United States Patent [19]

Davis

[11] **3,856,094**

[45] **Dec. 24, 1974**

[54] **APPARATUS FOR UTILIZING COMPATIBLE PERFORATING FLUID IN WELL BORES**

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[73] Assignee: **Dresser Industries, Inc.,** Dallas, Tex.

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[21] Appl. No.: **411,982**

[52] **U.S. Cl.**..... **175/4.52,** 175/4.59, 166/162, 166/297

[51] **Int. Cl.**..... **E21b 43/116**

[58] **Field of Search** 175/4.52, 2, 4.59, 4.6; 166/162, 163, 165, 168, 297

[56] **References Cited**

UNITED STATES PATENTS

3,011,551	12/1961	Young et al.	175/4.52
3,115,932	12/1963	Reynolds	175/4.52
3,138,206	6/1964	Bruce et al.	175/4.52
3,433,302	3/1969	Shore	175/4.52 X
3,463,248	8/1969	Bell	175/4.52

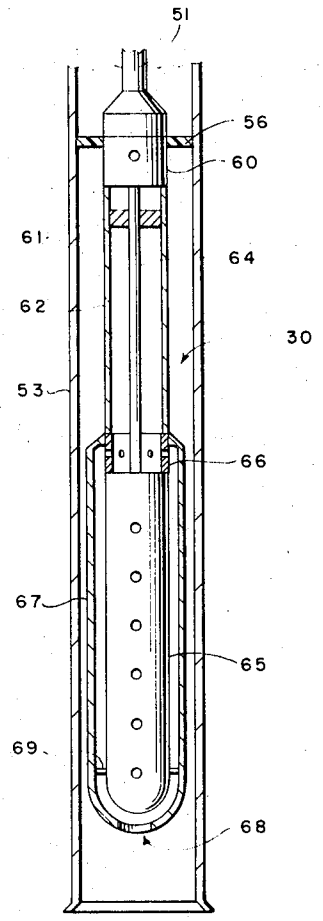
Primary Examiner—David H. Brown

Attorney, Agent, or Firm—William E. Johnson, Jr.

[57] **ABSTRACT**

A well tool apparatus having a perforating section at its lower end has an upper section comprised of a reservoir containing a compatible perforating fluid and a pump for pumping such fluid down through the perforating section and out the lower end of the tool. Means are provided for causing the perforating fluid to displace the well bore fluid in the region along the length of the perforating section, such displaced fluid being recaptured above a floating piston in the reservoir containing the perforating fluid. In an alternative embodiment, a protective shield is utilized around the perforating tool and means are provided for releasing the perforating fluid into the annulus between the shield and the perforating section, the lower end of the shield having a port for releasing the perforating fluid into the annulus between the instrument and the casing to be perforated.

