A. L. LOOMIS, P. E. KLOPSTEG, P. G. AGNEW AND W. H. STANNARD.

CHRONOGRAPH.

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1,376,890. **Patented May 3, 1921.**

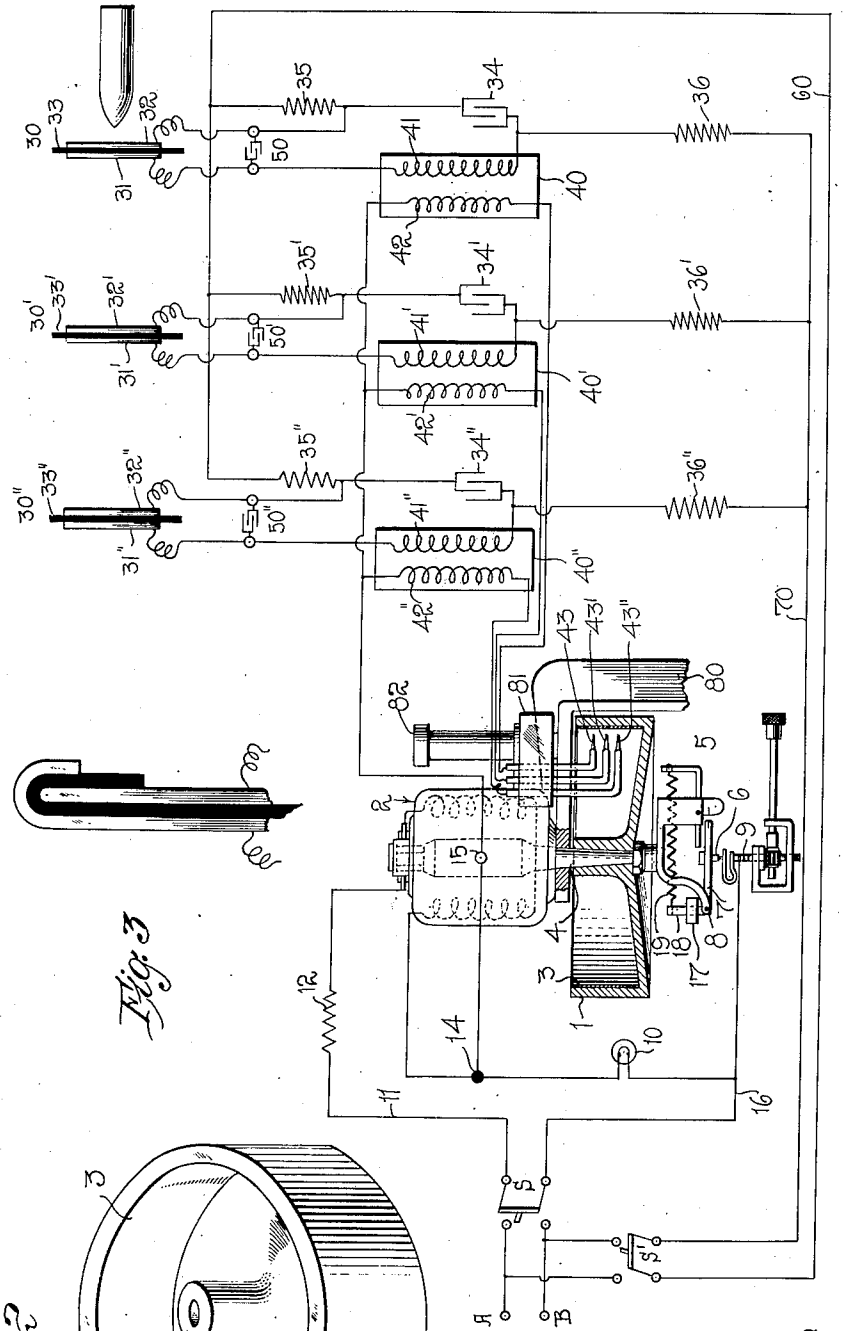

Fig. 1

Fig. 3

Fig. 2

Inventors
Alfred L. Loomis
Paul E. Klopsteg
Whitfield H. Stannard
Paul G. Agnew

UNITED STATES PATENT OFFICE.

ALFRED L. LOOMIS, OF THE UNITED STATES ARMY, PAUL E. KLOPSTEG, OF PHILADELPHIA, PENNSYLVANIA, PAUL G. AGNEW, OF WASHINGTON, DISTRICT OF COLUMBIA, AND WINFIELD H. STANNARD, OF GLEN ECHO, MARYLAND.

CHRONOGRAPH.

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To all whom it may concern:

Be it known that we, ALFRED L. LOOMIS, major, Ordnance Department, United States Army, whose residence is Tuxedo Park, Orange county, New York; PAUL E. KLOPSTEG, residing at Philadelphia, Pennsylvania; and PAUL G. AGNEW and WINFIELD H. STANNARD, residents of Washington, District of Columbia, and Glen Echo, Maryland, respectively, all citizens of the United States, have jointly invented a new and useful Improvement in Chronographs, of which the following is a specification.

The invention described herein may be used by the Government, or any of its officers or employees in prosecution of work for the Government, or by any other person in the United States, without payment of any royalty thereon.

This invention relates to electrical recording apparatus of the type used to record the occurrence of events at fixed or variable intervals and especially to that kind of electro-chronographic apparatus, in which small intervals of time are graphically recorded on a suitably prepared surface or strip on an isochronally moved drum, by causing an electric spark to jump from spark points to the drum at the instants that the events to be recorded take place.

All electric chronographs designed for the measurement of the short time intervals corresponding to the flight of a projectile over a limited portion of its trajectory, and it is such a constructional embodiment that is illustrated in the drawings, depend in their operation, upon two or more changes in electrical conditions caused by the projectile. In the instruments which have proved most practicable in the past for the measurement of projectile velocities, as for example, in the Boulenge chronograph, the projectile breaks the circuits, usually by rupturing wire screens in its path.

The breaking of any circuit by a projectile is necessarily irregular, to the extent that the break is irregular. The broken ends of the wire may continue to make contact with the projectile, a conductor, on either side of the break for a variable length of time and the circuit is not broken until one of the wires ceases to touch the projectile. Again the wires of the screen, especially if of copper insulated with cotton, may stretch appreciably before breaking, and the point at which the break takes place will also depend upon the relative positions of the projectile and wires at the time of impact. If a long pointed projectile is used the point may pass between the wires, thus delaying the time of the break over an interval depending on how close the wires are strung together and on how tightly they are stretched. Each time such wire screens are made up there is a slight change in the resistance of the circuit and moisture also changes such resistance. Consequently the measured interval is subject to a probable error of considerable magnitude from these sources alone and the distance between the points at which the breaks actually occur may be appreciably different from the measured difference between the screens in their normal positions.

An object of the invention is the utilization of the closing of a circuit upon the occurrence of the event to be recorded, rather than having the occurrence open a circuit. Thus the irregularities pointed out in connection with break circuits are eliminated and, as a result, shorter screen distances may be used without sacrificing accuracy in the measured interval.

Another object of the invention is the improvement in the rotating carrier for the record surface, and to that end a shallow cylindrical drum is used in which the record strip or ribbon is held in place against the inner periphery by centrifugal force as the drum is rotated. This manner of securing the record surface to the carrier permits of rapid changing of the strip after a record has been obtained without stopping the motor.

A further object is the employment of flat metal screens by means of which the projectile in piercing closes the circuit.

Another object of the invention consists in providing the electrical system employed with one or more condensers connected to a

source of energy and kept charged, and discharged through the primary of an induction coil by the passage of the projectile through the screen or screens, protecting such condensers by means of resistances connected between them and each side of the line and further increasing the discharge of the induced current in the secondary of the induction coil by connecting a condenser across the leads of each screen.

Another object is the design and arrangement of parts constituting the invention in such manner as to make a device simple to operate and also compact and readily transportable from place to place so that it may be used in the field for determining projectile velocities and the like and yet which device will not be influenced by the shock or vibration of the blast due to the firing of the piece.

With these and other objects in view, which will become apparent as the description proceeds, the invention resides in the construction, combination and arrangement of parts, hereinafter more fully described and claimed and illustrated in the accompanying drawings, in which like characters of reference indicate like parts throughout the several figures.

Referring more specifically to the drawings:

Figure 1 is a schematic arrangement of a form of apparatus embodying the invention and showing the drum and screens in cross section;

Fig. 2 is a perspective view of the drum;

Fig. 3 is a cross section of a modified form of screen which may be employed.

A shallow cylindrical drum 1 of known inner circumference mounted with its axis vertical is driven at a known constant speed by a small electric series motor 2. The motor may run on ball-bearings and is supported by a bracket 80. Inside the drum, on its inner periphery, a strip or ribbon of prepared paper 3, the record strip, which is by preference equal in length to the inner circumference of the drum is held in place by centrifugal force.

In order to maintain the motor at constant speed the lower end of the motor shaft 4 is provided with the governor indicated as a whole by 5. The governor rotates with the armature of the motor and as long as the speed is less than that desired, the contact 6 on the horizontal arm 7 of the bent lever, pivoted at 8, remains in contact with the fixed point 9. As long as 6 and 9 are closed full line voltage is applied to the motor in order to speed it up as the high resistance 10, preferably in the form of an incandescent lamp, is then short circuited.

The circuit of the motor is from the line at A through the switch S over 11 through resistance 12, through the armature and field of motor 2 in series to junction 14, then to the grounded frame of the motor at 15 over the frame, drum, and governor to closed contacts 6 and 9, over 16 to the other side of the line at B. The value of 12 depends on the voltage of the line and is so chosen that the motor 2 will receive the voltage for which it is designed.

When the speed of the motor exceeds the value at which it is to be maintained, the governing mass 17 on the vertical arm 18 of the bent lever, moves outward, due to the centrifugal force exceeding the tension of the spring 19. In moving outward mass 17 swings the lever on its pivot 8 causing arm 7 to raise and so separate contacts 6 and 9. This causes the high resistance lamp 10 to be placed in series with the motor 2, diminishing the current thereto and thus reducing its speed. When the speed again attains its normal value, contacts 6 and 9 again close and the operation is repeated. The cycle of operations described, occurs many times a second, the lamp 10 flickering as an indication that the current is on and that the governor is functioning properly.

The recording system of the chronograph consists of independent electrical units, three being shown in the drawings, one for each plate or screen and corresponding spark point used. Each unit comprises an induction coil, a primary condenser, two charging resistances, and an auxiliary condenser.

As the units are identical only one need be described. The screen 30, consists simply of two conducting surfaces, tin foil or sheet metal, 31 and 32 separated by a layer of insulation 33. The main condenser 34 is connected in series with two charging resistances 35 and 36 to the source of energy by means of leads 60 and 70, the resistances being placed one on each side of the particular condenser, in order to guard or protect the unit against short circuits, either internal or external to the condenser. The induction coil represented by 40, has its primary 41 connected one side to the main condenser 34 and the other to one of the conducting surfaces 31 of the screen 30. The other surface 32 of the screen is connected to the other side of the condenser 34. The secondary 42 of the coil 40 is connected one side to the spark point 43 and the other side to the frame of the motor at point 15. The spark point 43 is carried by a block of insulation 81 pivoted on the rod 82 which in turn is carried by the motor supporting bracket 80. By pivoting the point carrying block 81, the spark points can be swung out of operative relation with respect to the drum when it is desired to test out the circuit, or when a new record strip is inserted in the drum. An auxiliary condenser 50 is shunted directly across the screen terminals. The parts of the other units shown corresponding

to those of the unit described are indicated by the same reference characters primed (′) and a double primed (″).

Switch S′ connecting 60 and 70 to the line being closed, the main condenser 34 is charged and stores up a quantity of electricity, the amount of which is determined by the line voltage and the capacity of the condenser. The two guarding or charging resistances 35 and 36 do not prevent the complete charging of the condenser 34, the operation being merely retarded slightly by the presence of these resistances, but they prevent destructive currents when the discharging circuit of the condenser is closed.

A projectile piercing the screen 30, closes the screen circuit by the projectile, a conductor, bridging the two conducting surfaces 31 and 32. The closing of this low resistance circuit releases the energy stored by the condenser 34 and permits of the discharge of the latter via the primary 41 of the induction coil 40, in spite of the fact that the time during which the circuit is closed may be of very short duration.

The discharge through the primary 41 induces a high potential difference in the secondary 42 so as to cause a spark to jump from the point 43 to the drum 1 and in doing so puncture the record ribbon 3. The extremely short time of contact between the screen elements 31 and 32 and the projectile limits this discharge, however, and does not permit all the available energy in the condenser 34 to become transformed into energy in the form of a spark. To improve this condition, thereby securing a hotter spark, the auxiliary condenser 50 is connected directly across the leads of the screen 30. The best capacity for this condenser has been found to be about one-half that of the main condenser 34.

The operation is as follows: With the contact at the screen 30 open, that is with the normal condition of the screen, the potential difference across the auxiliary condenser 50 is the same as that across the main condenser 34, and the potential differences oppose each other. When the projectile pierces the screen, contact is made with the two elements 31 and 32 thereof. The auxiliary condenser now discharges more rapidly than the main condenser first, because of its smaller capacity and second, because 34 must discharge through primary 41, which acts as a choke coil, while 50 discharges directly over the plates 31 and 32 and the projectile. Consequently, after a very short interval (on the order of one millionth of a second) the potential difference of 50 has fallen considerably below that of 34 and this causes oscillations to be set up in the circuit 34, 41, 50, etc. and the oscillations persist after the screen contact has ceased and until condensers 34 and 50 have been restored to the same potential difference by the impressed line voltage.

The piercing of the first screen by the projectile causing a spark to jump from the first or upper point 43 through the record strip 3 to the drum 1 as described, produces a small hole in the strip. The drum continuing to revolve, the projectile upon piercing the second screen similarly causes a second hole to be produced in the strip by the spark from the second point 43′. The strip is now removed from the drum and this can be accomplished without stopping the rotation by merely lifting the strip out.

The distance between the two spark marks on the strip (measured in the direction of rotation) gives the exact time the projectile took to pass from the first to the second screen. Thus assuming the drum to have a known inner circumference of 500 mm., and to be driven at a constant speed of 25 r. p. s., the linear velocity of the strip is therefore 12,500 mm., p. s., and the distance between marks is found to be 250 mm., then the time it took the projectile to go from the first to the second screen must have been 1/50 of a second. Then if the distance between the screens was, say 50 ft., the average velocity of the projectile must have been 2,500 feet per second as it traversed 50 ft. in 1/50 of a second. In actual practice, however, none of these calculations need be made for by the use of a direct reading scale, the distance between the spark marks may be read directly in terms of velocity. Thus by the use of apparatus employing the invention the velocity of a projectile may be ascertained within 6 or 7 seconds after the shot has been fired, with the possibility of numerical error practically eliminated.

The third or lower spark point may be used if it is desired to place three screens in the path of the projectile, as it is sometimes desirable for very accurate work.

It is obvious of course that any screen may be connected to a spark point on more than one instrument and so check readings obtained. Further, it is possible by the use of this invention, to connect additional screens in parallel with any one of those shown without the use of additional condensers 34 and 50.

A chronograph embodying the principles of this invention may be calibrated and its normal running speed checked by any one of a number of methods, as by connecting it with some form of revolution counter, or a spark may be produced at the first point at the beginning of and a second spark be caused to jump at the exact end of a definite known time interval.

From the foregoing description it will be seen that the device can readily be made in portable form so that projectile velocities may be determined in the field, without the

necessity of any elaborate and permanent installations such as piers or pillars or complicated circuits, as the induction coils, condensers and resistances used are of ordinary commercial form and the circuit between them extremely simple.

Though the invention has been described as used to determine the velocity of projectiles, any other interval of time than that of the flight of a projectile may be measured so that the velocity of shell fragments and the propagation of detonation waves may for instance be determined.

What we claim as new and desire to secure by Letters Patent is:—

1. The method of recording projectile velocities which consists in causing the projectile to close the discharging circuit of a constantly charged capacity; converting the discharged energy into a spark, and recording the spark discharge on an isochronally moving record surface.

2. The method of recording projectile velocities which consists in causing the projectile to close the discharging circuit of a constantly charged capacity; converting the discharged energy into a spark; and recording the spark discharge on a record surface moving with constant speed, and maintained in place by centrifugal force.

3. The method of measuring projectile or shell velocities which consists in causing the missile to successively close the discharging circuits of constantly charged capacities; converting the discharged energy into sparks; recording the sparks on an isochronally moving record surface, and ascertaining the distance between spark marks.

4. The method of measuring projectile or shell velecities which consists in causing the missile to successively close the discharging circuits of constantly charged capacities; converting the discharge energy into sparks; recording the sparks on a record surface moving with constant speed and maintained in place by centrifugal force; and then ascertaining the distance between spark marks.

5. The method of measuring small time intervals which consists in successively closing the discharging circuits of constantly charged capacities, converting the discharged energy into sparks, and recording the sparks on an isochronally moving record surface.

6. The method of measuring small time intervals which consists in successively closing the discharging circuits of constantly charged capacities; converting the discharged energy into sparks; and recording the sparks on a record surface moving with constant speed and maintained in place by centrifugal force.

7. The method of measuring small time intervals which consists in successively closing the discharging circuits of constantly discharged capacities; converting the discharged energy into sparks; recording the sparks on an isochronally moving record surface; and ascertaining the distance between spark marks.

8. The method of measuring small time intervals which consists in successively closing the discharging circuits of constantly charged capacities; converting the discharged energy into sparks; recording the sparks on a record surface moving with constant speed and maintained in place by centrifugal force; and then ascertaining the distance between spark marks.

9. An electric chronograph, comprising in combination an isochronally driven, conducting record support carrying a record strip, a spark point contiguous thereto; an electric circuit; a contact-making screen therein; a constantly charged condenser; resistances connected in the circuit at each side of the condenser; an induction coil, the primary of which is connected on one side to the condenser and on the other to the screen, and the secondary of which is connected across the record support and the spark point; the other side of the condenser connected to the screen; and a second condenser connected across the screen contacts so that when the circuit is closed at the screen it will discharge across such contacts, while the first condenser will discharge through the primary of the coil and will cause a spark between the point and the support due to the induced current in the secondary of the coil.

10. In chronographs of the class described, the combination of a shallow cup-shaped drum of conducting material driven at constant speed; a record ribbon carried by the drum and held against its inner periphery by centrifugal force; a spark point within the circumference of the drum and contiguous to the ribbon; an electric circuit; a contact-making screen therein; a constantly charged condenser; resistances connected in the circuit at each side of the condenser; an induction coil, the primary of which is connected on one side to the condenser and on the other to the screen and the secondary of which is connected across the record support and the spark point; the other side of the condenser connected to the screen; and a second condenser connected across the screen contacts so that when the circuit is closed at the screen it will discharge across such contacts, while the first condenser will discharge through the primary of the coil and will cause a spark between the point and the support due to the induced current in the secondary coil.

11. An electric chronograph, comprising in combination an isochronally driven, conducting record support carrying a record strip; a spark point contiguous thereto; an electric circuit; a contact making screen

therein; a condenser connected across the circuit; an induction coil, the primary of which is connected on one side to the condenser and on the other to the screen; and the secondary of which is connected across the record support and the spark point; the other side of the condenser connected to the screen; and a second condenser connected across the screen contacts so that when the circuit is closed at the screen it will discharge across such contacts, while the first condenser will discharge through the primary of the coil and will cause a spark between the point and the support due to the induced current in the secondary of the coil.

12. In chronographs of the class described, the combination of a shallow cup-shaped drum of conducting material driven at constant speed; a record ribbon carried by the drum and held against its inner periphery by centrifugal force; a spark point within the circumference of the drum and contiguous to the ribbon; a condenser connected across the circuit; an induction coil, the primary of which is connected on one side to the condenser and on the other to the screen, and the secondary of which is connected across the record support and the spark point; the other side of the condenser connected to the screen; and a second condenser connected across the screen contacts so that when the circuit is closed at the screen it will discharge across such contacts, while the first condenser will discharge through the primary of the coil and will cause a spark between the point and the support due to the induced current in the secondary coil.

13. An electric chronograph, comprising in combination an isochronally driven, conducting record support carrying a record strip; a spark point contiguous thereto; a screen consisting of two conducting surfaces separated by insulating material; an electric circuit; a constantly charged condenser therein; resistances connected in the circuit at each side of the condenser; an induction coil, the primary of which is connected at one end to one of the screen surfaces and at the other end to the condenser, and the secondary of which is connected across the support and the spark point; a connection between the other side of the condenser and the other screen surface, and a second condenser connected across the screen surfaces, so that when the circuit is closed by bridging the screen surfaces it will discharge across such surfaces, while the first condenser will discharge through the primary of the coil and will cause a spark between the point and the support due to the induced current in the secondary of the coil.

14. In chronographs of the class described, the combination of a shallow cup-shaped drum of conducting material driven at constant speed; a record ribbon carried by the drum and held against its inner periphery by centrifugal force; a spark point within the circumference of the drum and contiguous to the ribbon; a screen consisting of two conducting surfaces separated by insulating material; an electric circuit; a constantly charged condenser therein; resistances connected in the circuit at each side of the condenser; an induction coil, the primary of which is connected at one end to one of the screen surfaces and at the other end to the condenser, and the secondary of which is connected across the support and the spark point; a connection between the other side of the condenser and the other screen surface, and a second condenser connected across the screen surfaces, so that when the circuit is closed by bridging the screen surfaces it will discharge across such surfaces, while the first condenser will discharge through the primary of the coil and will cause a spark between the point and the support due to the induced current in the secondary of the coil.

15. In an apparatus for electrically meausuring time intervals, the combination with a uniformly-moving motor-driven recording surface support; of a record surface secured thereto by centrifugal force; a spark point contiguous thereto; a constantly charged capacity; and a transformer so connected that when the capacity is discharged the energy will be transformed into a spark at the point and a mark obtained on the record surface.

16. In chronographs of the class described, the combination of a shallow cup-shaped drum driven at uniform speed, of a record surface held against its inner periphery by centrifugal force, a spark point contiguous thereto; a constantly charged capacity; and a transformer so connected that when the capacity is discharged the energy will be transformed into a spark at the point and a mark obtained on the record surface.

17. In an apparatus for electrically measuring time intervals, the combination with a uniformly-moving motor-driven recording surface support; of a record surface secured thereto by centrifugal force; a spark point contiguous thereto; a constantly charged capacity; a transformer, and a contact maker so connected as to discharge the capacity and transform its stored energy into a spark at the point to produce a mark on the record surface.

18. In chronographs of the class described; the combination of a shallow cup-shaped drum driven at uniform speed; of a record surface held against its inner periphery by centrifugal force; a spark point contiguous thereto; a constantly charged capacity; a transformer, and a contact

maker so connected as to discharge the capacity and transform its energy into a spark at the point to produce a mark on the record surface.

19. In electrical apparatus for measuring projectile or shell velocities, the combination with a uniformly-moving motor-driven recording surface support, of a record surface; a spark point contiguous thereto; a constantly charged capacity; a transformer and a contact making screen, so connected as to discharge the capacity by the missile piercing the screen and have its stored energy transformed into a spark at the point to produce a mark in the record surface.

20. In electrical apparatus for measuring projectile or shell velocities, the combination of a shallow cup-shaped drum driven at uniform speed, of a record surface held against its inner periphery by centrifugal force; a spark point contiguous thereto; a constantly charged capacity; a transformer and a contact making screen, so connected as to discharge the capacity by the missile piercing the screen and have its stored energy transformed into a spark at the point to produce a mark in the record surface.

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