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M. SCHLUMBERGER
WELL CONDITIONING APPARATUS
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Serial No.
405,024
8 Sheets—Sheet 1

Fig. 1.

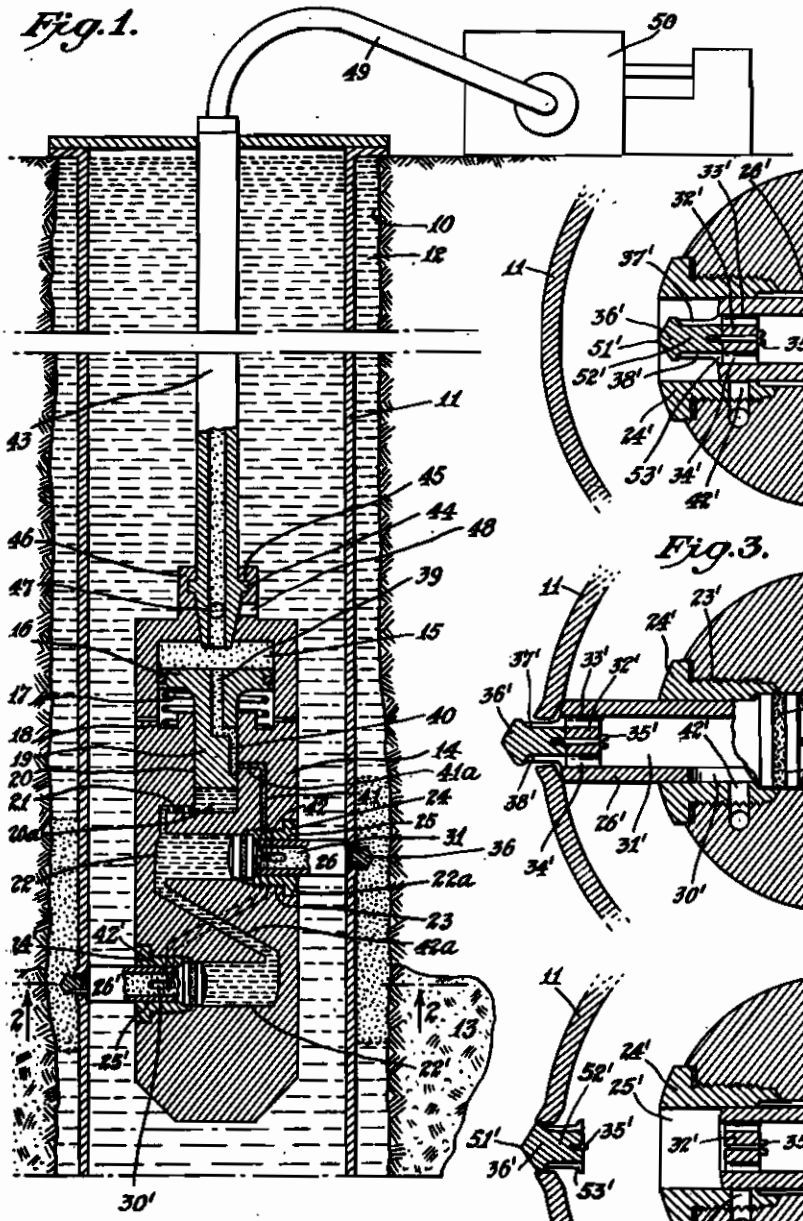
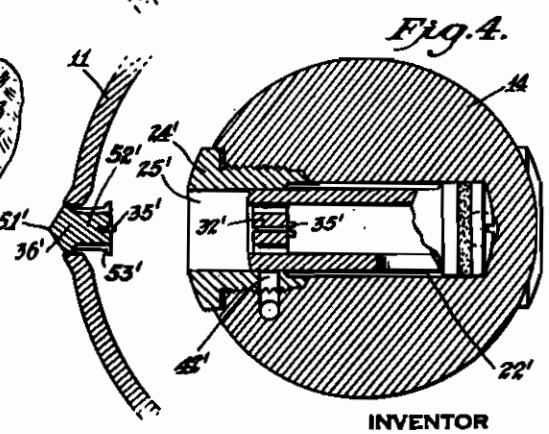


Fig. 2.

Fig. 3.

Fig. 4.



INVENTOR
Marcel Schlumberger
BY
Hoguet, Kearny & Campbell
ATTORNEYS

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Fig. 5.

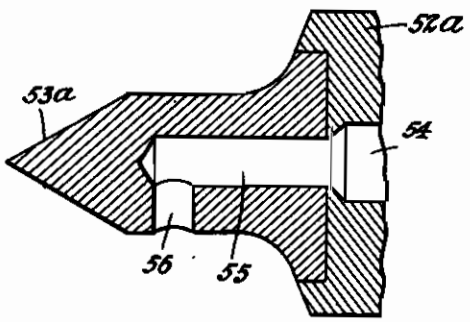


Fig. 6.

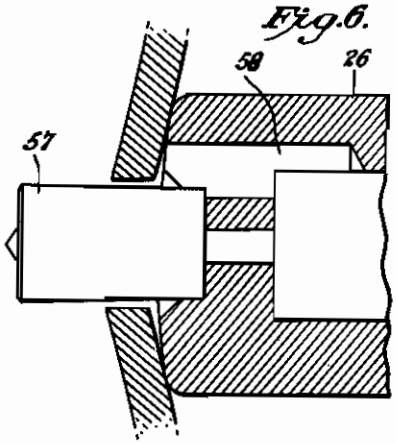


Fig. 7.

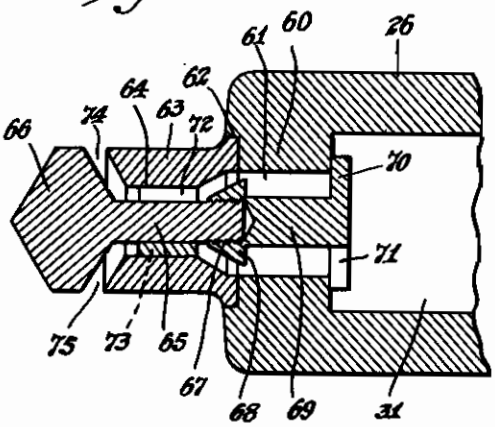
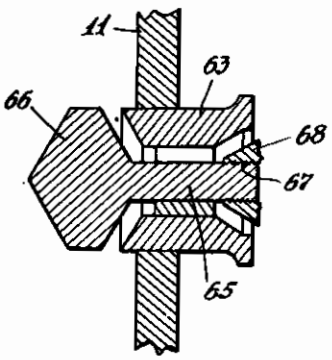


Fig. 7a.



INVENTOR
Marcel Schlumberger
BY
Hoguet, Neary & Campbell
ATTORNEYS

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BY A. P. C.

