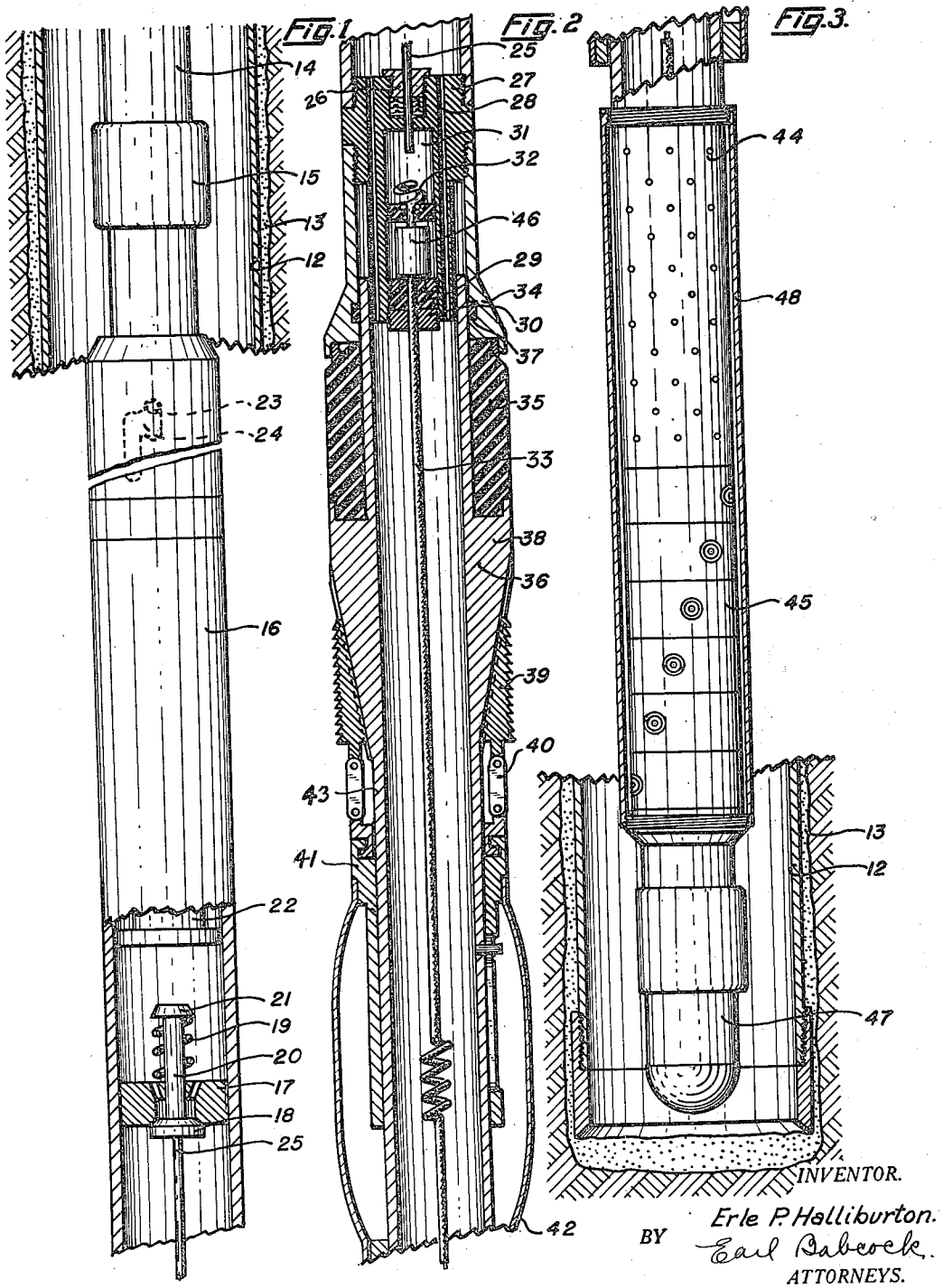
Aug. 15, 1939. E. P. HALLIBURTON 2,169,559

