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FIG. 8.

FIG. 9.

FIG. 10.

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ABSTRACT OF THE DISCLOSURE

Method and apparatus for use in controlling 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. A tubular member is inserted in the drill string. The tubular member has arranged thereon a fluid-inflatable packer adapted to close off the annulus surrounding the tubular member. Plugs pumped from the surface cause sleeves arranged within the tubular member to shift under the application of fluid pressure and open ports and passages to the inflatable packer to first close and later reopen the annulus and to bypass the plugged bore of the tubular member. A port may be opened above the annulus closure upon application of a predetermined fluid pressure to permit fluid to circulate down the drill string and up the annulus between the drill string and the borehole wall. Alternatively, fluid may be applied to the formation surrounding the lower end of the drill string below the annulus closure by application of a predetermined fluid pressure in said drill string to unplug the bored of said tubular member after said inflatable packer has closed off the annulus and before the packer has been deflated to open the annulus.

Background of the invention

The present invention generally concerns method and apparatus for shutting off a well during drilling operations. More particularly, the invention concerns method and apparatus for closing off the annulus between a drill string and a borehole wall and conducting operations thereafter in order to remedy blowouts 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 minimum time and cost. Mud losses and mud costs are reduced because it is not necessary to optimize mud weight while attempting to determine or “feel” for a high pore pressure (e.g., 13 pounds/gallon equivalent) formations 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 slow-down 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 familiar to those familiar with the art of well control. In addition, the blowout preventer or annulus packoff tool may be used to pump heavy fluids and/or cement into high pressure formations to seal and/or abandon the portion of hole below the packoff tool. The tool could be left in the hole after such operations and, therefore, be expendable. Other applications for use of the annulus packoff tool are when a subnormal or a “lost circulation” zone is encountered in drilling and it becomes desirable to seal off the annulus above such zone so that lost circulation material or cement can be pumped into the zone at the same time keeping the annulus above the zone full of fluid for well control purposes.

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

Summary of the invention

In accordance with the teachings of one embodiment of the invention, the apparatus includes an inflatable packer element designed to seal in open hole or in casing mounted on a solid tubular member which is insertable in a drill string. The tubular member contains ports and passageways and two internal slidable sleeves which permit inflating and deflating of the packer element. It also contains a circulation port above the packer element which is initially closed by a shear-out plug. The internal sleeves are actuated by up-pumpdown plugs and surface-applied pump pressure.

In the normal drilling position, the packer element is deflated and drilling fluid circulation is through the center of the tubular member with no obstructions. Both internal slidable or slidable sleeves are maintained in place with shear pins. Inflating of the packer element is achieved by pumping down the drill string a plug which engages the lower inner sleeve. The pins holding the lower inner sleeve shear and the sleeve shifts down to expose a passageway in the tubular member connecting the interior of the tubular member and the interior of the packer element. Check valves located in that passageway retain the fluid within the packer element. As the sleeve shifts, the fluid pressure inflates the packer element and seals the annulus. The check valves trap the pressure and keep the packer element inflated. Circulation above the inflated packer element is achieved by applying additional surface pump pressure. At the elevated pressure, the shear-out plugs in the circulation port will release to open the port and permit fluid to flow from within the tubular member into the annulus between the tubular member and the well bore wall or casing wall. Deflating of the packer element is accomplished by pumping down the drill string a second plug slightly larger in diameter than the first plug to engage the upper inner slidable sleeve. The retaining pin shears under surface pump pressure to permit the upper sleeve to move down and expose packer element deflation and bypass passageways, which permits the packer to
deflate and fluid circulation to bypass the two plugs within the tubular member and continue downward through the tool.

In another embodiment of the invention, the apparatus includes an inflatable packer element designed to seal in an open hole or in casing mounted on a solid tubular member which is insertable in the drill string as in the previously described embodiment. The tubular member also contains ports and passageways and internal shiftable or slidable sleeves which permit inflating and deflating of the packer element. However, there is no circulation port above the packer element. The internal sleeves are actuated by pump-down plugs and surface applied fluid pressure. After inflating the packer element to close off the annulus, additional fluid pressure applied to the plug in the lower internal sleeve causes the plug to shear and reopen the bore of the tubular member to permit fluid to flow through the drill string to formations below the annulus closure.

