United States Patent

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[73] Assignee **Lynes, Inc.**

[54] METHOD AND APPARATUS FOR POSITIONING AND GRAVEL PACKING A PRODUCTION SCREEN IN A WELL BORE

22 Claims, 8 Drawing Figs.

[52] U.S. Cl. 166/278, 166/51
[51] Int. Cl. E21b 43/04
[50] Field of Search 166/278, 51, 187

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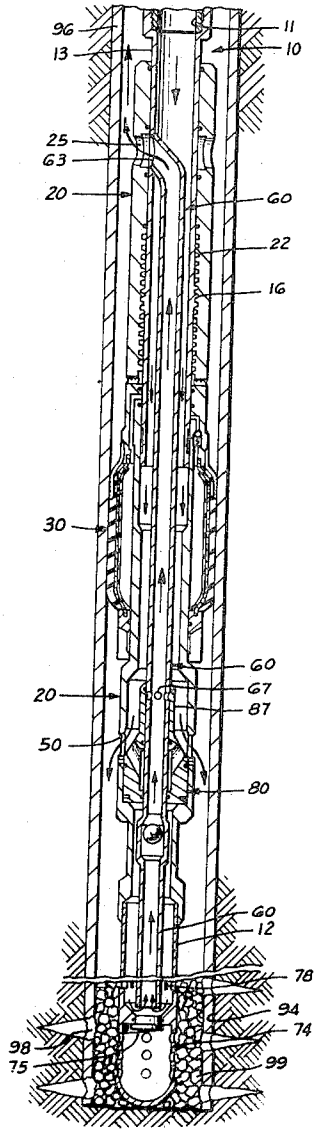
ABSTRACT: A method and apparatus for positioning and gravel packing a production screen in a well bore wherein a housing provided with a reinforced inflatable element and the production screen is coupled to a tubular means which is positioned in a well bore on a tubular string. The tubular means and housing are coupled together and form a crossover mechanism whereby fluid may be circulated in the well bore and then to the apparatus when the reinforced element is not sealed in the well bore to accomplish desired operations. When the element is inflated to seal in the well bore it actuates slip means to anchor the apparatus in the well bore. The tubular means then can be positioned longitudinally of the housing so that the crossover mechanism provides suitable flow passages for gravel packing the well bore around the production screen. Thereafter, the tubular string and means can be manipulated to deflate the element and disconnect the housing from the production screen, as desired.



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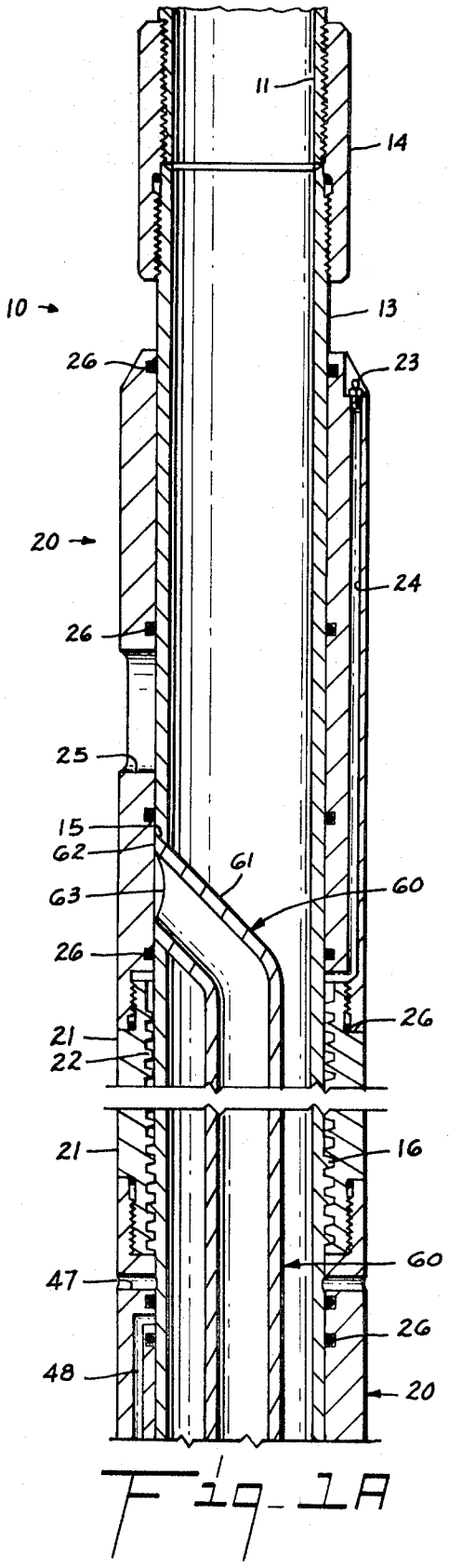

