TEST REPORT T67-10-1

DEVELOPMENT OF TEST METHODS FOR THE FIVE-INCH AIR GUN

by

DAVID MARCUS

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Quality Assurance Directorate
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ABSTRACT

Phase 1 of a program to improve methods of high-g shock testing using the 5-Inch Air Gun at Frankford Arsenal is reported. The program's objectives are to perfect the air gun test method for military materiel and to measure the shock applied in the air gun. Methods of firing the air gun and measurement techniques are described. The work resulted in a start toward accomplishing the overall objectives and also provides a basis for further investigations.

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INTRODUCTION

The purpose of this program is to improve methods of testing military materiel in order to improve quality standards and provide an improved product. The 5-Inch Air Gun subjects items to high orders of pneumatically controlled shock that simulate the field operational environment. The work reported herein summarizes efforts thus far accomplished to meet the following objectives:

1. Perfect a method of using the air gun which will result in variable and repeatable applied shocks.

2. Measure the shock amplitude, wave shape and time duration on the test items fired in the air gun.

The great improvements in ordnance materiel during the last decade have largely been in the form of increased sophistication of weapons systems, subsystems and components. These improvements have paralleled advances made in modern technology. There is increased emphasis on application of miniaturization techniques and the use of complex electronic, mechanical and electro-mechanical assemblies. Economy in utilization of space requirements require precise design for strength. Cost economy makes overdesign as well as underdesign prohibitive. Because it is necessary to design components to maximum stress levels, in order to obtain the most "efficient" design, it is important to identify the weak regions and the failure mechanisms.

One of the most severe environments encountered is the shock to military items fired from a gun. Shock testing items in the field presents various difficulties such as the use and maintenance of instrumentation and recovery of fired items and their analysis. Thus it is more convenient and economical to secure the desired test information by simulating the shocks in the laboratory.

This report presents an account of work to date on a program for improvement of pneumatically controlled test methods for materiels and components that simulate gun firing shock in the laboratory. The test facility used for this work is the 5-Inch Air Gun at Frankford Arsenal. This report represents the results of Phase I of this program.

GENERAL DESCRIPTION OF AIR GUN

The 5-Inch Air Gun is a device which uses compressed air to apply high level, short duration shocks to test items such as fuzes and small electronic assemblies. It consists of a 5-Inch naval gun which has been modified by smooth boring its barrel and adding a closed end extension to the barrel (see figure 1). The overall length of the modified gun is 56 feet. It uses high pressure air piped into its breech from a compresser-reservoir system to apply high g forces to a projectile assembly. The item being tested is attached to the projectile. The projectile consists of an aluminum cylinder which closely fits the barrel. When the projectile is propelled through the barrel from the breech it compresses the air ahead of it until the projectile motion is arrested. Expansion of the air in the barrel returns the projectile to the breech end.

Shock levels up to 30,000 g are experienced by test items. The level of the shock can be controlled by varying the firing pressure and the weight of the projectile assembly. Two methods are used for firing - each with a unique means of retaining the projectile until the desired air pressure is attained. These methods are called the Diaphragm Method and the O-Ring Seal Method and are discussed in the following paragraphs.

DIAPHRAGM (Ruptured Disc) METHOD

The Diaphragm Method of firing the air gun uses a 6 1/2-inch diameter aluminum diaphragm with a circular groove machined into its surface. Figure 2 is a photograph of the complete projectile-diaphragm assembly. With this arrangement, the diaphragm fractures suddenly along the groove when the high pressure air results in a force exceeding the shear strength of the aluminum. The grooves are of different depths thereby requiring different breaking forces resulting in varying the acceleration levels. For this application, 24 ST-T4 aluminum having a shear stress of 41,000 psi has been found satisfactory. Prior to the use of aluminum, naval brass was used and a variety of other materials have been suggested. Based on theoretical calculations tempered with empirical factors, a fairly accurate prediction of shock levels is attained by selection of different groove depths. Figure 3 is a diagrammatic representation of the shock pulse obtained when firing with the diaphragm method. Figure 4 is a cross-section representation of the diaphragm firing method.

O-RING SEAL (Orifice) METHOD

The O-Ring Seal method uses a piston and orifice assembly arrangement for firing the air gun. Figure 5 is a cross-section representation of the firing arrangement, and figures 6 and 7 are photos of the piston and orifice assembly. High pressure air is delivered to the breech as in the diaphragm method. The high pressure air is sealed off by the sliding piston at the orifice holes. The O-rings on the sliding piston provide a seal against the high pressure air getting to the back of the piston. To fire the piston, low pressure air (200 psi) is directed through the breech door and filler insert to the back of the piston. The piston moves forward and uncovers the air ports permitting the high pressure air to "see" the back of the piston. As a consequence the piston is given a sudden acceleration down the gun barrel.

Figure 8 is a diagram of the pulse shape generated by the presently used piston orifice combinations. By using different orifice configurations, sizes and spacing it is possible to vary the nature of the shock pulses generated. Various pulse shapes and time durations are feasible. The original insert designed for this method of firing was fabricated entirely of aluminum and was one piece. The air pressure forces involved in the firing caused this single piece insert to elongate considerably due to stretching at the weak section at the orifices. Subsequently, a two part insert consisting of an aluminum spacer block and a steel orifice sleeve was made and serves satisfactorily (see figure 7).

MEASUREMENT OF ACCELERATION PULSES

One of the unique phases of this program was the instrumentation of the projectile to obtain the acceleration records. The system used is pictured in figure 9. Various modifications to the air gun were made to permit use of this instrumentation method. An access port for low noise cable was machined into the barrel of the air gun at a point 12 feet from the breech end. A special fitting (figures 10 and 11) was fabricated to permit feed-through of the low noise signal cable without loss of barrel pressure. When not in use this opening is capped.

Several pressure transducers have also been provided. Their location was on the high pressure piping system and not directly into the breech or barrel. Records from these transducers have thus far been treated as informational. Given sufficient data it may be possible to establish a correlation between the pressure data and the acceleration .ata.

CONCLUSIONS

Phase 1 of the program has resulted in a start to perfecting a test methodology for materials tested in the 5-Inch Air Gun. Using the O-Ring Seal method repeatable shocks can be applied. Further work will be required to provide a variable shock pulse. This can be accomplished by providing controlled air flow to the rear of the projectile. One method of doing this is to vary the size and configuration of the orifice holes. Although some measurements have been obtained with the existing measurement system, further effort will be required to refine the instrumentation techniques. Perfection of the measuring method in future work will result in the ability to obtain a large amount of data. It will then be possible to compare the air gun data with field data. The comparison of this data (by existing computer programs) will provide a basis for perfecting air gun simulation techniques.

The number of different pulses obtainable is unlimited with application of the O-Ring Seal Method. The two part chamber insert design is more economical than a single unit, since in this case many orifice configurations can be made and tried more cheaply than with the one part design.

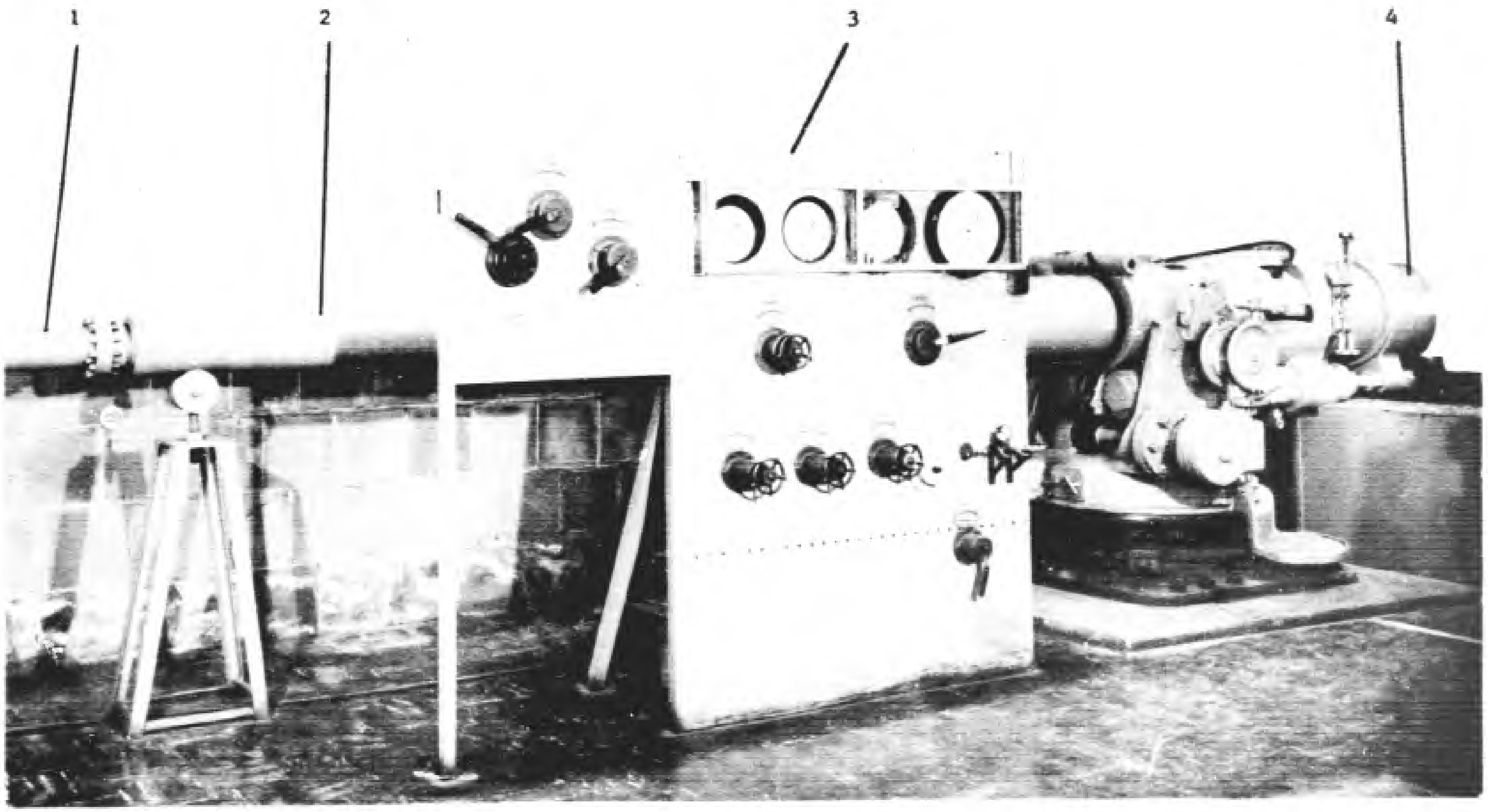
RECOMMENDATIONS

An air gun test method should be included in Mil Std 331 for fuze and fuze components, and other dynamic test specifications for materials.

A variety of orifice configurations be designed, fabricated and tested.

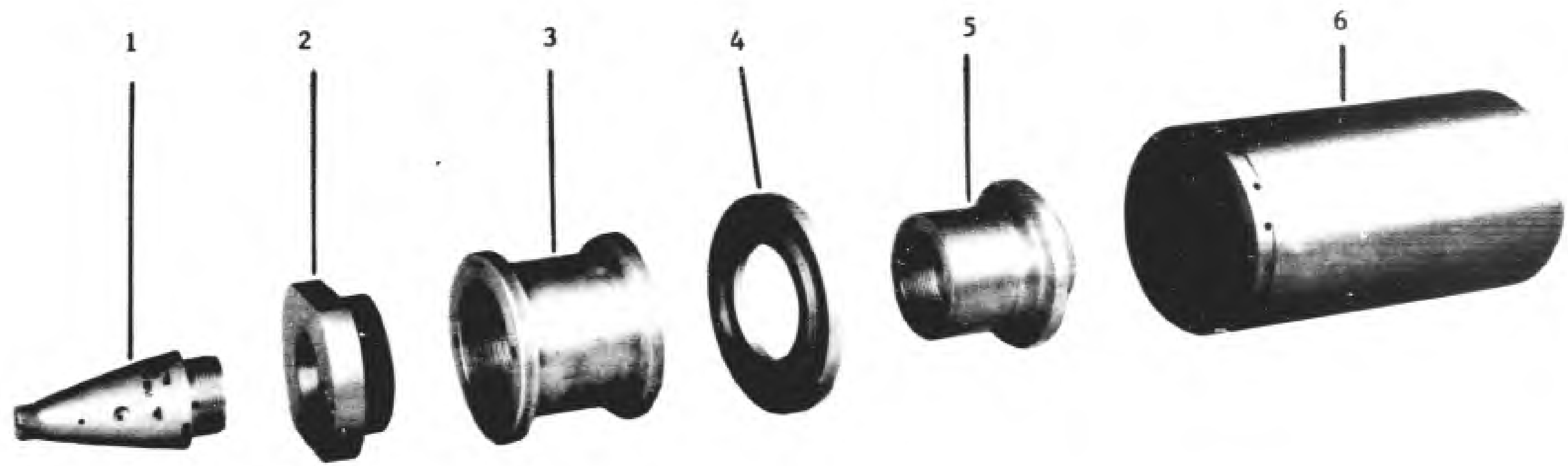
Instrumentation techniques be further refined to arrive at consistent and reliable recording of the applied air gun shock pulse.

Air gun shock pulses be analyzed and represented in terms of the shock spectrum for broadening the scope of materials testing and for comparison with field shock data.



