

March 15, 1966

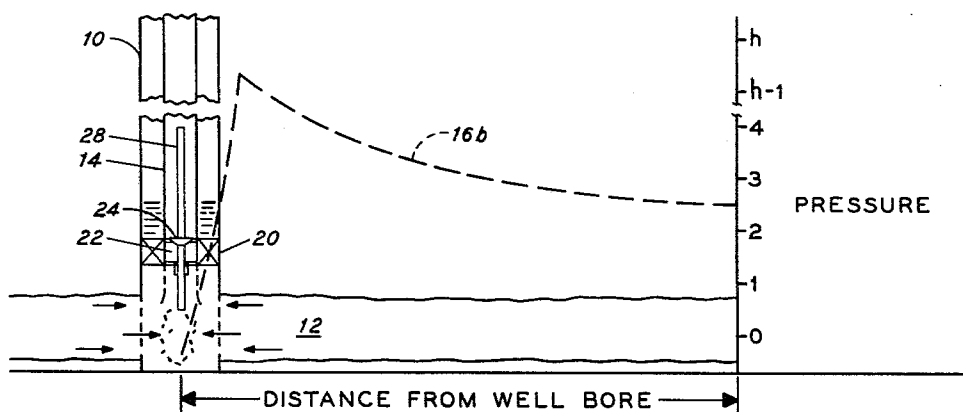
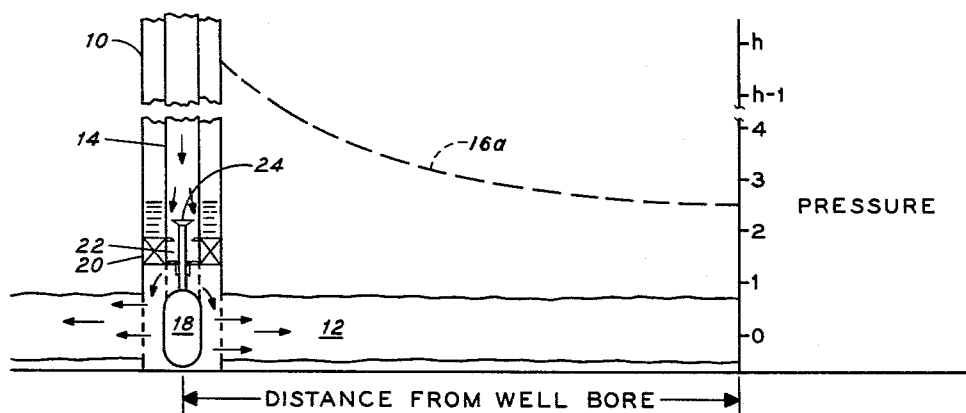
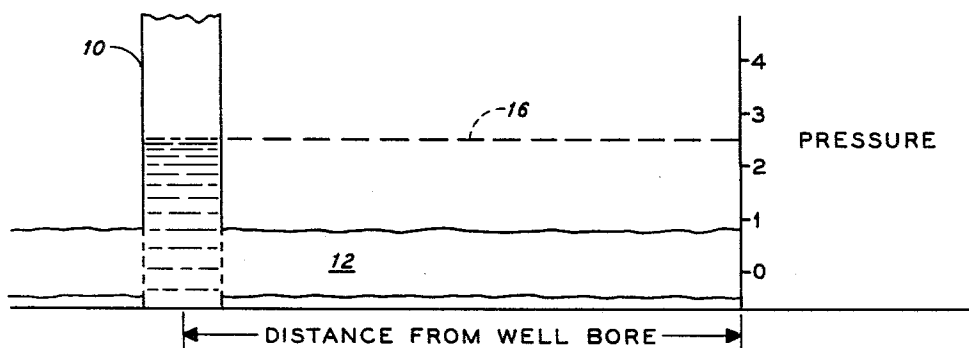
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3,240,273

