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WELL COMPLETION APPARATUS

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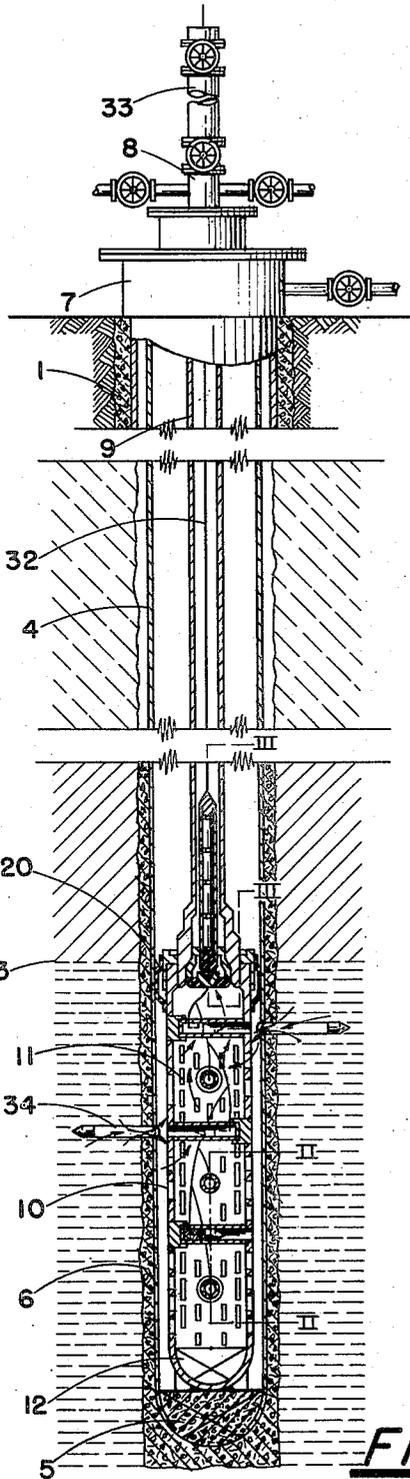


FIG. 1.

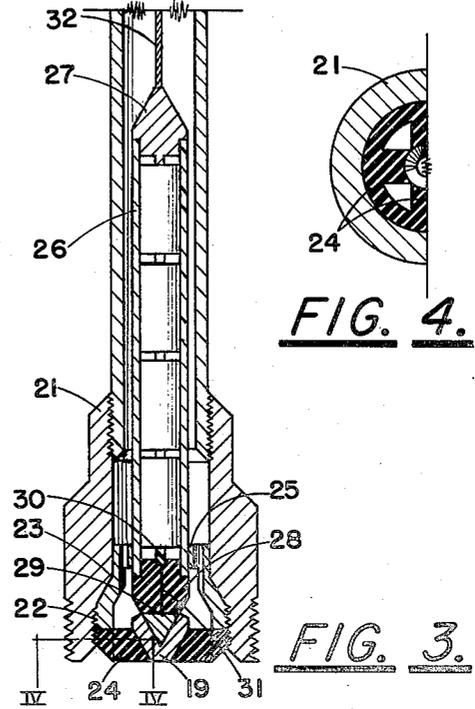


FIG. 4.

FIG. 3.

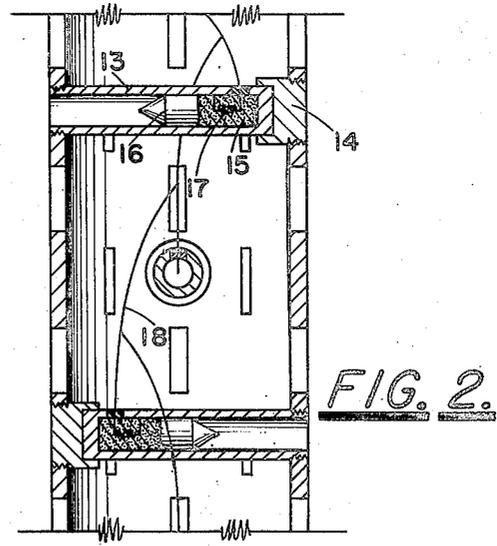


FIG. 2.

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# UNITED STATES PATENT OFFICE

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## WELL COMPLETION APPARATUS

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1 Claim. (Cl. 166—5)

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The present invention is directed to apparatus for completing or working over oil and gas wells, particularly those which produce under high pressure.

The principal object of the present invention is the provision of apparatus for the completion of wells drilled for oil and gas which makes possible the bringing of the well into production without subjecting the perforations or drainage openings into the producing formation to a head of fluid having a higher hydrostatic pressure than the formation pressure and containing solids that can plug such openings.

