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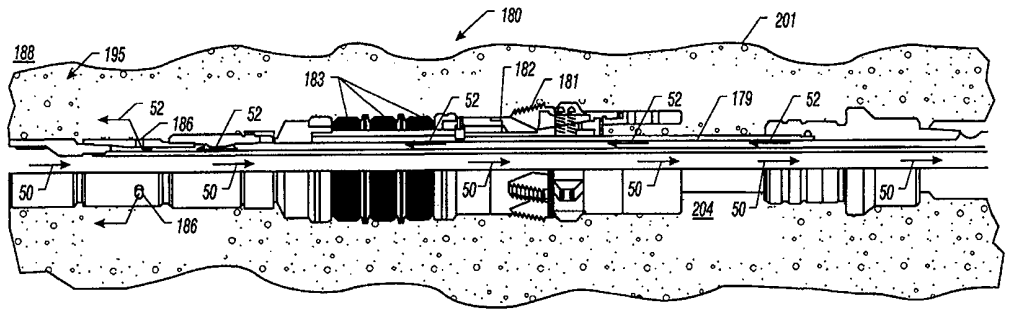


(57) Abstract

The present invention provides apparatus and method for gravel packing open holes wherein hydrostatic pressure is maintained above the formation pressure ("overburdened condition") throughout the gravel pack process. The apparatus includes a completion string which contains a flow restriction device, a crossover device and a packer each above and below the crossover device. The string is set in the wellbore with the flow restriction device adjacent the producing formation. The upper packer and the crossover device are set, which allows the gravel fluid to pass to the annulus, and return through the string. After gravel packing, the lower packer is set. The crossover device and the upper packer are retrieved from the wellbore leaving the flow restriction device and the lower packer in the wellbore. The system maintains the wellbore under overburdened condition throughout the gravel packing process.

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# APPARATUS AND METHOD FOR OPEN HOLE GRAVEL PACKING

## BACKGROUND OF THE INVENTION

### Field of the Invention

This invention relates generally to oil well completion strings and more particularly to a hydrostatically-balanced open hole gravel pack system wherein hydrostatic pressure is maintained on the formation throughout the gravel packing operations.

### Description of the Art

To obtain hydrocarbons from earth's subsurface formations, wellbores or boreholes are drilled into hydrocarbon-bearing formations or producing zones. After drilling a wellbore to the desired depth, a completion string containing various completion and production devices is installed in the wellbore to produce the hydrocarbons from the production zone to the surface. In one method, a fluid flow restriction device, usually containing one or more serially connected screens, is placed adjacent the production zone. Gravel is then packed in the space or annulus between the wellbore and the screen. No casing is installed between the screens and the wellbore. Such completions are called "open hole" completions and the systems used to gravel pack are called open hole gravel pack systems.

In commercially used open hole gravel packing system a completion string is frequently utilized for gravel packing. The completion string usually includes a screen near its bottom (or the downhole end), at least one packer or packing element above the screens, and a mechanism above the packer that allows gravel slurry to flow it from the surface to the annulus between the screens and the wellbore, and the clean fluid to return from the completion string to the surface. To gravel pack the annulus between the formation and the completion string, packer is set to form a seal between the completion string and the wellbore, the packer prevents the hydrostatic pressure from being applied to the formation, which prevents, for a period of time, maintaining the hydrostatic pressure above the formation pressure (the "overbalanced condition" or "overburdened condition") during the gravel pack operation. Thus, the formation pressure can exceed the hydrostatic pressure, which can cause hole damage or well collapse and damage to the filter cake.

A substantial number of currently drilled wellbores are highly deviated or horizontal. The horizontal wellbores are extremely susceptible to damage if the overbalanced conditions are not maintained throughout the gravel pack operations or during any other completion operation. Maintaining the wellbore under overbalanced condition throughout the gravel packing, especially in highly deviated and horizontal wells is very desirable. The present invention provides a gravel pack system and method which maintains the pressure on the formation

above the formation pressure throughout the gravel packing operation. The present system also is simpler and easier to use, thereby reducing the overall completion or gravel pack operations time and cost.

## SUMMARY OF THE INVENTION

The present invention provides apparatus and method for gravel packing open holes wherein hydrostatic pressure on the formation is maintained above the formation pressure throughout the gravel pack process. In one embodiment, the gravel pack apparatus includes a completion string which contains a fluid flow restriction device, a crossover device uphole of the fluid flow restriction device and a packer above and below the crossover device. The completion string is conveyed in the wellbore to position the flow restriction device adjacent the producing formation while maintaining the wellbore under overburdened conditions. The upper packer and the crossover device are set while maintaining the wellbore under overburdened condition. This allows the gravel fluid to pass to the annulus and return through the completion string. The returning fluid crosses over to the annulus above the upper packer. After gravel packing, the lower packer is set. The portion of the completion string above the lower packer, which includes the crossover device and the upper packer are retrieved from the wellbore, thus leaving the fluid flow restriction device and the

lower packer in the wellbore. In this particular embodiment, setting the lower packer after the gravel packing process has been completed enables maintaining the hydrostatic pressure on the formation throughout the gravel packing process.

Examples of the more important feature of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

## BRIEF DESCRIPTION OF THE DRAWINGS

For detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals:

**Figures 1A-1D** show a schematic diagram of a gravel pack string for placement in the wellbore and the wellbore fluid flow path to hydrostatically balance the formation.

**Figures 2A-2D** show a schematic diagram of the gravel pack string with the upper or service packer set and the fluid flow path which enables maintaining the hydrostatic pressure on the formation.

**Figures 4A-4D** show the gravel pack system of **Figures 1A-1D** after the Run-in tool and the service packers have been removed, leaving the screen and the liner packer in the wellbore.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figures **1A-1D**, **2A-2D**, **3A-3D, and 4A-4D** show a gravel pack system **10** according to one embodiment of the present invention in various stages of gravel pack operations.

Referring to **Figures 1A-1D**, the system **10** includes a fluid flow restriction device **100** having a number of serially disposed screen assemblies **110a-110c**. The fluid flow restriction device **100** terminates at the bottom end of the string **10** with a plug **112** and a casing joint **114**. Each screen assembly, such as assembly **110a**, includes an outer shroud **120** and an inner sand screen **122**. The shroud **120** protects the internal parts of the screen assembly **110a** from direct impact of the wellbore fluid **202**, while the screen **122** prevents gravel , sand and other small solid particles from penetrating into the flow restriction

device inside **116**. The screen **122**, however, maintains the string inside **116** in fluid communication with the formation **200**. Any fluid **40** supplied from the surface into the opening **116** at a pressure greater than the pressure to the formation **200** travels downhole to the plug **112**. This fluid then returns uphole (return fluid **42**) via an opening **124** at the casing joint **114**. The returning fluid **42** passes through the screen assemblies **110a-110c** (as shown by arrows **43**) to the annulus **204** between the flow restriction device **100** and the wellbore **201** and travels uphole via the annulus **204**, as shown by arrows **44**. The purpose of the flow restriction device **100** is to prevent solids present in the production fluid **202** to pass into the opening **116** of the string **10**. It also prevents passage of any gravel though the screens **122** into the completion string inside **116** that is supplied to the annulus **204** from the surface.

A liner packer **150** is disposed uphill of (above) the flow restriction device **100**. A casing nipple **160** and a knock-out isolation valve **165** are serially coupled between the liner packer **150** and the flow restriction device **100**. A running tool **140** in the liner packer **150** is used to convey the liner packer **150** and the flow restriction device **100** into the wellbore **201**. An end **140a** of the running tool couples a swivel sub **162** in the casing nipple **160**. The swivel sub **162** allows the tool portion above or uphole of the swivel sub **162** to rotate while maintaining stationary the tool portion **163** below the swivel sub.

The liner packer **150** includes setting slips **151** and one or more packing elements **152**. A liner packer setting dog (not shown) when moved downhole, causes the packer elements **152** to set, i.e., extend outward to the wellbore inside walls. Seals **144** in a junk bonnet **145** at the top of the liner packer **150** allow a polished stinger **143** to maintain seal. In the above-described configuration, the running tool **140** is attached to the section of the completion string that includes the liner packer assembly **150** and the flow restriction device **100** (referred to herein as the "bottom hole assembly" or the "BHA"). This allows an operator to rotate and release the running tool **140** from the bottom hole assembly to pull out the upper section of the completion string **100** out of the wellbore **201**, leaving behind the BHA in the wellbore **201**.

A crossover port assembly or device **170** is coupled uphole of the liner packer assembly **150** through the stringer **143**. The crossover port assembly **170** includes a port **172** which is initially closed off by a sleeve **174**. When the port **172** is closed, as shown in **Figure 1C**, fluid supplied under pressure from the surface flows down to an opening **176** in the crossover port assembly **170** and continues to flow through the liner packer assembly **150** and the flow restriction device **100** as show by arrows **40**. When the sleeve **174** is moved downward, i.e., downhole, the port **172** opens. If the flow path below the port **172** is blocked, then any fluid supplied to the completion string **10** above the port **172** will flow through the port **172** and into the annulus **204** and eventually return

uphole through the openings **116** in the completion string **10**, liner packer **150** and the crossover device **170** via opening **116**. In the particular embodiment of **Figures 1A-1D**, a gravel pack kit **185** and a service packer **180** are disposed uphole of the crossover device **170**.

The service packer **180** can be hydraulically set to block or restrict fluid flow through the annulus **204** uphole of the crossover device **170**. The gravel pack kit **185** includes a port **186** that allows the fluid to flow from the completion string inside **116** to the annulus **204** above the service packer **180** as more fully explained below. The service packer **180** includes slips **181** and a plurality of packing elements **183**. Thus, the gravel pack system or completion string **10** shown in **Figure 1A-1D** includes in a substantially serial relation a flow restriction device **100**, a liner packer **150** above the flow restriction device **100,** a crossover port assembly tool **170**, and a service packer **180** uphole of the crossover device **170**. The gravel packing around the flow restriction device **100** while maintaining the hydrostatic pressure above the formation pressure will now be described while referring to **Figures 1-4**.

The completion string **10** shown in **Figures 1A-4D** is conveyed into the wellbore **201** to a desired depth to position the flow restriction device **100** adjacent the producing formation **200**. A wellbore fluid **40** is pumped from a source thereof at the surface (not shown) into the completion string **10**. The fluid

flows through the string **10** as shown by the arrows **40** and returns to the surface via the annulus **204** as shown by the arrows **43**. The fluid in the wellbore maintains the hydrostatic pressure over the formation **200**, i.e., maintains the wellbore under overburdened condition.

Once the string **10** is correctly positioned in the wellbore **200**, the running tool **140** is released (or disengaged) from the liner packer **150** by rotating the pipe or the work string (attached above the string **10**), which rotates the string **10** above the swivel sub **162**. The work string is then moved up or uphole, which causes the slips **181** of the service packer **180** to move over members **182**, which sets the packer elements **183** of the service packer **180** (See **Figures 2A-2D** ). Setting of the service packer **180** blocks any fluid flow through the annulus **204** around the packer elements **183**. Since the fluid in the string **10** remains in fluid communication with the formation **200**, it maintains the hydrostatic pressure on the formation **200**.

After setting the service packer **180**, a ball **190** is dropped into the completion string **10**, which moves the sleeve **174**, thus opening the port **172**. The ball **190** seats in position in the crossover assembly **170** and prevents fluid flow through the crossover assembly **170** past the ball **190**. The movement of sleeve **174** also opens a reverse fluid flow path **177** in the crossover port assembly which is further in fluid communication with fluid path **179** in the

service packer assembly **180**. Thus, activating or setting the crossover assembly **170** causes any fluid supplied from the surface to flow through the string **10** to the port **172** and then over to the annulus **204** via the port **172**. The fluid then flows downhole through the annulus **204** and passes through the screens **110a-110c** and then into the string opening **116** as shown by arrows **50** (**Figures 2A-2D**). The fluid then flows uphole through the opening **116** in the flow restriction assembly **100** and then through openings **117** and **118** respectively in the liner packer **150** and the crossover tool **170**. The fluid then crosses over to the line or opening **179** through the service packer via crossover opening **177**. The fluid from line **179** passes into the annulus **204** above the packer **180** via port **186** in the crossover kit **195**. The downhole fluid flow path after the setting of the crossover assembly **170** is depicted by arrows **50**, while the uphole fluid flow path of the returning fluid is shown by arrows **52**. Thus, during the setting of the crossover assembly **170** to establish fluid flow below the service packer via the annulus **204**, the fluid in the wellbore **201** remains in fluid communication with the formation **200**, thereby maintaining the hydrostatic pressure on the formation **200**.

Still referring to **Figures 2A-2D**, once the service packer **180** has been set, fluid **188** with gravel or sand **189** (also know in the art as "propant") is pumped into the string **10** from a source at the surface (not shown). The gravel fluid **188** flows to the annulus **204** around the flow restriction device **100**. The

flow restriction device **100** prevents the gravel **189** from entering into the tool inside **116**. The gravel **189** deposits or settles in the annulus **204** while the filtered fluid enters the opening **116** and travels uphole as shown by arrows **52**. The supply of the gravel fluid is continued until the annulus **204** around the flow restriction device **100** is packed with the gravel **189**.

Referring to **Figures 3A-3D**, after the desired amount of gravel **189** has been packed around the flow restriction device **100**, the work string is picked-up, which opens bypass **220** in the service packer **180**. Clean fluid **222** is pumped downhole, which flows down along the fluid path shown by arrows **55** and returns uphole though the flow opening **224** via the port **172**. This reverse circulation removes any excess sand or gravel from the work string.

The junk bonnet **144** is then sheared off. The packer setting dog sub **154** is then removed. The liner packer **150** is then set and the string pulled out of the wellbore **201** leaving the flow restriction device **100**, the liner packer **150** and the tubing **230** in the wellbore (**Figures 4A-4D**).

It should be noted that in the particular method of this invention described herein, the liner packer **150** is set after the gravel pack operation has been completed, which allows maintaining the hydrostatic pressure on the formation throughout the gravel pack operations, thus, maintaining overbalanced or over

burdened condition during all stages of the gravel packing operations. This system **10** also requires no gravel pack ports in the hook-up. Full inner dimensions or diameter is available throughout the operations. This method causes no swabbing or disturbance of the open hole filter cake.

The gravel pack system described herein above may utilize an combination of devices or any configuration that allows maintaining the hydrostatic pressure on the formation throughout the completion operations, such as gravel pack operations described above. The devices, such as packers, run-in tools, flow restriction devices described herein above are known in the oil field and thus are not described in great detail.

While the foregoing disclosure is directed to the preferred embodiments of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

**WHAT IS CLAIMED**:

1. A method of gravel packing a wellbore while maintaining said wellbore in an overburdened condition with a completion string having a flow restriction device that restricts flow of gravel and provides a fluid path between said wellbore and inside of said completion string, said method comprising:

- conveying said completion string in said wellbore to position said fluid flow restriction device adjacent a selected formation while maintaining the wellbore in the overburdened condition, the space between the wellbore and the completion string defining an annulus;
- setting the completion string to establish a first crossover fluid flow path in said completion string uphole of the fluid flow restriction device while maintaining said wellbore in the overburdened condition, said first crossover fluid flow path allowing fluid supplied to the completion string to pass from said completion string to said annulus;
- setting the completion string to establish a return fluid path in said completion string while maintaining said wellbore in the overburdened condition, said return fluid path allowing fluid flowing from said selected formation into said completion string through said flow restriction device to said annulus uphole of said first crossover fluid flow path; and

- supplying fluid containing propant ("gravel fluid") under pressure to said completion string, thereby causing said gravel fluid to flow into and gravel pack said annulus downhole of said first crossover fluid path.

2. The method of claim 1 wherein setting the completion string to establish the return fluid path includes establishing a second crossover fluid flow path uphole of said first crossover fluid flow path.

3. The method of claim 1 further comprising continuing to supply said gravel fluid until an annulus between said formation and said flow restriction device is packed with desired amount of the gravel.

4. The method of claim 1 further comprising setting a first packer in said completion string uphole of said first crossover fluid flow path while maintaining said wellbore under the overburdened condition.

5. The method of claim 4 wherein first packer restricts fluid flow from said annulus below said packer to the surface.

6. The method of claim 5 further comprising setting a second packer between said flow restriction device and said first crossover fluid flow path.

7. The method of claim 5 further comprising retrieving a portion of said completion string to the surface leaving said flow restriction device in said wellbore.

8. The method of claim 1 wherein setting the completion string to establish a first crossover fluid flow path includes hydraulically opening a valve in said completion string that allows fluid to communicate between said completion string and said annulus.

9. A method of gravel packing a wellbore with a completion string while maintaining the wellbore under overburdened condition, said completion string having a flow restriction device, a crossover device uphole of the flow restriction device and a first packer between the crossover device and the flow restriction device and a second packer uphole of the crossover device, wherein the crossover device in a first mode provides a fluid passage to the flow restriction device through the string and in a second mode blocks the fluid flow through the string and allows said fluid to flow into an annulus between the string and the wellbore, said method comprising:

(a) conveying the completion string in the wellbore to position the flow restriction device adjacent a selected formation selected location, with the crossover device in said first mode;

(b) setting the crossover device to the second position;

(c) setting the second packer, said packer preventing fluid flow through the annulus uphold of the crossover device; and

(d) supplying fluid with propant to the completion string to gravel pack the annulus around the flow restriction device.

10. The method of claim 1 further comprising setting the first packer.

11. The method of claim 10 further comprising retrieving the completion string while leaving the flow restriction device and the first packer in the wellbore.

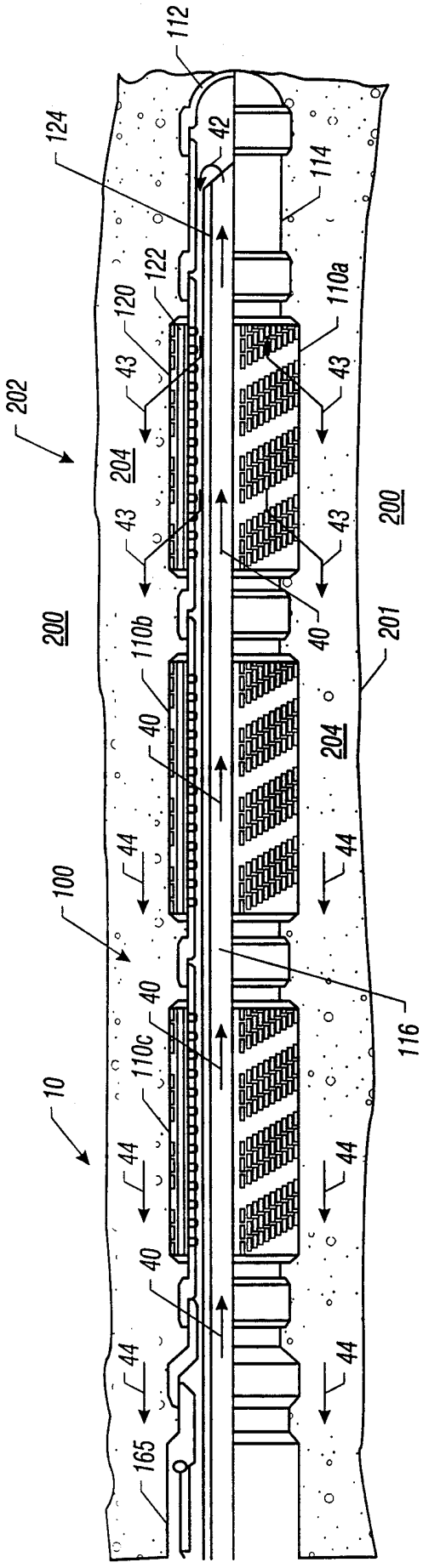


FIGURE 1A

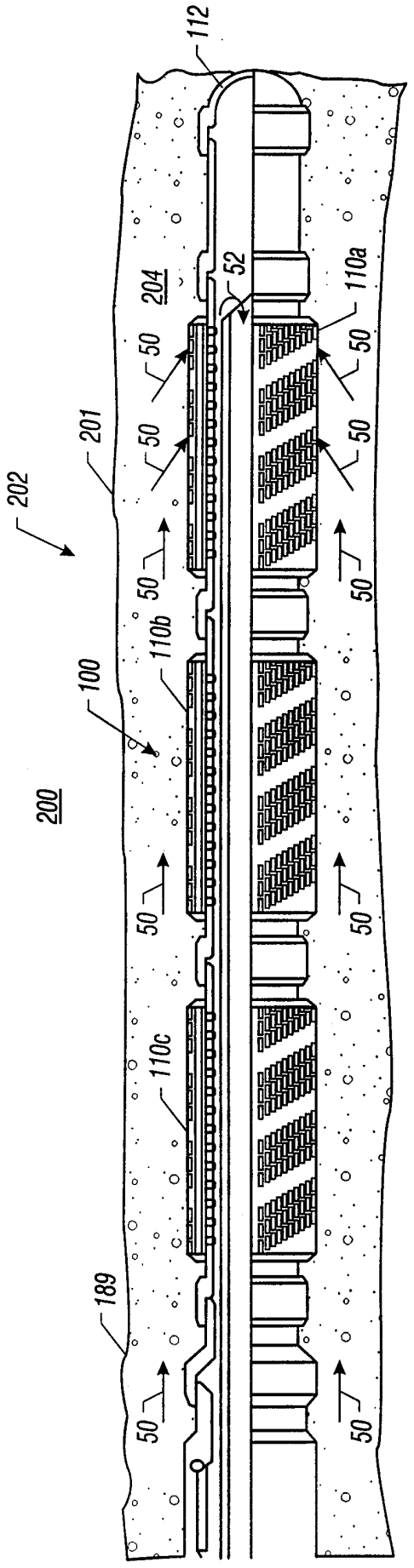


FIGURE 2A

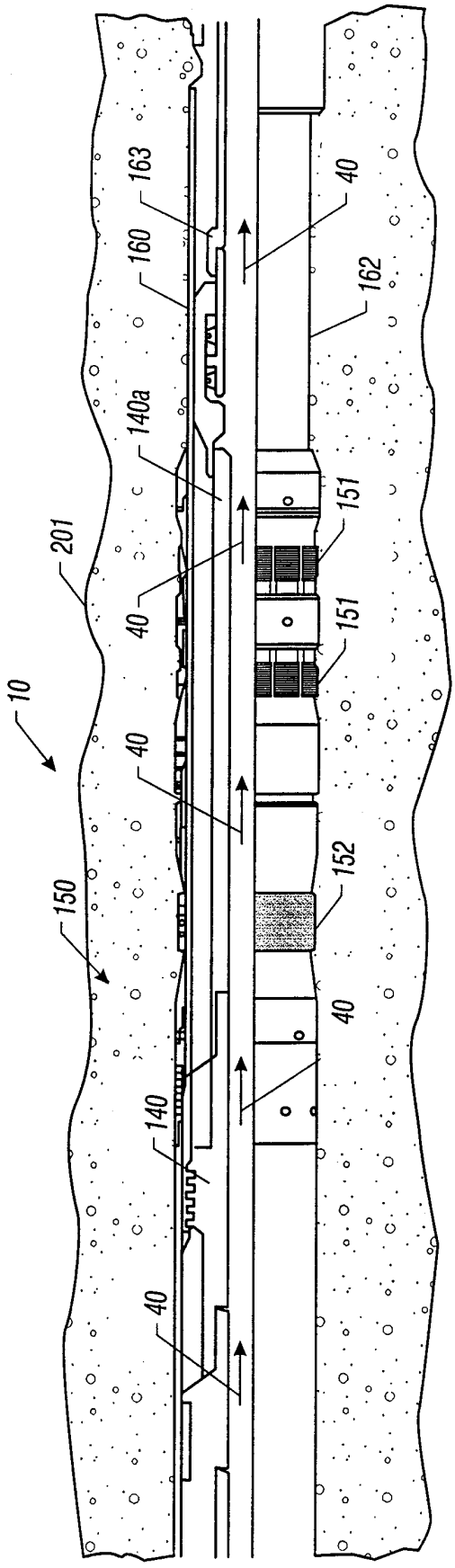


FIGURE 1B

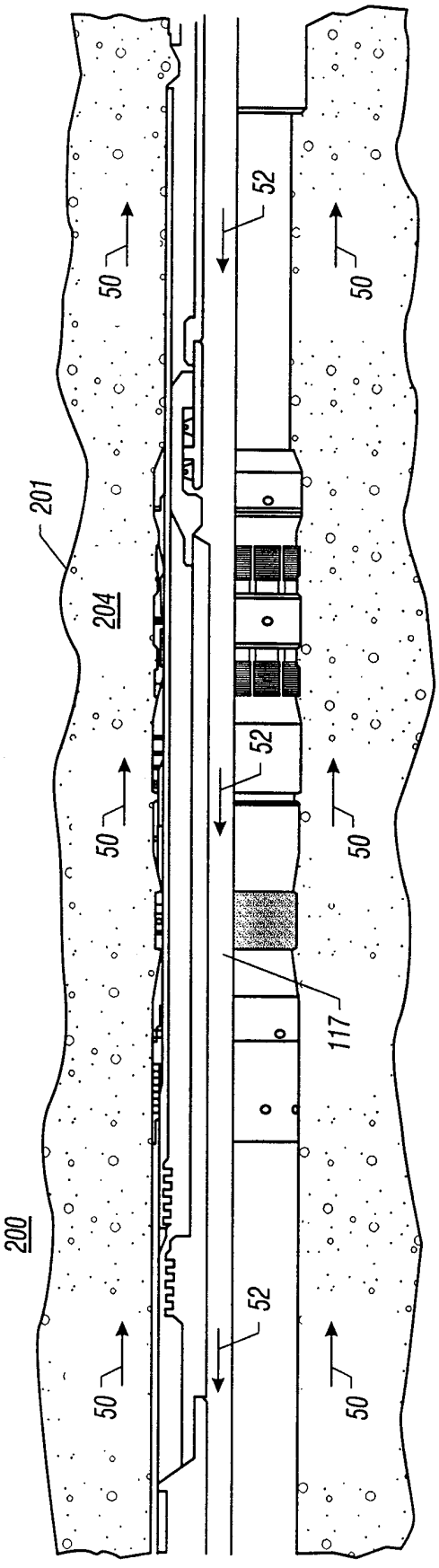


FIGURE 2B

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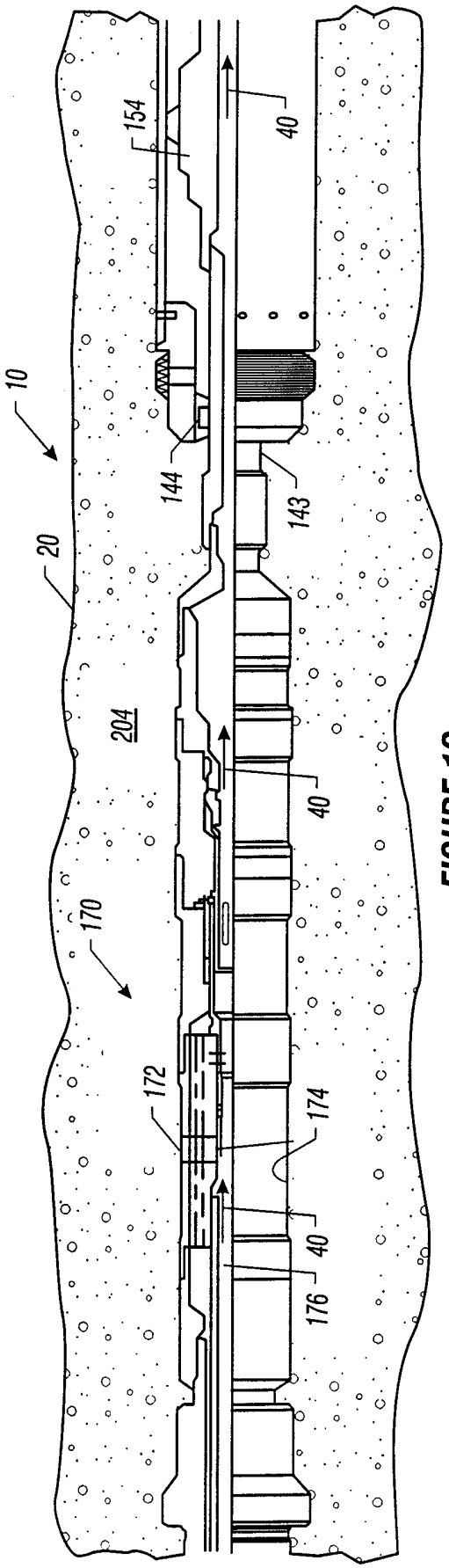


FIGURE 1C

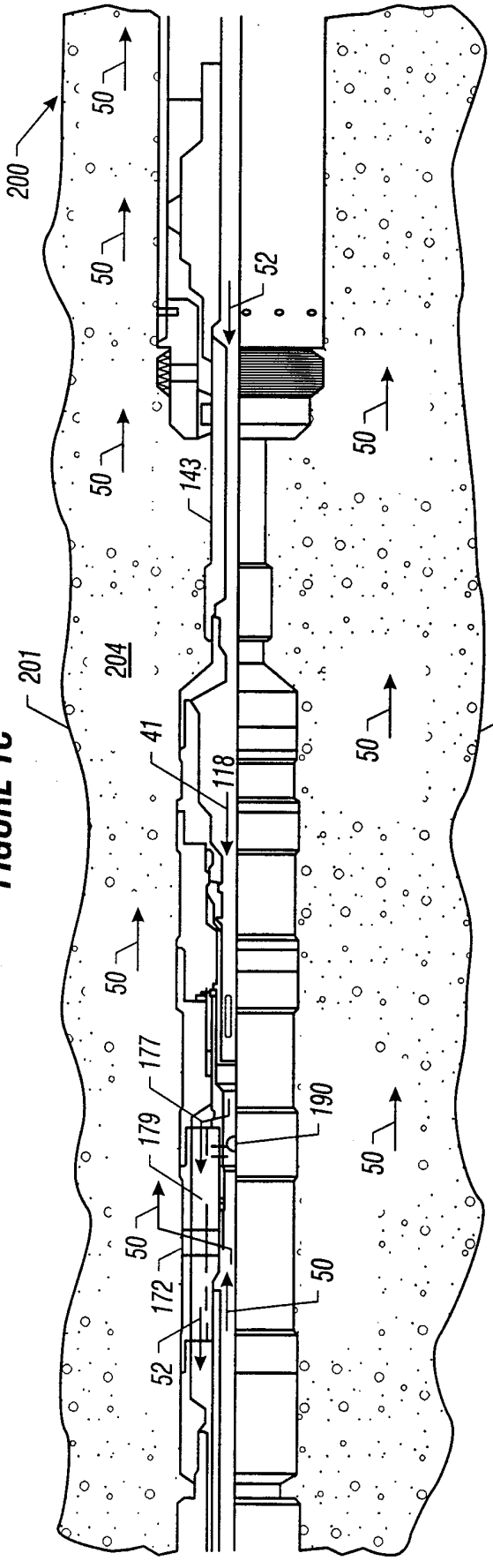


FIGURE 2C

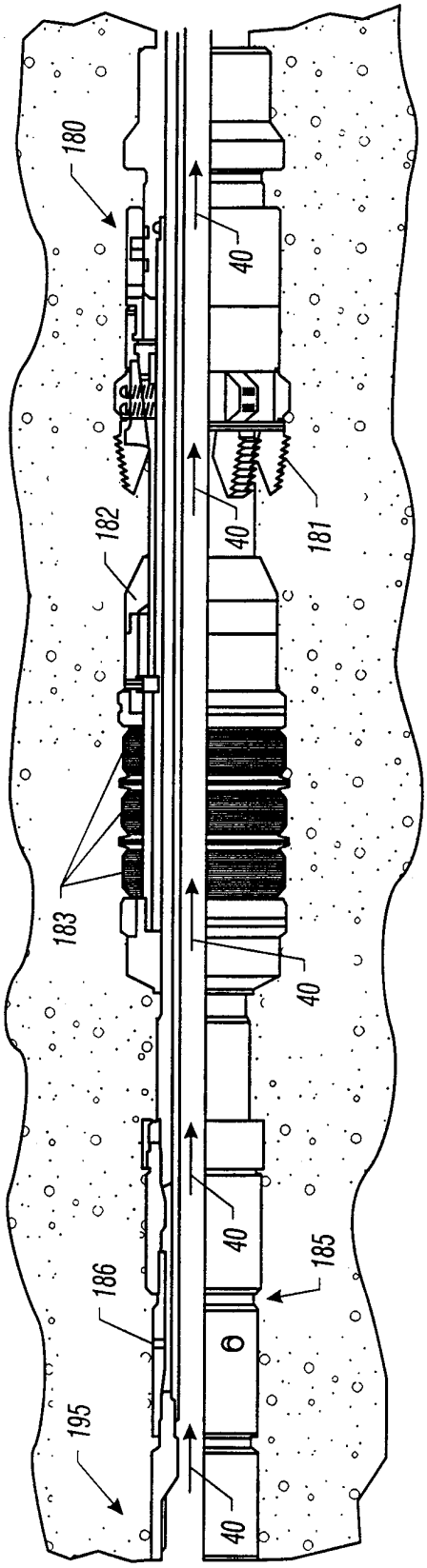


FIGURE 1D

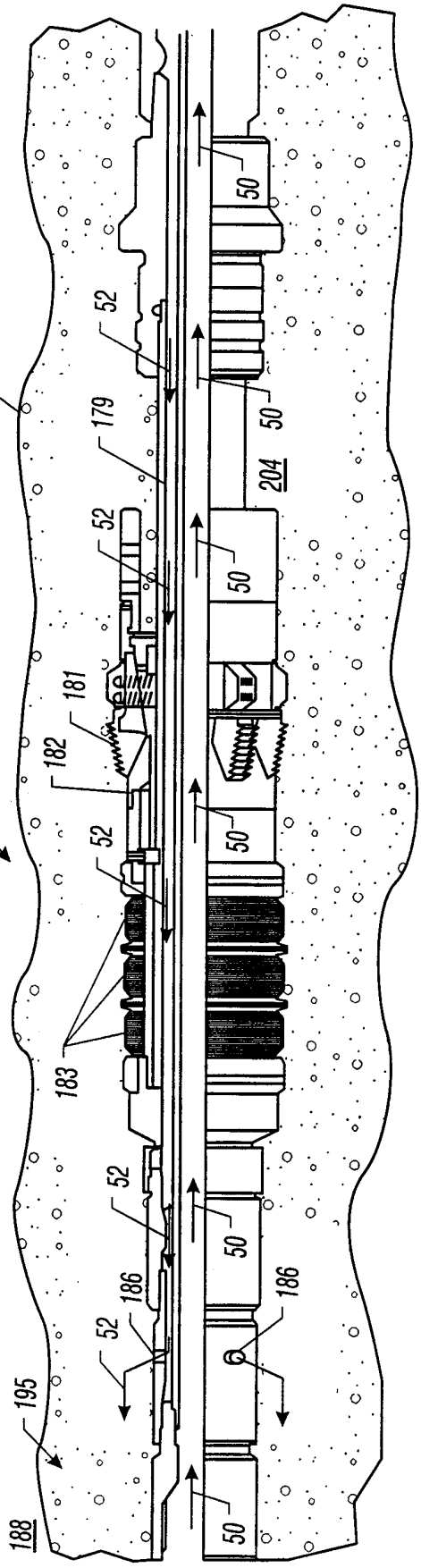


FIGURE 2D

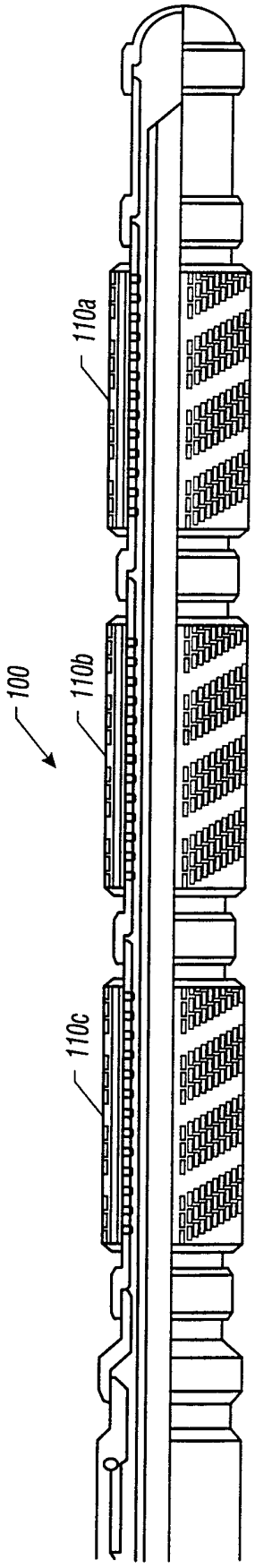


FIGURE 3A

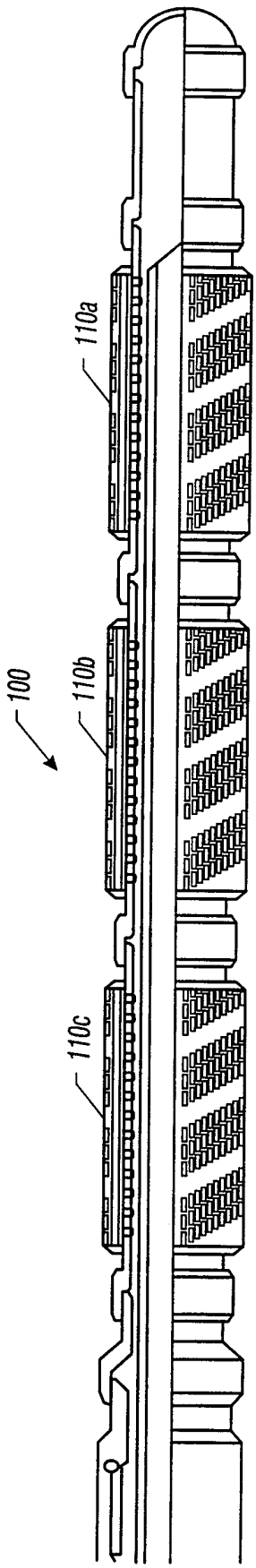


FIGURE 4A

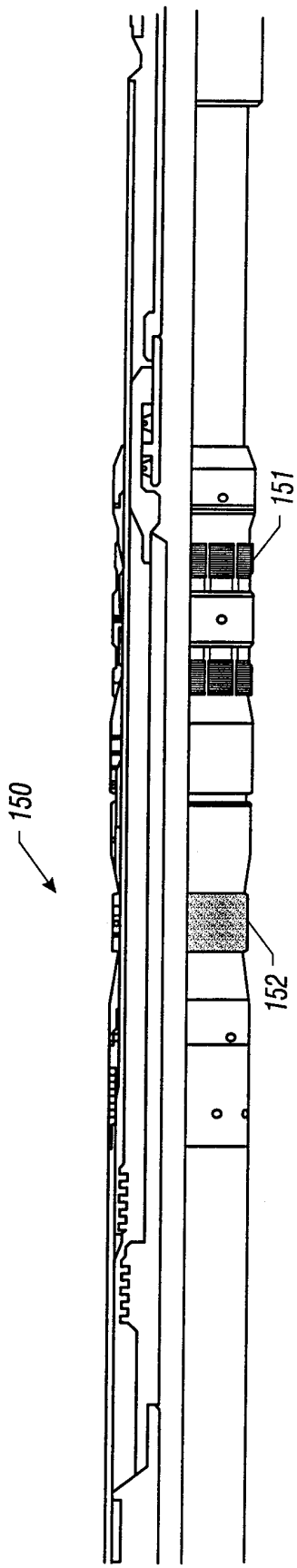


FIGURE 3B

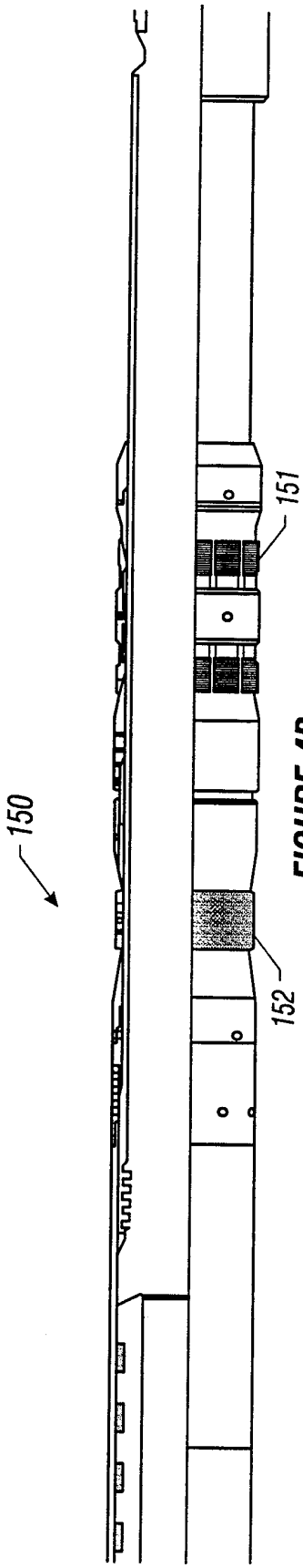


FIGURE 4B

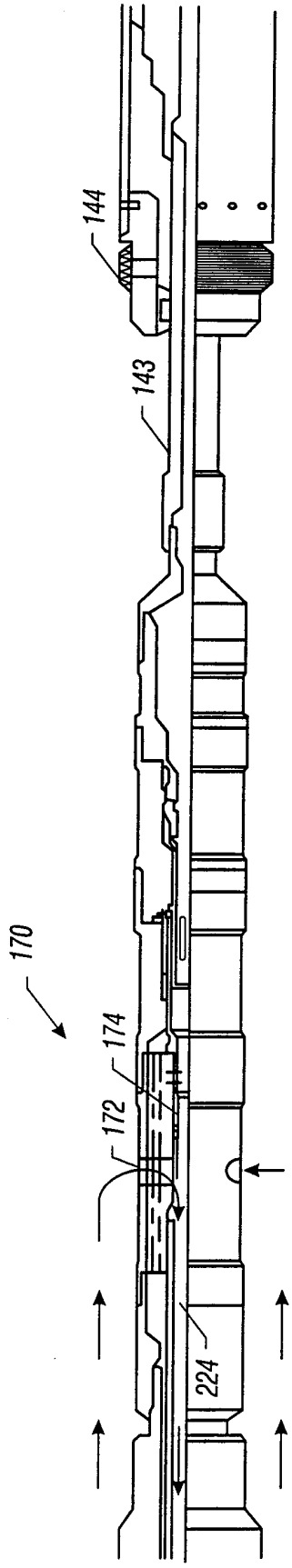


FIGURE 3C

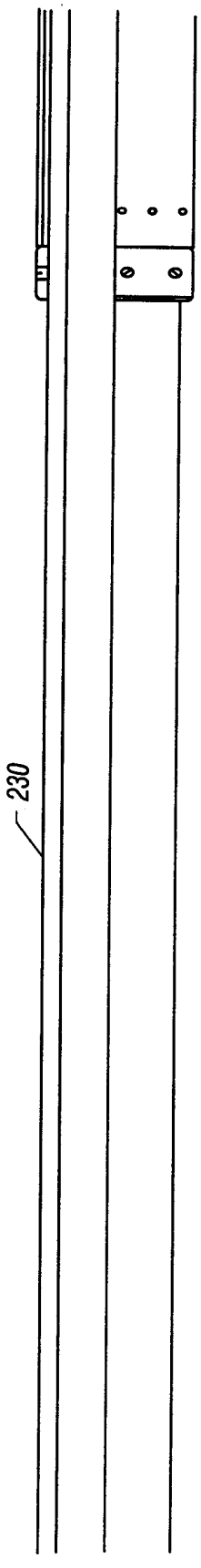


FIGURE 4C

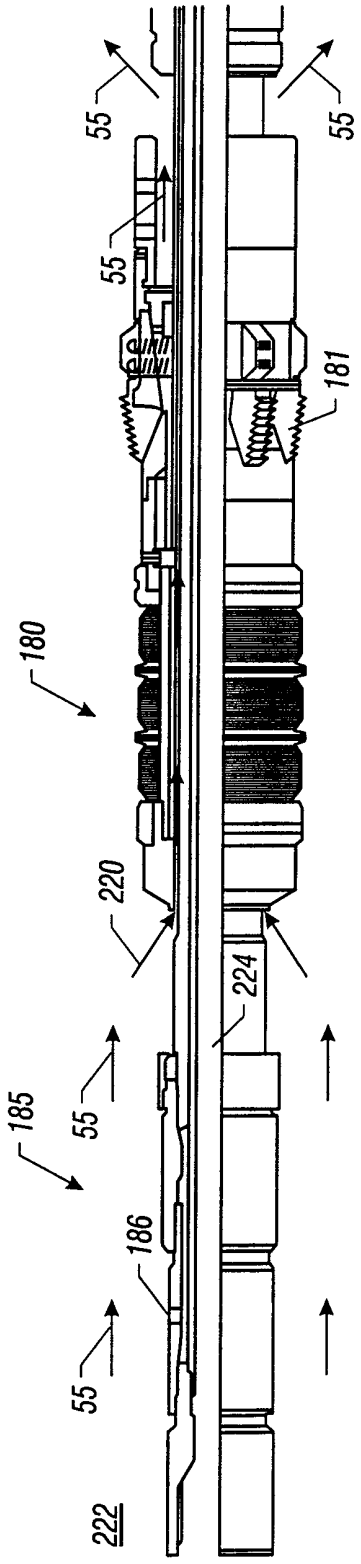


FIGURE 3D

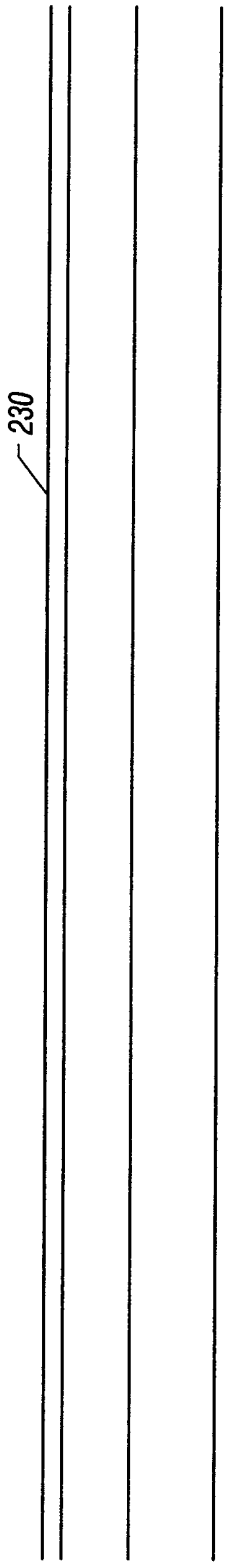


FIGURE 4D

# INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 99/16813

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | PETE DUHON ET AL: "New Completion Techniques Applied to a Deepwater Gulf of Mexico TLP Completion Successfully Gravel Pack an Open Hole Horizontal Interval of 2400 Feet" OTC PROCEEDINGS 1998 OTC-8586, 4 May 1998 (1998-05-04), pages 1-13, XP002120001 page 3, paragraph 2 page 6, paragraph 4 -page 7, paragraph 1 --- | 1,3 |
| A | US 5 373 899 A (DORE EDDIE E ET AL) 20 December 1994 (1994-12-20) column 1, line 31-33 column 1, line 38-41 ----- | 1 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 22 October 1999 | 05/11/1999 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Schouten, A |

1

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# INTERNATIONAL SEARCH REPORT

ormation on patent family members

Inter nal Application No
PCT/US 99/16813

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 5373899 A | 20-12-1994 | AU 5964994 A | 15-08-1994 |
| | | WO 9417280 A | 04-08-1994 |