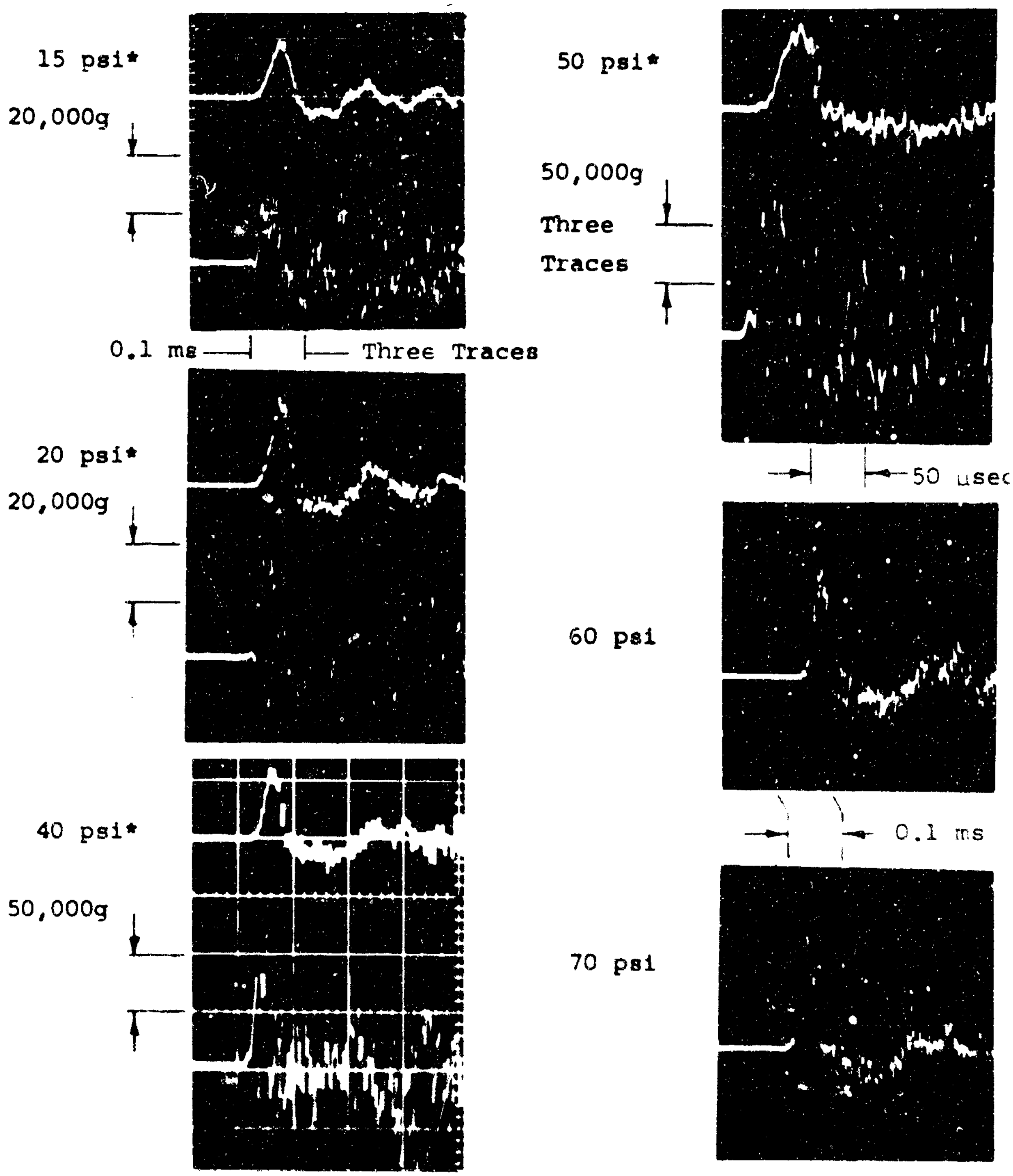


FIG. B-1. MECHANICAL FILTERS FOR ACCELEROMETER AND VELOCITY TRANSDUCER



A - Filtered B - Unfiltered

FIG. B-2. MECHANICAL FILTER RESPONSE TO SHORT IMPACTS



*Top Trace: Mechanically Filtered Accelerometer
Bottom Trace: Unfiltered Accelerometer

