June 23, 1964 G. H. BRUCE ETAL 3,138,206

PERFORATING IN WELLS

Filed Sept. 5, 1961

FIG. 2.

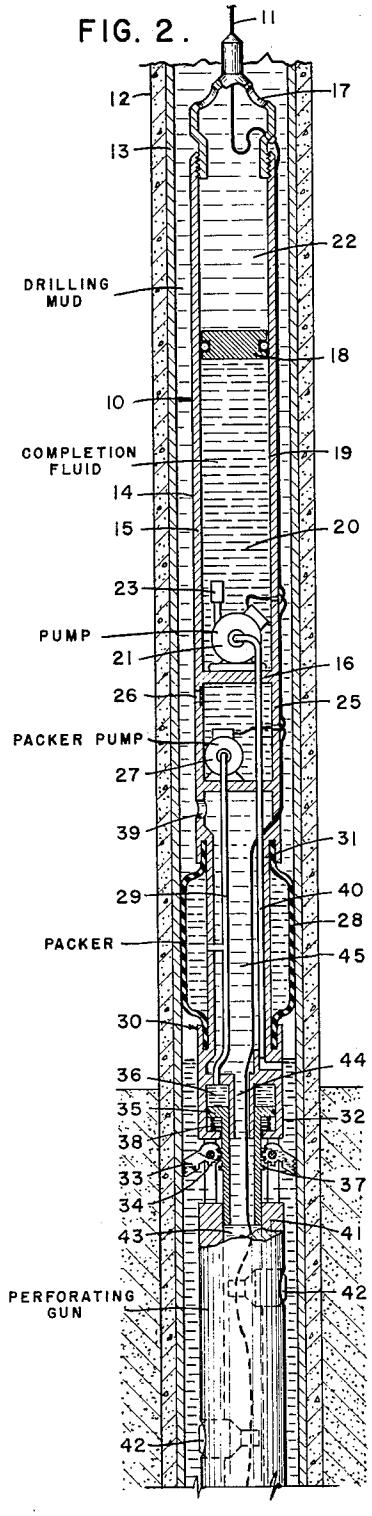
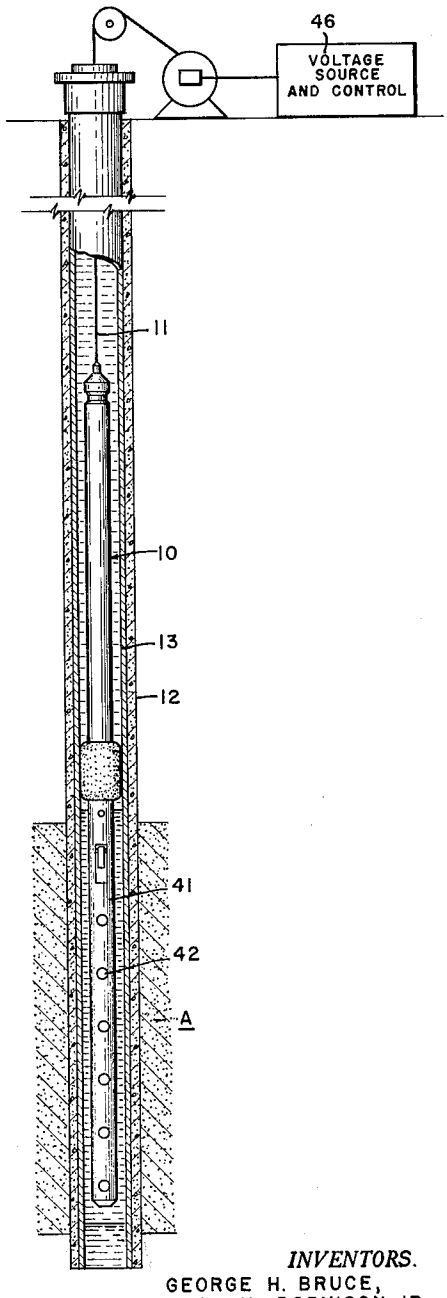


FIG. 1.



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United States Patent Office 3,138,206 Patented June 23, 1964

3,138,206

PERFORATING IN WELLS

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Filed Sept. 5, 1961, Ser. No. 135,961
6 Claims. (Cl. 166—55.1)

The present invention concerns method and apparatus for producing clean perforations in wells and particularly perforating from within a "casing" pipe string not containing an inner "tubing" pipe string.

To complete wells so that clean, uncontaminated perforations are produced the perforations cannot be made in contact with drilling mud. When tubing is in place within the casing pipe, drilling mud initially blanketing the area to be perforated is easily displaced with a slug of completion fluid, although it may be difficult to maintain the slug in place. However, when no tubing is within the casing pipe, as would be the case prior to running tubing or without running tubing (the increasingly popular "tubingless" completion), there is no available technique or apparatus for use therewith for blanketing an area in which perforations are to be made with completion fluid. The stringent and conflicting requirements for completion fluids complicate and make difficult formulation of such a technique and the design of such apparatus, for the completion fluid must be free of solids or contain solids that are easily removed by chemical treatment and it must have low fluid loss characteristics. To maintain the well under control, the completion fluid must have a controllable density as high as 2 to 2.5 lbs./cu. ft. for high pressure wells, and it must be available in large volumes for if tubing has not been set in the well, the entire well must be filled with completion fluid. This latter requirement necessitates use of an inexpensive completion fluid in order to keep the procedure economical.

