ANNULAR PRESSURE CONTROL SYSTEM

Abstract: Annular pressure control system for control of the annular space pressure at drilling through one or more hydrocarbon-containing formations, the drilling being accomplished from a unit floating on the surface of the sea, with a drill string brought through a riser extending from the unit to a blow out preventer or well head on the sea bed, distinguished in that the annular pressure control system during operation is arranged sealingly in the annular space between the riser and the drill string, the annular pressure control system comprising: an outer anchoring slip for stationary, but releasable, fastening to the riser, an outer sealing towards the riser, an inner running slips for fastening to the drill string, a slip sealing towards the drill string, such that the drill string can be rotated and be brought down or up, a pump with inlet in the annular space below the sealings and outlet in the annular space above the sealings, and a power unit for operation of the pump, with coupling for power and control from the surface.
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
Annular pressure control system

Field of the invention

The present invention relates to drilling through hydrocarbon containing formations for later to be able to produce hydrocarbons. More specifically, the invention relates to pressure control at such drilling, to keep the pressure of a drilling fluid within acceptable limits, the drilling being accomplished from a unit floating on the sea surface, with a drill string brought through a riser extending from the unit to a blow out preventer on the sea bed.

Background of the invention and prior art

For drilling a drill string with a drill bit in its lower end is used. The drill string is rotated from the surface, such that the drill bit penetrates the underground formations. The drill string consists of sections of drill pipe. After drilling out a section length, casing is arranged, to close against the surface of the penetrated formation. A drilling fluid (mud) is used while drilling, which circulates from the surface down through the drill string, out from the drill bit and back to the surface through an annular space formed between the drill string and the surrounding penetrated formation or pipe on the outside of the drill string. The drilling fluid flowing back through the annular space entrains drilling cuttings, which is fragments of the penetrated formations. For floating installations, such as floating platforms or ships, it is normal to have a blow out preventer on the sea bed, and to have a riser outside of the drill string from the blow out preventer to the floating installation, such that the installation can be disconnected if required. The pressure of the drilling fluid is adapted such that it balances the pressure of the formation (pore pressure) that is penetrated, by adapting the weight and composition of the drilling fluid. If the pressure of the drilling fluid becomes too low, fluid from the formation can enter into the drilling fluid or problems can occur with stability where the formation is weak, such as regions with shale. If the pressure of the drilling fluid becomes too high, fracturing of the formation will take place, and drilling fluid can leak into the formation. The pressure of the drilling fluid increases downward into the well bore until the well is horizontal. The static pressure of the drilling fluid must generally be adapted to be between the pore pressure of the formation and the pressure that results in damage in form of fracturing, and the mud weight must be sufficient to hinder collapse of penetrated shale zones. To have circulation of the drilling fluid as explained above, an additional pressure is applied by use of surface positioned mud pumps. The difference between the static pressure and the pressure at circulation of the drilling fluid increases with the length of the well bore and with narrow tolerances between the drilling string and outside pipes, because of
friction in the path of flow. The properties of the drilling fluid are also essential for the extent of friction loss. The problems is significant at drilling in depleted formations, drilling in sub sea completed wells, drilling in depleted high pressure reservoirs, drilling in deep waters, and drilling of long wells and extensions wells from floating installations.

In depleted formations the pore pressure of the formations and the related fracturing pressure are reduced. The fracturing pressure decreases as a result of stress reduction in the formation, related to the depletion. Normally, several zones of formation have to be penetrated at drilling, each zone having a specific limit for minimum and maximum allowable pressure for the drilling fluid. The useful pressure interval of a specific zone, and particularly the combination of zones to be penetrated by a well bore, can for long, narrow well bores be lower than the difference between static well pressure and the well pressure at circulation of the drilling fluid (circulation pressure).

There are devices known to reduce the difference between the circulation pressure and the static pressure of the well. More particularly, systems are known functioning by introducing a pump device in the annular space, to pump drilling fluid up from the annular space to the surface, such that the pressure gradient of the annular space below the pump device can be shifted towards lower pressure. However, the known devices function by the pump being driven by a turbine arranged in the drill string, such that the devices follow the axial displacement of the drill string. The turbine results in additional pressure loss for circulation, and also pressure fluctuations of the drilling fluid. The known devices also are relatively complicated and are so far not implemented in industrial scale. They also have disadvantage by inappropriate function before the drilling fluid circulation is commenced. Further, it seems to be very difficult to provide acceptable sealing elements to be moved with the drill pipe as drilling proceeds. For further information, reference is made to Baker Hughes, INTEQ Turbolift and SPE/IADC 79821, "A new Downhole Tool for EDC Reduction", Bern, Hosie, Bansal, Stewart, Lee, presented at SPE/IADC Drilling Conference, Amsterdam, the Netherlands, 19-21 February 2003.

A further known device is the ORIBIS/DORS concept, ref.: US patent No. 6 454 022, Sep. 24, 2004, "Riser tube for use in great sea depth and method for drilling at such depth", which prescribes evacuation of the annular space inside the riser such that only air is present down to a level above the blowout preventer on the sea bed. This solution however provides great uncertainty with respect to safety because an explosive air-gas mixture can be formed in the riser, and also, increased wear on the drill pipe because it is rotated in an air filled riser without surrounding drilling fluid for lubrication.

There is a demand for simpler devices than the above-mentioned, without the associated problems as described.
Summary of the invention

The above-mentioned demand is met by providing an annular pressure control system for control of the annular space pressure at drilling through one or more hydrocarbon-containing formations, the drilling being accomplished from a unit floating on the surface of the sea, with a drill string brought through a riser extending from the unit to a blow out preventer or well head on the sea bed. The annular pressure control system is distinguished in that during operation it is arranged sealingly in the annular space between the riser and the drill string, the annular pressure control system comprising:

- an outer anchoring slips for stationary, but releasable, fastening to the riser,
- an outer sealing towards the riser,
- an inner running slips for fastening to the drill string,
- a slip sealing towards the drill string, such that the drill string can be rotated and be brought down or up,
- a pump with inlet in the annular space below the sealings and outlet in the annular space above the sealings, and
- a power unit for operation of the pump, with coupling for power and control from the surface.

The annular pressure control system is preferably arranged on a dedicated riser section, preferably with the pump and power unit arranged removably on the outside of the riser section. The dedicated riser section, having pump and power unit mounted, preferably has outer diameter allowing feeding through a rotary table on the floating unit. The pump and power unit can preferably be brought down, fastened and taken off and up by use of cable operations, independently of lowering or retrieving of the riser.

It is preferable if the inner and outer anchoring slips and sealings can be brought down, installed, uninstalled and brought up, with the drill string, with devices for locking and connecting to a dedicated riser section with pump and power unit, the pump and power unit preferably being arranged on the outside of the riser section, but they can also be arranged on the inside.

With the term connection for power and control from the surface, it is meant that the power for operation of the pump unit is not provided with a turbine in a drill string, but is delivered separately from the surface through a cable or pipe, preferably through an umbilical. The power unit is preferably run hydraulically, electrically or electro-hydraulically. With the term anchoring slips it is also meant other means than anchoring slips for fastening or anchoring through the riser and drill string, respectively, for example is installation of a nipple profile in the riser or the riser section a possibility, such that the annular pressure control system is locked to the riser with locking bolts that are activated and anchored in the nipple profile. Optionally can a so called "no go" be used to set sealing elements. The pump and power unit can be integrated as one unit, likewise can
the outer anchoring slips and the outer sealings be integrated as one unit, and the inner anchoring slips and the inner sealings can be integrated as one unit. The disclosure of sealings, slips, pump and power unit in the patent claims are to be construed as disclosure of functional features that can be arranged in integrated units as indicated above.

The inner (running) slips for fastening to the drill string are preferably hydraulically controlled through an umbilical. The inner slips is preferably used at setting down and taking up of the elements of the annular pressure control system (sealing part) that is arranged within the riser, however other methods and means for installation and uninstallation can be useful, and elements can be pre-installed.

The annular pressure control system preferably comprises pressure control of the pump, preferably adjustable from the surface such that the suction pressure below the pump at any time is kept at a settable appropriate pressure.