Fig. 1A

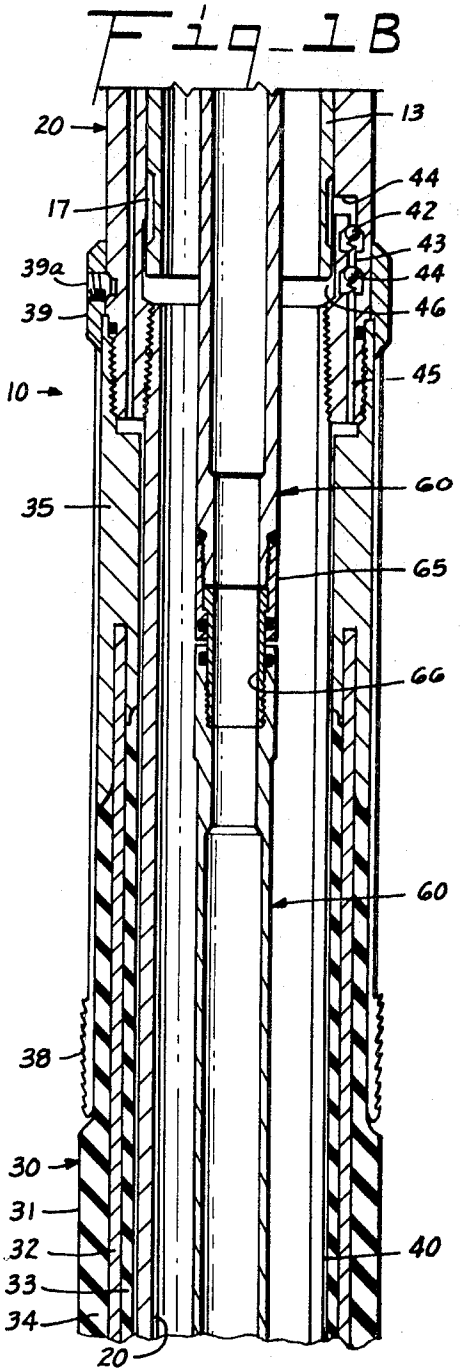

Fig. 1B

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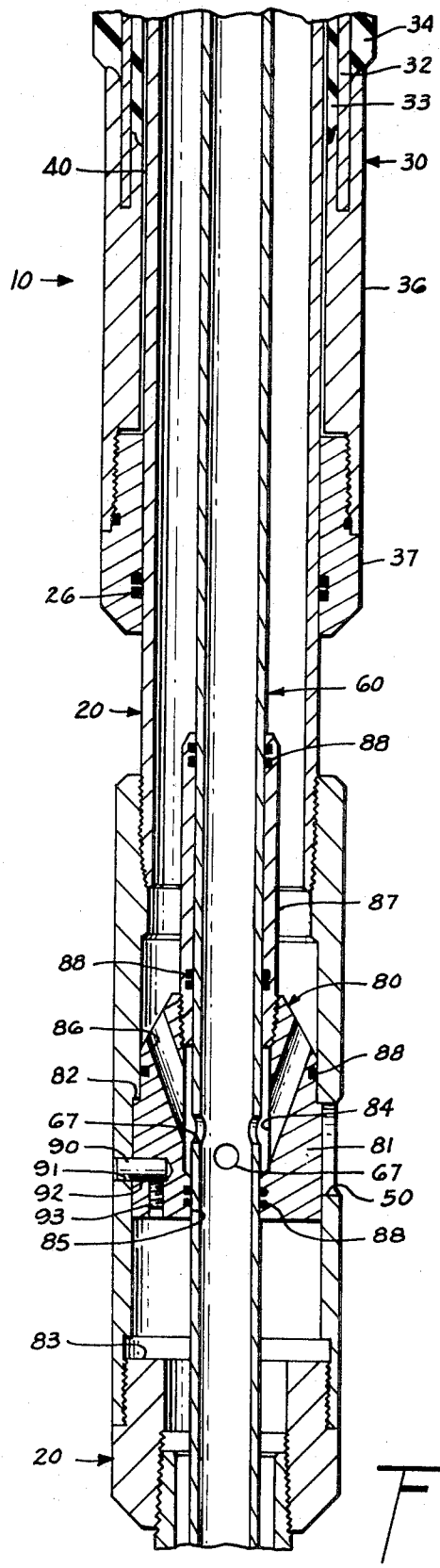

Fig. 1C

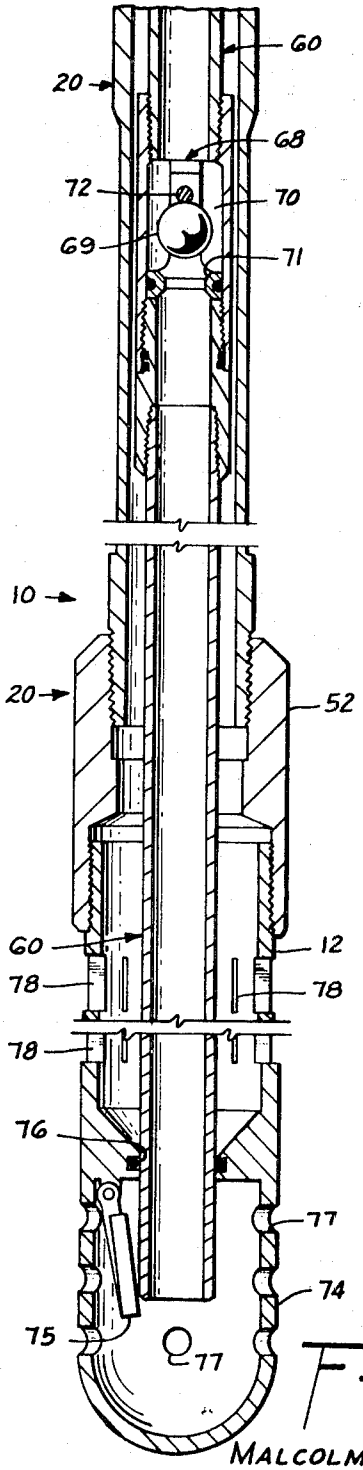

Fig. 1D

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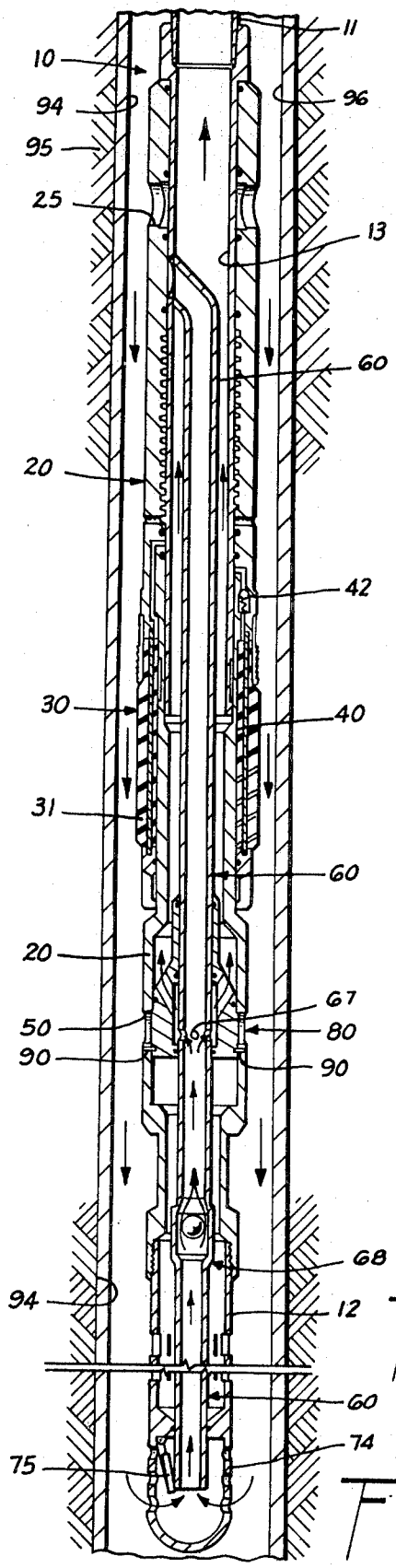