Another object of the present invention is the provision of apparatus for completing a well which enable the operator to prepare his well for production completely before the producing formation is tapped, this operation being made the last operation in the completion process.

An additional object of the present invention is the provision of means for completing oil and gas wells after the setting of casing which will permit removal of drilling and pipe handling equipment from the well location before the ordinary waiting time for cement setting has elapsed prior to perforating the casing and formation for production.

Further objects and advantages of the present invention will appear from the following detailed description of the accompanying drawing in which—

Figure 1 is a vertical section through a well completed in accordance with the present invention with the completion apparatus in place;

Figure 2 is a detail, in vertical section, of the gun perforator-screen combination constituting one feature of the present invention; and

Figure 3 is another detail, in vertical section, of the device used to actuate the gun.

Fig. 4 is a horizontal sectional view on IV—IV of Fig. 3.

Referring to the drawing in detail, numeral 1 designates a borehole drilled into or through a formation containing oil or gas the top of which is indicated at 3. In the practice of one embodiment of the present invention the borehole is drilled through the producing formation and then casing 4, provided with a float shoe 5, such as that illustrated on page 227 of the 1942 Composite Catalog, is suspended in the well. Cement 6 is then forced into place behind the casing and allowed to set.

Thereafter, the upper end of the well is fitted with a well-completion assembly 7, such as that shown at page 1589 of the 1942 Composite Cata-

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log, including a casing hanger, a tubing hanger, and a Christmas tree, the latter being indicated as a whole by numeral 8. Suspended from the tubing hanger is string 9 of tubing carrying at its lower end a screen 10 provided with slots 11 and a back-pressure valve 12. Any conventional type of screen may be employed, including those which are referred to as prepacked liners, as illustrated, for example, at page 1420 of the 1942 Composite Catalog.

In adapting the screen for use in the practice of the present invention, however, there are inserted inside the screen a number of gun barrels 13. Each gun barrel is a cylinder having a closed end set in a socket 14 screwed into the wall of the screen and having an open end screwed into the opposite wall of the screen. The closed end of the barrel constitutes a powder chamber 15 ahead of which is arranged a bullet 16. The powder chamber is provided with a firing filament 17, the various filaments being connected in series or in parallel, as desired, to a conductor 18 soldered or otherwise connected to a metal contact 19. Each firing filament is also grounded to its gun barrel. It will be understood that electrical devices for spacing the occurrence of the shots may be arranged in the firing circuit. Likewise, the firing filaments may be connected to a firing device operated by a go-devil in a manner known in the art.

If desired, the screen may be provided at its top with a suitable packer 20, such, for example, as the packer shown at page 2291 of the 1942 Composite Catalog, or other numerous packers illustrated in this catalog. Also, if desired, a safety joint may be added to the assembly above the screen, which will permit releasing the tubing from the screen. Such a safety joint is illustrated in the 1942 Composite Catalog on page 2296.

The tubing in this case is provided with a separate section 21, onto the lower end of which the screen is screwed. This lower end is flared outwardly and is provided with internal screw threads 22 into which is inserted a plug composed of a metal cup 23 carrying inwardly directed circumferentially-spaced arms 24 of Bakelite or similar material, in which is fixed the metal contact 19 which, in the embodiment shown, has a conical shape. The space between the arms 24 permits the flow of fluid down through the tubing to the screen. The metal cup 23 has an inwardly directed flange 25 for the purpose hereinafter indicated.

In the arrangement shown, the power necessary

to fire the gun is supplied by a magazine of batteries composed of a cylindrical chamber 26 having at one end a metal plug 27 and at the other end a plug 28 of insulating material, such as Bakelite, having a metallic tip 29 connected to a button 30 on the inner face of the plug by a conductor 31. The assembly is suspended on a wire line 32, which may be introduced into the tubing through a lubricator 33 arranged at the top of the Christmas tree. This lubricator is of a type well known in the art, such as that illustrated on page 970 of the 1942 Composite Catalog as Unit 5. With this type of lubricator it is possible to introduce into or remove from the production tubing, under formation pressure, any device of suitable size without releasing the pressure inside the tubing. It will be understood that when a go-devil type firing mechanism is employed the go-devil will take the place of the cylinder 26. It may be mentioned here also that the cylinder 26, instead of being a container for batteries, can be merely a weight constituting one terminal of a source of power, such as a generator, arranged at the surface. The circuit of the generator can be kept closed until this terminal makes contact with the metal contact 19 at the bottom of the tubing. It will be observed in the embodiment shown that the cylinder 26 is metallic and serves to close the battery circuit when tip 29 and contact 19 are engaged by virtue of its engagement with flange 25. It will be understood that flange 25 may be provided with suitable circumferentially spaced slots to permit the passage of fluid.

In the practice of the present invention, the casing is first set at a point opposite the producing formation and cemented in place. In the embodiment shown the cementing was performed with the float in the shoe at bottom, in which case, when all of the cement is in place as shown, there is nothing above the guide shoe requiring drilling. In a different type of cementing operation there may be a column of cement in the casing to be drilled out after the cementing operation is completed. In any case, any loose solids are washed out of the casing, leaving in it only clear fluid. Preferably this fluid should be lighter than drilling fluid, a light oil or clear water being suitable. There are two objectives in using such a fluid. The first is that when the casing opposite the producing formation is perforated it is detrimental to have a heavy fluid, such as mud, in the casing because it will run into the perforations and contaminate the formation and, what is more serious, plug up the perforations. Such plugged perforations are a hindrance to proper drainage of the reservoir and they result in flow being concentrated at the one or two openings that may be cleaned through ordinary cleaning operations to put wells on production; the concentrated flow results in costly damage to well screening equipment. Furthermore, it is desirable to bring the well into production as soon as the casing is perforated and this can't be done if there is in the casing or in the producing string a fluid having a hydrostatic head greater than the formation pressure.

The second objective in replacing dirty fluid in the casing is to make possible the setting of screen without having the perforations in the screen plugged up during setting or producing operations with solids suspended in the fluid in the casing. In former types of well completions the setting of screen, especially where the screen includes a prepacked liner, in such a manner as

to have the screen or the liner operate efficiently, has been a serious problem by virtue of the universal practice, dictated by necessity, of having a head of drilling mud in the casing when the casing is perforated so as to keep the well under control. In the completion operation of the present invention, in which the screen is placed before the perforation is effected, the necessity for using drilling mud or other heavy fluid in the casing is eliminated. Accordingly, the problem of fouling the screen or prepacked liner, as the case may be, is avoided.

With the casing free of all fluid except clean, preferably light, fluid, the casing head, together with the tubing hanger and string of tubing with its attached screen, is installed. Packer 20, when employed, is set, and the lubricator 33 is installed on the Christmas tree. Then, sufficient setting time for the cement having been allowed, the magazine 26 is lowered on a wire line through the lubricator to fire the gun barrels. In the embodiment shown, the screen contains six gun barrels. It will be understood that this number can be increased or decreased and their position changed as desired. In Figure 1, numeral 34 designates the path taken by the bullets. As soon as the perforating is completed, the magazine is withdrawn from the tubing and the well is placed on production. By reason of the fact that a light fluid may be employed in this completion operation, the necessity for swabbing and pipe handling is eliminated. Therefore, according to the present invention, as soon as the casing is set, the tubing and screen hung, and the well head equipment installed, the drilling equipment and all pipe handling equipment can be moved to a new location, resulting in a considerable saving in time and expense.

In the foregoing description reference has been made to the replacement of heavy fluid in the well by a light fluid, the hydrostatic head of which is less than formation pressure. This is a particular feature of the present invention which is not necessarily confined in its practice to this specific embodiment described herein. It is applicable to work-over jobs and to testing operations, as well as to original completions. As is well understood, a work-over job ordinarily involves the killing of the well by the introduction or accumulation of a heavy fluid followed by operations such as the packing off of the formation to be worked upon, which operation involves the removal of the producing string, in some cases a squeeze cementing job, and usually a perforating job. These operations are expensive and time consuming, requiring also the presence on the location of the derrick structure. According to the present invention, such a job is simplified, especially where an open-ended producing string is employed, merely by first killing the well, then performing such operations as are required, as for example, squeezing cement into the formation to be worked, followed by removal of excess cement. Next, the heavy fluid in the well is replaced by a light fluid, such as, for example, oil, well head equipment is installed, and a perforating gun is introduced into the tubing through a suitable lubricator and spotted opposite the formation to be perforated. Perforation is then effected, the gun withdrawn, and the well placed on production. As will be clear, this procedure eliminates many of the expensive operations hitherto required to achieve this purpose.

The nature and objects of the present invention having been thus described and illustrated,

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what is claimed as new and useful and is desired to be secured by Letters Patent is:

A screen for an oil well carrying a plurality of laterally disposed gun barrels each adapted to discharge a bullet from its outer end laterally from said screen and each containing a firing chamber, the inner end of each barrel being sealed whereby the firing of the bullet does not leave an opening for the entry of sand and debris into said screen, a bullet in each barrel arranged for projection outwardly ahead of said firing chamber, a firing filament in each of said firing chambers, means for connecting said screen to a string of tubing, and an electrical contact carried by the upper end of said screen, electrically connected to each of said firing filaments and

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arranged for contact with an electrical terminal lowered through said tubing.

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