Preferably, hydraulic control of sealings and slips is arranged.

The annular pressure control system preferably has connection to an umbilical, for transfer of all power (electric, hydraulic), electric, optical or hydraulic signals.

Drawings

The invention is illustrated with drawings, of which:

Figure 1 is a section of the annular pressure control system according to the invention,

Figure 2 is a principal sketch of the annular pressure control system of the invention, as installed during operation,

Figure 3 illustrates the pressure conditions during drilling through different zones of formation,

Figure 4, 5 and 6 illustrate the pressure conditions related to the depth at different drilling situations.

Detailed description

To illustrate the problem relevant to the invention, reference is first made to Figure 3, illustrating six different reservoir (formation) zones with pressure for each formation zone, depicted P1 to P6 respectively. Zone No. 4 is depleted, such that the pressure P4 is relatively low, and correspondingly the pressure for fracturing is reduced. The maximum allowable pressure at circulation is therefore limited by the reduced pressure for fracturing of zone 4 (P4). The static well pressure represents the weight of the static drilling mud when no circulation takes place. The static well pressure must balance the highest formation pressure, which is found in zone 1 (P1), if the riser is disconnected from the sub sea well, which can take place in several situations, for example bad weather or other floating installations being on a collision course. The pressure increases towards the right in the figure, and it appears that the well pressure at
circulation is significantly higher than the static well pressure, as the circulations pressure
is depicted with a dotted line. If drilling is to take place without fracturing in zone 4, the
circulation pressure must be kept below the pressure resulting in fracturing in zone 4. As
apparent in Figure 3 the pressure difference between the fracturing pressure of zone 4 and
the circulation pressure of the well is very small, providing a narrow margin for drilling.
With the present invention circulation pressure is decreased such that it is situated
significantly closer to the static pressure of the well.

Reference is further made to Figures 4, 5 and 6, for further illustration of the
functionality of the present invention. In the figures the pressure increases towards the
right and the depth of drilling increases downward in the figures, and it is illustrated how
the pressure increases downward in the well. The static pressure is depicted as one line,
and the dynamic pressure, i.e. the pressure at circulation, is depicted as a line of lower
inclination. As apparent, the dynamic pressure, the pressure at circulation, will at the
depth where the line for the dynamic pressure crosses the fracturing pressure, become too
high, such that the formation is fractured. By use of the present invention the pressure
gradient is shifted towards the left in the figure, i.e. towards lower pressure. This is
illustrated with a dotted line in the figures. On the figures the dynamic well pressure is
lower than the pore pressure for the upper most parts of the well, this is however no
problem unless the formation is open towards the annular space, which is not the situation
in practice for the upper part of the well. So Figure 4 illustrates drilling at a narrow range
for acceptable pressure (pressure window) which can be the situation at drilling
conditions as initially described. Figure 5 illustrates the problems of drilling through
depleted reservoirs, which appears by parallel displacement in the lower part of the well
of the pore pressure and fracturing pressure. On Figure 6 the conditions at drilling in deep
waters are illustrated.

With the annular pressure control system according to the present invention the
drilling fluid in the annular space is pumped up towards the surface from the location
where said system is installed. The suction pressure to the pump device is adjusted
according to which pressure control that is appropriate. For Figures 4 to 6 this
corresponds to parallel displacements of the dynamic drilling fluid pressure by use of the
annular pressure control system according to the invention, as illustrated with a dotted
line in Figures 4 to 6.