Fig. 2

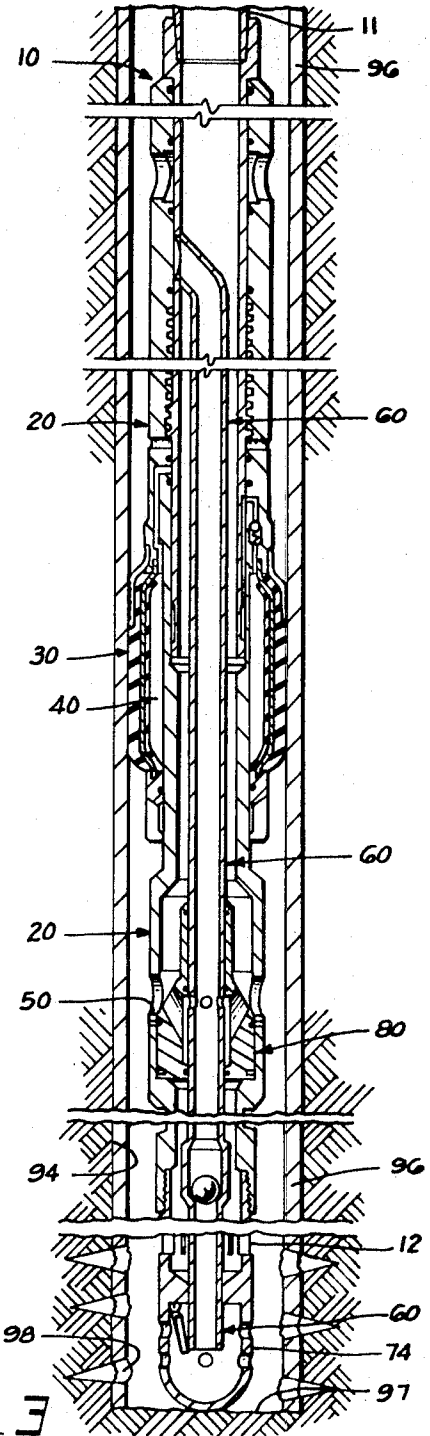

Fig. 3

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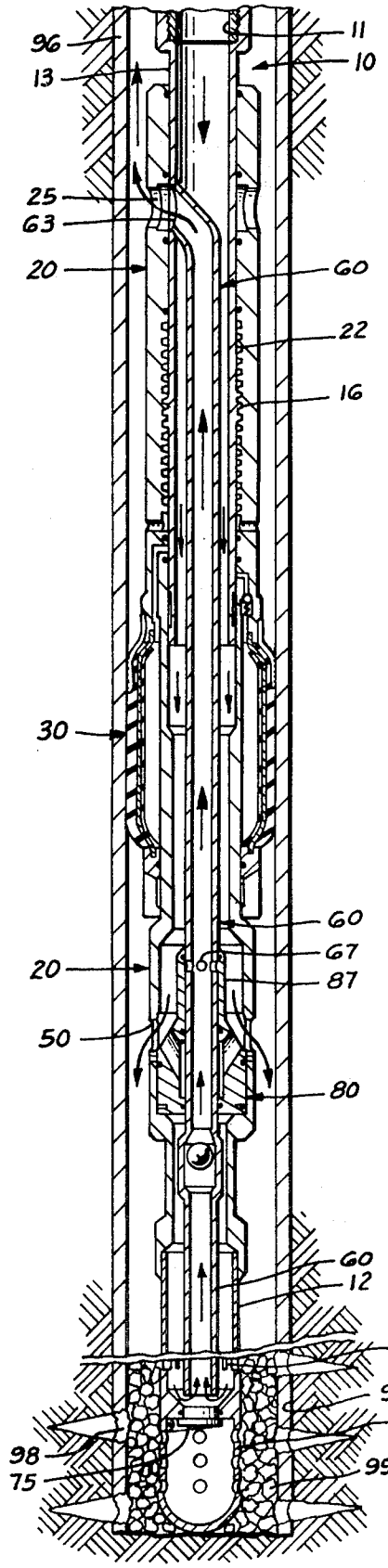

FIG. 4

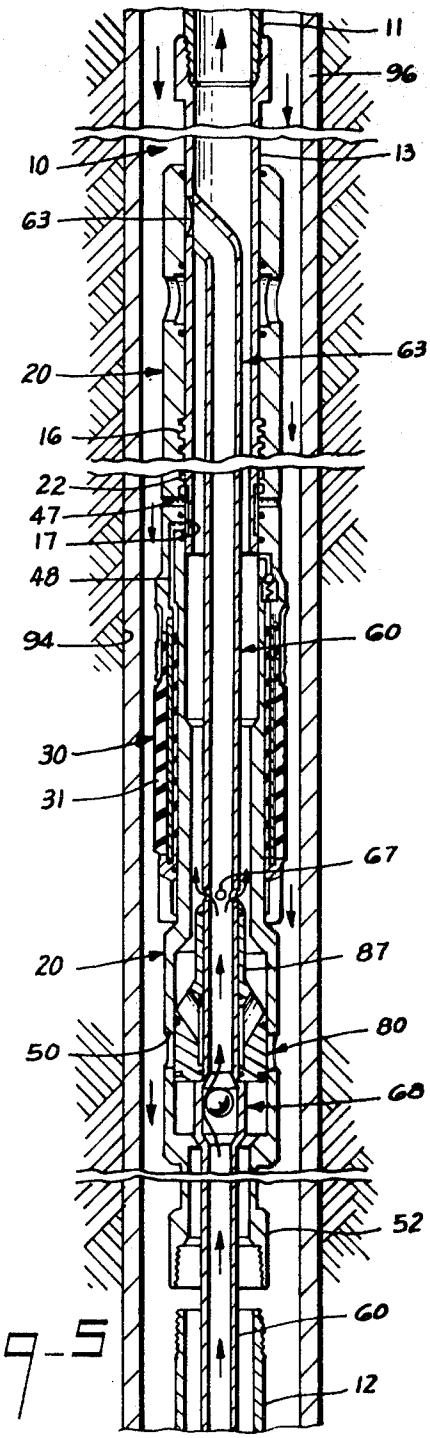

FIG. 5

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METHOD AND APPARATUS FOR POSITIONING AND GRAVEL PACKING A PRODUCTION SCREEN IN A WELL BORE

BACKGROUND OF THE INVENTION

This invention relates to method and apparatus for positioning and gravel packing a production screen in place at the bottom of an oil, gas, water, or other type of well bore or borehole drilling into the earth.