FORMATION TESTER

Filed July 6, 1937 2 Sheets-Sheet 1



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Fig. 4

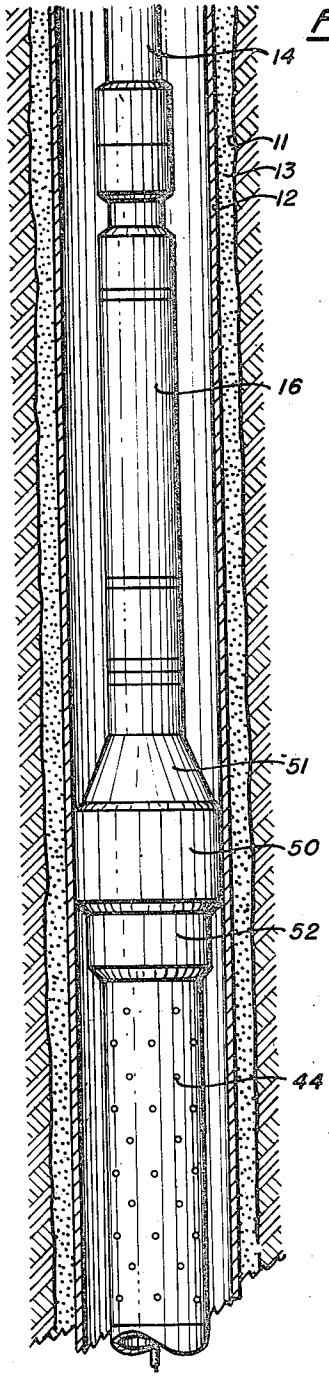
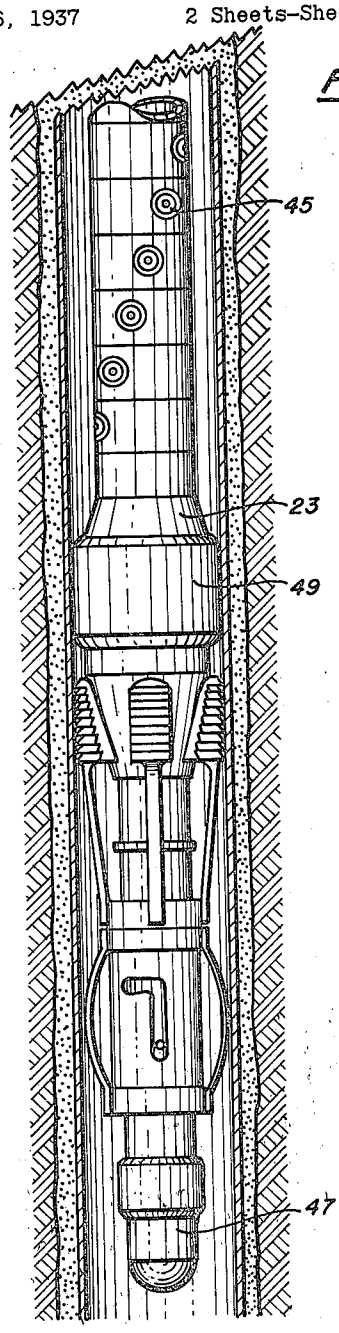


Fig. 5



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2,169,559

FORMATION TESTER

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Application July 6, 1937, Serial No. 151,996

5 Claims. (Cl. 166—1)

This invention relates to apparatus adapted for use in oil wells or the like and more particularly to a formation tester provided with means for perforating casing in the well.

It is common practice in the art of producing oil to cement a casing in place in the well and then perforate the casing, as by means of a gun, at the horizons where it is thought that oil or gas occurs. After the casing is perforated the formations are tested for oil or gas.

In accordance with the present invention, it is proposed to perforate the casing and test the formation practically simultaneously and by means of a single operation. The casing adjacent the zone to be tested is first packed off from the remainder of the well by means of one or more packers lowered into the well on empty drill pipe or tubing. A valve in the drill pipe is then opened, connecting the drill pipe to the packed off portion of the casing. This portion of the casing is then perforated to allow fluid to enter it from the zone tested and flow through the valve into the drill pipe. The valve is then closed, the packer or packers released and the apparatus removed from the well with an uncontaminated sample of the formation fluid in the drill pipe.

By testing in this manner several important advantages over known procedure are obtained.

The sample of the fluid is obtained quicker and at less expense since both the perforating and testing are done in one operation.

The sample of the fluid is obtained practically simultaneously with the perforating so that it is more apt to be uncontaminated and representative of the fluid in the formation being tested.

The hydrostatic pressure of the mud or other fluid in the well is largely relieved before the gun is fired. This is important since it makes it possible to insure against bursting of the casing (as is apt to occur where a gun is fired in an incompressible liquid in the casing) without resorting to special and expensive means.

Accordingly, it is one object of the invention to devise a combination formation tester and casing perforating device which will be capable of practically simultaneously perforating the casing and testing the formation of an oil well.

