Oct. 11, 1966 D. H. FLICKINGER ETAL 3,277,962

GRAVEL PACKING METHOD

Filed Nov. 29, 1963 3 Sheets-Sheet 1

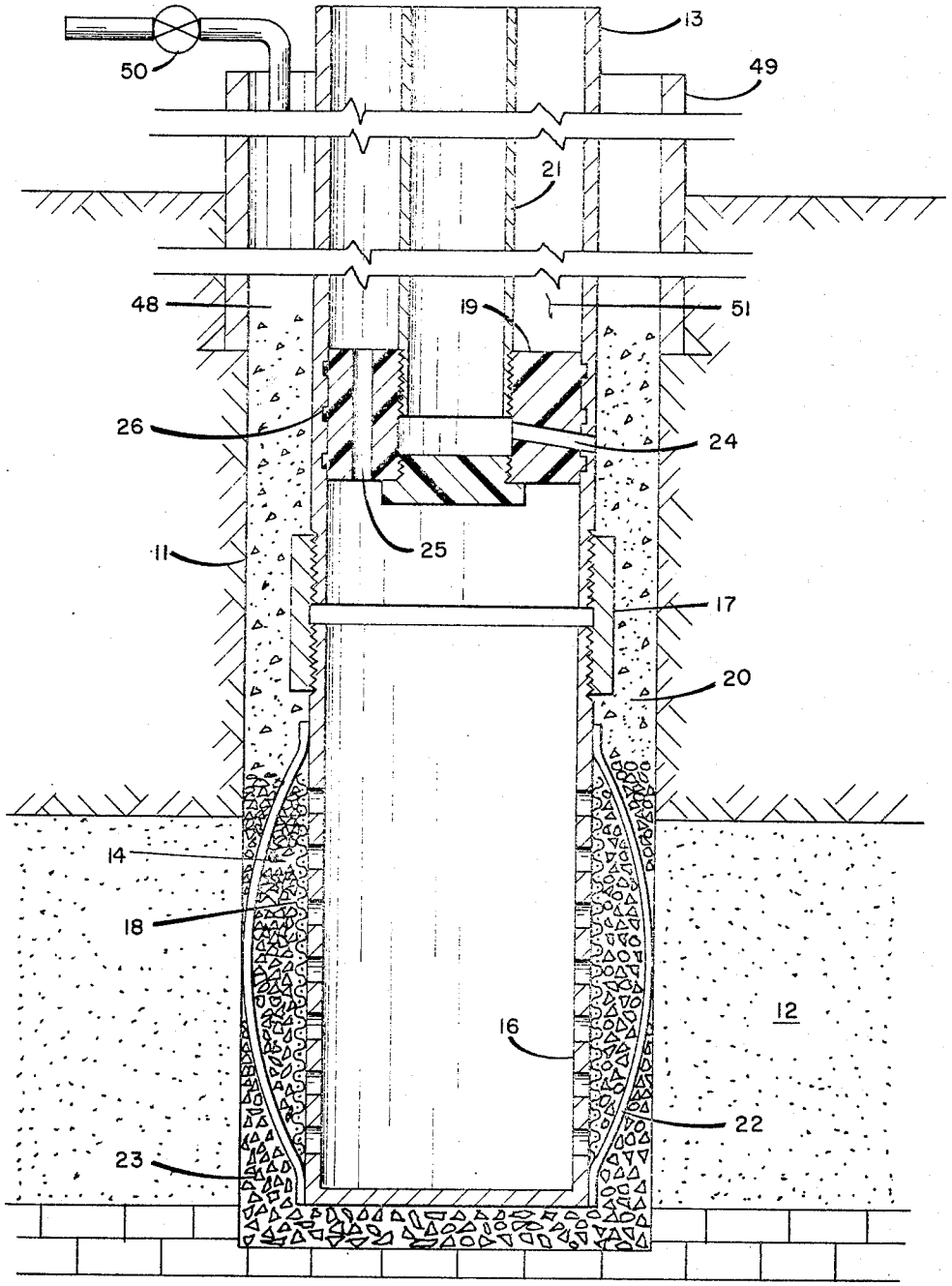


FIG. - 1

DON H. FLICKINGER
GEORGE C. HOWARD
CLARENCE R. FAST
WILLIAM G. BEARDEN
INVENTORS.

BY William G. McClain
ATTORNEY.

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GRAVEL PACKING METHOD

Filed Nov. 29, 1963 3 Sheets-Sheet 2

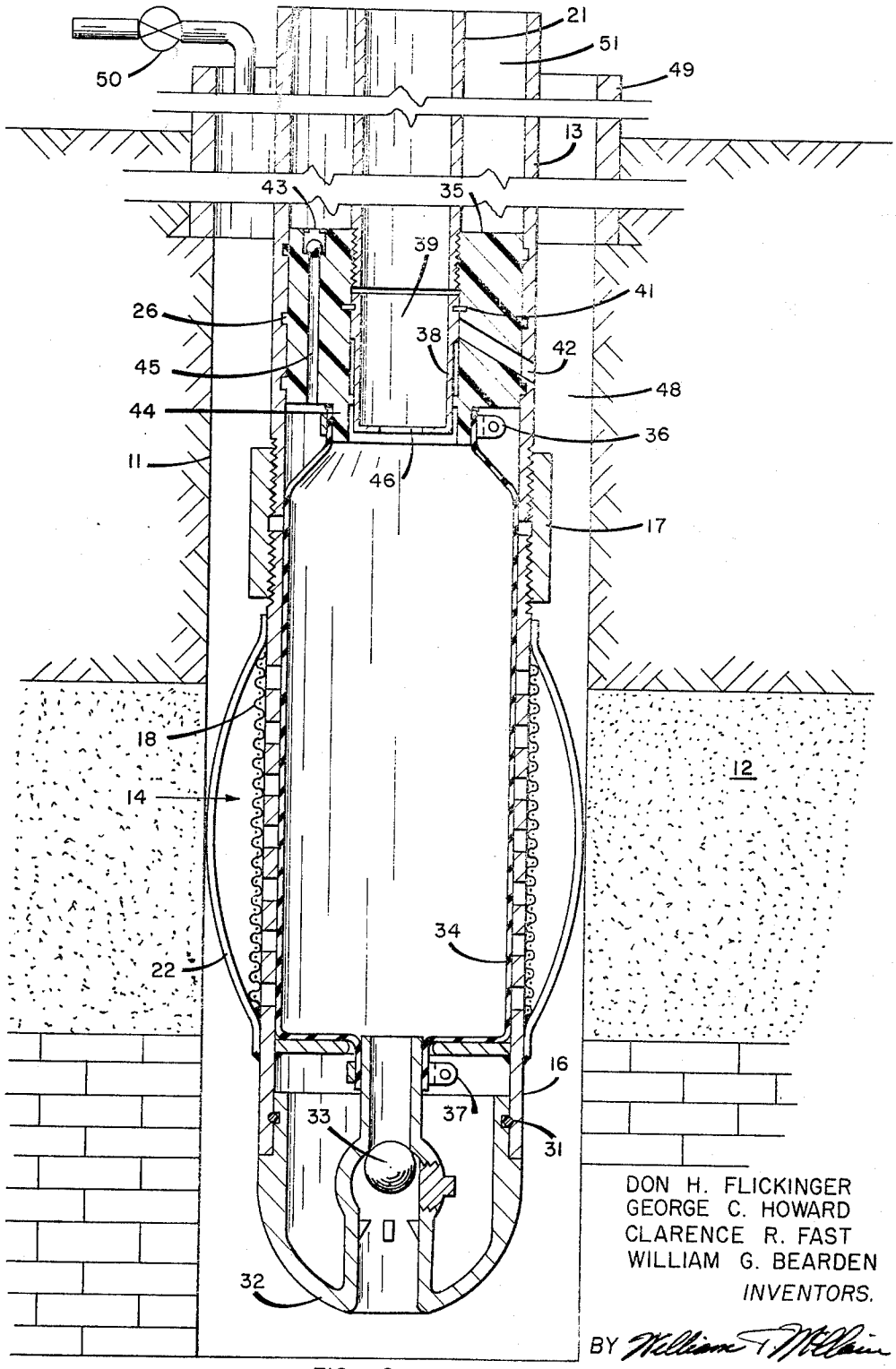


FIG. - 2

DON H. FLICKINGER
GEORGE C. HOWARD
CLARENCE R. FAST
WILLIAM G. BEARDEN
INVENTORS.

BY William T. McClain
ATTORNEY.

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Filed Nov. 29, 1963 3 Sheets-Sheet 3

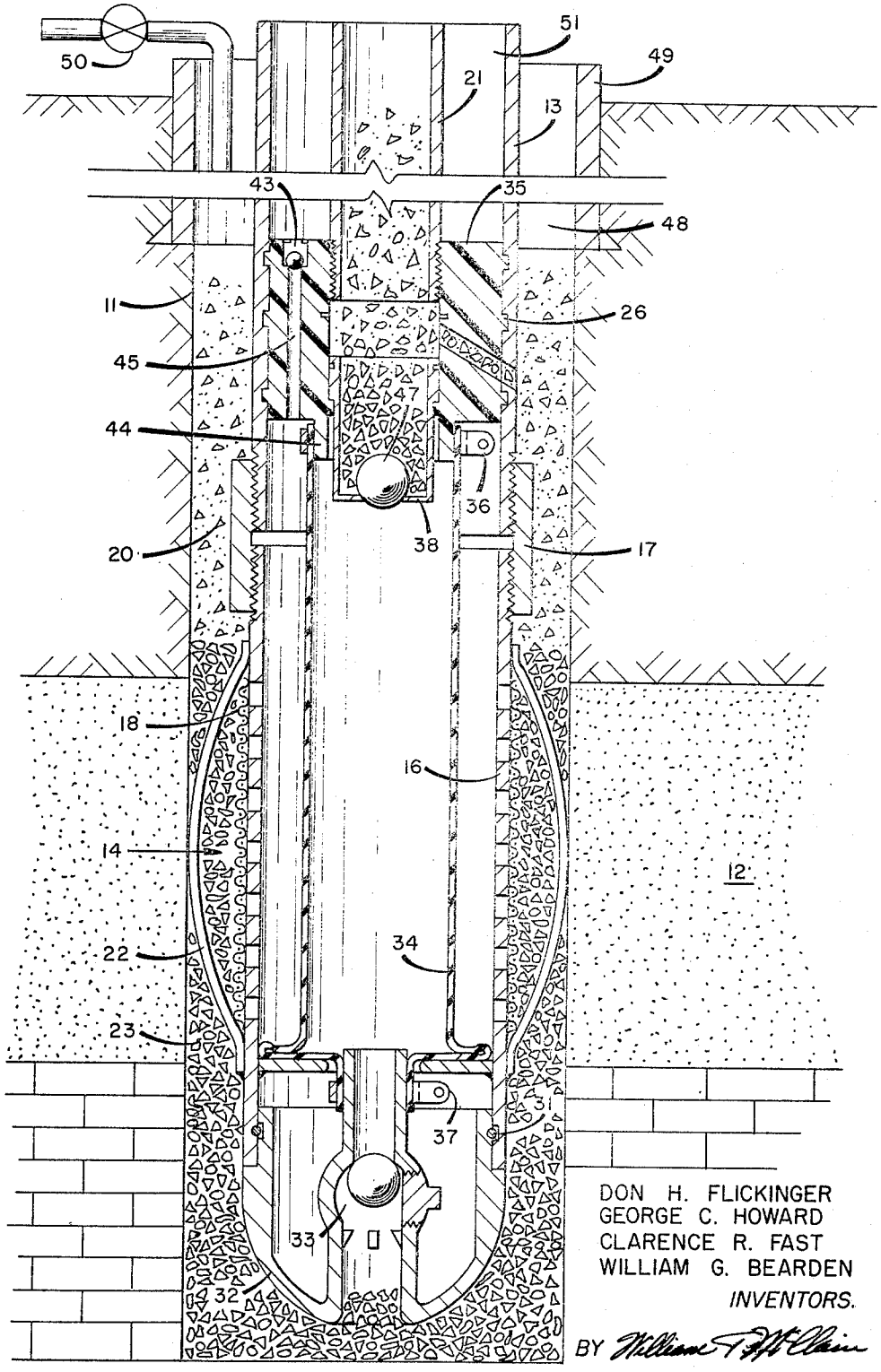


FIG. – 3

DON H. FLICKINGER
GEORGE C. HOWARD
CLARENCE R. FAST
WILLIAM G. BEARDEN
INVENTORS.

BY William T. McClain
ATTORNEY.

United States Patent Office 3,277,962 Patented Oct. 11, 1966

3,277,962

GRAVEL PACKING METHOD

Don H. Flickinger, George C. Howard, Clarence R. Fast, and William G. Bearden, Tulsa, Okla., assignors to Pan American Petroleum Corporation, Tulsa, Okla., a corporation of Delaware

Filed Nov. 29, 1963, Ser. No. 326,880
6 Claims. (Cl. 166—15)

This invention relates to well completions wherein a filtering material, such as gravel or other such particles, is positioned in a well between a producing formation and a screen member to restrain the production of sand or the like in the well. More particularly, the invention relates to an improved method of placing a gravel packing material in a well and for preventing the subsequent movement of the placed gravel packing material.

The use of gravel or the like for restraining formation sand or other such producing formation substances from entering a well is well known in the art. Such techniques are generally referred to as "gravel packing," which term as used herein includes the use of gravel, cement clinker, sand or other such particles of a preselected size. It has been determined that a major problem in preventing formation sand production is movement of the gravel packing material placed between the screen member and the formation. Various methods have been employed in an effort to prevent such movement of the gravel packing material. Typically, mechanically set packers or relatively light plugs of cement have been set over the gravel packing material near the top of the screen for this purpose. In general, however, it has been found that with such techniques it is nevertheless very difficult to fully pack the annular space below the packer or plug, and subsequent shifting of the gravel packing material allows formation sand to enter the well, causing erosion of the screen member and resulting in expensive remedial measures. The screen member may also be eroded by the gravel packing material itself unless movement is prevented.

A primary object of the present invention is an improved method of gravel packing which is both economical and effective. A more specific object of the invention is a method of fully packing the annular space between the screen member and a formation, and of restraining the shifting of particles of gravel packing material placed in the well. Other objects of the invention wlil become apparent by reference to the following description of the invention.

It is well known to place casing in a well for various purposes, such as to prevent cave-ins of the well bore, to prevent underside fluid flow, etc. Such primary cementing typically is performed by circulating a cement slurry down the casing and up the annular space between the casing and the formation. In such cementing practice, a column of cement fills the casing-bore hole annulus to a desired height, and normally the cement column extends along the casing for a considerable distance.

In accordance with the present invention, the primary cement employed in cementing the casing is employed to compress gravel packing material placed in the annular space between a screen member and a producing formation, and to permanently hold the gravel packing material in place in the well. The primary cement thus serves both to secure the casing in the well and to compress the gravel packing material so as to restrain the movement thereof.

According to the invention, a pipe string having a screen member extending downwardly therefrom is positioned in a well at a desired depth, with the screen member opposite a producing formation. The annular space between the screen member and a producing formation traversed by the well is filled with a suitable gravel packing material. After the gravel packing material is placed, a cement slurry is employed to fill the annular space between the casing and the wall of the well for a substantial distance along the casing immediately above the gravel packing material. The cement slurry is in contact with the top of the gravel packing material so that the column of cement compresses the gravel pack. After the casing-well annulus is filled to the desired height with the cement slurry, the cement is allowed to set so that the casing is cemented and movement of the gravel packing material is permanently restrained.

Where a well has been drilled with a clear drilling fluid, such as water or air, the bore hole may be circulated clean, the screen member placed opposite a producing formation and gravel packing material placed in the well. However, where a drilling mud, such as one comprising a suspension of clay in water is used, the bore hole adjacent the area to be gravel packed must be cleansed of the drilling mud prior to placing the gravel packing material, or else there will be a tendency for the drilling mud to plug the interstices between the gravel particles so that fluid flow through the gravel pack is inhibited. Therefore, in such instances, it is generally deirable to remove drilling mud from the bore hole prior to placing the gravel pack.

The invention will be better understood by reference to the following description of two preferred methods of completing a well in accordance with the invention and to the accompanying drawings wherein:

FIGURE 1 is a schematic illustration of well completion apparatus in a bore hole which has been drilled with a clear drilling fluid;

FIGURE 2 schematically illustrates well completion apparatus according to the invention placed in a bore hole drilled with a drilling mud; and

FIGURE 3 schematically illustrates the well of FIGURE 2 after placing gravel packing material and cement in accordance with the invention.

Referring to FIGURE 1, a bore hole **11** is drilled into the earth and traverses a producing formation **12** which may be an oil-bearing sand or the like. When it is desired to produce the well, a string of casing **13** is placed in the well with a screen member **14** extending downwardly from the casing so that the screen member is opposite producing formation **12**. The screen member may comprise a slotted liner **16** or other suitable perforated tubular element connected by coupling **17** to the lower end of the casing string. If the well is drilled to a depth substantially below the producing formation, the screen member may be positioned between sections of casing. A well packer, cement plug or other suitable means may be employed below the screen member to support the gravel packing material in the well. The slotted liner preferably is enclosed with a relatively fine-mesh screen material **18**, such as wire wrapping plastic and glass fiber, sand-plastic or nutshell-plastic which is provided with openings large enough to pass water, oil or other such fluids but small enough to prevent the in-flow of the gravel packing material **23**.

Secured in the lower end of casing **13** immediately above screen member **14** is a crossover tool **19** connected to the lower end of tubing **21** positioned inside casing **13** and extending upwardly to the surface of the earth. The crossover tool is sealed in the casing and permits flow communication between the interior of tubing **21** and the casing-well annulus, as well as providing flow communication from the inside of the casing above the tool to the inside of the casing and the interior of the screen member positioned below the tool. One or more centralizers **22** may be employed to evenly space the screen member

from the well wall so that a suitable quantity of gravel packing material can be placed around the screen member in a continuous manner.

The annular space between the screen member 14 and the bore of the well traversing the producing formation 12 is filled with a gravel packing material 23, employing, for example, in the completion of wells drilled in an Athabasca tar sand, a −20+40 mesh Ottawa sand or similar size permeable cement clinker. The gravel packing material may be placed in the well by various techniques. A technique preferred in the instance where the well is drilled with a clear drilling fluid is to circulate the bore hole clean, and then close annulus 48 between casing 13 and surface or intermediate casing 49 by means of valve 50 on the wellhead. A slurry of the gravel packing material in water or other suitable liquid is then circulated down tubing 21 through passageway 24 in the crossover tool 19 into the casing-well annulus. By virtue of its greater density the gravel packing material settles toward the bottom of the screen member, and the circulating fluid passes through screen wrapping 18 and perforated liner 16, upwardly through passageway 25 into the tubing-casing annulus 51. It is to be understood that a plurality of passageways 25 and 24 generally are employed in the crossover tool spaced apart to provide suitable flow distribution across the tool. As the annular space between the screen member and the well wall fills with the gravel packing material, the point of complete fill-up may be determined by a rather sharp rise in pressure when the gravel packing material fills this annular space above the top of the screen member. Advantageously, in order to insure that the gravel packing material is well compacted, a high fluid pressure, typically in the range of about 300 to 500 p.s.i.g. is applied to the pack. This may be done either prior to or subsequent to placing the cement slurry. It is generally recommended that a volume of gravel packing material approximately 1½ times the volume of the annular space surrounding the screen member be employed. The lowermost portion of the gravel packing material will extend slightly below the lower boundary of the producing formation, and likewise, the topmost part will extend slightly above the upper boundary of the producing formation.

Upon placing the gravel packing material in the well as described above, valve 50 is opened and the casing is cemented above the packed open hole, with the column of cement extending upwardly along the casing to the desired height in the well. The cementing may be performed using the crossover tool described above, or the crossover tool may be removed, if desired, and a cementing tool, such as a DV multiple stage cementer (Halliburton Company) inserted into the casing string may be employed in placing the cement. Generally, it is preferred to fabricate the crossover tool from a drillable material, such as plastic, magnesium, aluminum, etc. As shown in the drawings, the crossover tool is fabricated from a plastic material, and secured to the casing by rings 26 fitted into grooves cut into the inside wall of the casing. If preferred, the screen member 14 may be filled with sand to the openings left in the casing for the crossover tool, or a flapper-type check valve below the crossover ports may be installed so that it may be trip-closed when tubing 21 is pulled, following gravel packing of the annulus. In any event, the cement slurry is circulated down tubing 21 and through the crossover passageway 24 to the casing-well annulus 48 with the displaced fluid flowing out through valve 50. In this manner, the hydrostatic head of the column of cement 20 compresses the gravel packing material 23 and pressure may be maintained on the cement until it has set. The cement slurry will not penetrate the gravel so as to plug it up, however, it will exert a physical compressing force thereon, assuring the most compact packing. After the cement has been allowed to set, any excess cement may be drilled out of the pipe, and sand washed from inside of the liner to permit a full diameter completion of the well through the producing formation. In this manner the operator is assured of the gravel being well compacted and completely constrained in place by the column of cement above it.

Where the well which is to be completed has been drilled with a drilling mud, such as one comprising a suspension of clay in water, it is desirable to remove the drilling mud from the walls of the bore hole adjacent the area to be gravel packed. In such instances, the following procedude described in connection with FIGURES 2 and 3 may be employed in accordance with the present invention. As before, a bore hole 11 is drilled into the earth and traverses a producing formation 12. A string of casing 13 is placed in the well with a screen member 14 extending downwardly from the casing so that the screen member is opposite a producing formation. The screen member comprises the screen wrapping material 18, preferably wrapped on the outside of perforated liner 16 as mentioned above, and centralizer 22 may be employed to position the screen member in the bore hole.

The screen member 14 is connected onto the lower end of casing 13 by coupling 17. Connected to the lower end of screen member 14 by coupling 31 is float shoe 32 provided with check valve 33 which permits unidirectional flow outwardly to the well annulus. Positioned inside screen member 14 is innerliner 34 connected at its upper end to crossover tool 35 by fluid-tight connection 36, and at its lower end to float shoe 32 by fluid-tight connection 37. Innerliner 34 is formed of a flexible material, such as a rubber or nylon fabric, which is impermeable to water or other such liquids.

As before, crossover tool 35 provides flow communication between the inside of tubing 21 and the casing-well annulus 48, and also between the tubing-casing annulus 51 above the tool and the space between the innerliner 34 and the inside of screen member 14. As described above, crossover tool 35 may be of the type removable from the casing or it may be fabricated of a drillable material, such as plastic or aluminum, and secured in the casing as before. Crossover tool 35 is provided with a sliding sleeve 38 positioned in passageway 39 and secured therein by shear pins 41, so that the top of the sliding sleeve covers the opening to passageway 42 in the position shown in FIGURE 2. Sleeve 38 is sealed in a fluid-tight manner against the interior of passageway 39 so that when in the up position the inside of tubing 21 communicates only with the interior of innerliner 34. Passageway 45 is provided with check valve 43 to provide unidirectional upward flow from the space between innerliner 34 and the interior of screen member 14 to the tubing-casing annulus 51. Extending downwardly from passageway 39 is a tubular extension 44 upon which the upper neck of innerliner 34 is mounted in a fluid-tight manner by connector 36. At the lower end of sleeve 38 there is provided a circular shoulder 46 having a diameter less than the internal diameter of the sleeve. When it is desired to pass fluid through tubing 21 to the casing-well annulus, a plug member, such as ball 47, may be passed downwardly through tubing 21 to close the opening in the lower end of the sleeve 38 as shown in FIGURE 3. By the application of a preselected fluid pressure to fluid in tubing 21, shear pins 41 are sheared and sleeve 38 drops down to open passageway 42 connecting the tubing interior with the casing-well annulus.

When it is desired to complete a well using the apparatus of FIGURES 2 and 3, water or other suitable flushing fluid is passed from the surface downwardly through tubing 21, passageway 39, float shoe 32 and check valve 33 into the well bore at a suitable flow rate and velocity to wash drilling mud from the well bore. The flushing medium, together with the relatively fine particles of suspended solids in the drilling mud pass upwardly in the casing-well annulus and out of the well. When the well bore is sufficiently cleansed of drilling mud, ball 47 is dropped down tubing 21 to engage with shoulder 46 and

