Feb. 9, 1960 J. J. ROBERTSON 2,924,173

WELL PERFORATOR FIRING MEANS

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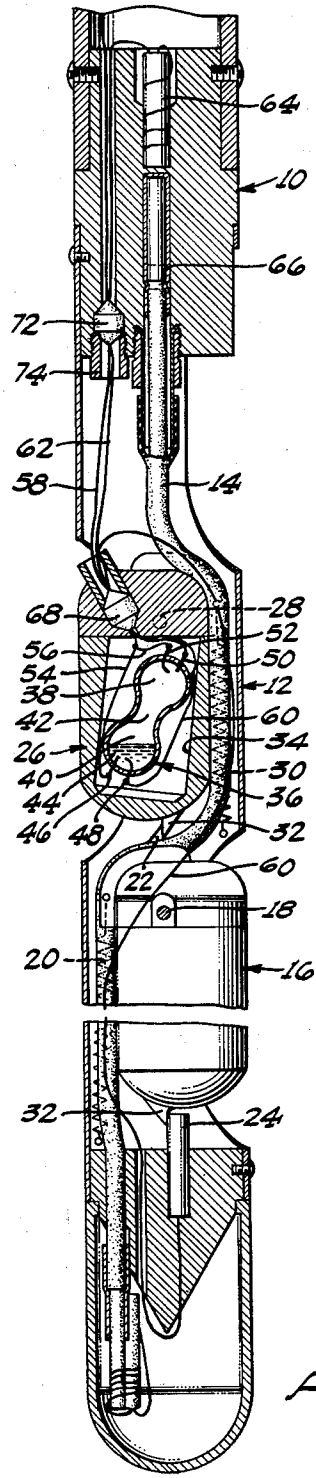


FIG. 1.

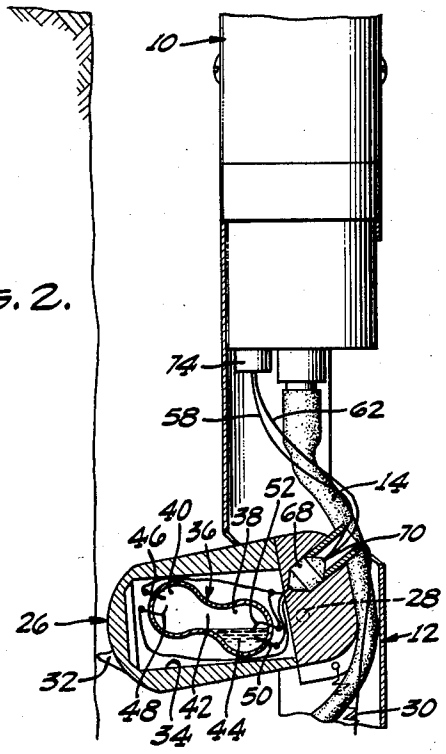


FIG. 2.

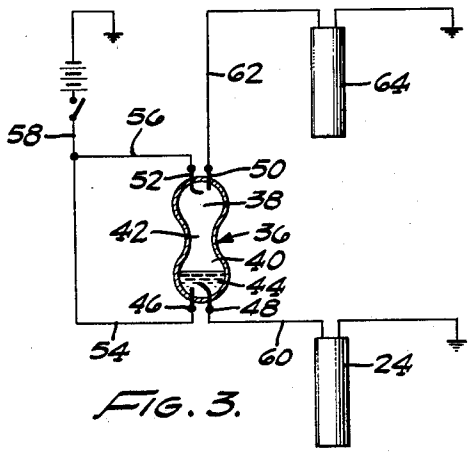


FIG. 3.

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WELL PERFORATOR FIRING MEANS

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Application June 19, 1956, Serial No. 592,411

10 Claims. (Cl. 102—20)

This invention relates to well perforating means and more particularly to means for controlling the firing of the perforating means upon positioning thereof in a well.

It has been the practice in the completion of wells such as oil and gas wells drilled by the rotary method to perforate the well casing adjacent the producing formation to admit oil and gas from the formation to the well. This perforation has been accomplished with the drilling mud in the casing and before the well was capped. It has become the practice more recently to perforate after the tubing has been inserted into the well, the well head equipment affixed and the drilling mud removed. This latter method requires lowering through the relatively small tubing the perforating assembly to the vicinity of the producing formation and then perforating.