FIG. B-3. SAMPLE ACCELERATION OSCILLOGRAMS — VHg TESTER (10-lb Payload)

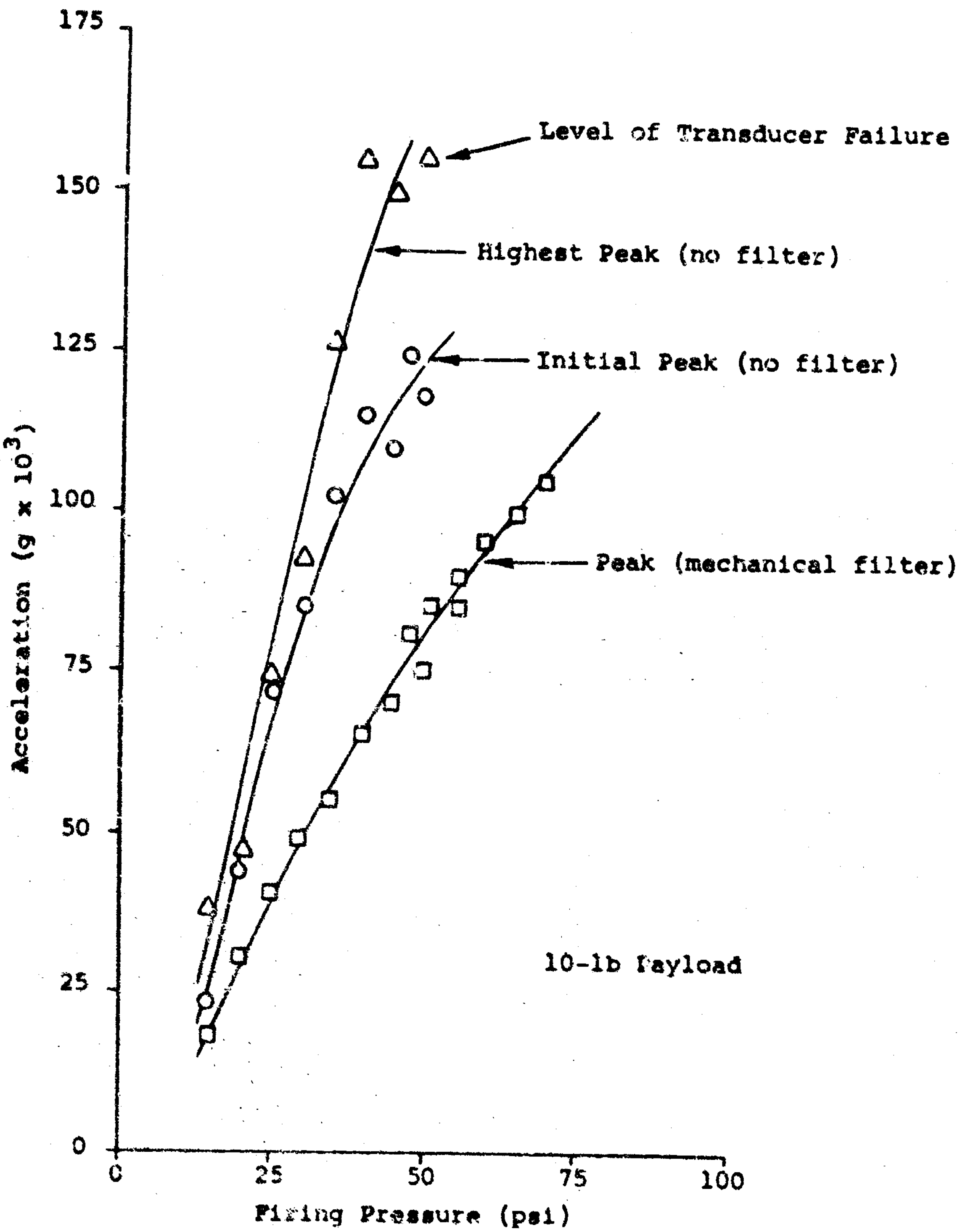
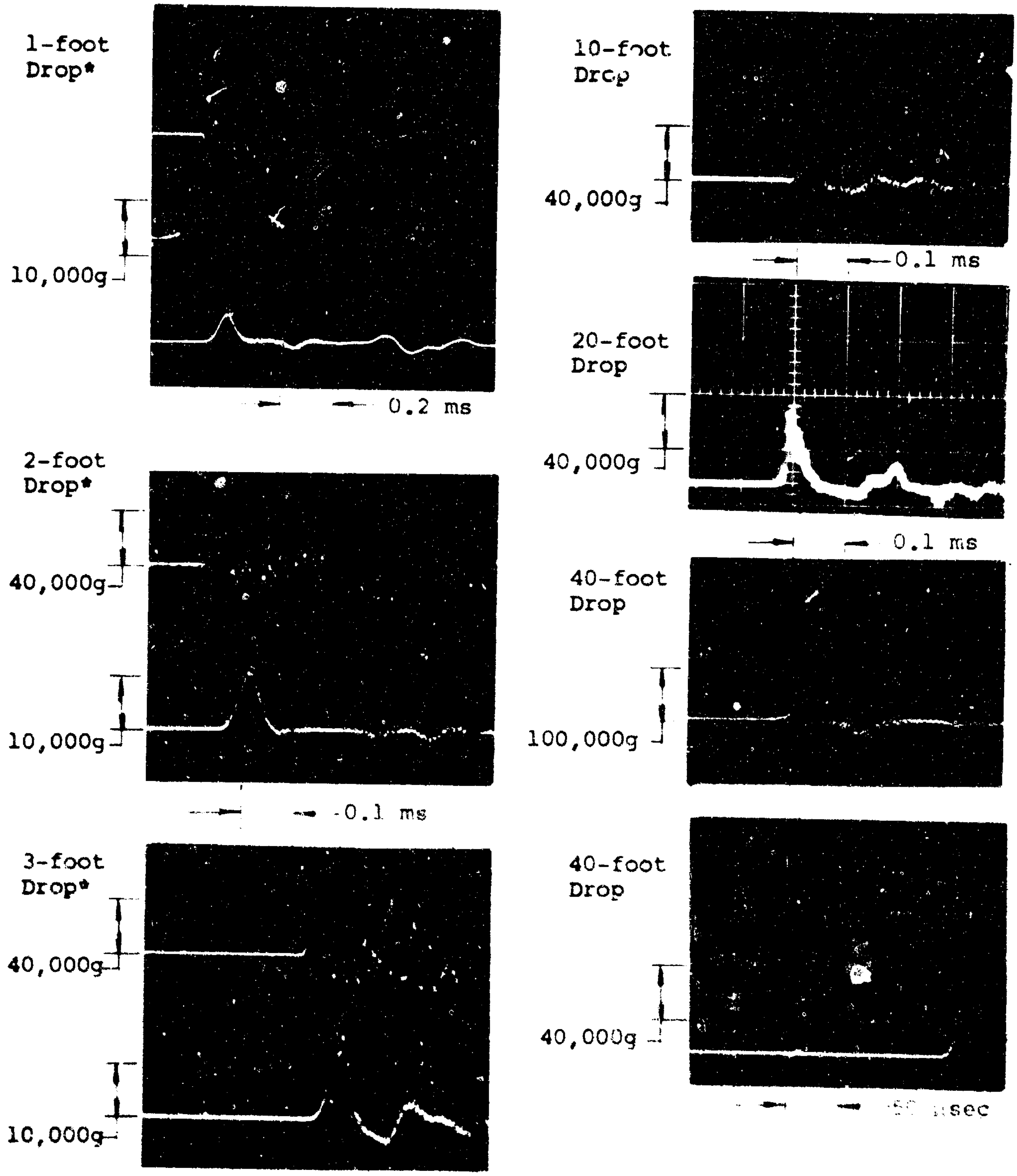


