TM-67-7

COMPONENT EVALUATION DURING SHOCK

by

A. J. Buschman, Jr.

May 1967

U.S. ARMY MATERIEL COMMAND
HARRY DIAMOND LABORATORIES
WASHINGTON, D.C. 20438

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Destroy this report when it is no longer needed. Do not return it to the originator.

AD

AMCMS Code: 5910.22.63016
HDL Proj. No. 65200

TM-67-7

COMPONENT EVALUATION DURING SHOCK

by

A. J. Buschman, Jr.

May 1967

U.S. ARMY MATERIEL COMMAND
HARRY DIAMOND LABORATORIES
WASHINGTON, D.C. 20438

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

ABSTRACT

A test method was developed that allows direct wire monitoring of an item during application of shock. The method employs the air gun facilities of HDL. The test item is mounted in a target body that is impacted by the air gun projectile. Peak accelerations of 20,000 g with a duration of 0.75 msec have been obtained. At present the components evaluated, primarily resistors and capacitors, have shown very small dynamic changes.

1. INTRODUCTION

Most electronic circuitry in the presence of a snock environment is required only to survive—that is, as long as it performs within the design limits after an interval equal to several times the shock duration, the circuitry is adequate. This is not the case in the Lunar Penetrometer Program. In this program the electronics must collect, process, and transmit data during the time the penetrometer is impacting the target.

Accurate information on the surface structure of a remote target can be obtained by analyzing the acceleration signature of an impacting projectile (ref 1 and 2). NASA proposed to apply this technique to the problem of determining the surface characteristics of the earth's moon prior to manned landings. Two large factors prevented the direct application of the technique developed. They were the remoteness of the moon and its lack of an atmosphere. The remoteness could be overcome by a space vehicle acting as a relay station. The lack of an atmosphere is a more formidable problem. The penetrometers require a normal impact which is obtained readily by spin or drag stabilization in conjunction with the proximity of the launch equipment and the target surface.

To obtain a normal impact on the lunar surface, a complex and prohibitively expensive test vehicle would be required. This could be avoided by using an accelerometer that is not directionally sensitive. In this way, a large number of penetrometers could be released above the lunar surface and allowed to fall freely, surveying a large area instead of one point as with the controlled impact test vehicle.

HDL, under Defense Purchase Request L-31,945 with the Langley Research Center of NASA, had the task of developing an omnidirectional accelerometer. Reference 3 presents the results of an investigation of four methods of obtaining an omnidirectional accelerometer. Two methods were considered worthy of further development.

The first method employed hollow piezoelectric spheres. Effort at HDL produced directional sensitivity deviations of ±20 percent. This effort was then continued by an accelerometer manufacturer who had been independently following this course. To date the manufacturer has produced accelerometers with directional sensitivity deviations of ±5 percent over a limited acceleration range.

The second method considered worthy of further investigation consisted in employing a conventional triaxial accelerometer and computing the instantaneous magnitude of the acceleration by obtaining the square root of the sum of the squares of the three orthogonal acceleration signatures. Reference 4 presents a comprehensive study of methods of obtaining the instantaneous magnitude of an acceleration signature by employing conventional uniaxial accelerometers. Reference 5 presents HDL's effort to develop the circuitry required to compute the instantaneous magnitude of the acceleration signature by one of the methods presented in reference 4. Some work was done on this circuit under contract to improve the low frequency response (2 Hz). Little improvement could be realized without greatly increasing cost and circuit complexity.

At this point in the penetrometer program, interest was growing in circuit behavior during impact since all data were to be collected, processed and telemetered during this time. Computing Devices of Canada (CDC) under contract to NASA was developing a telemetry transmitter to be used in the communications link of the penetrometer. CDC began a component evaluation program to qualify components for their telemetry. Their test consisted in subjecting components to a dynamic pressure equal to that calculated to be experienced by components encapsulated in a sphere impacting concrete at 200 fps (ref 6). Reference 6 also contains valuable mechanical properties of several commercial encapsulants.

This test method provides valuable information on component behavior; however, the component was not accelerated during test. To obtain data during shock, HDL's task was changed from the development of an omnidirectional accelerometer to the development of a test method capable of monitoring component behavior during acceleration where the peak is 20,000 g, and the duration is 1 msec.

2. DEVELOPMENT OF TEST METHOD

High-energy shock testing (velocity changes greater than 50 fps) is difficult in the laboratory. Most conventional methods are survival tests only. The component is evaluated before and after the test to determine the effect of the shock on critical parameters. In most applications, transient changes during the shock are not detrimental to performance, as long as the component returns to the initial condition within a few shock pulse durations following the shock. In the penetrometer application behavior during shock is most important, and methods to adapt conventional laboratory shock testing equipment to this need were investigated.

Some conventional high-energy shock testing equipment available at HDL is briefly described here for background information.

2.1 Hyge Actuator

In this test, a piston is placed in a long tube that can be closed at both ends. The piston is accelerated by high pressure air through a quick-opening valve. Peak acceleration of 5000 g with rise times of 2 msec can be achieved. The total acceleration pulse width is approximately 6 msec. The piston is decelerated at a rate determined by the pressure in front of it. In general, high acceleration pulses of a short time are followed by low-level deceleration over a long time. The total travel of the piston is about 40 ft.

The method requires long cables, which are accelerated and decelerated along with the piston. Cable noise becomes a problem with travel distances of this magnitude. The noise problem is further complicated by the high pressures experienced in the chamber in front of the piston. The cable is gathered by the piston as it moves down the tube. To date, only one cable has been used to monitor the output of an accelerometer. Mechanical noise due to the piston gathering the wire is a problem area. The piston also cuts the wire because it is forced into the small gap between piston and tube wall.

2.2 Air Guns

This test method consists of accelerating a projectile in a gun by high-pressure air. The gun is 100 ft long and has a smooth bore. The projectile leaves the gun at velocities up to 600 fps. Within 1 ft of leaving the gun, the projectile enters a catch box made of 2-in. thick steel plate. The far end of the catch box holds the target which is made up of various amounts of 1-in. thick lead plates. The projectile penetrates the lead and comes to rest. The lead is good for only one test but is capable of being remolded.

This test is capable of very high peak deceleration, 100,000 g, with pulse widths of approximately 50 μsec followed by a lower deceleration for a longer time when a flat nose piece is used. A conical nose piece is capable of longer pulses, 3 to 5 msec, with a lower acceleration peak.

Several attempts have been made to obtain data during impact. All methods attempted to make electrical contact with the projectile just before impact. In this way very high impedance circuits are open circuited during most of the test. Noise pickup is a severe problem; oftentimes the high impedance circuits are saturated before the data can be collected.

A direct connection all during the test would be difficult due to the length of the gun. The cable would not be strong enough to take the acceleration at the start of the test as well as the deceleration upon impact. Data would be lost in the cable noise. The cables would most likely have to be replaced after each test.

2.3 Wire in Bore Technique

The advantage of this method is that it permits testing in the environment of primary interest in fuze design. The test item is placed in the projectile of an artillery weapon. Wires are connected directly to the projectile through a special collecting cone and then taken out through the bore of the weapon. The wires are supported at the muzzle so that they are on the axis of the bore. Tension is applied to the wires so that all slack is removed.

The weapon is then loaded with propellant in the prescribed manner and fired. The projectile gathers the wires in the collecting cone as it moves down the length of the bore. Data can be collected from time zero until exit, when the wires are broken. This technique works well with either rifled or smooth bore weapons.

In smaller weapons, the projectile can be recovered by firing into a catch box filled with sawdust. The primary disadvantage of this method is the field test conditions required because of the inherent danger whenever artillery weapons are fired. A comprehensive report with a detailed description of the technique as well as test results is being prepared.

2.4 Modified Air Gun

A brief outline of this method is given here. Appendix A contains a complete description of this test facility.

An extension tube was placed in front of the air gun. This tube carried the projectile from the gun into the catch box. The projectile could impact the target without leaving the tube. A breech was made in the extension so that a target body could be inserted in the tube in front of the lead target. The target body had a lead nose piece. The components to be tested were placed within the target body with leads coming out through the side of the breech. The projectile was then fired in the normal manner. The projectile impacts the target body accelerating it to a peak of 20,000 g. The duration of this impact was 750 μsec. The target body then travels a few inches before it impacts into the normal lead target. The second impact had a lower peak deceleration but of longer duration. The total travel at the target body was kept to within 6 in. In this way very short lengths of cable were accelerated and decelerated so that cable noise was very small.