METHOD AND APPARATUS FOR WELL STIMULATION

Filed June 29, 1961

5 Sheets-Sheet 1



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5 Sheets-Sheet 2

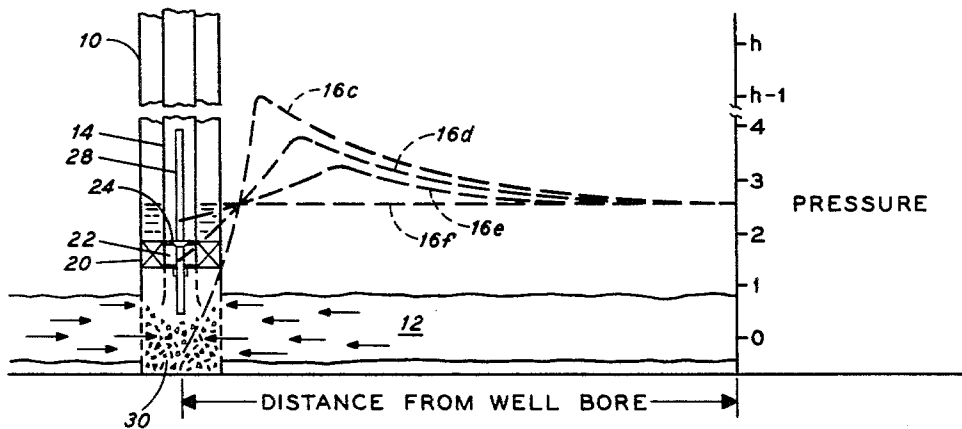


FIG. 4

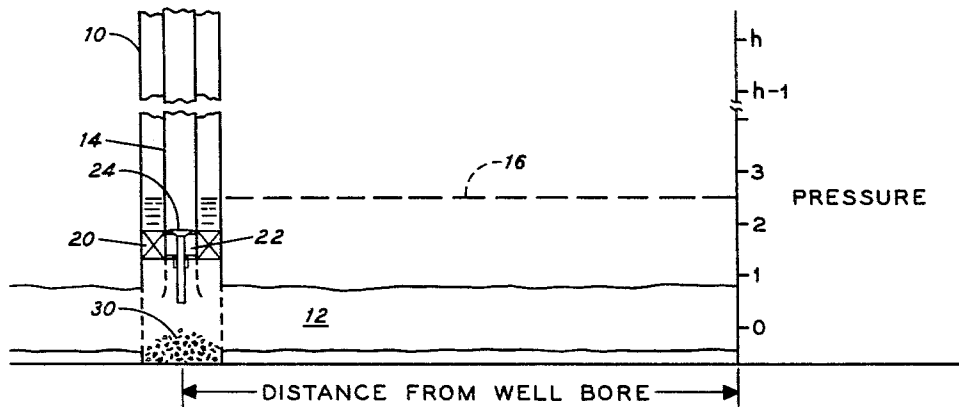


FIG. 5

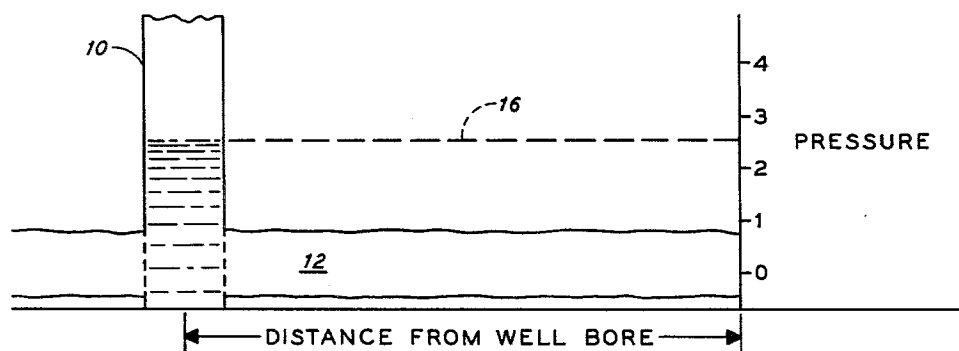


FIG. 6

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5 Sheets-Sheet 3

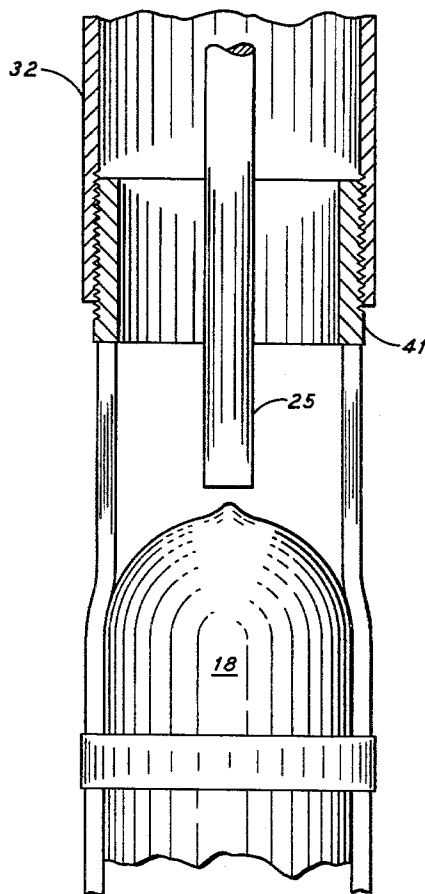
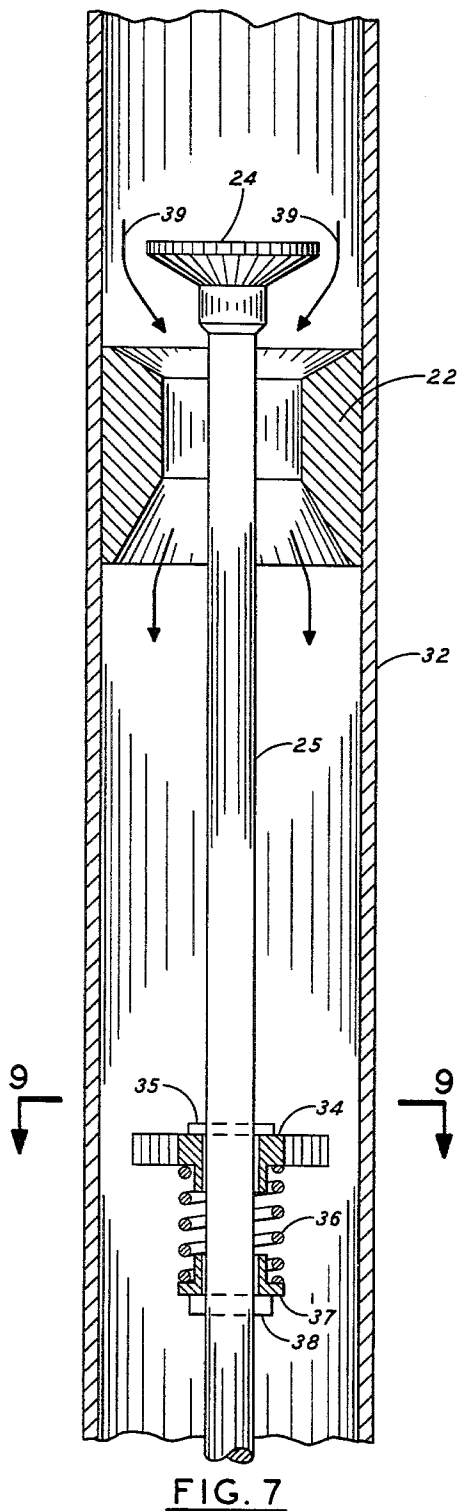


