

March 12, 1968

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3,372,755

APPARATUS FOR WELL FLOW STIMULATION

Filed June 29, 1965

3 Sheets-Sheet 1

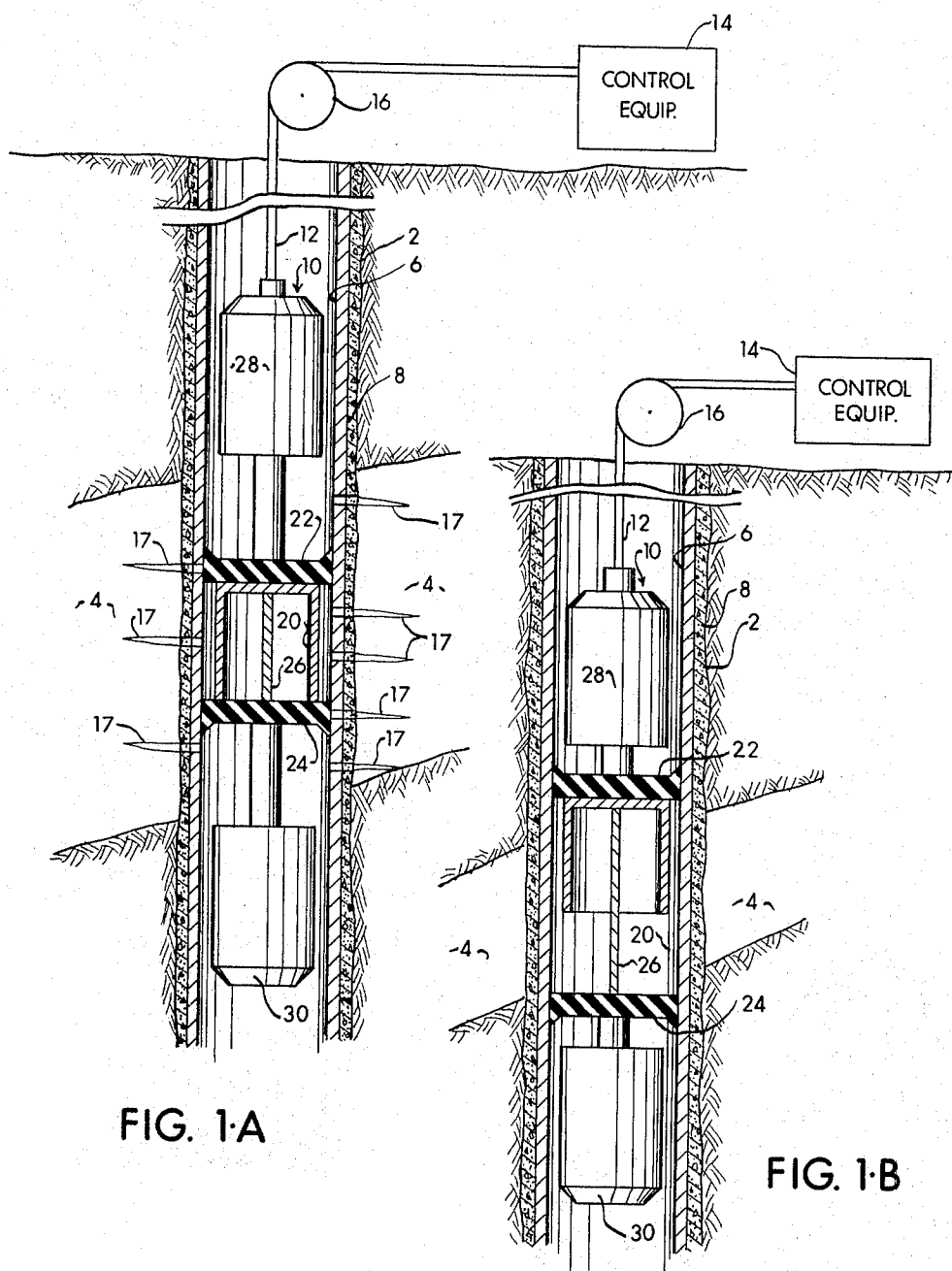


FIG. 1-A

FIG. 1-B

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3 Sheets-Sheet 2

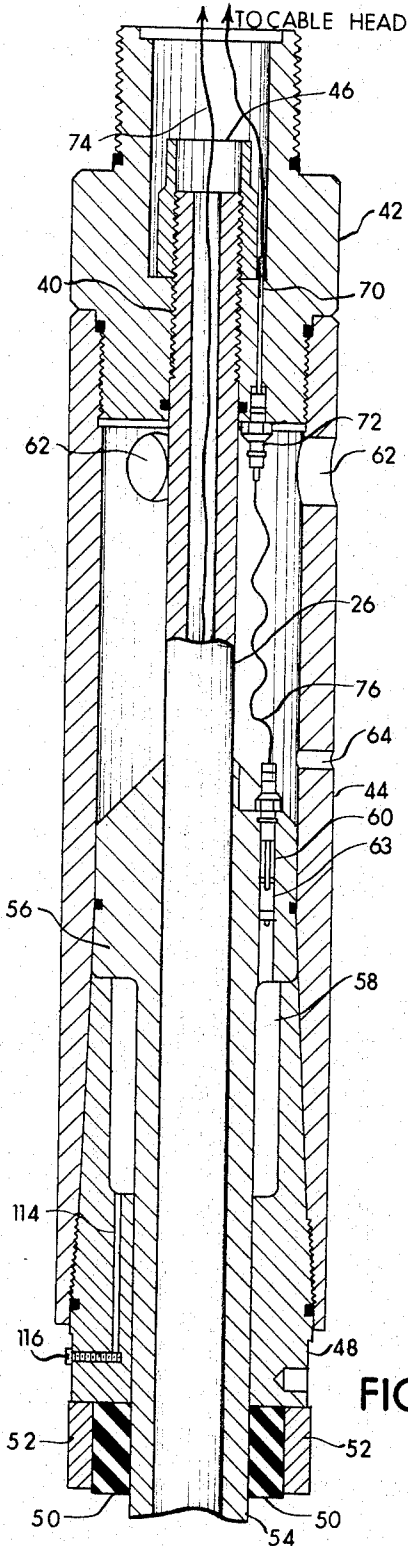


FIG. 2

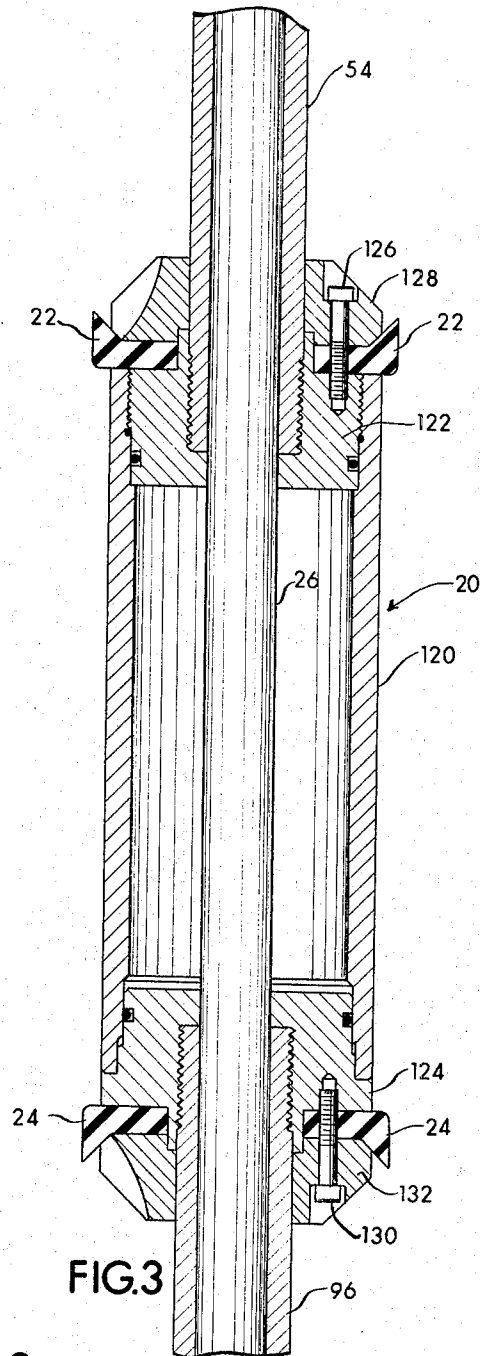


FIG. 3

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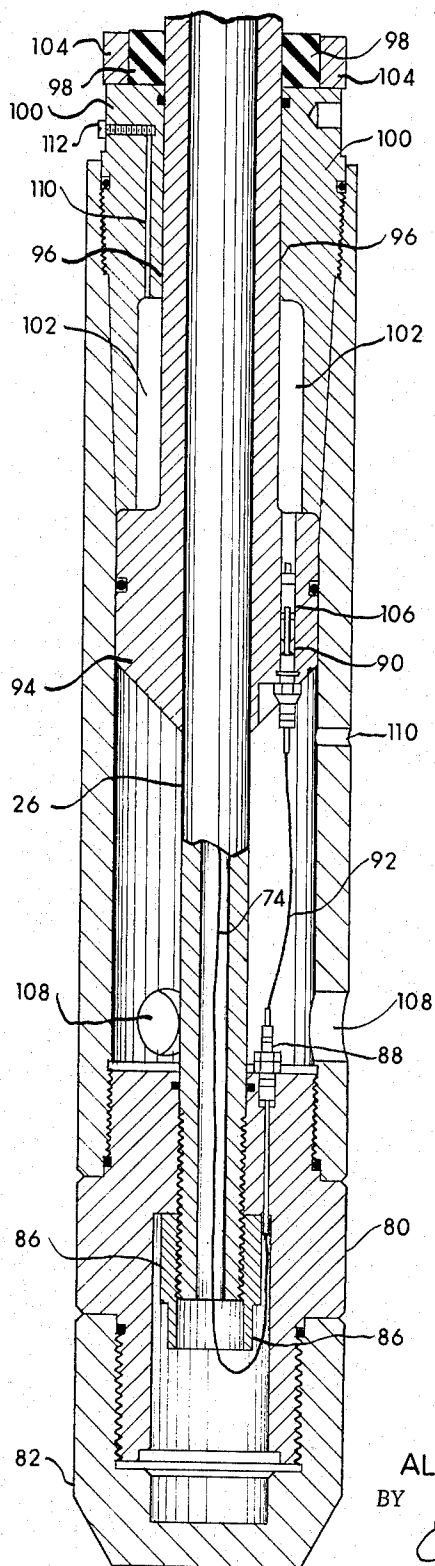
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FIG. 4



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APPARATUS FOR WELL FLOW STIMULATION
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ABSTRACT OF THE DISCLOSURE

This apparatus for improving the flow of fluid from an earth formation tapped by a perforated cased borehole includes a chamber defining an air space. One