The target body also contained an accelerometer. The accelerometer was monitored with a charge amplifier whose output was displayed on an oscilloscope.

3. PROCEDURE AND RESULTS

After considering the above four methods of obtaining high energy shock, the modified air gun method was chosen to evaluate components. This method provides shorter duration pulses than available in the other three methods; and the distance traveled by wires during the test is small. This greatly reduces the cable noise during testing and allows greater sensitivity. The modified air gun test provided the necessary amplitude and pulse duration required by the penetrometer mission.

The following components have been monitored during shock in the modified air gun test:

(1) Resistors, carbon composition

(2) Capacitors, tantalum

(3) Commercial transistorized subcarrier oscillator

(4) HDL 1-kHz time-base oscillator

(5) Commercial 1-kHz time-base oscillator

(6) Tape-wound magnetic cores

Each category required special test equipment. The procedure and results are presented for each category.

3.1 Resistors

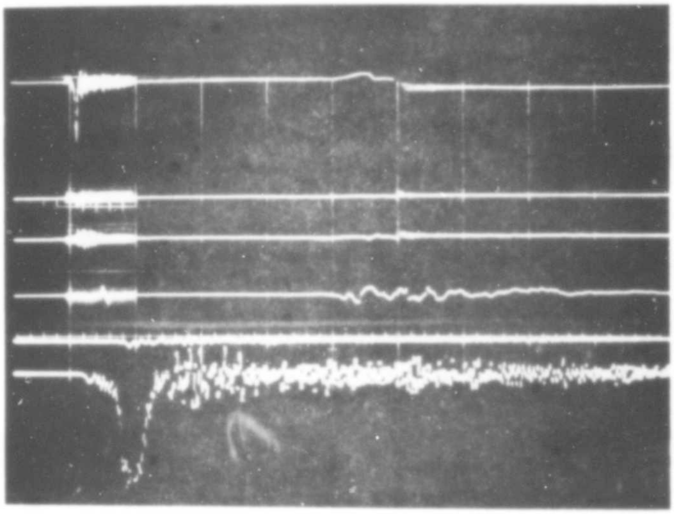
Carbon composition resistors (1/4-W) in the ranges of 1, 10, and 100 k-ohm were tested. The resistor tested was placed in one arm of a d-c bridge whose output was monitored on a scope. Two resistors were monitored during each test, one axial and one radial with respect to the direction of the impact. Since the bridges were relatively simple to construct and required minimal accessory equipment, each test contained a control unit along with the axial and radial component. The control unit consisted of a resistor with the same bridge configuration as the other two units, except that the control resistor did not experience the shock; only its cable was placed in the target body. In this way, cable noise could be monitored in the configuration used to monitor component changes.

Data were taken by photographing the display of a dual-beam scope. Typical data photographs are presented in figure 1 for two tests. The upper beam contains a four-channel plug-in unit, which monitors the accelerometer, the axial component, the radial component, and the control unit. The upper beam, triggered by the projectile breaking a wire just before impacting the target body, sweeps at a rate of 5 msec/div. The lower beam was delayed and sweeps at a rate of 0.5 msec/div. The lower beam monitors the axial component and the accelerometer. All sweep-monitoring components had a sensitivity of 0.296 percent/div. Increasing voltage indicates a decrease in resistance.

Table I presents data obtained on carbon composition resistors. As expected, the data were scattered and not reproducible. At this time the effects of repeated tests and the resulting g hardening cannot be separated from the random nature of the data.

Table I presents data on resistors in two encapsulants. The goal was to obtain a test procedure that would eliminate all effects except acceleration. It was conceivable that hydrodynamic pressures were generated within the encapsulant upon impact. To lessen this possibility, the components were encapsulated in a rigid foam. The density of the foam was 24 lb/ft^3 (that of epoxy is 74). The strength of the foam is greatly reduced and could possibly reduce the acceleration level by allowing the component to move. To remove this possibility, the component holders were changed so that a minimum amount of epoxy could be employed to hold the component in place against a metal surface. In this way the component could neither move in the direction of the metal nor be affected by a large head of epoxy. This method was employed where allowed by component size and is referred to throughout this report as the minimum epoxy method.

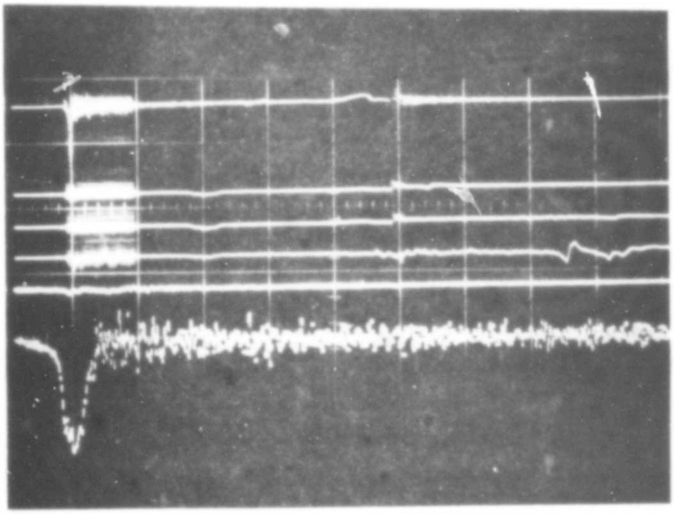
VELOCITY 197 FT/SEC
ACCELERATION 8900 g PEAK



TRACE	SENS/DIV	mSEC/DIV
ACC	10,000 g	5.0
AXIAL	0.3%	5.0
RADIAL	0.3%	5.0
CONTROL	0.3%	5.0
AXIAL*	0.3%	0.5
ACCEL *	5,000 g	0.5

* 4 mSEC DELAY

VELOCITY 192 FT/SEC
ACCELERATION 9100 g PEAK



TRACE	SENS/DIV	mSEC/DIV
ACC	10,000 g	5.0
AXIAL	0.3%	5.0
RADIAL	0.3%	5.0
CONTROL	0.3%	5.0
AXIAL*	0.3%	0.5
ACCEL *	5,000 g	0.5

* 4 mSEC DELAY

Fig. I Typical Data Obtained With 10-kohm Carbon Composition Resistors During Shock.

Table I. Test Data on Carbon Composition Resistors During Shock

Component value (kΩ)	Inpact velocity (fps)	Peak accelera-tion (g)	Acceleration duration (μsec)	Axial response delay (μsec)	Radial response delay (μsec)	Axial change (o/o)	Radial change (o/o)	Control change (o/o)	R_{axial}	R_{radial}
FOAM										
100	172	6300	433	NC	NC	NC	NC	.005	NC	NC
100	175	7600	465	243	NC	.098	NC	NC	.522	NC
100	193	12500	510	472	NC	1.04	NC	.026	.925	NC
100	194	12100	447	NC	NC	NC	NC	.090	NC	NC
100	289	19700	552	154	191	.010	.018	NA	.278	.346
10	197	9000	645	300	NC	.021	NC	NC	.465	NC
1	173	7300	637	277	NC	.113	NC	NC	.434	NC
1	197	8350	710	339	NC	.185	NC	NC	.477	NC
1	191	9000	636	NC	364	NC	.024	NC	NC	.572
Min. Epoxy										
100	223	16300	456	183	NA	.083	NA	NC	.401	NC
100	224	9550	671	NC	NC	NC	NC	NA	NC	NC
100	224	8000	778	362	NC	.047	NC	NA	.465	NC
100	262	16000	613	810	504	<.05	<.05	NA	1.32	.822
100	257	17300	589	424	574	.069	.018	NA	.714	.974
100	294	22500	545	NA	348	NA	.049	NA	NC	.638
100	290	2600	542	365	343	.024	.007	NA	.673	.632

R - Ratio of component response delay to acceleration duration

NA - Not applicable

NC - No change

All that could be concluded was that carbon composition resistors were not sensitive to large peak accelerations as long as the pulse duration was about 700 μsec. The ratio of the delay in component change to the impact pulse duration is an indication of the frequency response of the component. The ratio presented in table I shows the natural period of the resistors was more than four times the duration of the acceleration. It is believed that the carbon resistor would be very sensitive to longer pulses. Prior efforts with carbon resistors showed them to be relatively reliable pressure transducers in applications where pressures changed very slowly.

