Jan. 5, 1960 J. L. FOSTER 2,919,646

WELL EXPLOSIVE DEVICES

Original Filed Aug. 15, 1946

2 Sheets-Sheet 1

Fig. 1

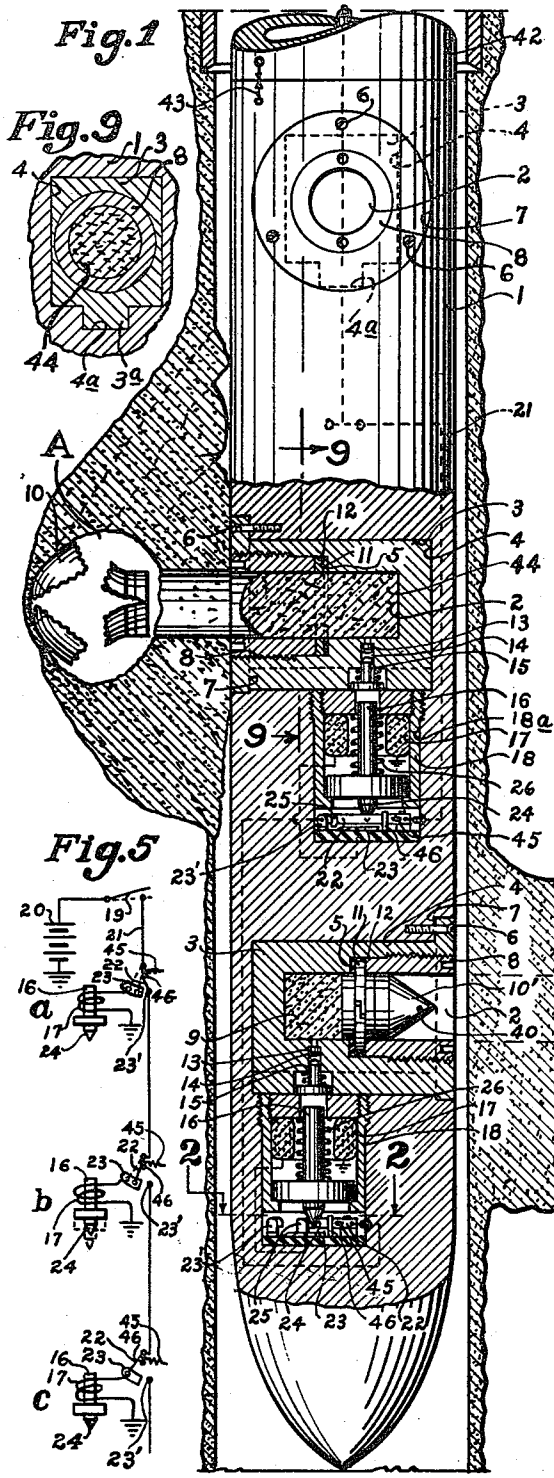

Fig. 9

Fig. 2

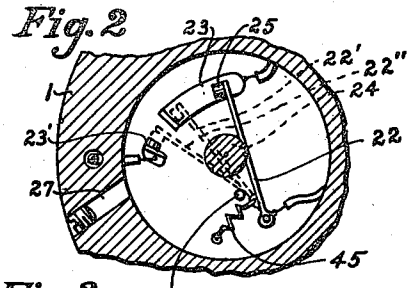

Fig. 3

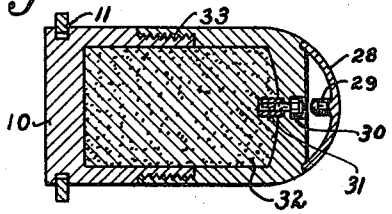

Fig. 4