sufficient fluid pressure is applied to the interior of tubing **21** to shear pins **41** and cause sleeve **38** to move downwardly to establish flow communication between tubing **21** and the casing-well annulus. Then, a slurry of a suitable gravel packing material, as described above, together with water or other suitable fluid, is circulated down tubing **21** into bore hole **11** to place the gravel packing material in the well around screen member **14**. As before, valve **50** is closed. The particles of gravel packing material drop out in the well bore, with the circulating fluid passing through the screen member **14** and upwardly through passageway **45**. The gravel packing material is placed as described above, and if desired, fluid pressure applied to the placed gravel packing material upon filling to aid in compacting it. After the gravel packing material has been suitably placed, valve **50** is opened and a cement slurry is passed down tubing **21** and into casing-well annulus with the column of cement directly contacting the top portion of the pack to further compact the gravel packing material. Pressure may be maintained on the cement slurry until it has set to aid in compressing the gravel packing material placed in the well. As described above, cement **20** may be excluded from the interior of innerliner **34** by the use of sand or a check valve, and after the cement has set, any excess cement may be drilled out and a full diameter completion of the well through the producing formation may be effected.

As noted above, it is essential to the invention that the column of primary cement **20** be placed directly on top of the gravel packing material placed in the well, and the operations hereinbefore described constitute preferred schemes in accordance with the invention. However, other techniques of placing the gravel packing material and the cement may be utilized to accomplish the desired result. For example, in the method described in connection with FIGURE 1, the gravel packing material may be circulated into place using a reverse circulation technique wherein the gravel packing material and circulating medium are passed down the annulus and up tubing **21**, so that crossover tool **19** is not required. The gravel packing material may also be dumped into the casing-well annulus at the surface at a sufficiently slow rate to insure that the annular space between the bore hole and the screen member is completely filled. In a somewhat similar manner, the gravel packing material may be first placed in the well with the screen member and casing subsequently drilled or jetted into place so that the gravel packing material surrounds the screen member as mentioned above. The primary cementing, of course, may be performed using conventional techniques and tools to place the cement column directly on top of the placed gravel packing material. Various of the techniques mentioned above may be utilized in the practice of the invention, although all are not necessarily of equal effectiveness in all situations. For example, the method and apparatus described in connection with FIGURES 1 through 3 have been especially developed for use in wells drilled in Athabasca tar sand.

It is to be understood that the height of the cement column placed on top of the gravel packing material may vary considerably, but is always effective to compress the gravel packing and restrain its movement. The height of the cement column is greater than that of a mere seal or plug, and preferably it extends upwardly above the gravel packing at least about 300–500 feet, although a height of about 100 feet may be satisfactory under some circumstances. For example, a column of heavy drilling mud may be allowed to remain in the well on top of a relatively short cement column to satisfactorily effect suitable compression of the gravel packing material.

The foregoing description of the present invention has been given for the purpose of exemplification, and from the above, various alterations and modifications, coming within the spirit and scope of the invention, will become apparent to the artisan.

We claim:

1. A method of completing a well in which a pipe string is suspended within a casing which comprises:

positioning a screen member extending downwardly from said pipe string and at a desired depth in the well;

filling the space between the screen member and the wall of the well opposite the productive formation with a gravel packing material;

circulating a fluid downwardly through said pipe string and laterally through a conduit means to discharge said fluid at a point in the annulus between said casing and said well above said gravel packing material, said circulating fluid including a cement slurry;

during such circulating, maintaining the annulus from said point upwardly in free fluid communication with the exterior of said well so that fluid in said annulus can be displaced by the circulation of said fluid;

stopping the said circulating of the fluid with said cement slurry being in contact with said gravel packing material so as to compress such gravel packing material;

allowing said cement slurry to set whereby said pipe is cemented and movement of said gravel packing material is restrained.

2. The method of claim **1** wherein said screen member has a diameter substantially at least as great as the diameter of said pipe string.

3. A method as defined in claim **1** wherein a hydrostatic pressure of at least about 300 p.s.i. is applied to the top of said gravel packing material after being placed in said well.

4. The method of claim **1** wherein the height of the resulting cement column placed on top of said gravel packing material is at least about 300 feet.

5. A method as defined in claim **1** including the step of applying a pressure to the top of said cement slurry until it has set.

6. A method as defined in claim **1** including excluding cement from the interior of said screen member until said cement has set.

References Cited by the Examiner

UNITED STATES PATENTS

2,597,554	4/1952	West	166—20
2,623,595	12/1952	West	166—20
2,978,027	4/1961	Widmyer	166—19

JACOB L. NACKENOFF, *Primary Examiner.*

J. A. LEPPINK, *Assistant Examiner.*