end of the chamber is closed, and the other end of the chamber is sealed with a detachable closure member. A propelling charge is provided for moving the two plugs in opposite directions for developing an implosion zone to open plugged perforations in the borehole.

This invention relates to apparatus for stimulating the flow rate of an oil or gas well, and more particularly relates to improved apparatus for unclogging the flow passages in a subsurface earth formation containing oil or gas.

It is now well known that oil and gas is found trapped in subsurface earth formations or strata, and that boreholes are drilled into these formations for the purpose of providing a flow path or channel by which the oil or gas may be brought to the surface of the earth. It is also well known that after the borehole is drilled to the proper depth, it is usually lined with a steel casing or pipe, and that after the casing has been properly placed in the borehole, cement is forced into the annulus of the borehole to seal off the formation. Thereafter, perforations are made in the casing, cement, and surrounding formation material to provide channels through which the oil and gas may pass from the formation into the well casing.

What is not so well known is that the oil and gas in the earth is not contained in a large cavity or basin, but instead is dispersed or diffused throughout relatively solid but porous rock. Thus, when the oil and gas flows through the formation and into the perforations, these fluids tend to carry loose sand grains and particles of debris into the perforations. Over a period of time, more and more of the tiny particles will enter the perforations and eventually the perforations will become substantially clogged.

