Nov. 22, 1960 J. J. DOUGLASS 2,960,931

JET PERFORATING ASSEMBLY FOR OIL WELLS

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Fig. 1

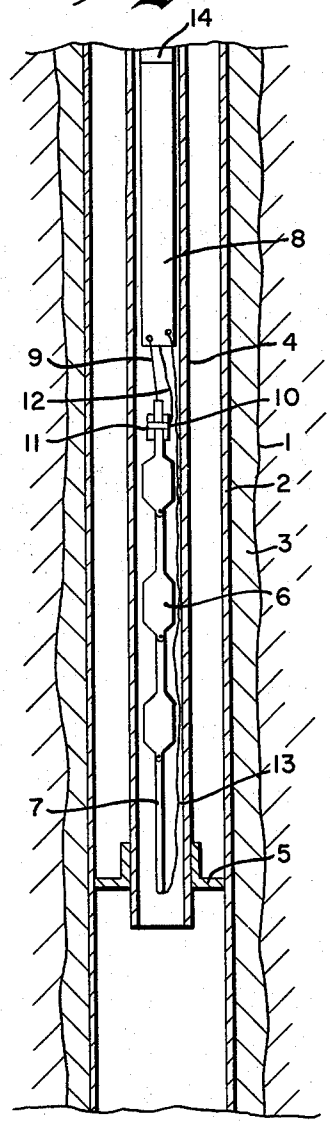

Fig. 2

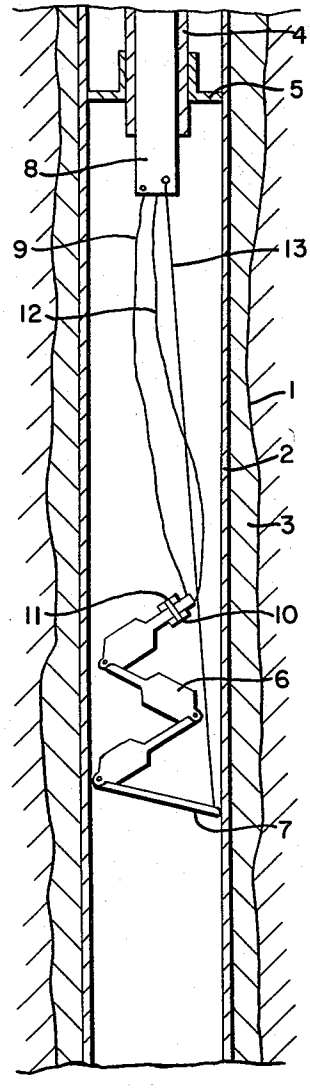

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Fig. 5

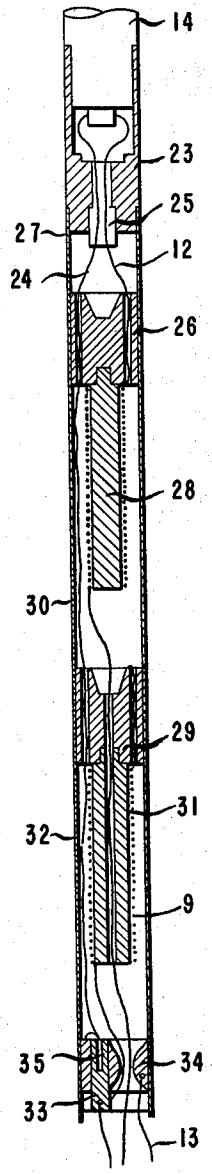

Fig. 6

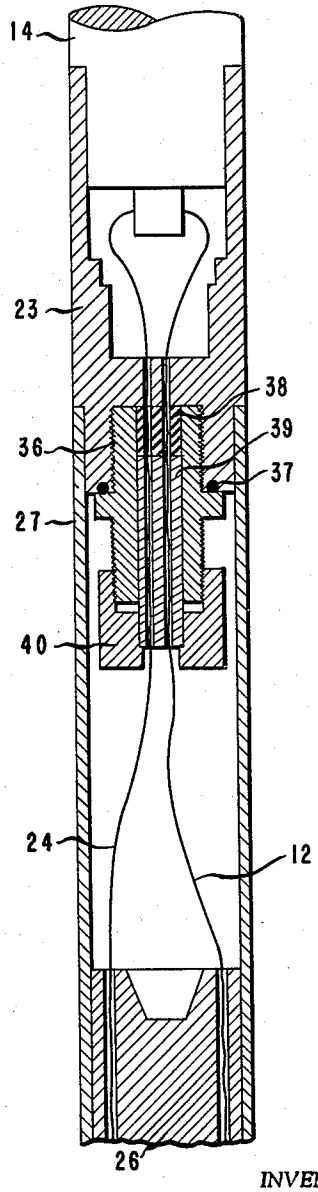

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Fig. 3

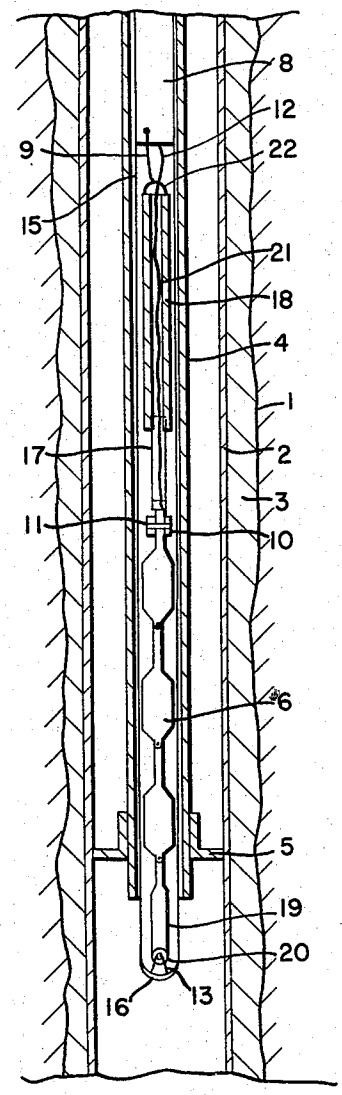
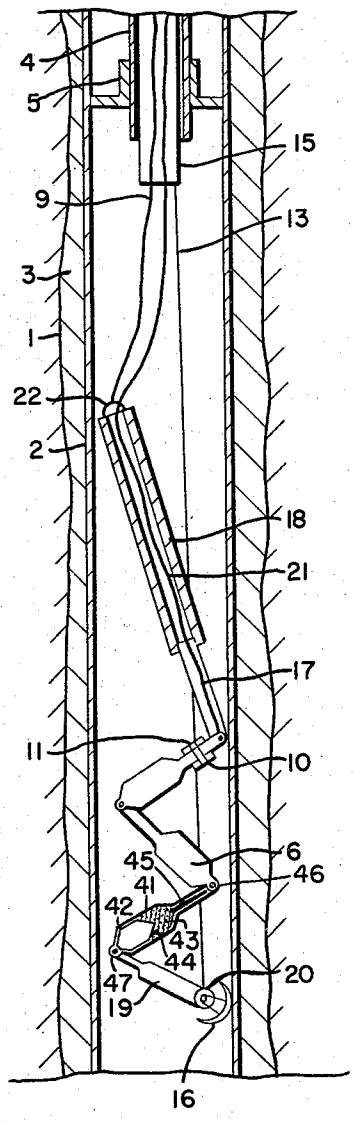


Fig. 4



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JET PERFORATING ASSEMBLY FOR OIL WELLS

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4 Claims. (Cl. 102—21.2)

The present invention relates to an assembly of shaped-charge perforating units for use in "through-tubing" completion of oil wells. More particularly, the present invention relates to an assembly of shaped-charge perforating units for use in "through-tubing" completion of oil wells, in which assembly means are provided for lowering and positioning the perforating units in the well casing.

After an oil well has been drilled, the well walls are cased to prevent the introduction of undesirable fluids and solids into the well. The casing consists of a metal pipe cemented into position. In order to prepare the well for production, the casing and the cement layer are perforated in the zone of the well surrounded by oil-bearing strata. In this step, known as well completion, the so-called jet, or shaped-charge, perforator is widely used. The shaped-charge perforator essentially comprises a charge of high-velocity detonating explosive having a metal-lined cavity, usually conical. Upon detonation of the charge, the liner is expelled as a high-velocity jet having excellent penetration power.

