April 28, 1964 J. W. ROGERS 3,130,575

IMPACT TEST APPARATUS

Filed June 19, 1961

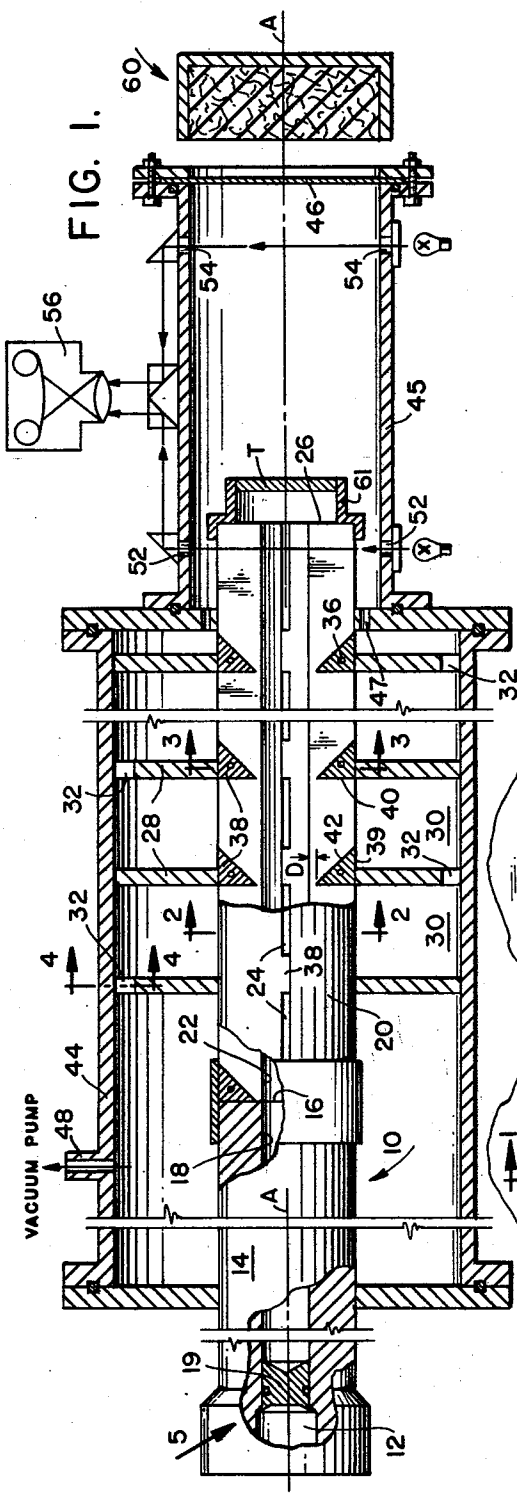


FIG. 1.

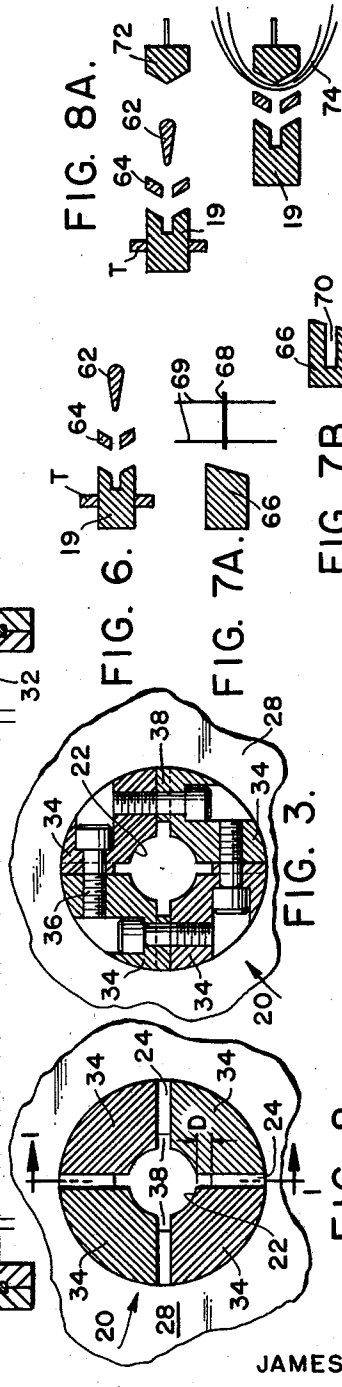


FIG. 2.

FIG. 8A.

FIG. 8B.

