June 13, 1944. J. V. DUNHAM 2,351,023

CHRONOGRAPH

Filed Nov. 13, 1941

Fig. 1.

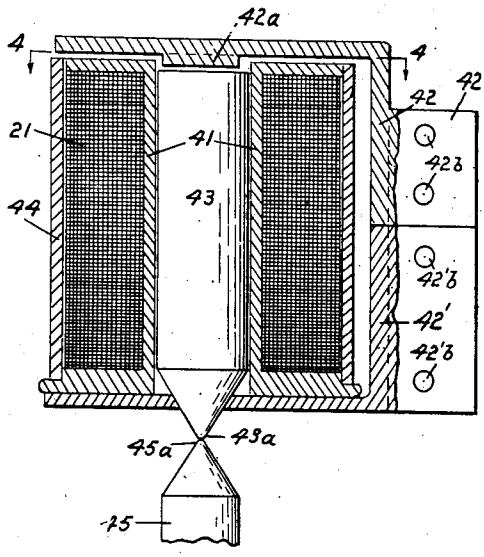


Fig. 2.

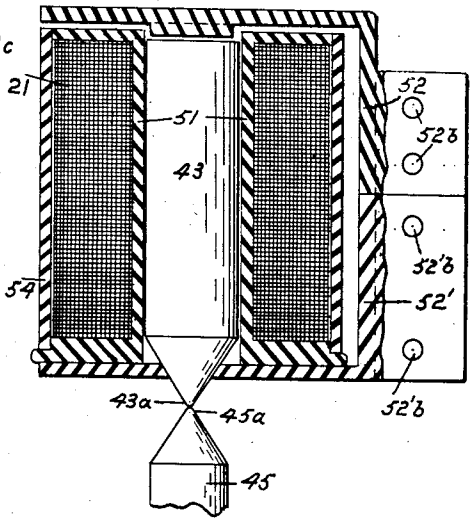


Fig. 3.

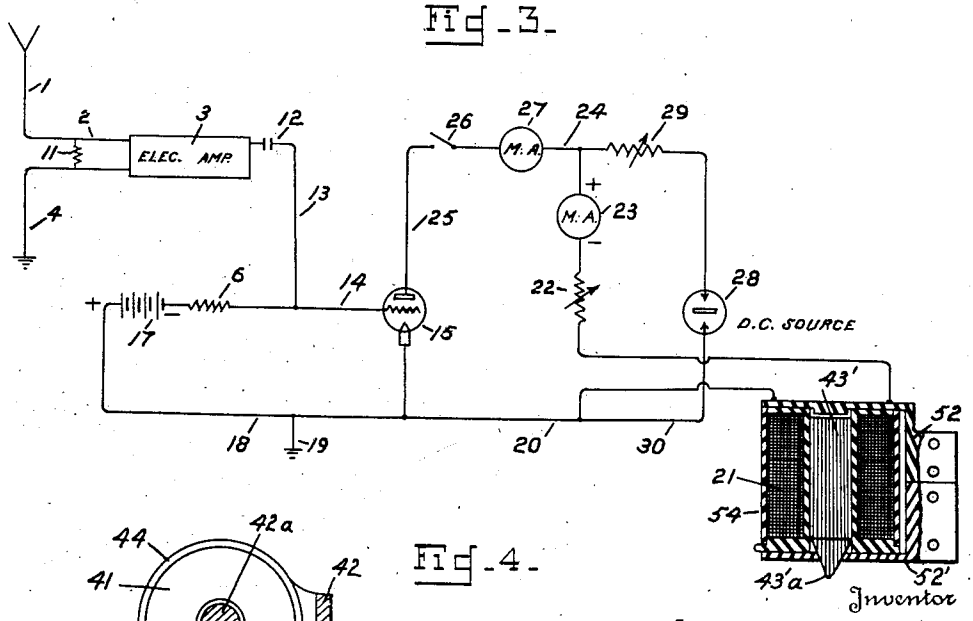


Fig. 4.

Inventor

James V. Dunham

By G. J. Kessenich & J. H. Church

Attorneys

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CHRONOGRAPH

James V. Dunham, Southampton, Pa.

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9 Claims. (Cl. 161—15)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to means for eliminating time delay in chronographs particularly of the Le Boulenge type.

An object of this invention is to provide a chronograph, particularly of the Le Boulenge type in which the time delay due to the decay of a magnetic field therein is materially reduced.

Another object of this invention is to provide a Le Boulenge chronograph with means for increasing its accuracy when used in combination with an electronic shunt circuit similar to the one described in the patent of Dunham and Rechel, No. 2,146,723 issued on February 14, 1939.

Another object of this invention is to provide means on a Le Boulenge chronograph whereby the chronometer and registrar are released within time intervals which are shorter than any heretofore existing.

The Le Boulenge chronograph has been in use for about eighty years and has proven to be a rapid and comparatively trouble-free instrument for recording projectile velocities. However, considerable doubt has existed as to the accuracy of the chronograph and opinion has varied among its different users. Applicant has made an exhaustive study of the factors which cause the inaccuracy of the chronograph and has provided corrective means for enhancing the accuracy of the chronograph to an extent not hitherto realized in the art.