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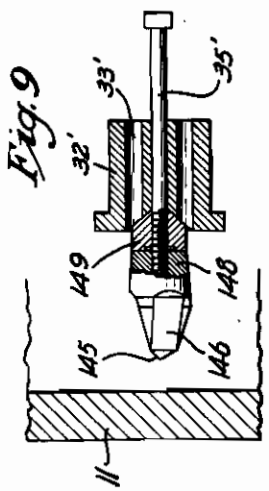

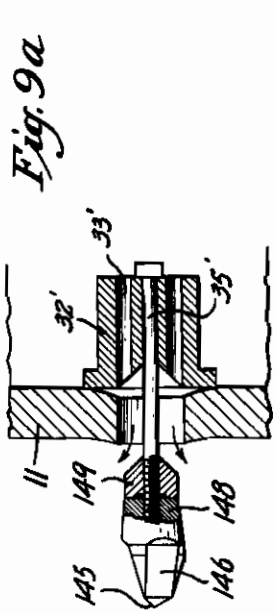

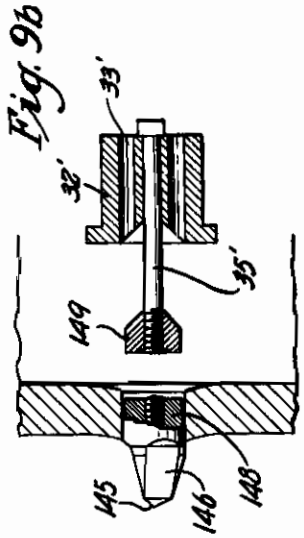

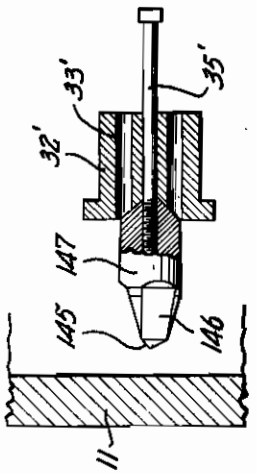

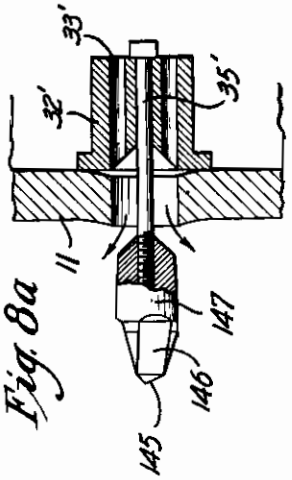

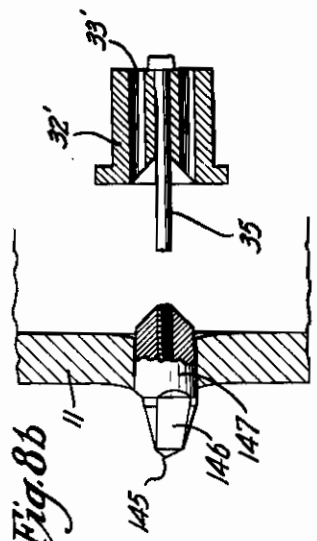

INVENTOR:
Marcel Schlumberger
BY
Hoguet, Keavy & Campbell
ATTORNEYS

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Fig. 10

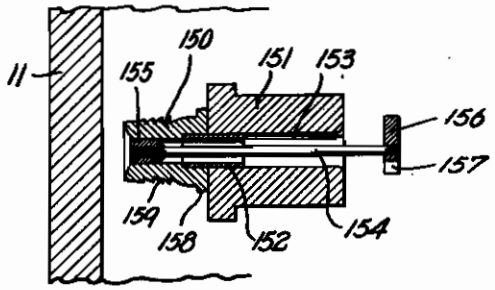


Fig. 10a

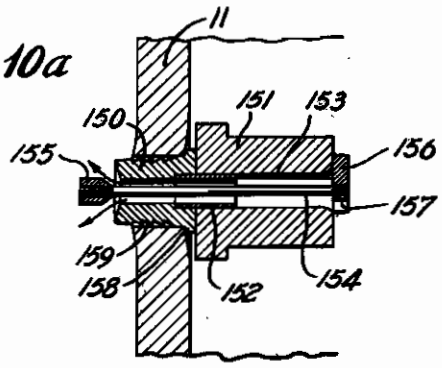
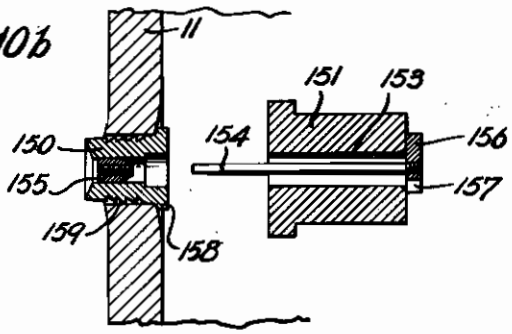


Fig. 10b



INVENTOR:
Marcel Schlumberger
BY
Noguet, Neary & Campbell
ATTORNEYS

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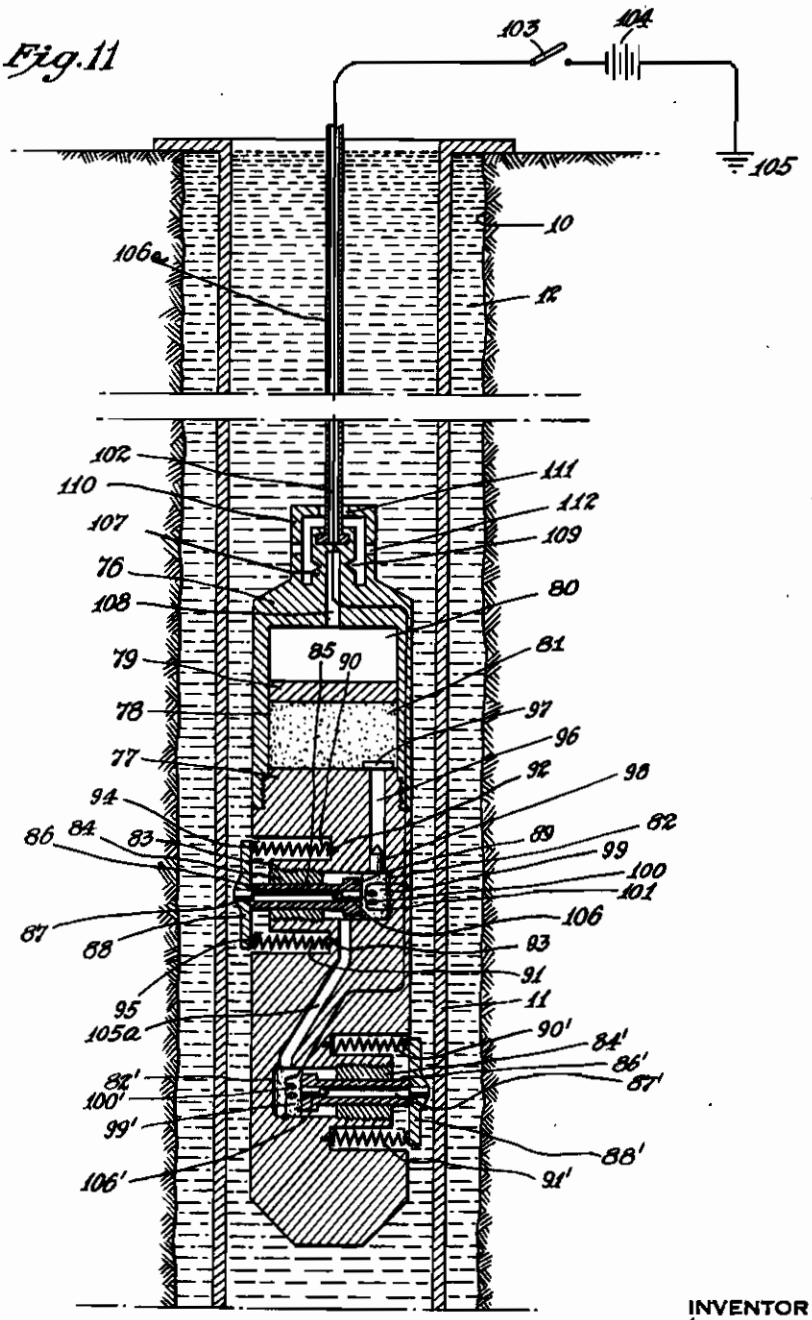
Fig. 11



