

March 6, 1945.

P. W. MARTIN

2,370,909

GUN FIRING MEANS

Filed Aug. 16, 1943

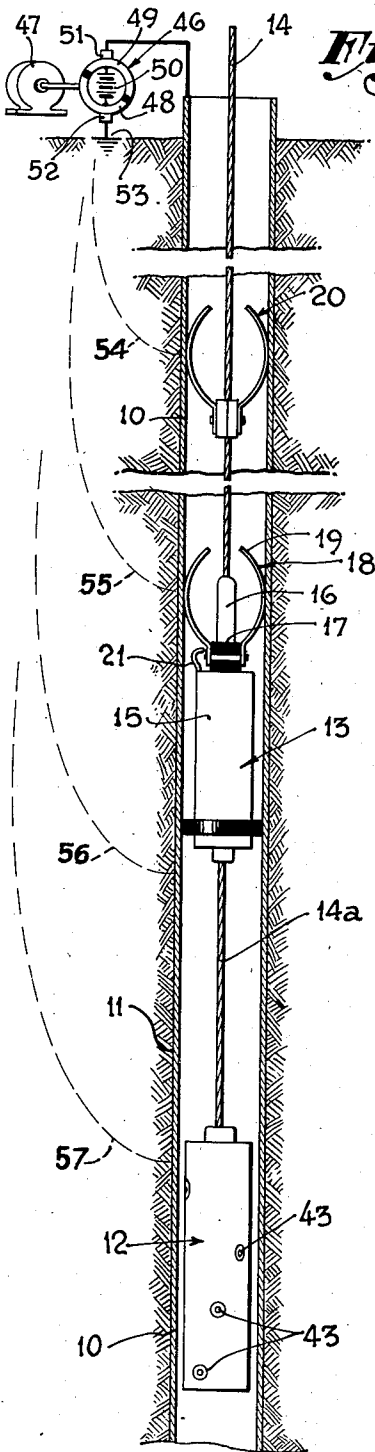


Fig. 1

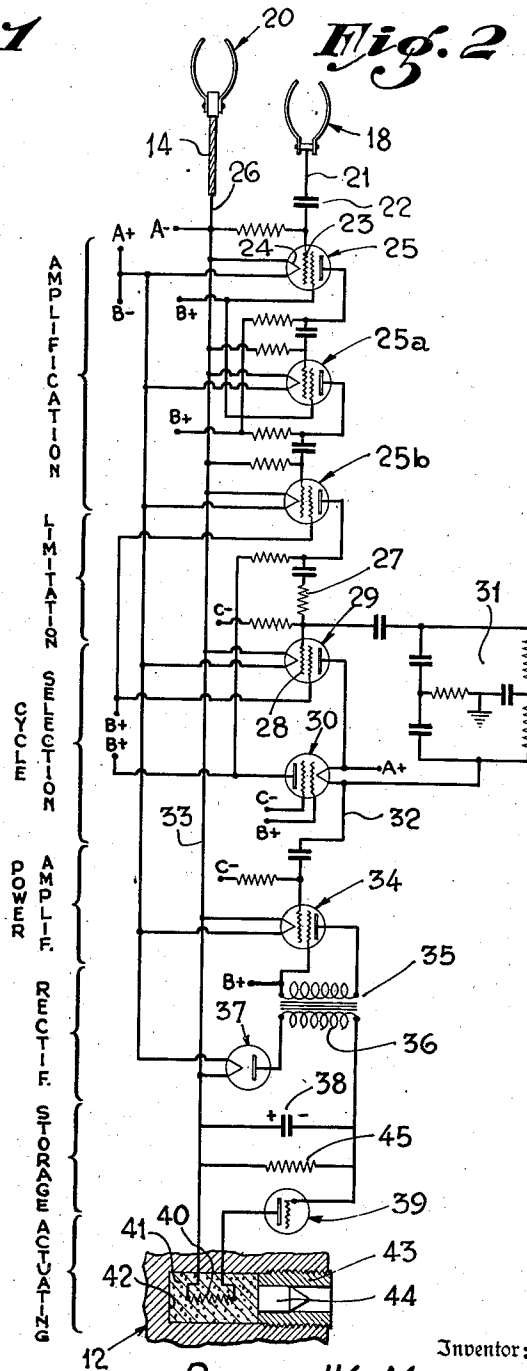


Fig. 2

Inventor:

PHILIP W. MARTIN,

38

Philip W. Martin

Attorney.

UNITED STATES PATENT OFFICE

2,370,909

GUN FIRING MEANS

Philip W. Martin, Huntington Park, Calif.

Application August 16, 1943, Serial No. 498,800

13 Claims. (Cl. 164—9.5)

My invention relates in general to a method and means for controlling or producing an action at an inaccessible point below the surface of the earth and relates in particular to the firing of an explosive charge in a perforating gun positioned within a casing in a well.

To provide openings in a casing in a well, through which oil may pass from the oil bearing formation into the interior space of the casing, perforating guns are now employed wherein the expansive force of an explosive charge is employed to propel a projectile through the casing wall, leaving an opening therein through which fluid may flow from the formation into the casing. Perforating guns of this character are now fired by two different methods. One of these methods is to connect the perforating gun to an electric cable, that is to say, a cable having an insulated conductor extending therein, this conductor being connected to electrical firing means in the gun, and when the gun is suspended at the desired level in the well, a current is transmitted through the conductor to actuate the firing means. The second method is to provide the perforating gun with a firing mechanism having a movable external part by which it may be actuated. The perforator gun, so equipped, is lowered into the well by means of a standard wire line or cable and a weighty object, called "go-devil," is then slidably connected to the cable and allowed to descend within the well so that it engages the movable part of the firing device, and by moving the same, actuates the firing device. Reasonably satisfactory results have been obtained in the use of this method, wherein a firing member is placed around the cable and allowed to descend so that it will strike an exposed part of the firing mechanism of the gun. However, in the use of this method there are a number of disadvantages to be considered, namely the ever present possibility of the "go-devil's" being hung up in the well so that it fails to reach and fire the gun, and the type of mechanism employing a go-devil may be fired by movement of the external part of the firing device. The gun firing method first named, wherein a conductor equipped cable is employed, has as disadvantages the necessity of transporting the specially prepared cable to each job, the handling of this cable at the job, upkeep and replacement of cable owing to the failure of insulation, and rupture of electrical conductors in the cable, the delay and labor encountered as the result of failure of insulation or electrical conductors in a cable while the gun is being lowered by the cable into the

well, making it necessary to pull the gun so as to replace the faulty cable with another.

It is an object of my present invention to provide a device and a simple method for firing an explosive charge in a perforating gun which has been lowered into a well, which avoids the use of cable equipped with electrical conductors and avoids the use of go-devils, thereby eliminating the disadvantages involved in the use of the old method and means referred to in the preceding paragraph. Where my new invention is employed, the service of perforating a casing in a well requires only transportation of relatively light equipment to the site of operations.

It is an object of the invention to provide a method of firing a perforating gun in a well, wherein a gun is equipped with electro-responsive firing means, the lowering of the gun and the firing means into the well by use of ordinary wire line, cable, pipe or sucker rod, and transmitting electrification to the electro-responsive means by use of a simple device situated at the top of the well.

A further object of the invention is to provide a firing device adapted to be connected to a gun which is lowered into a well by use of ordinary wire line or cable, this firing means having a mechanism which is responsive to a characteristic electrical signal which is transmitted from the surface of the ground.

It is also an object of the invention to provide a method and apparatus wherein the electro-potential signal is transmitted to the upper end of the casing which projects down into the well and in which the perforating gun is to be operated, and wherein the signal is picked up by the electro-responsive control located in proximity to the gun through use of means wherein the signal is picked up by measuring the electro-potential drop along a portion of the casing or earth.

Further objects and advantages of the invention will be brought out in the following part of the specification.

Referring to the drawing which is for illustrative purposes only,

Fig. 1 is a schematic view showing a preferred form of my invention in the well.

Fig. 2 is a diagram of the electrical equipment forming a part of my invention.

In Fig. 1 I have shown a casing 10 lining a well 11. For the purpose of perforating the casing at a desired level below the surface of the ground so as to admit fluids from the exterior of the casing to its interior, I have shown a perforating gun 12 which may be of any known electri-

cally operated type. For example, this gun 12 may be of any of the types disclosed in one or more of the following U. S. patents: No. 1,582,184, No. 2,022,976, and No. 2,037,955, wherein electric current ignites a fuse or primer associated with each of one or more charges of powder, and Patent No. 2,029,490, wherein powder charges are selectively fired in series relation instead of simultaneously.

The gun 12 is connected to a firing device or control 13, preferably by means of a comparatively short electrical cable 14a. The gun 12 and the device 13 are lowered into the well by means of an ordinary cable or wire line 14 so as to bring the gun 12 into the portion of the casing 10 selected for perforating. The device 13 includes a water tight shell 15 with an upwardly projecting cable attachment 16 which has around its lower portion an annular insulator 17 to support casing contacting means 18, preferably consisting of a cage comprising bow springs 19 which slide vertically along the inner surface of the casing 10 and make electrical contact therewith. A second means for electrical contact of the device 13 with the casing is provided at a point above the cage 18. In the ordinary practice of the invention this upper contact of the cable 14 with the casing 10 is accomplished by the actual engagement of the cable 14 with the inner surface of the casing, resulting from the fact that the casing in a well which has been drilled to a considerable depth is not straight and that the cable will rub thereagainst at one or more bends in the casing. I have, however, for purpose of illustration, shown such additional contact means as bow springs 20 clamped on the cable 14 so as to be electrically connected thereto, these bow springs sliding along and making contact with the interior of the casing 10. The cages 18 and 20 are not necessary in all practices of the invention. For example, when there is salt water or mud in the well, contact with the casing or earth need not be made.

The device 13 has means which acts in response to impulses transmitted through the wall of the well to control or produce a useful act which, in the preferred embodiment of the invention, consists in the control or actuation of perforating means within the casing.

The device 13, as shown in Fig. 2, includes a conductor 21 which connects the cage 18 with a condenser 22 which is connected to the grid 23 of the first tube 25 of the amplification section of the device. The filament 24 of this tube 25 is grounded through a conductor 26 with the cable 14 which is arranged to make electrical connection with the wall of the well, preferably the casing 10, at a point spaced from the cage 18. As hereinbefore explained, this contact of the cable 14 with the casing 10 may be through engagement of the cable 14 with the casing 10 at a bend therein, or by use of the bow springs 20 mounted upon and electrically connected to the cable 14. In the connection of the members 18 and 20 to the apparatus, transformer or impedance coupling may be employed, but I have preferred to use the resistance capacitance coupling shown in the upper part of Fig. 2. In the amplification section of the device I have shown three stages of common resistance capacitance coupled voltage amplifiers employing three tubes which may be any of the types known to the art of electronics. I have, however, shown tubes 25, 25a and 25b as being of the pentode type having A and B battery connection and associated condensers and resistances, etc., as indicated in the diagram which may be

readily interpreted or read by those acquainted with this art.

In the device shown in Fig. 2, the tubes 25, 25a, and 25b have a gain of fifty per stage or an overall gain of 2500 in the first two tubes, so that a very small effective voltage will give practically square wave output from the tube 25b, which feeds into the voltage divider 27, and, since, the tube 25b is used to the limit of its voltage capacity, no greater voltage can be drawn from the power supply provided by the amplification section for the following parts of the equipment. Accordingly, this voltage divider 27, forming a part of the voltage limitation section of the device, has the effect of limiting the maximum voltage that can pass to the grid 28 of the tube 29. The voltage divider also furnishes a high impedance load to feed the output of the cycle selection section of the device, which employs tubes 29 and 30 and in conjunction with the resistance and condenser network 31 form a selective circuit which determines the cycle or timing of the potential or electrical impulses which may pass through the conductors 32 and 33 to the grid and filament of the tube 34, forming a part of the power amplification section of the device.

The power amplification section includes a transformer 35 having a secondary winding 36 which, through a thermionic rectifier 37 of the rectification section of the device, feeds a storage condenser 38 which forms the principal element of the storage section of the device. The final or actuating section of the device 13 includes an electrical valve shown as a grid glow tube, gastriode or diode, 39, connected in series with the condenser 38 and with a means 40 which is responsive to a flow of current to produce an act or effect desired at an inaccessible point below the surface of the earth. The means 40 is shown as a high resistance filament which heats or glows in response to a flow of electric current therethrough so as to ignite a powder charge 41 in a powder chamber 42 of the gun 12, Fig. 1. This powder chamber 42 is disposed at the inner end of a gun barrel 43, and the effect of the burning of the powder charge 41 is to impel a projectile 44 outward at high velocity so that it will perforate the casing 10. A high resistance conductant 45 is bridged across the storage condenser 38 to serve as a bleeder to bleed off random pulses that might get through the cycle selection section of the device, thereby providing a safety element. In the operation of the equipment shown in Fig. 2, potential or electron impulses are transmitted down through the well. If these impulses are of the same periodicity as that for which the cycle selection section of the device 13 has been adjusted, these impulses, highly amplified, will be stored by the condenser 38 at a rate much higher than the rate at which the bleeder 45 is capable of bleeding the charge from the condenser 38, and when the voltage of the condenser 38 reaches the break-down value of the valve tube 39, negative electrons will flow across from the cathode to the plate of the tube 39 and then through the electrically responsive means 40. Therefore, in order to actuate the means 40, it is necessary that the actuating impulses shall be fed to the condenser 38 for a period of time which is characteristic of the electrical values of the various parts of the device 13. If stray impulses pass through to the condenser 38, or the feeding of selected impulses to the condenser 38 is continued prior to the actuation of the valve tube 39, the bleeder 45 will bleed the con-

denser 38 down to substantially zero potential difference between its plates.

In the operation of my invention I apply potential or electrical impulses to the electric current or potential carrying wall structure extending along the hole, for example, the earth, casing, metal members in the hole, or fluids or mixtures of current or potential transmitting capacity in the well, and herein the term "wall" in association with the well or hole is intended to include the foregoing, but, in the preferred practice of the invention, the impulse producing means is connected to the top of the casing. These impulses may be unidirectional, alternating, or superimposed. In Fig. 1 I show a commutator 46 drivable at constant speed by a motor 47. This commutator has segments 48 and 49 connected to opposite poles of a direct current power source such as a battery 50. The segments 48 and 49 are engaged by brushes 51 and 52 which are respectively connected to the casing 10 and to a ground connection 53. The rotation of the commutator 46 results in the feeding of positive and negative electron impulses to the casing 10, which flow down the casing and into the formation, such impulses passing to the ground connection 53 through divided paths in the formation as indicated by lines 54, 55, 56 and 57. There is a potential drop along the casing, and therefore these electronic impulses produce a potential difference between the contact means 18 and 20, or a potential difference between input conductors 21 and 26 of the device 13. These impulses may be very small, but the amplification section of the device 13 under the control of the input impulses produces at the output of the tube 25b impulses of a magnitude to ultimately accomplish actuation of the electro-responsive means 40. For example, when the device 13 is at a depth of four or five thousand feet within the well, the impulses picked up by the input conductors 21 and 26 will be weak as compared to the impulses which are picked up when the device is positioned only one or two thousand feet below the surface of the ground, but when the device is operated within the range for which it is designed, the impulses transmitted through the limitation section to the cycle selection section will be all of substantially the same potential, regardless of the depth within the well at which the device 13 receives the controlling impulses.

I have produced a device which is capable of operation at great depth within the well, through use of impulses of low periodicity, and the adjustment of the selective section of the unit to receive or pass only these selected low periodicity impulses. A further feature of my invention is the use of a frequency of impulses below the damping or impulse absorbing capacity of the earth materials which I have found to be effective against the passage of high frequency potential impulses down the wall of the well or down the casing to any great depth. In the invention disclosed I produce, transmit, and pick up potential impulses having a frequency below a value which I term the impulse suppression value of the sub-surface structure, which includes both the well casing and the formation. This sub-surface structure appears to have an effect, such as a condenser or capacitance effect, whereby impulses are absorbed or suppressed, which suppression may be the moving out of the potential impulses to such an extent that the potential or current flow is substantially constant. This impulse suppression

value of the sub-surface structure varies with depth and also with the structural characteristics of the formations penetrated. My invention comprehends the use of impulse frequencies of 25 per second and below. For depth greater than four thousand feet, I have employed a frequency of seven impulses or cycles per second. The equipment, when adjusted for operation at such low frequencies, will, of course, operate satisfactorily at any depth within the well, although higher frequencies may be employed in the shallower wells, and under favorable earth conditions.

I claim as my invention:

1. A method of producing a desired action in an electro-responsive device in a cavity below the surface of the earth, comprising: transmitting along the wall structure of the cavity impulses below the impulse suppression value of the sub-surface structure between the position at which the impulses are originated and the position at which they are picked up; picking up these impulses at a position remote from the position at which they are originated and employing the picked up impulses to produce impulses of greater and operative magnitude; and directing these electrical impulses to an electro-responsive means for producing said desired action.

2. A method of producing a desired action in a cavity below the surface of the earth, comprising: transmitting through the earth electro-potential impulses in such a manner that they may be picked up along the wall of the cavity; picking up these impulses at a position remote from the position at which they are originated and employing the picked up impulses to produce impulses of a greater and operative magnitude; accumulating these electrical impulses so as to build up an electro-potential charge; and directing the electro-potential charge to an electro-responsive means for producing said desired action.

3. A method of producing a desired action in a cavity below the surface of the earth, comprising: transmitting along the wall structure of the cavity impulses of a frequency below the impulse suppression value of the subsurface structure between the position at which the impulses are originated and the position at which they are picked up; picking up these impulses at a position remote from the position at which they are originated and employing the picked up impulses to produce impulses of greater and operative magnitude; accumulating these electrical impulses so as to build up an electro-potential charge; and directing the electro-potential charge to an electro-responsive means for producing said desired action.

4. A method of producing a desired action in a well below the surface of the earth, comprising: transmitting along the wall structure of the well electro-potential impulses of predetermined character; picking up these impulses at a position remote from the position at which they are originated and employing the picked up impulses to produce impulses of a greater and operative magnitude; accumulating these electrical impulses so as to build up an electro-potential charge; and directing the electro-potential charge to an electro-responsive means for producing said desired action.

5. A method of producing a desired action in a well below the surface of the earth, comprising: transmitting along the wall structure of the well impulses of a frequency below the impulse suppression value of the subsurface structure between the position at which the impulses are

originated and the position at which they are picked up; picking up these impulses at a position remote from the position at which they are originated and employing the picked up impulses to produce impulses of greater and operative magnitude; accumulating these electrical impulses so as to build up an electro-potential charge; and directing the electro-potential charge to an electro-responsive means for producing said desired action.

6. A method for actuating in a well a perforating gun or other device having electro-responsive means for the operation thereof, comprising: transmitting down through the wall structure of the well impulses having a frequency below the impulse suppression value of the subsurface structure between the position at which the impulses are originated and the position at which they are picked up; picking up in the proximity of said device said impulses and stray impulses; separating said transmitted impulses from said stray impulses; and employing said transmitted impulses to control the operation of said electro-responsive means of said device.

7. A method for actuating in a well a perforating gun or other device having electro-responsive means for the operation thereof, comprising: transmitting down through the wall structure of the well impulses having a frequency below the impulse suppression value of the subsurface structure between the position at which the impulses are originated and the position at which they are picked up; picking up in the proximity of said device said impulses and stray impulses; separating said transmitted impulses from said stray impulses; magnifying and accumulating said transmitted impulses; and directing the accumulation of said transmitted and magnified impulses through said electro-responsive means.

8. In means for actuating in a cavity below the surface of the earth, a device having electro-responsive actuating means, the combination of: means for applying potential impulses to the earth; means in proximity to said device for picking up said potential impulses and under control thereof directing an actuating current to said electro-responsive means of said device, comprising means to receive said impulses; means for employing said impulses to produce electro-potential impulses of greater magnitude; storage means for accumulating said impulses of greater magnitude; means connecting said storage means to said electro-responsive means of said device; and an electrical valve for controlling the discharge of said storage means through said electro-responsive means.

9. In means for actuating, in a cavity below the surface of the earth, a device having electro-responsive actuating means, the combination of: means for applying potential impulses of selected frequency to the wall structure of said cavity; means in proximity to said device for picking up said potential impulses and under control thereof directing an actuating current to said electro-responsive means of said device, comprising means to engage said wall structure of the cavity to receive impulses therefrom; means for employing said impulses to produce electro-potential impulses of greater magnitude; means for blocking electro-potential impulses of a frequency different from said selected frequency; storage

means for accumulating the magnified impulses which pass through said blocking means; means connecting said storage means to said electro-responsive means of said device; and an electrical valve for controlling the discharge of said storage means through said electro-responsive means.

10. In means for actuating, in a cavity below the surface of the earth, a device having electro-responsive actuating means, the combination of: means for applying to the wall structure of the cavity potential impulses of a frequency below the effective impulse suppression value of the structure; means in proximity to said device for picking up said potential impulses and under control thereof directing an actuating current to said electro-responsive means of said device, comprising means to engage said wall of the cavity to receive impulses therefrom; means for employing said impulses to produce electro-potential impulses of greater magnitude; means for blocking electro-potential impulses of a frequency different from said frequency; storage means for accumulating the magnified impulses which pass through said blocking means; means connecting said storage means to said electro-responsive means of said device; and an electrical valve for controlling the discharge of said storage means through said electro-responsive means.

11. Means for actuating in a well perforating gun or other device having electro-responsive means for actuation thereof, the combination of: means for applying electro-potential impulses to the upper part of the wall structure of the well so that said impulses will travel down said wall structure; means engaging the wall structure of the well at spaced points and having parts operating in response to the potential drop between said spaced points to produce an actuating current; and means to direct said actuating current to said electro-responsive means of said gun.

12. Means for actuating in a well a perforating gun having electro-responsive means for actuation thereof, the combination of: means for applying to the upper part of the wall structure of the well an electro-potential impulse so that said impulse will travel down said wall structure; means to receive said impulse engaging the wall structure of the well at spaced points and having parts operating in response to the potential drop between said spaced points to produce an actuating current; and means to feed said actuating current to said electro-responsive means of said gun.

13. Means for actuating in a well a perforating gun having electro-responsive means for actuation thereof, the combination of: means for applying to the upper part of the wall of the well electro-potential impulses so that said impulses will travel down said wall; means connected to said gun engaging the wall of the well at spaced points in proximity thereto and having parts operating in response to the potential drop between said spaced points to produce current impulses; means for accumulating said current impulses; and means for feeding said accumulated current impulses to said electro-responsive means of said gun.

PHILIP W. MARTIN.