FIG. 8

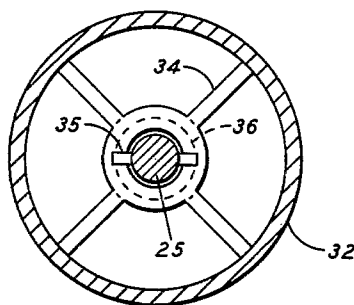


FIG. 9

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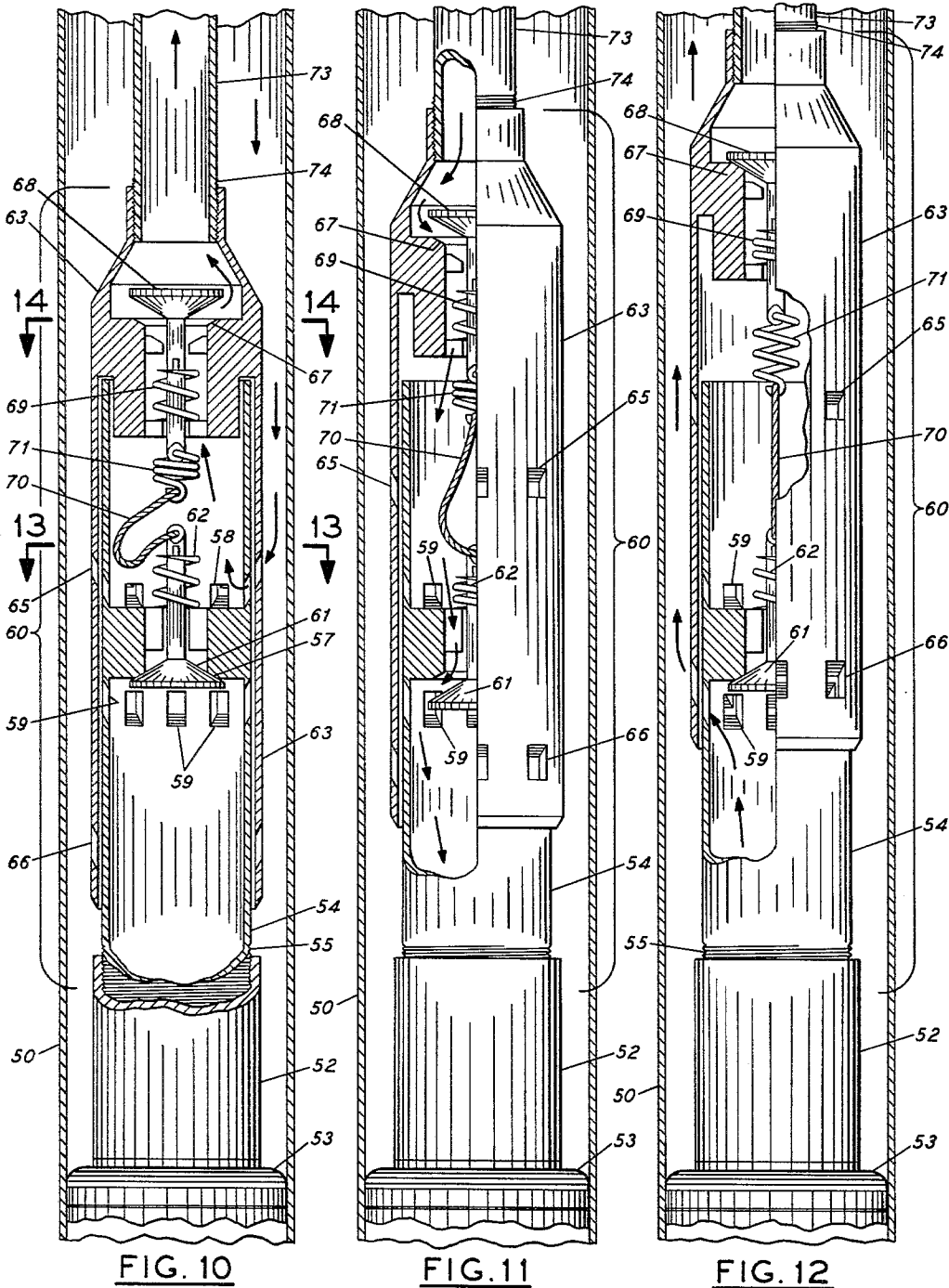