It is a further object of the invention to devise means adapted to perforate the casing of an oil well and obtain an uncontaminated sample of the fluid in the formation of the well on the outside of the casing by causing the fluid to flow through the perforations so made.

It is a further object of the invention to provide means and methods for obtaining an uncontaminated sample of fluid in the formation of a well by sealing off a portion of the casing adjacent the formation to be tested, perforating this portion of the casing, allowing the fluid to flow through the perforations into drill pipe or other receptacle and then closing a valve so that the sample may be brought to the surface of the well uncontaminated by mud or other fluid in the well.

It is a still further object to provide means and methods for perforating casing filled with incompressible liquid while insuring against bursting of the casing.

Other objects and advantages reside in certain novel features of the arrangement and method, as will be more apparent from the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a vertical fragmentary side view partially in cross-section of the upper portion of a combination tool constructed in accordance with the principles of the invention, the tool being shown as located within an oil well;

Figure 2 is a vertical cross-sectional view of the central portion of the combination tool of Figure 1;

Figure 3 is a view partially in cross-section and partially in side elevation of the lower portion of the combination tool shown in Figures 1 and 2, Figures 1, 2 and 3 showing contiguous parts of the same device;

Figure 4 is a view in side elevation of the upper portion of a modified form of the invention; and

Figure 5 is a view in side elevation of the lower portion of the combination tool of Figure 4, Figures 4 and 5 showing contiguous parts of the same device.

Referring to the drawings in detail, and first to the embodiment of the invention shown in Figures 1, 2 and 3, it will be seen that the apparatus is there shown as located within an oil well 11 which is provided with a casing 12, the casing being held in place by means of a body of cement 13. The apparatus may be lowered into the well by means of tubing or drill pipe 14 to which it is connected by a suitable collar 15.

The upper portion of the apparatus shown in Figure 1 is in general constructed the same as a known type of formation tester known in the trade as a "Halliburton J type tool". The construction of this tool is shown and described in detail in the United States patent to Erle P. Halliburton, Reissue No. 20,688 of April 5, 1938, on original Patent 2,092,062 dated September 7, 1937, for "Apparatus for testing oil wells".

Other types of testing tools may be used, as will readily be appreciated by those skilled in the art.

As shown herein, the formation tester per se includes a cylindrical body 16 carrying at its lower end a valve seat 17 against which the valve 18 is adapted to seat under the influence of a coil spring 19. The upper end of the valve stem 20 is provided with an enlarged portion 21 against which a mandrel 22 is adapted to abut to force the valve 18 open. While the apparatus is being lowered into the well the mandrel is held away from the valve by means of a pin and slot connection shown in dotted lines at 23 and 24. Upon the drill pipe 14 being rotated to the right as viewed from the top, the mandrel 22 which carries the pin 23 will likewise be rotated and brought into the longitudinally extending portion of the J slot 24 so that when the drill pipe is further lowered with respect to the main body 16 of the tool the mandrel will move downwardly and open the valve. The main body 16 of the tool is preferably provided with hydraulic means for maintaining the parts in the proper position and for otherwise aiding in the operation of the tool as is now well known to those skilled in the art, but inasmuch as the present invention is not particularly concerned with this feature, it has not been shown in detail herein.

In accordance with the present invention, the formation testing tool has been modified to the extent that a depending rod 25 is integrally connected to the valve 18. This rod extends downwardly through a stuffing box or gland 26 located in a sub 27 connected onto the main body 16 of the formation tester beneath the valve. The sub is provided with a number of bore holes or passageways 28 throughout its entire length so that fluid may flow from a point beneath the sub upwardly and into the mandrel 22 and the drill pipe 14 when the valve 18 is opened.

Near its lower end the sub 27 is provided with an insulating plug 29 held in place by any suitable means such as the packing nut 30. By this construction a chamber 31 is formed which is effectively sealed from the space above and below the sub, with the rod 25 extending into it at its upper end.

Within the chamber 31 an electrical switch contact 32 is provided, this switch contact preferably being of the type in which a leaf spring is employed. The switch contact is connected to a battery 46 which in turn is connected to an electrical conductor 33 which is heavily insulated. The conductor extends downwardly through the insulating plug 29. If desired, the insulated conductor 33 may be provided with an armor of wire, in accordance with known practices. The conductor 33 is connected to any known gun firing means at its lower end, the firing means being in turn grounded on the apparatus. The gun firing circuit is thus closed when the valve 18 opens and the rod 25 moves downwardly to engage the switch contact 32, to ground this side of the battery.

