

Nov. 21, 1944.

HENRI-GEORGES DOLL

2,363,234

DELAYED ACTION FUSE

Filed Oct. 6, 1941

3 Sheets-Sheet 1

FIG. 1.

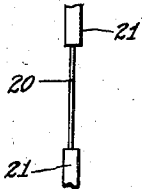


FIG. 1A.

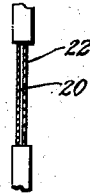


FIG. 1B.

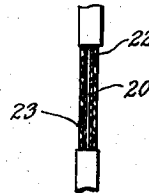


FIG. 2.

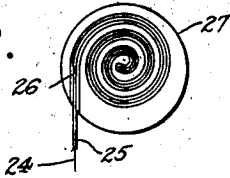


FIG. 2A.

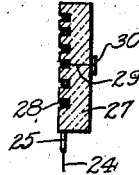


FIG. 3.

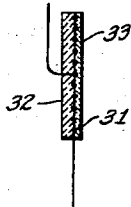


FIG. 3A.

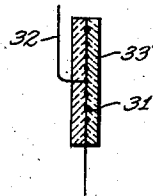


FIG. 4.

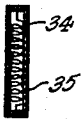


FIG. 4A.

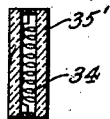


FIG. 4B.

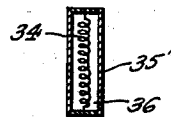


FIG. 5.

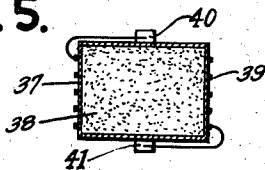
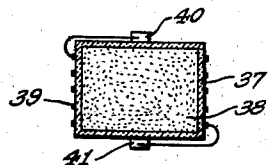


FIG. 5A.



BY

INVENTOR
HENRI-GEORGES DOLL
Hoguet, Reay & Campbell
ATTORNEYS

Nov. 21, 1944.

HENRI-GEORGES DOLL

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FIG. 6.

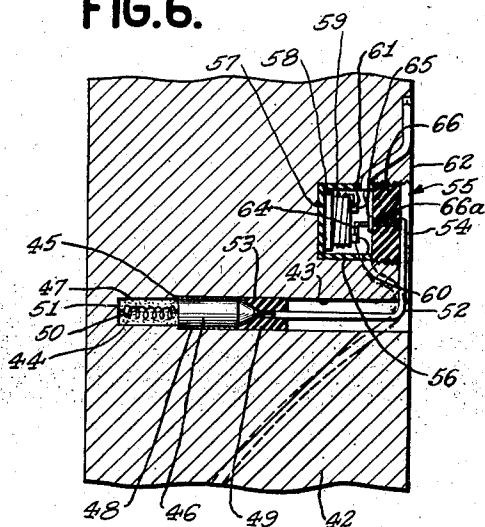


FIG. 6A.

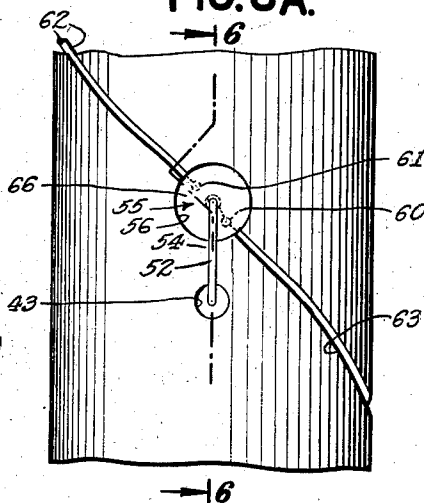


FIG. 7.

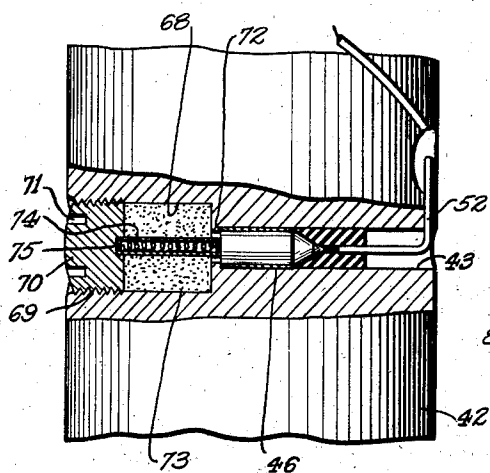
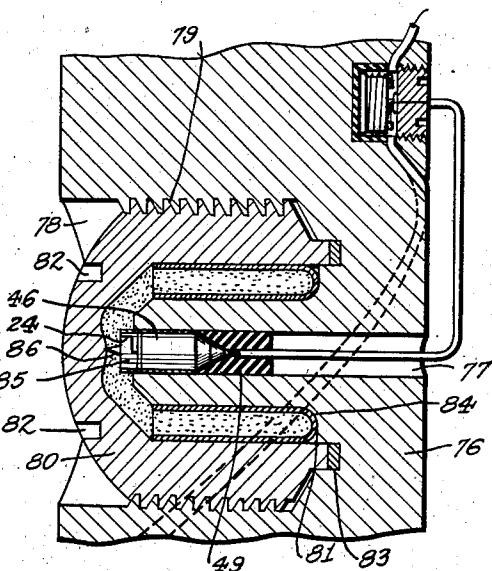


FIG. 8.



INVENTOR
HENRI-GEORGES DOLL
BY
Hoguet, Neary & Campbell
ATTORNEYS

Nov. 21, 1944.

HENRI-GEORGES DOLL

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FIG. 9.

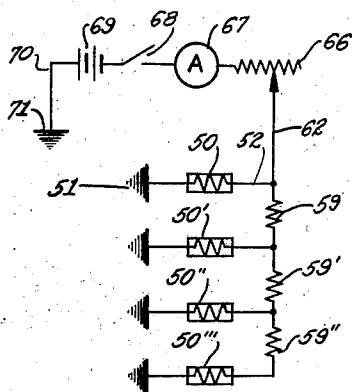


FIG. 10.

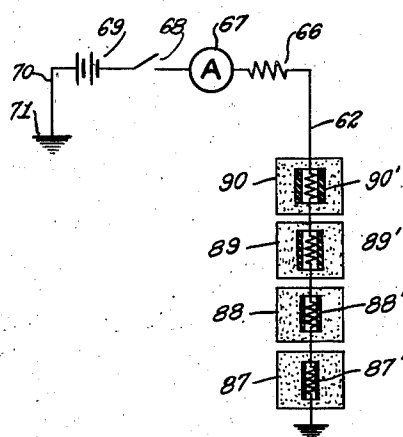
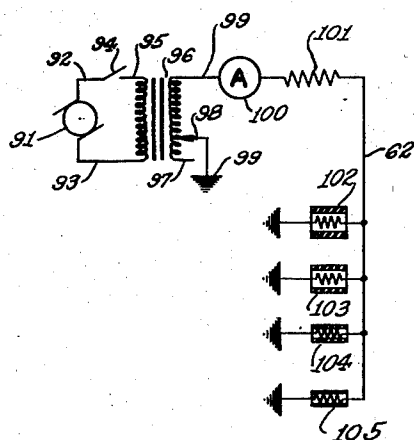


FIG. 11.



BY

INVENTOR
HENRI-GEORGES DOLL
Hoguet, Neary & Campbell
ATTORNEYS

UNITED STATES PATENT OFFICE

2,363,234

DELAYED ACTION FUSE

Henri-Georges Doll, Houston, Tex., assignor to
Schlumberger Well Surveying Corporation,
Houston, Tex., a corporation of Delaware

Application October 6, 1941, Serial No. 413,762

9 Claims. (Cl. 164—0.5)

The present invention relates to oil well tools and is particularly directed to a gun perforator for perforating oil well casings and the like and to a novel time delay fuse for selectively firing a projectile from a submerged gun, although it is not limited to such use.

Present day projectile firing mechanisms such as gun perforators and sample takers may be divided into two classes. In the first class, a plurality of guns in the gun firing mechanism are fired selectively and in the second the entire group of guns is fired simultaneously or in sequence once the sequence has been started. The selectively fired guns are generally preferred as they permit the projectiles to be fired individually at the will of the operator. Selective firing is generally accomplished by a relatively complicated switching mechanism lowered with the gun into the bore hole, or by other arrangements for sending current impulses of increasingly variable strength to heat the fuse wires directly.

This invention provides a simplified gun perforator which is selectively fired, yet has no moving switching parts in the gun, and which may be selectively fired without the necessity of supplying varying current impulses to the gun.

A primary object of the invention is to provide ignition means with a time delay for igniting an explosive charge.

Another object of the invention is to provide ignition means having quite different time delay periods, but containing electrically heated igniters which may have identical electrical properties.

Another object of the invention is to provide means in projectile firing apparatus of the above character for minimizing current leakage from the energizing conductor or conductors at the open contact caused by the firing of a projectile.

Other objects and features of the present invention will become apparent from the following detailed description taken in connection with the accompanying drawings, in which:

Figure 1 is a view in section of a conventional type fuse wire which is currently used for igniting an explosive charge in a perforating gun;

Figure 1A is a view in section of a fuse wire constructed according to the present invention and having thereon a layer of heat insulating material;

Figure 1B is a sectional view of a modified form of fuse wire which has been coated with two or more layers of similar or dissimilar heat insulating material;

Figures 2 and 2A are views in section through a spirally wound fuse;

Figures 3 and 3A are views in cross-section of a spirally wound fuse wire which has been imbedded between heat insulating members of varying thickness;

Figures 4 and 4A are views in section of helically wound fuses surrounded by varying thicknesses of heat insulating material;

Figure 4B is a sectional view of a helically wound fuse wire enclosed in a heat insulating tube similar to those shown in Figures 4 and 4A, but in which an air space is left between the wire and insulating tube;

Figures 5 and 5A are views in section of explosive cartridges which may be used in a perforating gun and in which explosive material is disposed within a heat insulating shell surrounded by a fuse wire;

Figure 6 is a partial view in longitudinal section, taken along line 6—6 of Figure 6A, of a perforating gun constructed according to the invention, showing one of a number of barrels and projectiles;

Figure 6A is a partial view in elevation of the perforating gun of Figure 6 illustrating the manner in which an insulated energizing conductor is mounted in the periphery of the gun;

Figure 7 is a partial view in longitudinal section of another simplified gun perforator employing a fuse of the type shown in Figures 4, 4A and 4B;

Figure 8 is a partial view in longitudinal section of another type of perforator illustrating the external wiring, insulated projectile, time delay fuse, and the connections between the external wiring and the fuse; and

Figures 9, 10 and 11 are schematic wiring diagrams illustrating various circuits for and various uses of the time delay fuses constituting the present invention.

The time delay fuses of the types shown in Figures 1, 1A, 1B, 2, 2A, 3, 3A, 4, 4A, 4B, 5, and 5A are adapted to be used in electrically firing explosive charges at a distance. They are particularly adapted for use in oil well tools such as gun perforators and sample takers, for example. In the following description, only their use in connection with gun perforators will be described, it being well within the scope of common engineering knowledge to adapt them in any similar device.

Time delay fuses according to the present invention comprise essentially an electrically heated resistance wire or other conductor of

electricity, a charge of powder or other explosive material, and means for delaying the transfer of heat from the resistance wire to the explosive charge. The heat from the small resistance wire may be transmitted to a relatively large mass of material, such as steel, for example, which must be heated for a considerable period of time before it reaches the powder ignition temperature. However, since this principle is relatively impractical due to the limited space available, it is preferred to surround the wire with a small quantity of heat insulating material, such as varnish, Celluloid, twine, rubber, fabric, varnished cambric, ceramic material, commercial spaghetti tubing, or the like, through which the heat must be transmitted to the explosive charge.

By varying the kind or amount of heat insulating material used, the time delay of ignition may be varied. If a non-inflammable heat insulating material is employed, it may be raised to the powder ignition temperature without burning. On the other hand, an inflammable heat insulating material will burn and the heat from the combustion assist in raising the explosive charge to its ignition temperature.

Figure 1 shows a fuse wire in its simplest form, comprising a resistance wire 20 connected in a suitable circuit (not shown) by conductors 21 through which current may be passed to heat it to a high temperature. The ignition of the explosive charge takes place as soon as the fuse wire 20 reaches the charge ignition temperature.

Figure 1A illustrates how the simple fuse wire of Figure 1 may be transformed into one suitable for use in a delayed action fuse. This may be accomplished by covering the wire 20 with an insulating material such as a coat of varnish 22, for example. It can be seen that the insulating material 22 will have the effect of impeding the transmission of heat so that, for a wire of same section and same nature and for a current of same intensity, a longer time will be required to ignite the powder surrounding the fuse of Figure 1A than the fuse of Figure 1.

The time delay action may be further increased by placing another coating of heat insulating material 23, such as a layer of fabric, for example, over the coat of varnish 22, as shown in Figure 1B. Tests have shown that the powder ignition may be readily delayed from a few seconds to several minutes, depending upon the kind and amount of heat insulation employed.

Figures 2 and 2A illustrate a modified form of time delay fuse in which a fuse wire 24, wound in the form of a spiral, is encased in a heat insulating tube 25 and placed in a spiral groove 26 cut into a disc 27 made of heat insulating material. Powder, powder paint (powder dissolved in acetone) or other suitable explosive material 28 is poured or packed into the groove 26 on top of and around the wire 24 and the tube 25. The inner end of the wire 24 is passed through a hole 29 in the disc 27 and is connected to a contact plate 30 mounted in the rear face of the disc 27.

When the wire 24 is heated, the heat passes through the tube 25 and after a characteristic time delay, ignites the explosive material 28, which in turn ignites the main body of powder (not shown). The explosive material 28 could obviously be dispensed with if desired. However, since large grain powder is sometimes employed for the main body of powder, in which case the contact area between the heated tube 25 and the powder would be variable, the time delay will

be more constant if the explosive material 28 is used. Its use is therefore preferred.

In the embodiments illustrated in Figures 3 and 3A, a fuse wire 31 wound in the form of a spiral is disposed between heat insulating discs 32 and 33 or 33'. The heat from fuse wire 31 must raise the temperature of the disc 33 to the powder ignition temperature before the powder (not shown) is ignited. Disc 33' of Figure 3A is thicker than disc 33 of Figure 3, and hence provides a greater time delay. The diameter of the discs 33 and 33' should always be preferably great compared to their thickness.

Figure 4 illustrates another useful form of the time delay fuse in which a fuse wire 34 is wound in the form of a helix and encased in a heat insulating tube 35. The tube is then disposed in a powder charge (not shown). The tube 35 impedes the flow of heat from the heated wire 34 to the powder charge and consequently causes a delay between the heating of the wire and the ignition of the powder charge. The time delay of the fuse of Figure 4 can be increased in several ways, for example, by increasing the thickness of the heat insulating tube 35 as shown in Figure 4A; or by increasing the diameter of the heat insulating tube 35 without changing its thickness, as illustrated in Figure 4B.

The fuse of Figure 4A is identical to that of Figure 4, except that the tube 35' is thicker than the tube 35 of Figure 4. The tube 35'' of the fuse shown in Figure 4B has the same thickness as the tube 35 of Figure 4, but it has a greater diameter than tube 35 of Figure 4, leaving an air space 36 around the wire 34, through which the heat must be transmitted before passing through the tube 35''. Thus the ignition of the powder charge is further delayed.

Figure 5 illustrates a time delay cartridge which may be inserted in a gun. The cartridge comprises a capsule 37 made of Celluloid or other suitable material which is filled with a charge of powder 38. A fuse wire 39 is wrapped around the capsule 37, and its two ends are connected to two contacts 40 and 41 on the capsule 37 by means of which it may be connected to an energizing circuit. If desired, the time delay may be increased by using a capsule 37' having a thicker wall than the capsule 37, as shown in Figure 5A.

In Figures 6 and 6A is illustrated a novel perforating gun in which a conductor for energizing the filaments which ignite the explosive charges in the gun is disposed in a groove formed in the periphery of the gun, and connections to the respective igniting filaments are made through the projectiles in the gun. Referring to Figure 6, 42 designates a gun perforator provided with a gun bore 43 which extends laterally therein and terminates rearwardly in a closed powder chamber 44 of slightly smaller diameter than the diameter of the bore 43. The bore 43 and the powder chamber 44 cooperate to form a shoulder 45 which provides a stop for a projectile 46 in the bore 43 and prevents the explosive charge 47 in the powder chamber 44 from being crushed by the pressure of the bore hole liquid on the projectile 46. The shoulder 45 is not essential, however, and it may be eliminated, if desired. If the proper type of explosive charge and fuse are used, the compression of the explosive charge by the projectile 46 will cause no trouble.

The projectile 46 is electrically insulated from the body of the gun perforator 42 by a sheath 48 of insulating material which may be an oxide

layer, a coat of insulating varnish, a Celluloid cup, or any other suitable insulating means. The projectile 46 is retained in place within the bore 43 by means of a rubber stopper 49 which also serves to prevent bore hole liquid from leaking into the powder chamber 44.

Within the powder chamber 44 is disposed a fuse cartridge 50, one end of which engages the rear face of the projectile 46 and the other end of which is grounded to the body of the perforating gun at the point 51. The insulated projectile 46 is connected to an insulated conductor 52 which extends through a hole 53 in the plug 49 and through a groove 54 formed along the surface of the body of the gun perforator 42 to a contact assembly 55 disposed in a cylindrical recess 56 located, for example, in the vicinity of the bore 43.

The contact assembly comprises an insulated container 57 within which is mounted a support 58 having a resistance winding 59 thereon. The terminals of the resistance winding 59 are connected to the contacts 60 and 61, respectively, which are connected in series with a conductor 62 disposed in a helical groove 63 formed in the periphery of the gun perforator 42. The contact 60 is also electrically connected to a conducting member 64 which normally engages a contact plate 65 mounted on the rear face of a plug 66 inserted or threaded in the recess 56. The conductor 52 which is connected to the projectile 46 is also connected to the contact plate 65. In this fashion the respective fuses for the explosive charges in the gun 42 may be connected in parallel with series resistances between them, as will be described in greater detail hereinafter in connection with Figure 9.

The conductor 62 in the groove 63 is connected at the surface of the earth (Figure 9) in series with a conventional type variable resistance 66, an ammeter 67 and switching means 68 to a source of electrical energy 69, the other terminal of which is connected through a conductor 70 to a ground point 71 at the surface of the earth. As shown in greater detail in Figure 9, the fuses 50, 50', 50'' and 50''' are connected in parallel with the series resistances 59, 59' and 59'' between them.

To assemble, the resistance winding 59 having its two ends connected to the contacts 60 and 61, respectively, is placed in the insulated casing 57 which is then disposed within the recess 56 in the gun perforator 42. One end of the conductor 52 is then passed through an aperture 66a in the plug 66 and is lightly soldered to the contact plate 65. A cartridge containing the explosive charge 47 and a fuse wire 50 is then placed in the powder chamber 44, as shown in Figure 6. The projectile 46, insulated except at the ends thereof and connected at the forward end to the conductor 52, is pushed into the bore 43 until it is seated against the shoulder 45 at which time its rear face is in engagement with the fuse wire 50. The rubber stopper 49, previously threaded over the wire 52, is pressed into position along with the projectile 46.

When it is desired to shoot the projectile 46, the switching means 68 (Figure 9) is closed at the surface of the earth and current is transmitted from the source of electric energy 69 through the ammeter 67, variable resistance 66, the conductor 62 and the conductor 52 to the fuse wire 50. This current heats the fuse wire 50 and ignites the explosive charge 47 in the

powder chamber 44, thereby impelling the projectile 46 out of the bore 43.

As the current continues to flow through the conductor 62 to shoot other similar projectiles in the gun perforator 42, there will be a slight leakage current from the contact member 64 through the bore hole liquid to the body of the gun perforator 42. This leakage current may be reduced by making the hole 66a in the plug 66 relatively small. It can also be decreased by making the plug 66 of rubber such that the hole 66a therein will partially close when the conductor 52 has been pulled out by the firing of the projectile 46.

In addition, one very effective method has been devised for decreasing the leakage current. It has been found that the electrical resistance between the exposed contact member 65 and the ground can be materially increased by maintaining the contact 65 at a positive potential with respect to ground. This may be readily accomplished when using direct current by grounding the negative pole of the source of electrical energy 69 and connecting the conductor 62 to the positive pole thereof. When this is done the flow of current from the contact member 65 causes a layer of gas to be formed on the surface thereof. The gas thus formed is a good electrical insulator and it reduces the leakage current to a minimum. This method is particularly effective as only a relatively small contact area is exposed to the well fluid. Also, since the member 65 is disposed in the recess 56 behind the plug 66, it is protected from the motion of the fluid in the hole so that the gas film is not disturbed.

In the embodiment illustrated in Figure 7 of the drawings, the gun perforator 42 is provided with a laterally extending gun bore 43 terminating rearwardly in a powder chamber 68 of greater diameter than the bore 43, the rear portion of which is threaded at 69 to receive a threaded plug 70. The plug 70 is provided with holes 71 therein to facilitate its removal by a conventional type spanner wrench. The bore 43 is provided with a shoulder 72 against which the projectile 46 is adapted to be seated. Within the powder chamber 68 is disposed an explosive charge 73 which is adapted to be ignited by means of a fuse wire 74 of the type illustrated in Figures 4, 4A and 4B of the drawings, one end of which engages the rear face of the projectile 46 and the other end of which is grounded to the plug 70 at the point 75.

The operation of the embodiment shown in Figure 7 is the same as that of the embodiment illustrated in Figure 6 and described above. One advantage of the construction illustrated in Figure 7 is that it permits a larger explosive charge to be employed while maintaining the same length gun bore and the same diameter gun body. This embodiment further illustrates the use of the time delay fuses of Figures 4, 4A and 4B in connection with a large volume of powder.

Figure 8 illustrates the use of delayed action fuses constructed according to the present invention in a conventional type perforating gun. Referring to Figure 8, the gun perforator 76 is provided with a laterally extending bore 77 having a projectile 46 therein. The bore 77 communicates rearwardly with a concentric cylindrical recess 78 which is threaded at 79 to receive a hollow cylindrical plug 80, forming a cylindrical powder chamber 81 between the plug 80 and the body of the gun perforator 76. The

plug 80 is provided with holes 82 to facilitate its removal by a spanner wrench and a gasket 83 is provided between it and the body of gun perforator 76 in order to insure a tight joint. Within the chamber, 81 is disposed an annular cartridge 84 having an explosive charge therein. Secured at the rear end of the projectile 46 is a fuse 85 of the type shown in Figures 2 and 2A of the drawings. One end of the wire 24 in the fuse 85 is connected to the rear face of the projectile 46 and the other end is connected to a conical member 86 which engages the plug 80. The circuit connections are essentially the same as described above in connection with Figures 6 and 6A.

In operation, the wire 24 in the fuse 85 is electrically heated by closing the switching means 68 at the surface of the earth (Figure 9). The heat from the fuse 85 ignites the powder paint 28 in the groove 26 (Figure 2A) after a characteristic time delay, in turn igniting the powder charge in the cartridge 84 and impelling the projectile 46 through the gun bore 77.

The schematic circuit of Figure 9 illustrates how selective firing may be accomplished with identical cartridges connected in parallel without interrupting the flow of current being sent to the perforating gun. The resistors 59, 59' and 59'' may, or may not, be identical, although as a practical matter it is preferable to have them identical. By way of example, the resistance of each of the fuses 50, 50', 50'' and 50''' may be two ohms and the resistance of each of the resistors 59, 59' and 59'' may be five ohms.

When it is desired to start the sequence of shots, the switching means 68 is closed at the surface of the earth. Because of the presence of the resistor 59 more current will flow through the fuse 50 than through any of the others so that it will be fired first. The variable resistance 66 may then be adjusted or the potential applied by the source of electric energy 69 altered until the proper current for firing the cartridge 50' is obtained. The same procedure will then be followed until the desired number of projectiles have been fired.

Although the current being supplied to the gun need not be interrupted, variations of current registered by the ammeter 67 may be observed as an indication of the firing of each shot. Any desired method may be employed to report the firing of each shot to the surface. For example, a pair of headphones connected across an inductance in series with the conductor 62 will give a characteristic sound each time a shot is fired. Alternatively, a shock-actuated switch may be located at or near the gun such that a circuit including suitable indicating means is momentarily completed or interrupted by the vibration created by the shooting.

If the variable resistance 66 has a high value, it will be possible to fire a great number of projectiles without altering either the applied potential or the adjustment of the variable resistor 66. In such case, the various projectiles in the gun perforator would fire almost immediately were it not for the delayed action produced in the fuses employed. Obviously the time between successive shots may be increased by successively increasing the amount of heat insulating material on the respective fuses. The same result could also be obtained by successively increasing the value of the resistances 59, 59' and 59''.

Figure 10 is a schematic wiring diagram illus-

trating the use of series connected delayed action fuses and indicating the manner in which the various projectiles in a gun perforator may be selectively fired with a substantially constant interrupted current when fuses with similar electrical characteristics are employed. In this embodiment, the conductor 62 is connected to the dissimilar, series-connected cartridges 87, 88, 89 and 90, the return current path being through the earth. The resistances of the fuse wires 87', 88', 89' and 90' in the cartridges 87, 88, 89 and 90 is relatively low, generally being in the neighborhood of a few ohms, while the resistance 66 is relatively high, such as, for example, fifty ohms or more. The fuse wires 87', 88', 89' and 90' are similar but the thickness of the heat insulation surrounding each is progressively increased so that they will all be heated to approximately the same temperature when the switching means 68 is closed, but the powder surrounding the fuse 87' will be ignited first, since it has the least insulation surrounding the fuse wire. If desired, the first cartridge 87' may be constructed without any special insulating material surrounding the fuse wire.

A short time after the cartridge 87 has ignited, the powder in the cartridge 88 will then be heated to its ignition temperature and in similar fashion the cartridges 89 and 90 will be ignited in that order.

In the event that one of the fuse wires should be broken by the firing of the projectile corresponding thereto, the circuit will be completed by the bore hole liquid which flows into the powder chamber and grounds the exposed contact. Any other known method may be employed for reCompleting the circuit when a fuse wire is broken. This may be accomplished by connecting the firing circuit and gun body to a pair of metallic surfaces which are electrically insulated from one another by a layer of insulating material. The device is disposed in the explosion chamber in such fashion that the insulating material is destroyed by the explosion. When this condition obtains, the two conductor surfaces are brought into engagement, grounding the circuit at that point and insuring a completed circuit even though the fuse wire is broken during firing.

If it is desired to discharge only certain of the cartridges, the circuit may be opened after the desired number of charges have been fired. Any suitable mechanism may be employed to count the charges as they fire. After part of the charges have been fired the balance or any part thereof may be fired by reclosing the switch 68.

The series circuit shown in Figure 10 may be further modified by providing fuses with graded resistances, as well as graded time delay means. In such case, a second series of fuses could be provided above the series illustrated in Figure 10 which would differ from those shown only in that each fuse would require a larger current to heat it to ignition temperature. The current would necessarily have to be increased to fire each successive series of cartridges. Accordingly, a large number of shots could be fired in a single circuit by using several series of fuses of varied resistance and varied time delay characteristics.

In Figure 11 is shown a schematic wiring diagram illustrating a plurality of delayed action fuses connected in parallel which may be selectively fired without interrupting the flow of cur-

rent to the perforating gun. As shown in the figure, a source of alternating current 91 is connected through the conductors 92 and 93 and a switch 94 to the primary winding 95 of a conventional type transformer 96. The secondary winding 97 of the transformer 96 is provided with a variable tap 98 which is grounded at the point 99 at the surface of the earth. The other terminal of the secondary winding 97 of the transformer 96 is connected through a conductor 99, an ammeter 100, a resistance 101 and the conductor 62 to a plurality of dissimilar, parallel-connected fuses 102, 103, 104 and 105, the other ends of which are connected to ground, the intervening earth serving as a return conductor.

The fuses 102, 103, 104 and 105 have similar electrical properties so that the same amount of current will flow through each cartridge and the same amount of heat will be developed. However, the fuses 102, 103, 104 and 105 are provided with different amounts of heat insulating material, the fuse 102 having the most and the fuse 105 having the least, or preferably none at all. Hence the fuses 105, 104, 103 and 102 will fire in that order. The sequence can obviously be interrupted at any time by opening the switch 94 and re-established again by reclosing the switch 94. The ammeter 100 will give visual indications of the shots fired because current increments will be observed when each fuse wire is broken due to the firing of a projectile. It will be noted that the operator need make no adjustments during the shooting sequence.

The embodiment of the invention illustrated in Figure 11 may be further modified by using fuses of different electrical resistance with equal time delay periods or a combination of fuses having both graded resistances and graded time delay periods. Such combinations greatly increase the number of shots which may be selectively fired without necessitating abnormally high voltages or currents.

The modifications described above are intended to be illustrative only and the invention is not intended to be limited in any way thereby but is susceptible of numerous changes in form and detail within the scope of the appended claims.

I claim:

1. In gun apparatus for use in wells, the combination of a body adapted to be lowered into a bore hole, said body having a plurality of gun bores therein and powder chambers therefor, an explosive charge in each of said powder chambers, a plurality of heating elements for igniting said explosive charges, and means for delaying the transfer of heat from each of said heating elements to the corresponding explosive charges, said delaying means having different thermal properties whereby the delay will be different for each of said elements.

2. In gun apparatus for use in wells, the combination of a body adapted to be lowered into a bore hole, said body having a plurality of gun bores therein and powder chambers therefor, an insulated projectile in each of said gun bores, an explosive charge in each of said powder chambers, heating elements for igniting said explosive charges, said heating elements each having one terminal grounded to the body and another terminal connected to a projectile, a plurality of heat insulating means for delaying the transfer of heat from said heating elements to the explosive charges corresponding thereto, said insulating means having different thermal prop-

erties, respectively, so chosen that the delay for each heating element will be different from the others, an energizing conductor mounted on the outside of the body, and electrical connections between said conductor and each of said projectiles.

3. In apparatus for igniting a plurality of explosive charges in a body lowered into a bore hole, the combination of a plurality of series-connected heating elements for igniting said explosive charges, means interposed between said respective heating elements and said explosive charges for delaying the transfer of heat to the explosive charges corresponding thereto, the thermal properties of said respective heat transfer delaying means being so chosen as to cause them to reach the ignition temperatures of the corresponding explosive charges at different times, and a source of electrical energy connected to said series of heating elements.

4. In apparatus for igniting a plurality of explosive charges in a body lowered into a bore hole, the combination of a plurality of series connected heating elements for igniting said explosive charges, a plurality of heat insulating members interposed between said heating elements and said explosive charges, each having different heat transfer characteristics so chosen that the ignition temperatures of the respective explosive charges will be reached at different times, and a source of electrical energy connected to said series of heating elements.

5. In apparatus for use in bore holes, the combination of a body adapted to be lowered into a bore hole, said body having a plurality of gun bores therein and powder chambers therefor, an explosive charge in each of said powder chambers, electrically connected heating means in each of said powder chambers for igniting the respective explosive charges therein, said respective heating means having different thermal properties so chosen as to cause them to reach the ignition temperatures of the explosive charges at different times, and a source of electrical energy connected to said series-connected heating filaments.

6. In bore hole apparatus the combination of a body adapted to be lowered into a bore hole, said body having a gun bore therein, an insulated projectile in the gun bore, a resistance winding disposed in a recess in the body near the gun bore, a source of direct current having its positive pole connected to said resistance winding a closure for the recess having a small bore therein, and an insulated conductor extending from said projectile and through the bore in the closure to one of the terminals of said resistance winding, whereby upon firing of said gun, said conductor is disconnected from said winding and an insulating medium is formed at the point of disconnection to reduce current leakage from the conductor.

7. In a gun perforator, the combination of a body adapted to be lowered into a bore hole, said body having a gun bore therein, an insulated projectile in the gun bore, means forming a groove in the periphery of the body and extending longitudinally of the body, a conductor in said groove, a resistance winding disposed in a recess in the body near said gun bore and connected in series with said conductor, a source of direct current having its positive pole connected to said conductor, a closure for the recess having a small bore therein, and an insulated connection between said projectile and said resist-

ance winding through the bore in the closure, whereby upon firing of said gun, said conductor is disconnected from said winding and an insulating medium is formed at the point of disconnection to reduce current leakage at said point of disconnection.

8. In a gun perforator, the combination of a body adapted to be lowered into a bore hole, said body having a gun bore therein, an insulated projectile in the gun bore, electrical igniting means connected between said projectile and ground, means forming a groove in the periphery of the body and extending longitudinally of the body, a conductor in said groove, a resistance winding disposed in a recess in the body near said gun bore and connected in series with said conductor, a closure for the recess having a small bore therein, an insulated connection between said projectile and said resistance winding

through the bore in the closure and a source of electrical energy having its positive terminal electrically connected to said conductor and its negative terminal electrically connected to ground.

9. In apparatus for igniting a plurality of explosive charges in a body lowered into a bore hole, the combination of a plurality of parallel-connected heating elements for igniting said explosive charges, means interposed between said respective heating elements and said explosive charges for delaying the transfer of heat to the explosive charges corresponding thereto, the thermal properties of said respective heat transfer delaying means being so chosen as to cause them to reach the ignition temperatures of the corresponding explosive charges at different times, and a source of electrical energy connected to said parallel heating elements.

HENRI-GEORGES DOLL.