This clogging phenomenon has always been a problem in oil and gas production, and have previously sought to be cured by detonating a charge of explosive in the well adjacent the clogged formation to dislodge these trapped grains of sand. Often this technique is successful, and since it has until now been the only available remedy for this problem it is accordingly in wide use in the industry. However, the well casing is sometimes badly damaged—and even split—by the explosion and the cement seal across the face of the formation is sometimes broken. Thus the improved fluid flow obtained by the conventional method is sometimes routed away from the casing perforations and the fluids which are sought to be captured tend to drain away and escape into a different formation.

These advantages are overcome with the present invention, and novel apparatus are provided which suck out and free the tiny channels in the formation adjacent the perforations in the casing.

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Accordingly, it is an object of the present invention to provide novel apparatus to improve fluid flow from a subsurface earth formation penetrated by a perforated cased borehole.

It is also an object of the present invention to provide novel apparatus to improve the rate of fluid flow from a clogged formation penetrated by a perforated cased borehole.

It is a specific object of the present invention to provide a novel apparatus of improving the rate of fluid flow from an earth formation penetrated by a perforated cased borehole and having its capillary-like channels clogged with comminuted material.

It is also a specific object of the present invention to provide a novel apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole and having its capillary-like channels clogged with comminuted material.

The advantages of the present invention are obtained with novel implosion-producing apparatus which includes means defining a generally empty chamber, one of the ends of which being separable therefrom, and explosive means for moving the chamber and the separable end in opposite directions to create a suction and implosion in the perforated zone of the well casing adjacent the formation. A preferred form of the invention includes elastomer packers formed to spread against the inner surface of the casing under the effect of the resistance provided by the well fluid so as to create a still more effective suction in the zone of the casing between the packers when the two packers are suddenly driven apart. This suction draws the clogging sand grains and debris out of the perforations in the formation, and fluid flow through the cleared formations is restored to its normal or former rate.

These and other objects and features of the present invention will be apparent from the following detailed description, wherein reference is made to the accompanying drawings.

In the drawings:

FIGURE 1-A is a pictorial and functional representation of novel apparatus disposed in a cased and perforated borehole for producing an implosion in the borehole adjacent a preselected earth formation.

FIGURE 1-B is a pictorial and functional representation of the apparatus depicted in FIGURE 1 after such apparatus has produced an implosion in the borehole.

FIGURE 2 is a detailed representation of the upper one-third portion of the apparatus depicted in FIGURES 1-A and 1-B.

FIGURE 3 is a detailed representation of the center one-third portion of the apparatus depicted in FIGURES 1-A and 1-B.

FIGURE 4 is a detailed representation of the lower one-third portion of the apparatus depicted in FIGURES 1-A and 1-B.

Referring now to FIGURES 1-A and 1-B, there may be seen a simplified representation of novel suction and implosion-producing apparatus 10 disposed in a borehole 2 at a depth adjacent a fluid-bearing formation 4 which has become clogged by loose sand grains. The borehole 2 is shown to contain a standard steel well casing 6 containing perforations 17, and having cement 8 between the outer wall of the casing 6 and the wall of the borehole 2. The novel suction and implosion-producing apparatus 10 is seen to be connected at one end to a typical logging cable

12 which is connected at the other end to suitable control equipment 14.

The cable 12 not only functions to transmit electrical control signals from the control equipment 14 to the apparatus 10, but also serves to suspend the apparatus 10 in the borehole 2. Thus, the cable 12 may be supported over the mouth of the borehole 2 by a measuring sheave wheel 16 which, in turn, may be suspended from any suitable means such as a traveling block hung from a conventional derrick.

Referring in particular now to FIGURE 1-A, it may be seen that the apparatus 10 includes a hollow cylindrical chamber 20, upper and lower packers 22-24 at the top and bottom of the chamber 20, a central guide rod 26 extending generally along the longitudinal axis of the apparatus 10, and upper and lower expansion assemblies 28-30 which, on command from a signal generated by the control equipment 14, suddenly drive the upper and lower packers 22-24 in opposite directions. When this separation of the packers 22-24 occurs, the upper end and side walls of the chamber 20 move upwardly along the upper packer 22, and the bottom wall of the chamber 20, which may be the lower packer 24, moves downwardly with the lower packer 24.