1. Barrel Extension
2. Gun Barrel, Smooth Bore
3. Control Panel
4. Breech

Figure 1. High g Five-Inch Air Gun System



1. Fuze
2. Fuze Adapter
3. Piston Body
4. Diaphragm
5. Piston Cap
6. Chamber Block

Figure 2. Exploded View of Air Gun Release Mechanism - Diaphragm Firing Method

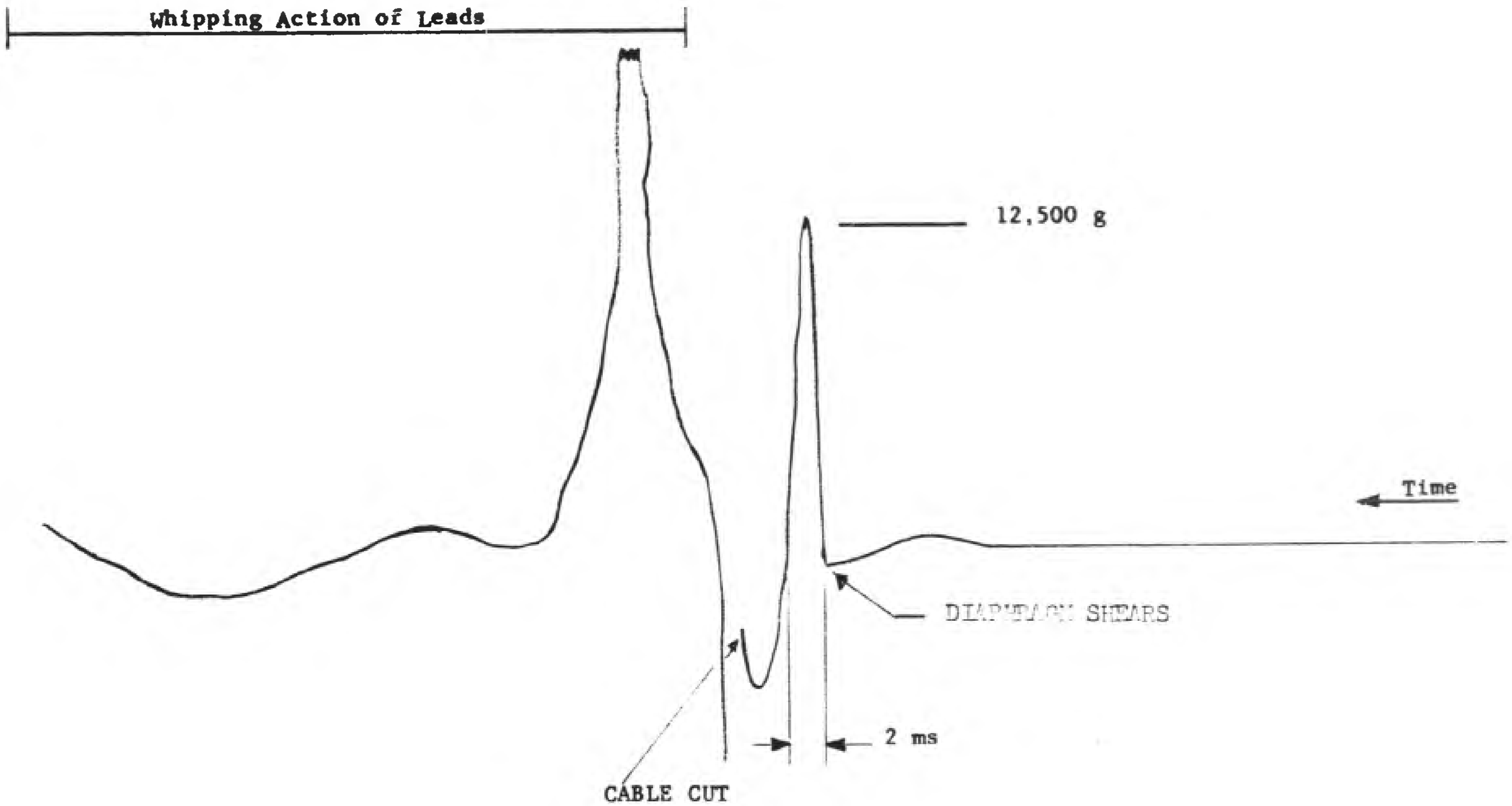
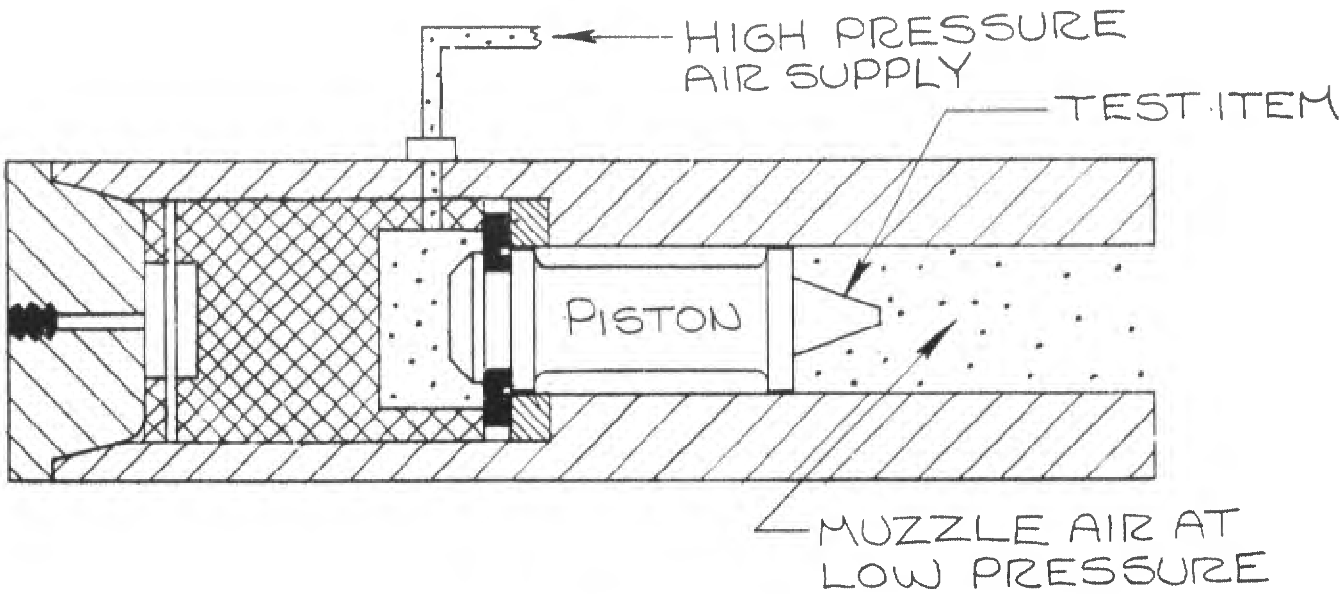
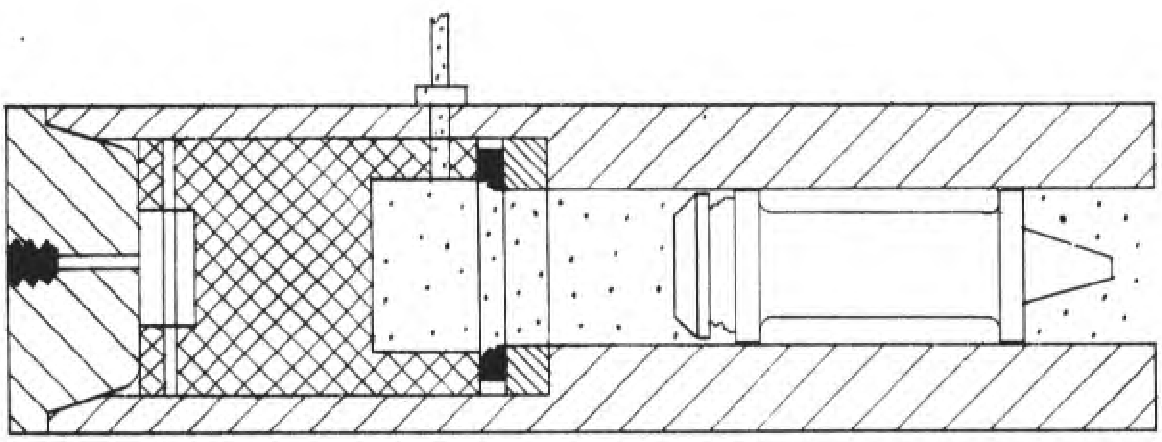