FIG. 10
FIG. 11
FIG. 12
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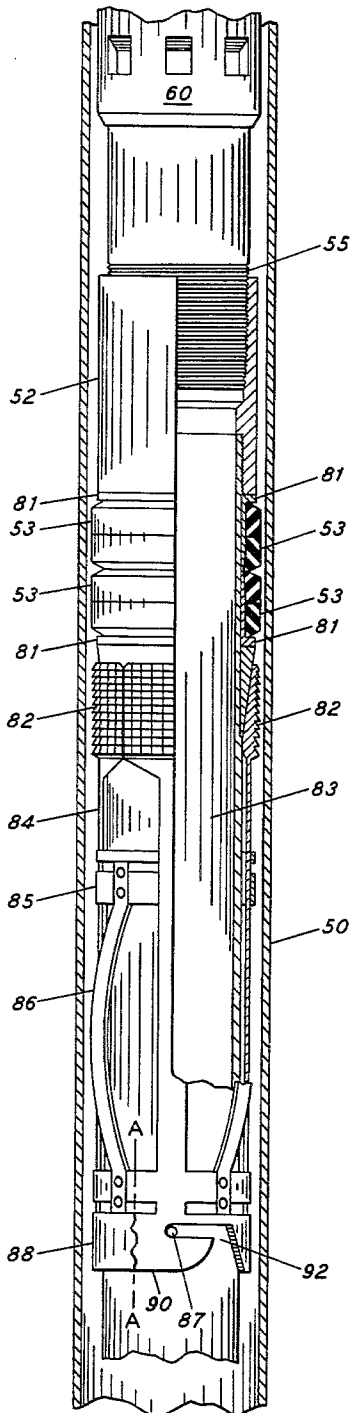


FIG. 15

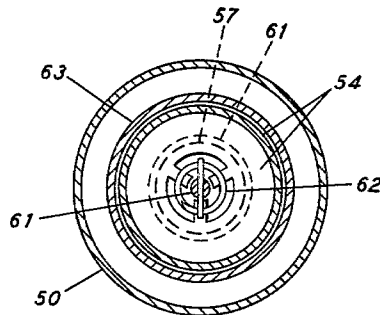


FIG. 13

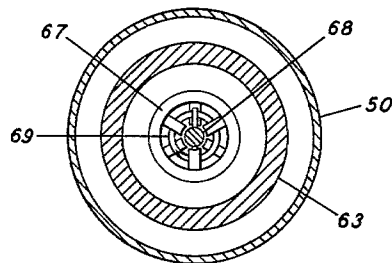


FIG. 14

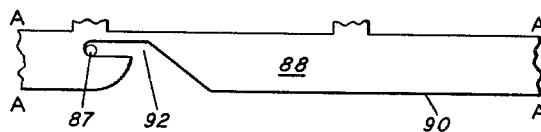


FIG. 16

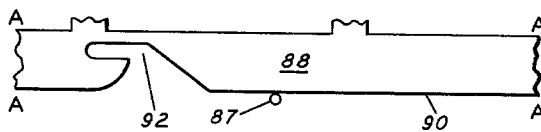


FIG. 17

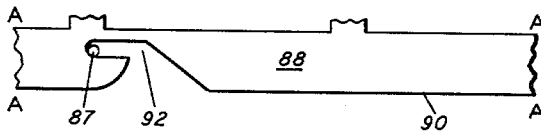


FIG. 18

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1

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METHOD AND APPARATUS FOR WELL STIMULATION

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Filed June 29, 1961, Ser. No. 120,603

8 Claims. (Cl. 166—36)

This invention relates to a method and apparatus for improving well productivity and more particularly, this invention relates to a method and apparatus for improving oil well productivity by providing a hydraulic surge from a producing formation by a sudden reduction in pressure in a well penetrating the producing formation to improve fluid flow therefrom.

Many oil wells are abandoned as being economically unproductive and many others are mediocre producers because of poor fluid flow from the producing formation into the production well. A prime cause of this sluggish fluid flow is plugging of the producing formation or of the production liner in the well adjacent the producing formation by unconsolidated or semiconsolidated foreign matter. For example, unconsolidated fine formation rock material deposited near the producing well may subsequently retard fluid flow by bridging. Deposition of asphalt or asphalt products in the formation surrounding the producing well is also a commonly encountered problem. These problems are particularly troublesome in wells located in low pressure formations or in wells located in higher pressure formations where the available drawdown differential between the formation and the producing well is incapable of removing fluid flow restrictions from the perforations of a well liner or from the formation.

One method heretofore known in the art and directed at improving fluid flow into a producing well from a formation is taught in U.S. Patent No. 2,361,558. As there disclosed, a sharp liquid surge is provided in a well by means of positioning a pressure-resistant frangible fluid filled container at a desired elevation in a well and fracturing the container to create a low pressure area in the liquid in the well to effect a surge of liquid from all directions by the compression of the gaseous fluid by the liquid column in the well. The method as taught therein depends on the height of the liquid column in the well to provide the hydraulic surge. As the frangible container is fractured, the liquid column in the well is left unsupported and it falls into the low pressure void thereby created. When the liquid column strikes the bottom of the space occupied by the low pressure fluid, a tremendous force is suddenly exerted on the well which absorbs the kinetic energy of the falling liquid column. The theory is that the fluid production from the well will be improved by means of the hydraulic surge therein created. Frequently, however, the sudden force exerted on the well, as described above, causes damage to the formation walls and does little to improve fluid flow therefrom.