In the current drilling position, the packer element is deflated and drilling fluid circulation is through the center of the tubular member with no obstructions. Both internal shiftable or slidable sleeves are held in place with shearing pins. Inflating of the packer element is achieved by pumping down a plug which engages the lower inner sleeve. The plug holds the lower inner sleeve to a predetermined surface pump pressure and the sleeve shifts down to expose a passageway in the tubular member connecting the interior of the tubular member and the interior of the packer element. Fluid pressure inflates the packer element and seals the annulus. The check valves located in the passageway trap the pressure and keep the packer element inflated. Pumping fluid through the tool is achieved by applying additional surface pump pressure which shears out the center portion of the pump-down plug. The sheared out center drops several inches and hangs in the tubular member. The annulus remains sealed. Deflating of the packer element is accomplished by shifting the upper inner sleeve downward by pumping down the drill string a second plug, slightly larger in diameter than the first plug or by use of a sinker bar or a wireline or macaroni tubing to shear the sleeve-holding pins. This action exposes deflating and equalizing ports and allows fluid circulation to bypass the internal plugs and then continue downward through the drill string. Alternatively, the upper plug may be of the shear-through type similar to the lower pump-down plug.

The tubular member is normally positioned just above the drill collars of the drill string. However, it can be located at other points along the drill string. The packer element 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 inflated packer element will be isolated from the annulus area above such seal.

Brief description of the drawings

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:

FIGS. 1-4 are elevational views showing apparatus arranged in accordance with the invention in four positions of operation: (1) drilling, (2) packer element inflation, (3) circulation above packer element and (4) packer element deflation;

FIGS. 5-7 are elevational views showing apparatus arranged in accordance with a modification of the invention in three positions of operation: (1) packer element inflation, (2) pumping through and (3) packer element deflation;

FIG. 8 is an enlarged view of a shearsable plug;

FIG. 9 is a view taken along the line 9-9 of FIG. 8; and

FIG. 10 is a view of the shearsable plug in the sheared position.

Detailed description of the invention

Referring to the drawings, in FIGS. 1-4 is shown an annulus packoff tool generally designated 10, adapted to be screw-threadedly connected in a drill string above drill collars. As shown, tool 10 is provided with a packed-up packer element 11 provided with a threaded upper end 12 adapted to be connected to drill pipe and provided with a flexible, inflatable packer element 15. The lower end of packer element 15 is secured to a collar 17 initially maintained in place by shear pins 18. An O-ring seal 19 is located on the inner surface of collar 17 to provide a seal on the outer surface of tubular member 11. The section of tubular member 11 above packer element 15 is provided with circulating ports or passageways 20 adapted, when open, to fluidly communicate the bore 21 of tubular member 11 and the annulus 22 surrounding the tubular member. A packer inflate passageway 23 extends from one of the passageways 20 to the interior of packer element 15. Two check valves 24, 25 are arranged in passageway 23. Branching off passageway 23 above packer element 15 is another passageway 26 formed in tubular member 11 which extends to the bore 21 of tubular member 11, but is sealed off from the bore by an upper shiftable or slidable sleeve 27 which is initially retained in position in bore 21 by means of shear pins 28. Upper sleeve 27 is provided with a plug seal shoulder 21, ports 30 and an outer recessed portion 31. A series of vertically spaced-apart O-ring seals 35 are arranged on the inner surface of tubular member 11 for the purpose of sealing off the various ports and passageways during operation of the tool. As shown in FIG. 4, when sleeve 27 is in its down position, recess 31 fluidly communicates packer deflate passageway 26 and a port or passageway 36 which extends between bore 21 of tubular member 11 and the annulus surrounding tubular member 11. A lower shiftable or slidable sleeve 40 is initially secured to the bore of tubular member 11 by shear pins 41. Sleeve 40 is provided with a plug seating shoulder 42 and ports 43. Sealing rings 44 are located on the inner surface of tubular member 11 to seal off the inner end of passageway 20 when sleeve 40 is in its initial or upper position, as seen in FIG. 1. The outer ends of passageways 20 are initially closed by blowout plugs 46. A plug 50, shown in FIG. 2, is provided with a seating surface 51 which engages seat 42 in sleeve 40. It is also preferably provided with fishing neck 52 to aid in its removal. A similar but larger plug 53 is provided with a seating surface 54 which engages seat 29 of sleeve 27, as seen in FIG. 4. Plug 53 is also provided with a fishing neck 55. A bypass passageway 60 permits fluid circulation around plugged bore 21 of tubular member 11.

Operation of embodiment of FIGS. 1-4

The normal drilling position of the tool is shown in FIG. 1. Packer element 15 is deflated and drilling fluid circulation is down through the center of bore 21 of tubular member 11. Both internal shifting sleeves 27 and 40 are held in place with shear pins 28 and 41, respectively. Packer element 15 is maintained in place by means of shear pin 18.