In the completion of oil, gas, and water wells for production purposes, it is frequently desired to place a production screen or sand screen at the level of the subsurface formation from which the oil, gas, or water is to be extracted and to pack the remainder of the well bore surrounding the exterior of the screen with gravel. Various types of gravel-packing apparatus have been heretofore proposed for accomplishing this purpose. Such previously proposed apparatus usually includes some form of sealing mechanism for sealing the annulus between the exterior of the gravel-packing apparatus and the wall of the well bore or well bore casing pipe during the gravel-packing operation. A gravel slurry is then pumped down the tubing string used to lower the apparatus into the well bore and ejected from the gravel-packing apparatus below the sealing mechanism at some point above the production screen. This distributes the gravel around the exterior of the production screen. The fluid used in pumping the gravel down the tubing string enters the screen and is returned to the annulus above the sealing mechanism by the gravel-packing apparatus.

The sealing mechanisms usually employed take the form of annular resilient swab cups which are mounted on the exterior of the gravel-packing apparatus. Unfortunately, these swab cups do not always provide a positive seal between the gravel-packing apparatus and the wall of the well bore or well bore casing pipe. Among other things, such swab cups may become worn or damaged during the running in process. In any event, if the seal is not adequate, then some of the gravel may pass back up the well bore annulus and deposit itself on top of the sealing mechanism. Such occurrence gives rise to a substantial danger of sticking the gravel-packing apparatus in the hole when the time comes to retrieve such apparatus following completion of the gravel-packing operation. Unfortunately, with the swab-cup-type of sealing mechanism, there is no readily available way of checking to see if such mechanism is providing an adequate seal.

Where a compression type packer is employed, the amount of compression that can be applied to the setting string may be limited by the customer to avoid damage to the screen. In some cases, it may not be possible to get a good seal of the packer even within the compression limits set by the customer, or well owner.

Also, there is not any arrangement to positively anchor the apparatus in the well bore, which may be checked to see if it is positively anchored in the well bore. Additionally, the gravel cannot be "packed" after it has been positioned which may be desirable in some situations.

SUMMARY OF THE INVENTION

It is an object of the invention, therefore, to provide new and improved method and apparatus for positioning and gravel packing a screen in a well bore having means for positively sealing the annulus between the apparatus and the wall of the well bore or well bore casing pipe as well as anchoring the apparatus in the well bore during the gravel packing operation.

It is another object of the invention to provide new and improved gravel-packing method and apparatus for positioning and gravel packing a production screen at the bottom of a well bore wherein the possibility of sticking the apparatus is minimized.

It is an additional object of the invention to provide new and improved gravel-packing method and apparatus which enables the bottom of the well bore to be washed out or cleaned before the gravel packing part of the subsurface operation is commenced.

It is a further object of the invention to provide new and improved gravel-packing apparatus which enables the production screen to be washed out or cleaned after the gravel packing part of the subsurface operation is completed.

Another object of the invention is to provide a positive seal and anchor in a gravel-packing tool whereby the anchor and seal may be tested to see if it is positively anchored and sealed and wherein the casing may be tested for leaks before the gravel is positioned in the well bore, or the well formation treated before the gravel is positioned in the well bore. Also, the anchoring and sealing enables the gravel to be compressed or packed after it has been positioned.

In accordance with the invention, gravel-packing apparatus for use in well bores comprises tubular means coupled to housing means which has a production screen thereon. The tubular means is connected to a tubing string when running the apparatus into a well bore. The apparatus also includes reinforced inflatable packer means carried by the housing means for sealing the annulus exterior to the housing means for actuating slip means to anchor the apparatus in the well bore when the packer expands. The housing and tubular means forms crossover means which includes downward flow means for enabling gravel pumped down the tubing string to flow out the housing means below the packer means and upward flow means for enabling fluid entering the production screen to flow out the housing means above the packer means.

For a better understanding of the present invention together with other and further objects and features thereof, reference is had to the following description taken in connection with the accompanying drawings, the scope of the invention being pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A–1D are cross-sectional views of different longitudinal portions of a representative embodiment of gravel-packing apparatus constructed in accordance with the present invention;

FIG. 2 is a cross-sectional view of the gravel-packing apparatus showing the operative condition thereof when the apparatus is being run into a well bore;

FIG. 3 shows the apparatus of FIG. 2 at the bottom of the well bore with the annulus-sealing packer mechanism inflated and the apparatus anchored in the well bore;

FIG. 4 shows the operative condition of the apparatus during the gravel-packing part of the subsurface operation;

FIG. 5 shows the apparatus disconnected from the screen after completion of the gravel-packing part of the subsurface operation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1A–1D, there are shown cross-sectional views of different longitudinal portions of a gravel-packing apparatus **10** constructed in accordance with the present invention. The uppermost portion of the apparatus **10** is shown in FIG. 1A, the lowermost portion in FIG. 1D, and intermediate portions in FIGS. 1B and 1C. For simplicity of illustration, some longitudinal portions of the apparatus have been omitted from the drawings, as indicated by the break lines. As shown in FIG. 1A, the upper end of the apparatus **10** is adapted to be coupled to the lower end of a tubular string **11** for purposes of running the apparatus **10** into the well bore. As seen in FIG. 1D, the lower end of the apparatus **10** is adapted to be coupled to the upper end of a production screen or sand screen **12** which is to be set and gravel packed in place at the bottom of the well bore.

The gravel packing apparatus **10** includes housing means coupled with tubular means or mandrel **13** which is connected to the lower end of the tubing string **11** by an internally threaded annular connector member **14**. The means or mandrel **13** includes a port or outlet **15** which extends through a

sidewall thereof near its upper end. Below outlet 15, tubular means or mandrel 13 is provided with threads 16 formed on the exterior thereof. An annular packer deflating groove 17 is formed in the exterior surface of the mandrel 13 near the bottom end thereof (FIG. 1B).

The tubular means mandrel 13 may be considered as part of or as an extension of the tubular string 11, if desired.