Another method practiced in the prior art to improve oil recovery from a producing formation has been the use of pressure bailers. The pressure bailer, as known in the art, utilizes the pressure differential between the well bottom and the interior of the bailer to cause a vacuum-cleaner-like action on the debris located at the bottom of the well. This is accomplished by lowering the pressure bailer, the interior of which is usually at atmospheric pressure, to the bottom of a liquid filled well. The pressure bailer is then opened to the bottom hole pressure so that liquid at the bottom of the well will enter and the resulting inrush of liquid carries

2

with it debris accumulated on the bottom of the well. The bailers are generally used to remove debris which has fallen into the well from unconsolidated formations penetrated by the well. The pressure bailers are not primarily a stimulation tool; however, if one were to be used as a stimulation tool, the falling fluid column would again create a sudden force on the well. If a bailer is allowed to gradually take in liquid to prevent the sudden force on the well caused by the falling fluid column, the hydraulic surge effect is not great enough to promote fluid flow from the formation.

It is an object of the present invention to provide a method and apparatus to create a relatively low pressure zone in a well selectively communicable with a preselected higher pressured producing formation, opening the relatively low pressure zone to communicate with the higher pressured formation while simultaneously isolating the fluid column in the well above the relatively constant low pressure zone, thereby causing a hydraulic surge in the well, the principal portion of said surge coming from the producing formation.

It is a further object of the present invention to provide a method and apparatus for promoting fluid flow from a producing formation by means of a hydraulic surge from said formation wherein the hydraulic surge may be repeated a plurality of times without removing the apparatus from the well.

Briefly, the present invention provides for improving fluid flow from a producing formation by causing a hydraulic surge from the formation by first establishing a zone of relatively constant pressure in a liquid column in a well selectively communicable with said formation, increasing the pressure on said formation, suddenly causing communication between said formation and said zone of relatively constant pressure and simultaneously isolating said zone of relatively constant pressure from the liquid column in the well to create a hydraulic surge, the principal portion of which comes from the producing formation.

Additional advantages and objects of the present invention will become apparent from the following detailed description and the accompanying drawings which are made a part of the present specification.

FIGS. 1 through 6 diagrammatically illustrate one form of apparatus during the successive steps of the method of the invention with graphic indications of the pressure differentials between the formation and the well.

FIG. 7 is a vertical view partially in section of the upper portion of one embodiment of apparatus useful in accomplishing the method of the present invention.

FIG. 8 is a continuation of FIG. 7 showing the lower portion of the same embodiment of apparatus useful in practicing the method of the invention.

FIG. 9 is a sectional view at 9—9 of FIG. 7.

FIG. 10 is a vertical view partially in section of an alternative embodiment of apparatus useful in practicing the method of the present invention, said apparatus positioned to remove fluids from the annulus between the well casing and the well tubing.

FIG. 11 is a vertical view partially in section of the same alternate embodiment of apparatus, said apparatus positioned to permit fluid flow through well tubing into a selected formation.

FIG. 12 is a vertical view partially in section of the same alternate embodiment of apparatus, said apparatus positioned to cause a fluid surge in the selected formation by permitting fluid flow from said selected formation into the annulus between the well casing and well tubing.

FIG. 13 is a sectional view at 13—13 of FIG. 10.

FIG. 14 is a sectional view at 14—14 of FIG. 10.

FIG. 15 is a vertical view partially in section of a packer suitable for use with the alternate embodiment of apparatus.

FIGS. 16, 17, and 18 are unrolled views of an improved locking cage in the packer illustrated in FIG. 15.

Referring specifically to FIG. 1, a well 10 is shown penetrating producing formation 12. The formation pressure near well 10 is represented by curve 16. The pressure scale for curve 16 is representative only and is not intended to indicate any particular formation pressures for which the method of the invention is useful. FIG. 1 illustrates the production well 10 and the producing formation in a static condition prior to practicing the method of the invention, as if the well were shut in so that there is no pressure differential across the wall of the well.

FIG. 2 diagrammatically illustrates one embodiment of apparatus, useful in practicing the method of the present invention, positioned in well 10. The apparatus as shown comprises a pack-off means 20, a means for creating a relatively constant pressure zone as, for example, frangible pressure-resistant container 18, a tubing string 14 communicating with the surface, a valve seat means 22 and a valve means 24 arranged to allow for interruptible communication through tubing string 14 between the producing formation 12 and the surface and adapted to break frangible container 18 when the valve means 24 seats.

As indicated by curve 16a the pressure on formation 12 is increased. This may be accomplished in any suitable manner, for example, a liquid column may be established in tubing string 14. The liquid extends up tubing string 14 a predetermined distance to give a desired pressure increase on formation 12. In many cases it is desirable not only to fill tubing 14 with liquid but also to pump liquid into formation 12 by means of pumps connecting to tubing string 14 at the surface. In this manner any reasonable pressure may be placed on the formation 12.