FIG. B-4. COMPARISON OF ACCELERATION CALIBRATION MEASUREMENTS USING FILTERED AND UNFILTERED ACCELEROMETERS



*Top Trace: Unfiltered accelerometer
Bottom Trace: Mechanically filtered accelerometer

FIG. B-5. SAMPLE ACCELERATION OSCILLOGRAMS — 40-FOOT TESTER

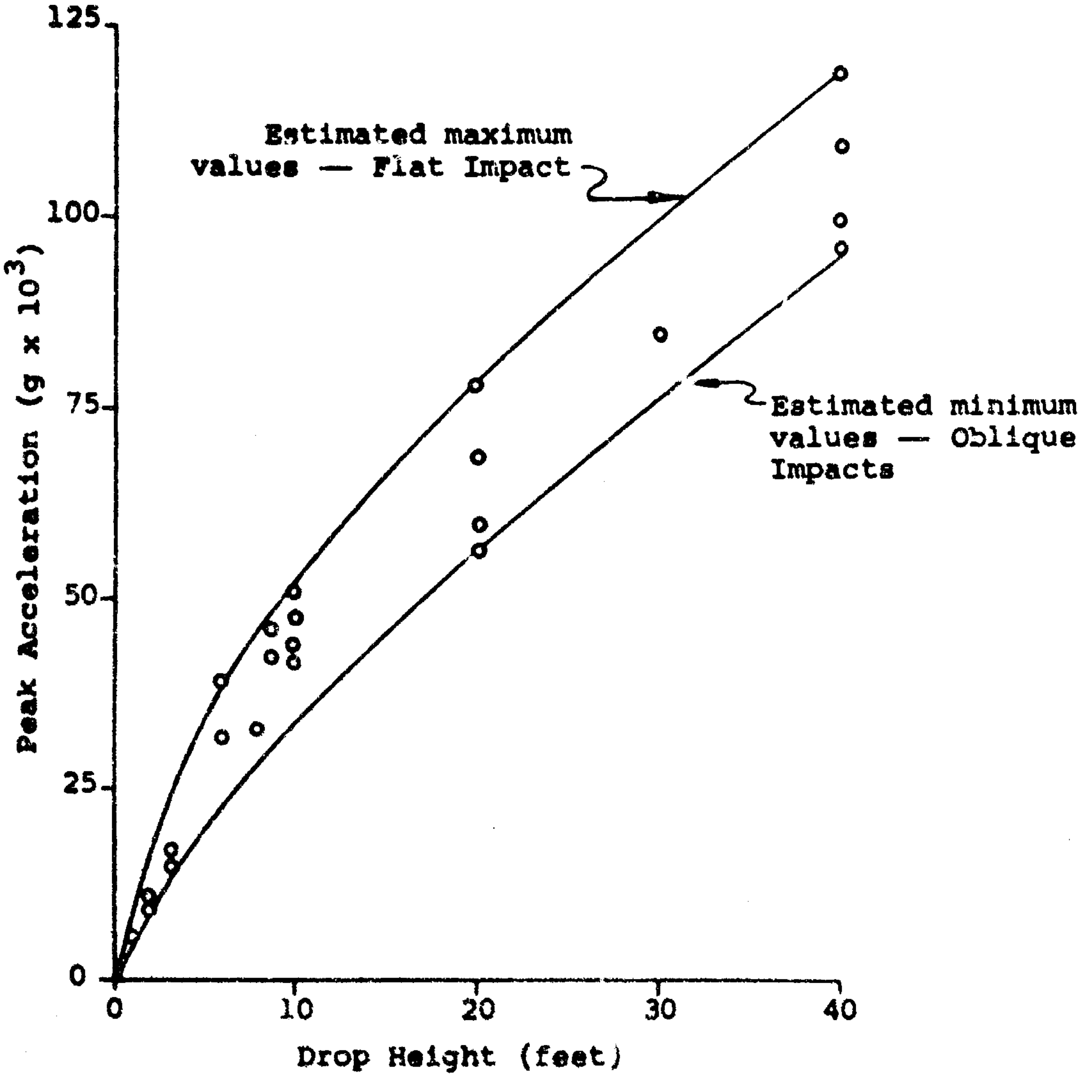


FIG. B-6. 40-FOOT GUIDED DROP TESTER CALIBRATION CURVE

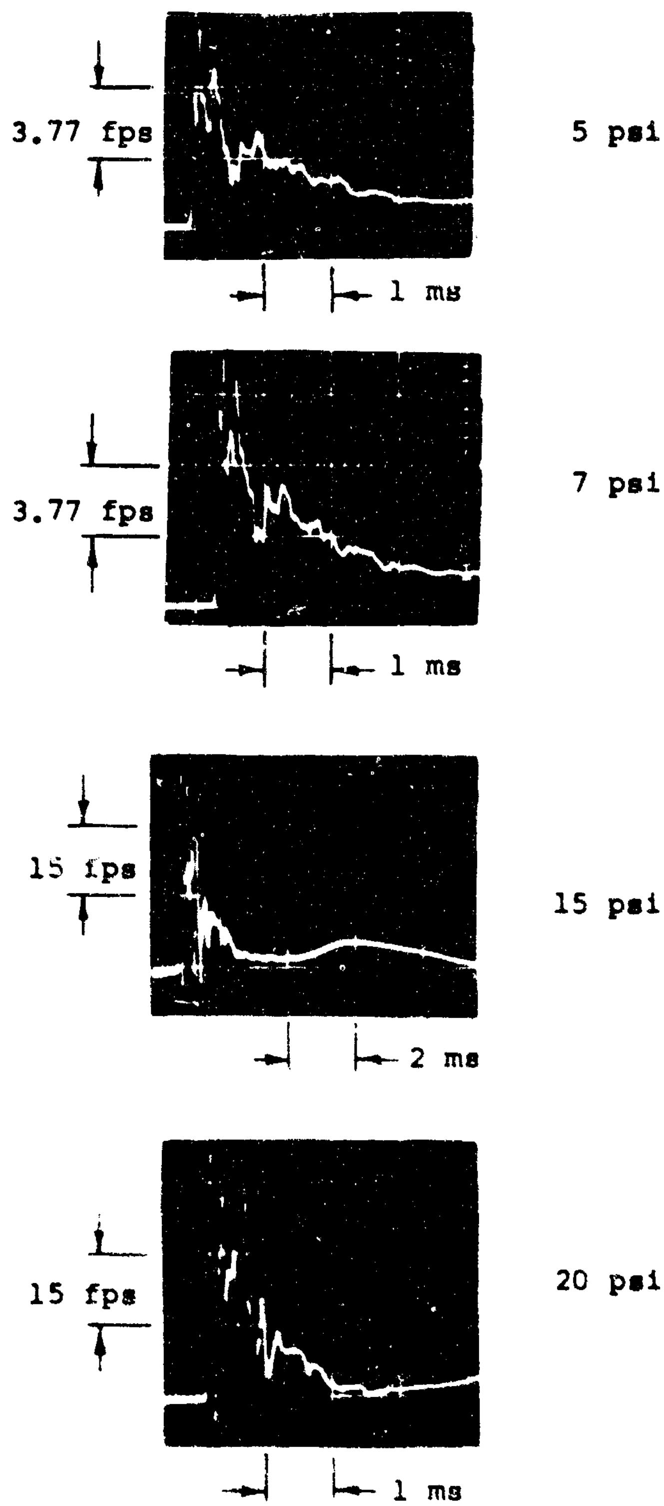


FIG. B-7. SAMPLE VELOCITY OSCILLOGRAMS
(10-lb Payload)