The housing means of the apparatus 10 further includes a tubular housing 20 having an upper portion extending over part of the mandrel 13, the remainder of such housing 20 extending downwardly to the production screen 12 located at the bottom of the apparatus. Housing 20 includes a sub 21 having internal threads 22 for engagement with the threads 16 on the exterior of the mandrel or extension 13 of tubular string 11. The threads 22 extend over a much longer longitudinal length than do the threads 16 on the mandrel 13. This provides a thread on the mandrel 13 for adjusting the longitudinal position of the tubular means or mandrel 13 relative to the housing 20. Such adjustment is produced by rotation of the tubing string 11 and, hence, the mandrel or extension 13 of the string 11 provided the housing 20 is held stationary. In FIGS. 1A and 1B, the mandrel 13 is shown in its lowermost position. The external diameter of the unthreaded portion of the mandrel 13 is such that the mandrel 13 can undergo rotation when the housing assembly 20 is held stationary. A grease-injection nipple 23 and a grease passage 24 are provided at the upper end of the housing 20 for purposes of lubricating the screw mechanism provided by threads 16 and 22. A row of upper outlets or ports 25 extend through the side wall of the housing 20 near the upper end thereof, only one of these outlets 25 being visible in FIG. 1A. Various O-rings 26 are provided for establishing fluidtight seals between the inner wall of the housing 20 and the outer wall of the mandrel 13, between the mating threaded couplings connecting together the different portions of the housing 20, and so forth.

The gravel packing apparatus 10 further includes a reinforced inflatable packer 30 carried by the housing 20 for sealing the annulus between the exterior of the housing 20 and the wall of the well bore or, as the case may be, the casing pipe set in such well bore. The upper end of the packer 30 is shown in FIG. 1B, while the lower end is shown in FIG. 1C. An intermediate portion of the packer 30 is omitted from the drawings. The packer 30 includes an annular resilient reinforced inflatable element 31 which encircles the body of the housing 20. This inflatable packer element 31 includes a flexible annular metallic member or sheath 32 between a pair of annular rubber members 33 and 34. The metallic member 32 may, for example, be formed of a woven wire or plastic braid material. The upper and lower ends of the inflatable element 31 are held in place by means of upper and lower sleeve members 35 and 36 which extend over the ends of the inflatable element 31. The inflatable element 31 is bonded to the interior of these sleeve members 35 and 36. The upper sleeve member 35 is threaded directly onto the body of the housing 20, while the lower sleeve member 36 is threaded onto a collar 37 which is slidably mounted on the housing 20, a fluidtight seal therewith being provided by O-rings 26. The collar 39 is provided with circumferentially spaced, longitudinally extending slots to form a plurality of fingers which have a slip surface 38 formed thereon at the lower end. The collar 29 is restrained against downward movement by resting on the shoulder of sleeve member 35 and is restrained against upward movement by the nut 29*a*. The thickness of the inflatable element 31 is such that an annular fluid passage or chamber 40 is provided between the interior thereof and the exterior of the underlying portion of the housing 20.

The housing means 20 also includes packer-inflating means responsive to fluid pressure within the housing 20 for inflating the inflatable packer element 31 and retaining it inflated. As shown in FIG. 1B, this packer-inflating means includes a passage 41, a check valve 42, a passage 43, a check valve 44, and a passage 45, the latter communicating with the inflating passage or chamber 40. The initial passage 41 communicates with the bore of the housing 20 by way of the annular groove 17 on extension 13 and a passage 46 formed by the clearance between the lower end of the mandrel 13 and the bore of the housing 20. The well bore fluid present in the housing means 20 flows into the inflating chamber 40 and inflates the packer element 31. The collar 37 will slide along the housing when the packer inflates and the check valves 42, 44 retain the element inflated.

The reinforced inflatable packer 30 further includes packer deflating means formed in the housing 20 and the tubular means or mandrel 13 for enabling the packer element 31 to be deflated when the mandrel 13 is at a selected longitudinal position relative to the housing 20. This packer-deflating means includes passages 47 (FIG. 1A) which extend laterally through the sidewall of the housing 20 and a longitudinal passage 48 having an outlet on the interior of the housing 20 just below the lateral passages 47. Passage 48 extends downwardly to and communicates with the inflating chamber 40 located inside the inflatable element 31. In the position shown in FIG. 1A, this packer deflating means is in an inoperative condition, the upper outlet of the passage 48 being closed by the mandrel 13. The packer deflating means is placed in its operative condition by the deflating groove 17 (FIG. 1B) at the lower end of the mandrel 13 when the mandrel 13 is moved upwardly so as to enable such groove 17 to bridge across from a point just above the passages 47 to a point just below the upper outlet of the passage 48. In this deflating condition, the well bore fluid previously pumped into the inflating chamber 40 is released by way of passage 48, groove 17, and passage 47 to the region exterior to the housing 20.

The housing 20 further includes gravel port means or gravel outlet means for enabling gravel to pass from the interior of the housing 20 to the exterior thereof. This gravel port means includes a series of gravel ports 50, only one of which is visible in FIG. 1C, which are formed in the lower part of the housing 20 at a point below the packer 30. These ports 50 are formed at circumferentially spaced positions on the housing 20. At the lower end of the housing 20, there is provided an internally threaded coupling member 62 (FIG. 1D) for coupling the lower end of the housing 20 to the externally threaded upper end of the production screen 12.

The gravel-packing apparatus 10 additionally includes crossover means carried within the housing 20 and including downward flow means for enabling gravel pumped down the tubing string 11 to flow out the housing 20 below the inflated packer 30 and upward flow means for enabling fluid entering the production screen 12 to flow out of the housing 20 at a point above the packer mechanism 30. The upward flow means includes a wash pipe or bypass 60 carried by the mandrel 13 (FIG. 1A and extending downwardly into the interior of the production screen 12 (FIG. 1D). The wash pipe 60 is an elongated tubular member having an outside diameter which, for most of its length, is substantially less than the inside diameter of the housing 20. The downward flow means includes the mandrel 13, the annular region between the wash pipe 60 and the mandrel 13, the annular region between the wash pipe 60 and the housing 20 and the gravel ports 50.

The upper end of the wash pipe 60 includes a bent portion 61 having an end 62 which is mounted in and fastened to the outlet 15 of the mandrel 13. An outlet 63 is provided at this upper end 62 of the wash pipe 60. This outlet 63 is adapted to communicate with the upper outlets 25 of the housing 20 for a selected longitudinal positioning of the mandrel 13 relative to the housing 20. Otherwise, the upper wash pipe outlet 63 is closed, a first closed position being that depicted in FIG. 1A.