In FIG. 3 curve 16b illustrates the pressure drop in formation 12 resulting from suddenly opening communication between the zone of constant pressure established by pressure-resistant frangible container 18 and the higher pressured producing formation 12. The frangible container 18 is shattered by the valve means 24 at it seats on valve seat 22. The valve means 24 may be actuated by any suitable means, for example, rod 28 dropped from the surface through tubing 14. Valve means 24 seats on valve seat 22 as it shatters frangible container 18. Therefore, the hydrostatic head of the liquid column in tubing string 14 above valve seat 22 is prevented from damaging the formation or lessening the effect of the liquid surge from the formation by the liquid column falling into the void created by the shattered low pressure frangible container 18.

Pressure curves 16c, 16d, 16e, and 16f in FIG. 4 illustrate the effect of isolating the newly created relatively constant pressure zone from the fluid column above valve seat 22. The resulting surge of high pressure liquid into the lower pressured zone is primarily from producing formation 12. As indicated by curves 16c, 16d, 16e, and 16f, there is no great force exerted on formation 12 caused by a falling fluid column.

FIGS. 5 and 6 illustrate the formation after completion of the hydraulic surge. In FIG. 5, debris 30 which has been removed from formation 12 is shown collecting on the bottom of well 10. The tubing string 14 is pulled from well 10 in a conventional manner. A conventional pressure bailer as described above may be run to clean the accumulated debris 30 from the bottom of well 10. In FIG. 6, well 10 and producing formation 12 are shown at the completion of the process. The producing well 10 is now ready for return to production.

FIG. 7 is a vertical view partially in section of the upper part of one embodiment of apparatus useful in prac-

ticing the method of the present invention. As there shown, the interior wall of a conventional formation packer or the wall of a tubing string is represented by 32. Valve seat 22 is arranged on wall 32 at a preselected place. The valve seat is adapted to receive valve means 24 and the extension 25 thereof. Initially valve means 24 is in a position to allow communication through valve seat 22 as indicated by arrows 39. The valve seat 22 and valve means 24 are adapted to interrupt communication there-through when the valve means 24 is seated in valve seat 22.

One suitable means of closing valve means 24 is a heavy rod inserted into the tubing string at the earth's surface and allowed to fall through the tubing string and strike valve means 24. The impact shears pin 35 and causes valve means 24 to seat in valve seating 22. Other suitable means, for example, a heavy ball or a sudden pressure surge, may be utilized within the spirit of the invention to close valve means 24.

Guide means 34 attached to wall 32 holds the valve means in its initial open position by means of shear pin 35 in the valve means extension 25. The valve means 24 may be spring loaded as for example, by spring 36, collar 37 and pin 38 in insure positive seating of valve means 24 when pin 35 is sheared.

FIG. 8 is a vertical view partially in section of the lower part of the same embodiment of apparatus shown in FIG. 7 illustrating one manner of operably connecting frangible container 18 and wall 32. As there shown, container 18 is carried on frame 41 and is secured to interior wall 32 by threaded connection. Valve means extension 25 is located immediately above frangible container 18 when valve means 24 is open to insure positive breakage of container 18 when valve means 24 is seated. Container 18 may be any suitable type of pressure-resistant frangible container. The container must be adjusted to resist the pressure to which it is subject prior to breaking it. The frangible container is preferably constructed of glass or plastic or a similar frangible material. One frangible container suitable for use in the present embodiment of apparatus is the Dowell Implosion Capsule as manufactured by the Dowell Manufacturing Company, a subsidiary of the Dow Chemical Company.

FIG. 9 is a sectional view taken at 9—9 of FIG. 7. FIG. 9 shows the portion of the guide means 34 which is open to liquid flow.

Referring now to FIGS. 10, 11, and 12, an alternative embodiment of apparatus is shown in the three positions required to perform the method of the invention. As herein illustrated, 50 represents a well casing. The method of the invention may be practiced in an uncased well, however, it is usually preferred in the art to case producing wells. The interior of casing 50 is packed off above a producing formation (not shown) by means of a packer 52. The pack-off is accomplished by means of packer element 53. The only communication therefore, between the producing formation and the surface of the earth is through tubing string 73, the surge stimulator assembly indicated as 60 and the interior of packer 52.

Lower body member 54 of the surge stimulator assembly 60 is secured to packer 52 by a suitable means such as the threaded joint at 55. Body member 54 is provided with a valve seating 57. Port means 58 are above valve seating means 57 and port means 59 are below valve seating 57. Valve 61 is mounted in the valve seat 57 and is spring loaded by spring 62 so as to be normally in a closed position, resistant to fluid flow from below.

Upper body member 63 is slidably mounted over lower body member 54. The body members 63 and 54 are desirably constructed to have tolerance close enough to prevent the passage of high pressure fluid therebetween. The upper body member is provided with ports 65 and ports 66. By selectively positioning the upper body member 63 with respect to the fixed lower body member 54, ports 65 in upper body member 63 may be selectively

5

communicable with ports 58 in lower body member 54 and ports 66 in upper body member 63 may be selectively communicable with ports 59 in lower body member 54. Upper body member 63 is provided with valve seating 67 and valve means 68. The valve 68 is spring mounted by spring 69 in a normally open to flow position. The valve 68 in upper body member 63 is connected to valve 61 in lower body member 54 by means of wire line 70 and spring 71. Upper body member 63 is connected to a string of tubing 73 extending from the surface by means of a suitable connection such as threaded joint 74.

