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Zero drill completion and production system

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(56) Related Art
US 5526878 A (DUELL et al.) 18 June 1996
US 5738171 A (SZARKA) 14 April 1998
US 5314015 A (STREICH et al.) 24 May 1994

ABSTRACT

The present invention is a method and apparatus for a one trip completion of fluid production wells. A completion tool string includes a pressure activated cementing valve, an external casing packer, a pressure activated production valve, an opening plug and a plug landing collar and a closing plug and seat. This tool series is assembled near the end of a production tube string upstream of the well production screen.

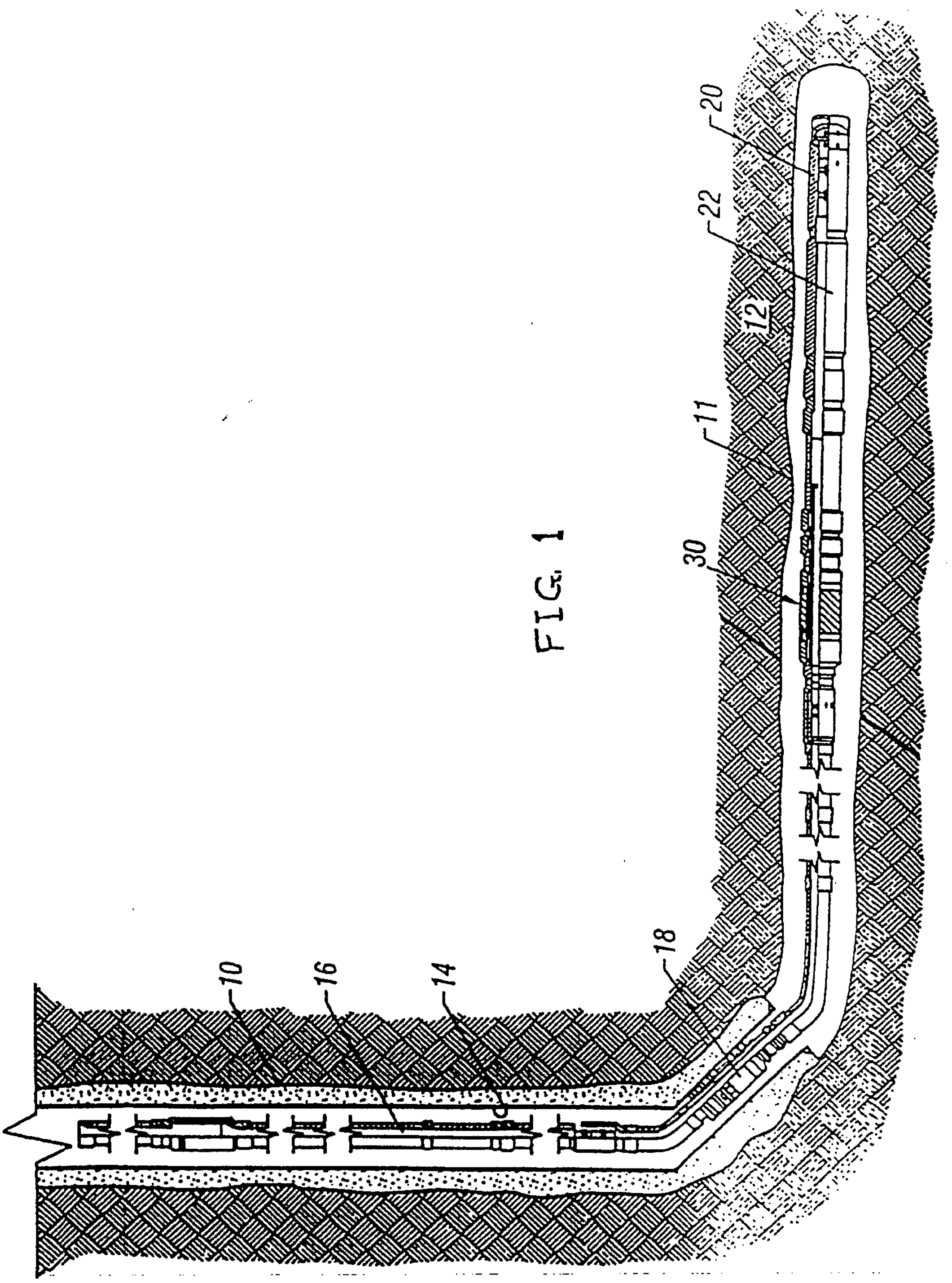

FIG. 1

P/00/011
Regulation 3.2

AUSTRALIA

Patents Act 1990

COMPLETE SPECIFICATION
STANDARD PATENT

Invention Title: **Zero drill completion and production system**

The following statement is a full description of this invention, including the best method of performing it known to us:

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to well completion and production methods and apparatus. Certain embodiments of the present invention have application to petroleum production wells.

Description of the Prior Art

The process and structure by which a petroleum production well is prepared for production involves the steps of sealing the production zone from contamination and securing production flow tubing within the well borehole. These production zones are thousands of feet below the earth's surface. Consequently, prior art procedures for accomplishing these steps are complex and often dangerous. Any procedural or equipment improvements that eliminate a downhole "trip", is usually a welcomed improvement.

Following the prior art, production tube setting and opening are separate "trip" events. After a well casing is secured by cementing, a production string is then positioned where desired within the borehole and the necessary sealing packers set. In some cases, the packers are set by fluid pressure internally of the tubing bore. After the packers are set, a cementing circulation valve in the production tube assembly is opened by tubing bore pressure, for example, and annulus cement is pumped into position around the production tubing and above the production zone upper seal packer.

This procedure leaves a section of cement within the tubing below the cementing valve that blocks the upper tubing bore from production flow. The blockage is between the upper tubing bore and the production screen at or near the terminal end of the tubing string. Pursuant to prior art practice, the residual cement blockage is usually removed by drilling. A drill bit and supporting drill string must be lowered into the well, internally of the production tubing, on a costly, independent "trip" to cut away the blockage.

It is not admitted that any of the information in this specification is common general knowledge, or that the person skilled in the art could reasonably be expected to have ascertained, understood, regarded it as relevant or combined it in anyway at the priority date.

SUMMARY OF THE INVENTION

It is an object of at least preferred embodiments of the present invention to position well production tubing within the wellbore, secure the tubing in the well by cementing, and open the tubing to production flow in one downhole trip.

In one aspect the present invention provides a method of completing a well comprising the steps of:

- positioning production tubing within a well borehole in flow communication with a well production zone, the production tubing having a pressure activated cementing valve and a pressure activated valve that comprises:

(i) an external jacket configured to pass a desired fluid flow;

(ii) an internal bore wall having at least one aperture; and

(iii) at least one frangible element positioned in an annular space between the external jacket and the internal bore wall, the at least one frangible element closing the at least one aperture;

- increasing fluid pressure within said production tubing to open said pressure activated cementing valve;

- pumping a desired quantity of cement down said production tubing and through said open cementing valve;

- closing said cementing valve;

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- opening said production valve by rupturing the at least one frangible element by increasing fluid pressure within said production tubing; and

- producing well fluid through said production tubing.

A well completion tool is also disclosed. The tool includes a cementing valve which has a cement flow channel from an internal pipe bore into a surrounding well annulus. The flow channel is opened by a fluid pressure displaced first sleeve element and closed by a fluid pressure displaced second sleeve element. A fluid pressure engaged well annulus barrier surrounds the pipe bore and is displaced along the pipe bore from the cementing valve. A production valve is positioned along the pipe bore from the annulus barrier in a direction opposite from the cementing valve. The production valve includes an external jacket configured to pass a desired fluid flow; an internal bore wall having at least one aperture; and at least one frangible element positioned in an annular space between the external jacket and the internal bore wall. The at least one frangible element closes the at least one aperture.

A well production string including production tubing is also disclosed. The production tubing has an internal flow bore and suspends an operative assembly of a cementing valve and a production valve. The cementing valve has a cement flow channel from an internal flow bore into a surrounding well annulus. The flow channel is opened by a fluid pressure displaced first sleeve element and closed by a fluid pressure displaced second sleeve element. The production valve is positioned along the production tubing from the annulus. The production valve includes an external jacket configured to pass a desired fluid flow; an internal bore wall having at least one aperture; and at least one frangible element positioned in an annular space between the external jacket and the internal bore wall. The at least one frangible element closes the at least one aperture.

An embodiment of the present invention relates to a production tubing string having the present well completion tool assembly attached above the production screen and casing shoe.

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This completion tool assembly includes an alignment of four basic tools in serial downhole order. At the uphole end of the alignment is a pressure actuated cementing valve followed by an external casing packer. Below the casing packer is a pressure actuated production valve and below the production valve is a bore plug landing collar

With the tubing string downhole and the open hole production screen located at the desired position within the well production zone, an opening plug is deposited in the tubing bore at the surface and pumped down the tubing bore by water, other well fluid or finishing cement until engaging a plug landing collar. Upon engaging the landing collar, the plug substantially seals the tubing bore to facilitate dramatic pressure increases therein. Actuated by a pressure increase within the tubing bore column, the external casing packer is expanded to block the borehole space annulus between the raw borehole wall and the packer body. An additional increase in pressure slides the opening sleeve of the pressure activated cementing valve into alignment of the internal and external circulation ports. Upon alignment of the circulation ports, tubing bore fluid such as cement is discharged through the ports into the wellbore annulus space. Due to the presence of the expanded external casing packer below the circulation ports, the annulus cement must flow up-hole and around the tubing above the packer.

When the desired quantity of cement has been placed in the tubing bore at the surface, the fluidized cement within the tubing bore column is capped by a closing pump-down plug. Water or other suitable well fluid is pumped against the closing plug to drive most of the cement remaining in the tubing bore through the circulation ports into the annulus. At the circulation port threshold, the closing plug engages a plug seat on the closing sleeve of the pressure actuated cementing valve. With a first pumped pressure increase acting on the fluid column above the closing plug seat, the cementing valve closing sleeve slides into a circulation port blocking position.

With the circulation port closed, a second pressure increase that is

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normally greater than the first develops a force on the plug seat of such magnitude as to shear calibrated retaining screws that hold the seat ring within the tubing bore. When structurally released from the tubing bore wall, the closing plug and plug seat impose a piston load on the short cement column supported by the opening plug and plug landing collar. This column load is converted to fluid pressure on the pressure activated production valve to force a fluid flow opening through the valve. When the pressure activated production valve opens, the residual cement column is discharged through the open valve below the packer.

Although the residual cement column is discharged into the production zone bore, the absolute volume of cement dispersed into the bore is insignificant.

As the closing plug is driven by the finishing fluid through the central bore of the production valve past the valve opening, the finishing fluid, water or light solvent, rushes through the valve opening to flush it of residual cement and debris. At this point, a clear production flow path from the production zone into the production tubing bore is open. When pressure on the finishing fluid is released, upflowing production fluid sweeps the residual finishing fluid out of the tubing bore ahead of the production fluid flow.