As shown in FIG. 1B, a swivel mechanism 64 may be provided for the wash pipe 60. This swivel mechanism 64 includes a swivel collar 65 which is threaded onto an upper portion of the wash pipe assembly 60 and a swivel stem 66 which is threaded onto a lower portion of the wash pipe 60. Swivel mechanism 64 enables rotation of the upper portion of the wash pipe 60 relative to the lower portion.

As shown in FIG. 1C, the wash pipe 60 further includes reverse circulation ports 67 formed in the wall thereof at a location in the vicinity of the housing assembly gravel ports 50. As indicated in FIG. 1D, the wash pipe 60 also includes a check valve mechanism 68 located therein below the reverse circulation ports 67. This check valve mechanism 68 includes a ball valve 69 which is movably contained in a cage 70. A valve seat 71 located below the ball valve 69 cooperates with such ball valve for preventing downward flow of fluid at this point in the wash pipe 60. A retaining pin 72 keeps the ball valve 69 in the cage 70 when fluid is flowing in an upwardly direction through the check valve mechanism 68.

As further shown in FIG. 1D, the lower end of the wash pipe 60 extends into a screen shoe subassembly 74 located at the bottom end of the production screen 12. Carried within the screen shoe 74 is any suitable valving arrangement such as flapper valve 75 which is maintained in an open position by the presence of the wash pipe 50. Associated with the flapper valve 75 is a biasing spring (not shown) for closing the valve 75 when the wash pipe 60 is removed. This closes a passageway 76 connecting the interior of the shoe 74 with the interior of the production screen 12. The sidewall of shoe 74 is provided with a series of relatively large sized perforations or passageways 77 which form a wash down screen for enabling removal of relatively large size solid particles from the bottom of the well bore. As indicated in FIG. 1D, the production screen 12 includes series of narrow elongated slots 78 formed in rows or bands around the body of such screen 12. These slots 78 enable entry of the hydrocarbon fluid to be produced from the adjacent earth formation, while at the same time preventing entry of sand particles and the like which may be dislodged from such earth formation.

The crossover means carried within the housing 20 further includes an annular valve mechanism 80 slidably mounted on the wash pipe 60 for selectively opening and closing the housing assembly gravel ports 50 and the wash pipe reverse circulation ports 67. This annular valve mechanism or slide valve 80 includes a body portion 81 which bears against the inner wall of the adjacent portion of the housing 20 and, among other things, provides a closure mechanism for blocking the annular region between the exterior of the wash pipe fluidtight and the interior of the housing 20. This prevents fluid from flowing downwardly from the upper portion of the housing 20 into the portion of such housing 20 located below the slide valve 80. In the position shown in FIG. 1C, the body portion 80 also serves to close the gravel outlet ports 50. A shoulder 82 is formed in the inner wall of the housing 20 for limiting the upward movement of the BODY portion 81. Downward movement is limited by the inwardly extending upper end 83 of the next lower portion of the housing 20.

The body portion 81 of slide valve 80 includes a central longitudinal passageway formed by an enlarged recess 84 and a lesser diameter passage 85 which slidably engages the exterior of the wash pipe 60. A series of inclined passages 86 extend from the recess 84 to an upper surface portion of the body member 81. An elongated sleeve member 87 is threadedly connected to the body member 81, such sleeve member 87 being adapted to slide on the exterior of the wash pipe 60. O-rings 88 provide fluid-tight seals at the places indicated. Initially, the slide valve 80 is held in the position shown in FIG. 1C by means of a set of shear pins 90, each of which is located in a pair of aligned lateral passages 91 and 92 in the housing 20 and the slide valve body member 81. Each shear pin is locked in place by a set screw 93 located in a threaded passage extending upwardly from the bottom of the body member 81.

OPERATION OF THE PREFERRED EMBODIMENT

Considering now the operation of the gravel-packing apparatus of FIGS. 1A–1D, such operation will be explained with the aid of FIGS. 2–5 which illustrate, in a somewhat simplified manner, various different operating conditions for the gravel-packing apparatus 10. FIG. 2 shows the initial phase of the operation where the apparatus 10, together with the production screen 12, is being run into a well bore by means of the tubing or drill pipe string 11. As shown in FIG. 2, a well bore 94 passes through a subsurface earth formation 95. The well bore 94 is lined with casing pipe 96. At the surface of the earth, prior to running in, the production screen 12 is connected to the lower end of the gravel-packing apparatus 10 and the upper end of the apparatus 10 is connected to the lower end of the lower joint of the tubing string 11. The apparatus 10 and screen 12 are then lowered into the well bore 94 by adding additional joints of pipe to the tubing string 11.

During the running in phase, the mandrel 13 is at its lowermost position relative to the housing 20, the packer 30 is deflated, the slide valve 80 is held at its uppermost position by shear pins 90 and the lower end of the wash pipe assembly 60 extends into the screen shoe 74 and keeps the flapper valve 75 open. During this running in phase, the well bore fluid can be reverse circulated for purposes of cleaning sand and debris out of the bottom of the well bore 94. Such reverse circulation is accomplished by pumping fluid down the annulus between the exterior of the tubing string 11 and the interior of the casing pipe 96. This fluid moves downwardly past the gravel-packing apparatus 10 and into the shoe 74 at the bottom of the screen 12. Such fluid then flows upwardly through the wash pipe 60 past the wash pipe check valve 68 and out through the reverse circulation ports 67 and into the annulus intermediate the wash pipe 60 and the housing 20. The fluid continues upwardly through this annulus, then through the interior of the mandrel 13 and the interior of the tubing string 11 and back to the fluid circulation equipment at the surface of the earth. In the typical case, this reverse circulation washing operation would only be conducted as the apparatus 10 approaches the bottom of the well bore 94.

The running in operation continues until the screen shoe 74 reaches the bottom of the well bore 94. At this point, it is desired to inflate the reinforced inflatable packer 30. This is accomplished by commencing normal circulation of the well bore fluid (fluid flowing down the interior of the tubing string 11). As indicated in FIG. 2, the position of the slide valve 80 prevents the fluid flowing downwardly through the tubing string 11 from leaving the housing 20 by way of the gravel ports 50. Check valve mechanism 68 prevents such fluid from flowing downwardly through the wash pipe 60. Thus, such fluid cannot leave the gravel-packing apparatus 10. This enables the well bore fluid to flow into the packer inflating chamber 40 and inflate the inflatable element 31. After sufficient time has elapsed for such inflation, the pump pressure is again increased to cause a shearing of the shear pins 90 and to force the slide valve 80 to its lowermost position. This opens the ports 50, which occurrence is indicated by a noticeable decrease in pump pressure at the earth's surface.

