Oct. 20, 1964 M. P. LEBOURG 3,153,449

METHOD AND APPARATUS FOR COMPLETING A WELL

Filed March 30, 1960

Fig. 1

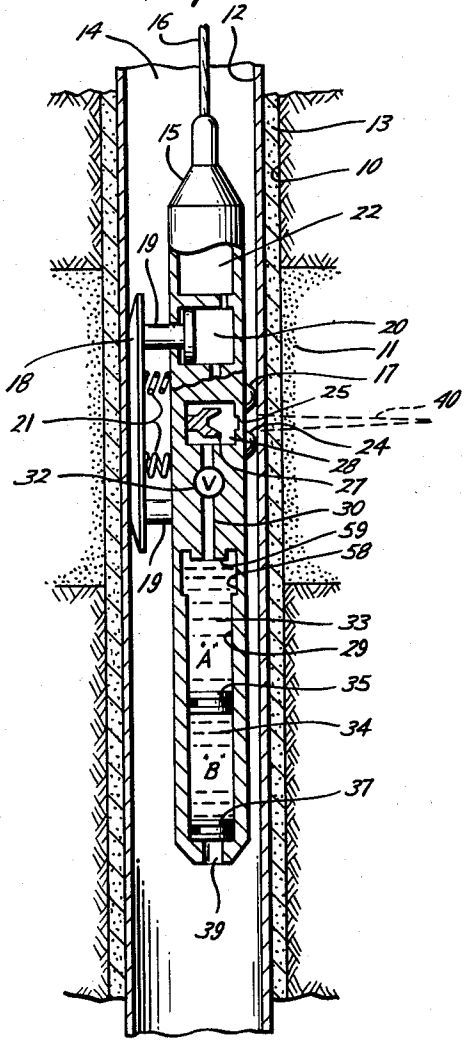


Fig. 2

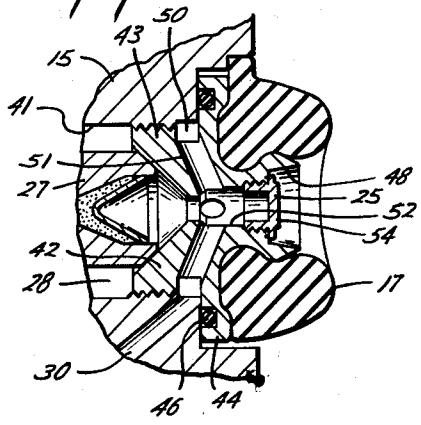
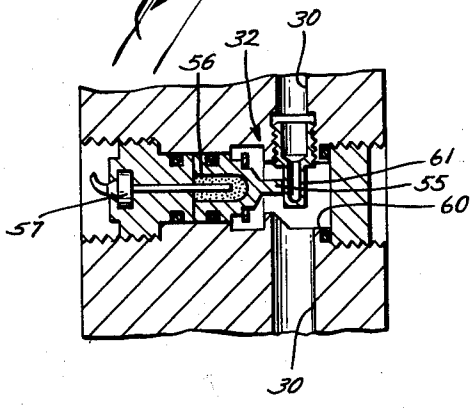


Fig. 3



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METHOD AND APPARATUS FOR COMPLETING A WELL

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This invention relates to perforations in oil wells and, more particularly, to a perforating apparatus and a method for selectively perforating and treating a formation.

With new and improved investigating techniques in subsurface exploration for oil in the oil industry, it has become possible to identify the boundaries of productive formations with considerable accuracy so that, for example, a productive formation with a thickness of, say, 6" may be located and opened for production. Heretofore, in completion techniques, emphasis has been placed on the need for a great number of perforations in the formations; however, it has now been determined that, in certain instances, a lesser number of perforations is sufficient for economical production. In fact, in many instances, only a single perforation is required to produce the formation. Of course, in extremely thin intervals of formation, there is only space enough for one perforation. A common problem found in many of the oil and gas formations opened by perforations is that the formations are so unconsolidated that, in production, the flowing fluids produce sand; that is, particles of sand from the formations are produced with the fluid. In the well bore, the sand may settle out so as to eventually fill up the well bore or may be carried to the surface with the fluid where its effect on production equipment is quite deleterious.

