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GRAVEL PACKING APPARATUS

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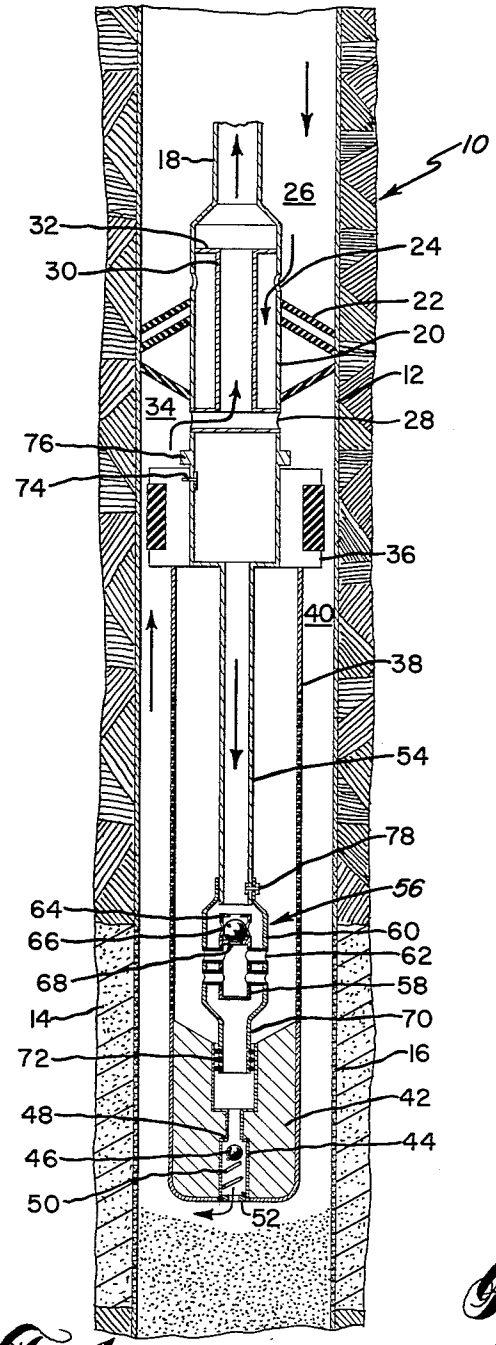



Fig. 1

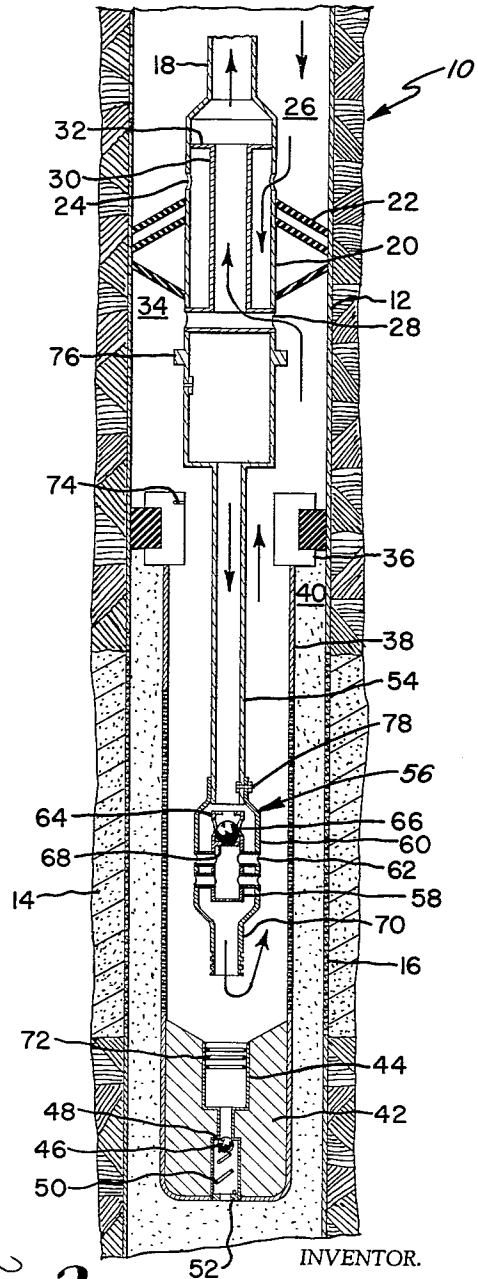



Fig. 2

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# GRAVEL PACKING APPARATUS

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This invention relates to gravel packing a liner in the borehole of a well and more particularly to a method and apparatus utilizing a single trip into a well for washing a liner into the borehole of the well to the desired depth and packing gravel in the space surrounding the liner.

A difficulty frequently encountered in oil and gas wells in some areas is caused by the migration of sand from the formation into the wells. The sand may plug production tubing and either seriously reduce or completely prevent production from the well. In some high pressure formations, the sand may be carried at a high velocity by the fluids produced from the well and rapidly erode tubing, valves and other equipment in the well. Producing sands in some areas are so friable that sand can be washed from the perforated section of casing extending through the formation and in the time it takes to make a round trip to install production tubing, the perforations will again be covered with sand.

In order to combat the sanding of the wells it is a common practice to install slotted liners in the borehole through the producing formation and to pack sand around the outer surface of the liner. The conventional method of placing liners is to wash the formation sand out of the borehole with open ended tubing, place the calculated sand fill in position in the hole, and then pull the tubing. A slotted liner is then washed into place. This method of installing a liner made an extra trip into the hole necessary. Moreover, failures were often encountered immediately after placing the well in production. The cause of the failure was suspected to be bridging of the gravel during the washing in of the liner which resulted in a nonuniform pack of sand around the liner.

This invention resides in a method and apparatus involving only a single trip into the well for washing a slotted liner into place through the formation sand in the borehole of a well, washing the formation sand from the borehole of the well while lowering the slotted liner to the desired location, breaking down the formation, packing a gravel fill around the outer surface of the liner, squeezing gravel packed around the liner into the formation, and cleaning the sand from within the liner to put the well in condition for production.

In the drawings:

FIGURE 1 of the drawings is a vertical sectional view of the apparatus of this invention as it is washed into place through the formation sand.

FIGURE 2 is a vertical sectional view showing the apparatus in condition for washing sand from the liner after the liner has been set in place and gravel has been packed around it.

Referring to FIGURE 1 of the drawings, a lower section of a well, indicated generally by reference numeral **10**, is illustrated with casing **12** set through an incompetent producing formation **14**. The casing **12** is perforated as indicated at **16** through the formation **14** to allow the formation fluids to flow into the well. Although this invention is illustrated in a well in which casing is set through the production formation **14**, its use is not limited to such installations and can be used when production is through an open borehole. It is



usually desirable to set casing completely through the incompetent formations, but in some instances casing may be set only to a formation above the producing formation **14**.

Extending down through the casing **12** is a tubing string **18** of a diameter smaller than the diameter of casing **12** to provide an annulus between the tubing string **18** and the casing **12** through which liquids can be pumped. Connected in and forming part of the tubing string **18** is a cross-over **20** provided with opposed cup sealing means **22** adapted to prevent flow either upwardly or downwardly between the outer surface of the upper cross-over **20** and the casing **12**. Cross-over **20** is provided with upper ports **24** above the sealing means **22** to provide communication between the lower part of tubing string **18** beneath the sealing means **22** and the upper annulus **26** above the sealing means **22**. Lower ports **28** are provided in the cross-over **20** and communicate with a central conduit **30** which in combination with an upper end plate **32** within the cross-over **20** places the lower annulus **34** below sealing means **22** in communication with the upper portion of the tubing string **18**.

A liner packer **36**, diagrammatically illustrated in the drawings, is connected to the tubing string **18** through a suitable means such as a conventional setting tool. For example the portion of tubing string **18** below the cross-over **20** may be a mandrel which can be backed out of the packer and the packer set by the weight of the tubing string. The packer **36** is connected to the upper end of a slotted liner **38** in the usual manner and is adapted to be set against walls of casing **12** to close the annular space **40** surrounding the slotted liner after that space has been filled with gravel.

Slotted liner **38** is provided at its lower end with a liner shoe **42** having a vertical passage **44** extending through it. A check valve is positioned in the lower portion of the passage **44** to prevent upward flow through the passage. In the apparatus illustrated in the drawings, the check valve consists of a ball **46** edged upwardly against a valve seat **48** by helical spring **50** held in place in the passage **44** by a bushing **52**.

Extending down through the liner **38** from the lower end of the tubing string **18** is a wash pipe **54**. Connected in and forming a part of the wash pipe **54** is a check valve assembly **56** adapted to allow flow from within the liner **38** into the wash pipe **54** but prevent flow from within the wash pipe **54** into the space within the slotted liner **38**. The check valve assembly illustrated in the drawings consists of a central sleeve **58** closed at its lower end and supported within a shell **60** by a plurality of inlet lines **62** which provide communication from outside of the shell **60** into the sleeve **58**. A valve cage **64** at the upper end of the sleeve **58** contains a ball-type check valve **66** adapted to seat on a valve seat **68** when flow is downward through the wash pipe **54**. A lower section **70** of the wash pipe **54** extends from the lower end of the check valve assembly **56** into the upper end of the passage **44**. Seal rings **72** engage the walls of the passage and lower extension **70** to direct liquid discharged from the lower end of the wash pipe **54** downwardly through passage **44**.

In the placing and gravel packing of liner **38** in the process of this invention, the apparatus is assembled at the well head as illustrated in FIGURE 1 and is lowered into the well on the lower end of the tubing string **18**. When the liner reaches the formation sand fill in the borehole, a liquid is pumped down the well through the annulus **26** and enters the lower portion of the tubing string **18** through the port **24** in the cross-over **20**. The

sealing means 22 engage the wall of the well, which in the structure illustrated in the drawings is the casing 18, to prevent flow around the cross-over 20. The liquid then flows down the wash pipe 54, through the lower section 70 and the passage 44, and out the lower end of the liner shoe 42. The liquid washes the sand from the casing upwardly around the liner 38 and into the lower ports 28 of the cross-over 20. The sand is carried upwardly from the well through the upper portion of the tubing string 18. Washing is continued until the liquid discharged at the well head is clean.

The tubing string 18 is then loaded with a liquid, preferably oil, and the formation broken down by pumping the oil down the tubing with the outlet at the well head from the annulus 26 closed to prevent returns of oil to the well head. During this phase of the operation the flow is downward through the tubing string 18, outward through the lower ports 28 into the annulus 34, and then into the formation through the perforations 16 in the casing 12. Gravel is added to the oil pumped down the tubing string 18 and the pumping continued with no returns to the well head thereby forcing the gravel and oil into the formation. The term gravel is used in this specification to designate the solids introduced into the well and distinguish them from formation sands and not to designate the size of the solid particles. The squeeze is continued at high casing pressures, for example about 2500 pounds per square inch, to pack the gravel around the casing 12.

After the squeeze is completed, the upper end of the annulus 26 is opened to allow circulation to the well head and the pumping of oil or other liquid containing gravel is continued to fill the annulus 40 between the liner 38 and the casing 12 with gravel. During this stage of the operation, the flow is downward through the tubing string 18, outward through lower ports 28 into the annulus 34, downward into the annulus 40 between the liner and the casing, inward through the slots of the liner 38 and through inlets 62, upward through the valve cage 64 in wash pipe 54, outward through upper ports 24 into the annulus 26, and then to the well head.

The filling of the annulus is continued until an increase in pressure indicates that the slots in the liner 38 have been covered with gravel. The tubing string is then released from the liner packer 36 and the liner packer set. Conventional apparatus for release of the tubing string from the packer and for setting the packer can be used. In the drawings such apparatus is represented diagrammatically by shear pin 74 connecting the lower end of the tubing string 18 to the liner packer 36 and a shoulder 76 on the outer surface of the lower end of the tubing string which allows the weight of the tubing string to be placed on the packer to set it against the casing 12 as indicated in FIGURE 2 of the drawings. The tubing string 18 is then lifted to raise the wash pipe 54 out of the passage 44. Liquid is then circulated down the annulus 26 through the upper port 24 into the wash pipe 54 and out the lower end of the wash pipe 54. The liquid returns up through the space within the liner into the lower ports 28 and into the upper portion of the tubing string 18. The circulation is continued until the returns at the surface are clear, which indicates that sand that may have passed through the liner has been removed from within the liner.

The apparatus of this invention allows the liner to be washed into place and gravel packed in a single trip into the well. The check valve assembly 56 at the lower end of the wash pipe 54, in combination with the check valve 46, directs flow out the lower end of the liner 38 during the washing in operation to permit the liner to be readily washed to the bottom of the hole. The check valve assembly 56 then allows the circulation necessary for cross-over filling of the annular space between the outer surface of the liner and the borehole wall or the casing.



I claim:

1. Apparatus for gravel packing a slotted liner in the borehole of a well comprising a tubing string, a crossover connected in the tubing string, said crossover having a lower port communicating with the interior of the upper part of the tubing string and an upper port communicating with the interior of the lower part of the tubing string, sealing means between the upper port and lower port closing the annulus between the crossover and the borehole wall, a liner detachably suspended from the lower end of the tubing string, a packer mounted on the outer surface of the liner near the upper end thereof and adapted to engage the wall of the well to close the annular space surrounding the liner, a passage extending downwardly through the lower end of the liner, a wash pipe connected to the lower end of the tubing string extending downwardly through the liner and communicating with the passage, an inlet in the wash pipe from the space within the liner into the wash pipe, and a check valve adapted to allow flow through the inlet into the wash pipe and prevent flow from the wash pipe through the inlet.

2. Apparatus for gravel packing a slotted liner in the borehole of a well comprising a liner, a packer connected to the upper end of the liner, a tubing string connected at its lower end to the liner and packer for running the liner in the well, a crossover in the tubing string, sealing means engaging the crossover and the wall of the well closing the annulus between the crossover and the wall of the well, said crossover allowing communication between the annulus around the tubing string above the sealing means and the tubing string below the sealing means and allowing communication between the annulus around the tubing string below the sealing means and the tubing string above the sealing means, a passage through the lower end of the liner, a check valve mounted in said passage adapted to allow downward and to prevent upward flow therethrough, a wash pipe connected to the lower end of the tubing string extending downwardly through the liner to communicate with the passage, an inlet passage in the wash pipe communicating with the space within the liner, and a check valve in the inlet passage adapted to allow flow from the space within the liner inwardly through the inlet and into the wash pipe and prevent flow from the wash pipe through the inlet to the space within the liner.

3. Apparatus for gravel packing a slotted liner in the borehole of a well comprising a slotted liner, a passage extending downwardly through the lower end of the liner, a one-way valve in said passage permitting flow downwardly therethrough, a packer adapted to engage the walls of the well mounted on the upper end of the liner, a tubing string extending down the well to the liner, said tubing string engaging the inner surface of the packer to prevent flow between the tubing string and packer, releasable means for suspending the packer and liner from the lower end of the tubing string, a crossover in the tubing string above the level of the packer, an upper lateral port in the crossover providing permanent communication between the annulus around the tubing string above the crossover and the lower part of hte tubing string, a lower lateral port in the crossover providing permanent communication between the annulus around the tubing string below the crossover and the interior of the tubing string above the crossover, means within the crossover permanently blocking flow from the tubing string above the crossover through the crossover to the tubing string below the crossover, sealing means extending from the outer surface of the crossover between the upper port and lower port to engage the wall of the well closing the annulus around the crossover, a wash pipe communicating with and extending downwardly from the lower end of the tubing string through the liner into the passage in the liner, and a one-way valve in the wash pipe permitting flow from within the liner into the wash pipe.

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