Further, reference is made to Figure 2, illustrating how the sealing part of the
annular pressure control system according to the invention preferably is arranged in the
annular space between the riser and drill string, and power units/motors, pumps and
umbilicals preferably being arranged outside to the riser. To achieve maximum technical
effect, the pump device will preferably be installed close to the blowout preventer on the
sea bed, but at limited requirement for lift the device can be placed higher up in the riser,
assuming a positive inlet pressure to the pump.
For further illustration of the annular pressure control system according to the invention reference is made to Figure 1, which in partial section illustrates the basic structure. More particularly, the annular pressure control system comprises an outer anchoring slips for stationary, but releasable, fastening to the riser 4, an outer sealing 5 towards the riser (here integrated with the outer anchoring slips 5), slip sealing 1 towards the drill string, such that the drill string can be rotated and simultaneously be brought down or up, with or without a differential pressure over the slip sealing, a pump 2 with inlet in the annular space below the sealings and outlet in the annular space above the sealings, and a power unit 3 for operation of the pump, with power provided from the surface, preferably through an umbilical connected to a dedicated coupling. The annular pressure control system further comprises an inner running slips 1 (here integrated with the slip sealing 1) for fastening towards the drill string, and preferably a release mechanism (not illustrated), for release in an emergency situation of the slips 1. Further, sensors are preferably arranged (not illustrated), which typically can comprise sensors for pressure, flow rate, temperature, position transmitters for components of the annular pressure control system, diagnostics, etc. The annular pressure control system can be provided with additional slip sealings and optionally additional pumps. The umbilical (not illustrated) has a dedicated coupling 6, and transfers for example hydraulics, electrical or hydraulic power, data and communication. The annular pressure control system also comprises surface-located equipment for power and hydraulics, monitoring and control, etc, and auxiliary equipment for deployment, fastening, sealing, release and taking up of the sealing part, pump and power unit.

The annular pressure control system is preferably operated synchronised with the mud pumps on the surface, such that when circulation is commenced, the annular pressure control system is started synchronised.

In the following the actual installation and operation of the annular pressure control system will be explained in further detail. The annular pressure control system can be installed and activated any time during the drilling process. Preferably the sealing part is installed and brought into the well bore on a conventional drill pipe, which means that the drilling process continues immediately after installation. The sealing part is preferably installed in a special built riser section. Pumps and power units are preferably installed on the outside or very close to the riser section, preferably such that they can be replaced without pulling the riser. The annular pressure control system is preferably fastened in a lower part of the riser, but this is not a requirement. A typical procedure for installation and operation is as follows:

1. Install a special built riser section in the riser above the BOP.
2. Pumps and power units/motors are mounted on the riser section, either when it is just below the drilling deck, or after installation of the riser section at required depth.

3. Lift up the sealing part of the annular pressure control system and lower it over the drill pipe while it is hanging in slips in the rotary table.

4. Lift up the drill pipe.

5. Fasten the sealing part on the drill pipe by fastening the inner slips to the drill pipe. The sealing part is then physically fastened to the drill pipe, but the sealing elements are not activated and there is no essential restriction to the flow during lowering.

6. Lift up and bring the sealing part on the drill pipe down into the well. Stop the lowering at intended location in the riser.

7. Heave compensate the drill pipe and activate the outer anchoring slip to fasten the sealing part to the inner wall of the riser.

8. Activate the outer sealings, i.e. the sealings to the inner wall of the riser.

9. Open the inner slips to release the drill pipe.

10. Set the pressure for pump suction under the sealing element, for thereby to control how the pump is to operate.

11. Start the mud pumps carefully.

12. Start the pump of the annular pressure control system.

13. Activate the slip sealing towards the drill string.

14. Increase the flow rate of the mud pumps gradually until the flow rate of circulation, simultaneously as the flow rate of the annular pressure control system pump synchronously is increased (preferably under automatic control).

15. Continue drilling until next drill pipe must be connected.

16. Reduce the flow rate of the mud pumps.

17. Reduce and stop circulation synchronously for the mud pump on the surface and the pump of the annular pressure control system, and connect further drill pipe.

18. When the coupling is completed, repeat from step 11.

If a device for continuous circulation is used in addition to the annular pressure control system of the invention, the pressure of the well will be in static condition also at connection of drill pipes. If however only the annular pressure control system of the invention is used, the pressure of the well bore will also be kept relatively constant.

