June 7, 1960 E. L. ARMI ET AL 2,939,318

APPARATUS FOR THE DETERMINATION OF INTERIOR BALLISTICS

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FIG. 1

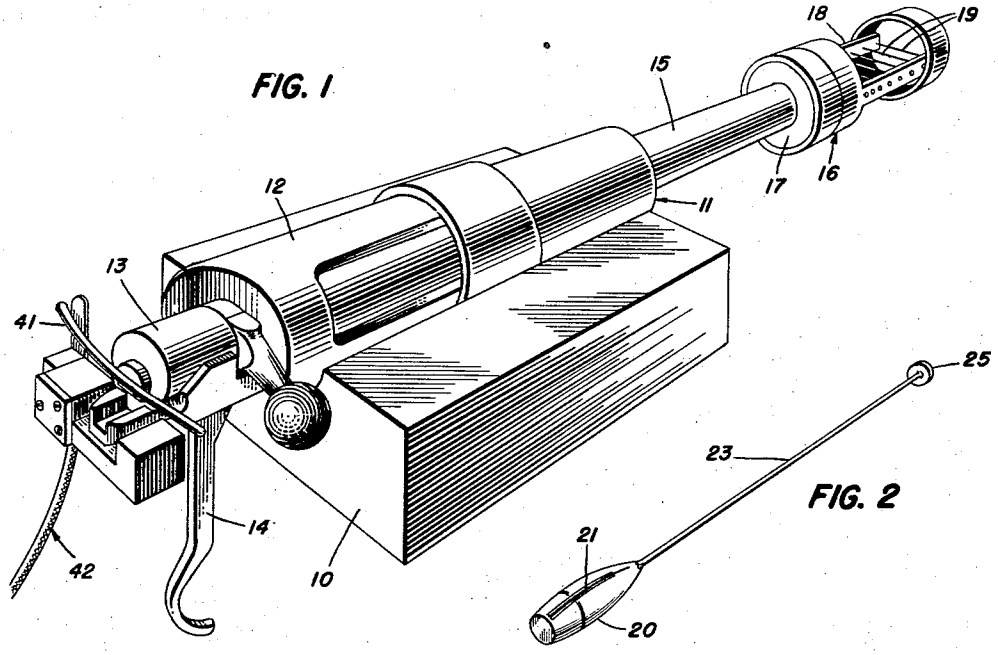
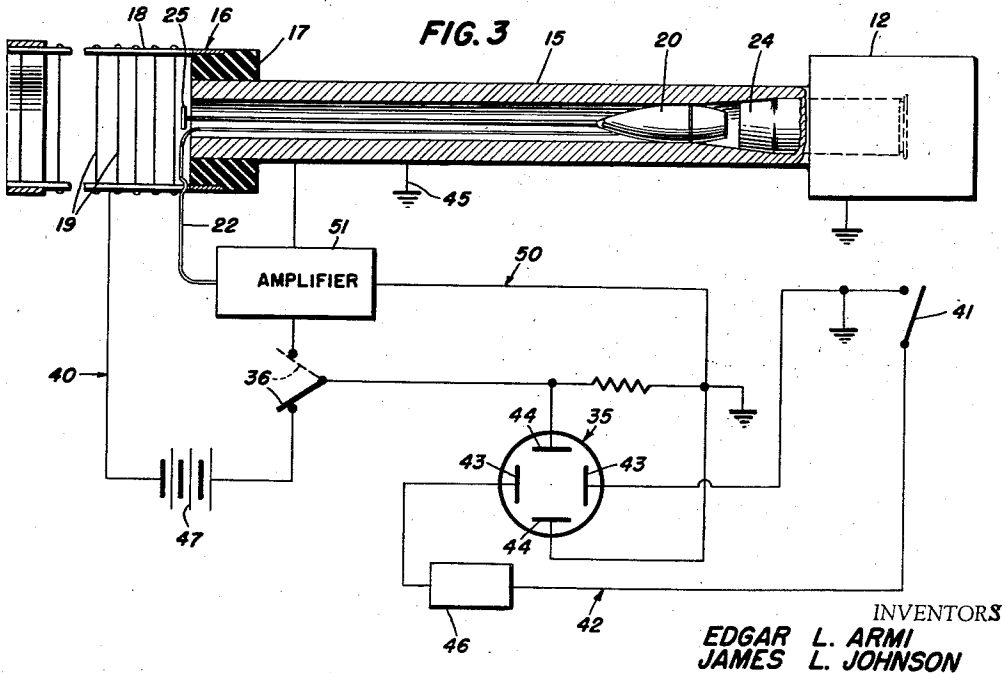