3.2 Capacitors

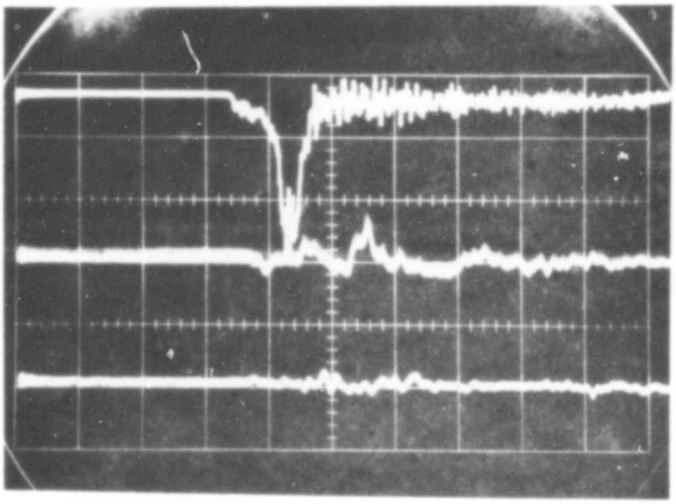
Tantalum capacitors of about 1 μF were monitored with Tektronix Type Q plug-in units—bridges driven by a 25-kHz oscillator. Each component in a test required a Q unit because the capacitor was placed in one arm of the bridge and the bridge balanced. Two components were tested simultaneously, one mounted axially, and one radially with respect to input acceleration.

Due to the proximity of two components in the test vehicle, a low frequency out-drift was observed on both components. It was necessary to remove the oscillator from one of the Q units, and couple it to the oscillator of the other Q unit. In this way, the units were driven at the same frequency, eliminating the low-frequency beat. It was then necessary to determine if the proximity of the components would present a cross modulation that would appear as if both components were changing due to the change experienced by only one. This was not a factor as shown during the calibration procedure.

Due to the lack of adequate equipment, only two components could be monitored during a test. It was not possible to observe cable noise when two components were being monitored. Cable noise was monitored at the sacrifice of data from one component. Cable noise was again observed by placing only the cable in the target body while the component was remotely located so that it did not experience the acceleration. Cable noise was also monitored when the bridge was balanced without the remote component. In this way, a more sensitive measure of the change in cable capacitance could be obtained, because the total capacitance was greatly reduced allowing an increase in sensitivity. Cable noise could be shown to be very small and not a factor in the total change experienced by the component.

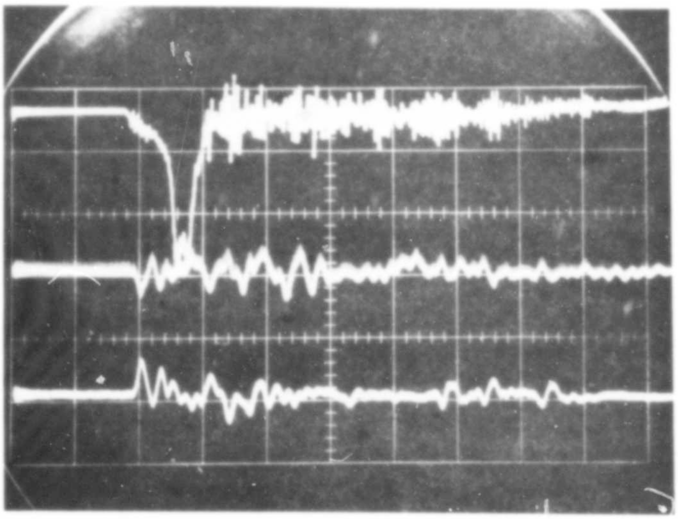
Data were taken by photographing the display of a dual-beam scope (fig. 2). Both beams have a sweep rate of 0.5 msec/div

VELOCITY 223 FT/SEC
ACCELERATION 12,400 g PEAK



TRACE	SENS/DIV	mSEC/DIV
ACCEL	5,000 g	0.5
AXIAL	1.0%	0.5
RADIAL	1.0%	0.5

VELOCITY 247 FT/SEC
ACCELERATION 11,600 g PEAK



TRACE	SENS/DIV	mSEC/DIV
ACCEL	5,000 g	0.5
AXIAL	1.0%	0.5
RADIAL	1.0%	0.5

Fig. 2 Typical Data Obtained With 10-μf
Tantalum Capacitors During Shock.

and are triggered 6 msec after the projectile breaks the wire. The two photographs in figure 2 are successive tests on the same components. They both display the accelerometer, the axial component and the radial component. Sensitivity for all sweeps was 1 percent/div. Increasing voltage indicates an increase in capacitance.

The results of the capacitor tests are presented in table II and are again inconclusive. There are no apparent trends due to the nonreproducible nature of the test as well as the erratic change experienced by the components. The delay between the input acceleration time zero and the component change time zero indicates that the components are very low frequency elements.

Solid tantalum capacitors have been tested in a hydrostatic pressure chamber. The results showed that small changes (approx 0.2%) occurred between 0 and 1000 psig. The component remained at this value between 1000 and 10,000 psig. In most cases shown in table II, this is the level of change recorded during acceleration.

Capacitors, therefore, appear to be low frequency devices that are sensitive to acceleration below a given level, then become saturated, and do not change until mechanical failure occurs.

3.3 Commercial Transistorized Subcarrier Oscillators

Subcarrier oscillators are available in a small package from a commercial source. Special units potted internally were purchased and tested during shock.

The 70-kHz subcarrier oscillator with a deviation of ±7.5 percent for input voltages from 0 to 5 V was monitored during shock with a subcarrier discriminator, Electro Mechanical Research Model 67D. The oscillator was tested with zero V input and the band edge set at plus and minus 20 V in the discriminator. The zero input was desirable to assure that noise was not introduced through either a cable or an internal battery. The manufacturer claimed the oscillator would remain linear down to a -1 V input. This was verified as part of the acceptance procedure before the impact testing began.

Both input and output of the discriminator were monitored during the test. In this way amplitude changes as well as frequency changes could be observed. The discriminator was not sensitive to amplitude changes one order of magnitude greater than that experienced by the subcarrier oscillator during shock. Data were taken by photographing the display of a dual-beam scope.

Table II. Test Data on Tantalum Capacitors During Shock.

Component value (µf)	Impact velocity (ft/sec)	Peak acceleration (g)	Acceleration Duration (µsec)	Axial response delay (µsec)	Radial response delay (µsec)	Axial change (o/o)	Radial change (o/o)	R_{axial}	R_{radial}
FOAM									
10	133	4600	896	543	439	+.037	-.116	.595	.489
10	173	8800	709	549	497	+.114	-.113	.774	.700
10	195	13400	660	540	556	+.158	-.095	.818	.842
10	261	14200	740	420	381	+.019	-.042	.567	.514
10	264	12000	645	366	256	-.061	+.120	.567	.396
1	222	10000	665	NC	NC	NC	NC	NA	NA
1	227	9200	685	310	NC	+2.00	NC	.452	NA
1	274	16100	580	NC	NC	NC	NC	NA	NA
MIN. EPOXY									
1	250	11600	730	NA	518	NA	+.15	NA	.709
1	262	13900	875	NA	475	NA	+.25	NA	.542
1	261	13900	600	562	304	200pf	NC	.936	.506
1	246	9850	616	14	15	-.45	+.22	.022	.024
1	224	8150	728	520	342	+.15	-.22	.714	.469
1	223	12400	660	170	NC	-.21	NC	.251	NA
1	247	11600	617	67	69	-.347	+.492	.108	.111
1	266	15000	647	NC	NC	NC	NC	NA	NA
1	264	11500	460	159	NC	-.35	NC	.345	NA

R - Ratio of component response delay to acceleration duration

NA - Not applicable

NC - No change

The upper beam contains a four-channel plug-in unit monitoring accelerometer output, discriminator output, and discriminator input at a sweep rate of 5 msec/div. This beam is triggered by the projectile breaking a wire just before impacting the target body. The lower beam is delayed and sweeps at a faster rate, 0.5 msec/div, while monitoring only the accelerometer and the discriminator outputs. Typical photographs are presented in figure 3.