Figure 3. 12,500 g Acceleration Shock Pulse Obtained in Air Gun Using Diaphragm Firing Method

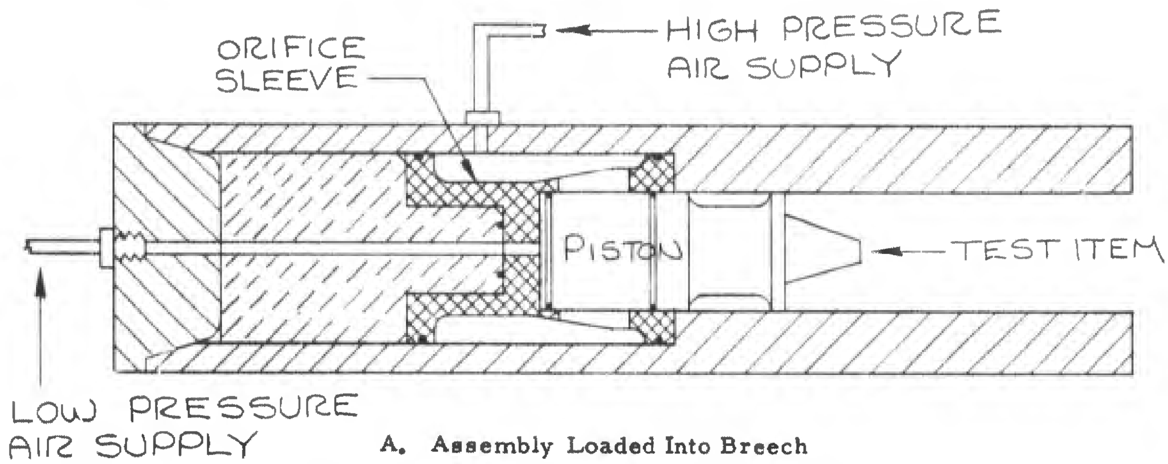


A. Projectile and Diaphragm in Place Prior to Rupture

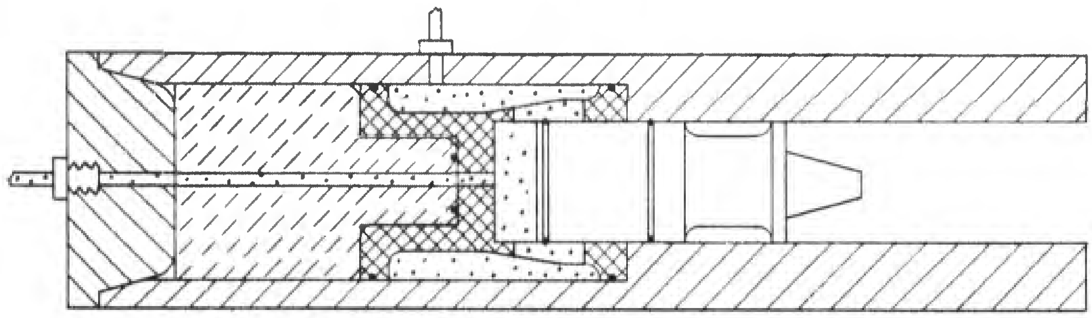


B. Diaphragm Ruptured and Projectile Accelerated Down Barrel

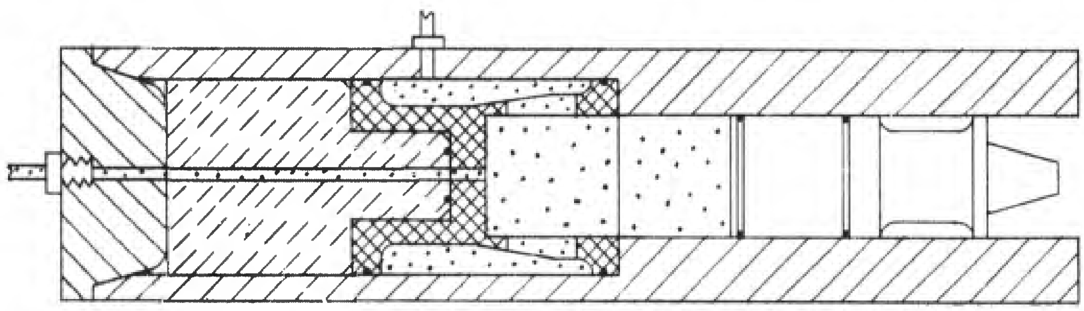
Figure 4. Diaphragm Method of Firing Air Gun