Thus, a primary object of the present invention is elimination of the need for large volumes of perforating fluid while at the same time maintaining all of the advantages achieved in producing clean perforations using the large volumes.

Briefly, the apparatus of the invention comprises a perforating tool; a packer arranged above the perforating tool; a reservoir containing perforating fluid arranged above the packer; means for expanding the packer and displacing drilling mud initially surrounding the perforating tool with the perforating fluid; and a bypass for transferring the displaced drilling mud from below to above the packer. The apparatus is lowered in a cased well containing drilling mud, the packer is expanded, and perforating fluid is pumped from above the packer to below it to displace drilling mud surrounding the perforating tool to above the packer. Once clean perforating fluid surrounds the perforating tool, the perforator is actuated to perforate the casing. If necessary, an anchoring device may be mounted on the tool to prevent downward movement of it.

The above object and other objects and advantages of the invention will be apparent from a more detailed description thereof when taken in the drawings wherein:

FIG. 1 is a schematic view including a cross section of the earth's subsurface showing a borehole having the apparatus of the invention suspended therein and also showing the surface power source and controls; and

FIG. 2 is a schematic view of a cross section of the earth's subsurface showing in greater detail the apparatus of the invention arranged in the borehole.

Referring to the drawings in greater detail for a more complete description of the invention, in FIG. 1 is shown

a well perforating tool 10 suspended on an electrically conductive cable 11 in a well bore 12 in which well pipe string 13 has been run and set. As seen more clearly in FIG. 2, well tool 10 is divided into various sections. An upper perforating liquid reservoir section 14 includes a tubular housing 15 closed at the lower end by plate member 16 and open at the upper end via openings 17. A sliding seal piston 18 is arranged in housing 15 and forms a chamber or reservoir 19 in which is arranged initially a completion fluid 20. A pump 21 is mounted in the lower end of chamber 19. The space 22 above piston 18 fills with drilling mud through openings 17 as piston 18 moves downwardly as the completion fluid is pumped from chamber 19 by means of pump 21. If desired, a suitable switch 23 may be arranged on pump 21 to automatically stop pump 21 upon contact of piston 18 therewith, or the operation of pump 21 may be controlled at the earth's surface.

Housing 15 is provided with a second packer inflate fluid reservoir or chamber 25 positioned below reservoir 19 and open to well fluids through a screened port 26.

A packer inflate pump 27 is arranged in chamber 25 and when in operation pumps well fluids from chamber 25 into the interior of an expansible sleeve packer element 28 through a conduit 29. The packer section 30 also includes a packer mandrel 31 on which packer element 28 is mounted.

An anchoring section 32 may be included if desired to insure that no downward movement of the tool occurs when very heavy drilling mud is displaced by the completion fluid. Without an anchoring device the tool may slip downwardly under such circumstances even though supported on a wire line. To anchor the tool, pivotal dogs 33 having outer serrated ends and inner gear teeth 34 may be moved outwardly by downward movement of an annular piston 35 slidable in a cylinder 36 and having gear teeth 37 engaging with teeth 34 of dogs 33. The dogs are retained normally in retracted position by means of spring 38 acting on the underside of piston 35. Fluid pressure for moving piston 35 downwardly against the bias of spring 38 is supplied to chamber 36 through conduit 29 from pump 27 and chamber 25.

A port 39 in housing 15 fluidly communicates the interior and exterior thereof at a point above expansible packer element 28. A conduit 40 leading from pump 21 terminates on the exterior of housing 15 at a point just below expansible packer element 28.

A gun perforating section 41 having a number of vertically spaced-apart gun elements 42 and being formed with a hollow interior to provide a fluid passageway 43 from the bottom to the top of the section is arranged below anchoring section 32. Passageway 43 is part of a continous isolated passageway which extends from the lower end of perforator section 41 to port 39 and includes a passageway 44 through anchoring section 32 and a passageway 45 through packer mandrel 31. Thus, when packer element 28 is inflated until it engages and forms a seal with the wall of pipe 13 the annulus surrounding tool 10 above and below packer element 28 is fluidly connected through passageways 43–45 and port 39.

Cable 11 supplies electrical power to pumps 21 and 27 and to gun elements 42 for operating the pumps and actuating the gun elements from the earth's surface. Box 46 (see FIG. 1) represents the power source and control units.