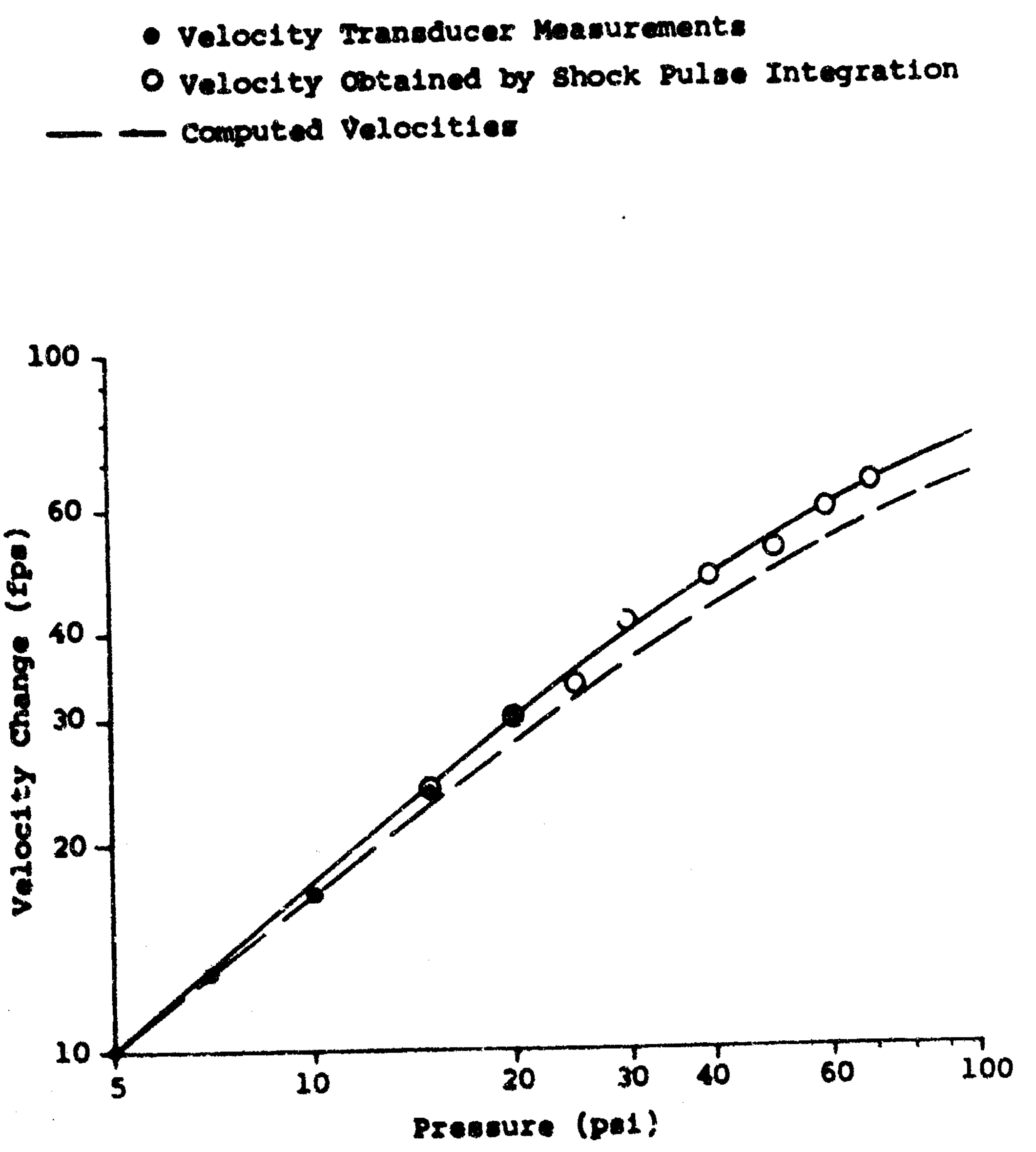


FIG. B-8. COMPARISON OF VELOCITY CALIBRATIONS — MEASURED AND COMPUTED

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13. ABSTRACT

Described is a portable tester capable of producing steel-on-steel impacts in the range of 100,000g with durations of from 40 to 45 microseconds. The 6-foot tall, 1700-pound machine has a payload capacity of 10 pounds and is operated with low pressure (100 psi) air. The tester is intended primarily for testing ordnance components associated with arming, fuzing and safing functions; tests are limited to secondary explosives weighing 10 grams or less.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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SHOCK						
SHOCK TESTERS						
HIGH IMPACT						
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SAFETY						

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