The results of two series of tests on the same unit are presented in table III. The unit was tested first in a hard encapsulant. It was believed that the weight of the encapsulant under acceleration generated dynamic pressures on the unit. The unit was then potted in 24-lb/ft^3 rigid foam. The tests at air gun pressures of 5 and 7 psig (2000 to 3500 g) in foam produced negligible changes. As shown in table III, noticeable changes began to appear at gun pressures of 10 psig (3800 g).

The percent change in the output frequency as well as the total deviation was determined by variations in the output of the discriminator.

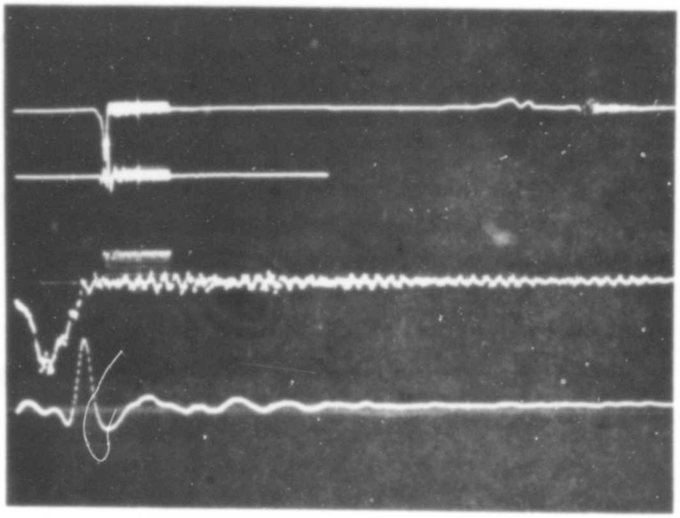
The data presented in figure 3 show changes of approximately 6 percent compared with changes of approximately 0.5 percent for the capacitors and of approximately 0.1 percent for resistors of figures 2 and 1. For this reason, the data shown on figure 3 were easier to analyze, as they were not masked by noise.

3.4 HDL 1-kHz Time Base Oscillator

One of the time base oscillators designed and built at HDL was monitored during shock. The oscillator was potted in 24-lb/ft^3 rigid foam. Data were taken by photographing the display of a dual-beam scope.

It is difficult to measure changes in a precision oscillator whose period is greater than the duration of the shock. It would be necessary to measure the period of each cycle for a few cycles before the shock, and several cycles following the shock. In this way, small changes would be observed. Gross effects only can be seen with a scope. Figure 4 presents the results of two tests in which gross effects were observed. The top photograph shows a small increase in the positive peak following the shock. The next few positive peaks decrease gradually back to their normal value. The negative peaks remain constant throughout the test.

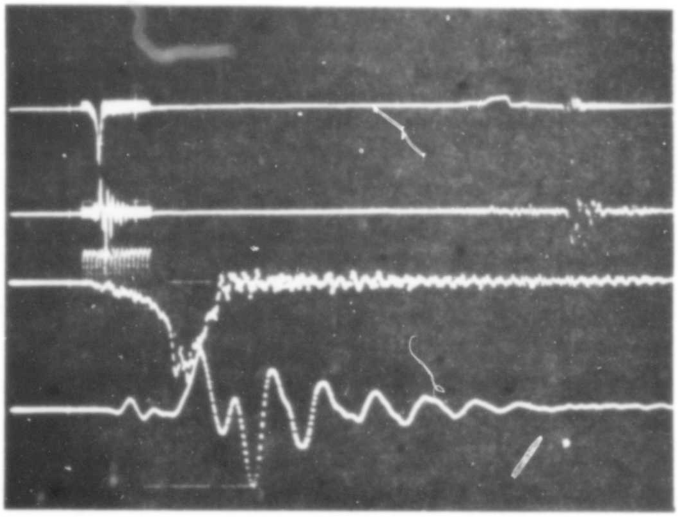
VELOCITY 134 FT/SEC
ACCELERATION 3700 g PEAK



TRACE	SENS/DIV	mSEC/DIV
ACCEL	5,000 g	5.0
DISC OUTP	10.0%	5.0
DISC INPUT	0.1 V	5.0
ACCEL *	2,500 g	0.5
DISC OUTP*	5.0%	0.5

* 6.75 mSEC DELAY

VELOCITY 137 FT/SEC
ACCELERATION 3800 g PEAK

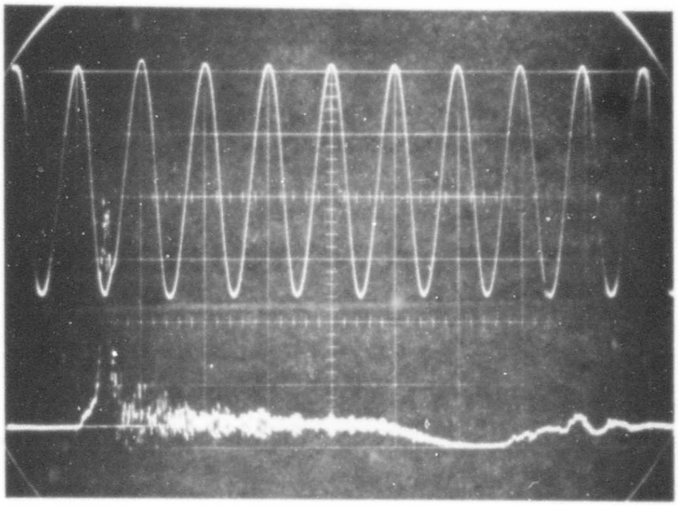


TRACE	SENS/DIV	mSEC/DIV
ACCEL	5,000 g	5.0
DISC OUTP	10.0%	5.0
DISC INPUT	0.1 V	5.0
ACCEL *	2,500 g	0.5
DISC OUTP*	5.0%	0.5

* 5.50 mSEC DELAY

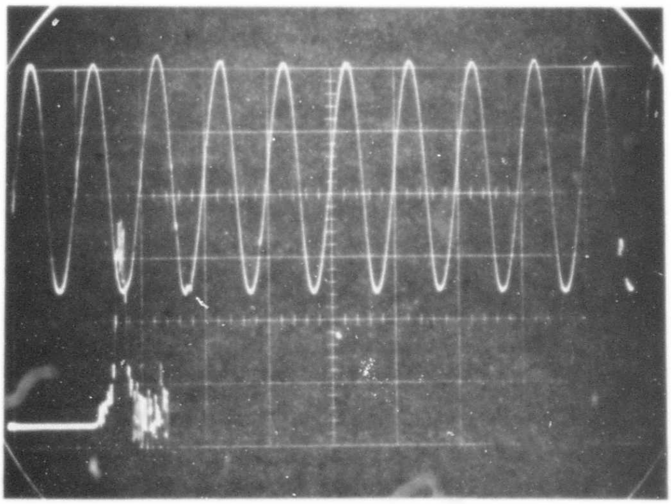
Fig. 3 Typical Data Obtained With A Commercial Subcarrier. Oscillator During Shock.

VELOCITY 277 FT/SEC
ACCELERATION 19,000 g PEAK



TRACE	SENS/DIV	mSEC/DIV
OSC	0.5 V	1.0
ACCEL	5,000 g	1.0

VELOCITY 271 FT/SEC
ACCELERATION 17,500 g PEAK



TRACE	SENS/DIV	mSEC/DIV
OSC	0.5 V	1.0
ACCEL	5,000 g	1.0

Fig. 4 Typical Data Obtained With An HDL 1-kHz Time Base Oscillator During Shock.

Table III. Test Data on Commercial Subcarrier Oscillator, Potted Internally.

Impact velocity (ft/sec)	Peak acceleration (g)	Acceleration duration (μsec)	Response delay (μsec)	Positive frequency change (o/o)	Negative frequency change (o/o)	Frequency deviation	Direction of impact
FOAM							
172	3740	1055	386	.489	.337	.412	Top
198	5820	962	339	.860	1.30	1.08	Top
221	6860	718	295	.850	1.21	1.03	Top
247	9700	717	288	1.10	1.80	1.46	Top
HARD POTTING							
103	1930	1326	351	2.75	2.18	2.46	Top
137	3820	1018	268	4.76	6.68	5.77	Top
105	2090	1237	89	1.48	.920	1.20	Side
134	3680	986	267	5.46	2.00	3.66	Side

The lower photograph also shows a small increase in the positive peak following the shock that gradually returns to its normal value. Again, the negative peaks remain constant. Other tests show that in every case the positive peak increases following the shock and returns to its original value within four cycles. In every case the negative peak was constant.