To solve this problem, treating fluids which consolidate the formation sand have been developed. A typical example of a treating fluid is a thermosetting sand consolidation plastic which contains formalin, a phenol-cresol mixture and stannous chloride. Heretofore, it has been necessary to remove the mud from the perforation zone and substitute another fluid such as water which would not plug the perforations thereby to prevent admission of the treating fluid to the formations. It is also quite critical to maintain the treating agent homogeneous by avoiding mixing with water or oil in the hole. Other common fluid treating operations are acidizing or treating the formations to provide a preferential oil or water flow. All of these operations are relatively complex, time consuming and expensive since there is no convenient way to introduce these fluids locally to the perforations.

It is accordingly an object of the present invention to provide new and improved perforating methods and apparatus for penetration of earth formations and the introduction of a treating fluid locally to the formation which mitigates the above-mentioned drawbacks.

A further object of the present invention is to provide new and improved methods and apparatus for treating penetrated formations in a simple and economical manner.

The method, in accordance with the present invention, involves lowering a perforating apparatus to the level desired to be perforated. Thereafter, a section of the well bore is isolated from the borehole fluid and the earth formations adjacent the isolated zone are perforated. Finally, the now isolated perforation is subject to the action of one or more treating agents.

Apparatus, in accordance with the present invention, included means for isolating a section of a well bore from bore-hole fluid, means for perforating the isolated section of the well bore and means for introducing one or more treating agents into the isolated perforation.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a cross section of a cased borehole wherein the apparatus by which the present invention is practiced is shown in cross section;

FIG. 2 is a partial cross section of a detail of the apparatus of FIG. 1; and

FIG. 3 is a partial cross section in detail of the apparatus shown in FIG. 1.

Referring now to FIG. 1, a borehole 10 traversing the various earth formations 11 receives a casing 12 which is suitably secured therein by a column of cement 13 between the casing and the borehole. In the casing 12, prior to the production of the well, is a well control fluid 14, such as mud, which is calculated to be at a higher pressure than the pressures expected to result from the opening of the formations to the casing so that the formation fluids are under control at all times.

A well completion tool 15 is adapted to be suspended in the casing by means of a cable 16 and winch (not shown) in a customary manner. A forward, annular sealing pad 17 and a back-off shoe 18 are positioned on opposite sides of the elongated tool body and arranged to move relative to one another between a contracted and extended position. To accomplish the relative movement, the back-off shoe 18 is connected to piston rods and pistons 19 which are received in hydraulic cylinders 20 (only one being shown in the tool body). Tension springs 21 are provided for facilitating the retraction of the back-off shoe 18 from the wall of the casing 12 toward the tool body at the completion of the operation. An exemplary hydraulic actuating system 22 for the cylinders 20 may be of the type illustrated in the Chambers Patent No. 2,674,313.

In the upper end of the tool, other devices such as radioactivity responsive instruments of various types may be employed to obtain logs of the formations so that the tool assembly may log the formation and, while still in the hole, a productive zone may be located and the perforator employed to open the formations.

The sealing pad 17 is secured to the tool body 15 and has a central opening 24. The tool 15 has a thin and frangible wall section 25 aligned with the central opening 24 which normally closes the same. To open the normally closed central opening 24, a conventional shaped charge 27 is disposed in a low pressure chamber 28 in the tool 15 and is adapted, upon detonation, to produce a perforating jet in a well known manner. The low pressure chamber 28 may, for example, be at atmospheric pressure and is connected to the upper end of a treating fluid cylinder 29 via a conduit 30, along which is disposed a normally closed valve 32. Treating fluid cylinder 29 is divided into upper and lower chambers 33, 34, respectively, by a first piston 35, with the first piston 35 and valve 32 defining the upper chamber 33 which contains a first treating fluid "A." A second piston 37 is normally disposed in the lower end of the cylinder 29 and the pistons 35, 37 define the second chamber 34 which contains a second treating fluid "B." The tool, on the other side of the lower piston 37, has an opening 39 to the borehole fluid, so that the hydrostatic pressure of the borehole fluid acts upon the second piston 37 while the tool is in the borehole. Since the valve 32 is closed, both treating agents "A" and "B" are maintained in their respective chambers 33, 34 under pressure. The agents "A" and "B" may,

for example, be a catalytic plastic resin and an activator which are operative in sequential steps to consolidate the formations.

To practice the method of the present invention, the tool is lowered to the level to be perforated. Next, a section of the casing 12, encircled by pad 17, is isolated from the borehole fluid 14; then the formations 11 are penetrated, as shown by the dotted line perforation 40, and the low pressure chamber 28 is connected to the perforation 40 in the formations 11 to flush or receive any mud which might have been entrapped within the isolated section from the formations. Following this, the first and second treating fluids "A" and "B" are sequentially introduced into the isolated section under pressure sufficient to enter the perforation 40 in the formations and to consolidate them. Finally, the seal between pad 17 and the casing 12 is removed and the formation perforation 40 is thereby placed in communication with the borehole fluid 14.