Connected onto the lower end of the sub 27 is the upper shoe 34 of a packer 35. The upper shoe 34 preferably cooperates with an upwardly extending sleeve on the lower shoe 36 of the packer. Between the sleeve and the shoe 34 suitable packing may be provided, as shown at 37, this being desirable in case the gun is to be sealed from the mud in the well while being lowered into position.

The construction of the packer 35 and the shoes 34 and 36, except for the features already mentioned, may be the same as that of an ordinary hook wall packer. Such a packer may have a wedge body 38 integrally connected with the lower shoe 36 and adapted to control slips 39 mounted by leaf springs 40 carried by a collar 41 which is prevented from rotating in the casing by means of drag springs 42. The assembly just described may be mounted upon a section of pipe 43 which extends downwardly from and is connected to the lower shoe of the packer.

Connected to the lower end of the pipe 43 is a strainer or section of perforated pipe 44 and to the lower end of this a gun 45 for perforating casing is attached.

Guns for perforating casing are now well known to those skilled in the art and for this reason the construction of the gun has not been shown herein in detail. Any suitable gun may be employed, for example, the gun shown in the British patent to Delamare-Maze, No. 287,839, complete accepted February 26, 1929, for "A device for perforating oil well casings in situ". As taught in this British patent, the gun may be provided with a number of barrels containing projectiles which may be shot from the barrels either simultaneously or in succession and which may be fired either electrically or by fuse. As illustrating the preferred form of the invention, the present arrangement has been illustrated as having electrical means for firing at least the first shot and it is for this purpose that the electrical conductor 33 and the switch 25—32 has been provided.

The battery 46 used in supplying the motive power for the firing of the gun is preferably located within the chamber 31 as mentioned above but may be located in any other convenient place, if desired. For purpose of illustration, only one battery 46 has been shown, but obviously as many may be used as are necessary.

Beneath the gun 45 a bull plug or closing member 47 is provided. If desired, a pressure recording apparatus or "pressure bomb" may be located in this part of the assembly in accordance with the usual practice in the formation tester art.

To keep the interior of the assembly dry while it is being lowered into the well, and also to provide an air chamber around the gun as taught in the British patent referred to above, an outer sleeve 48 may be provided around the gun 45 and the strainer 44. In using the sleeve 48 there is additional safety in operation due to the fact that there is less danger of liquid entering the chamber 31 and prematurely grounding the switch contact 32. Also the powder in the gun is better protected and the gun barrels need not be individually sealed against the entrance of mud.

However, an important advantage results when the sleeve 48 is left off of the tool (as shown in Figures 4 and 5) or is used merely to protect the gun without covering the strainer 44. If the sleeve 48 is left off, the pressure of the mud in the well beneath the packer is relieved when the valve 18 is opened and since this occurs just prior to the firing of the gun, it will be apparent that the gun is not being fired into a body of incompressible liquid under high hydrostatic pressure, as would otherwise be the case. The liquid in the packed off portion of the casing has an avenue of escape into the empty drill pipe and is subjected only to atmospheric pressure or substantially that pressure when the gun is fired instead of the pressure of the entire weight of mud in the well. The danger of bursting the casing is thus largely obviated. Another advantage worth

mentioning is that the firing of the gun can be heard at the surface of the well so that the operator can readily tell whether the gun has operated properly.

The sleeve 48, when employed, may be screw threaded onto the section of pipe 43 and onto the lower portion of the gun, as illustrated in Figure 3. Obviously, when the projectiles are fired from the gun they will perforate this sleeve, as well as the casing 12 and the body of cement 13.

The operation of the assembly shown in Figures 1, 2 and 3 is as follows:

Assuming that the apparatus has been lowered to the horizon where the casing is to be perforated and the formation tested, the hook wall packer is set so as to seal the lower portion of the well from the portion above the packer, thus shutting off any mud or other fluid in the well from this lower portion. The drill pipe is now rotated and lowered to cause the mandrel 22 to open the valve 18. This automatically starts the firing of the gun as described above and the projectiles are shot from the gun through the sleeve 48, the casing 12 and into the formation of the well. It is to be noted that the arrangement is such that the firing is automatic upon the opening of the valve. Since the valve 18 must open before the gun is fired, there is always an empty receptacle (the drill pipe) connected to the packed off portion of the casing when the gun goes off.

Any fluid in this formation will flow through the perforations made in the casing, sleeve 48, the strainer 44, the passages 28 in the sub 27, upwardly through the valve 18, the mandrel 26 and into the drill pipe as soon as the gun ceases firing. After a sufficient length of time the drill pipe is raised, lifting the mandrel 22 off of the valve stem 20, thus allowing the valve 18 to close under the influence of the spring 19 and entrapping the sample of fluid from the formation in the drill pipe. Upon further raising of the drill pipe, the packer is released and the entire assembly removed from the well with the entrapped sample. After the packer is released, mud or other fluid in the well will flow through the strainer 44, but this mud cannot enter the drill pipe because the valve 18 is then closed and the sample in the drill pipe will thus remain uncontaminated.

A slightly modified form of the invention is shown in Figures 4 and 5. In this arrangement, the upper portion of the assembly may be the same as shown in connection with the embodiment in Figures 1, 2 and 3, and consist of a formation tester 16 constructed as shown in Figure 1. The difference between this tool and that of Figure 1 resides in the fact that two packers have been employed with the strainer 44 and gun 45 located therebetween. As shown in Figure 5, the lower packer 49 may be identical with the packer 35 shown in Figure 2. It is controlled by means of slips and operating mechanism similar to that described in connection with the packer 35 in Figure 2 and similarly marked. The upper packer 50 has shoes 51 and 52 similar to the shoes 34 and 36 of Figure 2, but this packer is not provided with slips, these being unnecessary since the lower shoe 52 is held against downward movement by being connected structurally to the upper shoe of the packer 49. Thus, one set of slips, namely, those used in connection with the lower packer 49, prevent downward movement of both packers 49 and 50. Upward movement is of course prevented by the weight of the drill pipe. The other parts in the assembly of Figures 4 and 5 are the same as those in Figures 1 to 3 and have been similarly designated.

The operation of the tool of Figures 4 and 5 will be apparent from the description above in connection with the embodiment of Figures 1 to 3, the only difference being that the section of the casing to be perforated is sealed below, as well as above, from the remainder of the well. Upon this portion of the casing being perforated, fluid will flow into the drill pipe 14 through the strainer 44 as described above and when the drill pipe is lifted both packers 49 and 50 will be released.

While only two embodiments of the invention have been disclosed, it is obvious that various changes may be made. The gun may be fired by mechanical, rather than by electrical means, in response to the opening of the valve 18 and the formation tester itself may take a wide variety of forms. Two valves may be employed instead of the one shown at 18, and various devices which improve the operation of the formation tester, such as equalizing valves for use with the packers, and various safety features may of course be employed. In place of a poppet type valve, a stop cock valve can be employed. While the apparatus shown has been designed primarily for testing through casing, it is sometimes desirable to perforate cement or tight sand in an open or uncased hole and the apparatus with suitable modifications is capable of such use. Various and numerous changes may be made without departing from the spirit of the invention or the scope of the annexed claims.

I claim:

1. Apparatus for testing the formation of a cased well comprising, in combination, a testing tool and a casing perforating tool connected together to provide an assembly adapted to be lowered into the well as a unit, said testing tool having a valve therein, and said perforating tool having means associated therewith operable in response to the opening of the valve in the testing tool for operating the perforating tool.

2. Apparatus for testing the formation of a well comprising, in combination, a pipe, a testing tool and a gun for perforating a portion of the wall of the well, the tool and gun being connected together and mounted on said pipe to provide an assembly adapted to be lowered into the well as a unit, said testing tool having a valve and means associated therewith for operating the valve in response to movement of said pipe and said gun having firing means associated with and operated by said valve operating means and adapted upon the opening of said valve to cause the gun to fire.

3. Apparatus for testing the formation of a cased well, comprising, in combination, a pipe, a formation tester connected to the pipe and a casing perforating gun connected to the tester, said tester having a valve and operating means therein adapted to open and close the valve upon manipulation of the pipe, said gun having means associated therewith for firing the same, said firing means being controlled by movement of the valve operating means to open the valve, thereby insuring against firing of the gun with the valve closed.

4. Apparatus for testing a formation behind the casing in a well, comprising, in combination, a pipe, a formation testing tool having a valve, mounted on the pipe, a gun perforator having firing means, also mounted on the pipe and unitary means controlled by movement of the pipe for

actuating both the valve of said testing tool and the firing means of said gun perforator in a single operation.

5. Apparatus for testing a formation behind the casing in a well, comprising, in combination, a pipe, a formation testing tool having a valve, mounted on the pipe, a gun perforator having firing means, also mounted on the pipe and unitary means controlled by movement of the pipe for actuating both the valve of said testing tool and the firing means of said gun perforator in a single operation, said gun firing means including an electric switch and means connected to said valve for closing the switch when the valve opens.

ERLE P. HALLIBURTON.