Slight distortions are introduced following the shock. The distortions were not large enough to affect the period of the oscillator within the accuracy of the monitoring system. The period of the oscillator as determined from the few cycles before the shock varies approximately 2 percent. This variation was due to the scope sweep rate and was not the oscillator changing period. The oscillator was shocked nine times, and continued to function after each impact.

3.5 Commercial 1-kHz Time Base Oscillators

Four time base oscillators made for HDL under contract were monitored during shock. The oscillators were potted in hard potting. Data were taken by photographing the display of a dual-beam scope.

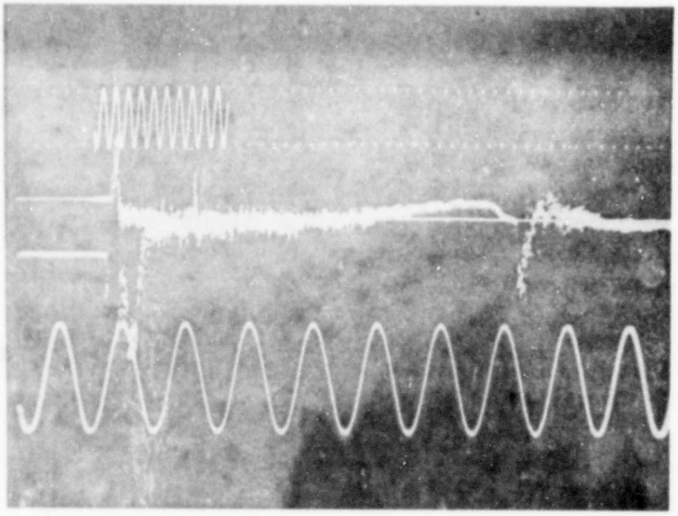
The difficulty discussed above in measuring the period of a precision time base oscillator applies here. However, the result presented in figure 5 shows that the amplitude of these oscillators did not change during shock. They also show that the output was not distorted even during the period in which the impact occurred.

The top photograph shows some zero shift in the accelerometer output. This was due to the accelerometer cable, which was replaced before the next test. The apparent loss of signal in the lower picture was due to a broken cable. The unit functioned properly after the test.

Accurate period measurements taken before and after the tests given below show very small changes.

Ser No.	T Before (μsec)	T After (μsec)	ΔT (μsec)
13	1000.908	1000.873	-0.035
14	999.242	999.245	+0.003
18	999.488	999.486	-0.002
19	999.375	999.327	-0.048

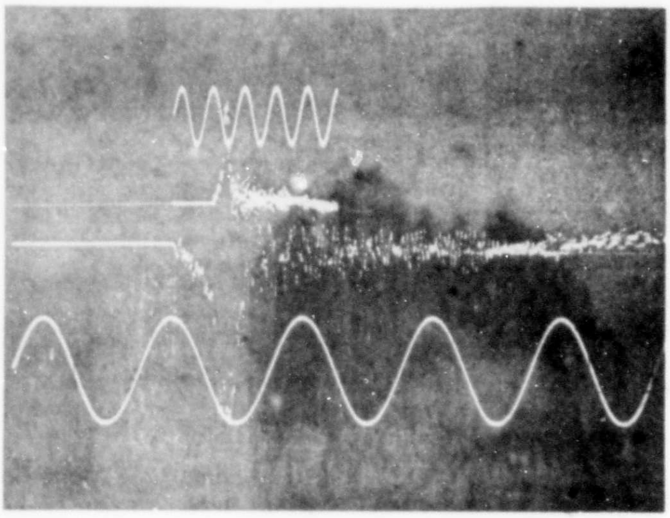
VELOCITY 225 FT/SEC
ACCELERATION NOT AVAILABLE



TRACE	SENS/DIV	mSEC/DIV
OSC	2.0 V	5.0
ACCEL	10,000 g	5.0
ACCEL*	5,000 g	1.0
OSC *	1 V	1.0

* 7 mSEC DELAY

VELOCITY 271 FT/SEC
ACCELERATION 12,700 g PEAK



TRACE	SENS/DIV	mSEC/DIV
OSC	2.0 V	2.0
ACCEL	10,000 g	2.0
ACCEL *	5,000 g	0.5
OSC *	1.0 V	0.5

* 5.0 mSEC DELAY

Fig. 5 Typical Data Obtained With a Commercial 1-kHz Time Base Oscillator During Shock.

The oscillators continued to drift slowly toward the initial values indicating a relaxation of stresses introduced upon impact.

3.6 Tape-Wound Magnetic Cores

Two types of magnetic cores were tested, one especially prepared to survive spin acceleration and the other not so prepared. Both were 134 Maxwell cores and were held in the component chamber of the target body using a minimum amount of epoxy.

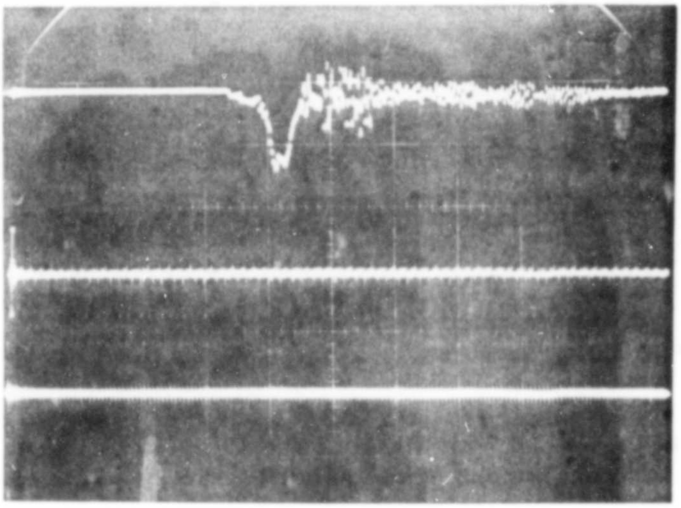
The cores are made of 0.0005-in. magnetic tape wound on a bobbin, and having a paper jacket around the outside turn for protection against mechanical damage. The tape was not restrained at the edges and had no support between windings so that it was free to move during acceleration. It has been shown that because of longer times involved spin acceleration caused more damage to the core than impact acceleration. Special preparation consisted of removing the bobbin ends and the paper jacket to allow the tape ends to be coated with a mold release, Vidax AR. The core was then encapsulated to support the ends of the tape. The mold release was necessary to prevent straining the tape when the encapsulant was cured.

Data were taken by photographing the display of a dual-beam scope. The cores are driven with square-wave pulses of 400 mA peak. The core was driven positively for 5 μsec, 1-μsec rise and fall time, followed by a negative pulse of the same amplitude and configuration after a 1-μsec delay. This was done at the rate of 32 kHz so that there was a delay of 18 μsec between the negative pulse and the following positive pulse. The output voltage of the core was displayed on the scope. Figure 6 presents the results of two tests. The accelerometer output and the axial component were chopped, since they were both on the upper beam. The radial core output was displayed on the lower beam, and therefore shows every pulse.

Results are given in table IV. Tape-wound cores are very sensitive to acceleration as evidenced by the large changes in the amplitude of the output signal. They are also very high frequency devices as indicated by the ratio of time of peak change to rise time. They appear to have a threshold shown by the delay column. The delay was measured as the time between the accelerometer t_o and the core t_o. The cores ring for several pulse durations following the shock, indicating that damping is below critical.