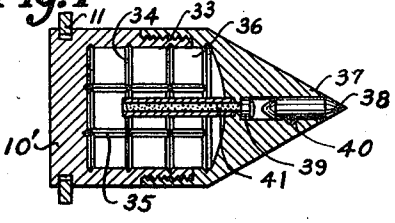

Fig. 5

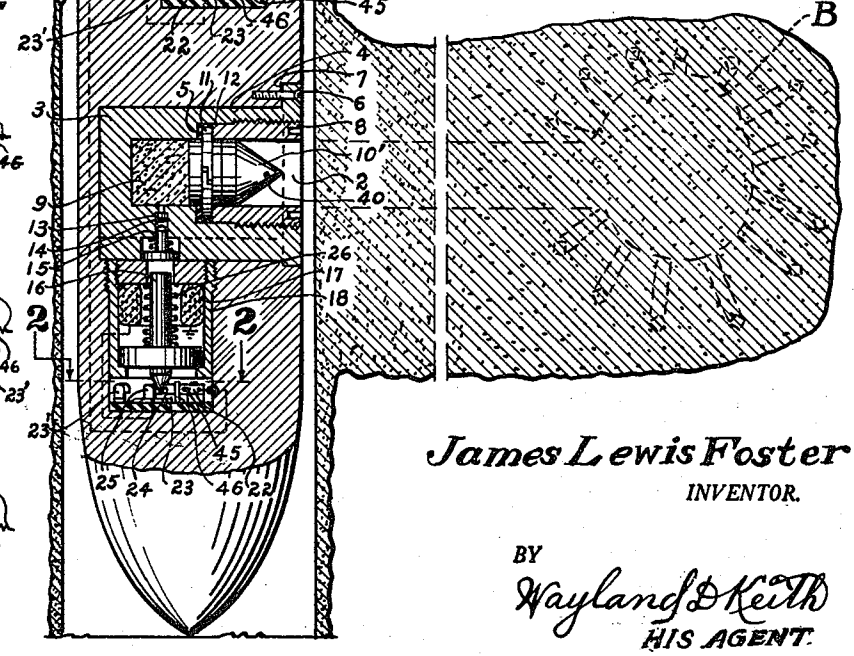

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Fig. 6

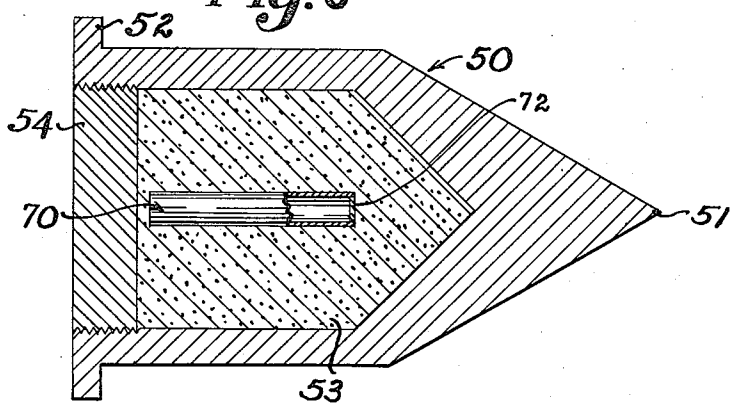


Fig. 7

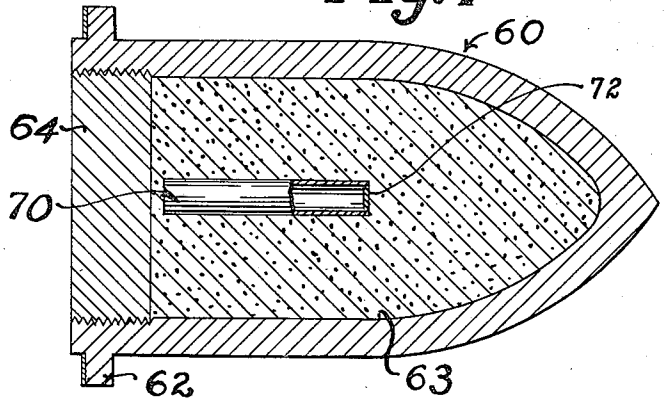
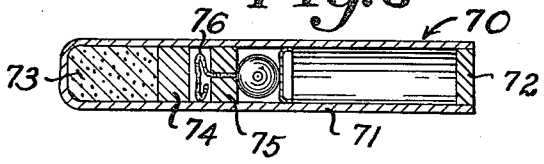