The packers 22-24 are preferably formed so as to expand outwardly against the inner surface of the casing 6, as they move respectively up and down in the borehole, and thus they tend to correspondingly reduce the pressure in the space in the casing 6 between the two packers 22-24. Of course, the perforations 17 which connect this space with the formation 4 serve to communicate this suction with the tiny capillary channels throughout the fluid-bearing formation 4, and any loose sand grains which occupy the perforations 17 tend to be sucked out of the perforations 16 and into the casing 6. FIGURE 1-A shows the apparatus 10 prior to being actuated, and FIGURE 1-B shows the relative position of the major components of the apparatus 10 after it has been actuated to produce the implosion. It has been found that the apparatus 10 performs best if the casing 6 is first filled with fluid such as drilling mud.

Referring now to FIGURE 2, there may be seen a detailed representation of the internal structure of the upper one-third portion of the apparatus 10 which comprises the upper expansion assembly 28. In particular there may be seen the upper end portion of the guide rod 26 having threads 40 at its upper end, and upper end fitting 42 in threaded engagement with the guide rod 26, and an upper barrel 44 in threaded engagement with the end fitting 42. The end fitting 42 may be seen to be secured to the guide rod 26 by means of an assembling nut 46 which is screwed on to the upper end of the guide rod 26. In the lower end of the upper barrel 44 there is a barrel plug 48 abutted by an elastic shock absorber 50 which is housed, in turn, in a metallic and cup-like shock absorber ring 52. Slidably disposed inside the shock absorber 50 and barrel plug 48 there is the upper end section of the upper piston 54, which is capped by an upper piston head 56 slidably inserted in the upper barrel 44.

It will be noticed that the downward surface of the upper piston head 56 forms, with the barrel plug 48, an annular space for containing the upper propelling charge 58. This, in turn, is detonated or ignited by means of an igniter 60 which communicates with the upper propelling charge 58 through a small aperture 63 in the upper piston head 56, and when such ignition is effected, the upper propelling charge 58 drives the upper piston head 56 and upper piston 54 slidably along the guide rod 26, and within the shock absorber 50 and barrel plug 48, toward the upper end fitting 42. Fluids trapped in the upper barrel 44 are ejected through ports 62 so as not to impede the upward movement of the upper piston head 56 and piston 54.

As hereinbefore explained, it is desirable that only a mild implosion be produced although it is also desirable that separation of the upper and lower packers 22-24 be

effected as suddenly as possible. Accordingly, there is also provided in the wall of the upper barrel 44 a gas exhaust port 64, which is spaced a preselected distance upward of the upper propelling charge 58, and which serves to vent the expanding gases produced by ignition or detonation of the upper propelling charge 58 when the upper piston head 56 moves up and past the port 64.

As hereinbefore stated, the separation of the upper and lower packers 22-24, which are depicted generally in FIGURES 1-A and 1-B is effected by means of a signal supplied over the cable 12 from the surface control equipment 14. Accordingly, in FIGURE 2 there may be seen a portion of an electrical lead 70 which may be connected at one end to the cable 12 by any suitable connection means, and which is coupled at the other end to an insulated connector 72 inserted in the upper end fitting 42. Also coupled to the cable 12 is a second lead 74 which passes into the guide rod 26 (which is hollow) to extend down to the lower expansion assembly 30 as will be apparent in the discussion of FIGURE 4.

The connector 72 in the upper end fitting 42 is, in turn connected by a flexible conductor 76 to the primer 60. As may be seen, there is a space inside the upper barrel 44 between the upper end fitting 42 and the upper piston head 56. Thus, when the upper piston head 56 is driven towards the upper end fitting 42, as hereinbefore explained, the flexible conductor 76 is merely folded up in an accordion-like manner.