6 Claims, 4 Drawing Figures



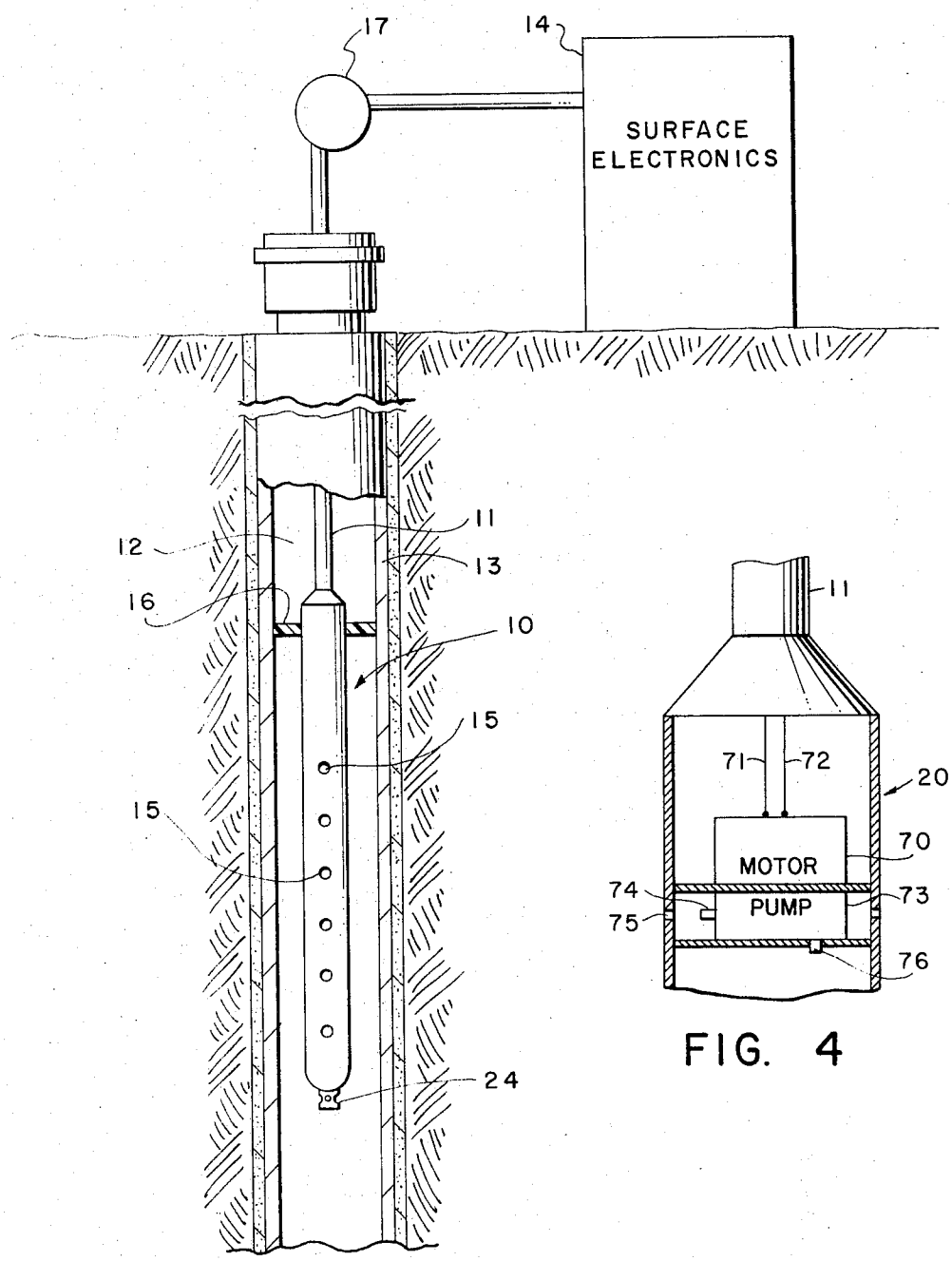

17
14
SURFACE ELECTRONICS
12
11
13
16
10
15
15
24

FIG. 1

11
71
72
20
MOTOR
70
74
PUMP
73
75
76

FIG. 4

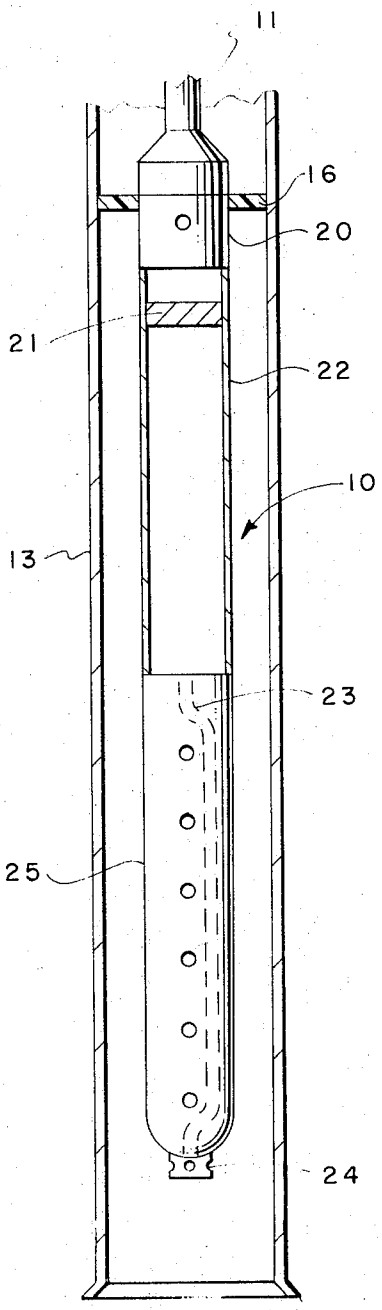


FIG. 2

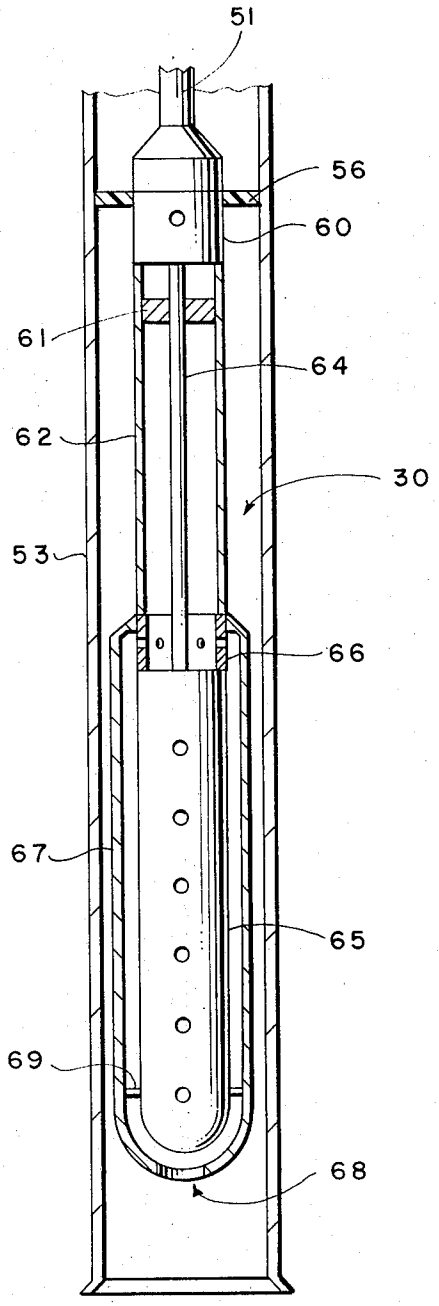


FIG. 3

APPARATUS FOR UTILIZING COMPATIBLE PERFORATING FLUID IN WELL BORES

BACKGROUND OF THE INVENTION

The present invention releates generally to method and apparatus for producing clean perforations in wells and particularly to method and apparatus for displacing well fluids within a cased borehole in the area to be perforated with fluids which are compatible with perforations.

When an oil well casing is perforated in the presence of well fluids containing colloids and other particulate matter for pressure control, the perforation in the oil-bearing formation is often sealed with a filter cake. The prior art has recognized that it is desirable to displace the fluids in the area of the perforation with so-called "completion fluids" in order to produce clean perforations. Typical of such prior art is U.S. Pat. No. 3,138,206 to George H. Bruce et al; U.S. Pat. No. 2,842,205 to Allen et al; and U.S. Pat. No. 2,963,088 to Corley. For example, in the Bruce et al patent, the completion fluid is pumped from a reservoir into the annulus between the perforating section and the casing to be perforated. This device attempts to cause the displaced well fluid to be pumped down to the open lower end of the perforating section and up through the interior of a packer and out into the annulus above the packer. However, such a device as is shown in the Bruce et al reference is quite complex and expensive to fabricate. Furthermore, in the Bruce et al system, the compatible fluid is introduced into the annulus above the perforator and is thus dependent upon the displaced fluid being pumped down the annulus and then back up through the interior of the perforator. Thus, the interior of the perforator has to be modified to provide a tortuous path around the shaped charges within the gun. It should also be appreciated that the Bruce et al apparatus is dependent upon extremely intricate piping to maintain a separation between the well fluids and the compatible perforating fluid.