FIG. 2

FIG. 3



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FIG. 4

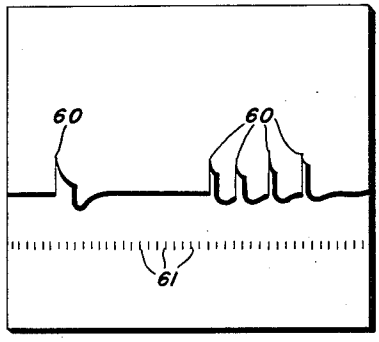
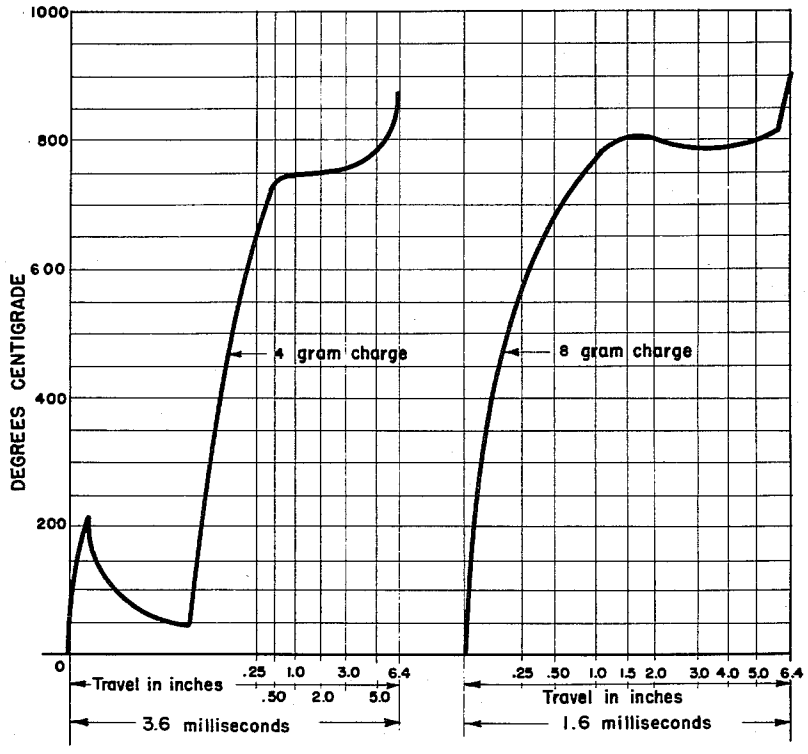


FIG. 5



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APPARATUS FOR THE DETERMINATION OF INTERIOR BALLISTICS

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3 Claims. (Cl. 73—167)

This invention relates to an apparatus for determining interior ballistic characteristics of a projectile and more particularly to a method and apparatus for accurately ascertaining the interfacial temperature changes induced by a bullet fired through a gun barrel bore.

Heat measurement apparatus and a method for determining frictional interfacial temperature between a bullet and a gun bore utilizing a freely falling weight apparatus were disclosed in copending application Serial No. 295,624, filed June 26, 1952.

Advances in the ordnance art have necessitated accurate ballistic studies into the hitherto unknown variables inherent in propelling a projectile, in order to incorporate in a gun design compensating factors which will provide for greater accuracy. Interior ballistics relating particularly to the heat increment resulting solely from the frictional resistance between the periphery of a bullet and the lands and grooves of the rifling within the bore have not been determined accurately. The conventional ballistic tests produced a resultant temperature which included the summation of the heat input resulting from the frictional resistance from the propelled bullet, the heat input from the hot expanding powder gases, and other possible incidental heat from radiation, convection, and conduction. Furthermore, it is desirable to be able to determine accurately the individual contribution by each of the variables to the total heat input and how the factors vary at determinable stages. Therefore, the present invention contemplates providing an accurate means for determining that heat increment of the summation of the total heat which is the effect produced solely by the frictional contact between the projectile periphery and the gun barrel. Furthermore, this invention will provide a means for measuring the temperature at the interfaces between the projectile and the gun bore at predetermined intervals as the projectile is accelerated through the gun barrel bore during actual firing with actual powder charges as distinguished from simple impact testing.

The present invention has as an object to provide an apparatus for accurately determining the frictional heat generated by a projectile passing through the gun barrel during actual firing.

Another object of this invention is to provide means for determining frictional heat generated at specific points and intervals by a bullet as it is projected through the barrel of the gun.

A further object of the invention is to provide means for accurately determining the frictional interfacial temperature at spaced intervals of projectile passage through the bore of a gun.