FIG. 3 shows the gravel-packing apparatus 10 with the packer 30 inflated and with the ports 50 open. As there indicated, screen shoe 74 is resting on the bottom 97 of the well bore 94. A series of perforations 98 have been previously shot through the lower portion of the casing pipe 96 for enabling entry of the hydrocarbon fluid from the surrounding earth formation into the well bore casing pipe 96.

If desired, the well bore formation beneath the inflated packer may be acidized or treated before proceeding with the gravel-packing operations. This is accomplished by pumping the treating fluid down the tubing string 11 and into the well bore beneath the inflated packer 30.

With the packer 30 inflated, a pull may be exerted on the tubing string 11 at the earth's surface to assure that the packer is set in the well bore opening. In some circumstances, it is desirable to test the casing 96 for leaks before proceeding and this may be done by injecting fluid at the earth's surface into the annulus between the casing 96 and tubing string 11 and suitable pressure applied to test the casing for leaks. The tubing string 11 is then rotated a predetermined number of turns to place the apparatus in condition for the next phase of the subsurface operations. Rotation of the tubing string 11 moves

the mandrel 13 in an upwardly direction relative to the housing 20. The coupling mechanism for converting rotary movement to longitudinal movement is provided by the screw mechanism formed by mandrel threads 16 and housing threads 22. For this operating condition, the threads 16 on the mandrel 13 are at approximately their midposition. This upward movement of the mandrel 13 opens the wash pipe outlet 63 at the upper end of the wash pipe 60. The upward movement of the wash pipe 60 moves the reverse circulation ports 67 up into the sleeve member 87 of the slide valve 80, thus closing such reverse circulation ports 67. The upward movement of the wash pipe 60 also withdraws such wash pipe from the screen shoe 74 which, in turn, permits the flapper valve 75 to close as shown in FIG. 4.

The apparatus 10 is now ready to commence the gravel-packing part of the subsurface operations. A mixture of gravel and clean water or other well bore fluid is pumped from the surface of the earth down the tubing string 11. By using the tubing string 11 as the circulating string for the carrier fluid and gravel, the problem of picking up mill scale is eliminated, which would otherwise be present if the fluid and gravel were circulated down the casing without a crossover mechanism. This gravel slurry flows down the interior of the mandrel 13 and the annular region between the inner wall of the housing 20 and the exterior of the wash pipe 60. The gravel slurry is then deflected by the slide valve 80 and leaves the housing 20 by way of the gravel ports 50, the slide valve 80 thus also serving as a gravel-deflection device. The gravel slurry then moves downwardly by way of the annular region exterior to the housing 20 and the production screen 12 to the bottom of the well bore 94. The fluid part of the slurry enters the screen 12 through the slots 78, leaving the gravel particles deposited around the exterior of the screen 12. This forms the desired gravel pack, part of which is indicated at 99 in FIG. 4. The fluid flowing into the screen 12 enters the outlet at the lower end of the wash pipe 60 and flows upwardly through the interior of such wash pipe 60. This fluid leaves the upper end of the wash pipe 60 by way of wash pipe outlet 63 and housing outlet 25 which are located above the packer 30. The fluid then flows upwardly through the annulus exterior of the tubing string 11 and is thereby returned to the fluid circulation equipment located at the surface of the earth. When the gravel pack 99 is built up to the point where the top of the pack is above the top of the slots 78 in the screen 12, there is a noticeable increase in pump pressure which informs the operator that the desired gravel packing has been completed.

After the gravel-packing phase of the subsurface operation is completed, it is desired to disconnect the gravel packing apparatus 10 from the production screen 12 and to remove such apparatus 10 from the well bore 94. To do this, it is first necessary to deflate the packer 30. This is accomplished by again rotating the tubing string 11 a predetermined number of turns. This further rotation produces the condition shown in FIG. 5. As there shown, the threads 16 on the mandrel 13 are at the upper end of the threads 22 on the interior of the housing 20. This upward movement of the mandrel 13 moves the packer-deflating groove 17 at the lower end of the mandrel 13 up to a position where it bridges the upper outlet of the longitudinal packer-deflating passage 48 and the lateral packer-deflating passage 47. This releases the high-pressure fluid from within the packer 30 and causes the inflatable element 31 thereof to deflate, such deflated condition being the case shown in FIG. 5. This upward movement of the mandrel 13 and wash pipe 60 also serves to close the outlet 63 at the upper end of the wash pipe 60. In addition, it causes the upper end of the wash pipe check valve mechanism 68 to engage the underside of the slide valve 80 and to move such slide valve 80 upwardly so as to close the gravel ports 50. At the same time, the reverse circulation ports 67 are moved to a position above the sleeve member 87 so that such ports 67 are now reopened.

After the packer 30 is deflated, further rotation of the tubing string 11 serves to disconnect the coupling member 52 at the lower end of the housing 20 from the production screen 12. Thereupon, the rotation of the tubing string 11 can be discontinued and the gravel packing apparatus 10 withdrawn from the well bore 94. This leaves the production screen 12 packed in at the bottom of the well bore. Thereafter, a string of production tubing is run into the well bore and connected to the screen 12 for purposes of producing the oil or other hydrocarbon fluid contained in the earth formation adjacent the screen 12.

In some cases, it is desirable to pack the sand around the screen. Since the present invention is anchored in the well pipe 96 when the inflating packer actuates the slips 38, the packing of the sand can be affected by increasing the hydraulic pressure in the tubing string which is transmitted to the sand around the screen. This is accomplished before the running in string is disconnected from the screen.

Before the wash pipe 60 is withdrawn from the production screen 12, the well bore fluid can be reverse circulated for purposes of cleaning out the interior of the production screen 12. During such reverse circulation, fluid flows down the annulus exterior to the housing 20, into the screen 12 through the now open top thereof, into the wash pipe 60 through the outlet at the bottom thereof, upwardly through the lower part of the wash pipe 60, outwardly through the reverse circulation ports 67, upwardly through the annular region intermediate the housing 20 and the washing pipe assembly 60, upwardly through the tubing string 11 and back to the surface of the earth.

The gravel is in effect fine particles of sand which particles are larger than the slots in the screen and serve to filter any formation solids from the fluid flowing from the formation to aid in preventing clogging of the screen.

The present invention can be run without the flapper valve 75. If desired, other arrangements can be employed to disconnect the production screen from the running in string. For example, a J-slot arrangement may be employed.