As used herein, except where the context requires otherwise the term 'comprise' and variations of the term, such as 'comprising', 'comprises' and 'comprised', are not intended to exclude other additives, components, integers or steps.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description of an embodiment of the invention following hereafter refers to the several figures of the drawings wherein like reference characters in the several figures relates to the same or similar elements throughout the several figures and:

FIG. 1 is a schematic well having an embodiment of the present invention in place for completion and production;

FIG. 2 is a partial section of the present well completion tool assembly in the run-in condition;

FIG. 3 is a partial section detail of the cementing valve run-in setting;

FIG. 4 is a partial section of the present well completion tool assembly in the packer inflation condition;

FIG. 5 is a partial section of a closed, pressure actuated cementing valve;

FIG. 6 is a partial section detail of the open cementing valve;

FIG. 7 is a partial section of the present well completion tool assembly in the annulus cementing condition;

FIG. 8 is a partial section of the present well completion tool assembly in the cement termination condition;

FIG. 9 is a partial section detail of the closed cementing valve;

FIG. 10 is a partial section of the present well completion tool assembly in the production flow opening condition; and

FIG. 11 is a partial section detail of the pressure actuated production valve.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The invention utility environment is represented by the schematic of **FIG. 1** which illustrates a well bore **10** that is normally initiated from the earth's surface in a vertical direction. By means and procedures well known to the prior art, the vertical well bore may be continuously transitioned into a horizontal bore orientation **11** as desired for bottom hole location or the configuration of the production zone

12. Usually, a portion of the vertical surface borehole **10** will be internally lined by steel casing pipe **14** which is set into place by cement in the annulus between the inner borehole wall and the outer surface of the casing **14**.

Valuable fluids such as petroleum and natural gas held within the production zone **12** are efficiently conducted to the surface for transport and refining through a string of production tube **16**. Herein, the term "fluid" is given its broadest meaning to include liquids, gases, mixtures and plastic flow solids. In many cases, the annulus between the outer surface of the production tube **16** and the inner surface of the casing **14** or raw well bore **10** will be blocked with a production packer **18**. The most frequent need for a production packer **18** is to shield the lower production zone **12** from contamination by fluids drained along the borehole **10** from higher zones and strata.

The terminal end of a production string **16** may be an uncased open hole but is often equipped with a liner or casing shoe **20** and a production screen **22**. In lieu of a screen, a length of drilled or slotted pipe may be used. The production screen **22** is effective to grossly separate particles of rock and earth from the desired fluids extracted from the formation **12** structure as the fluid flow into the inner bore of the tubing string **16**. Accordingly, the term "screen" is used expansively herein as the point of well fluid entry into the production tube.

Pursuant to practice of the present invention, a production string **16** is provided with the present well completion tool assembly **30**. The tool assembly is positioned in the uphole direction from the production screen **22** but is often closely proximate therewith. As represented by **FIG. 1**, the production packer **18** (if necessary), the completion tool assembly **30**, the production screen **22** and the casing shoe **20** are preassembled with the production tube **16** as the production string is lowered into the wellbore **10**.

With respect to **FIG. 2**, the completion tool assembly **30** comprises a pressure activated cementing valve **32**, an external casing packer **34**, a pressure activated production valve **36** and a plug landing collar **38**. Each of these devices may be known to those of ordinary skill in some modified form or applied combination.

As shown in greater detail by **FIG. 3**, the pressure actuated cementing valve provides circulation ports **40** and **42** through the inside bore wall **60** of the tool and the outer tool casing **62**. Axially sliding sleeve **44** is initially positioned to obstruct a fluid flow channel between the inner ports **42** and the outer ports **40**. This position is secured by a calibrated set-screw **64**, for example, for a well run-in setting. Upon a satisfactory down-hole location, the sleeve **44** is positionally displaced, as shown in by **FIGS. 6** and **7**, by high fluid pressure applied within the tool flow bore from fluid circulation pumps. Force of the fluid pressure shears the retainer screw **64** to allow displacement of the sleeve **44** from the initial obstruction position between the flow parts **40** and **42**. When the ports **40** and **42** are mutually open, well cement may be pumped from within the internal bore of the tool and tubing string through the ports **40** and **42** into the well annulus around the tubing string. Use of the term "cement " herein is intended to describe any substance having a fluid or plastic flow state that may be pumped into place and thereafter induced to solidify.

Closure of the fluid channel through ports **40** and **42** is accomplished by a second sliding sleeve **46** as illustrated by **FIGS. 8** and **9**. A landing seat **48** for a closure plug **54** is secured to the inside bore wall of the tool by shear screws **49**, for example. Procedurally, the cement slurry tail is capped by a wiper closing plug **54**. The closing plug is pumped by water or other suitable well working fluid down the tubing string bore until engaging the plug landing seat **48**. When the plug engages the seat **48**, fluid pressure in the bore may be increased to 1000 psi, for example, within the tool flow bore. Such pressure is admitted through fluid ports **66** against the end area of closing sleeve **46**. Force of the pressure shears the retainer screw **68** and shifts the sleeve **46** against the sleeve **44** and between the circulation ports **40** and **42**. Additional pressure against the closing plug and seat 48, 5000 psi, for example is operative to shear the assembly screws **49** and drive the plug **54** and seat **48** further along the tool bore.

The external casing packer **34** is any device that creates a seal in the wellbore annulus around the tube string. A common example of a casing packer provides an expansible elastomer boot around an internal tube body. An internal bore of the tube body is coaxially connected with the production tube string. The expansible boot is secured to the tube body around the perimeter of the two circumferential edges of the boot. A fluid tight chamber is thereby provided between the boot edges and between the tube body and the inside surface of the expansible boot. This chamber is connected by a check valve controlled conduit to the interior bore of tube body. Hence, pressurized fluid within tube body expands the boot against the casing or borehole wall.

A simplified example of a pressure actuated production valve **36** is shown by **FIG. 11** to include an annular chamber **70** between an internal bore wall **72** and an external jacket **74**. The external jacket **74** may be slotted pipe or a screen to pass the desired fluid flow. The internal bore wall is perforated by a plurality of apertures **76** distributed along the axial length of the bore wall. These apertures **76** are initially closed by a fluid pressure displaced fluid flow obstacle such as a sliding sleeve similar to the sleeve **44** in the cement valve. Alternatively, the aperture **76** may be initially closed by reed members **78** shown by **FIG. 11** as having a frangible assembly with the internal bore wall **72**. A predetermined magnitude of fluid pressure within the tool flow bore partially ruptures the reed **78** connections to the bore wall **72** to bend the reeds **78** to a fixed open position.