The surge stimulator assembly 60 and packer 52 are preferably connected at the surface and are lowered into the borehole by means of tubing string 73. Packer 52 is positioned above the formation to be stimulated and pack-off element 53 is set to pack off the annulus between stimulator assembly 60 and casing 50 from the formation.

Referring now specifically to FIG. 10, the surge stimulator assembly 60 is positioned as there shown by a downward force exerted on tubing 73 from the surface after packer 52 has been set. By this adjustment lower body member 54 and upper body member 63 are positioned to allow communication between the interior of tubing string 73 and the annulus above packer elements 53, through ports 65 and ports 58 and valve seat 67. Valve 61 in lower body member 54 is in its normally closed position and valve 68 in upper body member 63 is opened to fluid flow. In this position, liquid in the annulus will flow to the interior of surge stimulator assembly 60 through the communication provided by ports 58 and 65. From there the liquid may be pumped to the surface by means of a suitable pump inserted in the interior of tubing 73. The fluid in the annulus is removed in this manner to provide a zone of relatively low pressure selectively communicable with the producing formation below packer elements 53.

In FIG. 11 the stimulator assembly 60 has been moved to its second position. This adjustment is accomplished by raising the tubing string 73 a predetermined distance at the surface. In this position there are no ports in line to open communication between the interior of the stimulator assembly 60 and the annulus. Valve 68 in upper body member 63 is in its normal position which allows fluid flow through the valve. Spring loaded valve 61 in lower body member 54 is shown in the opened position. When the tool is in the position as shown in FIG. 11, the formation is pressurized by means of a liquid column which is established in tubing 73 and pressure applied thereon. The pressure applied to the liquid opens spring loaded valve 61 to liquid flow into the formation to be stimulated. The formation is pressurized to a predetermined pressure. This pressure should be in excess of the static formation pressure and preferably should be in the order of at least 200 p.s.i. above the static formation pressure.

Referring now to FIG. 12, the surge stimulator assembly 60 is shown in its third position. As there shown, the upper body member 63 and lower body member 54 have been expanded to their expandable limit by raising the tubing string 73 a predetermined amount to its highest position. Valve means 61 is closed to fluid flow up the interior of surge stimulator assembly 60 and the liquid column remaining in tubing string 73 is isolated from the constant pressure zone in the annulus by the surge stimulator assembly 60. Ports 59 in lower body member 54 and ports 66 in upper body member 63 are now open thereby allowing communication between the annulus and the producing formation. Since the annulus is at a low relatively constant pressure which is substantially atmospheric pressure and the formation is under an elevated pressure as heretofore described, a fluid surge is created from the formation. When pressurized fluid in the formation is suddenly relieved to the lower pressure annulus as shown in FIG. 12, the highly pressurized fluid in and

6

about the formation suddenly surges through the stimulator tool into the annulus. This surge of fluid brings about the well stimulation as provided by the method of the invention. Since valve 68 is closed by cable 70 when the surge stimulator assembly 60 is expanded to maximum position, no damaging force is exerted on the formation by the hydrostatic head created by the fluid column in tubing 73 above the stimulator assembly 60.

FIG. 13 is a section taken at 13—13 of FIG. 10 showing the casing 50, the upper body member 63, the lower body member 54, valve seat 57, valve means 61, and spring 62. As there shown, the path for fluid flow through valve seat 57 is illustrated.

FIG. 14 is section 14—14 of FIG. 10 showing casing 50, upper body member 63, valve seating 67, spring 69 and valve 68. As there shown, the path for fluid flow through valve seat 67 is illustrated.

FIG. 15 is a vertical view partially in section illustrating an improved packer useful in the present invention. The improved packer is particularly useful when it is desired to stimulate at different producing horizons in a well without having to pull the tubing string out of the well after each stimulation. The packer as here shown may be run in on the tubing string with the stimulator tool, and the packer set, stimulation accomplished, the packer freed, the tool moved to a new location in the well and the cycle repeated.

The packer illustrated in FIG. 15 is similar to a CO Packer of the valveless, hook-wall type manufactured by Lane-Wells, Incorporated and shown on page 2916 of the Composite Catalog of Oil Field Equipment and Services, 1958—59, published by World Oil. Two important improvements, however, have been incorporated into that design to prepare the packer for use with the stimulator assembly.

In order that the packer may be set and then released it is necessary that the packer mandrel 83 is free to turn when the rubber packing rings 53 are expanded against the well wall or the casing. To allow the packer to rotate when the packing rings are expanded, bushings 81 are inserted between the mandrel 83 and the packing rings 53. The bushings 81 are preferably sized so that when the packing rings are fully expanded the bushings 81 contact each other and thus substantially completely separate the packing rings 53 and the mandrel 83.

The second improvement in the packer in FIG. 15 comprises important modifications in the locking cage 88.