In operation, tool 10 is lowered in casing 13 on cable 11 until gun section 41 is located adjacent a zone or interval A it is desired to perforate. Once the tool is properly positioned, pump 27 is actuated by means of surface controls 46 to pump well fluids from reservoir 25 through conduit 29 into the interior of packer element 28 and into cylinder 36. If desired, instead of using well

fluids, opening 26 could be eliminated and a closed reservoir 25 could be filled with a fluid of any desired composition. Pumping of fluids from reservoir 25 through conduit 29 moves piston 35 downwardly against the bias of spring 38, which movement causes dogs 33 to pivot outwardly until the serrated ends engage the wall of pipe 13 to anchor tool 10. Also, fluid from reservoir 25 enters packer element 28 and expands it until the space between well tool 10 and the wall of pipe 13 is sealed off. Then pump 21 is actuated by the surface controls 45 to pump completion fluid from chamber 19 through conduit 40 to the space surrounding tool 10 below packer element 28 to displace drilling mud to above packer 28 through passageways 43–45 and port 39. As the completion fluid displaces the drilling mud, sliding seal piston 18 moves downwardly, and drilling mud occupies the space 22 initially occupied by the completion fluid in housing 15. Once substantially all of the completion fluid in reservoir 19 has been pumped to below packer 28, piston 18 engages switch 23 and automatically shuts off motor 21. However, if desired, pump 21 can be turned on and off through surface controls 46. After completion fluid 20 has displaced drilling mud surrounding perforator section 41, gun elements 42 may be actuated through surface controls 46 to perforate pipe 13 and interval A.

Following perforation of interval A tool 10 is removed from well pipe 13 by pulling on cable 11. Prior to pulling on the cable, packer element 28 is deflated by reversing pump 27 to relieve the pressure on piston 35, pressure in cylinder 36, and pressure within packer element 28. This permits dogs 33 to retract under the bias of spring 38, and packer element 28 to deflate so that the tool may be removed from the borehole easily.

The completion fluid which enters the perforations will remain in the perforations even if drilling mud again occupies the volume adjacent the perforations. Thus, no difficulty will be encountered in producing the well. The pressure required to initiate flow will be negligible and all perforations will produce.

The completion fluid may be water with starch or CMC to reduce filtration or oil containing a soluble fluid loss additive or other completion fluids such as those disclosed in U.S. Patent 2,898,294 entitled "Well Completion Fluids," filled December 24, 1956 by G. G. Priest et al., and U.S. Patent 2,894,584 entitled "Well Completion," filed December 24, 1956 by G. G. Priest et al.

Having fully described the apparatus, method of operation, and objects of the invention, we claim:

1. Apparatus for producing clean perforations in a well comprising:
- a housing adapted to be lowered in a well pipe and having a first chamber initially containing completion fluid and a second chamber containing another fluid;
- an expansible packer arranged on said housing adapted to close off the annulus between said housing and said well pipe when expanded;
- an open-ended perforator tool connected to the lower end of said housing and having a flow path through the interior and between the ends thereof;
- said housing having a flow path through the interior thereof extending from above said packer to said perforator flow path and a first opening above said packer fluidly communicating said housing flow path and the interior of said pipe;

- said housing having a second opening fluidly communicating said first chamber and the interior of said well pipe to allow drilling fluid to flow into said first chamber;
- a floating piston arranged in said first chamber separating said completion fluid and drilling fluid;
- a first pump arranged in said first chamber for pumping completion fluid;
- a first conduit connected to said first pump and extending to below said packer adapted to conduct completion fluid pumped by said first pump to the exterior of said housing below said packer to displace drilling fluid through said flow paths and said housing first opening;
- a second pump arranged in said second chamber for pumping said other fluid;
- a second conduit connected to said second pump and extending to the interior of said packer for conducting said other fluid pumped from said second chamber to expand said packer; and
- an electrical conductor cable connected to said housing for suspending said housing in said well pipe and for transmitting electrical energy to actuate said perforator and operate both of said pumps.

2. Apparatus as recited in claim 1 including said housing having a third opening fluidly communicating said second chamber and the interior of said well pipe to allow drilling fluid to flow into said second chamber.

3. Apparatus as recited in claim 1 including means arranged on said housing for releasably anchoring said housing in said well pipe.

4. Apparatus as recited in claim 3 wherein said anchoring means includes fluid responsive means adapted to be actuated by said other fluid contained in said second chamber.

5. Apparatus for producing clean perforations in a well comprising:
- a housing containing a reservoir of completion fluid adapted to be arranged in a well pipe;
- a fluid expansible packer surrounding said housing adapted to close off the annulus between said housing and said well pipe when expanded;
- a perforator mounted on the lower end of said housing;
- means for conducting completion fluid from said reservoir to below said packer;
- means for conducting drilling fluid through said perforator and said packer to above said packer;
- means for pumping completion fluid through said completion fluid conductor means;
- means for pumping packer inflate fluid into said packer to expand said packer; and
- means for actuating said pumping means and said perforator.

6. Apparatus as recited in claim 5 including means arranged on said housing for releasably anchoring said housing in said well pipe.

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