March 29, 1949. H. G. BUSIGNIES ET AL 2,465,351

PROJECTILE TIMING

Filed March 26, 1943

Fig: 1.

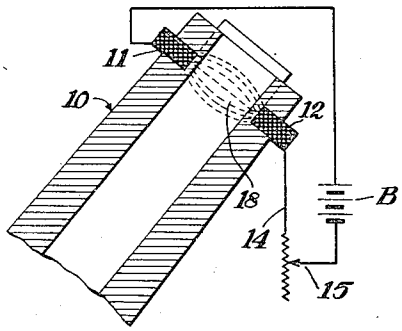


Fig: 2.

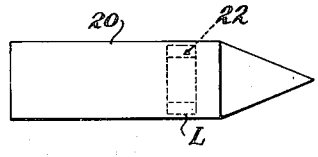


Fig: 3.

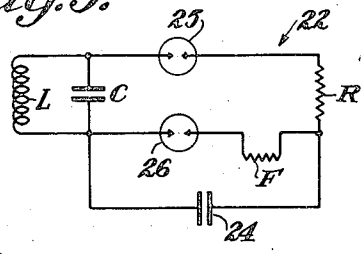


Fig: 4.

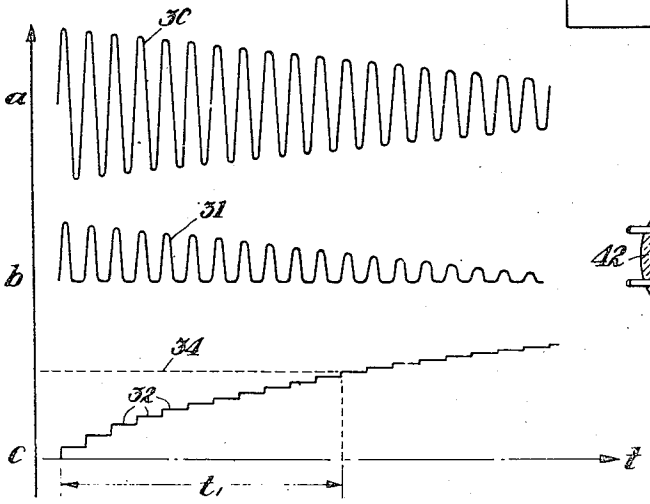
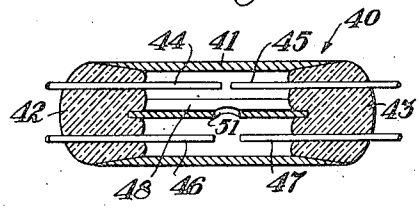


Fig: 5.



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PROJECTILE TIMING

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Application March 26, 1943, Serial No. 480,632

10 Claims. (Cl. 102—70.2)

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This invention relates to munitions and more particularly to time control of detonatable projectiles such as shells fired by guns.

In the copending application of E. M. Deloraine entitled "Electrical detonation system," Serial No. 388,036, filed April 11, 1941, which application is now abandoned, several forms of electromagnetically controlled fuses for detonatable shells are disclosed. The initiation of the timing operation for certain of the electrical fuses therein disclosed is controlled by the firing of the shell through a magnetic field located at the muzzle of the gun. The intensity of the field is controlled and the circuit for the fuse is so constructed and arranged as to provide a surge of voltage which is used to perform a timing operation with the view to detonating the shell a determinable time interval after the firing of the gun.

One of the objects of our invention is to provide an improved method and means in addition to those disclosed in the aforesaid Deloraine application for electromagnetically timing the detonation of a shell.

Another object of our invention is to provide an improved electrical time control circuit for the fuse element of detonatable shells.

According to our invention, the muzzle of the gun firing the detonatable shell is provided with magnetic means for the establishment of a magnetic field the intensity of which is controlled similarly as set forth in the aforesaid Deloraine application. The detonatable shell is preferably provided with a point detonating fuse of the combination impact and time character together with an electrical circuit for timing within limits the firing of the fuse. This circuit includes a shock excitable L.-C. circuit which produces an oscillatory wave when the shell is projected through the magnetic field. The speed of the shell and the intensity of the field determine the amplitude of the oscillations established in the L.-C. circuit. Arranged in parallel with the fuse element of the circuit is an energy storing device such as a condenser, together with means for rectifying the oscillations of the L.-C. circuit whereby rectified energy is stored in the condenser. When the voltage of the stored energy reaches a predetermined amount the energy is discharged through the fuse element, thereby detonating the explosive charge of the shell. This discharge of the stored energy is controlled by a gas-filled tube which is carefully constructed to operate at substantially a predetermined voltage.

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For increased accuracy of the timing operation, the rectifier means and the energy discharge tube may be combined as a single gas-filled tube having two pairs of electrodes, such as disclosed in our co-pending divisional application, Serial No. 550,130, filed August 19, 1944, now Patent No. 2,444,427. One pair of the electrodes may be used to perform the rectifying operation while the second pair of electrodes control the discharge of the stored energy. By associating the two pairs of electrodes in a single tube, the ionization at the first pair of electrodes may be used to periodically prime the gap at the second pair of electrodes. That is to say, the periodic conduction occurring at the rectifying operation of the first pair of electrodes will each time partially ionize the gap between the second pair of electrodes so that when the voltage of the stored energy closely approximates the predetermined value, the second pair of electrodes will conduct in synchronism with the conduction at the first pair of electrodes. Thus, the detonation will occur a time interval equal to substantially a multiple of the wavelength at which the L.-C. circuit is tuned. This interval, however, will vary according to the muzzle velocity of the shell and the intensity of the magnetic field. By increasing the magnetic field, the shell will explode sooner, and should the muzzle velocity be less than normal the interval will be increased so as to substantially compensate for the decrease in muzzle velocity.

For a further understanding of the invention, reference may be had to the following detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatical, longitudinal cross sectional view of the muzzle of a cannon or other shell projecting device provided with means for establishing a magnetic field.

Fig. 2 is a side elevational view of a shell provided with an electromagnetically operated fuse;

Fig. 3 is a schematic wiring diagram of the electromagnetically operated fuse.

Fig. 4 is a graphical illustration of the timing operation of the electrically operated fuse; and

Fig. 5 is a view in longitudinal cross section of a gas-filled tube which may be used in the electrical timing circuit.

Referring to Figs. 1, 2, 3 and 4, a gun muzzle 10 is shown provided with a pair of magnetic coils 11 and 12 connected by circuit 14 to a source of energy B and a rheostat 15 by which the energy supplied to the coils 11 and 12 is controlled. The coils 11 and 12 are suitably arranged in the muzzle 10 so as to provide a magnetic field 18

through which the shell 20, such as shown in Fig. 2, must pass when projected by the gun. The shell is provided with an electromagnetically operated timing circuit 22, Fig. 3. This timing circuit comprises a resonant L.-C. circuit which is responsive to the field 18 when the shell is projected therethrough to set up an oscillatory wave 30 (curve *a*, Fig. 4). It will be understood, of course, that the coils 11 and 12 are so arranged as to provide a desirable amount of magnetic flux where the coil L will cut the same when the shell is fired from the gun.

The timing circuit 22 includes a fuse element F and an energy storing device such as condenser 24. The oscillations 30 established by the L.-C. circuit are rectified by means such as a gas-filled tube 25 and applied through a limiting resistor R to the condenser 24. Connected in parallel with the rectifier tube 25 and resistor R on the one hand and the condenser 24 on the other hand is the fuse element F and an energy discharge tube 26. This timing circuit makes up into a compact unit which is enclosed within the shell substantially as indicated in Fig. 2. The coil L is preferably disposed adjacent the side wall of the shell, but other arrangements may be made so long as the circuit will be shock excited when the shell is projected through the magnetic field 18.

The operation of the electromagnetically controlled timing circuit may be better understood by reference to Fig. 4 in which all the curves are applied to the same time base. Curve *a* as hereinbefore stated represents the oscillatory wave 30 established in the L.-C. circuit. Curve *b* represents the pulses of rectified energy 31 produced by the rectifier tube 25 in response to the wave 30. Curve *c* represents the building up of stored energy in the condenser 24 according to the supply of the rectified energy 31. It will be noted that the energy stores up in "steps," the stored energy increasing in voltage a small amount for each of the steps 32. Since the wave 30 is damped and the pulse energy 31 decreases in time, the steps 32 of the stored energy become less and less as the shell continues in its flight.

Assuming that the level 34 represents a predetermined voltage value at which the tube 26 will conduct, it will be clear that energy of the condenser 24 will discharge through the fuse element F a time interval t_1 after the firing of the shell. By varying the field intensity 18 by manipulation of the rheostat 15, the rapidity of the voltage build-up at the condenser 24 may be controlled. Thus, the time interval required for the stored energy to build up to the level 34 may be varied at the position of the gun by controlling the rheostat 15. It will, therefore, be clear that according to our invention, the accuracy of fuse timing is greatly improved.

In Fig. 5, we have shown an improved gas-filled tube construction 40, such as disclosed in our aforesaid co-pending divisional application, which may be used in the place of the tubes 25 and 26 of Fig. 3. The tube 40 comprises a metal sleeve 41, such as nickel, the ends of which are closed by glass beads 42 and 43. Disposed through the beads are two pairs of electrodes. The first pair 44, 45 correspond to the electrodes of the tube 25 while the second pair of electrodes 46, 47 correspond to the electrodes of the tube 26. Disposed between the two pairs of electrodes is a partition 48 which may be of any suitable form so long as it provides a limit communication between the spaces containing the two pairs of

electrodes. For example, the partition may comprise the form of a screen or other foraminous member or as shown, may comprise a plate having one or more openings 51 disposed in the vicinity of the gaps between the electrodes 44, 45 and 46, 47. The gas filling the tube may comprise any suitable inert gas such as neon, argon, helium, krypton or any desired mixture thereof.

The electrodes 44, 45 are so spaced as to provide rectification of a substantial portion of each positive half of the oscillating cycles of the wave 30. Upon conduction, the ionization of the gas at the gap between electrodes 44, 45 will provide a partial ionization through the opening 51 to the gap between electrodes 46, 47. This partial ionization, however, is insufficient to cause conduction between the electrodes 46, 47 until the voltage across these electrodes is nearly high enough to initiate the conduction. When this predetermined voltage value is reached, this partial ionization which occurs each time conduction is established between the electrodes 44, 45 determines the instant at which the electrodes 46, 47 conducts. Thus, it will be clear that the conduction of the electrodes 46, 47 occurs an interval of time after the firing of the gun equal to a multiple of the oscillations of the wave 30. This provides for a more accurate prediction of the detonation of the shell according to the adjustment of the rheostat 15.

It will be recognized by those skilled in the art that the partition 48 may be dispensed with where the spacing between the two pairs of electrodes is such that the ionization occurring at the electrodes 44, 45 will produce the desired partial ionization at the electrodes 46, 47. For compactness, however, the partition 48 is desirable so as to limit the ionization of the space at the electrodes 46, 47 upon conduction at electrodes 44, 45.

While we have shown and described the principles of our invention in connection with a specific apparatus, we recognize that various changes and modifications may be made therein without departing from the invention. For example, rectifying and discharge means other than gas-filled tubes may be used in the timing circuit. It is our aim, therefore, to cover in the appended claims all such changes and modifications as fall within the scope of the invention.

We claim:

1. A method of timing the detonation of a shell having an electromagnetically responsive circuit for timing the fuse thereof, comprising establishing a magnetic field through which the shell must travel when projected by the firing of a gun whereby the circuit is shock excited to produce an oscillatory wave, rectifying said wave, storing the rectified energy, and applying the stored energy in a manner to effect control of the fuse element for detonation of the shell when the stored energy reaches a predetermined voltage.

2. The method defined in claim 1, wherein the strength of the magnetic field is adjusted to control the amplitude of the wave produced in the circuit thereby determining substantially the time interval between the firing of the gun and the detonation of the shell projected thereby.

3. An electromagnetically operated timing circuit for the fuse element of detonatable shells, comprising means shock excitable by the passage of the shell through a magnetic field to produce an oscillatory wave, an energy storage device, means for rectifying the energy of said wave to charge said storage device, and means to dis-

charge the stored energy of said device in a manner to control the ignition of said fuse element for detonation of the shell when the stored energy reaches a predetermined voltage.

4. An electromagnetically operated timing circuit defined in claim 3, wherein the shock excitable means comprises a resonant circuit having inductance and capacitance.

5. The electromagnetically operated timing circuit of claim 3, wherein the rectifying means comprises a gas-filled tube.

6. The electromagnetically operated timing circuit defined in claim 3, wherein the means for discharging the stored energy includes a gas-filled tube.

7. The electromagnetically operated timing circuit defined in claim 3, wherein the rectifying means and the means for discharging the stored energy each comprise a gas-filled tube.

8. An electromagnetically operated timing circuit for the fuse element of detonatable shells, comprising means shock excitable by passage of the shell through a magnetic field to produce an oscillatory wave, an energy storage device, a gas-filled tube having two pairs of electrodes, one pair being connected in circuit as a rectifier for rectifying the energy of said wave to charge said storage device, the second pair of electrodes being connected in circuit as an energy discharge device operable when the stored energy reaches a given voltage to discharge the stored energy through said fuse element.

9. An electromagnetically operated timing circuit for the fuse element of detonatable shells, comprising means shock excitable by passage of the shell through a magnetic field to produce an oscillatory wave, an energy storage device, a gas-filled tube having two pairs of electrodes, one pair being connected in circuit as a rectifier for rectifying the energy of said wave to charge said storage device, the second pair of electrodes being

connected in circuit as an energy discharge device operable when the stored energy reaches a given voltage to discharge the stored energy through said fuse element, and means providing a limited communication between said two pairs of electrodes so that the periodic ionization at said one pair of electrodes operates to partially ionize the gas particles at the gap of the second pair of electrodes, thereby insuring conduction of the latter electrodes in substantial synchronism with conduction of the first pair of electrodes when the voltage of the stored energy closely approximates said given voltage.

10. The electromagnetically operated time control fuse defined in claim 9, wherein the last-named means comprises a partition disposed between the two pair of electrodes, said partition having means permitting the limited communication between the spaces in which the two pairs of electrodes are disposed.

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