The plug landing collar **38** may be an extension of the production valve sleeve that continues an open flow continuity of this tool flow bore through a plug seat **56**.

The above described tubing string assembly is lowered into the well bore **10** with the packer **18** unset and the external casing packer **34** deflated. The cementing valve **32** ports **40** and **42** are closed as shown in **FIG. 3**. The production flow screen **22** is positioned where desired and an opening pump-down plug **50** is placed in the tubing string bore to be pumped by well finishing cement down to the landing collar **38** for engagement with the plug seat **56** as shown by **FIG. 4**. If desired, the plug **50** may also be transferred downhole by water or other well working fluid. With the plug **50** secure upon the landing collar plug seat **56**, fluid pressure within the tubing bore is increased against the opening plug **50** to inflate the packer **34**. This event blocks the well annulus between the production screen **22** and the cementing valve **32**.

Next, fluid pressure within the tubing bore is further increased to shift the cementing valve **32** opening sleeve **44** by shearing the set screw **64**, as shown by **FIG. 6**. Shifting the opening sleeve **44** opens a flow channel through the circulation ports **40** and **42**. When the circulation port channel opens, cement flows through the channel and up the borehole annulus around the production tubing as shown by **FIGS. 6** and **7**.

The total cement volume requirement for a particular well is usually calculated with considerable accuracy. Accordingly, when the desired quantity of cement has been pumped into the tubing bore, a closing pump-down plug **54** is placed in the bore to cap the cement column. Behind the closing pump-down plug **54**, water or other suitable well working fluid is pumped to complete the cement transfer and settle the closing pump-down plug **54** against the cementing valve plug seat **48**. With the tool flow bore closed by the plug **54**, the flow bore pressure may be increased behind the plug. An increase of tubing bore pressure to 1000 psi, for example, against the plug **54** and seat **48** causes a shift in the valve closing sleeve **46** thereby closing the fluid communication ports **40** and **42**. Illustrated by **FIG. 9**, fluid pressure enters the sliding sleeve annulus through pressure port **66** to bear against the end of the closing sleeve **46**. When sufficient, the pressure force shears the screw **68** and moves the sleeve **46** between the ports **40** and **42**.

Thereafter, the tubing bore pressure is increased again, to 5000 psi, for example, to shear the plug seat retaining screws **49** and release both the seat **48** and the closing plug **54**. When released, the free piston nature of the plug and seat unit drives against the residual cement column that was isolated between the opening pump-down plug **50** and the closing pump-down plug **54**. Pressure against the closing pump-down plug **54** is thereby transferred to the residual cement column and consequently to the pressure activated production valve **36**. Referring to **FIGS. 10** and **11**, this increased pressure against the production valve **36** ruptures flow port closure reeds **78** to permanently open the flow ports **76** between a production flow annulus and the tubing bore. Continued pressure against the residual cement column purges the residual cement through the newly opened production valve ports **76** into the well bore below the packer **34**.

It will be understood by those of skill in the art that the number and distribution of the flow ports **76** is configured to bridge the length of the plug **54** whereby cement and well working fluid may simultaneously exit the flow port **56** into the wellbore as plug **54** passes the open flow ports as illustrated by **FIG. 11**

Another active mechanism in the process of opening the production valve **36** is the seal bias of the plug **54** bore sealing fin **58**. The wiping bias of the fin **58** is oriented to seal uphole fluid pressure within the production tube bore from passing between the fin and tubing wall. Conversely, when the static pressure within the wellbore is greater than the static pressure in the production tube bore, the plug **54** sealing fin bias will allow wellbore fluid flow past the fin **58** into the production tube bore. Hence, it is not essential for the plug **54** to be pressure driven past the flow port **76** opening.

At this point, the well completion process is essentially complete and the well is ready to produce. However, some operators may choose to transfer a cement contamination fluid into the production zone bore to assure a subsequent removal of the residual column cement from the well bore.

Having fully described the preferred embodiments of the present invention, various modifications will be apparent to those skilled in the art to suit the circumstances of a particular well and manufacturing capacity. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of completing a well comprising the steps of:

- positioning production tubing within a well borehole in flow communication with a well production zone, the production tubing having a pressure activated cementing valve and a pressure activated valve that comprises:

(i) an external jacket configured to pass a desired fluid flow;

(ii) an internal bore wall having at least one aperture; and

(iii) at least one frangible element positioned in an annular space between the external jacket and the internal bore wall, the at least one frangible element closing the at least one aperture;

- increasing fluid pressure within said production tubing to open said pressure activated cementing valve;

- pumping a desired quantity of cement down said production tubing and through said open cementing valve;

- closing said cementing valve;

- opening said production valve by rupturing the at least one frangible element by increasing fluid pressure within said production tubing; and

- producing well fluid through said production tubing.

2. The method of claim 1, further comprising:

- combining an external casing packer and a plug seal with said production tubing, said plug seal being positioned between said production valve and a point of well fluid entry into said production tubing;

- delivering a pump-down plug into said plug seal to thereby allow a fluid pressure increase for inflating said external casing packer;

- delivering a closing pump-down plug against said pressure activated cementing valve to allow a fluid pressure increase to close said cementing valve; and

- displacing said closing pump-down plug from obstructing a flowpath through said production valve.

3. The method of claim 1 wherein said production string assembly further comprises a production packer positioned up-hole from said cementing valve.

4. A method of completing a well substantially as herein described with reference to the accompanying figures.

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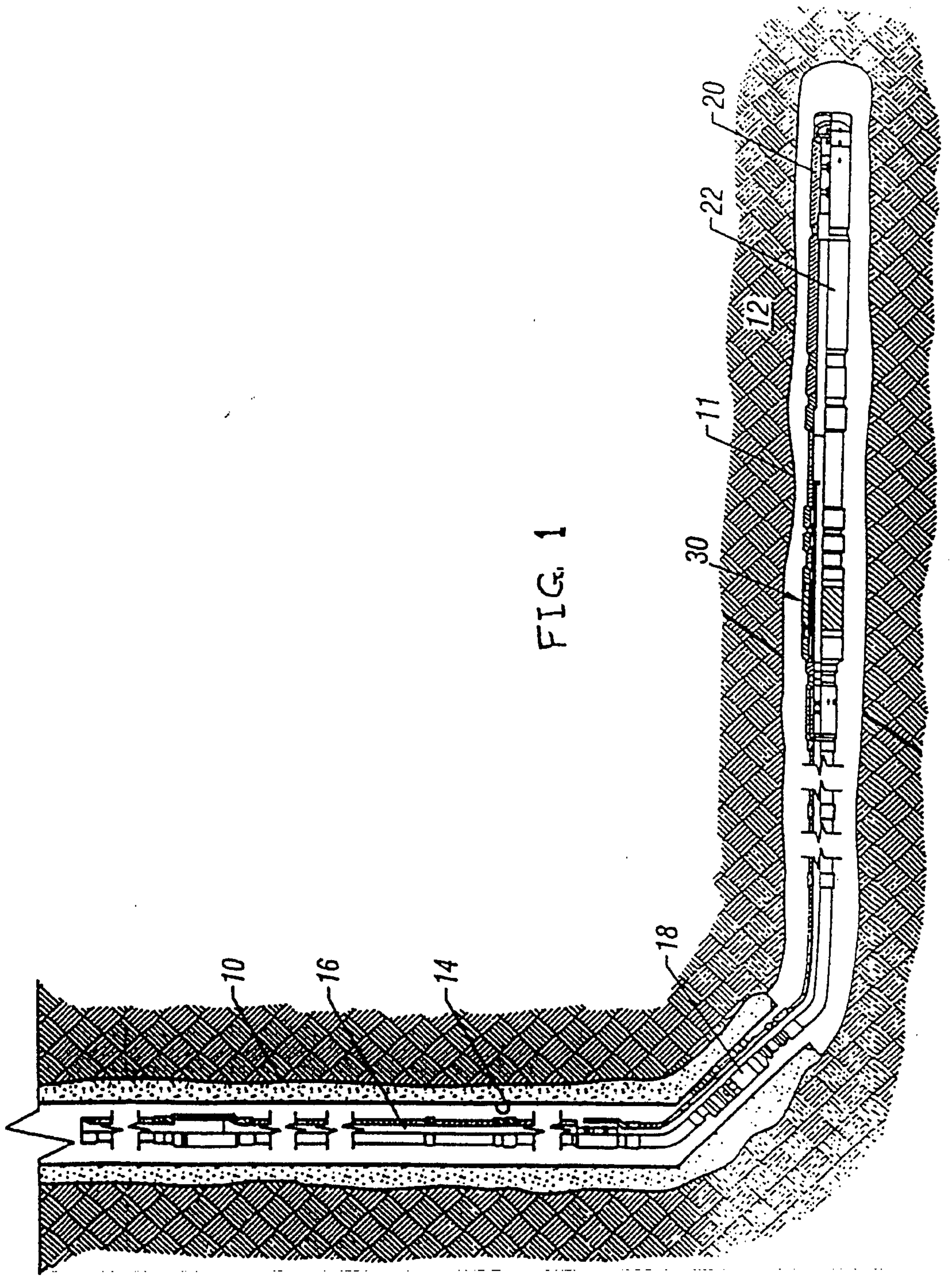

FIG. 1

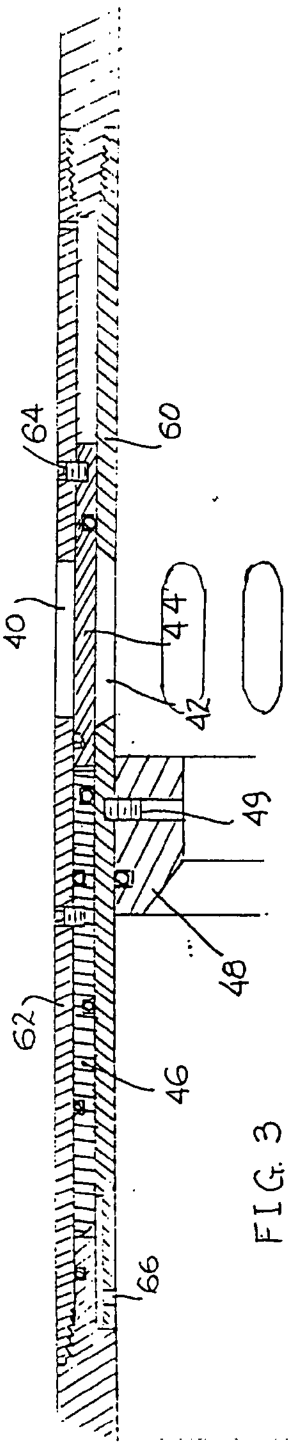

FIG. 3

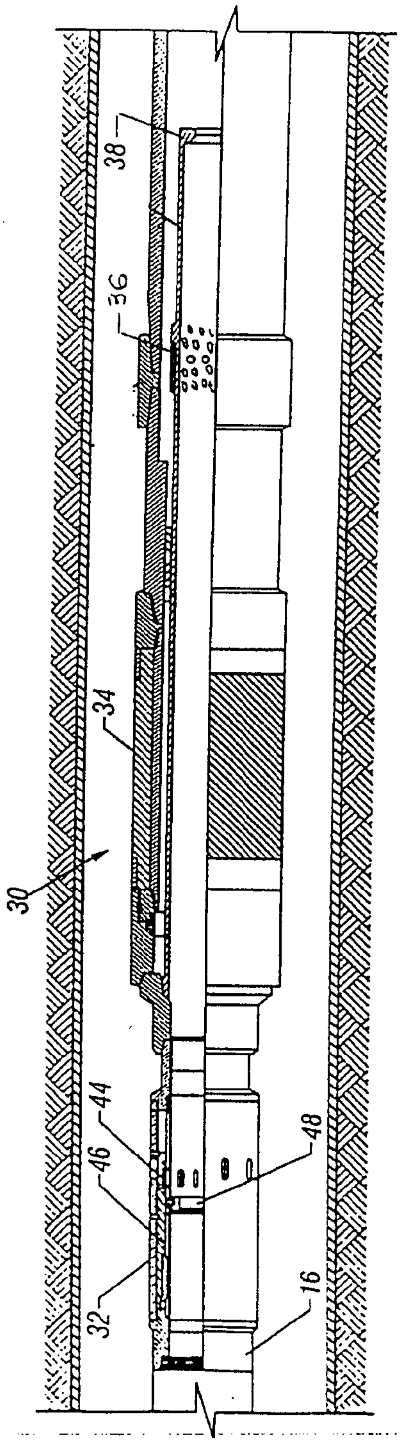

FIG. 2

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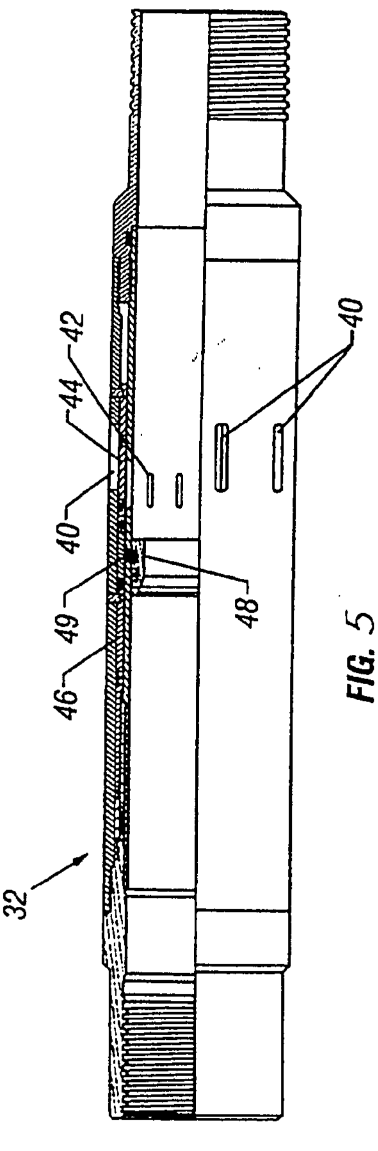

FIG. 5

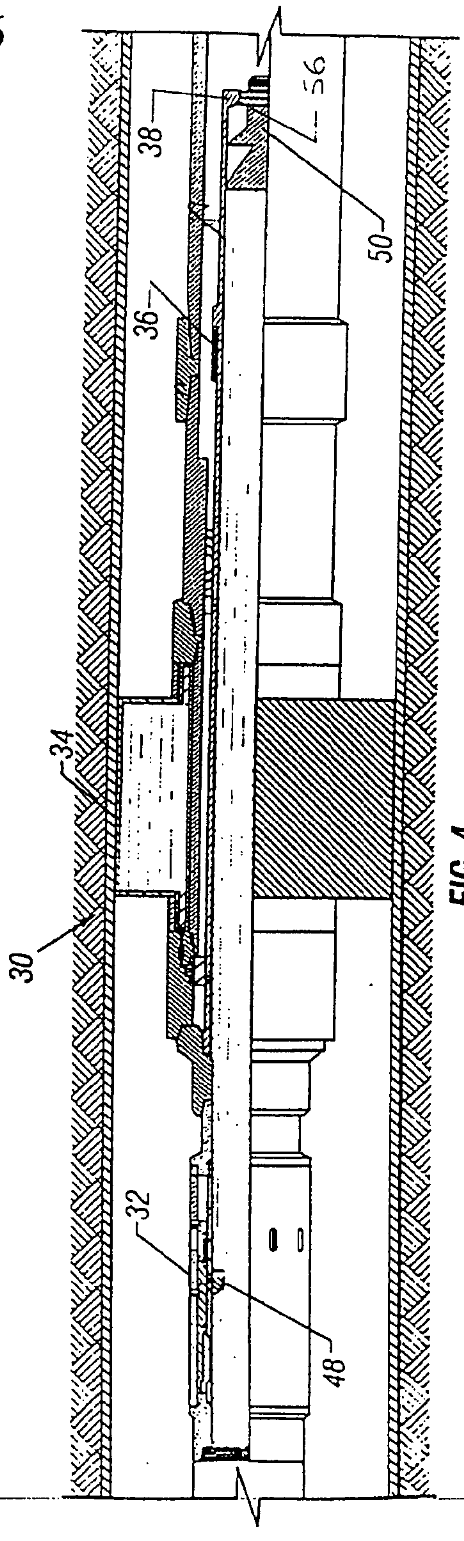

FIG. 4

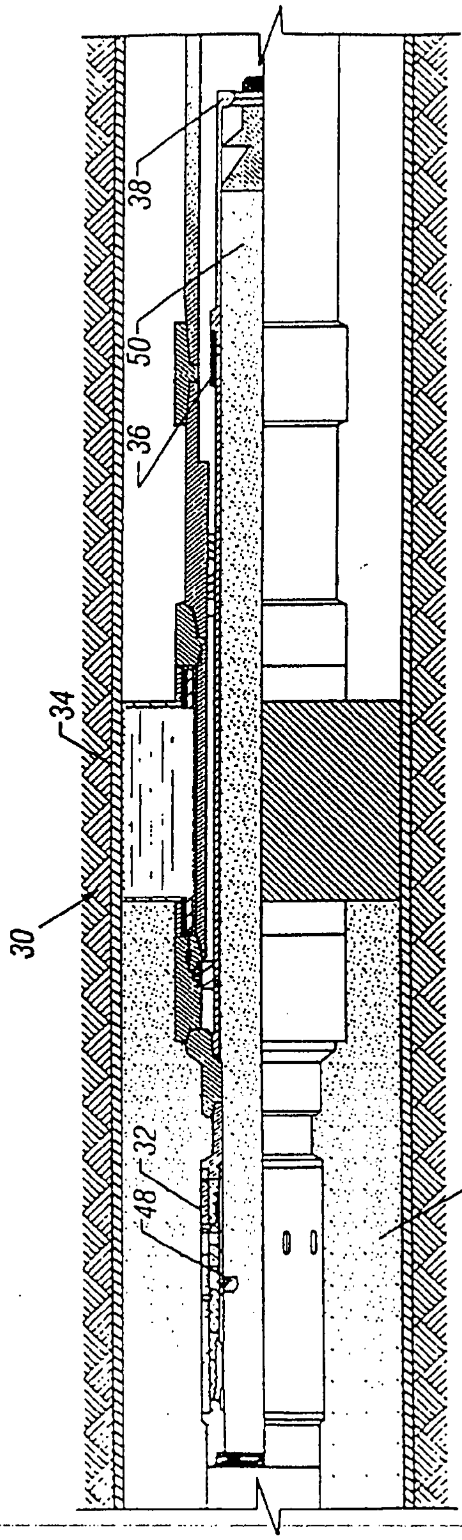

FIG. 7

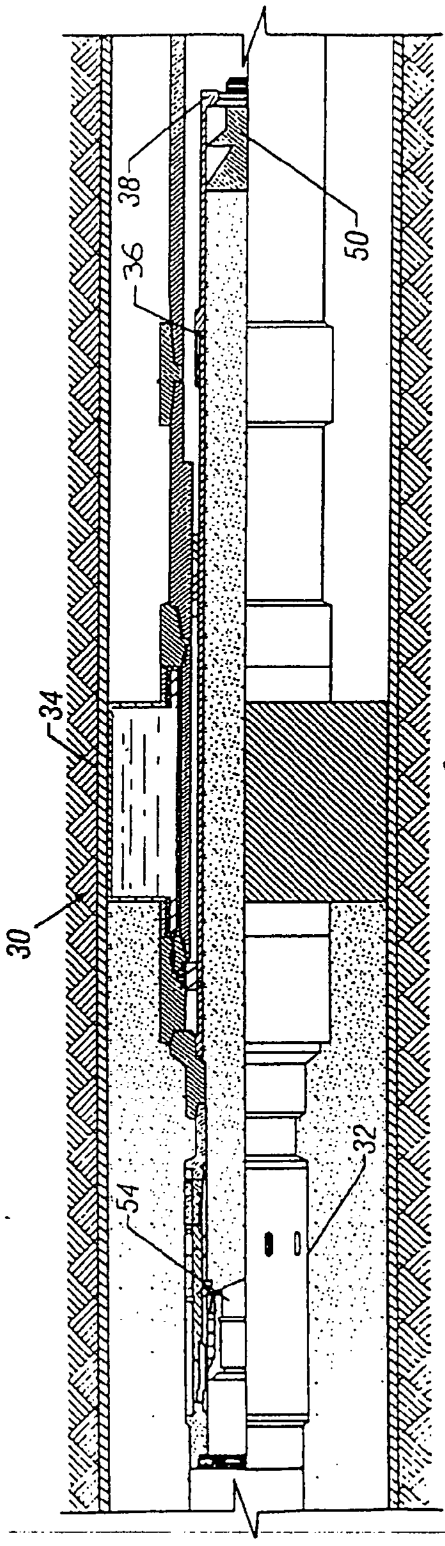

FIG. 8

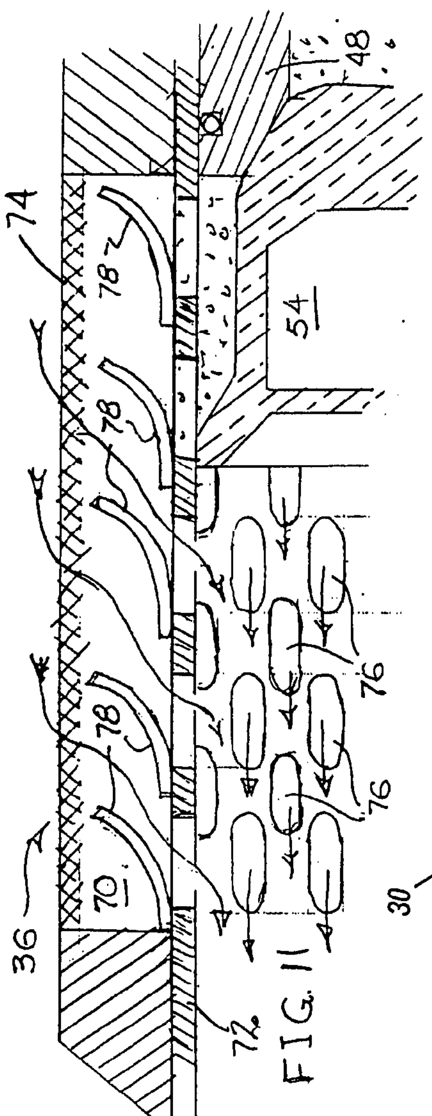

FIG. 11

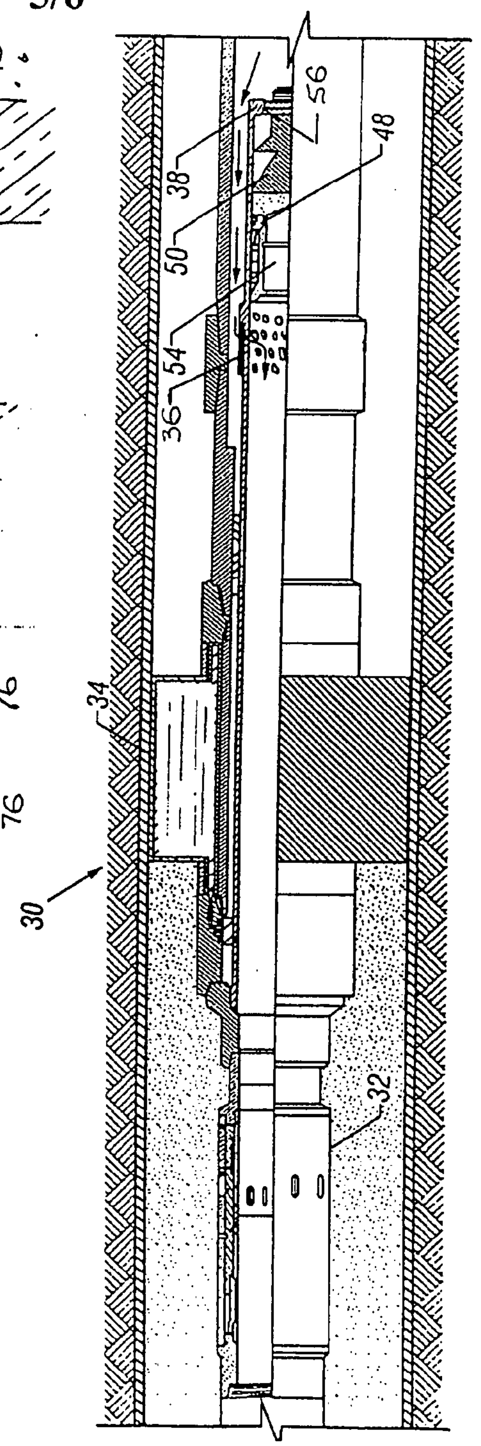

FIG. 10

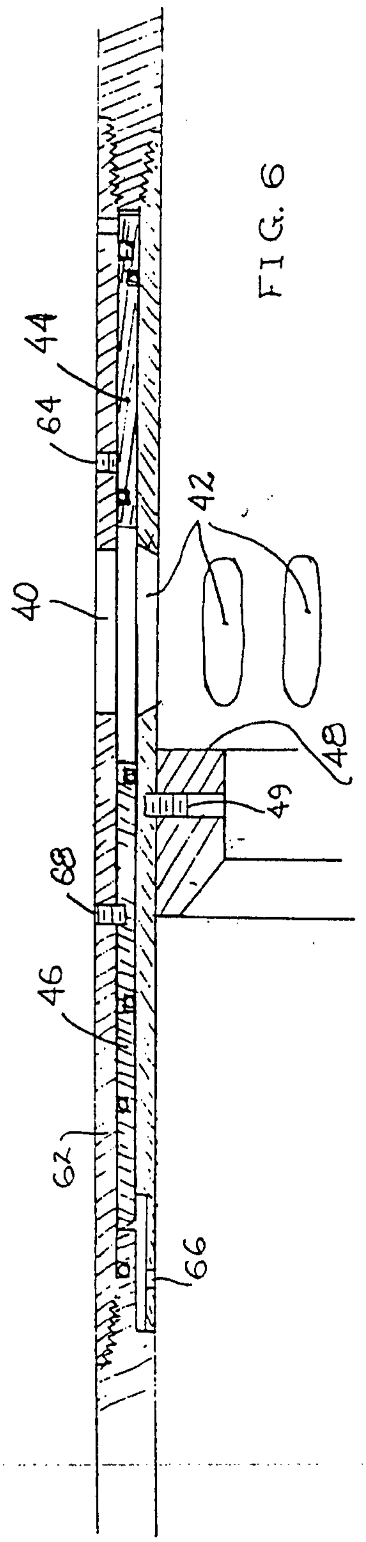

FIG. 6

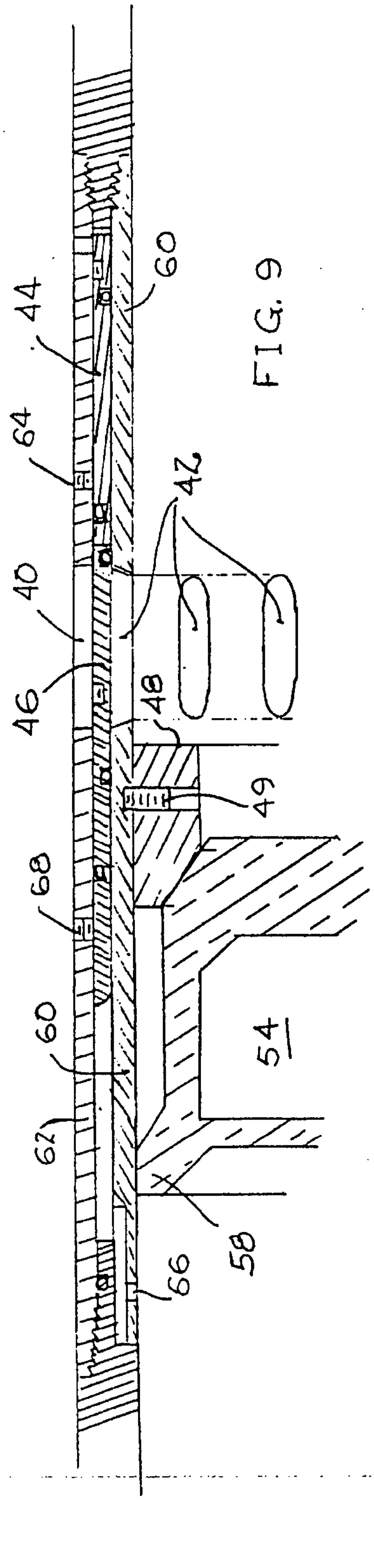

FIG. 9