It is therefore the primary object of the present invention to provide a new and improved method and apparatus for displacing the well bore fluid in the area of the casing to be perforated with a fluid which is compatible with such perforations; and

It is another object of the invention to provide a new and improved method and apparatus for displacing well bore fluid with compatible perforating fluid without necessarily modifying the interior of the perforating gun.

These and other objects of the present invention are accomplished, generally, by a method and apparatus which utilizes a flow passage through the interior of a perforating tool, the upper end of the flow passage being connected to a reservoir containing a compatible perforating fluid and the lower end of the flow passage having a port beneath the perforating tool opening into the annulus exterior to the perforating tool whereby the compatible perforating fluid may be pumped into the annulus at the lower extremity of the perforating gun to displace the well fluids in the area to be perforated. In an alternative embodiment, an external shield is placed around the perforating section having a lower outlet and a top inlet port in fluid communication with the compatible perforating fluid whereby the perforating fluid enters the annulus at the lower end of the perforating gun to displace the well fluids in the area to be perforated.

These and other objects, features and advantages of the present invention will be more readily appreciated from a reading of the following detailed specification and drawing, in which:

FIG. **1** is an elevated schematic view, partly in cross section, illustrating the earth's subsurface having a borehole and having the apparatus of the present invention suspended therein and also showing the surface electronics section which is used in conjunction with the apparatus according to the present invention;

FIG. **2** is an elevated view, partly in cross section, of the apparatus according to the present invention;

FIG. **3** is an elevated view, partly in cross section, of an alternative embodiment of the apparatus according to the present invention; and

FIG. **4** is an expanded elevated view, partly in cross section, of a portion of the apparatus according to the present invention.

Referring now to the drawing in more 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 or casing **13** has been run and set. The conductive cable **11** extends to the earth's surface and in a manner known to those in the art is connected to the surface electronics section **14.** The instrument **10** includes a plurality of shaped charges **15** or some other such well known perforating elements, for example, bullet perforators. The instrument **10** also carries a flexible rubber-like diaphragm member **16** which restricts fluid movement to the area below the diaphragm as will be more readily appreciated from the following description. It should be appreciated that a conventional hoisting mechanism **17** at the earth's surface in conjunction with the conductive cable **11** allows the instrument **10** to traverse the borehole **12** until such time as the perforating elements **15** are in the proper location to perforate the pipe **13.**

Referring now to FIG. **2,** there is illustrated in greater detail the apparatus **10** according to the present invention. The top sub **20** of the instrument **10** contains a DC motor illustrated in FIG. **4,** coupled to a rotary pump through an appropriate gear box. The rotary pump is pressure-balanced by drawing on well fluid for intake at the hydrostatic head existing at the point of operation. A floating piston **21** contained within the fluid reservoir **22** is arranged such that the rotary pump within the top sub **20** transfers well fluid to the top side of the floating piston **21.** The reservoir **22** is filled with a compatible perforating fluid which may be, for example, water with starch or CMC to reduce filtration or oil containing a soluble fluid loss additive or some other such completion fluids such as those disclosed in U.S. Pat. No. 2,898,294 entitled "WELL COMPLETION FLUIDS," or in U.S. Pat. No. 2,894,584 entitled "WELL COMPLETION," each of such patents being issued to G. G. Priest et al. It should be appreciated that the reservoir **22** is preferably sufficiently large to equal or exceed the volume of the annulus area between the perforating section **25** and the casing or pipe **13** along the length of the perforating section. The reservoir **22** is connected by means of a delivery tube **23** to an outlet **24** at the lower extremity of the perforating section **25** of the instrument **10.** Although not illustrated, it should be appreciated that the per-

forating elements 15 are connected in a conventional manner to the conductive cable 11 to enable the activation of such elements.

Referring now to FIG. 4, there is illustrated in greater detail the top sub 20 of the instrument 10. A conventional DC motor 70, having electrical conductors 71 and 72 carried by the cable 11, is connected through an appropriate gear box or other means to a rotary pump 73. The pump 73 has an inlet 74 in fluid communication with the port 75 and also has an outlet 76 in fluid communication with the fluid in the reservoir 22 above the piston 21 illustrated in FIG. 2.