As illustrated in FIG. 2, packer element 15 is inflated by pumping plug 50 down the drill string and through a portion of the bore 21 of tubular member 11. Seating surface 51 of plug 50 engages seating shoulder 42 of sleeve 40. Pins 41 shear at a predetermined pressure; e.g., 625 p.s.i. surface pump pressure, and sleeve 40 shifts down to its lower limit to open the inner end of ports 20 to permit fluid to channel through one of the ports 20, check valves 24, 25 and passageway 23 into the packer element 15. As a packer element 15 inflates, shear pin 18 shears at a predetermined pressure; e.g., 600 p.s.i., and collar 17 slides upwardly on tubular member 11 allowing packer element 15 to expand and seal off annulus 22.

Circulation above inflated packer element 15 is effected as illustrated in FIG. 3 by applying additional

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pump pressure. At a higher predetermined pressure, e.g., 1650 p.s.i. surface pump pressure, one of the two shear-out or blowout plugs 66 releases from port 20 to permit fluid to move from bore 21 into the annulus above the packer. The other shear-out plug is included for safety purposes.

Deflating of the packer is accomplished, as illustrated in FIG. 4, by pumping down the drum string a second plug 53 which is slightly larger in diameter than plug 56. Seating surface 54 of plug 53 engages seat 29 of sleeve 27 and pin 28 shears at a predetermined pressure, e.g., 625 p.s.i. surface pump pressure to permit sleeve 27 to move downward thereby exposing deflating and bypass passageways to permit fluid to exit from packer element 15 and downward circulation to bypass the two plugs through bypass passageway 60 in tubular member 11A and port 43 in sleeve 40 and the lower bore 21 of tubular member 11 and pass downward through the drill bit, not shown. The packer fluid passes upwardly through deflating passageway 26, recess 31 in sleeve 27 and port 36 in tubular member 11 into annulus 22 surrounding tubular member 11.

Referring to FIGS. 5–10, there is shown an annulus packoff tool generally designated 10A adapted to be screwed-threaded connected in a drill string above drill collar as in the embodiment of the invention shown in FIGS. 1–4. All of the components of the tool shown in FIGS. 1–4 which are identical to the components of the tool shown in FIGS. 5–10 have similar numeral designations. The tool 10A is similar to tool 10, except in tool 10A there is no circulation port or passageway 20. In addition, the lower plug member 50A is adapted to form the lower inner shiftable sleeve 40 downwardly is a shear-through type plug which is shown in detail in FIGS. 8, 9 and 10. Referring to those figures, plug 50A is provided with a stationary outer section 56 having an outer seating surface 51A adapted to engage seat 42 of inner sleeve 40. A stable center section 57 of plug 50A is movable downwardly with respect to section 56 thereof and is initially pinned to section 56 by means of shear pin 58. Section 57 is provided with upper shoulders 59 which engage the upper end of section 56 when section 57 moves downwardly relative to section 56. As shown, the upper portion of section 57 is formed of cross members 62 which provide flow passages when section 57 is in its lower position. The lower portion of section 57 forms a solid piston portion provided with O-ring 61 and closes off the bore of section 56 when in the position shown in FIG. 8. Application of surface pump pressure causes shear pin 58 to shear and moves section 57 downwardly until shoulders 59 engage the upper end of section 56. Fluid flow is then provided through the plug member 50A by way of the passages formed by cross members 62.

Operation of embodiment of FIGS. 5–10

In the normal drilling position of the tool, not shown, packer element 15 is deflated and drilling fluid circulation is down through the center of bore 21 of tubular member 11A. Both internal shifting sleeves 27 and 40 are held in place with shear pins 28 and 41, respectively. Packer element is maintained in place by means of shear pin 18.

As illustrated in FIG. 5, packer element 15 is inflated by pumping a plug 50A down the drill string and through a portion of the bore 21 of tubular member 11A to engage seat 42 of sleeve 40. Pins 41 shear at a predetermined pressure, e.g., 625 p.s.i. surface pump pressure, and sleeve 40 shifts to its lower position. Plugs 50A and 56 and passageway 20 to permit fluid to channel therethrough past check valves 24 into packer element 15. As the packer element inflates, shear pin 18 shears at a predetermined pressure, e.g., 600 p.s.i., and collar 17 slides upwardly on tubular member 11A.

Pumping fluid through the tool is achieved by applying additional surface pump pressure, e.g., 625 p.s.i. which causes shear pin 58 to shear and forces center section 57 of pump-down plug 50A downwardly. The walls of section drops until shoulders 59 engage the upper end of section 56. The annulus remains sealed; however, the flow path through the drill string is open, as shown in FIG. 6.