Until recently, the well-completion operation preceded the installation in the well of the small-diameter tubing through which the oil flow from the producing zone of the well to the surface is controlled. To prevent the well from flowing before the valves can be installed and set, the perforating is done while the heavy drilling muds are still in the well, the muds providing a hydrostatic pressure great enough to prevent the flow of oil from the perforations. The presence of the muds is disadvantageous, inasmuch as they flow into the perforations in the casing and may clog the perforations. Therefore, the use of a more recently developed procedure for well-completion, the so-called "through-tubing" method in which the perforating is done in the absence of the drilling muds, is becoming widespread in the industry.

In the "through-tubing" method, the casing is perforated after the tubing and valves have been set in place. This procedure naturally requires the lowering of the perforating units through the small-diameter tubing. Perforating units of numerous designs have been developed for use in this procedure. Because of the small diameter of the tubing, perforating units designed to be lowered through the tubing in firing position, i.e. with their longitudinal axis directed towards the tubing wall, must be very short. Loss of penetrating strength due to the small size is inevitable. In order to overcome this loss of penetration, units have been developed which are lowered through the tubing with their axes parallel to the tubing wall and are tilted into firing position in the well casing. Most of these tilting units, however, require a relatively intricate mechanism to effect the tilting. An improved perforating unit and assembly, the units of which are tilted into firing position in a simple and readily effected manner, therefore, have been developed.

This unit, which is described in detail, along with the assembly, in copending application Serial No. 663,285, filed June 3, 1957 by P. J. Bryan and assigned to the present assignee, comprises a shaped-charge perforating unit provided with exterior pivot elements, a number of the units being pivotally interconnected by means of these elements to form a chain-like assembly. This assembly can be lowered through the tubing vertically, so that no decrease in size with attendant loss of penetration is required, and tilted within the well casing into firing position in a simple manner.

The lowering and positioning of the perforating unit assembly may be accomplished merely by two cables which extend from the assembly in the well to the earth's surface, one cable being attached to the uppermost unit and the other cable, in the form of a yoke, to the lowermost unit. This lowering and positioning method has one main drawback, the necessity for the long lengths of cable, usually thousands of feet of each cable, which extend to the surface. Obviously, the handling of such lengths of cable is cumbersome and annoying, and the elimination of these long cables is highly desirable.

Accordingly, an object of the present invention is the provision of lowering and positioning means in the assembly of pivotally interconnected perforating units, which means do not necessitate the use of two long lengths of cable. Another object of the present invention is the provision in the assembly of such means which are simple in design and readily operated. A further object of the present invention is the provision of lowering and positioning means in an assembly of pivotally interconnected perforating units, which means can also be used to retract the units from the firing position and to withdraw the units from the well, if desired.

I have found that the above objects may be achieved when I incorporate into an assembly of pivotally interconnected shaped-charge perforating units an elongated housing containing a coil of electrical initiation wire and a coil of a length of supporting cable which passes through a release element within the housing and is fastened to the uppermost perforating unit, an aligning cable attached at one end to the housing and at the other end to the lowermost perforating unit, and means for actuating the release element.

In order to describe the invention more fully, reference is made to the accompanying drawings, in which:

Figure 1 illustrates schematically a chain of the interconnected shaped-charge perforating units as lowered through the tubing in accordance with one embodiment of the present invention,

Figure 2 illustrates schematically the same chain of perforating units in perforating position within the well casing,

Figure 3 illustrates schematically a chain of the interconnected shaped-charge perforating units as lowered through the tubing in accordance with another embodiment of the present invention,

Figure 4 illustrates schematically the chain of perforating units of Figure 3 in perforating position with the well casing,

Figure 5 is a view in cross-section of the positioning head assembly of the present invention, and Figure 6 is a detail view of one section of the positioning head assembly.

In all figures, identical parts are indicated by the same symbols.

In Figures 1 and 2, 1 is the natural wall of the well formed by the drill, 2 is a metal casing within the well, 3 is a filling cement between wall 1 and casing 2, 4 is a tubing within casing 2, and 5 is a spacing element used to center tubing 4 within casing 2. All of the foregoing represent typical well construction features.

6 represents a perforating unit of the chain, the lowest unit 6 being connected by its lower pivot element to a stop link 7 and the uppermost unit 6 being connected

through its upper pivot element to the positioning head assembly 8 by a supporting cable 9.

10 represents a mercury safety switch connected to a pair of electrical conducting wires 12 which pass therethrough and thence to electric initiator 11.

13 represents the aligning cable attached at one end to the lower section of stop link 7 and at the other end to the positioning head assembly 8 which is attached to a conventional casing collar locator 14, which is lowered into the well on a cable.

In the embodiment shown in Figures 3 and 4, perforating units 6 are contained in protective metal tubing 15 forming an extension of the housing of positioning head assembly 8, the bottom end of which tubing is sealed by a nose piece 16. The uppermost unit 6 is attached through its upper pivot element to the hollow standoff tube 17 of sinker bar 18. The lowest unit 6 is attached to a stop link 19 connected to nose piece 16 and having a reel 20 upon which is wound aligning cable 13, the free end of which is connected to the lower end of metal tubing 15. Sinker bar 18 has a longitudinal bore 21 through which the electrical conducting wires 12 are passed, the wires being led from bore 21 through hollow standoff tube 17 and then to the mercury switch 10. The supporting cable 9 of positioning head assembly 8 is attached to bail 22 provided at the top of sinker bar 18. Furthermore, Figure 4 shows one unit cut away to illustrate the shaped-charge unit structure, namely, 41 is a case body, 42 is a case cover, 43 is a charge of a high-density detonating explosive, 44 is a metal liner in the cavity of charge 43, 45 is a booster charge, and 46 and 47 are pivot elements externally positioned on case body 41 and case cover 42, respectively.

In Figure 5 showing in detail positioning head assembly 8, 14 again indicates the casing collar locator in which the connections for the electric conducting wires are made and which is inserted into the upper portion of adapter sleeve 23. Adapter sleeve 23 has two longitudinal bores through which pairs 12 and 24 of electrical wires are passed, wires 12 and 24 then being passed through a compression sealing arrangement 25 which prevents the entrance of well fluids in the housing above the seal. 26 represents a tube adapter which is attached to adapter sleeve 23 by a spacer tube 27. To the lower end of adapter 26, a reel 28 is fastened. Another tube adapter 29 is provided and is attached to tube adapter 26 by another spacer tube 30. A reel 31 also is provided at the end of adapter 29, to which is attached by means of spacer tube 32 a release mechanism consisting of a release stud 33 which is held within release block 34 and can be disengaged by actuation of release electric blasting cap 35. The supporting cable 9 is threaded through a longitudinal bore of adapter 29, the upper end of the cable being secured to the adapter 29, and is wound around reel 31. The unwound portion of cable 9 is led through the bore in release block 34, through the aperture at the base of release stud 33, and thence to the uppermost perforating unit 6 or the bail 22 of the sinker bar 18. An anchor stop fastens the cable in the aperture and holds the cable taut between the aperture and the perforating unit or the bail when the units are suspended in the vertical position in the well.

Electrical conducting wires 12 after passage through the compression sealing means 25 are led through a longitudinal bore in adapter 26, are wound around reel 28, and then passed through a central bore in adapter 29 and in reel 31 and through release block 34. After their emergence from the positioning head assembly, the wires 12 are connected to the mercury switch-initiator arrangement.

After passage through the sealing means 25, electrical conducting wires 24 are led through longitudinal bores in adapters 26 and 29 and then are connected to release electric blasting cap 35, one of the pair of wires being grounded to the release block 34.

In accordance with one embodiment of the invention, aligning line 13 is shown attached to the lower portion of release block 34.

In Figure 6 showing in detail the compression sealing arrangement 25 of positioning head assembly 8, the casing collar locator 14, the adapter sleeve 23, tube adapter 26, spacer tube 27, and wires 12 and 24 are as shown in Figure 5. 36 represents a compression stud screwed into the lower section of sleeve adapter 23, an O-ring 37 being provided to insure a tight fit. Within the central bore of stud 36 are inserted a rubber sealing plug 38 adjacent the surface of sleeve adapter 23 and a metal plug insert 39 below plug 38, the insert extending a short distance below stud 36. 40 indicates a compression nut which is screwed onto stud 36 and surrounds the extended portion of insert 39. Wires 12 and 24 are led through longitudinal bores in adapter sleeve 23, plug 38, insert 39, and adapter tube 26 and thence through the remaining sections of the positioning head assembly 8.

The lowering and positioning of the shaped-charge perforating units 6 basically is accomplished by means of the two cables: the supporting cable 9 from which the units 6 are suspended during the lowering operation and the aligning cable 13 which effects the collapse of the units 6 into firing position in the zone of the well to be perforated.

In operation, in accordance with the embodiment of the invention illustrated in Figures 1 and 2, the supporting cable 9 after passage through the aperture in release stud 33 of the positioning head assembly 8 is fastened directly to the uppermost unit 6. The anchoring stop is attached to cable 9 at the aperture to prevent further pay-out of the cable, the cable between the aperture and unit 6 being of sufficient length to permit the suspension of the perforating unit chain at the desired distance from the positioning head assembly 8. One end of the aligning cable 13 is fastened to the release block 34 and the other end is fastened to the lower end of stop link 7 attached to the lowermost unit 6 of the chain. The length of aligning cable 13 is such that the perforating units collapse into firing position at the desired distance from the positioning head assembly 8 and that the aligning cable 13 remains slack when the supporting cable 9 is under tension. The entire assembly then is lowered through the tubing 4 into well casing 2 by conventional means, e.g. by means of casing collar locator 14, to the well zone to be perforated, the supporting cable 9 being taut, aligning cable 13 remaining slack. Then, the release electric blasting cap 35 is actuated, rupturing release stud 33 and permitting further pay-out of supporting cable 9. The aligning cable 13 thereby becomes taut and pivots stop link 7, which is of greater length than the diameter of the well casing 2, into the bridging position, while units 6 collapse upon themselves into firing position. The aligning cable 13 thus becomes the support for the perforator chain, the stop link 7 providing additional support. When the mercury safety switch 10 is in the tilted position due to the collapse of the units, the firing circuit is completed and passage of the firing current through line 12 actuates initiator 11 which brings about the detonation of the explosive charges in units 6. After the charges are detonated, the positioning head assembly 8, which is reusable, is retrieved. By use of aligning cable of strength just sufficient to support the units when in firing position, retrieval of the units before actuation, if desired, can be effected by an upward pull on the assembly, which snaps the aligning cable and permits retraction of the units into the vertical position, in which position they are again supported by supporting cable 9 and can be withdrawn through the tubing and from the well.

The assembly and operation in accordance with the embodiment illustrated in Figures 3 and 4 is similar to those afore-described. Instead of being directly attached to the perforating unit chain, the supporting cable 9 is attached to sinker bar 18 from the standoff tube of which

the chain is suspended. The metal tubing **15** is positioned about the units and the sinker bar and attached to the positioning head assembly **8**. The aligning cable **13** is fastened to and wound upon spool **20** of stop link **19**, the free end of cable **13** being attached to metal tubing **15**. The nose piece **16** is attached to the bottom of tubing **15** and fastened to stop link **19**. Then, the entire assembly is lowered through the well tubing and into the well casing to the desired depth, the supporting cable **9** being under tension throughout the lowering operation. Rupture of the release stud **33** by release electric blasting cap **35** permits further pay-out of cable **9**, and the sinker bar **18** falls, forcing units **6** out of tubing **15**. As the units fall, the aligning cable **13** pays-out its entire length and becomes taut. The units **6** then tilt into firing position and are supported by aligning cable **13** and also by stop link **19**. In accordance with both embodiments of the invention, the firing line **12** is of a length sufficient that it remains slack during the operations.

As is obvious from the afore-described operation of the assembly, the essential features of the assembly are: the elongated housing which may or may not surround the perforating unit chain, the supporting cable by which the chain is supported during the lowering, the aligning cable which positions the units and thereafter supports them, and the release element and its actuation means which effect the further pay-out of the supporting cable and, thus, the positioning of the units.

The stop link of course may be omitted from the assembly of either embodiment of the invention without deleterious effects on the operation of the assembly. When the stop link is omitted from the assembly, the aligning cable is attached to the lower pivot element of the lowermost unit. The use of the stop link is preferable, however, inasmuch as it provides additional support for the units when in firing position. The presence of the sinker bar in the assembly illustrated in Figures 3 and 4 also is not essential to the operation of the assembly, its function being merely to accelerate the fall of the perforating units from the protective metal tubing. If desired, the support cable can be attached to the uppermost unit of the assembly as in the embodiment illustrated in Figures 1 and 2.

The protective metal tubing, which constitutes an extension of the housing of the positioning head assembly, may be an integral length of metal tubing or may be made up in sections which are interconnected about the perforating units and, if used, the sinker bar. For ease of handling, the use of the sections of the tubing is preferred.

Although they do not constitute an essential feature of the present invention, reels generally will be provided in the assembly for both the supporting cable and the electrical initiation wire, since the reels afford a convenient means of retaining the lines in the proper position within the housing. The use of other of such means, however, is fully within the scope of the present invention.

Many forms of release elements are known and may be adapted for use in the assembly of the present invention. Especially suitable is the exemplified destructible stud, which may be ruptured either by mechanical means or by an explosive charge contained within the stud, for example by a release electric blasting cap, many types of which are available and were designed specifically for use with destructible studs.

As a safety measure, a mercury safety switch may be provided in the electric initiation circuit, inasmuch as the presence of the switch prevents the actuation of the explosive charges of the perforating units unless the units are in the tilted, or firing, position. As afore-mentioned, the electrical initiation wires after passage through the positioning head assembly are led to the switch and thence to the electric initiator which actuates the perforating units. Equally feasible, however, is the omission of the switch from the circuit, in which case the wires are directly connected to the electric initiator. The initiator preferably is of the type especially designed for use under conditions of high temperature and pressure and may be attached either to the top unit of the chain or to the bottom unit, the arrangement of the perforating units illustrated in the accompanying drawings being reversed when the initiator is attached to the bottom unit. In the case of bottom initiation, the mercury switch, if used, may be attached to the uppermost unit and the wires may be led from the switch and along the units and then attached to the initiator.

The housing preferably is sealed above the coil of initiation wire in order to prevent the entrance of well fluids, which may contain conductive salts which might interfere with the electric connections made in the casing collar locator. The specific sealing means if not critical, and any suitable means, for example the compression stud shown in Figure 6, may be used.

The invention has been described in detail in the foregoing. It will be apparent, however, to those skilled in the art that many variations are possible without departure from the scope of the invention. I intend, therefore, to be limited only by the following claims.

I claim:

1. An assembly for perforating oil wells comprising an elongated housing, a coil of a length of supporting cable contained in said housing, a release mechanism at the bottom of said housing through which said supporting cable is threaded and which locks said supporting cable in place until said release mechanism is actuated, means for actuating said release mechanism whereby said supporting cable will pay out of said housing, a plurality of pivotally interconnected shaped-charge perforating units, the uppermost unit being connected to said supporting cable below said release mechanism, an electric initiator attached to said uppermost shaped-charge perforating unit, electrical initiation wires attached to said initiator, a coil of electrical initiation wire within said housing, and an aligning cable attached at one end to the bottom of the lowermost shaped-charge perforating unit and at the other end to said housing.

2. An assembly according to claim 1, wherein said release mechanism comprises a destructible stud actuated by an explosive charge contained in a recess within said stud.

3. An assembly according to claim 1, wherein a protective metal tubing which constitutes an extension of said housing surrounds said plurality of perforating units prior to actuation of said release mechanism.

4. An assembly according to claim 3, wherein said supporting cable is attached indirectly to said uppermost perforating units by means of a sinker bar.

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