In the operation of the apparatus according to FIG. 2, the pump within the upper sub 20 is activated by a DC voltage applied from the earth's surface along the conductive cable 11 to cause the piston 21 to move down within the reservoir 22 and force the compatible perforating fluid from the reservoir 22 through the tube 23 and out through the outlet 24 into the annulus at the lower end of the perforating section 25 and then upward along the exterior of the perforating section 25 in the annulus between the instrument 10 and the casing 13. The outlet 24 includes a plurality of holes equally spaced to ensure that the incompatible well fluid is swept cleanly from the annulus. As the incompatible well fluid is swept upwardly, it enters the reservoir 22 above the floating piston 21 and is kept from going further up the borehole by the diaphragm 16.

It should be appreciated from the foregoing description of the apparatus of FIG. 2 and the operation thereof, that such an instrument offers vast superiority over the systems which have been built in accordance with the prior art. By causing the compatible fluid to be pumped into the annulus at the bottom of the perforating section, there is no concern with such intricate internal piping as is required with the prior art wherein it is necessary to maintain the compatible fluids separate from the incompatible well fluids. The simple operation of the apparatus according to FIG. 2 allows the compatible fluid to be pumped out of the bottom of the apparatus and the incompatible well fluids to be displaced from around the perforating section 25 and merely be added to the reservoir above the floating piston 21.

Referring now to FIG. 3, there is illustrated an alternative embodiment of the present invention wherein an instrument 30 is adapted to traverse the earth borehole by means of the electrical conductor 51 in a manner as described with respect to the apparatus of FIG. 2. The apparatus 30 also includes a rubber diaphragm number 56 to restrict fluid movement to the area below the diaphragm. The upper sub 60 of the apparatus 30 includes a DC motor coupled to a rotary pump through an appropriate gear box, for example, as is illustrated in FIG. 4. A concentric tube 64 contains the necessary firing circuit for firing the perforators, for example, shaped charges contained within the perforating section 65. As with the embodiment illustrated in FIG. 2, the floating piston 61 is adapted to move within the reservoir 62 and to force the compatible perforating fluid in the reservoir 62 beneath the floating piston 61 into the annulus in the area beneath the apparatus 30. The lower end of the reservoir 62 is closed by the sub 66. The sub diverts the compatible fluid from the reservoir 62 through equally-spaced distribution ports to completely fill the annulus between the perforating section 65 and an encircling shield member 67. The shield member 67 completely surrounds the perforating section 65 and has a lower outlet 68 through which the compatible perforating fluid can enter the annulus at the lower end of the instrument 62 and thus be pumped through the annulus between the shield 67 and the casing 53. The spacers 69 help to maintain the concentricity of the shield 67 with respect to the perforator section 65. The port 68 at the lower end of the shield 67 distributes the compatible fluid throughout the annulus between the shield 67 and the casing 53. The reservoir 62 contains an adequate amount of compatible perforating fluid to cover the length of the perforator section 65.

In the operation of the apparatus according to FIG. 3, the rotary pump within the upper sub 60 is activated from the earth's surface by a voltage applied over the conductive cable 51. The compatible well fluid in the reservoir 62 beneath the floating piston 61 is pumped through the plurality of ports in the lower sub 66 and thus into the annulus between the shield 67 and the perforator section 65. The continued pumping action causes the compatible fluid to be forced down through the lower port 68 and thus into the annulus between the shield 67 and the casing 53 and back up to the portion of the reservoir 62 above the floating piston 61. It should thus be appreciated that there has been described with respect to the embodiment of FIG. 3 an apparatus which enables compatible perforating fluid to be released at the bottom of the perforating tool and which allows compatible perforating fluid to be between the perforating apparatus and the casing to be perforated without resort to internal piping within the perforating gun and which thus allows conventional perforating guns to be used. As soon as the compatible perforating fluid has displaced the incompatible well bore fluid, the perforator elements are activated by the firing circuit within the concentric tube 64 from the earth's surface and the perforating section, for example, having a plurality of shaped charges, perforates through the expendable shield 67, the casing 53 and on into the earth formations.

Thus there have been described and illustrated herein the preferred embodiments of the present invention which provide new and improved method and apparatus for providing compatible perforating fluids between well perforators and the casing to be perforated. It should be appreciated, however, that those skilled in the art will be able to modify these embodiments but that such modifications will fall within the scope of the present invention. For example, instead of having a single reservoir divided by a floating piston, first and second reservoirs can be used, the first for collecting the displaced well bore fluid and the second for transporting the compatible fluid.

The embodiments of the invention is which an exclusive property or privilege is claimed are defined as follows:

1. An apparatus for perforating casing in an earth borehole, comprising:
- an elongated instrument adapted to traverse said borehole;
- a reservoir within said instrument;
- a piston within said reservoir dividing said reservoir into an upper section and a lower section, said upper section having at least one intake port for receiving borehole fluids;
- a perforating section connected to the lower end of said instrument having a plurality of perforating el-

ements therein, said perforating section having a fluid channel along its length at least to the lower extremity of said perforating elements, said fluid channel being in communication with the lower section of said reservoir and having at least one outlet port for releasing fluid from said lower section of said reservoir into the annulus between said lower perforating elements and said casing; and

means for activating said piston.

2. An apparatus for perforating casing in an earth borehole, comprising:

an elongated instrument adapted to traverse said borehole;

a reservoir within said instrument;

a piston within said reservoir dividing said reservoir into an upper section and a lower section, said upper section having at least one intake port for receiving borehole fluids, and said lower section having at least one outlet port for releasing any fluid in said lower section;

a cylindrical perforating section connected to the lower end of said instrument having a plurality of perforating elements therein;

a cylindrical, expendable shield encircling said perforating section to form an annulus between said shield and said perforating section, said lower section outlet port being in communication with said formed annulus, said shield having at least one outlet port at a location at least to the lower extremity of said perforating elements for releasing fluid from said formed annulus into the annulus between said shield and said casing; and

means for activating said piston.

3. An apparatus for perforating casing in an earth borehole, comprising:

an elongated instrument adapted to traverse said borehole;

a reservoir within said instrument;

a piston within said reservoir dividing said reservoir into an upper section and a lower section, said upper section having at least one intake port for receiving borehole fluids;

a perforating section connected to the lower end of said instrument having a plurality of perforating elements therein; and

means for releasing at least a portion of any fluid in said lower section of said reservoir into the borehole at a point at least to the lower extremity of said perforating elements and to pump any borehole fluid displaced by said lower section fluid into said upper section of said reservoir.

4. The apparatus according to claim **3** wherein said lower section of said reservoir contains a compatible perforating fluid.

5. The apparatus according to claim **4** including in addition thereto means carried by said instrument for preventing any substantial flow of borehole fluid up past the upper section of said reservoir.

6. An apparatus for perforating casing in an earth borehole, comprising:

an elongated instrument adapted to traverse said borehole;

first and second fluid reservoirs within said instrument, said first reservoir having at least an inlet port for receiving borehole fluids, and said second reservoir having at least one outlet port for releasing any fluid in said second reservoir;

a cylindrical perforating section connected to the lower end of said instrument having a plurality of perforating elements therein;

a cylindrical, expendable shield encircling said perforating section to form an annulus between said shield and said perforating section, said second reservoir outlet port being in communication with said formed annulus, said shield having at least one outlet port at a location at least to the lower extremity of said perforating elements for releasing fluid from said formed annulus into the annulus between said shield and said casing; and

means for causing any fluid in said second reservoir to be released out through said outlet port and to cause displaced well bore fluids to be pumped into said first reservoir.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,856,094

DATED : December 24, 1974

INVENTOR(S) : Mike Davis and Floyd O. Bohn

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the Heading:

After "INVENTOR: Davis, Mike" insert --and Bohn, Floyd O., both of--.

Signed and sealed this 15th day of July 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks