

April 28, 1959

B. M. CALDWELL

2,883,932

WELL PERFORATING FIRING MEANS

Filed Sept. 2, 1955

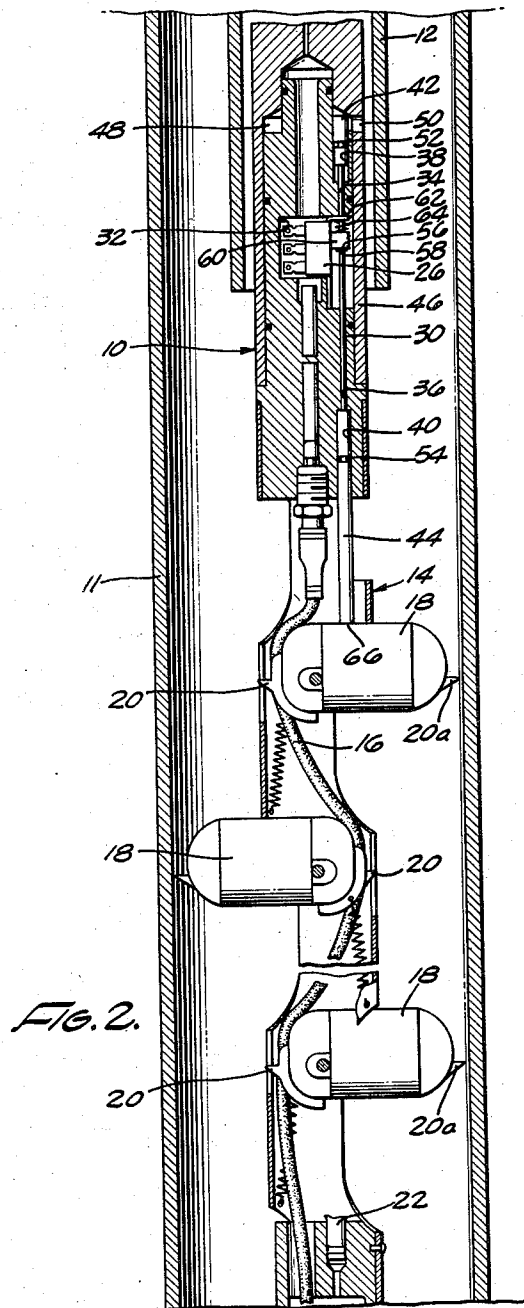
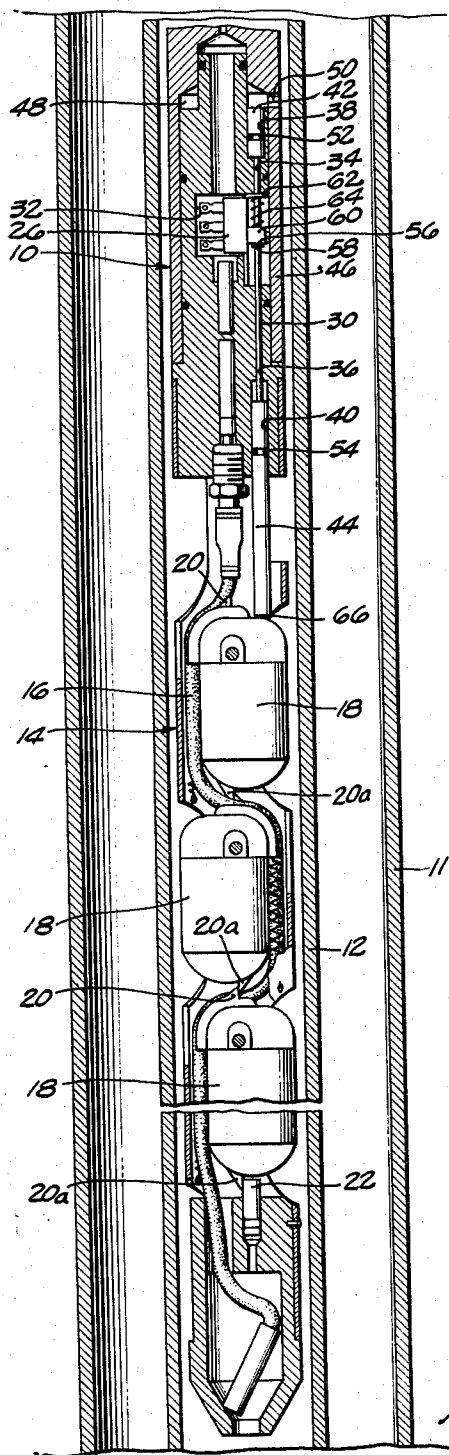


FIG. 2.

INVENTOR.
BLAKE M. CALDWELL

BY

Lyon & Lyon
ATTORNEYS

1

2,883,932

WELL PERFORATING FIRING MEANS

Blake M. Caldwell, Fort Worth, Tex., assignor, by mesne assignments, to Welex, Inc., Fort Worth, Tex., a corporation of Delaware

Application September 2, 1955, Serial No. 532,248

10 Claims. (Cl. 102—20)

This invention relates to well perforating firing means and particularly to switch actuating means for firing a well perforating assembly adapted to be run through well tubing to be fired after emergence from the lower end of such tubing.

In the completion of wells drilled by the rotary method, it has long been the practice to perforate casing set in the well adjacent the producing formation for the purpose of providing ingress to the well from said formation. Such perforating formerly was done before the well was capped and while the heavy drilling mud was within the casing, and after perforating, the well was completed for production by removing the mud, running tubing into the well and capping same. More recently, however, the practice of running in the tubing, affixing the well head equipment, and replacing the drilling mud with clean fluid, all prior to perforating, has gained considerable popularity in the field, and in this method the perforating assemblies used must be adapted to be lowered through the tubing until, upon emergence therefrom in the vicinity of the oil-bearing formation, the perforating can be accomplished.

Equipment for perforating wells completed in the aforementioned manner has now been devised and a particularly effective type of such apparatus is that wherein the assembly is arranged so that during the lowering of same through the tubing the perforating units are in vertical alignment with the axis of the tubing, but upon emergence of the assembly from the lower end of the tubing, said units are permitted to pivot to a horizontal firing position. Such apparatus is disclosed in Patent No. 2,543,814 of W. H. Thompson et al. dated March 6, 1951, and entitled "Means and Method of Tilting Explosive Charges in Wells." An improvement upon the Thompson et al. patent, which patent does not provide for a retraction of the apparatus after emergence from the bottom of the tubing, resides in an application for United States Letters Patent filed February 19, 1954, by Blake M. Caldwell and Joe P. Wier, Serial Number 411,349, entitled "Tilting Charge Well Perforating Assembly." A further improvement upon such apparatus resides in an application for United States Letters Patent filed October 8, 1954 by Blake M. Caldwell and Harrold D. Owen, Serial Number 461,236 entitled "Well Perforating Assembly." It is with improvements in the apparatus disclosed in the latter application that the instant invention is particularly concerned.

In such apparatus there is provided a firing head from which is suspended an elongated carrier, pivotally carrying shaped charges, the shaped charges being resiliently urged to horizontal position, but by interlock means normally being held in axial disposition with respect to the carrier. An explosive release means, such as a squib, abuts a detent on the bottom shaped charge and upon

2

firing of the squib the bottom shaped charge is permitted to pivot to horizontal position, releasing the others so that they too may assume horizontal, or firing, position. Control means are provided in such apparatus whereby the shaped charges may not be fired in the event they are prevented as by well obstructions from attaining the described firing position.

As shown in the aforesaid application, Serial Number 461,236, such control means comprises a release arm interlocked with the uppermost shaped charge, which release arm, upon the pivoting of said charge, throws an arming switch to which it is connected through a plunger element. Thus after the apparatus is lowered into the well, the explosive squib may be exploded from the surface by means of suitable electrical circuitry, whereupon the shaped charges and release arm pivot to a horizontal firing position. In this respect it may be noted that the position need not be horizontal, but may be at a predetermined angle from the vertical. Pivoting of the shaped charges and release arm causes the plunger to actuate the arming switch, activating a suitable circuit, which enables a detonating fuse to be fired, which in turn fires the shaped charges.

The instant invention is concerned specifically with improvements in the nature of the interconnecting plunger between release arm and arming switch. In the aforesaid apparatus, said plunger is positively connected both to switch and to release arm, which release arm in turn is interlocked with the uppermost shaped charge. Moreover, the bottom area of the plunger is effectively subjected to well pressure, whereas the upper area of the plunger is sealed from such well pressure. Consequently, under suitable pressure conditions it is quite possible that upon explosion of the squib and release of the interlock, the release arm could travel faster than adjacent shaped charges, due to fluid pressure on the outside of the plunger, whereby to cause firing of the shaped charges before the uppermost charges have been enabled to reach optimum firing position, and it is the principal object of this invention to provide a means whereby well pressure cannot have this effect.

Additionally, it is to be noted that in the prior structure a release arm is provided, whereas it would be more desirable to provide a shaped charge itself, thus obtaining an additional perforation. Since, however, in the prior structure the plunger must be positively connected to the release arm, replacement of such release arm by a shaped charge would require special construction and attendant expense. It is the further purpose of this invention to provide a plunger arrangement whereby it is as feasible to use a shaped charge immediately adjacent the plunger as it is to use a non-firing release arm.

These and other objects and features and advantages of the present invention will be apparent from a consideration of the following specification taken in conjunction with the accompanying drawings in which:

Figure 1 shows a longitudinal sectional view of the perforating assembly incorporating the instant invention, wherein the shaped charges are in vertical disposition, and

Figure 2 shows the same view with the said shaped charges pivoted to horizontal firing position.

In its general aspect, the invention comprises a firing head 10 supported by a conductor cable, not shown, which is suspended in the well from the surface, the well casing 11 having tubing 12 suspended therein. Carried by the firing head 10 is an elongated carrier 14, through

3

which passes a detonating fuse 16 detonated by the firing head. Said detonating fuse passes adjacent shaped charges 18, which charges are pivotally mounted within the carrier and are resiliently urged to horizontal position, being fired by the detonating fuse. Said charges are, however, by means such as the detents 20 held interlocked in axial disposition with respect to the carrier. A release means, which could be solenoid or other electrically operated stop means, but which is shown here as the explosive cartridge or squib 22, is electrically connected through a suitable conductor to an arming switch 26 and abuts the detent 20a of the bottom shaped charge. Upon firing of the squib, the bottom shaped charge is permitted to resiliently pivot to horizontal position. Pivoting of the bottom shaped charge releases the next shaped charge for similar resilient pivotal movement to horizontal position, and the process is repeated to permit each charge to assume firing disposition.

Additionally, control means are provided whereby the shaped charges may not be fired from the surface in the event they are prevented, as by well obstructions, from reaching a proper firing position. Thus a plunger 30 is connected to the switch 26 and abuts the uppermost of the shaped charges 18. Upon horizontal pivoting of the shaped charges, the plunger 30 is moved upwardly, throwing the arming switch 26 and thereby permitting a firing of the detonating fuse and consequently the shaped charges.

It is with the nature of the plunger arrangement that this invention is particularly concerned, and in essence said invention resides in the arrangement whereby the plunger is exposed at either end to well pressures, whereby differential areas exposed to hydraulic pressure may serve to prevent premature firing of the shaped charges, and may enable the convenient use of an additional shaped charge rather than a release arm in the perforating apparatus.

Detailed description of the general perforating assembly is set forth in the aforesaid application, Serial Number 461,236, and it is believed that the general description of said assembly set forth above suffices, but for the arming switch control means. In this regard a chamber 32 is provided within the firing head 10, which chamber houses the arming switch 26, which switch comprises a common double pole, double throw switch actuated by the plunger 30, it being sufficient to say as previously set out that such switch when thrown actuates the circuitry, which enables the firing of the shaped charges 18 after pivotal movement of said shaped charges.

The plunger 30 is slidable in bores 34 and 36 of the firing head, which firing head is provided with counterbores 38 and 40 to slidably receive piston elements 42 and 44 extending from the plunger 30. An adapter 46 which serves as a support means for the entire assembly and which is connected as by screws or otherwise to the firing head 10, and which additionally defines with the firing head a chamber 48, is ported as at 50, so that well pressure may exist within said chamber 48 against the piston 42. Sealing rings 52 and 54 seal the counterbores 38 and 40, respectively.

The plunger 30 is provided with a collar 56 and retaining pin 58, said collar abutting against the actuating arm 60 of the arming switch 26. An abutment plate 62 extends from said arming switch and a compression spring 64 is interposed between said plate and the actuating arm 60, whereby to urge said arm and consequently the plunger 30 to a downward position, in which position of course the arming switch 26 does not permit the firing of the shaped charges 18. The lower end 66 of the piston extension 44 of the plunger 30 merely abuts the uppermost of the shaped charges 18.

It is thus seen that since both ends of the piston extensions of the plunger 30 are exposed to well pressures, the force of the well pressure applied to the bottom of the plunger does not move the plunger upwardly and

4

cause inadvertent or premature arming of the switch 26. Indeed, by suitable design of the cross-sectional areas of upper and lower pistons, the resultant force on the said plunger may be adjusted to be downwardly, i.e., the cross-sectional area of the piston 42 may be larger than the cross-sectional area of the piston 44. On the other hand, because of the large pressures involved, it is most desirable that the cross-sectional area of the bottom piston 44 be very slightly larger than that of the upper piston 42, large enough so that the resultant force is in an upward direction but is insufficient to overcome the effect of the spring 64 and the friction in the system. This enables the well fluid to assist the uppermost shaped charge in moving the switch to armed position. It is, of course, undesirable that the cross-sectional area specifications be such that a resultant upward force exists sufficient to overcome spring and friction.

Additionally, it is seen that no particular interconnecting means is required between the bottom of the plunger 30 and the uppermost shaped charge 18, it only being necessary that the shaped charge meet said end in its upward pivot to firing position. Consequently, the same shaped charges can be used in the assembly as uppermost shaped charges as those used therebelow, and special design of an uppermost shaped charge is unnecessary.

While there has been described what is at present considered a preferred embodiment of the present invention, it will be apparent to those skilled in the art that various modifications and changes may be made without departing from the essence of the invention, and particularly that the invention herein presented is adapted to various types and kinds of tools other than well perforating assemblies. It is intended to cover herein all such modifications and changes as come within the true scope and spirit of the appended claims.

I claim:

1. In a well perforating assembly having an arming switch adapted to actuate a firing circuit for shaped charges pivotally mounted in said assembly the combination of: a firing head having a sealed chamber therein and mounting said switch in said chamber and a plunger slidably mounted within said firing head and operably connecting said switch and said shaped charges to close said switch upon pivoting of said shaped charges, said plunger having each of its extremities exposed to well fluid pressure and being resiliently biased by forces including the resultant hydrostatic force acting on the exposed extremities of said plunger to maintain said switch open prior to pivoting of said shaped charges.

2. In a well perforating assembly having an arming switch adapted to close a firing circuit for a shaped charge pivotally mounted in said assembly the combination of: a firing head having a sealed chamber therein and being adjacent said shaped charge, said firing head mounting said switch in said chamber, and a plunger slidably mounted within said firing head and operably connecting said switch and said shaped charge to close said switch upon pivoting of said shaped charge, said plunger having each of its extremities exposed to well fluid pressures and being resiliently biased by forces including the resultant hydrostatic force acting on the exposed extremities of said plunger to maintain said switch open prior to pivoting of said shaped charges.

3. In a well perforating assembly having an arming switch adapted to close a firing circuit for a shaped charge pivotally mounted in said assembly the combination of: a firing head having a sealed chamber therein and being adjacent said shaped charge, said firing head mounting said switch in said chamber; a plunger slidably mounted within said firing head and operably connecting said switch and said shaped charges to close said switch upon pivoting of said shaped charge and the movement of said plunger towards said switch, said plunger having

5

each of its extremities exposed to well fluid pressures; and resilient means urging said plunger towards said shaped charge and maintaining said switch open prior to pivoting of said shaped charge, the exposed cross-sectional area of the plunger extremity adjacent said shaped charge being larger than the exposed cross-sectional area of said other plunger extremity to hydrostatically bias said plunger toward said switch to assist in closing said switch upon pivoting of said shaped charge.

4. In a well perforating assembly having an arming switch adapted to close a firing circuit for a shaped charge pivotally mounted in said assembly the combination of a firing head having a sealed chamber therein and being adjacent said shaped charge, said firing head mounting said switch in said chamber; and a plunger slidably mounted within said firing head connected to said switch and abutting said shaped charge to close said switch upon pivoting of said shaped charge towards said switch, said plunger having each of its extremities exposed to well fluid pressures and being resiliently biased by forces including the resultant hydrostatic force acting on the exposed extremities of said plunger to maintain said switch open prior to pivoting of said shaped charges.

5. In a well perforating assembly having an arming switch adapted to close a firing circuit for a shaped charge pivotally mounted in said assembly the combination of: a firing head having a sealed chamber therein and being adjacent said shaped charge, said firing head mounting said switch in said chamber; a plunger slidably mounted within said firing head connected to said switch and abutting said shaped charge to close said switch upon pivoting of said shaped charge towards said switch, said plunger having each of its extremities exposed to well fluid pressures; and resilient means urging said plunger towards said shaped charge and maintaining said switch open prior to pivoting of said shaped charge toward said switch, the exposed cross-sectional area of the plunger extremity adjacent said shaped charge being larger than the exposed cross-sectional area of said other plunger extremity to hydrostatically bias said plunger toward said switch to assist in closing said switch upon pivoting of said shaped charge.

6. In a well perforating assembly having an arming switch adapted to close a firing circuit for a shaped charge pivotally mounted in said assembly the combination of: a firing head having a sealed chamber therein and being adjacent said shaped charge, said firing head mounting said switch in said chamber; and a plunger slidably mounted within said firing head and operably connecting said switch and said shaped charge to close said switch upon pivoting of said shaped charge and the movement of said plunger towards said switch, said plunger having each of its extremities exposed to well fluid pressures, the exposed cross-sectional area of the plunger extremity adjacent said shaped charge being smaller than the said exposed cross-sectional area of said other plunger extremity to hydrostatically bias said plunger away from said switch and maintaining said switch open prior to pivoting of said shaped charge.