While there has been described what is at present considered to be a preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. Apparatus for attaching to a well tubing for positioning and gravel packing a production screen in a well bore comprising:
   a. housing means;
   b. tubular means coupled to said housing;
   c. inflatable reinforced packer means carried by said housing means;
   d. crossover means formed by said housing and tubular means for discharging gravel and fluid pumped down the tubular means into the well bore around the production screen and for flowing fluid from the production screen out of said housing means into the well bore above said packer means; and
   e. said housing being provided with passage means for conducting fluid from the tubular string for inflation of said reinforced element and there being check valve means in such passage means to retain inflation of said element.

2. The invention of claim 1 including slip means for aiding in anchoring said housing in the well bore.

3. The invention of claim 1 wherein said crossover means includes a wash pipe connected adjacent its upper end with said tubular means to communicate externally of said tubular means and which extends longitudinally of said tubular means and through said housing means to provide a lower open end for communication with the well bore.

4. The invention of claim 1 wherein said crossover means includes a wash pipe connected adjacent its upper end with said tubular means to communicate externally of said tubular means and which extends longitudinally of said tubular means and through said housing means to provide a lower open end

for communication with the well bore and slide valve means between said wash pipe and housing means.

5. The invention of claim 1 wherein said crossover means includes a wash pipe connected adjacent its upper end with said tubular means to communicate externally of said tubular means and which extends longitudinally of said tubular means and through said housing means to provide a lower open end for communication with the well bore and check valve means in said wash pipe.

6. The invention of claim 1 including cooperating thread means on said tubular means and said housing means to accommodate relative longitudinal movement therebetween.

7. The invention of claim 1 wherein said housing means and said tubular means are provided with passage means for deflation of said packer means.

8. Apparatus for attaching to a well tubing for positioning and gravel packing a production screen in a well bore comprising:

a. a tubular mandrel adapted to be coupled to the lower end of a tubular string and having thread means on the exterior thereof;

b. a tubular housing having internal thread means for engagement with said external thread means on said mandrel;

c. said housing having upper and lower outlets;

d. a reinforced inflatable packer carried by said housing intermediate the upper and lower outlets for sealing the well bore exterior of said housing;

e. a wash pipe carried by the mandrel and extending downwardly into the production screen, said wash pipe including:

1. an upper outlet adapted to communicate with the upper outlet of said housing;

2. port means formed in the wall of said wash pipe in the vicinity of said lower housing outlet; and

3. check valve means located within said wash pipe below the port means for passing fluid in only an upward direction; and

4. annular valve means slidably mounted on said wash pipe for selectively opening and closing said lower outlet in said housing and said wash pipe.

9. The invention of claim 8 wherein said housing is provided with passage means for conducting fluid from the tubular string for inflation of said reinforced element and there being check valve means in such passage means to retain inflation of said element.

10. The invention of claim 8 including shear pin means for initially holding said annular valve means in a position for closing said lower housing outlet until the fluid pressure in said housing exceeds a predetermined amount which is greater than the predetermined amount for inflation of said reinforced packer.

11. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to inflate the packer and seal and anchor it against the well bore wall;

c. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer; and

d. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer.

12. The method of claim 11 including the step of disconnecting the tubular string and housing from the production screen.

13. The method of claim 12 including the step of circulating fluid down the well bore and up into the lower end of the wash pipe after disconnecting.

14. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to first inflate the packer and seal and anchor it against the well bore wall which also anchors the housing and production screen in the well bore and then increasing the pressure to open a slide valve in the housing beneath the packer to the well bore;

c. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer; and

d. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer.

15. The method of claim 14 including the step of disconnecting the tubular string and housing from the production screen.

16. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to inflate the packer and seal and anchor it against the well bore wall;

c. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer;

d. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer; and

e. increasing the pressure in the tubular string while retaining the packer sealed and anchored against the well bore wall to pack the gravel around the production screen.

17. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to first inflate the packer and seal the anchor it against the well bore wall which also anchors the housing and production screen in the well bore and then increasing the pressure to open a slide valve in the housing beneath the packer to the well bore;

c. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer;

d. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer; and

e. increasing the pressure in the tubular string while retaining the packer sealed and anchored against the well bore wall to pack the gravel around the production screen.

18. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. circulating fluid down the well bore annulus and in the lower end of a bypass tube carried by the tubular string and then into the housing and up the tubular string to the earth's surface to wash and clean out the well bore;

c. conducting fluid pressure in the tubular string to inflate the packer and seal and anchor it against the well bore wall;

d. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer; and

e. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer.

19. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to first inflate the packer and seal it against the well bore wall which also anchors the housing and production screen in the well bore and then increasing the pressure to open a slide valve in the housing beneath the packer to the well bore;

c. opening a bypass above the packer to the well bore by rotating the tubular string relative to the housing; and

d. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer.

20. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to inflate the packer and seal and anchor it against the well bore wall;

c. placing a tension on the tubular string to determine if the packer is anchored against the well bore wall;

d. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer; and

e. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer.

21. A method of positioning and gravel packing a production screen in a well bore having a casing comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to inflate the packer and seal and anchor it against the well bore wall;

c. injecting fluid under pressure in the well bore around the string to test the casing for leaks;

d. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer; and

e. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer.

22. A method of positioning and gravel packing a production screen in a well bore comprising the steps of:

a. positioning a tubular string in the well bore which carries a housing having a reinforced inflatable packer and production screen thereon;

b. conducting fluid pressure in the tubular string to first inflate the packer and seal and anchor it against the well bore wall which also anchors the housing and production screen in the well bore and then increasing the pressure to open a slide valve in the housing beneath the packer to the well bore;

c. injecting fluid through the tubular string and into the well bore beneath the packer to treat the well bore formation beneath the packer;

d. rotating the tubular string to communicate a bypass carried by the tubular string with the well bore above the inflated packer and the interior of the production screen beneath the packer; and

e. pumping gravel and liquid down the tubular member and housing and out into the well bore beneath the inflated packer to surround the production screen and then circulating the liquid through the screen, up the bypass, and out into the well bore above the packer.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,627,046 Dated December 14, 1971

Inventor(s) HENRY W. MILLER and MALCOLM G. COONE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 62, change "29a" to --39a--.
Column 4, line 53, change "1A" to --1A)--.
Column 5, line 19, change "50" to --60--.
Column 5, line 56, change "extend" to --extends--.
Column 6, line 57, change "have" to --has--.
Column 12, line 16, before "string" insert --tubular--.

Signed and sealed this 30th day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents