April 23, 1940. E. L. DAVIS ET AL 2,198,573

METHOD AND APPARATUS FOR GRAVELING WELLS

Filed March 29, 1938

FIG. 1.

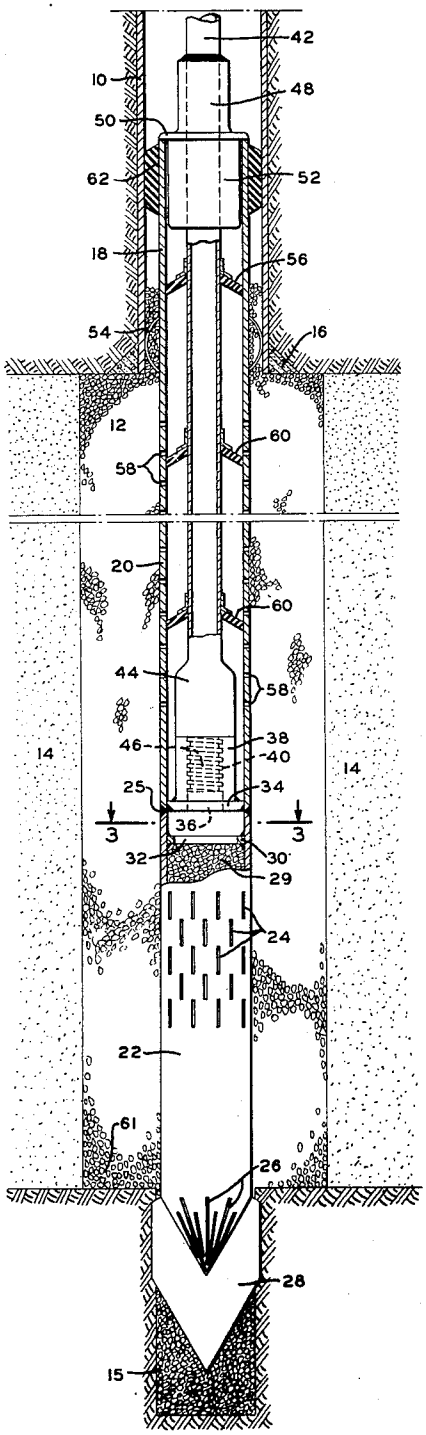

FIG. 2.

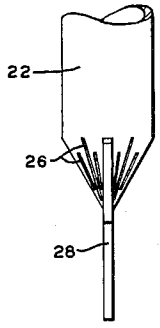

FIG. 4.

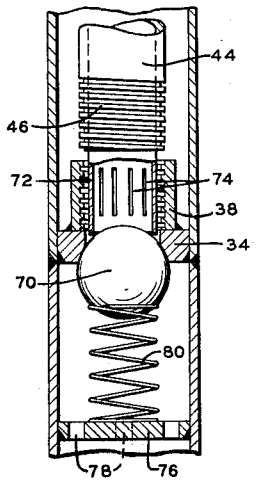

FIG. 3.

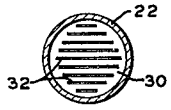

FIG. 6.

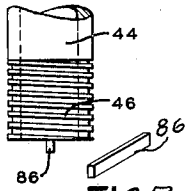

FIG. 7

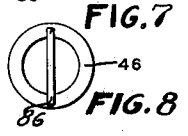

FIG. 8

FIG. 5.

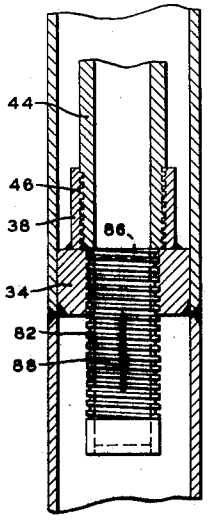

FIG 9

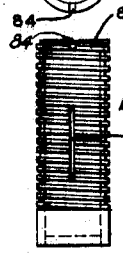

FIG. 10.

EUGENE L. DAVIS
HOWARD S. COLE, JR.
W. EDWARD LARSON
NORMAN C. WELLS
INVENTORS

BY R. J. Dearborn
Daniel Stryker
ATTORNEY

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METHOD AND APPARATUS FOR GRAVELING WELLS

Eugene L. Davis, Long Beach, Calif., Howard S. Cole, Jr., Fort Worth, Tex., Wason Edward Larson, San Pedro, and Norman C. Wells, Artesia, Calif., assignors to The Texas Company, New York, N. Y., a corporation of Delaware

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14 Claims. (Cl. 166—1)

This invention relates to a method and apparatus for completing wells and more particularly to the gravel-packing of a well, i. e., the placing of a bed of gravel or other granular material in a well at the place where oil or other fluid to be produced enters from the surrounding formations. The principal object of the invention is to provide a method and apparatus for placing the gravel effectively without danger to the well which might otherwise occur through the sticking of equipment in the well, the misplacing of the gravel, or for other reasons.

The advantages and benefits to be gained from placing a gravel wall around the liner or screen of a well for eliminating sand trouble, when the producing formations are known to cause trouble from sanding or sloughing, are now well known. The gravel reduces the infiltration of sand into the liner by entrapping this sand in its interstices and also protects and supports the walls of the well during the producing of the well.

When gravel-packing is conducted with the normal or direct circulation method, a fluid such as drilling mud is usually circulated down through the tubing to the bottom of the well and then upwardly through the annular space between the tubing and the casing. Gravel is added to the circulating fluid and passes outwardly from the lower end of the tubing string, usually through a ball check valve, and into the cavity or space provided at the bottom of the well in the producing sands. The gravel freely collects or bridges at the check valve and it is often necessary to remove and then replace the tubing string in order to repack the well.

Another method of gravel-packing which is frequently unsuccessful comprises first placing gravel in the hole and then dropping or forcing the liner, usually provided with a "chisel" point, down through the gravel to the proper position in the producing zone. It is not always possible to force the liner down to the desired point and to keep it centered in the hole and occasionally the liner becomes stuck in the gravel with consequent added expense and time delay in completing the well.

In accordance with this invention, after the drilling operations have been completed, usually with the underreaming of the well cavity in the producing zone, a partially slotted liner, the slotted portion of which subsequently serves as the well screen, is run into the hole on a string of pipe or tubing. The tubing is attached to the inside of the liner by means of a safety or releasable joint at the lower end of the liner. A properly conditioned carried fluid such as drilling mud is circulated down through the annular space between the tubing and the casing and then upwardly through the tubing. Gravel is added to the drilling fluid and, upon reaching the well cavity, the drilling fluid passes into the tubing through slots in a perforated bull plug attached to the liner and then upwardly to the surface. The gravel thus is deposited in the well cavity around the slotted liner or screen and forms an effective pack.

Upon completion of the packing operations, the tubing is disconnected from the liner at the releasable joint and removed from the well and a packer or adapter is then placed in the well so as to seal the space between the upper end of the liner and the well casing. In order to prevent the drilling fluid and gravel from entering the top of the liner, a device attached to the tubing just above the top of the liner serves to divert mud and gravel downwardly around the sides of the liner, and also serves to center the tubing within the liner and to maintain this centering action throughout the operation of disconnecting the tubing from the liner at the releasable joint. Means are also provided for preventing the drilling fluid from by-passing the gravel by entering the liner through its upper slots and leaving through the lower slots, as well as for automatically closing the opening in the lower portion of the liner when the tubing is disconnected at the releasable coupling or joint. The liner is provided with means for preventing its rotation while the tubing is being disconnected and also with means for centering it within the casing.

For a better understanding of the invention, reference may be had to the accompanying drawing in which:

Figure 1 is a vertical elevation, partly in section, through a well cavity showing one embodiment of the packing apparatus in position after the gravel has been placed but before the tubing has been removed;

Figure 2 is a side elevation of the lower end of the bull plug;

Figure 3 is a view taken on line 3—3 of Figure 1 looking in the direction of the arrows;

Figure 4 is an enlarged sectional elevation showing a modification of the releasable coupling;

Figure 5 is a sectional elevation showing another modification of the releasable coupling, while

Figures 6, 7, 8, 9 and 10 show, in spaced relation, parts of the modified coupling of Figure 5.

In Figure 1 is shown the lower portion of a well having a casing 10 and an enlarged cavity 12 formed by under-reaming the producing sands or formation 14. A "rat hole" 15 may be formed at the bottom of the cavity for centering the liner. The casing is secured in the hole as by cement 16 in the usual manner. A liner 18 comprising a tube or pipe somewhat smaller than the internal diameter of the casing 10 and having a slotted or perforated portion forming a screen 20, has attached at its lower end a bull plug 22. The bull plug comprises a length of tubing or pipe of substantially the same diameter as the liner 18 and is provided throughout its center portion with slots or perforations 24. The bull plug is secured to the lower end of the liner 18 as by welding at 25 and is provided at its lower end with additional slots 26 and a laterally extending plate 28, the purpose of which will be brought out hereinafter. The bull plug 22 is preferably filled with gravel or other granular material 29 before it is attached to the liner 18, and a circular plate or disc 30 having slots 32 is adapted to be secured in the bull plug as by welding directly above the space containing the gravel. The lower end of the liner just above the bull plug is provided with a plate or disc 34 which is preferably welded into the liner and this plate has an opening 36 and an upwardly projecting box 38 provided with internal left hand threads 40.

The plate 34 with its threaded box 38 forms one part of a releasable coupling by means of which the liner 18 and bull plug 22 are attached to and suspended from the string of tubing 42. The lower end 44 of the tubing string is provided with a threaded projection 46 having left hand threads and adapted to be screwed into the box 38.

In order to prevent the gravel from entering the upper end of the liner 18 a diverter plug or collar 48 is secured as by welding to the tubing 42. This plug is provided with a lateral portion 50 adapted to cover the upper end of the liner, and also with a downwardly extending enlarged portion 52 having a sliding fit within and adapted to substantially close the upper end of the liner while the coupling 38—44 is being disconnected. The plug portion 52 also serves to center or rather to space the upper end of the liner 18 concentrically with the tubing 42. A plurality of spacer guide members 54 are attached to the liner 18 and serve to space the same evenly from the casing 10. A swab 56 is preferably secured around the tubing 42 below the plug 48 to prevent as far as possible circulating fluid from passing down into the liner 18. In order to prevent the carrier fluid or drilling mud from by-passing the gravel in the cavity 12 by entering the liner through the upper slots 58 and leaving the screen portion of the liner through the lower slots, other swab members 60 may be secured to the tubing and spaced at intervals throughout the length of the screen portion 20.

In the operation of the form of the invention thus far described, the bull plug 22 is first filled with gravel 29 and the slotted plate 30 then placed in the upper end of the plug. The bull plug is attached as by welding to the lower end of the liner 18 and the liner then attached to the lower end of the tubing 42 by means of the threaded connection 38—44. The swabs 56 and 60 are, of course, secured to the tubing before the connection 38—44 is made. The diverter plug is welded to the tubing with the liner hung freely at the well head. After assembling, the device is lowered into the well on the tubing string until the bull plug 22 reaches the bottom of the cavity 12 and passes into the rat hole 15. The plate 28 will prevent rotation of the liner when the tubing is to be disconnected at the coupling 38—44. The carrier fluid, which may be a drilling mud of low viscosity in order to allow the gravel to drop out while at the same time being sufficiently viscous to hold the gravel and prevent it from bridging before it gets in place, is then circulated down through the space between the tubing 42 and the casing 10. The fluid will enter the bull plug through the slots 24 and 26 and will pass upwardly through the gravel therein and through the tubing 42 to the surface. Gravel 61 is then added to the circulating fluid and passes downwardly therewith until it reaches the cavity 12. The swabs 60 will prevent the fluid from by-passing the gravel which will be forced down to the bottom of the cavity, whereupon the fluid will enter the bull plug, as before stated, through the slots 24 and 26 and return to the surface through the tubing string. Gravel may be added to the circulating fluid continuously or it may be added intermittently, the circulating fluid serving to wash the gravel down to the cavity.

When about half of the gravel has been placed in the well it is preferable that the mud be conditioned with some suitable chemical so as to reduce the gel strength so that it can then enter the tubing more easily. The remainder of the gravel is then circulated into the cavity by means of the conditioned mud until the cavity and preferably part of the space between the casing and the upper end of the liner 18 have been filled. When the proper amount of gravel has been placed in the well, the mud is displaced with water until clear water reaches the surface through the upper end of the tubing string. The tubing is then rotated in a right hand direction so as to unscrew the connection 38—44 and during this unscrewing operation the enlarged portion 52 of the diverter plug 48 will substantially close the upper end of the liner so as to prevent gravel which may have accumulated at that point from entering the liner. The swab 56 will also aid in this respect. The tubing is then withdrawn from the hole and a suitable packer or adapter 62 lowered into position so as to seal the space between the upper end of the liner 18 and the casing 10. The hole is then bailed so as to remove the water and the well is in condition for production.

It is possible that the velocity of the gravel carrying mud through the upper rows of slots 24 in the bull plug may tend to pack gravel at this point and leave an unpacked hole below. Again, the upper end of the hole 15 may become bridged over with gravel due to the passing of the fluid through the upper slots 24 and into the tubing through the opening 36. In order to prevent future flow of sand from below such a bridge into the liner, a somewhat modified form of releasable coupling is shown in Figure 4, in which the plate 34 is provided with a seat for a ball valve 70 preferably formed of a phenolic condensation product such as Bakelite. The threaded end 46 of the tubing is provided with a short sleeve extension 72 which has a plurality of vertical slots 74 formed therein. A plate 76 having a plurality of holes 78 is welded into the upper end of the bull plug and serves as a support for a compres-

sion spring 80 adapted to bias the ball valve 70 upwardly toward its seat in the plate 34. Thus, when the threaded end 46 of the tubing is connected to the threaded box 38, the circulating fluid will pass through the slots 74 and upwardly through the tubing. However, upon unscrewing the end 46 from the box 38, the ball valve 70 will be forced upwardly and will engage its seat in the plate 34 when the tubing is removed, thus preventing further upward flow. In time the valve will become sanded in place and deterioration of the spring 80 will have no effect upon its action.

Figures 5 and 6 show another modification of a device for preventing upward flow from the bull plug after the tubing has been removed. A threaded plug 82 having the same pitch and lead as the threads of the joint 38—44 is provided at its upper end with a lateral slot 84 adapted to be engaged by a corresponding key 86 secured to the lower end of the threaded extension 46. In the made-up position, slots 88 in the threaded plug 82 provide for circulation in either direction, but upon unscrewing the connection 38—44 the key 86 causes the plug 82 to turn until the slots 88 have passed upwardly within the plate 34. The key 86 will be disengaged from its slot 84 on removing the tubing and circulation will thus be prevented.

It will be noted that in case it is desired to use normal or direct circulation during or after the gravel-packing operation, this may be done since all of the forms as shown in Figures 1, 4 and 5 provide for circulation in either direction.

As an alternative method of preventing the carrier fluid or drilling fluid from by-passing the gravel in the cavity 12 by entering the liner through the upper slots 58 and leaving the screen portion of the liner through the lower slots, the swabs 58 and 60 may be dispensed with, and the annular space between the tubing and the liner may be filled with a soft, salve-like, water-insoluble material such as grease, other viscous fluids, or impermeable solids or semi-solids which would prevent the circulating fluid from entering into the liner from its upper end and which, at the well temperature, would be sufficiently viscous so that it would not pass outwardly through the slots in the liner. After the gravel packing operation has been completed, the material filling the liner can be removed by bailing, by circulating with suitable fluid, by being dissolved in a suitable solvent, or other means.

A still other method of forcing the circulating fluid to descend through the full length of the annular space between the formation and the liner consists in placing in the liner opposite the screen portion 20 a lining of cement, metal or other material which will close the liner slots and which can be subsequently drilled out after the gravel-packing operation is completed. In this case the left hand screw connection 38—44 may be placed at the upper end of the liner 18 rather than at its lower end since the operation will be the same after the lining has been drilled out.

Obviously many modifications and variations of the invention may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated by the appended claims.

We claim:

1. Apparatus for gravel-packing a well comprising a string of pipe extending from the surface to a point near the bottom of the well, a tube having a perforated screen section, said tube surrounding and spaced from the lower end of said pipe, a releasable connection between the lower end of said pipe and a point in said tube below said perforated section, a tubular extension closed at its lower end and connected to and extending downwardly from the lower end of said screen tube, said extension having perforations in its lower end and in its side walls and adapted to be filled with a quantity of granular material.

2. Apparatus for packing a well with granular material comprising a perforated liner tube, a tubular extension connected to and projecting downwardly from the lower end of said liner tube, said extension being closed at its lower end and containing a quantity of granular material, said extension containing perforations through which liquid to be produced can pass to the interior of said extension and means for lowering said liner tube into a well comprising a string of drill pipe and a releasable connection between the lower end of said pipe string and the lower end of said liner tube.

3. Apparatus for packing a well with granular material comprising a string of pipe extending from the surface to a point near the bottom of the well, a perforated liner tube surrounding and spaced from the lower portion of said pipe, a releasable coupling between the lower end of said tube and the lower end of said pipe string, said coupling including a left hand screw connection, a perforated bull plug connected to and extending downwardly from the lower end of said liner tube, said bull plug containing a quantity of granular material, and means attached to and projecting laterally and downwardly from the lower end of said bull plug so as to engage the earth formation and prevent rotation of said bull plug and liner while said pipe string is being disconnected from said liner at said releasable coupling.

4. Apparatus for packing a well with granular material comprising a perforated tube adapted to be placed in the productive zone of a well, a string of pipe extending from the surface to a point near the bottom of the well, the lower portion of said pipe being within said tube, means for releasably coupling the lower end of said tube to the lower end of said pipe including a threaded connection, a collar secured to said pipe and forming a tight cover for the upper end of said tube during the graveling operation, said collar having an extension projecting downwardly into the upper end of said tube so as to maintain the upper end of said tube substantially closed while said coupling is being unthreaded.

5. An assembly for use in placing gravel or like material in a well, comprising a string of pipe extending from the surface to an oil-producing zone, a tubular member having perforations therein and adapted to be placed in the well opposite said oil-producing zone and around but spaced from the lower portion of said pipe, a releasable coupling between the lower end of said pipe and said tubular member, said coupling containing an opening connecting the interior of the pipe with the space exterior of said tubular member, and a plug secured to said pipe for tightly covering the upper end of said tubular member, the arrangement being such that when circulating a carrier fluid containing gravel downwardly in the well around said pipe string, said plug will prevent the gravel and carrier fluid

from entering said tubular member at its upper end so that the carrier fluid will enter said pipe through said releasable connection while said gravel will be deposited so as to form a filter bed around said tubular member.

6. An assembly for use in placing gravel or like material in a well, comprising a string of pipe extending from the surface to an oil-producing zone, a tubular member having perforations therein and adapted to be placed in the well opposite said oil-producing zone and around but spaced from the lower portion of said pipe, a releasable coupling between the lower end of said pipe and said tubular member, said coupling containing an opening connecting the interior of the pipe with the space exterior of said tubular member, a plug secured to said pipe for tightly covering the upper end of said tubular member during the graveling operation, the arrangement being such that when circulating a carrier fluid containing gravel downwardly in the well around said pipe string, said plug will prevent the gravel and carrier fluid from entering said tubular member at its upper end, so that the carrier fluid will enter said tubing through the opening in said releasable connection while said gravel will be deposited so as to form a filter bed around said tubular member, and means cooperating with said releasable coupling for closing the opening therein when the pipe string is uncoupled from said tubular member.

7. Apparatus for gravel-packing a well comprising a string of pipe extending from the surface to a point near the bottom of the well, a perforated screen tube surrounding and spaced from the lower portion of said pipe, a releasable coupling between the lower end of said tube and the lower end of said pipe string, said coupling including a left hand screw connection and an opening connecting the interior of said pipe with the exterior of said screen tube, and means for automatically closing said opening when said coupling is disconnected, said means comprising a valve, means for biasing said valve toward said opening, and means on the lower end of said pipe for holding said valve away from said opening while the screen tube and pipe are connected.

8. Apparatus for gravel-packing a well comprising a string of pipe extending from the surface to a point near the bottom of the well, a perforated screen tube surrounding and spaced from the lower portion of said pipe, a releasable coupling between the lower end of said tube and the lower end of said pipe string, said coupling including a left hand screw connection and an opening connecting the interior of said pipe with the exterior of said screen tube, and means for automatically closing said opening when said coupling is disconnected, said means comprising a valve, means for biasing said valve toward said opening, and a slotted sleeve connected to and projecting downwardly from the lower end of said pipe, so as to hold said valve away from said opening while said coupling is made up.

9. Apparatus for packing a well with granular material having a casing and an enlarged cavity in the producing formation comprising a tubular member provided with perforations to form a well screen, means for lowering said tubular member into said cavity comprising a string of pipe, a releasable connection between the lower end of said pipe string and said tubular member at a point below said screen portion, means for closing the space between said pipe and the upper end of said tubular member while said releasable coupling is being disconnected, and a plurality of flexible packing members secured to said pipe and engaging the inner surface of the screen portion of the tubular member so as to prevent the circulation of fluid longitudinally through said tubular member while connected to said pipe string, and a packing member adapted to seal the upper end of said tubular member from said casing.

10. Apparatus for gravel-packing a well having a casing and an enlarged cavity in the producing formation comprising a tubular member provided with a perforated screen section, means for lowering said tubular member into said cavity comprising a string of pipe, a releasable connection between the lower end of said pipe string and said tubular member at a point below said screen section, means for uncoupling said connection so as to remove said pipe string from the well after the gravel-packing operation, and means for preventing gravel and fluid from entering said tubular member through its upper end or through its perforations comprising a quantity of a soft, salve-like, water-insoluble material in the space between the pipe and the tubular member which material at the well temperature is resistant to displacement by the mud fluid and gravel but which is capable of being removed subsequently as by bailing.

11. Apparatus for gravel-packing a well having a casing and an enlarged cavity in the producing formation below said casing, a tubular member provided with a perforated screen section, a pipe string on which said tubular member is adapted to be lowered into said cavity, said tubular member being larger in diameter than said pipe string but smaller than said casing so that annular spaces are provided between said tubular member and said casing and between said tubular member and said pipe string, a releasable connection between the lower portion of said tubular member and the lower end of said pipe string, means for closing the upper end of the annular space between said tubular member and said pipe string during the graveling operation and while said coupling is being disconnected, the arrangement being such that on circulating granular material and a carrier fluid into said cavity through the annular space between said tubular member and said casing, the carrier fluid will pass around the tubular member and will enter the lower end of the pipe string to pass upwardly to the surface through said pipe string while the granular material will remain in said cavity, and packing means adapted to seal the annular space between said tubular member and said casing after the gravel has been placed in said cavity.

12. The method of gravel-packing a well provided with a cavity in the producing formation and a perforated tubular screen in said cavity and connected to the surface by means of a string of pipe, which comprises circulating granular material and a mud laden fluid downwardly into the well to the cavity through the space between the screen and the walls of the well so that the fluid will enter said pipe string and return to the surface while the granular material will remain in said cavity around the screen, conditioning the mud fluid so as to reduce its gel strength after the cavity has been partially filled with granular material and then continuing the circulation of the granular material and the conditioned fluid until the cavity has been filled with the granular material.

13. The method of packing a well provided with a cavity in the producing formations and a tubular member having a perforated screen portion, said member being connected to the surface by means of a string of pipe, which comprises circulating granular material and a carrier fluid into the well cavity through the space between the tubular member and the walls of the well while preventing the carrier fluid from entering the pipe string through the screen portion of the tubular member, causing the carrier fluid to enter the pipe string at a point remote from said screen portion so that the granular material will be deposited in said cavity around the tubular member, and then removing the pipe string from the well so that liquid to be produced can enter said tubular member through said screen portion and pass upwardly to the surface.

14. The method of packing with granular material a well provided with a cavity in the producing formation and a perforated tubular screen in said cavity and connected to the surface by means of a string of pipe, which comprises circulating granular material and a mud laden fluid downwardly into the well to the cavity through the space between the screen and the walls of the well so that the fluid will enter said pipe string and return to the surface while the granular material will remain in said cavity around the screen, discontinuing the circulation when the cavity is partially full of granular material, conditioning the mud fluid so as to reduce its gel strength, resuming the circulation of gravel and the conditioned fluid until the cavity has been filled with the granular material, displacing the mud fluid in the well with water, removing the pipe string from the well, sealing the space between the upper end of the screen and the wall of the well, and bailing the water from the well.

EUGENE L. DAVIS.
HOWARD S. COLE, JR.
W. EDWARD LARSON.
NORMAN C. WELLS.