INVENTOR
Marcel Schlumberger
BY
Hoguet, Neary & Campbell
ATTORNEYS

PUBLISHED
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BY A. P. C.

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Fig. 12

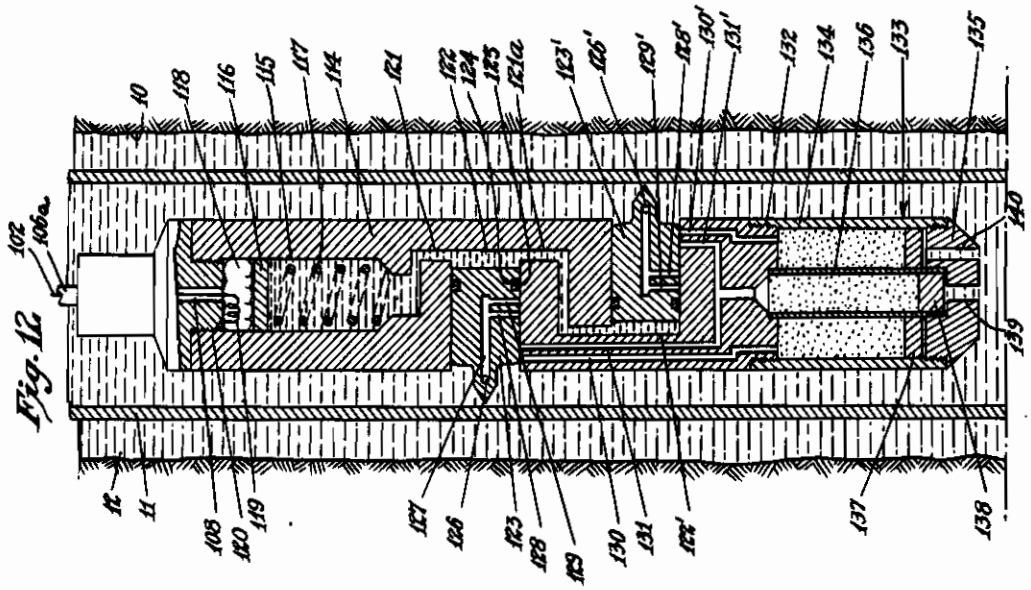
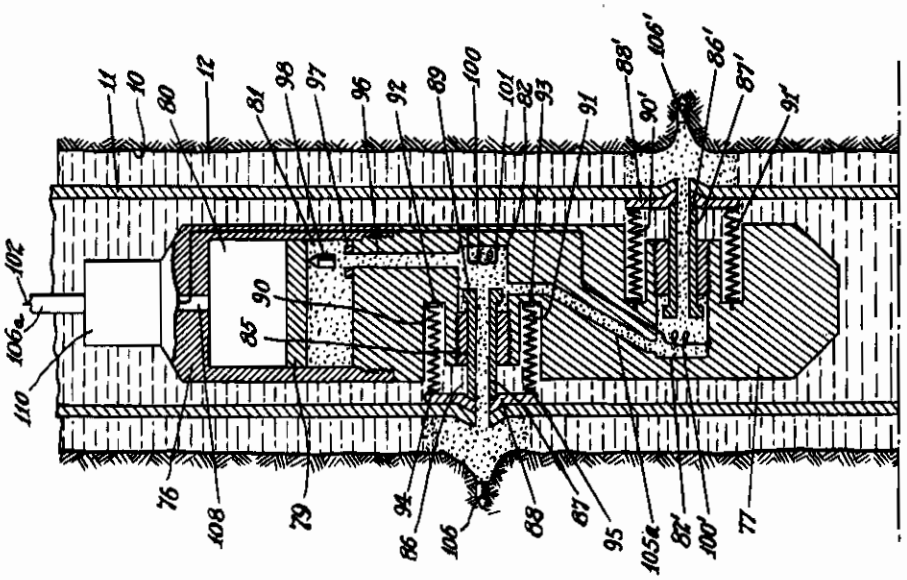


Fig. 11a



INVENTOR
Marcel Schlumberger
BY
Hoguet, Mary & Campbell
ATTORNEYS

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BY A. P. C.

M. SCHLUMBERGER
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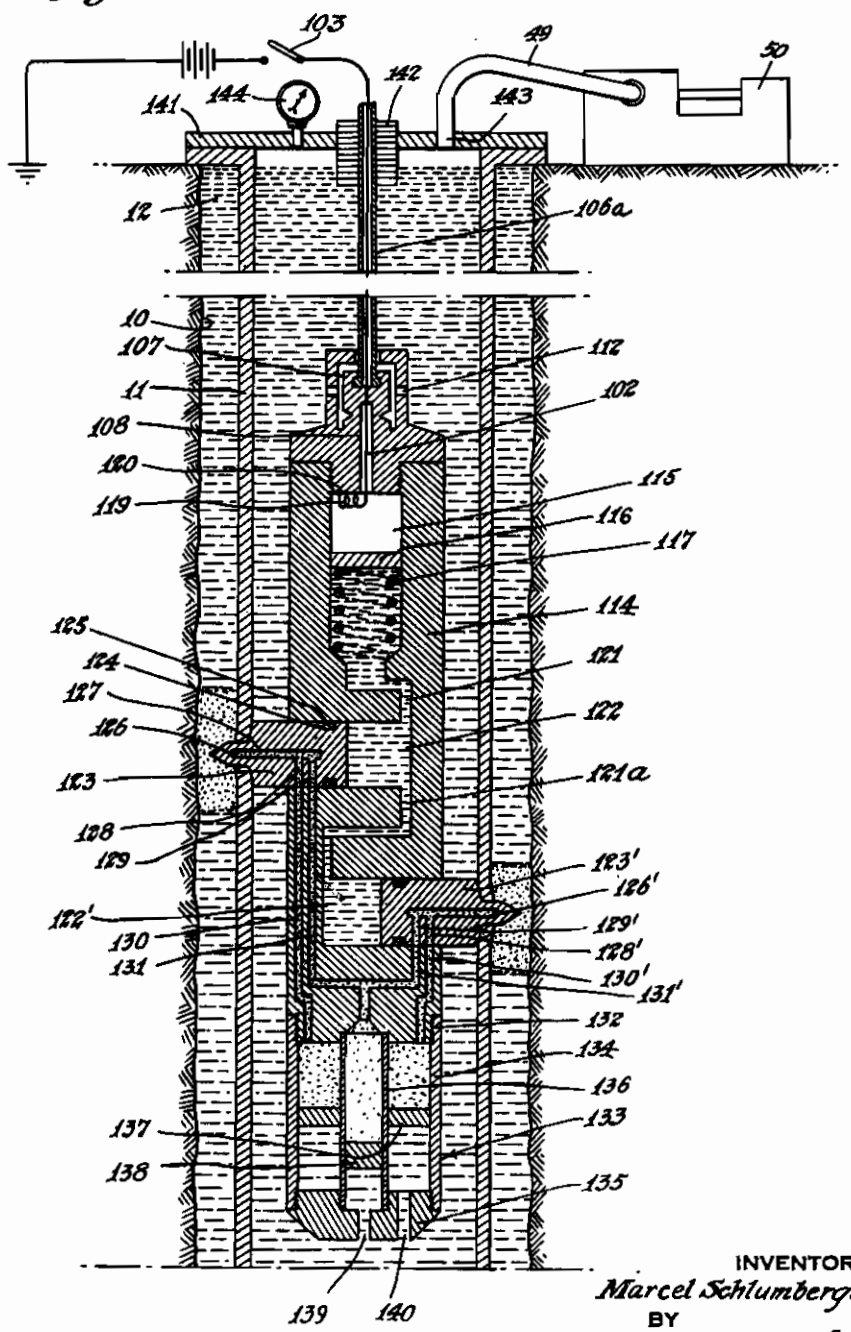
Fig. 12a



INVENTOR
Marcel Schlumberger
BY
Hoguet, Neary & Campbell
ATTORNEYS

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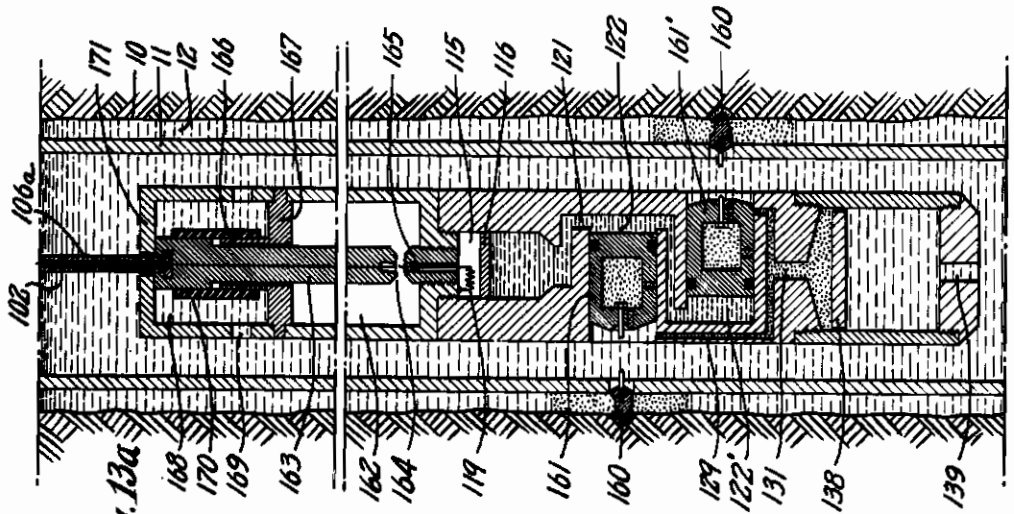

Fig. 13a

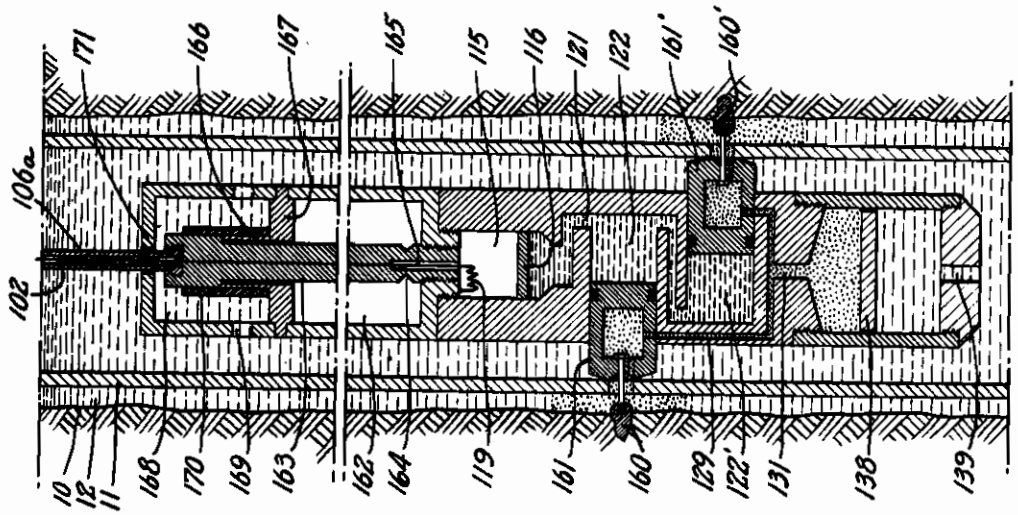

Fig. 13

INVENTOR:
Marcel Schlumberger
BY
Hoguet, Neary & Campbell
ATTORNEYS

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ALIEN PROPERTY CUSTODIAN

WELL CONDITIONING APPARATUS

Marcel Schlumberger, St. Gaudens, Haute Garonne, France; vested in the Alien Property Custodian

Application filed August 1, 1941

The present invention relates to new and improved methods and apparatus for sealing off the space between the wall of a bore hole and its casing at any desired depth or depths therein.

In the exploitation of oil wells drilled into the earth, good engineering practice requires that the space between the wall of the bore hole and the casing which is usually inserted therein be sealed off at a predetermined location or locations in order to prevent the flow of fluid or gas therealong from one subterranean bed to another. This is also essential in order to permit the oil bearing layers to be exploited separately.

Heretofore, it has been the practice to pump a suitable cement slurry through the casing to the bottom of the bore hole and up into the space between the casing and the wall of the bore hole. This method is adequate for sealing off the casing at points near the bottom of the bore hole, but it has not been found satisfactory for sealing off the casing at points at relatively great distances from the bottom of the bore hole. In the latter cases, the method is costly because of the large quantities of cement required and the seals produced are often ineffective because the cement is frequently not evenly distributed about the casing.

It is an object of the present invention, accordingly, to provide new and improved methods and apparatus for sealing off the space between the wall of the bore hole and its casing which are free from the disadvantages of the prior art noted above, and which are more simple, flexible and economical in operation.