It was no surprise to find cores to be very sensitive to acceleration, since magnetostrictive transducers have been

VELOCITY 250 FT/SEC
ACCELERATION 11,100 g PEAK

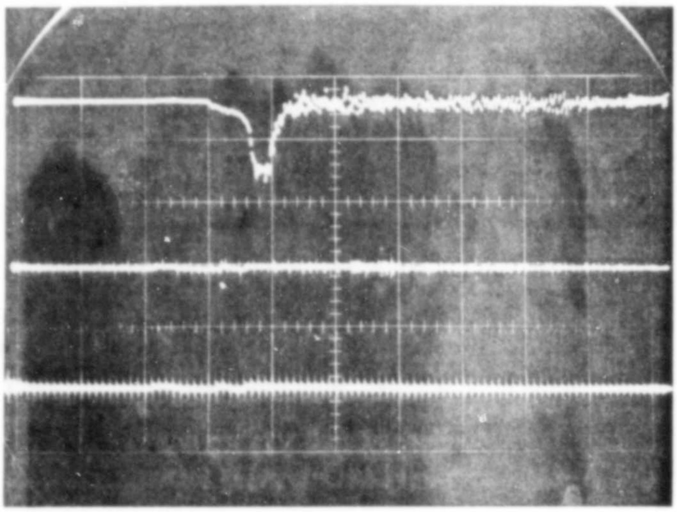


TRACE	SENS/DIV	mSEC/DIV
ACCEL *	10,000 g	0.5
AXIAL *	1.0 V	0.5
RADIAL *	1.0 V	0.5

* 5 mSEC DELAY

POTTED INTERNALLY

VELOCITY 260 FT/SEC
ACCELERATION 10,900 g PEAK



TRACE	SENS/DIV	mSEC/DIV
ACCEL *	10,000 g	0.5
AXIAL *	1.0 V	0.5
RADIAL	1.0 V	0.5

* 5 mSEC DELAY

NOT POTTED INTERNALLY

Fig. 6 Typical Data Obtained With Tape Wound Magnetic Cores During Shock.

Table IV. Test Data Obtained on Wound Magnetic Cores.

Impact velocity (ft/sec)	Peak acceleration (g)	Acceleration duration (μsec)	Positive output change (o/o)	Time of positive change (μsec)	Negative output change (o/o)	Time of negative change (μsec)	$R_{positive}$	$R_{negative}$	core
UNPOTTED CORE									
260	10800	726	13.7	411	12.1	369	1.06	.955	Axial
			20.9	390	19.9	345	1.01	.893	Radial
POTTED CORE									
257	11100	628	23.6	354	19.8	357	1.01	1.02	Axial
			20.3	351	17.2	359	1.00	1.02	Radial

employed for decades. HDL's requirement would be satisfied if the cores could be made to survive setback accelerations without permanent mechanical deformations that would alter their magnetic properties by more than 10 percent.

4. SUMMARY OF RESULTS

It has been shown that individual components, resistors and capacitors, change very little during shock. Carbon composition resistors changed less than 0.1 percent while solid tantalum capaitors changed less than 0.25 percent. Carbon resistors appear to have a very low mechanical natural frequency as shown by the delay in the peak change. Tantalum capacitors are also low frequency elements and are sensitive to small acceleration levels. They appear to become saturated and do not continue to change with increasing g levels.

The commercial subcarrier oscillator changed considerably during shock with changes as large as 6 percent at 4000 g. The changes in the oscillator show the advantage of testing a complete circuit over testing individual components.

The time base oscillators showed little change in output voltage and no frequency change could be detected within the limits of the oscilloscope. Accurate period changes during shock were not possible; however, before and after tests indicate changes of 0.005 percent existed. These changes were relaxed gradually over a long time indicating mechanical relaxation.

Tape-wound magnetic cores are very sensitive to shock, changing as much as 20 percent at 10,000 g. The cores are high-frequency elements and recover shortly after the impact so that no measurable permanent change occurred.

5. CONCLUSIONS AND RECOMMENDATIONS

Components can be monitored during shock with a peak g of 20,000 and the duration of 750 μsec. In the present test method cable noise appears to be the limiting factor when components change less than 0.1 percent. None of the components tested failed to survive the shock and only small dynamic changes were observed in individual components.

The pulse duration presently obtainable should be extended as much as possible. It would be a very valuable test method if the duration could be increased to 10 msec. At present it is only an indicator of results that can be expected in a gun environment.

It is evident from the limited data presented here that only a cursory evaluation of individual components is necessary. The component should be tested in the conventional air gun method to determine if it can survive the shock. The modified test method should then be used to see if changes during shock are less than 1 percent. If the component passes both tests it should be placed in a circuit and the complete circuit tested as a unit.

The instrumentation used in this test should be improved. The accelerometer output should be recorded on an instrumentation tape recorder. Only in this way can adequate information be obtained on the acceleration pulse as well as component behavior. It is not advisable to operate one beam of the oscilloscope in the chopped mode, especially when a four-channel plug-in unit is used. The chopping frequency is not high enough and data can be lost.

Work in this area must be coordinated with work in the gun environment area to determine the value of air gun testing in the overall artillery requirement of shock survival.

6. REFERENCES

(1) McCarty, J. L. and Carden, H. D., "Impact Characteristics at Various Materials Obtained by an Acceleration-Time-History Technique Applicable to Evaluating Remote Targets," NASA TN D 1269, June 1962.

(2) Schmid, W. E., "The Determination of Soil Properties in Situ by an Impact Penetrometer," Scientific Report No. 1, Princeton University, January 1966.

(3) Buschman, A. J., Jr., "Investigation of Four Methods of Obtaining an Omnidirectional Accelerometer—Phase 1," Harry Diamond Laboratories PR-65-1, 15 February 1965.

(4) Ryan, W. E., "Some Methods of Approximating an Omnidirectional Accelerometer with Multiple Uniaxial Accelerometers," Harry Diamond Laboratories TR-1243, 15 July 1964.

(5) Marcus, I. R., Miller, J. W., Jr., Buschman, A. J., Jr., "Circuit Realization of a Square Root Sum of Square Computer," Harry Diamond Laboratories, TR-1271, 25 January 1965.

(6) Brown, G. E., Dawson, J. E., and Beck, J. R., "High-Shock FM Transmitter," Final Report, Computing Devices of Canada Limited, 22 October 1965.

BLANK PAGE

APPENDIX A.—MODIFIED AIR GUN

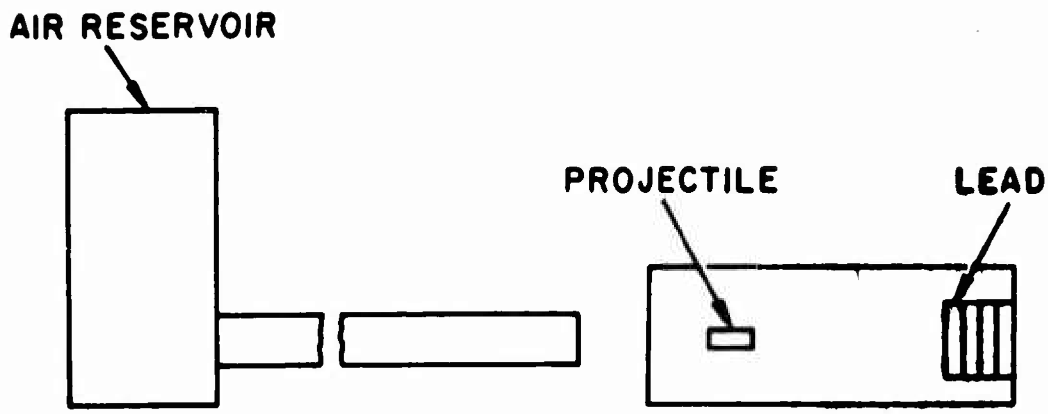
Figure A-1 is a schematic diagram of the conventional air gun test and the modified air gun test methods. In the conventional test method, the component is placed in the projectile. The projectile is placed in the 100-ft smooth bore gun through a breech near the air reservoir. A quick-opening valve applies the air from the reservoir to the projectile. The projectile is accelerated down the gun and exits at velocities up to 600 fps. The nominal weight of the projectile is 15 to 19 lb. The projectile is in free flight for approximately 3 ft before it impacts into a lead target. Penetration of 10 in. of lead can be obtained at the higher velocities. The peak acceleration is measured with a copper ball accelerometer. Peak acceleration and pulse duration are controlled by the exit velocity and projectile nose configuration.

In this test, the cargo is evaluated before and after the impact, to determine the effect of the impact. It indicates survival only, and serves as a guide before going to field testing in the gun environment. At present, there is little correlation between air gun testing and field testing due primarily to the lack of instrumentation in both areas.

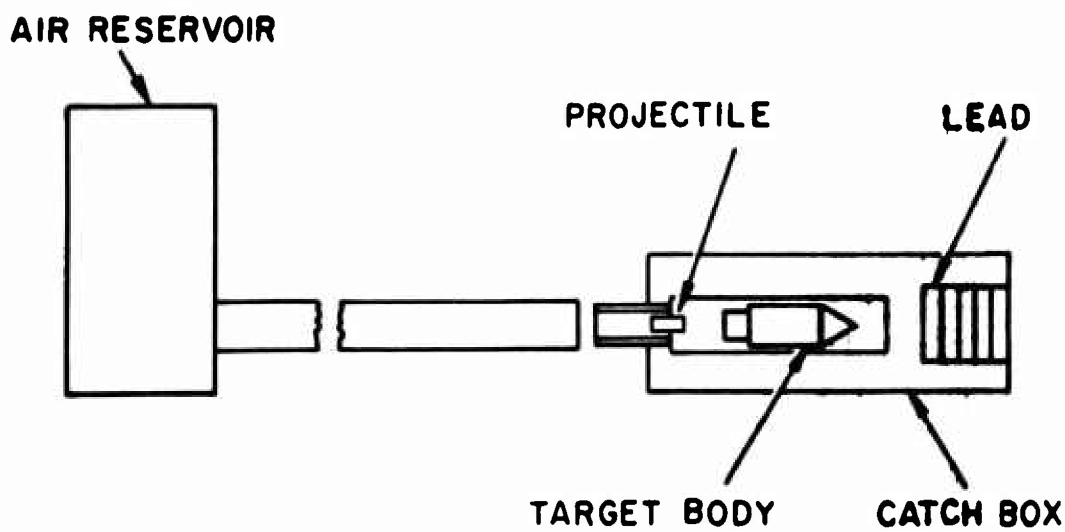
In the modified test method, a tube is placed in the catch box so as to guide the projectile from the gun into the catch box. In this way, the projectile is never in free flight; it is controlled at all times. The component to be evaluated is placed in a target body, which is placed within the additional tube and accelerated when impacted by a modified projectile. The modified projectile is fired from the gun as is the conventional projectile described above. The target body upon acceleration moves toward the lead target while still confined by the tube. It is within the tube when it impacts the lead target. The projectile and target body are contained during the entire test. The distance traveled by the target body can be as little as 6 in. This is the main advantage of this test method. Cable motion is very limited, so that cable noise and breakage are minimal. The main disadvantage of this method is the duration of the shock which at present is 750 μsec when the peak is 20,000 g.

The test method presented here has not been optimized. It was the first attempt to obtain data during higher level shock testing than had been previously possible. The method can be extended without greatly increasing the travel distance of the target body.

The target body and projectile are shown in figure A-2. The target body has a replaceable cylinder of babbitt, held in front to shape the leading edge of the acceleration pulse. The two



Conventional test method



Modified test method

Figure A-1. Schematic of both types of air gun tests.

cavities shown are deep enough to place components along the axis of the target body.

The components are potted in the small cup shown in figure A-2. They are placed in the slots and held in place with a small amount of filled epoxy. A cable clamp is screwed into the component cup to provide a good ground connection as well as secure the cable and remove the load from the component terminals. The plug that fills the top portion of this cavity also holds the component cup firmly in the bottom of the cavity. The plug has a hole in the center just large enough to allow the wires with connectors to pass through it.

The cables used to monitor the components are the same low-noise cables that are used with the accelerometer. Four-foot lengths with connectors on both ends are cut in half to make component test leads. The cables can be used several times depending on the acceleration level. After several tests the cables become well coated with the vaporized babbitt. The cables are sometimes cut by pieces of hot babbitt, become very noisy, and can no longer be used.

The projectile has a conical center with a thick ring around the outside diameter. The ring is larger than the cylinder of babbitt, so that it can pass around the babbitt before the cone comes in contact with it. The cone reduces the leading edge of the acceleration pulse by penetrating with an increasing area. The cone fans out near its base in an attempt to throw the flowing babbitt toward the outer ring, which has already passed over that portion of the babbitt. This was done to capture the babbitt and not allow it to flow from between the projectile and the target body. The babbitt was not contained due to the loading rate during impact. An impact at 150 fps distorts the babbitt cylinder more than a load of 125 tons applied slowly. Efforts in this area of controlling the flow of the babbitt can greatly increase the duration of the pulse.

The additional tube in which the impact occurs is made of a larger diameter pipe with four rails to guide the projectile (fig. A-3). The main gun portion has a 4-in. inside diameter. The projectile has an outside diameter of 3.990 in. The tube placed in the catch box is made of 5-in. inside diameter pipe bored out to remove all irregularities. One-inch diameter steel rods were then milled nearly in half along the length. Four of these machined rods were placed inside the pipe to make the effective inside diameter 4 in. The projectile and target body, after leaving the gun, are controlled at four points on their periphery. This also leaves four sections of the annular region open so that the air in front of the projectile does not move the target body before

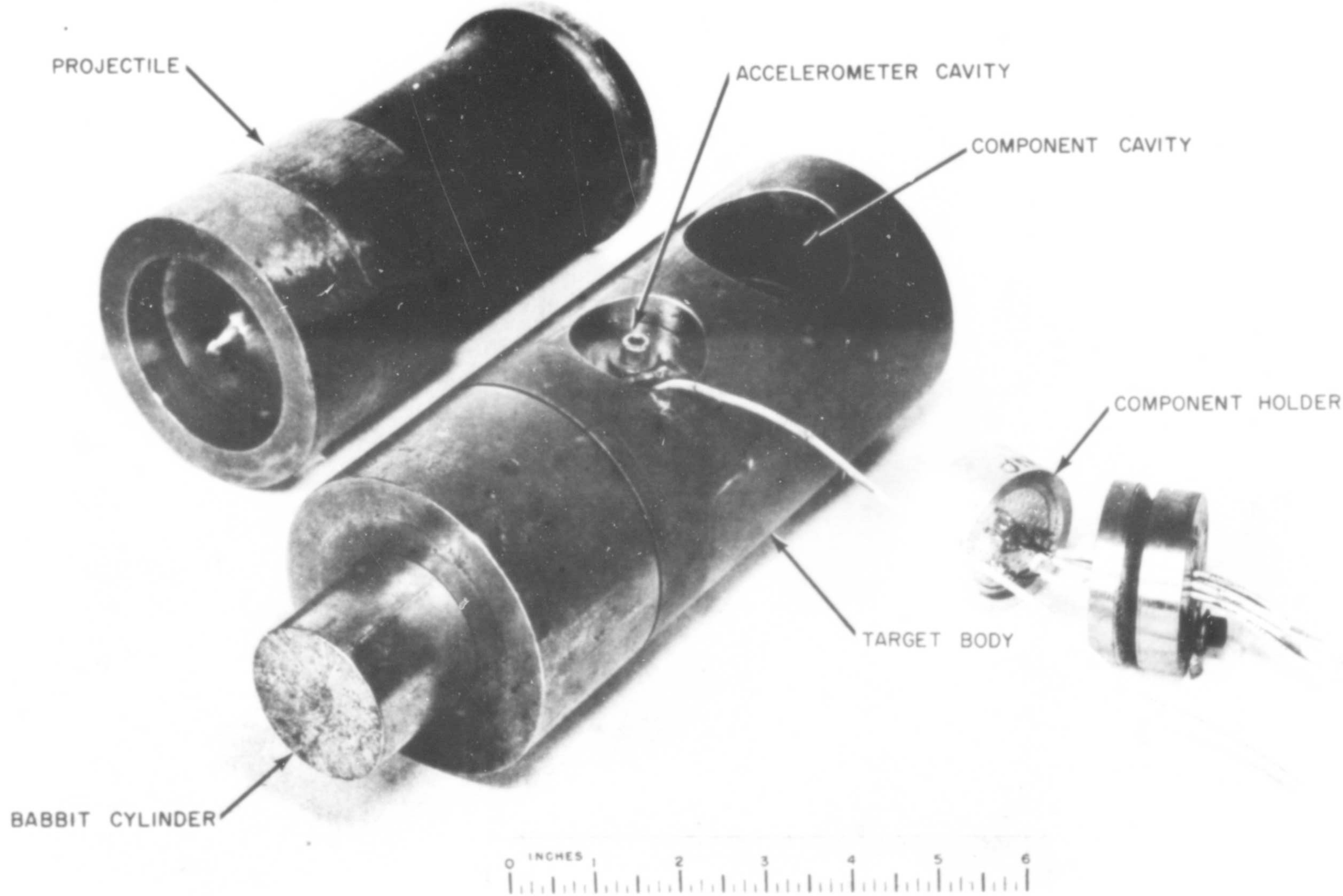


Fig. A-2 Projectile and target body used in modified air gun tests.

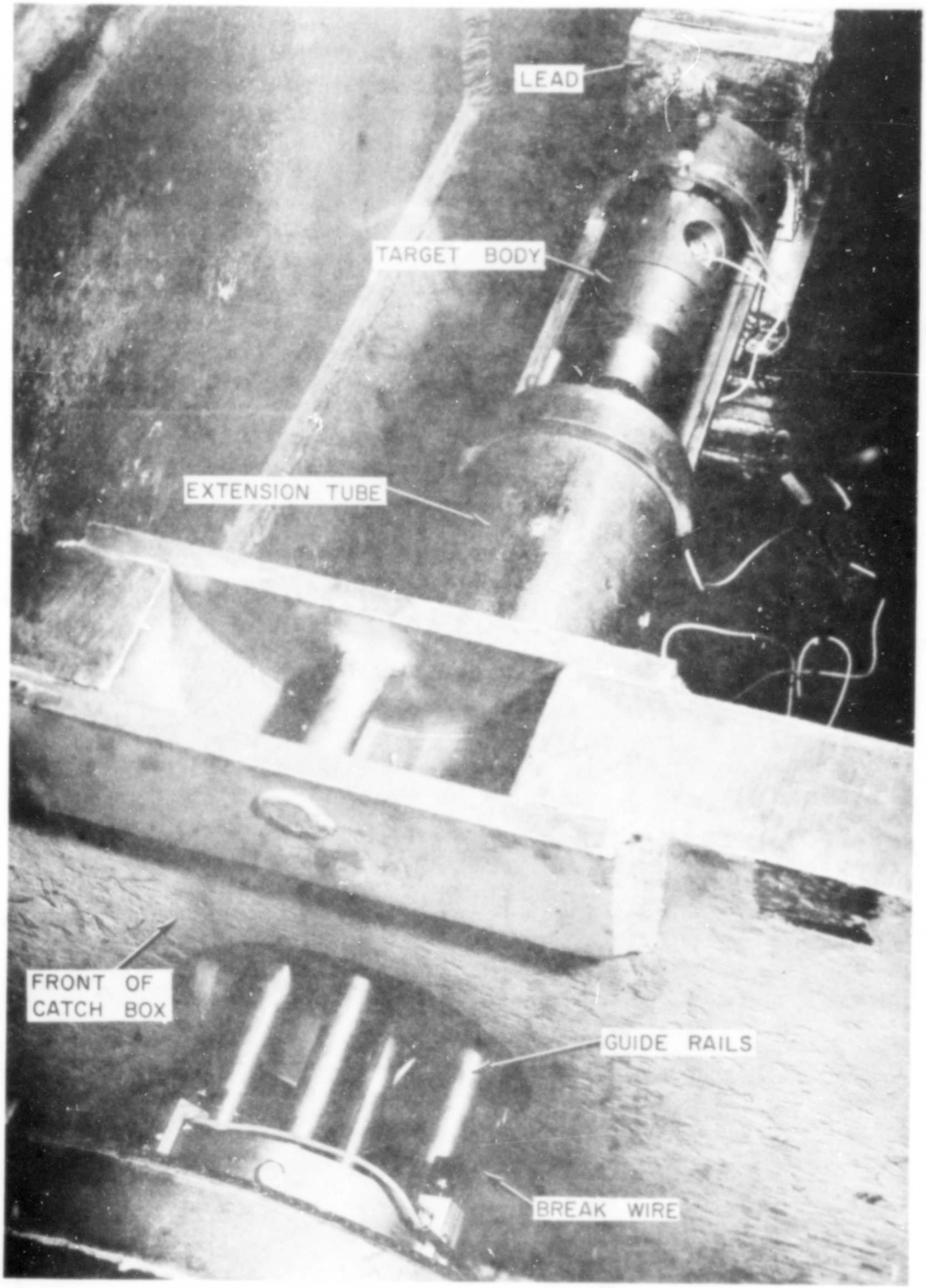


Fig. A-3 Extension tube in place for the modified air gun test.

the impact occurs. It also allows room for the cables from the target body to pass through the outside wall without being pinched off. During the impact, these four annular regions are filled with hot pieces of babbitt. The air flowing past the projectile and target body accelerates these pieces of babbitt to velocities greater than that of either target body or cables. Most of the high velocity tests had the cables cut by this flying babbitt. To prolong the life of the cables, a shield was made to completely fill the annular segment in which the cables traveled. The shield therefore had an inside diameter of 4.0 in. and an outside diameter of 5.0 in. The target body was placed in the tube through a breech because the catch box was not long enough to allow end loading. The shield was placed in the breech cover so that it was just forward of the cables at the start of the test. In this way the target body could move before the excess babbitt was removed by the shield. The air would then hold the babbitt against the shield so that it could not be accelerated and cut the cables. The breech cover was slotted along its edge to allow the cables to move without interference.

A breakwire was placed at the end of the main gun to trigger the oscilloscope. All data were taken by photographing the display on a dual-beam scope. Generally one beam was triggered by the breakwire and had a slow sweep speed in order to obtain data during the entire test. The other beam was delayed, and had a faster sweep speed to obtain as much data during the first impact as possible. Accessory equipment was used as needed for the various components tested. In general, the plug-in units for the scope were operated in a chopped mode to obtain four or more sweeps. It would be advantageous to take data on an instrumentation tape recorder instead of a single sweep scope as used here.

The accelerometer output was monitored with an Endevco Corporation Shock Monitor Model 2708 MZ. The shock monitor contains a charge amplifier and a peak holding circuit. The sensitivity of the charge amplifier can be adjusted so that the peak reading circuit displays peak g's directly. It was soon realized that the peak as shown by the indicator was cable noise during the second impact. It was then necessary to install a gate in the peak-indicating circuit. The output of the charge amplifier was not affected and accelorometer output during the entire test could be monitored on a slow sweep of the scope. The gate was triggered by the gate of the fast sweep of the scope which was delayed in order to present only the first impact. In this way, cable noise at the end of the test could be observed without obtaining false readings on the peak indicator.

The charge amplifier has provisions for inserting a filter before the peak indicator. All accelerometer data presented here have been filtered with a 1000-Hz low pass filter. The filter was supplied by Endevco Corporation and is down 3 db at 3300 Hz with a 6-db/octave rolloff.

Figure A-3 shows the extension tube in the catch box. The breech cover is removed to show the target body and the inside rails of the tube. The target body is normally placed closer to the main gun, but is shown in this position to show the babbitt cylinder in place.

TYPICAL IMPACT

To obtain more information during impact, high-speed motion pictures were taken. The breech cover was removed and the top guide rail replaced with a guide that could be fastened to the tube on both sides of the opening so that the impact was not obstructed.

Very little information was obtained from the photographs. The babbitt was vaporized upon impact sending out a dense cloud of vapor completely obscuring the area of impact. The projectile and target body appear to come together smoothly so that they are joined and continued locked together toward the lead plates at the end of the catch box. The accelerometer output presented in all the data of figures 1 through 6 shows the a-t signature to be relatively smooth with no large second peak. (A second peak would indicate that double impact had occurred.) During some of the higher pressure tests, increased ringing occurred near or shortly following the end of the acceleration pulse indicating that the babbitt was not completely contained between the impacting bodies, and the steel bodies came into contact with each other.

Some of the photographs show a third signal on the a-t signature. It was believed that this third pulse, same polarity as the first, was due to the accelerometer cable impacting the lead at the rear of the catch box. This was the primary reason for inserting the gate mentioned above. The gate would not pass the third spike so that the peak of the first was recorded.

BLANK PAGE

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Harry Diamond Laboratories Washington, D. C. 20438	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP ——

3. REPORT TITLE

COMPONENT EVALUATION DURING SHOCK

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

----

5. AUTHOR(S) *(First name, middle initial, last name)*

A. J. Buschman, Jr.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO OF REFS
May 1967	42	6

8a. CONTRACT OR GRANT NO. b. PROJECT NO. AMCMS Code: 5910.22.63016 HDL Proj. No. 65200 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) TM-67-7 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	NASA

13. ABSTRACT

A test method was developed that allows direct wire monitoring of an item during application of shock. The method employs the air gun facilities of HDL. The test item is mounted in a target body that is impacted by the air gun projectile. Peak accelerations of 20,000 g with a duration of 0.75 msec have been obtained. At present the components evaluated, primarily resistors and capacitors, have shown very small dynamic changes.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Impact testing						