The Le Boulenge chronograph is amply described in "Elements of Ordnance" by T. J. Hayes, 1939, John Wiley and Sons, New York, or the standard works of ordnance and gunnery by McFarland, 1929, Tschappat, 1917, or Lissak, 1915, all by the same publisher; also, Patent No. 1,357,281 to Du Pont issued November 2, 1920, and also Patent No. 51,905 to Le Boulenge issued January 2, 1866, describe the principle of operation of the Le Boulenge chronograph and the former patent relates to means for improving the accuracy of this type of chronograph.

In explaining the present invention, reference will be had to the prior art and accompanying drawing wherein:

Fig. 1 is a section taken through the center of one of the pair of standard conventional prior art coils and the metallic supporting members therefor.

Fig. 2 is a section taken through the center of one of the pair of coils and improved supporting members, and embodies this invention.

Fig. 3 shows the improved coil structure of Fig. 2 and a laminated core incorporated in the electronic tube circuit which is shown in Fig. 2 of Patent 2,146,723 to Dunham et al. issued February 14, 1939.

Fig. 4 is a sectional view taken substantially on line 4—4 of Fig. 1.

One of the greatest sources of inaccuracy in the Le Boulenge instrument resides in the fact that the two rods—the chronograph and the registrar—do not drop instantly upon the opening of the circuits through their respective magnets. The above mentioned Du Pont patent, issued November 2, 1920, provides means whereby the conventional core is of non-magnetic material so that residual magnetism in the core is not a factor. The results of applicant's studies have shown that a coil having a core made of magnetic material introduces a small inaccuracy which may be reduced by laminating the core, but more important the greatest source of inaccuracy has been found to reside in the time delay due to eddy currents in the metallic coil supports and eddy currents in the core when the flux in the coils collapse. These eddy currents produce a field which tends to hold the chronometer and registrar in suspended position and also produce a drag on those members when they move. A very marked change in accuracy results when the coil spool and support is made of a plastic or insulating material such as Bakelite instead of metal as has hitherto been the standard conventional practise for many years.

It is fundamental to realize that whenever a closed electrical path is present in a magnetic field, and the current producing the magnetic field is interrupted suddenly, eddy currents are induced and circulate in that electrical path. These eddy currents produce magnetic fields whose effect is to retard the demagnetization of the coil.

There are several low resistance paths within the field space of the electromagnets in the standard conventional chronographs hitherto used; namely:

(1) The brass spool on which the coil is wound.
(2) The solid iron of metallic core.
(3) The brass brackets which support the coil.
(4) The brass sheath surrounding the coil.

Referring to the drawing, Fig. 1 discloses the prior art arrangement and shows the standard conventional solenoid soil 21 with its brass spool 41, a pair of brass supports 42, 42', solid core

43 made of magnetic material and brass sheath 44. The soft iron portion 45 of the registrar or chronometer is shown in its held position. The core 43 and registrar or chronometer portion 45 is terminated by cones which touch in the slightly rounded points 43*a*, 45*a*. This arrangement permits the registrar or chronometer to hang vertically under the action of their weight.

Referring to the improved design, Figure 2 shows the improved solenoid coil 21 with its spool 51 of insulating material, pair of supports 52, 52' of insulating material, solid core 43 of magnetic material and sheath 54 of insulating material. The soft iron portion 45 of the registrar or chronometer is shown in its held position in Fig. 2.

Holes 42*b*, 42'*b* and holes 52*b*, 52'*b* in ears 42, 42', 53, 53' of members 42, 53 respectively are made of avail in supporting their composite coil structures.

By replacing the brass parts with non-metallic parts and by laminating the core a considerable improvement in accuracy results and it was found that with the unmodified electromagnet the maximum time delay would be .37 milliseconds or 17.2 feet per sec. for caliber .30 ammunition when recorded over a 150 foot base line; with the modified electromagnet the maximum error would be .02 millisecond or .93 foot per second.

In the Le Boulenge chronograph, the ideal condition would exist if the rod were to begin moving from rest as a free falling body at the instant the coil circuit was opened due to the passage of the projectile; a great step has been made in the approach to this ideal condition by eliminating from the field space of the electromagnet all metallic bodies which allow a free flow of eddy currents due to collapse of the associated current in the coil.

If the two chronograph coils are of the same physical structure and are assumed to have the same surroundings—a condition difficult to obtain in actual practise—the time delay in each coil would, to a certain extent, be compensated by the time delay in the other coil so far as the ultimate time measurement is concerned. However, this condition is believed not to exist absolutely, and consequently it is believed that the operation of the instrument cannot be relied upon to register velocities with invariable accuracy. Moreover, if the error due to the eddy current effect were constant and capable of measurement, the routine use of the instrument would be simplified if the error could be eliminated absolutely.

