United States Patent

Teng

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[45] **July 25, 1972**

[54] BALLISTIC COMPRESSION DECELERATOR

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[73] Assignee: **McDonnell Douglas Corporation**

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[52] **U.S. Cl.** ..... **73/167,** 73/432 SD

[51] **Int. Cl.** **G01n 17/00**

[58] **Field of Search** ..... 73/167, 12, 11, 432 SD

[56] **References Cited**

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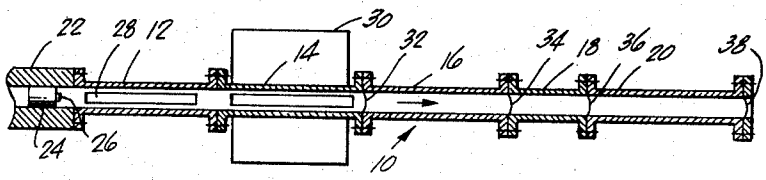
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Assistant Examiner—Denis E. Corr
Attorney—Walter J. Jason, Donald L. Royer and Robert O. Richardson

[57] **ABSTRACT**

Projectiles are recovered from free-flight for analysis of flight effects on the projectile. Recovery is accomplished by converting kinetic energy into controlled heat of compression which is dissipated in several stages. Shock compression is used during supersonic velocities of the projectile and adiabatic compression is used during sonic and subsonic velocities. Decelerator tubes having diaphragms within them are precharged to high pressure in front of the projectile to minimize the decelerating distance. The final diaphragm may or may not break depending upon the adiabatic pressure buildup.

6 Claims, 5 Drawing Figures



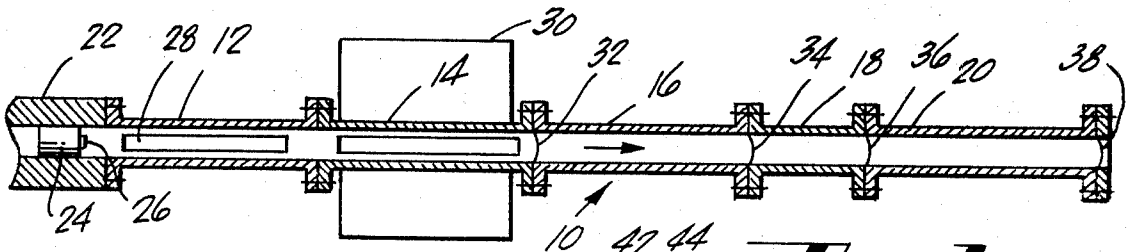


Fig. 1

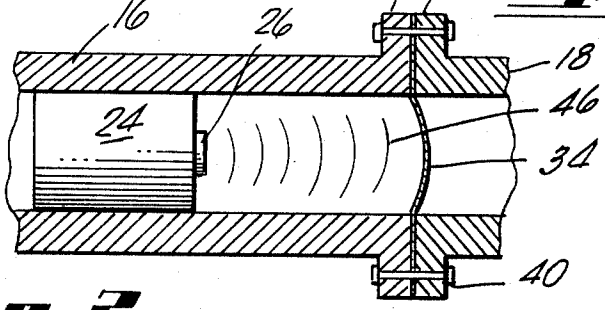


Fig. 2

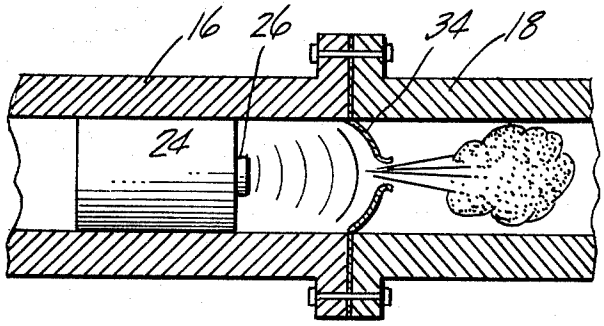


Fig. 3

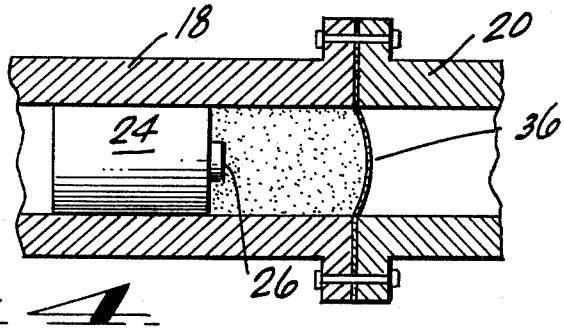


Fig. 4

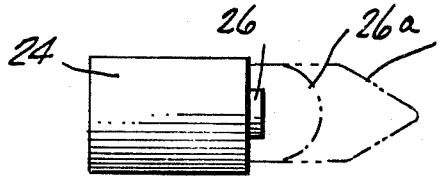


Fig. 5

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BALLISTIC COMPRESSION DECELERATOR