Deflating of the packer element 15 is achieved as illustrated in FIG. 7 by pumping down the drill string a second plug 53 which is slightly larger in diameter than plug 56. Seating surface 54 of plug 53 engages seat 29 of sleeve 27. Pin 28 shears at a predetermined pressure, e.g., 625 p.s.i. surface pump pressure, and permits sleeve 27 to move downward thereby exposing deflating and bypass passageways to permit fluid circulation to bypass plug 53 through bypass passageway 60 in tubular member 11A and port 43 in sleeve 40 and pass down through the drill bit, not shown. The packer fluid passes up through packer deflating passageway 26, recess 31 in sleeve 27 and port 36 in tubular member 11A and to the annulus surrounding tubular member 11A.

In both embodiments, instead of pump pressure, a sinker bar lowered on a wireline or macaroni tubing could be used to shear the sleeve-holding pins. As shown in FIGS. 5 and 6, a back pressure valve 70 is positioned in the bore of the drill string below packoff tool 10A. This valve allows fluid to be pumped down the drill string but prevents fluid flow upwardly therethrough. Although not shown in FIGS. 1–4, such a valve could also be used in the embodiment of the invention described with respect to those figures. If so used, it would not be necessary to maintain circulation pressure (drill string pressure above the packoff tool) above bottom hole formation pressure.

Changes and modifications may be made in the specific illustrative embodiments of the invention shown and described herein without departing from the scope of the invention as defined into the appended claims.

We claim:

1. Apparatus for controlling wells during drilling operations comprising:
   - a tubular member insertable in a drill string;
   - a fluid inflatable packer arranged on said tubular member adapted to close off the annulus surrounding said tubular member;
   - a first shiftable sleeve means initially having a flow path therethrough arranged in the bore of said tubular member and adapted to be shifted from a first to a second position when said fluid path therethrough has been closed off and fluid pressure applied to such closure;
   - a second shiftable sleeve means initially having a flow path therethrough arranged in the bore of said tubular member adapted to be shifted from a first to a second position when said fluid path therethrough has been closed and fluid pressure applied to such closure;
   - a plurality of fluid passageway means formed in the wall of said tubular member initially closed by said first and second sleeve means;
   - said first sleeve means when in said second position thereof opening one of said fluid passageway means to fluidly communicate said tubular member bore and the interior of said packer to permit said packer to inflate;
   - said second sleeve means when in said second position thereof opening other of said fluid passageway means to fluidly communicate the interior of said packer and the exterior of said tubular member to permit said packer to deflate and still other of said fluid passageway means to fluidly communicate the bore of said tubular member above and below said closure points to permit fluid flowing downwardly through said drill string to bypass said closure points.

2. Apparatus as recited in claim 1 including a circulation passageway formed in the wall of said tubular mem-
ber adapted to fluidly communicate the bore of said tubular member and the exterior thereof, said first sleeve means preventing flow of fluid through said circulation passageway when in the second position thereof, said second sleeve means preventing flow of fluid through said circulation passageway when in the second position thereof.

3. Apparatus as recited in claim 1 including said means adapted to close the flow path through said first sleeve means comprising a first plug member.

4. Apparatus as recited in claim 3 including means adapted to close the flow path through said second sleeve means comprising a second plug member having a greater diameter than said first plug member.

5. Apparatus as recited in claim 2 including means arranged in said drill string below said tubular member adapted to prevent flow of fluid upwardly therethrough and to permit flow of fluid downwardly therethrough.

6. Apparatus for controlling wells during drilling operations comprising:
   a tubular member insertable in a drill string;
   a fluid inflatable packer arranged on said tubular member adapted to close off the annulus surrounding said tubular member;
   a packer inflatable passageway in the wall of said tubular member extending between the bore of said tubular member and the interior of said packer;
   a valve means arranged in said packer inflatable passageway adapted to permit fluid to flow from the bore of said tubular member to the interior of said packer and prevent flow of fluid from the interior of said packer to the bore of said tubular member;
   a first packer deflate passageway in the wall of said tubular member extending between the interior of said packer and the bore of said tubular member;
   a second packer deflate passageway in the wall of said tubular member extending between the bore of said tubular member and the exterior of said tubular member;
   a first sleeve member arranged in the bore of said tubular member and shiftable from a first to a second position and provided with ports and an internal plug seat, said plug seat being adapted to engage a first plug to close off downward flow of fluid through said tubular member;
   a second sleeve member arranged in the bore of said tubular member above said first sleeve member and shiftable from a first to a second position and provided with an external recess, ports and an internal plug seat, said internal plug seat being adapted to engage a second plug to close of downward flow of fluid through said tubular member;
   a bypass passageway formed in the wall of said tubular member adapted to permit fluid to bypass the bore closures of said sleeve members when said first and second plugs engage said respective plug seats;
   the first position of said first sleeve member preventing flow of fluid from the bore of said tubular member to the interior of said packer through said packer inflatable passageway;
   the second position of said first sleeve member permitting fluid flow from the bore of said tubular member to the interior of said packer through said packer inflatable passageway, in fluid communication with the other end of said bypass passageway to permit flow of fluid from said bypass passageway into the bore of said tubular member;
   the second position of said second sleeve member permitting flow of fluid through said bypass passageway and through said first and second packer deflate passageways;
   a fluid circulation passageway extending between the bore of said tubular member and the exterior of said tubular member through said recess on said second sleeve member; said second sleeve member being moved from said first to said second position thereof by application of fluid pressure to said second plug; and
   said first sleeve being movable from said first to said second position thereof by application of fluid pressure to said first plug.

7. Apparatus as recited in claim 6 including:
   a fluid circulation passageway formed in the wall of said tubular member extending between the bore of said tubular member and the exterior thereof;
   a blowout plug initially closing said circulation passageway, said blowout plug being adapted to open said circulation passageway upon application of fluid pressure therefrom, the end of said fluid circulation passageway opening into the bore of said tubular member being closed when said first sleeve member is in said first position thereof and being open when said second sleeve member is in said first position thereof.

8. Apparatus as recited in claim 7 including means arranged in said drill string below said tubular member adapted to prevent flow of fluid upwardly therethrough and to permit flow of fluid downwardly therethrough.

9. Apparatus as recited in claim 6 in which said first plug, when seated in said first sleeve member, is adapted to shear at a predetermined fluid pressure to permit flow of fluid through said first sleeve member.

10. Apparatus as recited in claim 9 including means arranged in said drill string below said tubular member adapted to prevent flow of fluid upwardly therethrough and to permit flow of fluid downwardly therethrough.

11. A method of controlling formation conditions in a well bore 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 drill string bore to prevent downward flow of fluid therethrough only and closing off the annulus between the drill string and the well hole wall at positions spaced above the drill bit; and
   pumping and circulating drilling fluid downwardly through the annulus provided through the drill string bore and up the annulus through a bypass point spaced above the annulus and drill string bore close-off positions and subsequently opening the bore and annulus and resuming the flow of drilling fluid through the drill bit to the bottom of the drill string and up the annulus.

12. The method of controlling formation conditions in a well bore 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 bore of said drill string to prevent flow of fluid through said drill string bore; closing off the annulus between said drill string and the well hole wall; opening the bore of said drill string to permit fluid to flow down through said drill string and said drill bit; closing off the bore of said drill string above the first drill string closure point; circulating fluid past said drill string closure points and downwardly through said drill bit; and
   opening the annulus between said drill string and said borehole wall to permit fluid to circulate downwardly through said drill string and said drill bit and up the annulus.

13. The method of controlling formation conditions in a well bore 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 drill string bore to prevent only downward flow of fluid therethrough at a selected level in said well;
closing off the annulus between the drill string and well hole wall adjacent said closure in said drill string;
closing off the drill string bore to prevent downward flow of fluid therethrough at a level above the level of the previous closure of said drill string bore; and
opening the annulus and circulating fluid down said drill string past said closures in said drill string bore through said drill bit and up the annulus.

14. A method as recited in claim 13 in which after the first closure of said drill string bore and closure of said annulus but prior to the second closure of said drill string bore, circulating fluid down said drill string bore and up the annulus through a bypass point spaced above the annulus closure and drill string bore upper closure level.

15. Apparatus for controlling wells during drilling operations comprising:
a tubular member insertable in a drill string;
a fluid-inflatable packer arranged on said tubular member adapted to close off the annulus surrounding said tubular member when inflated;
a plurality of fluid passageway means formed in the wall of said tubular member including a fluid circula-
tion passageway located above said packer adapted to fluidly communicate the bore of said tubular member and the exterior thereof;
movable means arranged in the bore of said tubular member adapted to open and close said fluid passageways to the passage of fluids therethrough to control inflation and deflation of said packer and circulation of fluid through said circulation passageway; and
means adapted to move said movable means.

16. Apparatus as recited in claim 15 in which said movable means comprises slideable sleeves.

17. Apparatus as recited in claim 16 wherein said means for moving said slideable sleeves include plug members adapted to close the flow paths through said sleeves.

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