When utilizing the static electrical charge found to reside on a projectile in flight for operating the Le Boulenge chronograph, the antenna 1, lead lines 2 and 4, electronic amplifier 3, resistance 11, are the same as described in the above mentioned Dunham et al. patent. In this instance, the output coupling condenser 12 is connected by lead 13 to a grid lead 14 connected to the grid of a gaseous triode 15. The lead 14 is part of a circuit containing a resistance 16 of from .50 to 10 megohms, a grid biasing battery 17, a lead wire 18 from the positive terminal of the battery to the cathode of the gaseous triode 15, with a grounded wire 19 connected to such lead 18 between the battery and cathode. From the cathode a lead wire 20 extends to the lower terminal of the Le Boulenge electromagnet 21, the upper terminal of such electromagnet being connected to variable resistance 22 sufficient to limit the current in the electromagnet to approximately 140 milliamperes, the other terminal of such resistance being connected to the negative terminal of a milliameter 23, the positive terminal of such milliameter being connected to lead 24. The plate of the triode 15 is connected through a lead 25, in which may be interposed a switch 26 and a milliameter 27, to lead 24 which is connected through variable resistance 29, to the positive terminal of a full wave rectifier 28. Resistance 29 is sufficient to limit the current from the rectifier to the desired value. The negative terminal of the rectifier is connected through lead 30 to the lower end of the Le Boulenge electromagnet 21.

When a projectile passes the antenna 1, an electrical charge is induced therein, causing a change in the electrical potential of the grid of the input tube of the amplifier 3, the amplified effect of such change causing a change in the grid potential of triode 15 resulting in its ionization. Previous to the ionization of the triode, the current in electromagnet 21 from rectifier 28 is so regulated by resistances 22 and 29 as to suspend correctly the Le Boulenge rod. The low resistance of the triode, due to its ionization, causes a drop of potential across the electromagnet such that the current in the electromagnet is reduced to a value which allows the suspended rod to fall in the usual and well known manner.

The gaseous triode is deionized by opening switch 26. Two of the described devices are necessary for operating the Le Boulenge chronograph, one being connected to each of the chronograph electromagnets. In this arrangement it is advisable to use a laminated core 43' for the coil.

In conclusion, it has been found that the accuracy of the Le Boulenge chronograph can be greatly improved by making the coil spools and supports of a non-metallic substance. When the current is interrupted by a projectile breaking an electrical circuit in an arrangement similar to that shown in the above mentioned Du Pont patent, the error due to the use of a solid coil core over a laminated coil core is relatively small. Great care should be taken to secure iron of low retentivity for the coil core. However, when a solid magnetic coil core is used in conjunction with a circuit similar to that shown in Fig. 3 and described in the above mentioned Dunham et al. patent in which the coil 21 is constantly energized from a rectified source 28 the maximum deviation is approximately .3 millisecond greater than that obtained with a laminated core and consequently the use of a laminated core 43' becomes necessary if the advantages of other improvements are to be realized; the time lag introduced by the constantly energized shunt circuit 28, 29 is apparently due to the field of the core eddy currents which are produced by irregularities in the direct current source 28.

I claim:

1. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil circuit embodying a core and a movable registrar in association with said coil is altered in the process of measuring a time interval, the combination with the said coil and said core of an insulating support which permits a minimum flow of eddy currents when the current in the coil alters.

2. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil

circuit is altered in the process of measuring a time interval, a coil embodying a core and a movable registrar in magnetic association therewith, an insulating spool on which the coil is wound, and an insulating support for the spool.

3. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil circuit is altered in the process of measuring a time interval, a coil embodying a core and movable registrar in magnetic association therewith, an insulating spool on which the coil is wound, and insulating support for the spool and a laminated core for the coil.

4. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic circuit coil is altered in the process of measuring a time interval and said coil circuit is energized from a source of substantially constant voltage and wherein said coil is associated with a magnetic movable registrar, the combination with the magnetic coil of a non-metallic coil support which reduces to minimum the flow of eddy currents in the said support when the current in the coil alters, and a laminated core within the coil.

5. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil circuit is altered in the process of measuring a time interval, a coil in association with a magnetic registering armature, a voltage source of substantially constant magnitude for energizing the coil, constantly supporting means for the coil made solely of insulating material, and a laminated core within the coil for actuating the said armature.

6. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil circuit is altered in the process of measuring a time interval, a coil having a core and a movable registrar with magnetic coil in association with said core, said core being laminated.

7. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil circuit is altered in the process of measuring a time interval, the coil in said circuit having a core and a movable registrar in magnetic association with said core, the improvement which comprises support for said coil made solely of insulating material.

8. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil circuit is altered in the process of measuring a time interval and a coil in said support having a core and a movable registrar in magnetic association with said core, a voltage source of substantially constant magnitude for energizing the coil constantly, the improvement which comprises laminar structure in said core.

9. In a chronograph of the Le Boulenge type wherein the current in at least one magnetic coil circuit is altered in the process of measuring a time interval, and having a coil with a central core and a movable registrar in magnetic association with said core, a voltage source of substantially constant magnitude for energizing the coil constantly and a housing for the coil made solely of insulating material.

JAMES V. DUNHAM.