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3,173,486

APPARATUS FOR GRAVEL PACKING WELLS

Filed Oct. 3, 1961

3 Sheets-Sheet 1

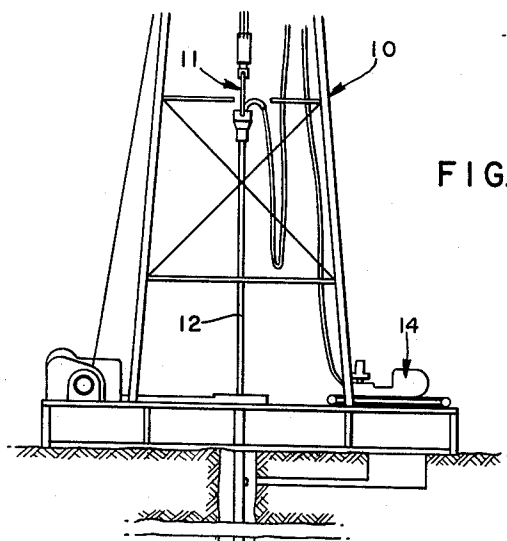


FIG. 1.

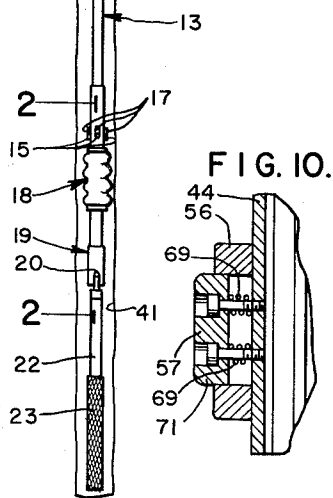


FIG. 10.

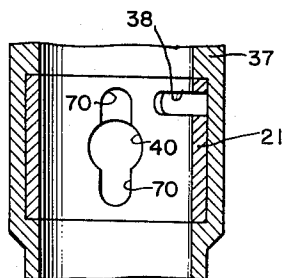
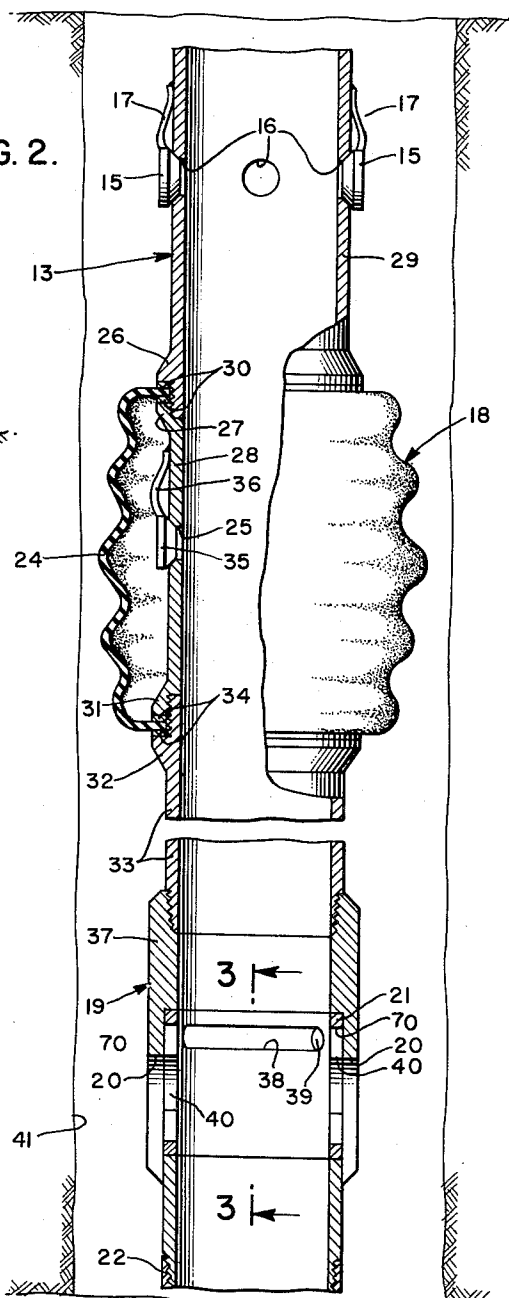


FIG. 3.

FIG. 2.



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3 Sheets-Sheet 2

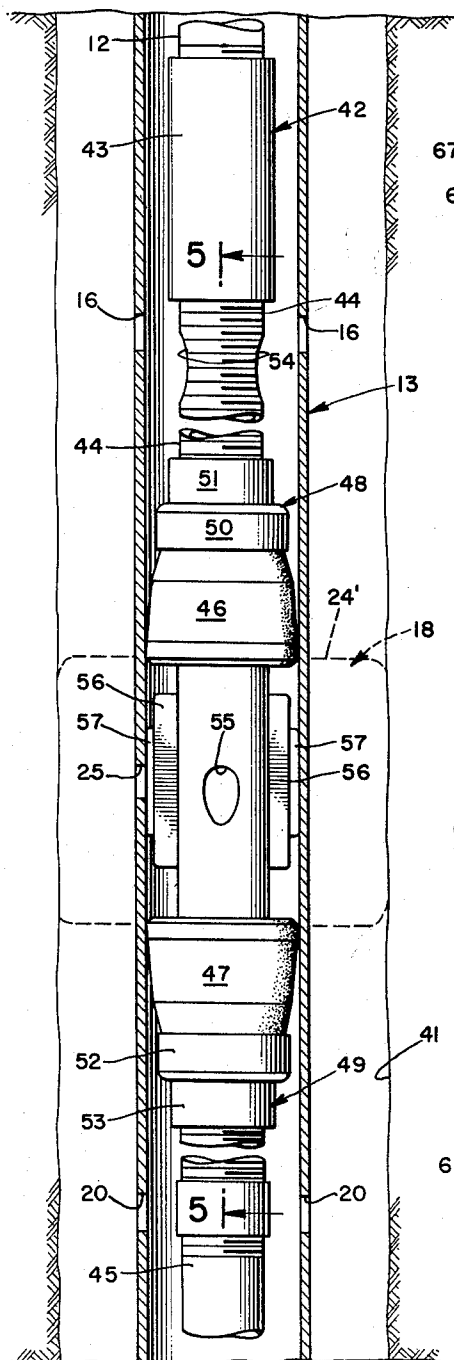


FIG. 4.

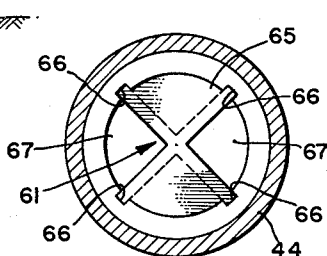


FIG. 6.

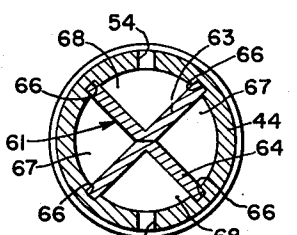


FIG. 7.

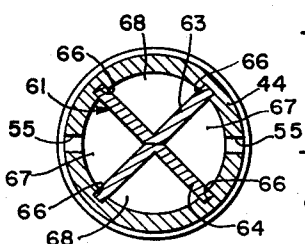


FIG. 8.

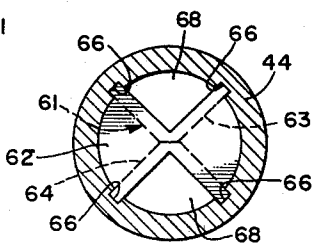


FIG. 9.

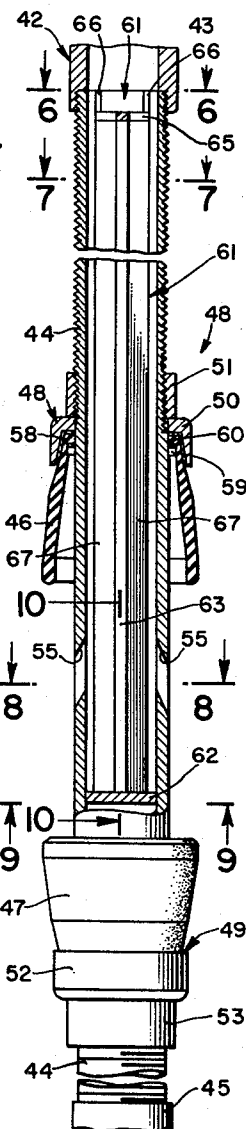


FIG. 5.

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APPARATUS FOR GRAVEL PACKING WELLS

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1 Claim. (Cl. 166-116)

This invention relates to the art of carrying out operations in well bores, and more particularly to a tool for use in a well.

The present invention will have a scope of application larger than that specifically described herein. For example, the invention may be useful in carrying out acidizing, water injection, or gas injection operations in most any type of fluid, such as a water or gas well, although the invention is not to be limited to such uses in these environments. However, the present invention has been found to be especially useful when employed in gravel packing and cementing oil wells.

In the past, it has been the practice to drill a well, lower casing into it, and cement the casing in place. Following this procedure, a method of underreaming the hole below the casing has been performed to provide a space below the casing larger in diameter than the inside diameter of the casing in order that gravel may be deposited in such a space. This underreaming operation takes a rather long length of time to perform and can be accomplished only with considerable difficulty.

The present invention overcomes the above described and other disadvantages of the prior art by providing an apparatus for use in a method of completing a well including the steps of lowering pipe of an outside diameter smaller than the inside diameter of the well bore to a first depth therein, setting a packer in the space between the external surface of the pipe and the well bore at a second depth therein above the first depth to prevent flow of fluid in the space from a position on one side of the packer to a position on the other side thereof, and packing gravel in the space between the pipe in the well bore below the second depth. By the use of such a method, underreaming is made unnecessary because cementing can be limited to the depth of the packer and the space below the packer filled with gravel. Note will also be taken that gravel packing may be conveniently performed prior in time to cementing, the packer and the gravel thus providing a lower support for a column of cement between the well casing pipe and the well bore. One outstanding feature of the present invention involves the use of the self same tool not only to set the packer, but also to perform an additional operation such as gravel packing or cementing or both of these additional operations.

According to another feature of the present invention, a packer assembly is provided including a length of pipe, an inflatable toroidal-shaped flexible membrane fixed to the pipe therearound, the pipe having an opening therethrough providing free and open communication between the interior thereof and the interior of the membrane, and means for providing a fluid tight seal for the opening. By using a valve seat on the external surface of the casing pipe around the opening therein into the membrane, and a valve to rest on the seat biased by a spring in a direction to close the casing opening, the packer may be easily and quickly set by the use of exactly the same apparatus that is employed in gravel packing and cementing. That is,

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means may be employed to direct fluid pumped into the upper end of a pipe inside the casing through the casing opening to inflate and expand the packer to seal off the space between the casing and the well bore above the packer from the space between the casing and the well bore below it.

The above described and other advantages of the present invention will be better understood from the following description when considered in connection with the accompanying drawings.

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a broken side elevational view of apparatus constructed in accordance with the present invention;

FIG. 2 is a longitudinal sectional view taken on the line 2-2 of the apparatus shown in FIG. 1;

FIG. 3 is a longitudinal sectional view of a sleeve employed in a port collar taken on the line 3-3 shown in FIG. 2;

FIG. 4 is a longitudinal sectional view of apparatus which may be employed inside a string of casing shown in FIGS. 1 and 2 in accordance with the invention, the casing and well bore in FIG. 4 being illustrated diagrammatically;

FIG. 5 is a sectional view taken on the line 5-5 of the apparatus shown in FIG. 4;

FIGS. 6, 7, 8 and 9 are transverse sectional views of the tool taken on the lines 6-6, 7-7, 8-8 and 9-9 respectively shown in FIG. 5;

FIG. 10 is a longitudinal sectional view taken on the line 10-10 of the tool shown in FIG. 5;

FIG. 11 is a side elevational view of the apparatus shown in FIG. 4 in a different position inside a string of casing illustrated schematically therein; and

FIG. 12 is a side elevational view of the apparatus shown in FIG. 4 in still another and different position inside a string of casing shown diagrammatically therein.

Some of the apparatus of the present invention is illustrated in FIG. 1 including a derrick 10 having means thereon including a kelly 11 to raise and lower a pipe 12 downwardly inside a string of casing 13 or raising it outwardly therefrom. A mud pump 14 is also shown in FIG. 1 for circulating a fluid downwardly through pipe 12 and receiving a return of the same, if the same does return, outwardly from the space at the top of the string of casing 13 between that string and the pipe 12.

At the lower end of the string of casing 13, valves 15 are shown which cover upper openings 16 through the wall of casing 13, as shown in FIG. 2, valves 15 being biased to their closed positions by leaf springs 17. Four valves 15, four openings 16 and four springs 17 are employed, only three valves 15 being indicated in FIG. 1 due to the view taken. The valves 15 are located 90° apart around the circumference of casing 13.

A bag packer 18 is provided around the circumference of casing 13 below valves 15 as shown in FIG. 1.

Casing 13 also includes a port collar 19 which is provided with openings 20 therethrough which may be opened and closed by rotation of a sleeve 21 shown in FIG. 2. The lower end of casing 13 includes a section of pipe 22 which is threaded onto the lower end of port collar 19, the lower end of pipe section 22 being covered with a screen 23. Screen 23 may be, for example, an 80 mesh wire screen.

As shown in FIG. 2, bag packer 18 may include a

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flexible or elastic membrane 24. Membrane 24 is shown in a deflated condition in FIG. 2, but may be inflated to the dotted line position indicated at 24' in FIG. 4 to a toroidal-shape by introducing fluid under pressure through an intermediate opening 25 through the wall of casing 13. The upper rim of membrane 24 is retained between a flange 26 and the upper end 27 of a pipe section 28 threaded onto a pipe section 29 of casing 13. The upper rim of membrane 24 may be provided with metal rings 30 bonded to opposite sides thereof.

The lower rim of membrane 24 is retained between a flange 31 on pipe section 28 and the upper end 32 of a pipe section 33 of casing 13 threaded onto pipe section 28. Membrane 24 may be provided with rings 34 on opposite sides of the lower rim thereof identical to rings 30. As shown in FIG. 2, opening 25 is provided with a valve 35 to control the flow of fluid therethrough. Valve 35 is biased by a leaf spring 36 to keep opening 25 closed unless the pressure in casing 13 thereat exceeds the pressure between the casing 13 and membrane 24.

Also, as shown in FIG. 2, port collar 19 comprises a body portion 37 threaded onto pipe section 33 in which sleeve 21 is rotatable. A slot 38 is provided in sleeve 21 in which a pin 39 fixed with body 37 slides to limit rotational movement of sleeve 21 inside body 37 to a predetermined angle. In the position shown, openings 40 in sleeve 21 shown in FIGS. 2 and 3 lie in registry with openings 20, whereby fluid inside casing 13 may pass outwardly of lower openings 20 therein. When sleeve 21 is rotated to its limit of travel in a right hand direction as viewed from the top of the well which has a bore indicated at 41 in FIG. 1, openings 40 will not lie in register with any portion of openings 20 shown in FIGS. 2 and 3, and fluid flow into or out of casing 13 through openings 20 from or into the bore 41 of the well will be prevented.

That apparatus shown in FIGS. 1, 2 and 3 is only a portion of the apparatus of the present invention. In actual practice, an internal construction indicated generally at 42 in FIG. 4 is also employed inside casing 13, the control of which is effected by manipulation of pipe 12. The internal construction 42 was not illustrated in FIG. 2 for the sake of clarity. However, construction 42 is in fact employed inside casing 13 in the vicinity of those structures shown in FIG. 2. Casing 13 is indicated generally in FIGS. 4, 11 and 12. However, casing 13 is indicated only diagrammatically in FIGS. 4, 11 and 12 for the sake of clarity. In FIG. 4, openings 16 are indicated by breaks in casing 13 as well as openings 25 and 20. Note will be taken that all of the openings 16, 25 and 20 are provided with closure means at 15, 35 and 21. The structure of such closure means themselves and their open or closed states are not illustrated in any of FIGS. 4, 11 and 12 for clarity; however, the open or closed states of these closure means will be specifically set out in the description to follow for each of the FIGS. 4, 11 and 12 individually.

Construction 42 includes a tool joint 43 into which pipe 12 is threaded. A threaded pipe section 44 is connected from the bottom of tool joint 43 to a stinger 45 at the lower end of the construction 42. Pipe 44 is threaded only at its upper and lower ends and not at the center thereof. Upper and lower Guiberson cups 46 and 47 are held in fixed spaced positions on pipe 44 by means of assemblies 48 and 49. Assembly 48 includes a retaining ring 50 and a lock nut 51. Assembly 49 includes a retaining ring 52 and a lock nut 53. The upper end of pipe 44 is provided with a pair of oppositely disposed ports or openings 54. Pipe 44 is also provided with a pair of oppositely disposed openings 55 therethrough between cups 46 and 47 as shown in both FIGS. 4 and 5.

A mounting bracket 56 is fixed with each side portion of pipe 44 between cups 46 in a position midway between ports or openings 55 around the circumference of pipe 44, a pawl 57 slidable in brackets 56 is also provided.

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Although the direction of cups 46 and 47 are reversed in both FIGS. 4 and 5, assemblies 48 and 49 are otherwise identical. For this reason, a sectional view of only assembly 48 has been illustrated and will be described. Cup 46 is provided with a metal backing plate 58 bonded thereto between cup 46 and retaining ring 50. Pipe 44 is provided with a flange 59. Cup 46 is thus retained effectively between nut 51 and flange 59. Shims may be employed between flange 59 and cup 46 to determine the axial position of cup 46 on pipe 44, one such shim 60 being shown in FIG. 5.

Substantially, all the structure shown in FIG. 4 is again shown in FIG. 5. However, ports 54 through opposite sides of pipe 44 are not shown in FIG. 5 because the sectional view of FIG. 5 is taken on the line 5—5 shown in FIG. 4 and a baffle assembly 61 is employed inside pipe 44 between a position slightly above ports 54 to the position of a plate indicated at 62 to cover the only port 54 which otherwise could be seen in the view of FIG. 5.

Baffle assembly 61 includes a pair of angle irons 63 and 64 which are welded together to the interior of pipe 44 to provide four separate longitudinal passageways from the position of plate 62 to a second plate 65. Angle irons 63 and 64 have their longitudinal edges located in four corresponding longitudinal slots 66 in the bore of pipe 44. Plate 65 is welded to the upper edges of both legs of each angle iron 63 and 64 as shown in FIG. 6, whereby fluid pumped downwardly through pipe 12 will enter only the longitudinal passageways between the legs of angle irons 63 and 64 indicated generally at 67 in FIG. 6. Fluid entering passageways 67 cannot escape from these passageways except through ports 55 in pipe 44 because no opening is provided through angle irons 63 or 64 or through pipe 44 except at ports 55. Fluid flow in passageways 67 cannot continue past ports 55 because passageways 67 are closed by plate 62 of a construction identical to plate 65, but located at a position 90° from that shown in FIG. 6. Fluid rising upwardly in pipe 44 can enter in a pair of oppositely disposed passageways 68 as shown in FIG. 9, but the upper end of these passageways 68 are closed by plate 65. Ports 54 are located below plate 65 through the wall of pipe 44 into passageways 68. Hence, fluid can flow outwardly of ports 54 should the same rise to the position thereof to a position below plate 62, such circulation being through passageway 68.

As used hereinbefore, what is meant by the fact that plate 65 covers passageways 68 is that plate 65 is welded to the upper edges of both legs of each of the flanges 63 and 64 as well as to the bore of pipe 44. Similarly, plate 62 is welded to the lower edges of both legs of each of angle irons 63 and 64 as well as to the bore of pipe 44.

The fact that openings 54 provide free and open communication between the upper ends of passageways 68 and the exterior of pipe 44 is illustrated in FIG. 7. Similarly the fact that openings 55 permit free and open communication between passageways 67 and the exterior of pipe 44 is illustrated in FIG. 8.

In FIG. 10, it will be noted that pawls 57 are biased outwardly by means of a pair of springs 69 from inside brackets 56.

The operation of the apparatus of the present invention is perhaps best illustrated in FIGS. 4, 11 and 12. After the well is drilled to the depth of bore 41 shown in FIG. 1, casing 13 is lowered therein to the position shown. Pipe 12 with construction 42 attached is then lowered to the position shown in FIG. 4. In this position, fluid flow out of ports 55 is prevented from entering the space above cup 46 or below cup 47 by the fluid tight fit thereof with the bore of casing 13, cups 46 and 47 being made of rubber. In the position shown in FIG. 4, construction 42 is employed to inflate membrane 24 by pumping circulation fluid thereinto to extend the same to the position 24' shown in FIG. 4. As this is being done, valve

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15 maintain opening 16 closed and sleeve 21 is rotated to a position such that no part of openings 40 lie in registry with openings 20. Thus, openings 20 are closed. Circulation fluid is pumped downwardly through pipe 12. This fluid enters passageways 67 and escapes from pipe 44 through ports 55. Further movement of this fluid in casing 13 is prevented by cups 46 and 47. Thus, this fluid is driven outwardly of opening 25, the force of the fluid overcoming the force of spring 36 and opening valve 35. The fluid pumped through opening 25 then enters the space between casing 13 and membrane 24 and fills membrane 24. Membrane 24 thus is expanded to the position 24' shown in FIG. 4. The expansion of membrane to the position of 24' thus seals off the space between casing 13 and well bore 41 thereabove from the space between casing 13 and well bore 41 therebelow. When circulation fluid is no longer pumped downwardly through pipe 12, the preponderance of pressure between casing 13 and membrane 24 over the pressure inside casing 13 between cups 46 and 47 then closes valve 35 and the same remains closed throughout the other operations to be described hereinafter. It is to be noted that valve 35 is especially important to the extent that the same, in accordance with an outstanding feature of the present invention, should provide a fluid tight seal to prevent fluid between casing 13 and membrane 24 from flowing through opening 25 back into the interior of casing 13. Any conventional type of valve 35 may be employed so long as it performs this function satisfactorily.

In accordance with the present invention, the next operating procedure is to lower pipe 12 to the position shown in FIG. 11 such that pawls 57 lie in an elongated slot 70 of openings 40 shown in FIG. 3. Pipe 12 is then turned until openings 40 in sleeve 21 lie in registry with openings 20. Sleeve 21 is in fact turned with pipe 12 because pawls 57 fall into slots 70. Pawls 57 can be removed from slots 70 in that lowering or raising of pipe 12 will cause pawls 57 to be placed inwardly of bracket 56.

After the foregoing preparations have been taken, well circulation fluid including gravel of a size larger than the meshes in screen 23 is pumped downwardly through pipe 12. This mixture enters passageway 67 and is pumped outwardly of ports 55 in the same manner that fluid for inflation of membrane 24 was circulated, as described previously. As before, cups 46 and 47 limit circulation of the gravel fluid mixture vertically in casing 13. The same therefore flows outwardly of openings 20. Flow of the fluid gravel mixture upwardly between casing 13 and well bore 41 above packer 18 is prevented by the pressure fit thereof between casing 13 and well bore 41. The fluid gravel mixture thus fills the space below packer 18, the gravel and fluid mixture initially being drawn downwardly from ports 20 to the bottom of bore 41. In particular, this flow characteristic takes place because stinger 45 extends downwardly contiguous to the bottom of screen 23 and circulation fluid, after it exits ports 20 as indicated by arrow 72, enters the open lower end of stinger 45 as indicated at arrows 73. Circulation fluid then travels upwardly through stinger 45 and pipe 44. Circulation fluid in the lower end of pipe 44 then enters passageway 68 and is pumped upwardly and outwardly of ports 54 in the space between casing 13 and pipe 12 above cup 46, flow being indicated by arrows 74 in FIG. 11.

When the foregoing operations are carried out with the construction 42 positioned as shown in FIG. 11, openings 20 are thus open while openings 16 and 25 are closed.

After gravel indicated at 75 in FIG. 12 is packed up near packer 18, pipe 12 is manipulated at the top of the well to again cause pawls 57 to lie in slots 70 of sleeve 21. Openings 70 are then closed by rotation of pipe 12, the same causing rotation of sleeve 21 to a position such that no portion of openings 40 lie in registry with openings 20. Construction 42 is then moved to the position shown in FIG. 12. In the position shown in FIG. 12, con-

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struction 42 is employed to direct cement through openings 16 into the space between casing 13 and well bore 41 above packer 18 in the same manner that circulation fluid was pumped into packer 18. In particular, openings 20 are closed as well as openings 25. A preponderance of pressure between cups 46 and 47 inside casing 16 opens valves 15 and cement flows outwardly of openings 16. As before, cement reaches openings 16 by pumping the same downwardly in pipe 12 through passageways 67 and outwardly of ports 55 into the space between pipe 44 and casing 13 below cup 46 and above cup 47.

From the foregoing, it will be appreciated that the prior art method of underreaming has been obviated in accordance with the present invention in that the well in which the apparatus of the invention is employed may be drilled of a substantially uniform bore throughout its length. In particular, the extent of cement in the well is limited to the depth of packer 18. The space below packer 18 can also be filled with gravel since circulation of the gravel fluid mixture introduced into space between well bore 41 and casing 13 out of openings 20 cannot rise in the bore 41 beyond the height of packer 18 therein. Note will also be taken that gravel packing may be conveniently performed in accordance with the present invention at a time prior to the time that cementing is performed. The packer 18, when filled with a circulation fluid and distended as indicated at 24' in FIG. 12 thus providing a lower support for cement pumped into the space between casing 13 and well bore 41 above packer 18 as indicated at arrow 76.

From the foregoing, it will also be noted that one outstanding feature of the present invention involves the use of the self-same casing 13 and construction 42 not only to set packer 18, but also to perform an additional operation such as gravel packing as illustrated in FIG. 11 or cementing as illustrated in FIG. 12 or both of these additional operations.

According to another feature of the invention, packer 18 with flexible or elastic membrane 24, opening 25, and valve 35 biased shut by leaf spring 36 can be easily and quickly set by exactly the same apparatus including the particular structure of casing 13 and construction 42 employed in gravel packing illustrated in FIG. 11 and cementing as illustrated in FIG. 12.

Although only one specific embodiment of the invention has been illustrated and described, many changes and modifications thereof will of course suggest themselves to those skilled in the art. The invention is therefore not to be limited to the embodiment selected for the disclosure herein, the true scope of the invention being defined only in the appended claim.

What is claimed is:

Well completion apparatus comprising: a string of casing, said casing having screen means covering its lower end; an inflatable toroidal-shaped elastic packer mounted on the external surface of said casing actuable to provide a fluid tight seal between the casing and the external surface of a well bore, said casing also having lower and upper openings therethrough respectively below and above said packer and an intermediate opening therethrough providing free and open communication between the interior of said casing and the interior of said packer, said casing also having means thereon actuable to open said intermediate and upper openings when the pressure thereat internally of said casing is greater than that externally thereof and to provide a fluid tight seal for said upper and intermediate openings when the pressure thereat inside said casing is less than that externally thereof, said casing also having a port collar for said lower opening; a pipe in said casing having fluid control means at the lower end thereof, said fluid control means including means on said pipe to provide upper and lower fluid tight seals between said pipe and said casing respectively at correspondingly spaced upper and lower positions, said upper and lower positions being spaced a distance less

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than the minimum vertical distance between any two of
said upper, lower and intermediate openings, said pipe
having a first opening from the interior thereof to the
exterior thereof between said spaced positions, said pipe
also having means forming a first passageway providing
free and open communication from the interior of said
pipe at the upper end thereof to said first opening, said
pipe also having a second opening therethrough above
said upper fluid tight seal, said pipe also having means
forming a second passageway separate and apart from
said first passageway providing free and open communi-
cation from the interior of said pipe at the lower end

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thereof to said second opening, a projection on said
pipe to open and to close said port collar; means for
lowering and raising said pipe inside said casing; and
means for pumping fluid into the upper end of said pipe.

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