BACKGROUND OF THE PRESENT INVENTION

A ballistic range as used herein is a scientifically-oriented artillery-like device for accelerating projectiles to high velocities for the purpose of studying free-flight and impact phenomena. A small projectile test specimen of the desired size and configuration is mounted on a sabot which adapts the specimen to the gun barrel. The rapidly expanding gases of an explosive charge behind the sabot sends it through a simulated environment chamber where it is subjected to rain, dust or other test material. Muzzle velocities generally attain a maximum of 30,000 feet per second and projectile sizes vary up to 1.5 inches in diameter or larger. For tests specifically conducted to study impact, the projectiles are directed into a target and in the process are either destroyed or heavily distorted. In free-flight tests, it has been highly desirable to recover the projectiles for analysis of the flight effects. A variety of techniques have been attempted, mostly unsuccessful due to cost, distances needed, and setup time. Until the present invention, the projectiles were destroyed on impact and test results were confined to high speed photographic pictures taken of the projectile at various stages along its flight path. Results at best were inclusive as readings from photographs lacked precision accuracy

A technique which has been successfully employed in stopping a projectile having a velocity up to 1,000 feet per second uses a series of axially aligned replaceable metal washers through which the projectile is fired. The projectile has a slightly larger diameter than the hole in the washers and the hole in the middle permits the greater portion of the projectile to pass through the washers. The washers thus act as energy absorbers during the deformation caused by the successive impacts of the projectile periphery with the washers. This process destroys the periphery of the projectile, a little each time a washer is struck, and hence, whole projectile recovery is not attainable. Another technique includes long shallow-tapered converging walls of the gun muzzle utilizing frictional deceleration on, and hence wear on, the projectile. In these approaches to the deceleration of the projectile some damage occurs and thus some measurements cannot be accurately made.

SUMMARY OF THE PRESENT INVENTION

This invention solves the recovery problem for guided projectiles specifically for rain and dust erosion testing but can be applied to any other ballistic test in which a non-separable sabot is utilized. The sabot with projectile test specimen is fired through a tube having diaphragms across its path to provide pressure compartments through which the sabot passed. The sabot acts as a driven piston that compresses gas in front of it until the pressure counteracts the propelling force of the sabot and it stops — undamaged. The principles employed convert kinetic energy into controlled heat of compression which is dissipated in several stages. Shock compression is used during supersonic velocities and adiabatic compression during sonic and subsonic velocities.

After the projectile has been launched down range, it passes vents which relieve the launch gases and the projectile assumes a near constant free-flight velocity as it goes through a test environment chamber where it is subjected to rain, dust or other environmental tests. While at supersonic velocity, a shock precedes the advancing projectile and compresses air or other gas in the tube ahead of it, causing the projectile to slow down. As the projectile slows, the pressure in front also decreases. A second stage high-pressure shock decelerator is precharged to a higher pressure than the low pressure shock decelerator and minimizes the decelerating distance of the projectile. Each pressure buildup, in turn, causes the diaphragms to rupture at an optimum predetermined pressure. The use and quantity of diaphragms depend on the gases employed in the decelerator tubes. After slowing to sonic or subsonic velocities, the projectile enters the adiabatic decelerator

and is slowed to a standstill. The final diaphragm may or may not break depending on the adiabatic pressure buildup. If a diaphragm does break, a plastic foam catcher will receive the projectile.

Major advantages of the present system are that the projectile can easily be recovered, totally intact, with no changes or alterations to the results induced by the test environment. The decelerator chamber can be easily built at low cost from materials readily available. The re-cycle time is short and operational costs are low. The decelerator is easily adapted to variables such as projectile velocity, heating, and mass by simple changes in the precharged pressures, the types of gases used, and the diaphragm thickness.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a vertical sectional view of the deceleration apparatus at the termination end of the range;

FIG. **2** is an enlarged sectional view of the sabot approaching a diaphragm at supersonic velocity;

FIG. **3** is an enlarged sectional view showing the advance shock wave rupturing the diaphragm;

FIG. **4** is an enlarged sectional view of the sabot approaching the diaphragm at subsonic velocity; an

FIG. **5** is a illustration of a sabot with alternate projectile configurations affixed thereto.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENT

Referring now to FIG. **1** there is shown a ballistic compression decelerator **10** consisting of a plurality of tubes **12**, **14**, **16**, **18** and **20**. These tubes are interconnected in alignment to provide a projectile path extension from ballistic muzzle **22** from which a sabot **24** with a test specimen projectile **26** thereon is fired. Each of these tubes are about 20 feet long and have an internal diameter of about 1 ⅝ inch. The test specimen **26** is of smaller diameter, such as one inch for example, so as not to engage and be damaged by the inner walls of the deceleration tubes. Details of construction and operation of the projectile launching structure to which the ballistic compression decelerator **10** are attached are not herewith shown and described, since such is well known and it is not the starting of the projectile but the stopping of it that is the concern of the present invention. It is herein sufficient to say that the projectile **26** has a velocity of up to 30,000 feet per second upon leaving muzzle **22**.

Tube **12** has a plurality of vents **28** to prevent compression of gases in front of the sabot and slows down before passing through the environmental chamber. These vents **28** also relieve the launching gases in order for the projectile to assume a near constant free-flight velocity when it continues through the test environment chamber **30**, over tube **14**, where the test specimen **26** is exposed to the affects of the environment (e.g., erosion by rain or dust).

Diaphragms **32**, **34**, **36** and **38** extend across the openings of the tubes at the points of interconnection and serve as a barrier so that the gas between the oncoming projectile and the diaphragm may be compressed. This compression causes the absorption of kinetic energy, causing the projectile **24** to slow down. The diaphragms preferably are made of a Mylar composition and are of a paper-thin thickness on the order of 0.005 inches thick. The term "Mylar" as used herein is the trademark of E. I. duPont deNemours & Company, Inc., and refers to the polyethylene terephthalate material manufactured by them. The temperature is proportional to the velocity to the projectile for the particular gas medium used. For example, at a velocity of 10,000 feet per second, the heat caused by compression, if the gas is air, would be 6,000° F. whereas for hydrogen, the temperature would be 2,000° F. During the supersonic phase of projectile flight, a shock precedes the advancing projectile and commences to compress the air or other gas, such as hydrogen or helium, in the decelerator tubes **16** or **18**, just in front of the projectile. The pressure within the

tube in front of the shock wave may be 20 psi whereas the pressure behind the shock wave may be as high as 200 psi so that when the shock wave reaches the diaphragm, it will cause the diaphragm to burst before the sabot **24** and test specimen projectile **26** reaches it As the projectile **26** slows down, the pressure in front of it also decreases.

As the projectile proceeds down its path into tube **18** and tube **20**, it slows to a sonic or subsonic velocity. These tubes, **18** and **20**, are second-stage shock decelerators which are precharged to a higher pressure than that of the low pressure shock decelerator tube **16**. As the missile continues at a subsonic velocity, the pressure is built up in each tube until it causes the associated diaphragm to rupture at some optimum predetermined pressure. The use and quantity of diaphragms depend on the gases employed in the decelerator tubes and the length of the tubes, as well as the free-flight velocity of the test specimen. Any number of tubes and their length may be used so that the projectile will continue along its free-flight path until it is slowed to a standstill. A final diaphragm **38** may or may not break depending upon the adiabatic pressure buildup. If the diaphragm **38** does break, a plastic foam catcher, not shown, will capture the projectile unharmed.

Reference is now made to the enlarged illustration in FIG. **2** which shows tube **18** secured to tube **16** by means of a plurality of connecting bolts **40**, peripherally connecting cooperating flanges **42** and **44** on the abutting ends of the tubes **16** and **18**. A diaphragm **34** is positioned in between to provide a means for pressurizing the chamber within tube **16** preceding projectile **26**. As the projectile **26** moves down the flight path, the pressure preceding the shock wave **46** may be on the order of 20 pounds per square inch, for example, and the pressure after the shock wave may be 200 pounds per square inch. When the shock wave **46** reaches the diaphragm **34** it will cause the diaphragm **34** to rupture, as shown in FIG. **3**. The diaphragm is punctured by the buildup in pressure and not by the projectile **24**. After the projectile has passed through a plurality of tubes having diaphragms over their ends, and the projectile is made progressively slower in velocity, there is no shock wave but there is a continuous buildup in pressure within the chamber until either the diaphragm ruptures or projectile stops. Such a pressure buildup is shown in FIG. **3** between diaphragm **36** and the projectile **26**.

The deceleration apparatus and technique just described stops the projectile **24** with its test specimen **26** of any desired configuration. As shown in FIG. **5**, it may be a cylindrical disk **26**, a hemisphere **26*a*** or a conical nose **26*b***, for example. One test of the effect of the environment upon the projectile is its loss in weight due to erosion. Such test specimens are carefully weighed before their attachment to the projectile **24** by means of a threaded connection, glue or some other means and, after the test, the test specimen is removed and again weighed to determine the amount of erosion suffered by its passage through the environmental chamber along the ballistic range. Of course, other tests may be made in light of the fact that the projectile and test specimen may be recovered unharmed after its flight through the simulated environment.

Some of the major advantages of the present system of compression deceleration of a ballistic projectile is that the projectile can easily be removed, totally intact, with no changes or alternations in the results induced by the test environment. The structure utilizing the invention can easily be built at low cost with materials readily available. The re-cycle time is very short, on the order of 15 minutes, requiring only the replacement of the punctured diaphragms. Variations are easily made as to projectile velocity, heating, and mass by simple changes in the precharging pressures, types of gases used, and diaphragm thickness.

Having thus described alternate forms of illustrative embodiments, it is to be understood that further modifications will readily occur to those skilled in the art and that it is to be understood that these modifications are to be considered as part of the present invention as claimed.

I claim:

1. In combination with a ballistic range wherein a projectile is accelerated to high velocities,

a ballistic compression decelerator for stopping said projectile without damage thereto, said decelerator comprising decelerator tubes through which said projectile passes, said tubes having diaphragms over the ends thereof to cause gas in front of said advancing projectile to compress,

said diaphragms being of a strength to cause a buildup of pressure in front of said projectile yet rupture before being pierced by said projectile, whereby said projectile is successively decelerated as it passes through successive tubes until said projectile is completely decelerated.

2. A ballistic compression decelerator as in claim **1** wherein said diaphragms are made of polyethylene terephthalate and have a thickness on the order of 0.005 inches.

3. A ballistic compression decelerator as in claim **1** wherein five tubes approximately 20 feet long are used, each having a diaphragm over the end thereof.

4. In combination with a ballistic range wherein projectiles are accelerated to high velocities through an environment test chamber,

a ballistic compression decelerator comprising a series of decelerator tubes through which said projectile passes and through which a shock wave proceeds the advancing projectile, said tubes having diaphragms over the ends thereof to cause air in front of said advancing projectile to compress,

some of said decelerator tubes being precharged to a higher pressure to reduce the decelerating distance of said projectile.

5. In combination with a ballistic range wherein a projectile may be accelerated to high velocities through an environment test chamber,

a ballistic compression decelerator including a low pressure shock decelerator tube through which a supersonic shock wave proceeds the advancing projectile, said tube having a diaphragm over the end thereof to cause air in front of said advancing projectile to compress,

said ballistic compression decelerator including a high pressure shock decelerator tube axially aligned with said low pressure shock decelerator tube having a diaphragm over the end thereof and precharged to a higher pressure than in said low pressure shock decelerator tube to reduce the velocity of said projectile to sonic and subsonic velocities after said projectile has passed through said low pressure shock decelerator tube, and

additional decelerator tubes axially aligned with said low and high pressure shock decelerator tubes having diaphragms over the ends thereof for building up pressure therein for slowing said projectile from sonic velocities to a standstill after said projectile has passed through said high pressure shock decelerator tube.

6. In combination with a ballistic range wherein a projectile may be accelerated to high velocities through an environment test chamber,

a ballistic compression decelerator for stopping said projectile without damage thereto comprising a low pressure shock decelerator tube through which a supersonic shock wave proceeds the advancing projectile, said tube having a diaphragm over the end thereof to cause air in front of said advancing projectile to compress,

a high pressure shock decelerator tube extending from said low pressure shock decelerator tube and having a diaphragm over the end thereof and precharged to a higher pressure than in said low pressure shock decelerator tube to reduce the velocity of said projectile to sonic and subsonic velocities, and

an adiabatic decelerator tube extending from said high pressure shock decelerator tube and having a diaphragm over the end thereof for building up pressure therein for slowing said projectile from sonic and subsonic velocities to a standstill.

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