Fig. 8



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United States Patent Office

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WELL EXPLOSIVE DEVICES

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Continuation of abandoned application Serial No. 690,762, August 15, 1946. This application May 26, 1953, Serial No. 357,589

3 Claims. (Cl. 102—20)

This application is a continuation application of my prior application Ser. No. 690,762, now abandoned, filed August 15, 1946, for Well Explosive Devices; which application in turn was a continuation in part of my prior application for Well Explosive Devices, filed December 2, 1942, Ser. No. 467,657, now Patent No. 2,408,419, granted October 1, 1946; which, in turn was a division of my prior application on Process of Treating Wells, filed March 17, 1939, Ser. No. 262,531, now Patent No. 2,307,729, granted January 5, 1943.

This invention relates to improvements in well explosive devices adapted for discharge of an explosive projectile in a subterranean formation to loosen up the formation and to facilitate the flow of oil or other fluid from an oil bearing formation into a well for withdrawal therefrom.

Heretofore, it has been common practice to lower large charges of high explosives into a well and to detonate these charges by mechanical or time-clock means. These charges, which consist of from ten quarts to five hundred quarts of pure nitroglycerin, are dangerous to the workmen handling them, dangerous to the public safety, since they must be moved over the public highways, and often do extensive damage to the well casing and equipment. The reason that these charges must be so large is that they depend entirely on concussion and reverberation to achieve the desired result of loosening and removing that part of the formation immediately adjacent the bore hole, wherein they are approximately axially disposed at the time of the detonation.

By placing a small amount of the explosive at various points in the earth formation and detonating this explosive, more advantageous results may be obtained than by placing a large amount of explosive within the bore hole and detonating it there.

While the drawings show one form of the apparatus for practicing the invention, it is to be understood that the invention relates to provisions for the more advantageous placing of explosives contained in projectiles at a point in the earth's stratum removed from the bore hole, and to projectiles for this purpose, so that the portion of the stratum lying between the point of explosion and the bore hole will be driven toward the bore hole by the force of the explosion.

It is obvious that varied results, such as blasting down a portion of the wall of the well, driving gathering holes with basins at the outer ends thereof, providing entries for formation solvents, providing enlarged sections in the bore hole for the anchoring of cement bridges, and other similar functions, may be produced by varying the forces of the explosives involved in the invention and by varying the types of projectiles used. These variations are to be considered within the scope of the invention herein disclosed.

The accompanying drawings show a preferred embodiment of the invention, together with modifications thereof, in which:

Fig. 1 is a fragmentary vertical section of an earth formation, showing the tool partly in elevation and partly in section, disposed in a well;

Fig. 2 is a fragmentary horizontal section through the tool on the line 2—2 of Fig. 1;

Fig. 3 is a longitudinal section through a form of projectile used in connection with the tool;

Fig. 4 is a similar view of a modified form of projectile used in the tool;

Fig. 5 is a diagrammatic view of a wiring diagram for sequentially firing a plurality of explosive charges within the tool;

Figs. 6 and 7 are longitudinal sections through modified forms of projectiles;

Fig. 8 is a longitudinal section through the detonator thereof; and

Fig. 9 is a fragmentary sectional view taken on the line 9—9 of Fig. 1, looking in the direction indicated by the arrows.

With more detailed reference to the drawing, the numeral 1 represents an elongated body of a tool which carries a plurality of radially disposed explosive chambers or cannons 2 which are preferably spaced along the length of the tool, preferably being turned in different radial directions thereto. These cannons have removable barrels 3, which removable barrels are polygonal, preferably square in cross-section, and which may be taken out of the tool 1. The sockets 4 in the tool 1 are preferably polygonal in cross-section, preferably substantially square, so as to complementally receive the respective removable barrels 3 therein. The removable barrels 3 are held in place in a recess or counter-bore 7 by bolts 6, and within the outer end of this barrel is disposed the threaded bushing 8 which engages a shear ring 11 and causes the ring to seat upon a gasket 5. This prevents moisture from entering the powder chamber 9. This threaded bushing 8 forms an extension of cannon barrel 3 or a second cannon barrel and is removed each time a new projectile is inserted. The body of the tool 1 has a longitudinal groove 4*a* formed therein along the lower side of recess 4, which groove is substantially square in cross section. The cannon barrel, which is of a cross-section to complementally fit within the recess 4 and groove 4*a*, has a firing pin 15 chambered within the portion of the barrel 3*a* which extends into groove 4*a*, which arrangement enables the barrel 3, cap 13, and firing pin 15 to be removed and replaced as a unit, thereby making more simple the servicing thereof.