Referring now to FIG. 2 for details of the apparatus, the tool 15 has a threaded bore 41 comprising the low pressure chamber 28 which receives the shaped charge 27. The shaped charge 27 may be secured between a rearward wall (not shown) of the chamber and the rearward portion 42 of a closure member 43. The closure member 43 is threadedly received in the bore 41 and a flange portion 44 is provided to overlap the body of the tool with an O ring 45 received between the flange and body of the tool to suitably seal the closure member 43 relative to the tool. The closure member 43 has a forward, hourglass shaped, tubular projection 48, and the sealing pad 17, which consists of an annular rubber packing element is secured to the forward projection 48. Intermediate of the flange 44 and the rearward portion 42 of the closure member 43 is an annular groove 50 which is connected by lateral ports 51 to a central bore 52. The central bore 52 is arranged to threadedly receive a thin walled, frangible closure piece 54 which has the thin walled section 25. The central bore 52 is also disposed in the closure member 43 so that it aligns with the central axis of the shaped charge 27. Hence, upon detonation of the shaped charge 27, the perforating jet, formed in the well-known manner, passes through the bore 52 shattering the thin walled section 25 of the closure piece 54 and thereafter develops the perforation 40 in the formation 11. The annular groove 50 of a closure member 43 is in fluid communication with the conduit 30 which, of course, leads to the treating fluid cylinder 29.

As shown in FIG. 3, the conduit 30 between the low pressure chamber 28 and treating fluid cylinder 29 is normally closed by a valve 32. A suitable type of valve 32, illustrated in FIG. 3, is the so-called break valve wherein the conduit 30 is separated into upper and lower sections by a transversely disposed bore 60 and one of the conduit sections sealingly receives a hollow, break member 61. The break member 61 is arranged to extend into the transverse bore 60 and be broken to open the upper conduit section to fluid flow. To break open the break member 61, a hammer 55 is slidably mounted in the bore 60 and actuated by an explosive 56, the explosive 56 being detonated by a conventional igniter 57 which is electrically connected (not shown) in a conventional manner to a surface power supply.

Returning to FIG. 1, to permit the use of segregated fluids, the cylinder 29 has an enlarged section 58 at its upper end and a slotted cylindrical projection 59 extends a short distance downwardly into the enlarged section. The length of the enlarged section 58 is made greater than the length of the first piston 35 so that when the piston 35 abuts the cylindrical projection 59 fluid from the second chamber 34 may bypass the first piston 35 passing through the slots in the slotted projection 59 into the conduit 30. Of course, if only one treating fluid is employed, it will readily be appreciated that the apparatus can easily be simplified for this purpose.

Types of treating fluids which may be employed by means of the present invention include: wetting agent fluids for obtaining preferential oil or water flow, radioactive marker fluids or acidizing fluids.

What is claimed is:

1. Perforating apparatus for use in a well bore containing a well fluid comprising: a tool having an annular elastomer shaped sealing member for isolating an area along the length of the bore from the well fluid; means in said tool for engaging the wall of the well bore to promote the contact of said sealing member with the well bore and the isolation of said area; said tool having a chamber adjacent to said annular sealing member which is normally closed; perforator means in said chamber suitably aligned with a central portion of said sealing member and arranged to develop, upon detonation, a perforation in the earth formations which is in fluid communication with said isolated area and said chamber; said tool having a treating fluid cylinder and a treating fluid for the formations therein and a conduit arranged to connect said chamber and said cylinder; a normally closed valve in said conduit arranged to be opened to couple the treating fluid to the isolated area; and means responsive to hydrostatic pressure of the well fluid in said tool for forcing said treating fluid into the isolated area.

2. Perforating apparatus for use in a well bore containing a well fluid comprising: a tool having an annular elastomer shaped sealing member for isolating an area along the length of the bore from the well fluid; means in said tool for engaging the wall of the well bore to promote the contact of said sealing member with the well bore and the isolation of said area; said tool having a chamber adjacent to said annular sealing member which is normally closed; shaped charge means in said chamber suitably aligned with a central portion of said sealing member and arranged, to develope, upon detonation, a perforating jet to produce a perforation in the earth formations, said perforating jet adapted to open said normally closed chamber and pass through said isolated area; said tool having a treating fluid cylinder a separating piston therein, treating fluids for the formations disposed to each side of said separating piston and a conduit arranged to connect said chamber and said cylinder; a normally closed valve in said conduit arranged to be opened to couple the treating fluid to the isolated area; means to open said valve after said shaped charge means is detonated; and means responsive to hydrostatic pressure of the well fluid in said tool for forcing said treating fluid into the isolated area.