A. Assembly Loaded Into Breech



B. Piston Moved by Low Pressure Air



C. Piston "Fired"

Figure 5. O-Ring Method of Firing Air Gun

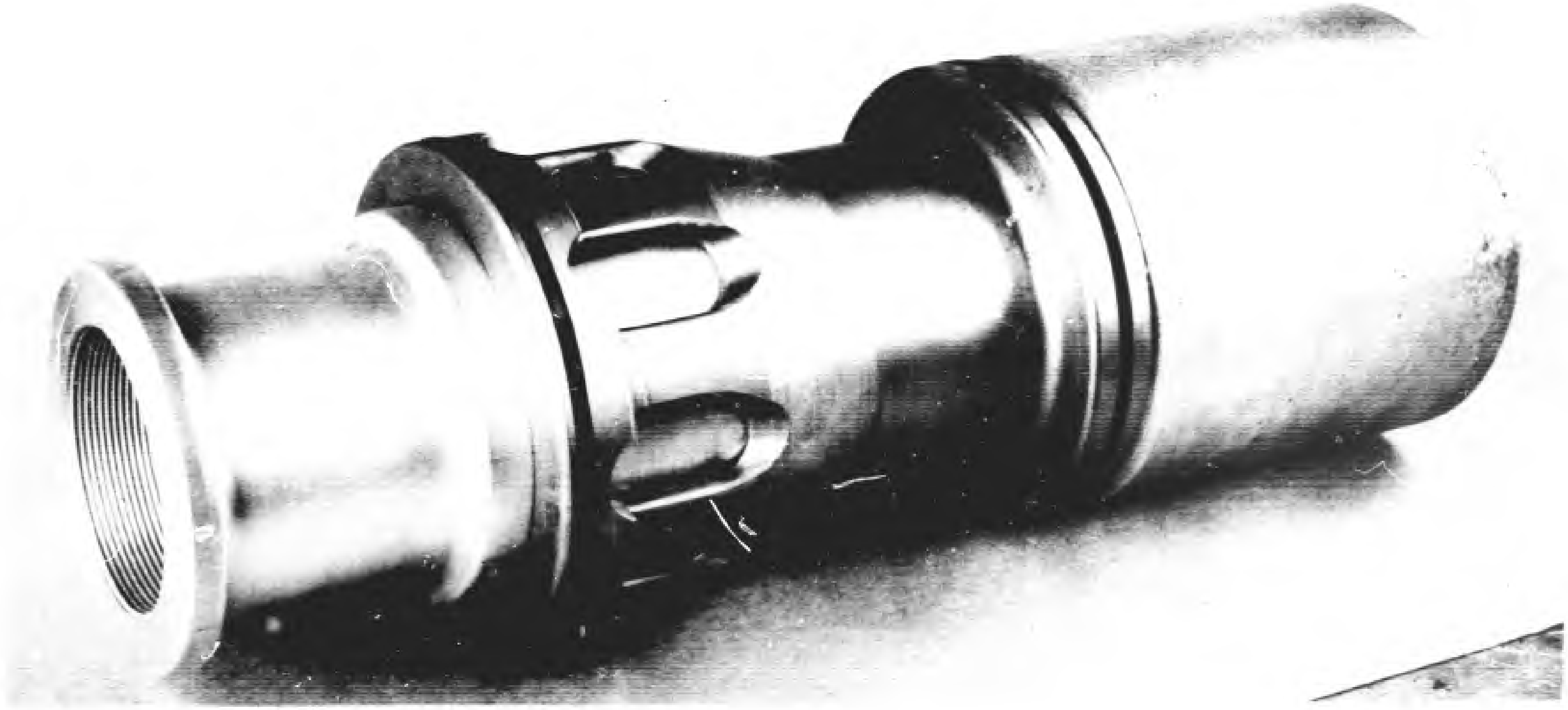


Figure 6. Piston and Orifice Assembly - O-Ring Seal Firing Method

Figure 7. Exploded View of Piston and Orifice Assembly - O-Ring Seal Firing Method

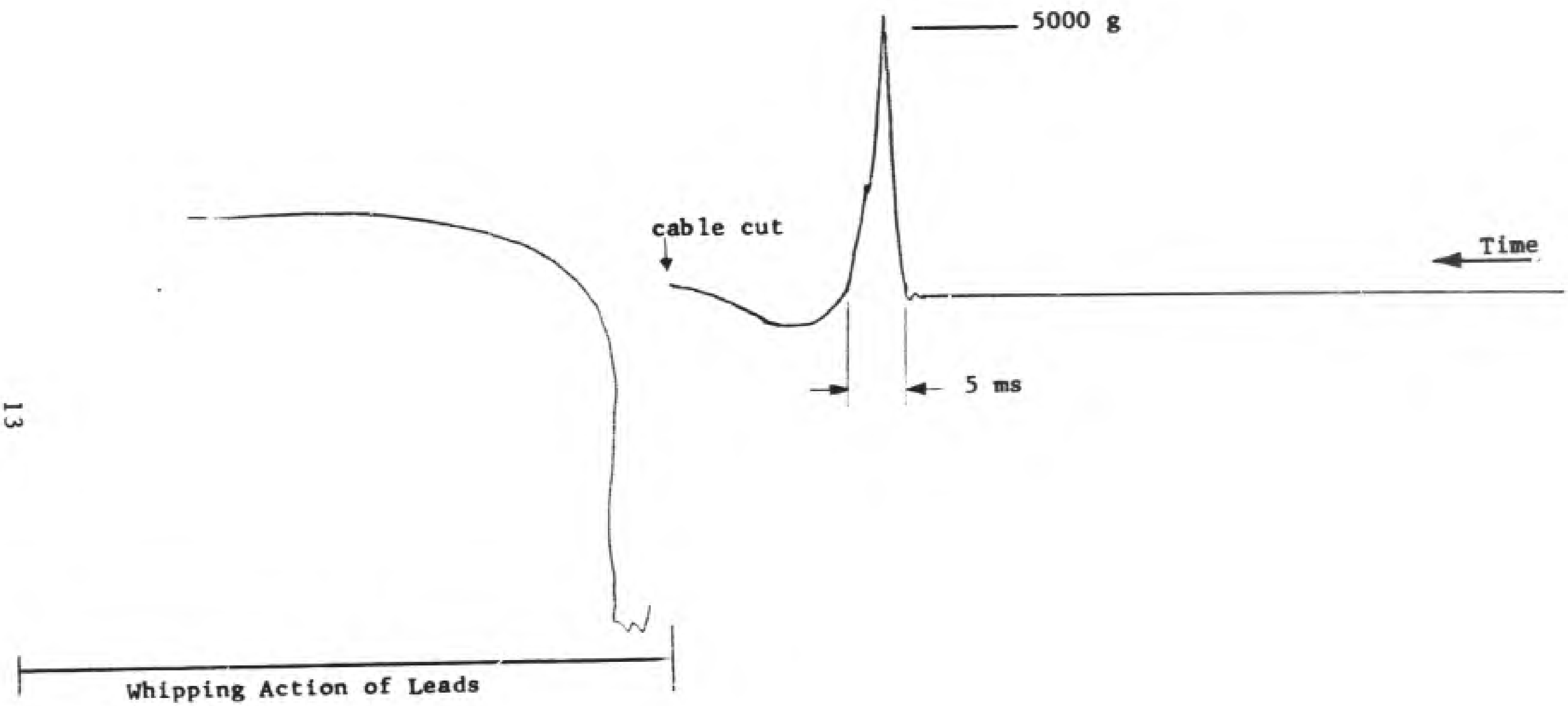


Figure 8. 5000 g Acceleration Shock Pulse Obtained in Air Gun Using O-Ring Seal Method