Before inserting the tool into a well, an explosive charge is placed within powder chamber 9 in each of the cannon bores or chambers 2 behind an explosive projectile 10 or 10′ therein, upon which projectile an expansive shear ring 11 has been fitted and slipped into an annular recess 12 in the cannon bore 2.

A percussion cap 13 is fitted into a lateral opening 14 in the cannon barrel 3, which lateral opening extends longitudinally of the tool, so that a firing pin 15 will detonate the cap 13 and the adjacent explosive charge in chamber 9 upon the striking of the firing pin 15 by an armature 16 which acts as a hammer. The hammer 16 is operated by an electro-magnetic coil or solenoid 17 when electrical energy is supplied thereto. The entire solenoid mechanism is contained in a casing 18 which casing is fitted in a longitudinal opening 18*a* formed at the inner end of recess 4. The casing 18 may be inserted into or removed from the tool through the recess 4 therein.

A single wire, with grounded return circuit, is shown in Fig. 5 and a relay switch is connected within this wired circuit 21 and has connection with the solenoid which is next to be operated so that the projectiles may be sequentially fired from cannon bores 2 by closing and opening a switch 19 in said circuit (Fig. 5), which switch is located

at the ground surface or at the mouth of the well. Upon closing the switch 19, a source of electrical energy, such as a battery 20, is connected with circuit 21 leading to the solenoids 17, which are in parallel with the circuit through secondary switches.

A switch arm 22 rests on a contact plate 23 (Fig. 2) which closes the circuit to the coil 17 and actuates the hammer 16 by the force exerted in magnetic coil 17. As the hammer 16 is moved to strike firing pin 15 (Fig. 1), a pointed end 24 of the hammer, which pointed end 24 is made of fibre or other insulating material and which normally holds the switch arm 22 retracted, is withdrawn and permits the switch arm 22 to be moved into the position shown in dotted lines and indicated at 22' (Fig. 2), by a spring 45 acting on the arm 22 until said switch arm is stopped by a stop pin 46.

In this position the contact point 25 is still in contact with the plate 23, although having moved to the opposite side of the axis of the hammer 16; however on the breaking of the circuit by the manual release of the switch 19, the solenoid 17 is deenergized, releasing the hammer 16, and upon return of the hammer 16 under pressure of a spring 26 bearing thereagainst, the pointed end 24 will push the switch point off the contact plate 23 against a contact 23', to dotted line position as indicated at 22'' (Fig. 2). By this movement of the switch arm 22, the first solenoid is entirely disconnected from the circuit and remains deenergized until the tool is removed and the mechanism reset when a new charge is inserted. A plugged opening 27 is provided through the wall of the tool 1 for the insertion of an instrument against the switch arm 22 for resetting the same, as shown in Fig. 2.

When the switch arm 22 moves to the dotted line position 22'' and engages contact 23' after firing the first charge, this closes the circuit 21 to the next succeeding solenoid 17 which is then ready to be fired by again closing switch 19, as described. This operation is repeated until all of the charges have been fired.

The wire 21 is shown schematically in Fig. 1 for clearness; however, it is to be understood that the tool 1 is to be drilled both longitudinally and transversely to accommodate the wire to the respective solenoids, designated *a*, *b*, and *c* in Fig. 5. This wire is shown leading onward from solenoid *c*, as any number of discharge units may be used. When the tool is cross-drilled, the holes will be plugged in the usual manner.

Several types of penetration are desirable, particularly for oil wells, two of which are shown. One type is indicated at A, where an explosive projectile is shot into the stratum for a short distance and the force of the explosive is used to blow the formation toward the well. In this manner, a formation which has become sealed with paraffin, mud or other foreign material that renders the formation non-productive of oil, may be removed by placing the projectile a short distance beyond the wall of the bore hole and detonating it so that this foreign substance will be loosened, and may be cleaned from the well. A new porous surface is thus produced which has a larger exposed area, thereby giving the well greater productivity.

