Feb. 11, 1969 W. J. BIELSTEIN ETAL 3,427,651

WELL CONTROL

Filed Nov. 23, 1966

Sheet 1 of 2

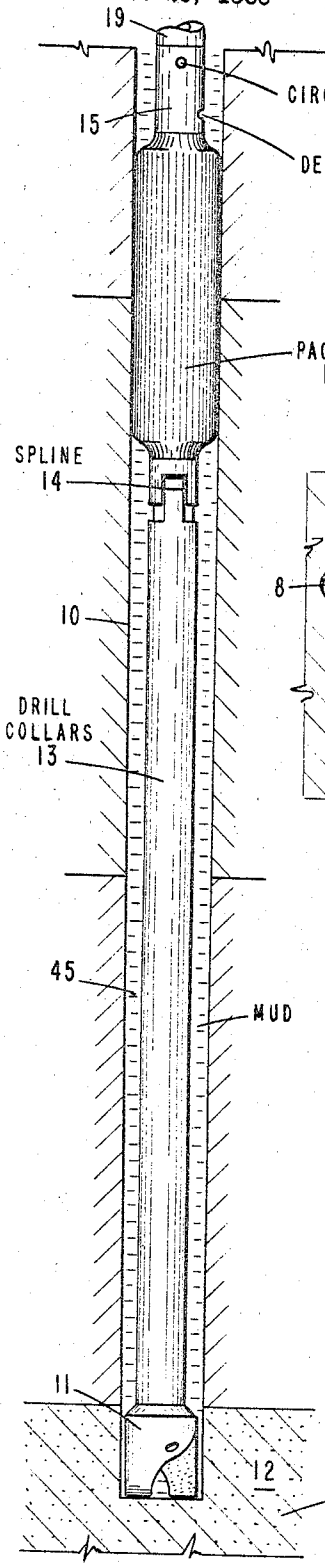


Fig. 1.

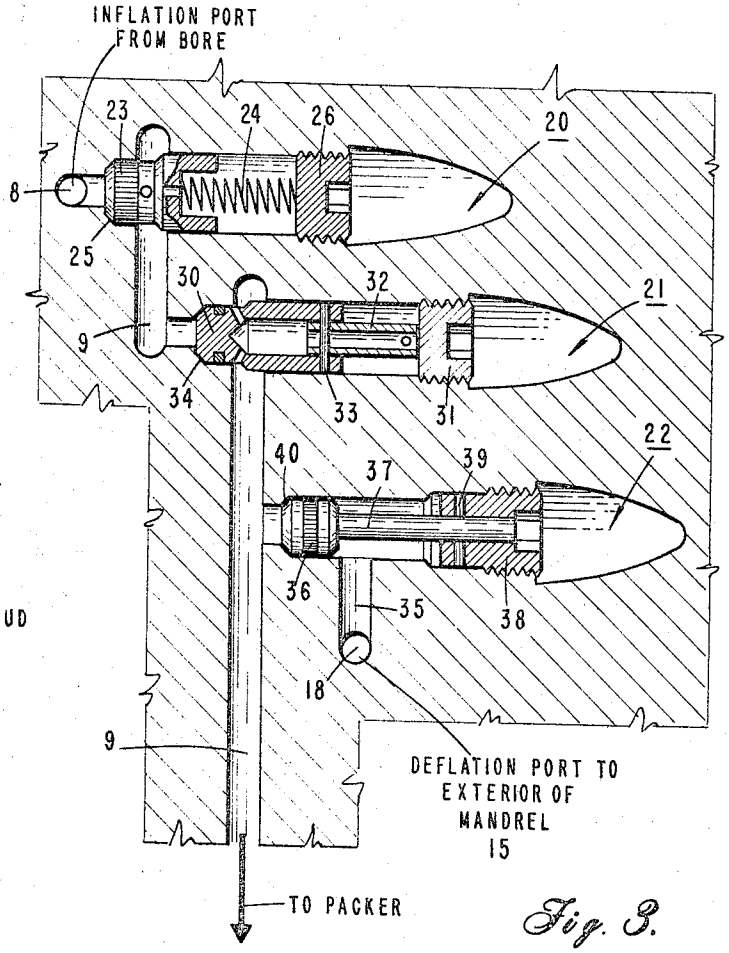


Fig. 2.

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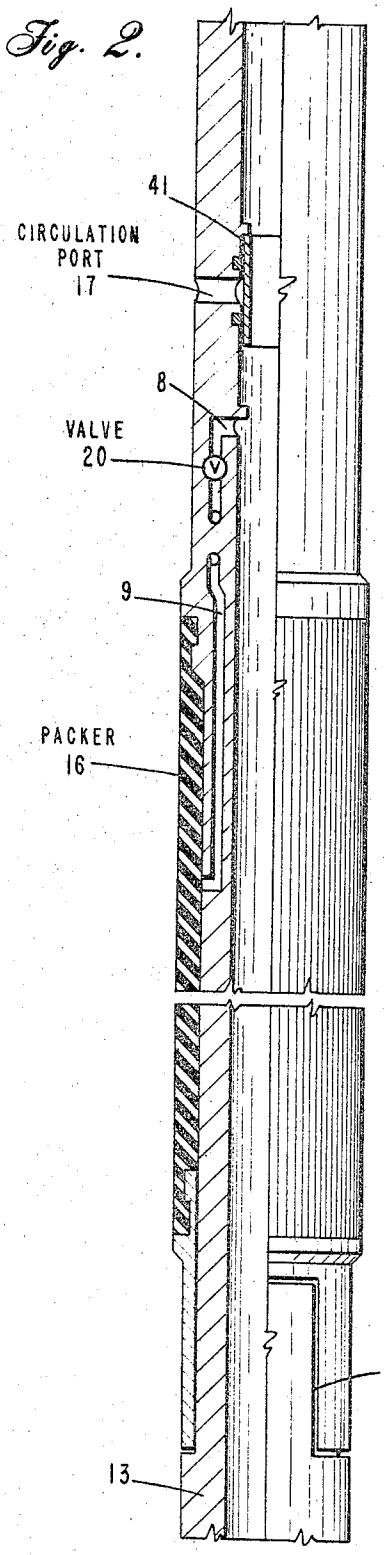
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Sheet 2 of 2

Fig. 2.



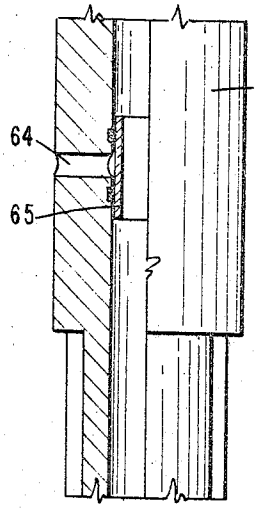


Fig. 4A.

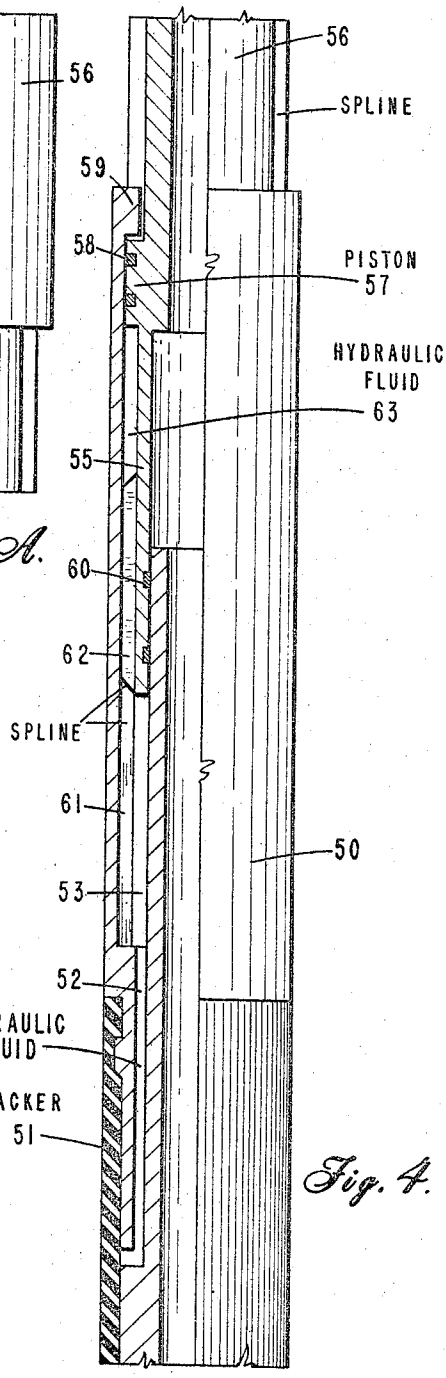


Fig. 4.

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WELL CONTROL

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U.S. Cl. 166—244 15 Claims
Int. Cl. E21b 43/00, 23/06, 21/00

The present invention generally concerns method and apparatus for shutting in a well during drilling operations. More particularly, the invention concerns method and apparatus for closing off the annulus between a drill string and borehole wall and conducting operations thereafter in order to remedy blowout or other undesirable well conditions that require correction.

In order to permit remedial action to be taken to control a well in which a blowout has occurred during drilling operations without hazard, the well is desirably shut in at the bottom of the hole. A blowout preventer is used to seal the annulus just above the zone that is providing an influx of fluid (oil, gas or water) caused by the reservoir pressure of that zone being greater than the hydrostatic pressure exerted by the normal circulating drilling fluid. Circulation of fluid above this point allows the well to be controlled without further influx of reservoir fluids and provides several distinct operating advantages. The time for well control is reduced. Also, density of the circulating fluid can be increased to the level required to control a high pressure zone with minimnum time and cost. Mud losses and mud costs are reduced because it is not necessary to optimize mud weight while attempting to determine or "feeling" for a high pore pressure (e.g., 13+pounds/gallon equivalent) formation in which to set intermediate casing. Other advantages achieved through the ability to circulate above the blowout preventer include desired minimization of surface casing length and thickness and substantial elimination of the previously required intermediate liners; e.g., liners set from 8 to 12 thousand feet. Further, faster drilling results from lowered mud weight and improved hydraulics and elimination of deliberate drilling rate slowdown to compensate for gas cutting of the mud or for potential hazard of crossing poorly defined pressure sealing faults. When the blowout preventer is released, normal circulation and operations can be restored using a heavier circulating fluid. The same circulation procedure can be used to allow time for healing a lost returns zone by keeping a heavy fluid from the lost returns zone either above or below the blowout preventer. Variations in the circulation technique will be obvious to those familiar with the art of well control.

A primary object of the present invention is to provide an improved blowout prevention method and apparatus for shutting in a well while conducting drilling operations. Although this invention primarily serves to control blowouts which occur while drilling the borehole, it may also be employed in healing lost returns zones and aiding in overcoming other problems encountered during drilling operations.

In accordance with the teachings of the invention, the apparatus includes an annular, flexible, fluid-expansible sealing means or packer arranged on a tubular member and inserted in a drill string; means are provided for controlling the introduction of fluid into the packer to cause expansion thereof and for controlling removal of the fluid from the packer to permit the packer to contract. In one embodiment of the invention, fluid pressure-operated valves control the introduction and removal of fluid from the packer, while in another embodiment of the invention, fluid movement into and from the packer is controlled by compression and tension of the drill string. The blowout preventer of this invention will normally be positioned just above the drill collars of the drill string. However, it can be located at other points along the drill string. The blowout preventer is capable of sealing the space between the drill string and the well bore either in open hole or in casing. The annulus area below the seal made by the packer will be isolated from the annulus area above such seal. Means are provided in the drill string to permit drilling fluid circulation above the blowout preventer seal. Also in accordance with the teachings of this invention, a method is provided for preventing blowouts in wells during drilling operations in which drilling fluid is circulated down the drill string and up the annulus between the drill string and the borehole wall which comprises the steps of sealing off the annulus between the drill string and the borehole wall; opening a circulation port in said drill string above said sealed-off annulus; and circulating drilling fluid, adjusted to a desired weight, through said circulation port to maintain control of the well.

The above object and other objects and advantages of the invention will be apparent from a more detailed description thereof when taken with the drawings wherein:

FIG. 1 is a sectional, elevational view illustrating one embodiment of the present invention;

FIG. 2 is a more detailed view of a portion of the apparatus shown in FIG. 1, partly in section;

FIG. 3 is a more detailed view of another part of the apparatus illustrated in FIG. 1, partly in section; and

FIGS. 4 and 4A are elevation views, partly in section, illustrating another embodiment of this invention.

Referring to the drawings, in FIG. 1 is shown a borehole **10** being drilled by a drill bit **11** into a high-pressure formation **12**. The upper end of the drill collars **13** attached to drill bit **11** are splined as at **14** to a tubular member or mandrel **15**, the upper end of which is connected to the lower end of a drill string **19**. An inflatable packer or sealing member **16** is arranged on mandrel **15**. A fluid circulation port **17** and a packer deflation port **18** are shown located above packer **16**.

As seen more clearly in FIG. 2, mandrel **15** is provided with a fluid passageway **9** which terminates at its lower end in the interior of packer **16** and at its upper end in the interior of mandrel **15** at port **8**. As seen more clearly in FIG. 3, three pressure-actuated valve members **20**, **21** and **22**, only one of which, valve member **20**, is shown in FIG. 2, are arranged in mandrel **15**. Valve member **20** is a check valve which includes a movable plug closure member **23** biased by a spring **24** to a seat **25** formed in an enlarged area of conduit **9**. Spring **24** is connected at one end to plug **23** and supported at the other end by a stop portion **26** of valve member **20**. This valve member is located closest to circulation port **8**. Valve member **21**, positioned next closest to circulation port **8** in fluid passageway **9**, includes a movable plug closure member **30**, which initially seats in an enlarged area **34** of passageway **9**, and a stop portion **31** to which is connected a shaft **32** secured initially to closure member **30** by means of a shear pin **33**. Another passageway **35** terminates in passageway **9** at one end and in deflation port **18** at the other end thereof. Valve member **22** includes a movable plug closure member **36**, which initially seats in an enlarged area **40** of passageway **35**, attached to a shaft **37** initially secured to a stop portion **38** of valve member **22** by means of a shear pin **39**.

Circulation port **17** in drill string **19** fluidly communicates the interior and exterior of the drill string and is provided with a slidable sleeve valve **41** which can be opened and closed by wire line. Such a valve is commercially available and may be of the type illustrated on page 3820 (vol. 3) of the 1966–67 "Composite Catalog of Oil Field Equipment and Services."

In the operation of this embodiment of the invention,

when high pressure formation **12** is penetrated by drill bit **11** and it is desired to inflate packer **16** and close off the annulus **45**, drilling is halted and the hydraulic pressure of the drilling fluid, circulated through drill string **19**, tubular member **15**, drill collars **13** and drill bit **11** and up the annulus **45** between the drilling apparatus and the borehole wall, is increased to a predetermined pressure; e.g., 800 p.s.i. higher than normal circulation pressure. Valve **41** maintains circulation port **17** closed. This hydraulic pressure acts on movable plug **23** of the pressure-operated check valve **20** through port **8** and conduit **9** against the bias of spring **24** to move plug **23** off seat **25** to open conduit **9** and permit fluid pressure to act on the plug portion **30** of fluid pressure-operated valve **21**. Under preferably a further increased hydraulic pressure force, shear pin **33** shears and plug **30** is moved off seat **34** and conduit **9** is opened completely. (Valve **21** is employed as a backup for valve **20**. Although preferably included in the valve system, it is not an essential component thereof. Valve **20** may be inadvertently opened in response to pressure surges of the circulating fluid which may occur. In such instances, valve **21** would remain closed and prevent accidental expansion of packer **16**.) Fluid pressure then expands packer **16** and seals the annulus **45** between tubular member **15** and the wall of borehole **10**, as illustrated in FIG. 1. Hydraulic pressure within the drill string and tubular member **15** is then decreased and pressure-operated valve **20** closes passageway **9** by movement of plug **23** to seat **25** under the bias of spring **24**. Fluid pressure is prevented from escaping from packer **16** and the packer is retained in inflated condition

Circulation port **17** is then opened by sliding sleeve **41** from closed position by means of a wire line and drilling fluid is then circulated down drill string **19** through circulation port **17** and up annulus **45** between the drill and the borehole wall. The drilling fluid weight can be adjusted to compensate for drilling through the higher pressure formation while the fluid is circulating or lighter circulating fluid may be employed in the event it is desired to treat a lost returns zone.

When it is desired to deflate packer **16**, the circulation port **17** is closed by returning slidable sleeve **41** to its closed position shown in FIG. 2 by means of a wire line and then increasing hydraulic pressure in the drill string and tubular member **15** to a predetermined pressure level; for example, 800 p.s.i. higher than the pressure required to open valves **20** and **21** and inflate packer **16**. This increased hydraulic pressure opens valve **20** and acts on plug **36** of valve **22** causing shear pin **39** to shear and moves plug **36** from seat **40** to a position which opens communication between passageways **9** and **35** and deflation port **18**. Hydraulic fluid in the annulus surrounding tubular member **15** then forces the fluid contained within packer **16** to flow through passageway **9**, passageway **35** and out deflation port **18** into the annulus surrounding tubular member **15**. Drilling may then be resumed.

Referring to FIGS. 4 and 4A, an embodiment of the invention is illustrated in which a tubular member **50** on which is arranged an inflatable packer **51** is provided with a passageway **52**, which terminates at its lower end in the interior of packer **51** and at its upper end in a chamber **53** formed by tubular member **50** and a lower extension portion **55** of the drill string **56**. Extension **55** includes a piston member **57** provided with seals **58** which engage the upper end of the tubular member **50**, which forms the outer wall of chamber **53**. An upper shoulder stop **59** is formed on tubular member **50** to limit upward movement of piston **57**. Lower seals **60** on extension **55** engage the inner wall of chamber **53** formed in tubular member **50**. Extension **55** is splined to keyways **61** in the outer wall of chamber **53** by key members **62**. Packer inflate fluid **63** is retained in chamber **53**.

As similarly described in the previous embodiment, a circulation port **64** provided in drill string **56** above packer **51** is opened and closed by means of a slidable valve sleeve **65** operated by a wire line.

In the operation of the embodiment of FIGS. 4 and 4A, during drilling, packer **51** is maintained in its normal deflated condition by tension in the drill pipe. Packer **51** and tubular member **50** are positioned in the drill string just above the drill collars. When it is desired or becomes necessary to inflate packer **51**, drilling is halted and the drill string and extension **55** are placed in compression by setting down weight on drill string **56**. Fluid **63** contained in chamber **53** is forced, by piston **57** as the piston moves downwardly, through passageway **52** into the interior of packer **51** to inflate the packer and seal off the annulus between tubular member **50** and the borehole wall. When it is desired to deflate packer **51**, weight on drill string **56** is picked up, which raises piston **57** to its initial position adjacent stop **59**, and fluid pressure in the annulus between the drill string and the borehole wall contracts packer **51** and forces the fluid **63** back into the storage chamber **53** through passageway **52**.

Circulation port **64** may be used in the same manner that it was used as described with regard to the embodiment of FIGS. 1, 2 and 3; that is, it may be opened by wire line to circulate fluid through the drill string and up the annulus between the drill string and the borehole wall when packer **51** is inflated and may be closed to prevent such circulation as desired.

Packer **51** is commercially available. This flexible seal may be of the type illustrated on page 3090 (vol. 2) of the 1962–63 "Composite Catalog of Oil Field Equipment and Services." Such a packer is designed to be set in a cased or open hole well bore.

Various modifications and arrangements may be made in the embodiments of the invention as illustrated and described herein without departing from the spirit and scope of the invention.

Having fully described the objects, advantages, apparatus and operation of our invention, we claim:

1. Apparatus for use in controlling wells during drilling operations in which drilling fluid is circulated down a drill string having a fully open bore therethrough and up the annulus between said drill string and the borehole wall comprising:

a tubular member having a fully open bore therethrough insertable in said drill string;

a fluid inflatable packer arranged on said tubular member adapted, when expanded, to close off the annulus between the drill string and the borehole wall; and

fluid control means connected to said tubular member for controlling introduction of fluid to said packer to inflate said packer and to permit removal of fluid from said packer to permit said packer to deflate;

said fully open bores through said tubular member and said drill string being maintained during all operations of said apparatus.

2. Apparatus as recited in claim **1** in which said fluid control means comprises:

first passageway means adapted to fluidly communicate the interior of said drill string and the interior of said packer;

first fluid pressure-operated valve means arranged in said first passageway;

second passageway means adapted to fluidly communicate the exterior of said drill string and the interior of said packer connected to said first passageway means; and

second fluid pressure-operated valve means arranged in said second passageway.

3. Apparatus as recited in claim **2** in which said first valve means includes means adapted to maintain said first passageway means open when fluid pressure acting on said first valve means is at a first predetermined pressure level and to maintain said first passageway means

closed when said fluid pressure is below said first predetermined pressure level; and

said second valve means includes means adapted to open said second fluid passageway means in response to fluid pressure of a second predetermined pressure level higher than said first predetermined pressure level.

4. Apparatus as recited in claim 3 in which said first valve means includes an additional fluid pressure-operated valve means adapted to open said first passageway means in response to fluid pressure between said first and second predetermined pressure levels.

5. Apparatus as recited in claim 1 in which said fluid control means includes a chamber adapted to contain packer inflate fluid; and

piston means arranged on the lower end of said drill string forming the upper end of said chamber adapted to move vertically relative to said tubular member;

said tubular member and said drill string being connected together in a manner such that when said drill string is placed in compression, inflate fluid contained in said chamber is forced by said piston into said packer to inflate said packer and seal off the annulus between said tubular member and the borehole wall and when said drill string is placed in tension, said packer is permitted to deflate and force said inflate fluid into said chamber.

6. Apparatus as recited in claim 1 including means on said drill string above said packer adapted to control circulation of fluid down said drill string and up the annulus between said drill string and said borehole wall above said packer when said packer is inflated.

7. Apparatus as recited in claim 6 in which said fluid control means comprises:

first passageway means adapted to fluidly communicate the interior of said drill string and the interior of said packer;

first fluid pressure-operated valve means arranged in said first passageway;

second passageway means adapted to fluidly communicate the exterior of said drill string and the interior of said packer connected to said first passageway means; and

second fluid pressure-operated valve means arranged in said second passageway.

8. Apparatus as recited in claim 7 in which said first valve means includes means adapted to maintain said first passageway means open when fluid pressure acting on said first valve means is at a first predetermined pressure level and to maintain said first passageway means closed when said fluid pressure is below said first predetermined pressure level;

said second valve means includes means adapted to open said second fluid passageway means in response to fluid pressure of a second predetermined pressure level higher than said first predetermined pressure level.

9. Apparatus as recited in claim 8 in which said first valve means includes an additional fluid pressure-operated valve means adapted to open said first passageway means in response to fluid pressure between said first and second predetermined pressure levels.

10. Apparatus as recited in claim 6 in which said fluid control means includes a chamber adapted to contain packer inflate fluid; and

piston means arranged on the lower end of said drill string forming the upper end of said chamber adapted to move vertically relative to said tubular member;

said tubular member and said drill string being connected together in a manner such that when said drill string is placed in compression, inflate fluid contained in said chamber is forced by said piston into said packer to inflate said packer and seal off the annulus between said tubular member and the borehole wall and when said drill string is placed in tension, said packer is permitted to deflate and force said inflate fluid into said chamber.

11. Apparatus as recited in claim 6 in which said control means on said drill string above said packer comprises:

a circulation port positioned adjacent the lower end of said drill string; and

valve means adapted to open and close said circulation port.

12. A method for controlling formation conditions in a borehole having a drill string with a fully open bore therethrough and with a drill bit on the lower end thereof positioned therein which comprises the steps of:

sealing off the annulus between said drill string and the borehole wall while maintaining said bore through said drill string fully open;

opening a circulation port in said drill string above said sealed-off annulus; and

circulating fluid down said drill string through said circulation port and up the annulus between said drill string and the borehole wall.

13. A method as recited in claim 12 in which said circulation of fluid is halted;

said circulation port is closed; and

the annulus between the drill string and the borehole wall is unsealed to permit circulation of fluid through the previously sealed-off portion of said annulus.

14. A method as recited in claim 13 in which the annulus between said drill string and the borehole wall is sealed adjacent the lower end of said drill string.

15. The method of controlling formation conditions in a well hole having a drill string with a drill bit on the lower end thereof positioned therein and which is adapted for circulation of a drilling fluid therethrough comprising the steps of:

closing off the annulus between the drill string and the well hole wall at a position spaced above the drill bit while maintaining a fully open bore through said drill string;

circulating drilling fluid through the drill string bore and the annulus through a bypass point spaced above the annulus close-off position; and

subsequently opening the annulus and resuming the flow of drilling fluid through the drill bit at the bottom of the drill string.

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U.S. Cl. X.R

166—184, 187, 315; 175—321