Another object of the invention is to provide new and improved apparatus of the above character which is adapted to perforate the casing, and also to inject sealing material into the space between the wall of the bore hole and the casing through the perforation or perforations formed therein.

Still another object of the invention is to provide new and improved apparatus of the above character in which the sealing material is directed to perforating and injecting means in the casing from a source located at the surface of the earth.

A further object of the invention is to provide new and improved apparatus of the above character wherein the sealing material is disposed in a container located in the casing with the perforating and injecting means and is adapted to be supplied therefrom to the injecting means.

Another object of the invention is to provide new and improved apparatus of hte above character wherein the means for injecting the sealing material forms a part of the perforating means and includes detachable means for plugging the perforation in the casing after the sealing material has been injected therethrough.

Still another object of the invention is to provide a new and improved method of the above character in which the sealing material employed is adapted to harden rapidly after having been injected into the space between the wall of the bore hole and the casing.

A further object of the invention is to provide a new and improved method of the above character wherein the sealing material at about the time of its injection into the space between the wall of the bore hole and the casing is mixed with an ingredient which causes it to harden rapidly.

Other objects and advantages of the invention will become apparent from the following detailed description of several preferred embodiments, taken in conjunction with the accompanying drawings in which:

Fig. 1 is a view in vertical section illustrating apparatus constructed according to the present invention for perforating the casing of a bore hole and for injecting sealing material into the space between the wall of the bore hole and the casing.

Fig. 2 is a cross-sectional view taken along line 2—2 of Fig. 1 and looking in the direction of the arrows, showing the perforating means in the normal inoperative position.

Fig. 3 illustrates the perforating means shown in Fig. 2 after the perforation of the casing has been completed.

Fig. 4 shows the perforating means of Fig. 2 in the retracted position after the perforating operation has been completed.

Figs. 5, 6, 7 and 7*a* illustrate a number of different forms of perforating punches constructed according to the present invention.

Figs. 8 and 8*a* are views in longitudinal section of a modified form of the apparatus shown in Fig. 1, which is adapted to be lowered into a bore hole on a conventional electrical cable.

Figs. 9 and 9*a* illustrate further modifications of the apparatus shown in Fig. 8.

Referring to Fig. 1, a bore hole 10 is shown having a casing 11 therein slightly smaller in diameter than the diameter of the bore hole 10, forming an annular space 12 between the wall of the bore hole 10 and the casing 11. For convenience it will be assumed that it is desired to form a seal in the space 12 in the vicinity of

the upper boundary of an oil bearing formation 13 traversed by the bore hole 10.

Within the casing 11 and in the vicinity of the formation 13 is disposed apparatus for perforating the casing and for introducing the sealing material into the space 12 between the wall of the bore hole 10 and the casing 11. This apparatus comprises a body 14 made of steel or other suitable material, having a cylindrical chamber 15 formed in the upper portion thereof within which is slidably mounted a piston 16 of relatively large area. The piston 16 is maintained normally near the top of the chamber 15 by means of a compression spring 17 which is seated in an annular recess 18 formed in the bottom of the chamber 15 and the upper end of which engages the lower face of the piston 16.

The lower portion of the piston 16 is formed as a coaxial cylindrical plunger 19 which is considerably smaller in diameter than the piston 16, and which is slidably mounted within a bore 20 communicating at its upper end with the cylinder 15. The bore 20 communicates through a passage 21 with a cylindrical chamber 22 which extends transversely of the body 14 and which terminates in an opening 22*a* formed in the wall of the body 14. The portion of the chamber 22 which is nearest the opening 22*a* is internally threaded at 23 to receive an externally threaded barrel 24 having a central bore 25 formed therein within which a cylindrical perforating and injecting element 26 is slidably fitted.

Located below the chamber 22 and communicating therewith through a passage 42*a* is a second chamber 22' in which is slidably mounted a perforating and injecting element 26'. Corresponding parts in the lower element 26' and associated apparatus are designated by primed reference characters. Usually there will be a plurality of perforating and injecting elements located about the periphery of the body 14. For the sake of simplicity, however, only two are shown in Fig. 1.

Referring now to Fig. 2, the injecting and perforating element 26' is slightly smaller in diameter than the diameter of the chamber 22' and it has a laterally extending rear portion 27' which cooperates with the barrel portion 24' to limit the extent of movement of the perforating and injecting means 26'. The rear portion 27' of the injecting and perforating element 26' is provided with a circumferential groove 28' within which is disposed suitable packing material 29' for providing a tight joint.

In one side of the perforating and injecting means 26' is formed an aperture 30' providing communication with the hollow interior 31' thereof. At the forward end of the perforating and injecting means 26' is provided a closure member 32' within which are formed a plurality of longitudinal extending passages 33' and 34'. Mounted on the closure member 32' and secured thereto by means of a suitable screw 35' is a punch 36' within which are formed a plurality of longitudinal grooves 37' and 38' which are adapted to register with the passages 33' and 34', respectively, permitting sealing material to be injected from the interior 31' of the perforating and injecting means 26' through the passages 33' and 34' and the grooves 37' and 38' into the space 12 between the wall of the bore hole 10 and the casing 11, as described in greater detail hereinafter.

Formed in the piston 16 is a longitudinally extending passage 39 which communicates with a longitudinally extending aperture 40 formed in the side wall of the plunger 19. The dimensions of the aperture 40 are so chosen that it is entirely closed when the piston 16 is in its uppermost position, but when the piston 16 is in its lowermost position it communicates with an aperture 41*a* formed in the wall of the chamber 20. The aperture 41*a* communicates with a downwardly extending passage 41 formed in the body 14 which in turn communicates with an aperture 42 formed in the wall of the bore 25 in the barrel 24.

The passage 41 continues downwardly through the body 14 and through the barrel portion 24 to an aperture 42' formed in the wall of the bore 25' in the barrel 24' located in the body 14 below the barrel 24.

In this embodiment of the invention, the apparatus is lowered into the casing 11 on a conventional string of drill pipe 43, at the lower end of which is formed a laterally extending flange 44 which is adapted to be rotatably received within a corresponding groove 45 formed in a head piece 46. The drill pipe 43 is provided with an aperture 47 which is adapted to register with a laterally extending passage 48 formed in the head piece 46 when the string of pipe 43 is rotated with respect to the head piece 46 for the purpose of placing the hollow interior of the drill pipe 43 in communication with the liquid within the casing 11.

At the surface of the earth, the string of drill pipe 43 is connected to a length of flexible tubing 48 to which fluid under pressure is supplied from suitable pumping means 50 located at the surface of the earth.

In operation, the body 14 is lowered on the string of drill pipe 43 until the perforating and injecting elements 26 and 26' are located approximately at the depth of the upper boundary of the formation 13 where it is desired to form the seal. A liquid cement mixture is then pumped from the pumping means 50 through the flexible tubing 48 and through the string of drill pipe 43 into the chamber 15. At this time, of course, the aperture 47 in the drill pipe 43 will be out of registry with the passage 48 in the head piece 46.