3. Perforating apparatus for use in a well bore containing a well fluid comprising: a tool having an annular elastomer shaped sealing member for isolating an area along the length of the bore from the well fluid; means in said tool for engaging the wall of the well bore to promote the contact of said sealing member with the well bore and the isolation of said area; said tool having a chamber adjacent to said annular sealing member which is normally closed; shaped charge means in said chamber suitably aligned with a central portion of said sealing member and arranged to develop, upon detonation, a perforating jet to produce a perforation in the earth formations, said perforating jet adapted to open said normally closed chamber and pass through said isolated area; said tool having a treating fluid cylinder and a treating fluid for the formations therein and a conduit arranged to connect said chamber and said cylinder; a normally closed valve in said conduit arranged to be opened to couple the treating fluid to the isolated area; means to open said valve after said shaped charge means is detonated; and means in said tool responsive to hydrostatic pressure of the well fluid for forcing said treating fluid into the isolated area including an opening in the tool to the well fluid and a piston in said cylinder disposed intermediate of said treating fluid and opening.

4. A method of treating earth formations traversed by a borehole where the borehole is lined with a casing cemented in place and the casing has a column of well control fluid therein comprising the steps of: packing off an area on a side of the casing from the pressure of the well fluid; developing a perforation through the packed off area extending through the casing and cement into formation material therebeyond; and injecting formation consolidation material under the pressure of the well fluid into such perforation prior to unpacking said area.

5. A method of treating earth formations traversed by a borehole where the borehole is lined with a casing cemented in place and the casing has a column of well control fluid therein comprising the steps of: packing off an area on a side of the casing from the pressure of the well fluid; developing a perforation through the packed off area extending through the casing and cement into formation material therebeyond, and sequentially injecting different formation treating materials into such perforation prior to unpacking said area.

6. A method of treating earth formations traversed by a borehole where the borehole is lined with casing cemented in place and the casing has a column of well control fluid therein comprising the steps of: placing the forward end of a chamber containing a shaped charge adjacent the casing and packing off an area of such casing about the shaped charge chamber from the pressure of the well fluid, firing the shaped charge while maintaining the area packed off to develop a perforation through the packed off area extending through the casing and cement into formation material therebeyond and thereupon receiving in said chamber fluid from such perforation at a pressure substantially less than that of the well fluid, and injecting treating material into such perforation prior to unpacking said area.

7. A method of treating earth formations traversed by a borehole where the borehole is lined with casing cemented in place and the casing has a column of well fluid comprising the steps of: placing the forward end of a chamber containing a shaped charge adjacent the casing and packing off an area of such casing about the shaped charge chamber from the pressure of the well fluid, firing the shaped charge while maintaining the area packed off to develop a perforation through the packed off area extending through the casing and cement into formation material therebeyond and thereupon receiving

in said chamber fluid from such perforation at a pressure substantially less than that of the well fluid, and injecting a consolidation agent into such perforation prior to unpacking said area.

8. A method of treating earth formations traversed by a borehole where the borehole is lined with casing cemented in place and the casing has a column of well control fluid therein comprising the steps of: lowering a completion tool in the well bore to a depth where the earth formations are anticipated to be productive, packing off an area on a side of the casing from the pressure of the well fluid, opening a perforation through such isolated area extending through the casing and cement into formation material therebeyond, injecting treating material into such perforation prior to unpacking said isolated area, and thereafter placing the treated formation in communication with the fluid in the well bore.

9. A method of treating earth formations traversed by a borehole where the borehole is lined with casing cemented in place and the casing has a column of well control fluid therein comprising the steps of: placing the forward end of a chamber containing a shaped charge adjacent the casing and packing off an area of such casing about the shaped charge, firing the shaped charge while maintaining the chamber packed off to develop a perforation through such isolated area extending through the casing and cement into formation material therebeyond and thereupon collecting in said chamber fluid from such perforation at a pressure substantially less than that of adjacent well fluid, injecting treating material into such perforation prior to unpacking said isolated area, and placing the treated formation in communication with the fluid in the well bore.

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