Still another object of this invention is to provide a sliding thermocouple capable of indicating the electromotive forces generated during propulsion of a bullet through the gun bore after actual firing.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following

detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a perspective view of a test stand embodying the present invention;

Fig. 2 is a perspective view of one form of a projectile which may be used with the invention;

Fig. 3 is a longitudinal sectional view of the embodiment of Fig. 1 wherein a bullet is shown positioned for firing and schematically illustrates an electrical circuit with an electromotive sensitive instrument therein;

Fig. 4 illustrates a photograph of the oscilloscope screen which graphically shows the vital timing intervals of the fired projectile; and

Fig. 5 illustrates graphically the plotted temperatures versus time and position of the fired projectile.

Referring to the drawings, in which like numerals designate the same parts throughout the several views, and more particularly to Fig. 1, there is illustrated a device constructed in accordance with the present invention which comprises a base **10** rigidly mounted to support the gun assembly **11**. The breech end **12** of the gun is securely mounted on the base **10** affording access to the breech bolt **13** and the firing mechanism **14**. A barrel **15** with conventional rifling or of a desired bore design is mounted on the gun assembly **11**. Tests conducted indicate accurate results are obtained from foreshortened barrels and the difficulty of maintaining an insulated conductor on a rapidly traveling projectile is substantially alleviated.

An annular adapter sleeve assembly **16** is securely mounted to the muzzle end of the gun barrel **15** through insulator bushing **17**. In the embodiment shown a pair of spaced parallel conductive bars **18** on sleeve assembly **16** are drilled at successive spaced intervals to accommodate a series of hardened steel wires **19** mounted in a plane normal to the axis of the barrel bore and in the path of projectile travel. However, a similar series of wires or comparable elements whether of a mechanical or electrical nature which will detect linear progression may be readily adaptable for use in conjunction with the barrel as by mounting thereon or external of the barrel for cooperation with the fired projectile. It will be readily appreciated that the severing of the wires **19** will be such as to cause imperceptible resistance to the flight of the projectile.

A bullet **20** conforming to the requisite tolerances and materials specified for the caliber gun to be used in the test is in the embodiment illustrated provided with an elongated slot **21** to accommodate a thermocouple lead wire **22**. Securely mounted and projecting from the nose of the bullet is an elongated rod **23** which will protrude from the gun barrel **15** when the projectile is securely seated in the breech end of the barrel. A wire severing disk **25** is mounted on the extreme end of the rod **23** and is aligned with the hardened wires **19**.

A cartridge **24** containing the desired powder charge is loaded within the breech at the base of the bullet **20** after the bullet has been seated within the breech bore. A conventional firing mechanism **14** is interconnected with the firing mechanism operated sweep switch **41** which when actuated will fire the cartridge **24**.

It will be observed that the bullet **20** and the barrel **15** provide a sliding hot junction of a thermocouple and the lead wire **22** affixed to the bullet periphery will transmit the electromotive forces generated between the barrel **15** and the bullet **20** to a suitable indicating instrument to be described.

The impact received from an explosive powder charge from cartridge **24** will force the bullet assembly through the barrel **15** with a motion which is approximately a constant acceleration. Therefore, it is desirable to correlate the position and time cycle of the bullet traveling

in an accelerated path with a function of the electromotive forces generated at various positions in the gun barrel so that a graphical analysis can be made by plotting temperature against time and position. It is found desirable also to obtain data for varying powder charges and the results for two such tests using a 4 gram and 8 gram charge are plotted in Fig. 5 and will be described hereinafter.

Various pyrometric means known in the art are adaptable for recording the temperature variations at the desired intervals. However, in the embodiment illustrated, a cathode ray oscilloscope tube **35** is employed which will indicate the relative positions and the interfacial electromotive forces generated by the traveling projectile at the respective locations within the gun bore **15**.

The electrical circuits constituting the recording system will be designated as the position-time circuit **40** and the electromotive force temperature circuit **50**. In the position-time circuit **40**; as the breech is bolted, a trigger operated sweep switch **41** closes the circuit **42** as the cartridge **24** is fired thereby completing the circuit **42** to the horizontal sweep plates **43** of the cathode ray oscilloscope **35** through the sweep circuit energizing source **46**. Selector switch **36** is operable between the position-time circuit **40** and the electromotive force temperature circuit **50** and when placed to close the position-time circuit **40** the energizing current of battery **47** will flow from the ground **45** through the barrel **15** and the traveling bullet assembly and when the disk **25** at the end of rod **23** on bullet **20** makes contact with each wire **19** in succession vertical deflections are produced on the cathode ray oscilloscope **35**. A photographic record made of the oscilloscope screen, illustrated in Fig. 4, clearly indicates the successive wire contacts made by the disk **25** as shown by the spaced peaks **60** relative to and measurable by spaced timing interval traces **61** which are placed on the oscilloscope screen **35**.

In order to determine the electromotive force temperature relationship at the desired points within the bore **15** the selector switch **36** is placed in the electromotive force temperature circuit **50** (as shown by the dotted line positioned in Fig. 3) and a flexible insulated lead wire **22** is securely fastened to the periphery of a similar projectile **20** in slot **21** and the projectile is then seated within the gun barrel bore. The free end of the lead wire **22** is passed through the bore and connected to a suitable amplifier **51**. As in the position-time circuit **40** after the powder filled cartridge **24** is inserted in the breech, the bolt **13** is locked and after the firing mechanism **14** is actuated the firing mechanism sweep switch **41** is closed thereby energizing the circuit **42** through the energy source **46** for the horizontal sweep circuit through plates **43** of the oscilloscope **35**. The electromotive force temperature circuit **50** which records the frictional electromotive force developed at the interfacial contact between the barrel and the bullet passes from the ground **45** through the barrel **15** to the sliding thermocouple which includes the barrel **15**, the traveling bullet **20** and the lead wire **22** through the amplifier **51** to influence the vertical deflecting plates **44** of the oscilloscope **35**. A photographic record of the oscilloscope tube **35** will indicate the electromotive force generated during bullet propulsion through the gun barrel bore. Converting the electromotive force values to corresponding temperature values and plotting them on the ordinate axis and the time-position values on the abscissa axis will present graphically a representation indicative of the interfacial temperature conditions during actual firing. Fig. 5 illustrates a combined graphical representation for test results using a 4 gram charge and an 8 gram charge.

Various powder charges may be used to produce the desired result in propelling projectiles from guns of various calibers and the results may be attained in a similar manner as above-described.

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 a ballistic device for determining the frictional interfacial temperature between a bullet and the bore of a gun barrel as the bullet is propelled therethrough, a position-time indicator comprising; a cathode ray tube having two pairs of deflection plates disposed in quadrature, a time trace generator connected to one of said pairs of plates, a plurality of conductive wires connected in parallel mounted on but insulated from said bore and spaced apart in a plane including the axis of said bore, means including a pair of mutually spaced bars composed of electrical conducting material for supporting said wires in advance of the muzzle end of said gun barrel, an annular member composed of insulating material mounted on said gun barrel and carrying said wire supporting means for insulating said wires from the bore, an elongated rod composed of electrical conducting material and having one end thereof secured to the nose of said bullet coaxial with said bore axis, a disk composed of electrical conducting material carried at the other end of said rod in a manner such that the wires lie in path of travel of said disk for progressively severing said wires as the bullet is propelled through said bore, a gun trigger-actuated switch secured to the breech end of said gun barrel to initiate operation of said time trace generator, a voltage source connected between said plurality of wires and one of said remaining deflection plates, and means including a conductor secured to said bullet for electrically connecting the other remaining deflection plate to said elongated rod.

2. In a ballistic device for determining the frictional interfacial temperature between a bullet and the bore of a gun barrel as the bullet is propelled therethrough, a position-time indicator comprising; a cathode ray tube having a pair of deflecting plates connected with a gun trigger-operated time trace generator, an annular member composed of insulating material secured to said barrel at the muzzle end thereof, a cylindrical sleeve mounted on said annular member and insulated from the muzzle of said gun barrel by the annular member, a pair of spaced conductive bars carried by said sleeve parallel with the axis of said bore, a ring secured to the terminal ends of said pair of conductive bars for supporting and maintaining said bars in spaced relationship, a plurality of wires electrically connecting said bars and arranged in the path of travel of said bullet in spaced parallel relationship, an elongated rod composed of electrical conducting material having one end thereof connected to the nose of said bullet and extending through said bore to a point to the rear of said wires, a disk carried at the other end of said rod and normally disposed in spaced relation with respect to the muzzle end of the gun barrel and the innermost wire of said plurality of wires for progressively severing said wires as the bullet is propelled through said bore, and means including a conductor secured to said bullet for electrically connecting and completing a circuit from an additional pair of deflecting plates of said cathode ray tube to said rod and disk to detect contact of said wires by said disk as the bullet progresses through said bore and said wires are engaged and severed by said disk.

3. In a position-time indicator for detecting the position of a bullet relative to the bore of a gun barrel as the bullet is propelled therethrough, a bullet extension means composed of electrical conducting material and carried by said bullet and extending substantially the length of said barrel bore, a disk element integrally formed on said bullet extension means and composed of electrical conducting material, a plurality of contact mem-

bers supported in advance of the muzzle end of said gun barrel, means including a pair of mutually spaced electrical conducting bars for supporting said contact members on said gun barrel in advance of the muzzle end thereof in a manner to consecutively intercept said disk element, an annular member composed of insulating material mounted on the muzzle end of said gun barrel for insulating said supporting means from said gun barrel and for supporting said supporting means thereon, and detecting means electrically connected between said bullet extension means and said contact members to register the interception of said contact members by said bullet extension means, and said detecting means having a time base for correlating said contact detections therewith.

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