The fluid pressure of the cement mixture within the chamber 15 forces the piston 16 downwardly against the pressure of the spring 17, moving the plunger 19 downwardly and applying pressure to a body of pressure transmitting fluid such as oil 20*a*, for example, contained within the bore 20 and the chambers 22 and 22'. The pressure of the oil 20*a* forces the perforating and injecting means 26 and 26' outwardly and radially against the casing 11, as shown in Fig. 1.

The application of pressure by the pumps 50 is continued until the punches 36 and 36' on the perforating and injecting elements 26 and 26', respectively, are forced through the casing 11 as shown in Fig. 1. At this time it will be noted that the aperture 40 in the plunger 19 is in registry with the aperture 41*a* in the wall of the bore 20 while the aperture 42 is in communication with the hollow interior 31 of the perforating and injecting means 26 through the aperture 30 therein. Accordingly, the cement mixture above the piston 16 is forced through the passage 39, the aperture 40, the aperture 41*a*, the passage 41, the aperture 42 in the perforating and injecting means 26, the passages 33 and 34 therein and the grooves 37 and 38, respectively, in the punch 36 into the space 12 between the wall of the bore hole 10 and the casing 11. In similar fashion, cement is also injected through the per-

forating and injecting means 26' into the space 12.

When a sufficient quantity of cement has been deposited in the space 12 to form a sealing ring therein, the operation of the pumping means 50 is stopped and the string of drill pipe 43 is rotated to bring the aperture 47 therein into registry with the passage 48 in the head piece 46. Fresh water is then pumped through the flexible tubing 49 for the purpose of cleaning out the interior of the string of drill pipe 43 and removing any excess cement therefrom.

The reduced pressure in the chamber 15 permits the coil spring 17 to restore the piston 16 to its uppermost position, thereby reducing the oil pressure in the bore 20. Under these conditions, the perforating and injecting means 26 and 26' are withdrawn from the casing 11 and into their normal positions, as shown in Fig. 2.

As shown in greater detail in Fig. 2 the punch 36' is provided with a conical forward portion 51', an intermediate portion 52' which is slightly smaller in diameter than the greatest diameter of the conical portion 51' and a rear portion 53' which diverges outwardly and abuts the forward end of the perforating and injecting element 26'. Experience has shown that a punch of this shape has a marked tendency to become jammed in the metal casing. As a result, a relatively large force is necessary to withdraw the punch after the casing has been perforated, from one to two tons being required for a perforating pressure of about fifteen tons.

The screw 35' which secures the punch 36' to the closure member 32' is made of relatively small section and is designed to break under a tensile stress which is less than that required to withdraw the punch 36' from the casing 11. Accordingly, when a force is applied to restore the perforating and injecting means 26' to its normal position, the screw 35' will break, leaving the punch 36' jammed in the casing 11, as shown in Fig. 4, forming an effective closure for preventing fluid transfer between the interior of the casing 11 and the space 12 between the wall of the bore hole 10 and the casing 11.

After the screw 35' has been broken, the perforating and injecting means 26' will return to its normal retracted position within the chamber 22', as shown in Fig. 4. Similarly, the perforating and injecting means 26 will be restored to its normal inoperative position. The body 14 may then be moved to another position in the bore hole or it may be withdrawn therefrom.

Instead of using a conventional cement mixture, the sealing material might comprise a product having the property of setting by hydration. Such materials may be kept out of contact with water by the novel perforating and injecting apparatus described above and would come into contact with water only after having been injected into the space 12.

It is also possible to use as sealing materials substances which are normally solid at the temperatures usually encountered in wells, but which flow freely at higher temperatures. Lead base alloys such as mixtures of lead and tin have been found satisfactory for this purpose. Such substances can be injected into the space 12 while in the molten state and form an effective seal upon solidification by cooling.

In Figs. 5 and 6 are illustrated a plurality of different punches which are not designed to form a closure for the perforation in the casing after the sealing material has been injected therethrough. In the embodiment shown in Fig. 5, the punch 52a is provided with a sharp conical point 53a and the sealing material is adapted to be supplied through an aperture 54 and a longitudinal passage 55 to a laterally extending passage 56 therein. By virtue of the laterally extending passage 56, a gyratory movement around the casing 11 is imparted to the sealing material, thus forestalling an uneven distribution of sealing material about the casing 11.

In Fig. 6, the punch 57 tapers inwardly from the front to the rear so that its front diameter is slightly greater than its rear diameter. A punch of this character produces a perforation in the casing 11 which is similar to that produced by a perforating bullet. The sealing material passes through passages 58 in the perforating and injecting element 26 and through the space between the punch 57 and the perforation in the casing 11 into the space 12 between the bore hole 10 and the casing 11.

The embodiment shown in Figs. 7 and 7a is adapted to form a closure for the perforation in the casing after the sealing material has been injected therethrough. In this embodiment, the injecting means 26 is provided with a forward closure member 60 in which is formed a centrally located aperture 61. In the front face of the perforating and injecting means 26 is formed a cylindrical recess 62 within which is tightly fitted a cylindrical member 63 provided with a central bore 64 within which is mounted the shank 65 of a punch 66.

The rear portion of the shank 65 is externally threaded at 67 to receive a threaded conical member 68 which is very weakly secured to a rod 69 on the end of which is formed a laterally extending disk 78 for limiting the longitudinal movement of the punch 66. The disk 70 is provided with one or more apertures 71 therein for permitting sealing material to pass from the hollow interior 31 of the perforating and injecting means 26 therethrough. The sealing material passes through the space between the aperture 61 and the rod 69 and through suitable apertures 72 and 73 formed in the cylindrical member 63 and the spaces 74 and 75 between the front face of the cylindrical member 63 and the rear face of the punch 66.

When the injection of the sealing material has been accomplished and force is applied to the perforating and injecting element 26 to withdraw it from the casing 11, the cylindrical member 63 becomes disengaged from the recess 62 and the weak connection between the conical member 68 and the rod 69 is broken, leaving the cylindrical member 63 tightly jammed within the perforation in the casing 11 as shown in Fig. 7a. It will be seen that the elements shown in Fig. 7a form a valve which serves as a closure for preventing fluid flow between the interior of the casing 11 and the space 12 between the wall of the bore hole 10 and the casing 11.

In Fig. 8 the punch, which otherwise works in the same way as that shown on Figs. 2–3 and 4, comprises a triangular point 145 in front, which continues by flats 146, and it is slightly conical at the back 147. It is screwed to the end of screw 35', which is slidably fitted inside a passage contained in the closure member 32' similar to that in Figs. 2–3 and 4, the screw 35' being however longer than in the embodiments mentioned above, so that the punch can perforate the casing completely and allow the cement arriving by apertures 33' to flow around its outer surface (Fig.

8a). As is seen on Fig. 8b, during the return stroke of the perforating and cementing means, the punch returning through the hole which it has perforated jams there due to its conical portion 147. Screw 35' breaks, as in the preceding case, while the punch plugs the hole which it has perforated.

The punch shown in Figs. 9a and 9b is similar to that shown in Figs. 8 and 8a, but it is formed of two parts 148 and 149 both screwed on screw 35', whose weak point is located at the joining of these two parts. When the closure member 32' returns to its normal position, the shaft breaks at this point and only the front part 148 of the punch remains jammed in the casing, while the rear portion is carried back by the perforating and injecting means. This device has the following advantage: after the operation, no part of the punch protrudes inside the casing.

In Figs. 10, 10a and 10b has been shown also a detachable punch 150, which is carried by the perforating and injecting means 151 by means of a flange 152. Both the punch and the perforating and injecting means comprises a central passage 153 for the cement. Inside this passage, a screw 154 having at its front end a valve head 155 is attached by its rear portion to the perforating and injecting means by a nut 156 containing apertures 157 permitting the free passage of the cement. Punch 150 perforates a hole in the casing and jams there, being held in front by shoulders 158 and behind by teeth 159 (Fig. 10a). The cement can then flow out through passage 153. During the return stroke of the perforating and injecting means, valve 155 jams inside punch 150 (Fig. 10b) while shaft 154 breaks at its weak point.

The perforating and injecting apparatus shown in Fig. 11 of the drawings is designed to be lowered into the bore hole on a conventional electrical cable of the type used in electrical well logging operations, for example. In this embodiment, the apparatus comprises a hollow cylindrical member 76 threadedly secured to a body 77, forming a chamber 78 within which a piston 79 is slidably mounted. Above the piston 79 is diposed a quantity of gas 80 under relatively high pressure and below the piston 79 is contained the sealing material 81.

Within the body 77 is formed a laterally extending open-ended chamber 82, the mouth of which is internally threaded at 83 to receive an externally threaded guide member 84 having a bore 85 formed therein. Slidably mounted within the bore 85 is a barrel 86 having a centrally located bore 87 and a flange 88 of relatively large diameter at its forward end. The barrel 86 is provided with a laterally extending flange 89 at its rear end which limits its movement within the bore 85. The barrel 86 is normally retained in the retracted position by means of a pair of coil springs 90 and 91 which are attached to the body 77 at the points 92 and 93 respectively, and to the flange 88 at the points 94 and 95 respectively.

Between the chamber 78 and the chamber 82 is a passage 96 which is closed at its upper end by a suitable closure means 97 for preventing the sealing material 81 from passing therethrough. In the lower portion of the passage 96 is disposed a bullet 98 which is adapted to pierce the closure means 97 to release the sealing material 82 as described in greater detail below.

Within the chamber 82 is disposed a charge of powder 99 which is adapted to be ignited by the passage of current through a filament 100, one end of which is connected to the body 77 at the point 101 and the other end of which is connected through a conductor 102 and a switch 103 to one terminal of a source of current 104, the other terminal of which is grounded at the point 105 at the surface of the earth.

Beneath the chamber 82 and communicating therewith by a passage 105a is a second chamber 82' and associated apparatus for firing a projectile 106' through the casing 11 at a point located about 180° away from the perforation made by the projectile 106. Corresponding parts in the lower firing apparatus are designated by primed reference characters. In practice a plurality of firing apparatuses spaced about the circumference of the body 77 will be used. For the sake of simplicity, however, only two are shown in Fig. 11.

In operation, projectiles 106 and 106' are placed in the rear portions of the bores 87 and 87' in the barrels 86 and 86' and the body 77 is lowered into the casing 11 by means of a cable 108. When the body 77 has been lowered to the depth where it is desired to effect a sealing operation, the switch 103 is closed, causing current to pass through the filaments 100 and 100' and igniting the charges of powder 99 and 99' in the chambers 82 and 82'. The force of the explosion projects the bullets 106 and 106' through the bores 87 and 87' in the barrels 86 and 86' and through the casing 11 as shown in Fig. 11a.

At the same time the force of the explosive gases drives the bullet 98 through the closure means 97 whereupon the pressure of the gas 80 acting through the piston 79 forces the sealing material 81 through the passage 96, the chamber 82 and the bore 87 in the barrel 86 into the space 12 between the wall of the bore hole 10 and the casing 11. It will be noted that the pressure of the sealing material in the chamber 82 will force the flange 88 on the barrel 86 into engagement with the casing 11 against the force exerted by the coil springs 90 and 91, thus preventing leakage of the sealing material into the casing 11 or the seepage of water from within the casing 11 into the space 12. Sealing material will also pass through the passage 105a to the chamber 82' whence it will be forced through the bore 87' in the barrel 86' into the space 12 at another location.

In this embodiment, special means is provided for releasing the gas 80 when the sealing operation is completed, in order to disengage the flanges 88 and 88' on the barrels 86 and 86' from the casing 11. This means comprises a head piece 107 within which is formed a longitudinally extending deadend passage 108. The head piece 107 is mechanically weakened slightly below the upper end of the passage 108 as shown at 109 in Fig. 11 and the cable 106 upon which the apparatus is lowered into the bore hole is secured thereto in any conventional manner. The head piece 107 is enclosed within a cylindrical casing 110 in the upper surface of which is formed an aperture 111 which is smaller in diameter than the diameter of the head piece 107. In the walls of the casing 110 are formed a plurality of passages 112 communicating with the liquid within the bore hole 10.

At the conclusion of a sealing operation, the flanges 88 and 88' on the barrels 86 and 86' are in effect locked to the casing 11, so that the body 77 cannot move. Hence, if sufficient tension is applied to the cable 106, it will break off the head piece 107 at the weakened portion 109, permitting

the gas 80 in the chamber 78 to escape through the passage 108, the passages 112 and the liquid in the bore hole 10 to the surface of the earth. The tension in the coil springs 90, 91, 90' and 91' is made sufficient to restore the barrels 86 and 86' to the normal retracted position when this occurs.

In Figs. 12 and 12*a* of the drawings is shown a modification of the apparatus shown in Fig. 11 in which two ingredients of the sealing material may be stored separately and mixed together at the time of injection into the space 12. This modification comprises a body 114 having a cylindrical chamber 115 formed therein within which a piston 116 is slidably mounted. The piston 116 is normally maintained in its uppermost position by means of a coil spring 117, the upper end of which engages the lower face of the piston 116 and the lower end of which is seated in the bottom of the chamber 115.

Above the piston 116 is located a conventional type cartridge 118 which is adapted to be ignited by means of a filament 119, one end of which is grounded to the body 114 at the point 120 and the other end of which is connected to the conductor 102 in the cable 106.

The chamber 115 communicates at its lower extremity with a passage 121 which in turn communicates with a laterally extending chamber 122 formed in the body 114. The chamber 122 has an opening at one end thereof to receive a cylindrical perforating and injecting means 123 provided with a circumferential groove 124 in the rear portion thereof in which is disposed suitable packing material 125 for providing a tight joint. The perforating and injecting means 123 is of the type shown in Fig. 8 and it is provided with a laterally extending passage 126 communicating with a longitudinal passage 127 which in turn communicates with two laterally extending passages 128 and 129 formed in the perforating and injecting means 123. The lower portion of the chamber 115, the passage 121 and the rear portion of the chamber 122 are filled with a pressure transmitting fluid such as oil, which transmits pressure from the piston 116 to the perforating and injecting means 123.

Below the chamber 122 and communicating therewith through a passage 121*a* is a second chamber 122' having a perforating and injecting means 123' slidably mounted therein. The apparatus associated with the perforating and injecting means 123' is like that described above in connection with the perforating means 123 and corresponding parts have been designated by primed reference numerals.

When the perforating and injecting means 123 and 123' are in the normal retracted position, the passages 128 and 129, and 128' and 129' are closed, but when they are moved into the perforating position as shown in Fig. 12*a*, the passages 128 and 129 register with corresponding passages 130 and 131 and the passages 128' and 129' with the corresponding passages 130' and 131' formed in the lower portion of the body 114. The lower portion of the body 114 is externally threaded at 132 to receive a conventional type bailer 133 which includes an outer cylindrical casing 134 threadedly secured to the body 114, into the lower end of which is threaded a plug 135. Within the casing 134 is formed a second casing 136 which extends from the plug 135 to the bottom of the body 114 in the vicinity of the passage 130. An annular piston 137 is slidably mounted within the casing 134 and a second piston 138 is slidably mounted within the casing 136. Within the plug 135 are formed a pair of passages 139 and 140 which communicate with the interiors of the casings 136 and 134, respectively. The two ingredients comprising the sealing material are placed above the pistons 137 and 138 respectively, in the casings 134 and 136 respectively.

The top of the casing 11 is closed off by means of a closure member 141 provided with a suitable stuffing box 142 which permits the cable 106 to be raised and lowered within the casing 11. The flexible tubing 49, which supplies fluid under pressure from the pumping means 50 is connected to a suitable inlet 143 in the closure member 141 and a conventional pressure indicating instrument 144 is provided for indicating the pressure of the liquid within the casing 11.

In operation, the body 114 is lowered to the approximate depth where the seal is to be made and is brought to rest at that position. The switch 103 is then closed, supplying current to the filament 120 and igniting the cartridge 118. The explosive gases created by the ignition of the cartridge 118 move the piston 116 downwardly against the force of the coil spring 117, increasing the pressure of the oil contained in the chamber 115, the passage 121 and the chambers 122 and 122', and forcing the perforating and injecting elements 123 and 123' through the casing 11, as shown in Fig. 12*a*. This brings the passages 128 and 129 in the perforating and injecting element 123 into registry with the passages 130 and 131, respectively, and the passages 128' and 129' in the element 123' into registry with the passages 130' and 131' respectively.

Pressure is now applied to the liquid in the bore hole by means of the pumping means 50 at the surface of the earth. This forces the liquid within the casing 11 through the apertures 139 and 140 in the plug 135 and against the pistons 138 and 137, respectively, moving them upwardly and forcing the respective ingredients of the sealing material contained in the casings 136 and 134, respectively, through the passages 130 and 131, respectively, in the body 114 through the passages 128 and 129, respectively, in the perforating and injecting means 123. From thence, the sealing material flows through the passage 127 in the perforating and injecting means 123 and out of the passage 126 into the space 12 between the wall of the bore hole 10 and the casing 11.

In similar fashion, sealing material is forced through the passages 130' and 131', respectively, and the passages 128' and 129', respectively, to the passages 121' in the perforating and injecting means 123'. This may be continued until the pistons 138 and 137 have reached their uppermost limits of travel, which event will be indicated by an increase of pressure at the pressure indicating instrument 144.

In order to retract the perforating and injecting elements 123 and 123' from the casing 11 it is necessary to release the powder gases from the chamber 115. This is done by applying tension to the cable 106 to break the head piece 107, thereby permitting the powder gases to escape through the passage 108 and the passages 112 to the liquid in the casing 11. This permits the coil spring 117 to restore the piston 116 to its normal position, releasing the pressure on the oil contained in the chambers 122 and 122' and permitting the perforating and injecting elements 123 and 123' to be withdrawn into their normal retracted positions.

For the sake of simplicity, only two perforat-

ing and injecting means 123 and 123' have been shown in Fig. 12 and described above. In actual practice, there may be a plurality of such perforating and injecting means disposed about the circumference of the body 114, each being actuated by the oil in the chamber 116, and each adapted to receive the sealing material ingredients from the casings 136 and 134.

The apparatus described above in connection with Fig. 12 enables a sealing material to be employed which comprises two or more substances which, when mixed, tend to harden rapidly. For example, a cement which sets relatively slowly might be placed above the piston 137 in the casing 134 and another substance such as, for example, sodium silicate, which when added to cement causes it to harden rapidly, might be placed above the piston 138 in the casing 130. In similar fashion, liquid latex and an acid might be used as the ingredients of the sealing material since they tend to produce a relatively solid substance when mixed together. Other suitable sealing materials will readily suggest themselves to those skilled in the art and they need not be set forth herein.

In Figs. 13 and 13*a* is shown a modification of the apparatus shown in 12 and 12*a*, comprising a special device for controlling the return stroke of the perforating and injecting means.

Punch 160 and perforating and injecting means 161 are similar to those shown in Figs. 7, 8 and 9, that is to say that the punch is adapted to jam in the casing when the perforating and injecting means returns to its normal position, so as to plug the hole previously perforated by this punch. The special device for controlling the return stroke of the perforating and injecting means comprises a chamber 162, of appropriate and rather large dimensions, provided in the body of the apparatus, above the powder combustion chamber 115. The pressure inside said chamber 162 is very low (atmospheric pressure for example) in relation to the pressure inside the bore hole. To obtain this result the chamber is tightly closed before the apparatus is lowered in the bore hole. For controlling the return stroke of the injecting means, this chamber is brought into communication with the powder combustion chamber. In this way the combustion gases then expand in the said chamber until a pressure is reached which is much lower than the pressure of the mud inside the bore hole. At this moment, due to this difference of pressure, the perforating and injecting means 161 is thrust inside chamber 122 carrying with it punch 160 which jams in the casing. The shaft of the punch then breaks, and the perforating and injecting means continuing its movement returns completely inside chamber 122 (see Fig. 13*a*).

The device for bringing chamber 110 into communication with chamber 162 may be of any type. In the figure, shaft 163 which is attached to the supporting cable 106 comprises a weak point 164 and is chambered out in its centre 165. The upper end of said shaft 163 goes through a flange 166, integral with a plate 167 which closes the upper part of the chamber 162, said upper end being located underneath another chamber 168, communicating with the inside of the well through holes 169. A rubber sleeve 170 tightly joins shaft 163 and flange 166. After the perforation followed by cementing, which is brought about by the ignition of the powder in chamber 115, the device is brought back to its normal position by means of strong traction on the cable, which has the effect of breaking shaft 163 at the level of the weak point 164. This brings chamber 115 into registry with chamber 162 by means of passage 165 and the perforating and injecting means then returns to its normal position as indicated above. The apparatus remains held by the cable by means of the upper end of shaft 163 abutting against the cover 171 of the apparatus.

It will be apparent from the foregoing that the invention provides novel methods and apparatus for producing a highly effective seal economically and in a short space of time. By virtue of the fact that the sealing material is injected through the same means which perforates the casing, sealing operations may be carried out more rapidly and with greater ease than has been possible heretofore.

MARCEL SCHLUMBERGER.