The locking cage 88 is a flat curved surface extending around mandrel 83. The improvement in the locking cage 88 and the manner of utilizing the improved packer in the invention can be better understood by reference to FIG. 16, FIG. 17 and FIG. 18 along with FIG. 15. FIG. 16, FIG. 17 and FIG. 18 are views of the locking cage 88 as it would look if it were cut at A—A on FIG. 15 and unrolled from its position around mandrel 83. The improvement in locking cage 88 comprises constructing the locking cage with a flat lower surface indicated at 90. A notch 92 is the only break in the flat lower surface 90 of locking cage 88. The notch 92 is provided with rounded corners to facilitate engaging and disengaging dowel pin 87 when mandrel 83 is rotated inside the locking cage 88.

In operation, the packer is connected to the stimulator tool 60 by collar 52 and positioned at a desired location in a well bore. The slips 82 are locked in a retracted position by dowel pin 87 held in the angular notch 92 as illustrated in FIG. 16. The slips 82 are unlocked from this retracted position by turning mandrel 83 about one-eighth turn counterclockwise. Friction spring 86 then forces slips 82 against the casing 50 as mandrel 83 is lowered. Continued lowering of mandrel 83 with resulting application of weight sets the slips 82 firmly against the casing 50 and expands the packing rings 53 to form the pack-off. By rotating mandrel 83 counterclockwise about one-fourth turn, the locking cage 88 and dowel pin 87 are in the relative position illustrated by FIG. 17 and the slips 82

and the packing rings 53 are locked in expanded position.

After the completion of the well stimulation procedure the mandrel 83 is rotated clockwise until the slips 82 are unlocked by dowel pin 87 engaging the angular notch in locking cage 88 as illustrated in FIG. 18. The slips may be disengaged by an upward motion of the tubing string and then retracted by the spring collar 85 to the original retracted position. The slips 82 and the packing rings 53 are now again locked in a retracted position. The simulator is ready to be repositioned and the operation repeated.

As is evident from the specification, the invention provides a novel method and apparatus for well stimulation.

The invention having been fully described and illustrated, we claim:

1. A method of improving fluid flow from a petroleum-bearing information penetrated by a well comprising establishing a zone of constant pressure in said well selectively communicable with said formation, injecting a liquid into said well to increase the pressure on said formation above said constant pressure while retaining said zone at said constant pressure, isolating said formation and said zone of constant pressure from said liquid in said well above said formation and opening communication between said formation and said zone of constant pressure to create a surge of fluid primarily from said formation into said zone.

2. A method of improving fluid flow from a producing formation penetrated by a well comprising positioning at a predetermined location in said well as pressure-resistant frangible container, injecting a liquid into said well to increase the pressure on said formation and said frangible container to a pressure above the pressure in said frangible container and simultaneously fracturing said frangible container and isolating said frangible container and said formation from the hydrostatic head of said liquid above said predetermined location in said well.

3. A method of improving fluid flow from a producing formation penetrated by a well comprising positioning at a predetermined location in said well a pressure-resistant frangible container, injecting a liquid into said well to increase the pressure therein to a pressure above the pressure in said frangible container, isolating that portion of said well containing said frangible container from the hydrostatic head of said liquid above said predetermined location and fracturing said frangible container to cause a fluid surge from said formation.

4. Apparatus for well stimulation comprising means for establishing a zone of relatively low pressure in a well selectively communicable with a producing formation, packer means packing off said well above said producing formation, liquid communication means extending through said packer means to establish a flow path between said formation and the surface, said liquid communication means providing the only flow path for liquid to said formation from said surface, means adjacent said packer means for closing said flow path to the downward flow of liquid, and means for opening communication between said producing formation and said zone of relatively low pressure.

5. Apparatus for well stimulation comprising a tubing string extending from the surface of the earth into a well, means packing off said well above a producing formation,

said pack-off means being in operable relationship with said tubing string to provide therewith the only communication from the earth's surface to said producing formation, means for establishing a zone of constant pressure selectively communicable with said producing formation, valve means adjacent said pack-off means and in operable relationship with said tubing string to first allow liquid flow to said formation from the surface through said tubing string and to later isolate said formation from liquid in said tubing string above said valve means and means for opening communication between said formation and said zone of constant pressure.

6. Apparatus for well stimulation comprising a tubing string extending into a well from the surface of the earth, valve means in said tubing string, said valve means normally open to liquid flow therethrough, a downward extension on said valve means, means packing off the annular space between the exterior of said tubing and said well wall, and a frangible pressure-resistant container located in said well below said valve means and positioned with respect to said downward extension so as to be in breakable contact thereto on closing said valve means.

7. Apparatus for well stimulation comprising a tubing string extending into a well from the surface, valve means in said tubing string, said valve means normally open to liquid flow therethrough, a downward extension on said valve means, means packing off the annular space between the exterior of said tubing and said well wall above said producing formation, a frangible pressure-resistant container operably connected to said tubing below said valve means and positioned with respect to said downward extension so as to be in breakable contact thereto on closing said valve means and means for closing said valve.

8. Apparatus for use in well stimulation comprising means establishing a zone of constant pressure in a well, packer means packing off said well above a preselected formation, liquid flow path means extending from the earth's surface through said packer means to provide the only fluid communication from the surface to said formation and cooperating means for simultaneously closing said liquid flow path means to the downward flow of liquid adjacent said pack-off means and opening communication between said zone of constant pressure and said formation.

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