In lowering an assembly through such tubing it is desirable to maintain the perforating units in vertical alignment permitting the units to pivot upon emergence from the tubing to a horizontal firing position. Such an assembly is disclosed in W. H. Thompson et al. patent No. 2,543,814, issued March 6, 1951, on "Means and Method of Tilting Explosive Charges." An improvement on this type of assembly which provides for the retraction of the assembly after emergence from the tubing is described in an application for United States Letters Patent filed February 19, 1954, by Blake M. Caldwell and Joe P. Wier, Serial No. 411,349, entitled "Tilting Charge Well Perforating Assembly." A further improvement upon such an apparatus resides in controlling the pivoting of the perforating units from the ground surface and also in guarding against unexpected firing of the units as described in an application for United States Letters Patent filed October 8, 1954, by Blake M. Caldwell and Harrold D. Owen, Serial No. 461,236, entitled "Well Perforating Assembly." It is with improvements in the apparatus disclosed in this latter application that the instant invention is particularly concerned.

In such an apparatus there is provided a firing head having an elongated carrier suspended therefrom. A plurality of pivotally mounted perforating units are mounted in the carrier biased towards a horizontal position but interlocked in a vertical position. Means are provided to release the interlock to permit pivoting of the units, and such latter mentioned means are actuated from the surface. As set forth in the latter mentioned application, the firing circuit for the individual perforating units cannot be completed until the interlock has been released and the units pivoted to their firing positions.

It is, therefore, an object of this invention to provide means preventing firing of the perforating units unless pivoted to the firing position.

It is a further object of this invention to provide means which in one position permit release of the interlocked perforating units and which after release of the units permit firing thereof.

It is still a further object of this invention to provide means whereby foreign matter encountered during lowering of the assembly into the well cannot affect the operation thereof to release the interlocked perforating units or permit firing thereof.

Other objects and advantages of this invention will be readily apparent from the following description:

In the drawings:

Figure 1 is a side elevation of a perforating assembly embodying this invention having portions thereof broken away.

Figure 2 is a fragmentary view similar to Figure 1 after release of the perforating units.

Figure 3 is a schematic wiring diagram.

The perforating assembly generally comprises a firing head **10**, supported from the surface by a conductor cable (not shown). An elongated carrier **12** is mounted upon and suspended from the firing head and has a firing fuse **14** threaded therethrough passing adjacent to the perforating units, in this instance, shaped charges **16**. The charges are pivotally mounted within the carrier **12** as by pins **18** and each is biased to a horizontal position by a spring **20**. During descent through the tubing of the well, however, the charges **16** are locked in axial disposition with respect to said carrier **12** by means of interlocking detents **22** and **32**. A blasting cap **24** engages the lower detent **32** on the lowermost shaped charge **16**, which cap is exploded from the surface of the well permitting spring **20** to pivot the bottom shaped charge to a horizontal position. This pivoting breaks the interconnection between detents **22** on upper end of the bottom shaped charge and **32** on lower end of the charge immediately above permitting similar pivoting thereof, thereby successively freeing each charge **16** in the carrier **12** to pivot to its firing position.

The above description of the device is believed adequate for the present application, but a more detailed description may be found in the above-mentioned United States patent application Serial No. 461,236. In any event, the instant invention is directed to means employed for completing the circuit for firing cap **24** permitting pivoting of the charges **16** to the firing position whereby said means arms the firing circuit for the shaped charges.

In general the invention involves an element inserted into the carrier and axially aligned therein by engagement with the shaped charge immediately below which element contains means for completing the circuit permitting release of the shaped charges to pivot to the firing position. The element upon release likewise pivots to a firing position thereby arming the shaped charge firing circuit.

The arming element **26** has an exterior shape similar to that of the shaped charge **16** and is pivotally mounted in the carrier by pins such as **28** and a spring **30** biases the arming element to a substantially horizontal firing position. The arming element **26** at its lowermost extremity has a detent **32** which interlocks with detent

22 on the upper extremity of the next lower shaped charge 16 in the carrier. Thus the arming element 26 is substituted for the top shaped charge in the carrier and pivots to an arming position as do the remaining shaped charges 16 upon exploding of cap 24.

The arming element 26 has a central chamber 34 containing a mercury switch generally designated 36 rigidly secured therein. The switch comprises an upper chamber 38 and a lower chamber 40 with a restricted throat 42 therebetween which eliminates accidental splashing of the mercury 44 during lowering of the assembly into a well.

During descent of the perforating assembly into a well the arming element 26 is in axial alignment with respect to carrier 12 and the mercury 44 is in lower chamber 40 of the switch completing an electrical circuit between contacts 46 and 48 which are spaced from one another and project through the electrically non-conductive shell of the switch 36 into chamber 40. Upon firing of cap 24 from the surface of the well and release of the interlocked charges the arming element 26 is pivoted to substantially a horizontal position whereby the mercury flows from chamber 40 into chamber 38 completing the electrical circuit between contacts 50 and 52 which are spaced from one another and project into chamber 38. To facilitate the flow of mercury from chamber 40 to chamber 38 the shell of switch 36 that is the longitudinal axis through the chambers 38 and 40 may be inclined to the vertical in the direction of pivoting of the arming element 26 a slight amount.

The contacts 46 and 52 are interconnected by wires 54 and 56 which at their union are fixed to wire 58 which at the surface of the well is connected to a suitable source of electrical power. The contact 48 is connected by wire 60 to cap 24 which cap is suitably grounded to the carrier while contact 50 is connected by wire 62 to an electrically operated blasting cap 64 which is likewise suitably grounded to the carrier.

Thus when the arming element is in the axially aligned position in the carrier the circuit through contacts 46 and 48 is completed to cap 24 which may then be fired by energizing the circuit from the well surface which as heretofore described permits successive pivoting of the shaped charges 16 and ultimately of the arming element 26. If the arming element should engage an obstruction in the well it will not pivot and consequently the mercury 44 would not flow into chamber 38 to complete the circuit between contacts 50 and 52, thereby preventing firing of the shaped charges. If the arming element does pivot to the firing position of Figure 2, i.e., the well bore is free of obstructions, then the mercury 44 flows into chamber 38 completing the firing circuit. A further electrical impulse will, under these conditions, fire cap 64, this in turn fires detonator 66 housed in firing head 10 which in turn fires the firing fuse 14 which sets off the shaped charges 16.

To protect the wire leads and the mercury switch from well fluids the wires 58, 60 and 62 pass through a plastic head 68 secured in a suitable bore in the arming element 26 and are held therein by gland 70 preventing the well fluids entering the arming element 26. Similarly, wires 53 and 62 pass through a plastic sealing head 72 fitted within a bore in firing head 10 and secured therein by a gland 74 preventing well fluids entry into the firing head 10.

Thus the arming element 26 is interlocked with the shaped charges 16 during lowering of the perforating assembly into the well and in this position completes an electrical circuit which may be energized to fire cap 24, permitting pivoting of the shaped charges and the arming element to the firing position wherein the arming element completes the firing circuit which may then be energized to fire the shaped charges.

While what hereinbefore has been described is the preferred embodiment of this invention, it is readily apparent that alterations and modifications can be resorted to without departing from the scope of this invention and such alterations and modifications are intended to be included within the scope of the appended claims.

I claim:

1. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; an explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member including a switch being entirely a part of said arming member for completing the circuit to said explosive member while said arming member is in axial alignment with said carrier, whereby current may be caused to flow through said completed circuit to fire said explosive member to release said elements from interlocked relationship.

2. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; an explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member including a switch being entirely a part of said arming member for completing the circuit to said explosive member while said arming member is in axial alignment with said carrier, whereby current may be caused to flow through said completed circuit to fire said explosive member to release said elements from interlocked relationship; and a shaped charge firing circuit; said switch completing said shaped charge firing circuit when said arming member is pivoted out of axial alignment with said carrier.

3. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; and explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member containing a pair of spaced contacts forming elements of said explosive member firing circuit and an electrically conductive fluid therein which when said arming member is in axial alignment with said carrier flows to a position bridging said contacts to complete said explosive member firing circuit.

4. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; an explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member containing a pair of spaced contacts forming elements of said

explosive member firing circuit and an electrically conductive fluid therein which when said arming member is in axial alignment with said carrier flows to a position bridging said contacts to complete said explosive member firing circuit; and a shaped charge firing circuit including a second pair of spaced contacts in said arming member; said electrically conductive fluid flowing in said arming member to a position bridging said second pair of contacts to complete said shaped charge firing circuit upon pivoting from the axially aligned position with respect to said carrier of said arming member.

5. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; an explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member having a pair of interconnected chambers therein; a first pair of spaced contacts in one of said chambers forming elements of said explosive member firing circuit; an electrically conductive fluid partially filling said one chamber when said arming member is axially aligned with respect to said carrier and bridging said first pair of spaced contacts thereby completing said explosive member firing circuit; and a shaped charge firing circuit including a second pair of spaced contacts in the remaining one of said chambers; said electrically conductive fluid flowing into the remaining chamber upon pivoting of said arming element and bridging said second pair of spaced contacts to complete said shaped charge firing circuit.

6. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; an explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member having a pair of interconnected chambers therein; a first pair of spaced contacts in one of said chambers forming elements of said explosive member firing circuit; an electrically conductive fluid partially filling said one chamber when said arming member is axially aligned with respect to said carrier and bridging said first pair of spaced contacts thereby completing said explosive member firing circuit; a shaped charge firing circuit including a second pair of spaced contacts in the remaining one of said chambers; said electrically conductive fluid flowing into the remaining chamber upon pivoting of said arming element and bridging said second pair of spaced contacts to complete said shaped charge firing circuit; and a restricted throat between said chambers.

7. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; an explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member having a pair of interconnected chambers therein; a first pair of spaced contacts in one of said chambers forming elements of said explosive member firing circuit; and electrically conductive fluid partially filling said one chamber when said arming member is axially aligned with respect to said carrier and bridging said first pair of spaced contacts thereby completing said explosive member firing circuit; and a shaped charge firing circuit including a second pair of spaced contacts in the remaining one of said chambers; said electrically conductive fluid flowing into the remaining chamber upon pivoting of said arming element and bridging said second pair of spaced contacts to complete said shaped charge firing circuit; the longitudinal axis through the chambers being inclined in the direction of pivoting with respect to the longitudinal axis of the carrier.

8. A well perforating assembly comprising; an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an explosive member maintaining said elements in an interlocked relationship; an explosive member firing circuit; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; said arming member having a pair of interconnected chambers therein; a first pair of spaced contacts in one of said chambers forming elements of said explosive member firing circuit; an electrically conductive fluid partially filling said one chamber when said arming member is axially aligned with respect to said carrier and bridging said first pair of spaced contacts thereby completing said explosive member firing circuit; a shaped charge firing circuit including a second pair of spaced contacts in the remaining one of said chambers; said electrically conductive fluid flowing into the remaining chamber upon pivoting of said arming element and bridging said second pair of shaped contacts to complete said shaped charge firing circuit; the longitudinal axis through the chambers being inclined in the direction of pivoting with respect to the longitudinal axis of the carrier; and a restricted throat between said chambers.

9. A well perforating assembly comprising: an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which then interlocked maintain said shaped charges in axial alignment with said carrier; means releasably maintaining said elements in interlocked relationship; electrically operated means for firing said shaped charges; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking elements; and electrical circuit means for energizing said electrically operated firing means including a switch being entirely a part of said arming member, said switch being open when said arming member is in axial alignment with said carrier and being operable to close in response to pivoting of said arming member out of axial alignment with said carrier.

10. A well perforating assembly comprising: an elongated carrier; a plurality of shaped charges pivotally mounted in said carrier and urged to pivot out of axial alignment with said carrier; interlocking elements on each shaped charge which when interlocked maintain said shaped charges in axial alignment with said carrier; an electrically operated explosive member maintaining said elements in interlocked relationship and adapted upon explosion to release said elements; electrically operated means for firing said shaped charges; an arming member in said elongated carrier urged to pivot out of axial alignment with said carrier and restrained against pivoting by engagement with one of the interlocking el-

ments; and electrical circuit means for independently energizing said electrically operated explosive member and said electrically operated shaped charge firing means including switch means being entirely a part of said arming member, said switch means being constructed and arranged to provide a closed circuit to said explosive member and an open circuit to said shaped charge firing means when said arming member is in axial alignment with said carrier, said switch means being operable in response to pivoting of said arming member out of axial alignment with said carrier to open the circuit to said

explosive member and to close the circuit to said shaped charge firing means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,232,627	Olson	Feb. 18, 1941
2,644,519	Kanady	July 7, 1953
2,664,157	Abendroth	Dec. 29, 1953

FOREIGN PATENTS

1,029,798	France	Mar. 11, 1953

Disclaimer and Dedication

2,924,173.—*John J. Robertson*, Fort Worth, Tex. WELL PERFORATOR FIRING MEANS. Patent dated Feb. 9, 1960. Disclaimer and dedication filed Nov. 14, 1967, by the assignee, *Halliburton Company*.

Hereby disclaims and dedicates to the Public the terminal portion of the term of the patent subsequent to Dec. 31, 1966.

[*Official Gazette March 5, 1968.*]