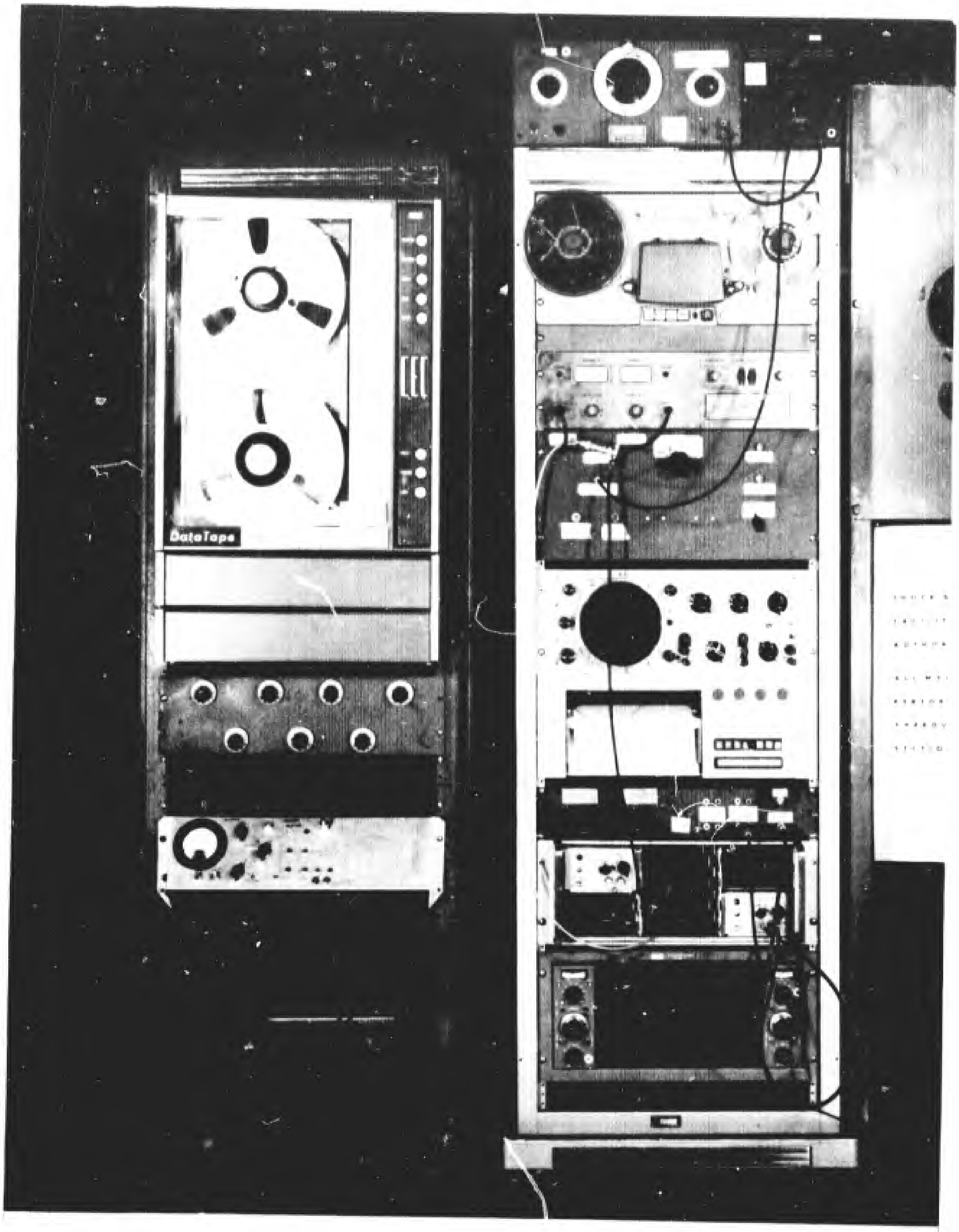


Figure 9. Instrumentation Used to Record Shock Pulses in Air Gun

Figure 10. Cable Feed-Through Assembly for Five-Inch Air Gun - Exploded View

Figure 11. Cable Feed-Through for Five-Inch Air Gun - Assembly Installed

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