Referring now to FIGURE 4, there may be seen a detailed representation of the lower expansion assembly 30 depicted generally in FIGURES 1-A and 1-B, which is in most respects identical to the upper expansion assembly 28 depicted in FIGURE 2. In particular, there may be seen a lower end fitting 80 having a conventional bull plug 82 threadedly engaged with its lower extension, and also being in threaded engagement with the lower end of the lower barrel 84 and the threaded lower end of the hollow guide rod 26. The lower end fitting 80 is further secured to the guide rod 26 by means of a lower nut 86, and lead 74 may be seen extending out of the bottom end of the guide rod 26 to couple with an insulated connector 88 which is inserted in the upper side of the lower end fitting 80. Coupling the connector 88 and the lower primer 90 is a flexible conductor 92 in the space between the lower end fitting 80 and the lower piston head 94. The lower piston 96, which is connected to drive the lower piston head 94, slidably movable about the guide rod 26 and in the lower shock absorber 98 and the lower barrel plug 100, and functions in cooperation with the lower piston head 94 and the lower barrel plug 100 to house the lower propelling charge 102. The lower shock absorber 98 is housed in a lower shock absorber ring 104 which may be secured to the lower barrel plug 100. The lower primer 90 ignites the lower propelling charge 102 by way of an aperture 106 in the lower piston head 94, and vents 108 and 110 are provided to exhaust fluids between the lower end fitting 80 and the lower piston head 94, and expanding gases produced by ignition or detonation of the lower propelling charge 102, respectively.

The "firing chamber" occupied by the lower propelling charge 102 may, if the lower piston head 94 fails to move past vent 110, be vented by means of channel 110 which is stoppered by screw plug 112. Similarly, channel 114 and screw plug 116 may be used to vent gases produced by ignition or explosion of the upper propelling charge 58 depicted in FIGURE 2.

Referring now to FIGURE 3, there may be seen a detailed representation of the central portion of the apparatus 10 depicted in FIGURES 1-A and 1-B, including the central portion of the hollow guide rod 26, the lower end of the upper piston 54, and the upper end of the lower piston 96. The chamber 20 generally represented in FIGURES 1-A and 1-B is shown here as composed of a hollow, tube-like, air box housing 120 which is threadably fixed at its upper end to an upper air box plug 122,

and which is slidably detachably connected at its lower end to a lower air box plug 124.

The upper air box plug 122 is threadably secured to the lower end of the upper piston 54, and the lower air box plug 124 is threadably secured to the upper end of the lower piston 96. Thus, when the upper propelling charge 58 is ignited, and the upper piston head 56 carries upper piston 54 and upper air box plug 122 in an upper direction, the air box housing 120 will be jerked loose from the lower air box plug 124 and carried upward with the upper air box plug 122. The lower air box plug 124 will, of course, be simultaneously and similarly be jerked loose from the lower end of the air box housing 120 and carried downward by the ignition of the lower propelling charge 102.

The upper packer 22 may be seen to be secured to the upper surface of the upper air box plug 122, by means of one or more bolts 126, and by the upper packer holder 128 which is generally frusto-conical in shape. It is also the function of the upper packer holder 128 to jam into the upper shock absorber 50, but not into the upper shock absorber ring 52. Thus, the upper shock absorber 50 and upper packer holder 128 operate to limit the upward travel of the upper piston head 56. Similarly, the lower packer 24 is secured to the lower air box plug 124 by one or more bolts 130 and the lower packer holder 132. The lower packer holder 132 is also generally frusto-conical in shape so as to strike the lower shock absorber 98 and not the lower shock absorber ring 104.

It should be noted that the upper and lower packers 22-24 are preferably generally plano-concave-like in shape, and that the upper packer 22 has its concave-like face or surface turned up and the lower packer 24 has its concave-like face or surface turned down. This tends to improve the function of the packers 22-24 in providing a gas-tight seal within the section of the well casing 6 which is between the two packers 22-24.

Numerous other variations and modifications may obviously be made in the structures and techniques herein described without departing from the basic concept of the present invention. Accordingly, it should be clearly understood that the forms of the invention described herein and shown in the figures of the accompanying drawings are illustrative only, and are not intended to limit the scope of the invention.