7. In a well perforating assembly having an arming switch adapted to arm a firing circuit for a perforating unit pivotally mounted in said assembly the combination of: a firing head having walls providing an enclosed chamber, said walls having a pair of openings therethrough, the arming switch being mounted within the chamber; a plunger slidably received in the openings of said walls and extending through the chamber and having each of its extremities exposed to well fluid pressure, said plunger being operably connected to the switch to close the switch upon sliding movement of said plunger, said plunger being constructed and arranged for engagement by the perforating unit to be slidably moved to close the switch upon pivotal movement of the perforating unit and being resiliently biased by forces including the resultant hydrostatic force acting on the exposed extremities of

6

said plunger to maintain said switch open prior to pivoting of said shaped charges; and means slidably sealing said plunger in the openings of said walls.

8. In a well perforating assembly having an arming switch adapted to arm a firing circuit for a perforating unit pivotally mounted in said assembly the combination of: a firing head having walls providing an enclosed chamber, said walls having a pair of opposed openings therethrough, the arming switch being mounted within the chamber; a plunger slidably received in the opposed openings of said walls and extending through the chamber and having each of its extremities exposed to well fluid pressure, said plunger being operably connected to the switch to close the switch upon sliding movement of said plunger, said plunger being constructed and arranged for engagement by the perforating unit to be slidably moved to close the switch upon pivotal movement of the perforating unit and being resiliently biased by forces including the resultant hydrostatic force acting on the exposed extremities of said plunger to maintain said switch open prior to pivoting of said shaped charges; and means slidably sealing said plunger in the openings of said walls.

9. In a well perforating assembly having an arming switch adapted to arm a firing circuit for a perforating unit pivotally mounted in said assembly the combination of: a firing head having walls providing an enclosed chamber, said walls having a pair of opposed openings therethrough, the arming switch being mounted within the chamber; a plunger slidably received in the opposed openings of said walls and extending through the chamber and having each of its extremities exposed to well fluid pressure, the exposed cross-sectional area of one of the extremities of said plunger being different from the exposed cross-sectional area of the other of the extremities of said plunger, said plunger being operably connected to the switch to close the switch upon sliding movement of said plunger, said plunger being constructed and arranged for engagement by the perforating unit to be slidably moved to close the switch upon pivotal movement of the perforating unit and being resiliently biased by forces including the resultant hydrostatic force acting on the exposed extremities of said plunger to maintain said switch open prior to pivoting of said shaped charges; and means slidably sealing said plunger in the openings of said walls.

10. A well perforating assembly comprising in combination: a firing head providing a sealed chamber therein; an elongated carrier mounted on said firing head; a well perforating unit exposed to well fluid and pivotally mounted on said carrier in axial disposition with respect thereto; resilient means urging said perforating unit to pivot from said axial disposition to lateral firing disposition; retaining means releasably holding said perforating unit in said axial disposition; means for operating said retaining means to release said perforating unit for movement from said axial disposition to said firing disposition under urgency of said resilient means; means for firing said perforating unit including an arming switch mounted in the chamber of said firing head, said arming switch having an armed position and a disarmed position; a plunger slidably mounted in said firing head and having a portion extending through said chamber; pistons carried by the ends of said plunger and slidably received in cylinders formed in said firing head, the outer extremities of said pistons being exposed to well fluid pressure, said plunger being operatively connected to said switch to move said switch between said armed and said disarmed positions upon sliding movement of said plunger and pistons in said firing head; second resilient means urging said plunger and pistons to a position disarming said switch; said plunger and pistons being freely slidable between positions to disarm and to arm said switch when said perforating unit is in said axial disposition, the cross-sectional areas of said pistons that are exposed to well

fluid pressure being such that the resultant hydrostatic force acting on said pistons is insufficient to move said plunger and pistons from said switch disarming position against the bias of said second resilient means and friction forces; one of said pistons being positioned to be engaged by said perforating unit as said perforating unit pivots from said axial disposition to said firing disposition to slide said plunger and pistons to move said switch from said disarmed to said armed disposition.

References Cited in the file of this patent

UNITED STATES PATENTS

2,328,309	Turecek et al.	Aug. 31, 1943
2,373,006	Baker	Apr. 3, 1945
2,644,519	Kanady	July 7, 1953

FOREIGN PATENTS

475,873	Canada	Aug. 7, 1951
---------	--------------	--------------