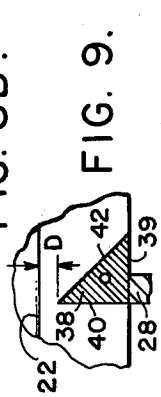


FIG. 9.

FIG. 6.

FIG. 7A.

FIG. 7B.

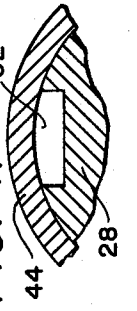


FIG. 4.

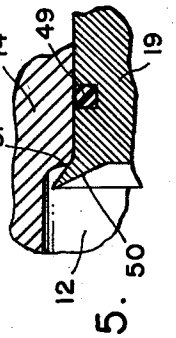


FIG. 5.

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IMPACT TEST APPARATUS

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4 Claims. (Cl. 73—12)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to a gun device for use in research, testing and the like, to shoot a projectile under accurately controlled conditions. The improvement of the present invention relates more particularly to controlling the release of the pressurized propellant gases present within a gun barrel as the projectile emerges from the gun.

For purposes of this specification, a "gun" is hereby defined as a projectile-impelling system including a tubular "gun barrel" along which the projectile is impelled by the sudden application of pressurized "propellant gases" behind the projectile. The gases may be provided by the ignition of an explosive gas, as in the case of a conventional gun, or by a mechanism for releasing or producing a charge of highly compressed gases, as in the case of the so-called "gas guns." The energy to impel the projectile is furnished by the expansion of the propellant gases in the gun barrel.

There has been a continuing need for an apparatus to stage high velocity impact experiments under accurately controlled conditions in the velocity range extending upward from 5000 feet per second. Prior art methods are chiefly methods in which the elements to be impacted are placed in the field of explosive force of a generally unconfined explosive charge. Only very rough control of the conditions of the experiment, such as the alignment of the elements to be impacted and their fragmentation, are possible with these methods. Furthermore, these methods are expensive in that the explosive charges must be especially manufactured and in that the experiments must be conducted at ordnance test facilities.

Solution of this problem has been made more difficult by the exacting and critical control of the conditions of experiment which may be required. Exemplary of a type of experiment having exacting requirements is a "Monroe effect" observation in which a metal specimen having a conical cavity is impacted against the surface of a metal plate. In certain instances, the penetration of the conical cavitied element into the plate produces a gasified jet of metal which emerges from the other surface of the plate. Fundamental information as to the properties of metals, such as equation of state data, may be obtained by investigating the critical configuration of the impacted element and the critical velocity of impacting which form the boundary conditions separating the instances when the gasified jet is produced and when it is not produced. The success of such investigations depend on accuracy of alignment of the impacted elements at the time of impact and the accuracy of velocity measurement. For example, where the test projectile is of the general size of a .50 caliber bullet, an alignment error of .001 inch or a velocity measurement error of one percent could significantly affect the conclusions of the experiment. Other examples of needs for staging accurately controlled impact experiments include study of the mechanics of penetration and testing of ordnance fuze components.

Staging impact experiments by shooting a projectile from from a gun are known. However, in prior art guns the presence of the pressurized propellant gas in the gun barrel behind the projectile as it leaves the muzzle has severely limited the accuracy and reproductibility of the projectile flight trajectory. These gases are under extremely high pressure and travel at high velocities, and upon the sudden unsealing of the muzzle when the projectile leaves the muzzle, the gases emerge from the muzzle in a blast which causes the projectile to yaw in flight rather than follow a true bore sight trajectory. As a result, such prior art guns are limited in practical use to the firing of projectiles which restore themselves to a rectilinear trajectory after leaving the gun, such as where the projectile is made to spin in flight by provision of rifling along the gun barrel bore and therefore spin stabilizes itself, or where the projectile has an aerodynamic shape which produces restoring moments during the flight. It therefore has been a hitherto unobtained objective to provide a gun which launches the projectile along a true non-yawing trajectory in the absence of such trajectory restoring means.

It was then considered that impact experiments in which a stationary target element is to be penetrated and passed through, such as for observing the aforesaid "Monroe effect," could be staged by placing the target element in abutting relationship against the muzzle of a smooth bore gun so that the gun barrel is in effect used as a sliding way to "rigidly" guide the projectile into impact with the target. This can be shown to be impractical; again because of the presence of the pressurized propellant gases behind the projectile. Apparently, the abutting target element constitutes such an obstruction as to prevent the proper relieving of these gases that the gun barrel would deform or burst under the tremendous pressure that is built up within. Another prior attempt proposed placing the target sufficiently far away from the muzzle of the gun to avoid damaging the barrel, but sufficiently close that the impact occurs before the motion of the projectile is significantly altered by the muzzle blast. However, it has been shown by test that, at best, this approach yields results in which only a very small proportion of rounds fired achieve the desired accuracy.

Also proposed, was modifying the gun with a conventional small bore weapon muzzle blast device of the type consisting of an extension to the gun barrel having a series of perforations along its length. This has not proved satisfactory because a shattering or breaking up of the projectile occurred before it hits the target. Although the reason for this shattering effect is not fully understood, it is believed that the projectile is subjected to thrust transients of such character as to cause high frequency vibrations, which in turn shatter the projectile.

The problem of accurate control of experimental conditions is further aggravated by presence of any air or gaseous medium ahead of the projectile in the barrel itself, or along its flight trajectory after leaving the barrel. This was partially overcome in the prior art by sealing the muzzle of the gun barrel with a diaphragm and evacuating the barrel so that the projectile motion in the gun barrel, at least, is unimpeded by the presence of such air. Nevertheless, existence of air medium along the subsequent flight lines of the projectile reduced the reliability of velocity measurements, and in some instances caused a shock wave to be attached to the projectile which adversely affected the experiment. This prompted an attempt to fire a projectile into an evacuated chamber. It was observed that the propellant gases released from the gun barrel disperse with a greater velocity than the projectile and that these gases therefore pass around and ahead of the projectile with the same effect as in the case of firing into a normal atmosphere.

As distinguished from these and other unsuccessful prior attempts, the objects of the present invention include:

(1) The provision of a gun device for use in research, testing, and the like to provide high velocity impacts under accurately controlled conditions.

(2) The provision of a gun device by which a projectile may be impelled along a non-yawing flight trajectory.

(3) The provision of a gun device by which a projectile may be accurately guided into direct impact with a stationary target.

(4) The provision of a gun device capable of launching a projectile along a flight trajectory which is substantially under a vacuum.

(5) The provision of a gun device in which provision is made to: (*a*) relieve the propellant gases present in the gun barrel behind the projectile prior to the projectile leaving the gun, and (*b*) to retard the dispersion of the propellant gas to permit the projectile to travel ahead of the gases.

Other objects, features and attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein:

FIG. 1 is a partial longitudinal section through a gun device embodying the present invention taken along line **1**—**1**, of FIG. 2;

FIG. 2 is an enlarged transverse section taken along line **2**—**2**, FIG. 1;

FIG. 3 is an enlarged section taken along line **3**—**3**, FIG. 1;

FIG. 4 is an enlarged fragmentary detail section taken along line **4**—**4**, FIG. 1;

FIG. 5 is a fragmentary detail section indicated by arrow **5**, FIG. 1;

FIGS. 6, 7A, 7B, 8A and 8B are diagrammatic views showing projectile and target fragmentation in certain impact experiments; and

FIG. 9 is an enlarged fragmentary detail section of FIG. 1.

Referring to FIG. 1, a gun device embodying the present invention is comprised of a gun **10** for shooting a projectile, the gun including a breech chamber **12**, a gun barrel **14** and a muzzle opening **16** from which the projectile is discharged. Gun barrel **14** is provided with a smooth cylindrical bore **18** having an axis A. A projectile **19** is initially disposed at the breech or rear end of bore **18** and breech chamber **12** contains means (not shown) such as an explosive charge or other gas source for suddenly applying pressurized propellant gases to the base of projectile **19**. Gun barrel **14** is of such length that an efficient expansion of gases is obtained to impel projectile **19** along bore **18** and out through muzzle opening **16**.

Attached to the muzzle end **16** of gun barrel **14** is a tubular unit **20** provided with an internal surface or bore **22** which forms an aligned extension of bore **18** and slidingly receives the projectile after it leaves the gun and guides it in continued rectilinear motion along axis A. Tubular unit **20** is provided with four equiangularly spaced slots **24** extending the length of the unit for venting or releasing the pressurized gases present in the gun barrel behind the projectile as the projectile travels along the unit. The aperture area provided by the slots is such that substantially all the pressurized gases are relieved by the time the projectile reaches the front end **26** of the tubular unit. It is to be noted that such longitudinally extending slots continuously vent the region immediately behind the projectile throughout its movement along the tubular unit **20**, so that the gases are relieved without application of thrust transients to the projectile.

A series of annular baffle plates **28**, **28** extend laterally from tubular unit **20** at regularly spaced intervals along the length of unit **20**, forming a series of annular chambers or compartments **30**, **30** into which the gases venting through slots **24** may expand. It will be apparent that adjoining compartments are communicated by the passageway area of bore **22** and slots **24**. This aperture area is of such physical relationship to the volume of the compartments that a very large proportion of the gases flowing into each chamber are entrapped in same for a residence time which is long relative to the time it takes the projectile to traverse its trajectory. This provides a delay of propagation of the gases in the direction of projectile travel to permit the projectile to travel ahead of the dispersing gases. (There are also small staggered openings **32**, best shown in FIG. 4, formed in the periphery of annular baffle **28**, but these openings have a negligible effect on the residence time of the gases since they are disposed at the outer extremity of each compartment where the gases have lost their pressure, openings **32** being provided for different purpose to be subsequently described).

The walls of tubular unit **20** are formed from separable quarter circle or quadrant sections **34**, **34** secured together by suitable means, such as threaded fasteners **36**. Associated with annular plates **28** are triangular boss sections **38** which are integrally formed at spaced intervals along one of the radial edges of each quadrant section **34** for maintaining the confronting radial edges in spaced relationship to provide the aforementioned slots **24**. As best shown in FIG. 9 each triangular boss portion **38** has a base side **39** which abuts the inner periphery of an associated plate **28**, and a side **40**, the surface of which is in the plane of the rear surface of the baffle plate. This additionally closes the aperture area communicating adjoining compartments and thus assists in increasing the residence time of the gases in the compartments. It is to be noted, however, that the passageway area of slot **24** is not fully restricted since boss portions **38** are radially spaced from bore **22** by a distance D, FIGS. 1, 2 and 9, so that in actuality slot **24** extends continuously along the length of unit **20**. The surface of the remaining side **42** of each boss portion **38** is inclined at a relatively sharp angle to the surface of side **40**. This sharp inclination angle reduces the likelihood of any of the expanding gases, which travel at a velocity substantially greater than the velocity of the projectile, being deflected around and ahead of a traveling projectile by the surface of boss portions **38**. It will be apparent that the baffles **28** and associated bosses provide labyrinth gas seal means between the gas compartments and a traveling projectile.

The forward portion of gun **10**, the majority of the length of tubular unit **20** and the baffle means **28** are enclosed by a large diametered pressure tight cylindrical housing **44**; and the forward end of unit **20** and a portion of the flight path of the projectile ahead of the unit are enclosed by small diametered pressure tight cylindrical housing **45**, which is closed at its front end by a rupturable diaphragm **46**. Housings **44** and **45** are communicated through bore **22** and slots **24**, and also through a series of apertures **47** formed in the transverse wall at the front end of portion **44**. Larger diameter housing **44** is provided with a connection **48** adapted to be connected to a vacuum pump, the previously described openings **32** in the baffle and apertures **47** between the housings being provided to assist in communicating all the spaces within housings **44** and **45** and the connection **48** for fast evacuation. This provides for the evacuation of air from housing **44**, housing **45**, gun barrel **14**, unit **20** and compartments **30**. However, breech chamber **12** is not included in such evacuable zone, there being an O-ring **49**, FIG. 5, in a recess formed in the outer surface of projectile **19** to assure a gas tight seal between the projectile and bore **18**. A flange **50**, FIG. 5, is formed in the base of projectile **19**, which flange seats against a shoulder **51** formed at the rear end of bore **18** and restrains the projectile against being pulled along the bore by the force of the vacuum. When the gun is fired and the force of the propellant gases are applied to the projectile, flange **50**

bends back and permits the projectile to proceed down the gun barrel. It is to be understood, however, that the gas relieving and gas retarding features of this invention have also proved successful in a normal atmosphere, so that it is not intended that the invention be limited to operation in such evacuated housing.

Formed in small diameter housing **45** is a pair of diametrically opposite windows **52**, which are disposed a short distance ahead of front end **26** of tubular unit **20** and which are aligned with a pair of slots **24** to provide a line of sight for optical instruments. Another pair of windows **54** disposed near the front end of housing **45** are additional optical instrument stations. The time of transit of projectiles and target fragments between these instrument stations may be measured by directing a narrow beam of light, such as may be produced by a point light source, through each pair of windows and thence by means of prisms into a high speed camera **56**, in which a strip of film moves continuously at a known speed. There the respective light beams are recorded as independent continuous streaks on the film. Passage of the projectile or target through the beams of light produce interruptions in these streaks permitting calculation of time of transit by direct measurements on the film. If desired, optical instrument windows (not shown) may be provided in the wall of large diameter housing **44** and aligned with slots **24** in order to observe projectile velocity prior to impact. After the projectile passes through the housing **45** it penetrates diaphragm **46**, and is then caught in a box **60** containing cotton or other soft material.

The operation of the above described invention can best be understood by again referring to the drawing. For example, to observe "Monroe effect" jets, a target plate T may be positioned slightly ahead of the front end **26** of tubular unit **20** by a suitable target support **61**. Housing **44** is evacuated and the gun is then actuated impelling the projectile **19** down bore **18** and along surface **22** of tubular unit **20**, which guides it into impact with target T. If desired, an expansible sleeve (not shown) of brass or other relatively soft material having a bore forming a further extension of bore **18** may be interposed between end **26** of unit **20** and the target to provide rigid guidance directly to target to thereby obtain maximum accuracy of alignment upon impact. The pressurized propellant gases present behind the projectile are fully dissipated through slots **24** before the projectile reaches end **26** of tubular unit **20** and the dispersion of the gases in the direction of travel of the projectile is impeded by the arrangement of baffles **28** and compartments **30**. Thus, by the time the projectile strikes target T there are substantially no pressurized gases in the region immediately behind the projectile which obviates the problem of deforming or bursting the gun barrel and causing yaw in the subsequent trajectory. These gas relieving and retarding features have been found to be so effective that front end **26** of unit **20** is under a substantial vacuum at the instant the impact takes place, and small diameter housing **45**, or at least the portion of it ahead of the progressing projectile, remains under vacuum conditions also. Where the Monroe effect is exhibited the test projectile and target are fragmented forming a jet of gasified metal **62**, FIG. 6, which travels down range at a velocity many times the velocity of the projectile, followed by a fragment **64** of plate T which was "plugged out" by the penetration of the plate by the projectile and which moves at about the velocity of the projectile. These fragments follow a substantially rectilinear trajectory aligned along axis A and are caught in box **60**.

FIGS. 7A and 7B show sequential conditions before and after impact in a penetration experiment in which a projectile **66** having a predetermined configuration is shot at a stationary short length of wire **68** which may be held in place at end **26** of tubular unit **20** by a pair of prepunctured diaphragms **69**. The impact produces a crater **70** in the projectile. It is to be noted that in this case a determination of the penetration into the projectile is sought so that in effect the target is being impelled against the wire.

FIG. 8A and 8B show sequential conditions in a novel use of the apparatus as a "wind tunnel" in which a model **72** having a predetermined configuration is inserted in the path of a jet **62** of gasified metal produced by impact. When the jet of metal strikes the model it forms a luminous shock wave **74** which may be recorded by a camera.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In apparatus for determining the effect of impact of a test projectile upon a target of type including;

(*a*) a gun of the type having a smooth bored barrel along which the test projectile is impelled under force of propellant gases behind the projectile, and

(*b*) a barrel extension having its rear end abutting the muzzle of said barrel,

(*c*) said barrel extension having a plurality of co-extensive elongated gas relieving slots extending through its wall and longitudinally aligned with the axis of the barrel extension and equi-angularly spaced about said axis,

the improvements comprising,

said barrel extension having disposed therealong between the front and rear ends of the slots,

(*d*) a longitudinally extending sequential series of gas expansion chambers surrounding the barrel extension and communicating with the bore through said slots,

(*e*) said series of chambers having in cooperative association therewith a series of restricted slot sets disposed at a transverse station located between pairs of adjacent chambers to restrict forward propagation of gas through the slots,

said restricted slot sets comprising a restricted slot means disposed in each of said equi-angularly spaced slots,

each of said restricted slot means forming an extension of the wall separating the chambers of the adjacent pair,

whereby emergence of gases from the front end of the barrel extension prior to emergence of the test projectile is substantially inhibited.

2. Apparatus in accordance with claim 1,

(*g*) each of said restricted slot means forming a radially inwardly directed transverse edge,

to thereby prevent damage to the test projectile from vibratory shocks experienced under sudden fluctuations in force of the propellant gas acting against the test projectile as the rear end of the test projectile passes each station containing a restricted slot set.

3. Apparatus in accordance with claim 1,

(*h*) each of said restricted slot means having its rear edge forming a continuation of the rear face of said wall separating the chambers and having its front edge forming a frontwardly divergent face inclined to the axis of the barrel extension.

4. Apparatus in accordance with claim 1, including

(*g*) an observation chamber into which the projectile is discharged from the barrel, and

(*h*) means for maintaining the series of chambers and the observation chamber under substantial vacuum.

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