What is claimed is:

1. Apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole, said apparatus comprising:

- a guide rod,
- a hollow cylinder disposed about the middle section of said guide rod,
- an upper piston means slidably disposed about the upper section of said guide rod,
- a lower piston means slidably disposed about the lower section of said guide rod,
- an upper cylinder plug means threadably engaged with and stoppering the upper end of said hollow cylinder and threadably engaged with lower end of said upper piston means,
- a lower cylinder plug means slidably detachably stoppering the lower end of said hollow cylinder and threadably engaged with the upper end of said lower piston means,
- upper packer means mounted on said upper cylinder plug means for engagement with the inner surface of said cased borehole,
- lower packer means mounted on said lower cylinder plug means for engagement with the inner surface of said cased borehole,
- upper sleeve means threadably engaged with the upper end of said guide rod and slidably disposed about said upper piston means,
- lower sleeve means threadably engaged with the lower

end of said guide rod and slidably disposed about said lower piston means,

upper sleeve plug means slidably disposed about a section of said upper piston means and threadably engaged with and stoppering the lower end of said upper sleeve means,

lower sleeve plug means slidably disposed about a section of said lower piston means and threadably engaged with and stoppering the upper end of said lower sleeve means,

an upper propelling charge for driving said upper piston means upward in said upper sleeve means and disposed in a substantially gas-tight cavity formed in said upper sleeve means by said upper piston means and said upper sleeve plug means,

a lower propelling charge for driving said lower piston means downward in said lower sleeve means and disposed in a substantially gas-tight cavity formed in said lower sleeve means by said lower piston means and said lower sleeve plug means,

upper elastic stoppering means mounted on said upper sleeve plug means for limiting upward travel of said upper piston means along said guide rod,

lower elastic stoppering means mounted on said lower sleeve plug means for limiting downward travel of said lower piston means along said guide rod,

ignition means for actuating said upper and lower propelling charges,

cable means connected at one end with said upper sleeve means and including at least one electrical conductor means connected with said ignition means, and

control means connected at the other end of said cable means and interconnected with said electrical conductor for electrically actuating said ignition means.

2. Apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole, said apparatus comprising:

- a guide rod,
- a hollow cylinder disposed about the middle section of said guide rod,
- an upper piston means slidably disposed about the upper section of said guide rod,
- a lower piston means slidably disposed about the lower section of said guide rod,
- an upper cylinder plug means threadably engaged with and stoppering the upper end of said hollow cylinder and threadably engaged with lower end of said upper piston means,
- a lower cylinder plug means slidably detachably stoppering the lower end of said hollow cylinder and threadably engaged with the upper end of said lower piston means,
- upper packer means mounted on said upper cylinder plug means for engagement with the inner surface and said cased borehole,
- lower packer means mounted on said lower cylinder plug means for engagement with the inner surface of said cased borehole,
- upper sleeve means threadably engaged with the upper end of said guide rod and slidably disposed about said upper piston means,
- lower sleeve means threadably engaged with the lower end of said guide rod and slidably disposed about said lower piston means,
- upper sleeve plug means slidably disposed about a section of said upper piston means and threadably engaged with and stoppering the lower end of said upper sleeve means,
- lower sleeve plug means slidably disposed about a section of said lower piston means and threadably engaged with and stoppering the upper end of said lower sleeve means,
- an upper propelling charge for driving said upper piston means upward in said upper sleeve means and dis-

posed in a substantially gas-tight cavity formed in said upper sleeve means by said upper piston means and said upper sleeve plug means,
 a lower propelling charge for driving said lower piston means downward in said lower sleeve means and disposed in a substantially gas-tight cavity formed in said lower sleeve means by said lower piston means and said lower sleeve plug means,
 upper elastic stopping means for limiting upward travel of said upper piston means along said guide rod,
 lower elastic stopping means for limiting downward travel of said lower piston means along said guide rod,
 ignition means for actuating said upper and lower propelling charges, and
 cable means connected with said ignition means.

3. Apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole, said apparatus comprising:
 a guide rod,
 a hollow cylinder disposed adjacent the middle section of said guide rod,
 an upper piston means slidably disposed about the upper section of said guide rod,
 a lower piston means slidably disposed about the lower section of said guide rod,
 an upper cylinder plug means for stoppering the upper end of said hollow cylinder and engaged with lower end of said upper piston means,
 a lower cylinder plug means for detachably stoppering the lower end of said hollow cylinder and engaged with the upper end of said lower piston means,
 upper packer means for engagement with the inner surface of said cased borehole,
 lower packer means for engagement with the inner surface of said cased borehole,
 upper sleeve means threadably engaged with the upper end of said guide rod and slidably disposed about said upper piston means,
 lower sleeve means threadably engaged with the lower end of said guide rod and slidably disposed about said lower piston means,
 upper sleeve plug means slidably disposed about a section of said upper piston means for stoppering the lower end of said upper sleeve means,
 lower sleeve plug means slidably disposed about a section of said lower piston means for stoppering the upper end of said lower sleeve means,
 an upper propelling charge for driving said upper piston means upward in said upper sleeve means,
 a lower propelling charge for driving said lower piston means downward in said lower sleeve means,
 upper elastic stopping means for limiting upward travel of said upper piston means along said guide rod,
 lower elastic stopping means for limiting downward travel of said lower piston means along said guide rod,
 ignition means for actuating said upper and lower propelling charges, and
 cable means connected with said ignition means.

4. Apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole, said apparatus comprising:
 a guide rod,
 a hollow cylinder disposed adjacent the middle of said guide rod,
 an upper piston means slidably disposed adjacent the upper section of said guide rod,
 a lower piston means slidably disposed adjacent the lower section of said guide rod,
 an upper cylinder plug means for stoppering the upper end of said hollow cylinder,
 a lower cylinder plug means for slidably detachably stoppering the lower end of said hollow cylinder,

upper packer means for engagement with the inner surface of said cased borehole,
 lower packer means for engagement with the inner surface of said cased borehole,
 upper sleeve means threadably engaged with the upper end of said guide rod and slidably disposed relative to said upper piston means,
 upper sleeve plug means slidably disposed relative to a section of said upper piston means for stoppering the lower end of said upper sleeve means,
 lower sleeve plug means slidably disposed relative to a section of said lower piston means for stoppering the upper end of said lower sleeve means,
 an upper propelling charge for driving said upper piston means upward relative to said upper sleeve means,
 a lower propelling charge for driving said lower piston means downward relative to said lower sleeve means,
 upper elastic stopping means for limiting upward travel of said upper piston means along said guide rod,
 lower elastic stopping means for limiting downward travel of said lower piston means along said guide rod, and
 ignition means for actuating said upper and lower propelling charges.

5. Apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole, said apparatus comprising:
 a guide means,
 chamber means located adjacent the middle section of said guide means for forming an air space,
 first piston means located adjacent one end of said guide means,
 second piston means located adjacent one end of said guide means,
 first plug means connected to said first piston means for stoppering one end of said chamber means,
 second plug means connected to said second piston means for stoppering the other end of said chamber means,
 first packer means interconnected with said first piston means for engagement with the inner surface of said cased borehole,
 second packer means interconnected with said second piston means for engagement with the inner surface of said cased borehole,
 first propelling charge for driving said first piston means in one direction relative to said guide means,
 second propelling charge for driving said second piston means in the other opposite direction relative to said guide means, and
 ignition means for actuating said first and second propelling charges.

6. Apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole, said apparatus comprising:
 chamber means for forming an air space,
 first plug means for stoppering one end of said chamber means,
 second plug means for detachably stoppering the other end of said chamber means,
 first packer means for engagement with the inner surface of said cased borehole,
 second packer means for engagement with the inner surface of said cased borehole,
 first propelling charge for driving said first plug means away from said second plug means, and
 second propelling charge for driving said second plug means away from said first plug means.

7. Apparatus for improving the rate of fluid flow from an earth formation tapped by a perforated cased borehole, said apparatus comprising:
 chamber means for forming an air space of reduced pressure,
 first packer element means formed to expand outwardly to seal off fluid above said chamber means,

second packer element means positioned below said chamber means and formed to expand outwardly to seal off fluid below said chamber means, and propelling charge for moving said first and second packer element means in opposite directions for developing an implosion zone to open plugged perforations in the borehole.

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