Another form of shot which may be placed, is that indicated by dotted outline at B. The amount of explosive 9 in chamber 2 is increased so as to drive the projectile a greater distance into the stratum than shown at A. This projectile may be so constructed as shown in Fig. 4, that it will be blown into bits, each of the fragments cutting a channel in the stratum, and in this manner a passage is formed for some distance out into the stratum with a basin at the outer end, and passages radiating from said basin, thus opening up producing stratum, or permitting chemicals to be introduced into certain types of formation where they will work with greater rapidity and effectiveness than if introduced into the immediate bore hole of the well.

Two types of projectiles are shown in Figs. 3 and 4, respectively. The type shown in Fig. 3 has a round nose 28 which is fitted with a firing pin 29 which strikes percussion cap 30. This ignites a fuse 31 which may be varied in length to delay the firing of the explosive charge 32 until the projectile has traveled the desired distance into the stratum. The interior of the projectile is accessible for loading as by forming it in sections screw-threaded together at 33. The nose 28 is crushed upon striking a formation of sufficient hardness and this drives the pin 29 against percussion cap 30. A short fuse is shown to indicate the placing of the explosive charge only a short distance from the bore hole. The shear ring 11 retains the projectile within the cannon barrel until the greater part of the explosive charge is burned. In this manner the full effectiveness of the charge is obtained upon the shearing of expansive shear ring 11.

The form of projectile, as shown in Fig. 4, is made preferably of cast metal, in two parts also screw-threaded together at 33', and has annular and longitudinal grooves 34 and 35 respectively, disposed within the chamber 36 which is designed to carry the explosive charge. This form is shown with a sharp nose and pointed firing pin 38, which may be advantageous in penetrating hard types of formation.

The pointed firing pin 38 is in position to strike a percussion cap 39 upon impact with a substantially non-yielding formation. To prevent the firing pin 38 from striking the percussion cap 39 too readily, a shear pin 40 is provided in engagement with the firing pin and which will shear when the projectile is driven into hard formation. Upon the detonation of cap 39 a powder train 41 will be ignited. The length of this powder train, together with the speed with which the powder burns, will be computed so as to permit the projectile to travel the desired distance into the formation before detonating the explosive contained in the chamber 36. This type of projectile will form a long passage with a basin at the end thereof and radiating passages outward therefrom, in the formation, as indicated at B in Fig. 1.

Other forms of projectiles are shown in Figs. 6 and 7, each of which is adapted to be filled with a high explosive powder and provided with a detonator to ignite and discharge the powder when the projectile has penetrated the formation to the desired extent.

In the form of invention shown in Fig. 6, the projectile is designated generally at 50 being in the form of a shell having a pointed forward end 51 of conical shape to penetrate the formation. The shell 50 has a surrounding rib 52 at the rear end thereof adapted to be secured in the manner of the ring 11 described above for holding the projectile in the tool. The interior of the projectile body 50 is filled with a high explosive powder 53 confined therein by a plug 54, which is screwed into the back end of the body and forms a seal for the explosive powder.

The form shown in Fig. 7 is similar to that illustrated in Fig. 6 and likewise has a body 60 provided nevertheless with a curved tapered nose portion 61. The high explosive charge 63 is packed in a chamber of somewhat larger capacity to accommodate a greater quantity of explosive than is provided in Fig. 6, and is confined by a plug 64 which seals the open side of the explosive chamber.

In each of these forms as shown in Figs. 6 and 7, a detonator 70 is confined and sealed within the explosive charge, the construction of which is shown more in detail in Fig. 8. Other suitable forms of detonators may be used if desired, although the one illustrated has advantages in construction and use thereof.

As shown in Fig. 8, the detonator 70 is formed with a cylindrical tube 71, one end of which is open initially and adapted to be closed by a seal 72. The opposite end is adapted to be packed with a primer charge of explosive as indicated at 73 having sufficient explosive power to detonate the explosive charge 53 or 63 in the projectile.

The primer charge 73 is confined in the tube 71 by an

explosive pellet which is slow burning and is known as a "delay pellet" as indicated at 74. Adjacent the delay pellet, but spaced therefrom, is an explosive element 75 preferably formed of an explosive compound such as the phosphorus compound used commercially in forming match heads and which is adapted to be ignited by friction in the customary manner of striking a match on an abrasive surface. The explosive element 75 has an orifice therethrough, through which passes a thread 76, one end of which is coiled in the space between the element 75 and the delay pellet 74, while the opposite end of said thread 76 is attached to a weight such as a ball 77. The thread 76 is flexible, but is coated with a suitable abrasive material to cause an ignition of the explosive element 75 as the thread is drawn through the orifice therein.

The ball 77 normally is confined in the retracted position shown in Fig. 6 by an element 78 such as a tissue paper or frangible disc that may be broken by force imparted to the ball, although normally this restraining element 78 will confine the ball in position. This element 78 is spaced from the end of the tube 71 so that the force imparted to the ball by a projecting movement of the projectile and its arrest in the formation will cause a continued movement of the ball after breaking the arresting element 78 and it will continue to travel through the length of the space in tube 71.

This action of the ball will draw the abrasive coated thread 76 through the explosive element 75 and thereby cause friction on said element to ignite the phosphorus compound. This, in turn, will ignite the delay pellet 74, but because of its slow burning character, it will not immediately ignite the primer charge 73 until the projectile has traveled a required depth into the earth formation as described above. When the delay pellet burns through the primer charge 75, the latter is ignited causing an explosion of the detonator, which in turn, ignites and detonates the explosive charge in the projectile. This will cause an explosion in the formation at the desired point according to the character of the projectile used and the delay action thereof, which, however, will loosen up the formation and cause the oil or other fluid to flow into the well in the manner described above.

The tool may be lowered into the well by any suitable means, such as a pipe 42 or a cable. If used on a drill stem, it can be screwed together in such manner that the direction of the cannon barrels can be determined, as by matching index marks 43 (Fig. 1) as the joints are screwed together. In this manner, the direction in which the projectile is fired may be determined from the surface.

The tool may be used also to obtain samples of formation in the proximity of the detonated projectile, as the force of the explosion of the projectile 10 or 10' will force a portion of the formation into a cannon barrel, as indicated at 44, which portion may be removed from the well for analysis.

On reloading the device, a new gasket 5 and a new shear ring 11, as well as a new projectile, will be required, as the projectile will shear these each time the cannon is detonated.

The lower end of the tool is preferably tapered to a point to facilitate its insertion into, as well as its removal from, the well after the explosion of the projectiles when the explosives would have forced a quantity of the formation into the bore hole.

Having thus described the invention, what is claimed is:

1. In a well explosive device, an elongated body, said body having at least one lateral recess formed in a side thereof, which recess is substantially polygonal in cross section, said body having a longitudinal opening formed therein near the inner end of said lateral recess, which longitudinal opening is arranged eccentrically with respect to the axis of said body, said longitudinal opening being in communication with said lateral recess, an electrically operated solenoid armature mounted within said eccentrically arranged longitudinal opening in said body, spring means for normally maintaining said solenoid armature in one position, an electrical coil surrounding said armature, an electric circuit connected with said coil, a first barrel complementarily fitted in said lateral recess in said body, said first barrel having a bore and a counterbore formed therein, a firing pin fitted within said first barrel and in axially aligned relation with said solenoid armature, a second barrel, having an axial bore formed therein, fitted within said counterbore of said first barrel so that the bores of said barrels will be in axially aligned relation, said first barrel having a lateral opening formed therein in communication with the bore thereof, which lateral opening is adapted to receive a percussion cap therein, which cap will be in alignment with said firing pin, means retaining said first barrel in said elongated body, and means retaining said second barrel in said first barrel.

2. The device as defined in claim 1, wherein said lateral recess in said body is substantially square in cross section.

3. The device as defined in claim 2, wherein a groove is formed in said body adjacent said lateral recess which is substantially square in cross section.

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