Wear on the sealing elements around the drill string can be indicated by an increase in the pump speed of the pump device mounted on or into the riser. Further sealing elements are preferably included in the annular pressure control system as a back-up. If all the sealings are worn out, the annular pressure control system can be de-activated and be retrieved by reversing the steps 9-2 in the above-mentioned procedure. Thereby the sealing elements can be replaced.
claims

1. Annular pressure control system for control of the annular space pressure at drilling through one or more hydrocarbon-containing formations, the drilling being accomplished from a unit floating on the surface of the sea, with a drill string brought through a riser extending from the unit to a blow out preventer or well head on the sea bed, characterised in that the annular pressure control system during operation is arranged sealingly in the annular space between the riser and the drill string, the annular pressure control system comprising:
   an outer anchoring slips for stationary, but releasable, fastening to the riser,
   an outer sealing towards the riser,
   an inner running slips for fastening to the drill string,
   a slip sealing towards the drill string, such that the drill string can be rotated and be brought down or up,
   a pump with inlet in the annular space below the sealings and outlet in the annular space above the sealings, and
   a power unit for operation of the pump, with coupling for power and control from the surface.

2. Annular pressure control system according to claim 1, characterised in that it is arranged with a dedicated riser section.

3. Annular pressure control system according to claim 2, characterised in that the pump and the power unit is arranged releasably on the outside of the riser section.

4. Annular pressure control system according to claim 2 or 3, characterised in that the dedicated riser section, with pump and power unit mounted thereon, has outer diameter that allows feeding through a rotary table on the floating unit.

5. Annular pressure control system according to claim 1, characterised in that the inner and outer slips and sealings can be lowered, installed, uninstalled and lifted up with the drill string, with means for locking and coupling to a dedicated riser section with pump and power unit.
6. Annular pressure control system according to claim 1, characterised in that the inner slips and the inner sealing are an integrated unit.

7. Annular pressure control system according to claim 1, characterised in that it comprises pressure control of the pump.

8. Annular pressure control system according to claim 1, characterised in that the outer slips and the outer sealing are an integrated unit.

9. Annular pressure control system according to claim 1, characterised in that the pump and power unit are integrated.

10. Annular pressure control system according to claim 1, characterised in that sealings and slips are hydraulically controlled.

11. Annular pressure control system according to claim 1, characterised in that it has coupling for an umbilical, for power, signal and control from the surface.
Figur 3

Drilling with narrow operational window

Figur 4
Drilling in depleted reservoirs

Figur 5

Drilling in deep water applications

Figur 6
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet.
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: E21B

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

SE, DK, FI, NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>WO 03006778 A1 (BAKER HUGHES INCORPORATED), 23 January 2003 (23.01.2003), whole document</td>
<td>1,2,7-11</td>
</tr>
<tr>
<td>X</td>
<td>US 20030066650 A1 (P. FONTANA ET AL), 10 April 2003 (10.04.2003), whole document</td>
<td>1,2,7-11</td>
</tr>
<tr>
<td>A</td>
<td>WO 2004085788 A2 (OCEAN RISER SYSTEMS AS), 7 October 2004 (07.10.2004)</td>
<td>1-11</td>
</tr>
</tbody>
</table>

[галерея]

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other mean
  "P" document published prior to the international filing date but later than the priority date claimed
  "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
  "&" document member of the same patent family

Date of the actual completion of the international search: 22 March 2006
Date of mailing of the international search report: 12 3-03-2006

Name and mailing address of the ISA/Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer
Christer Bäcknert / MRo
Telephone No. +46 8 782 25 00

Form PCT/ISA/310 (second sheet) (April 2005)
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>GB 2273948 A (RIG TECHNOLOGY LIMITED), 6 July 1994 (06.07.1994)</td>
<td>1-11</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>
International patent classification (IPC)
E21B 21/08 (2006.01)

Download your patent documents at www.prv.se
Cited patent documents can be downloaded at www.prv.se by following the links e-tjänster/anförda dokument. Use the application number as username. The password is 1lbpczbk4k.

Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

Cited literature, if any, will be enclosed in paper form.
<table>
<thead>
<tr>
<th>WO</th>
<th>0306778 A1</th>
<th>23/01/2003</th>
<th>GB</th>
<th>0305720 D</th>
<th>00/00/0000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>GB</td>
<td>2389130 A,B</td>
<td>03/12/2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NO</td>
<td>20031087 A</td>
<td>08/05/2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>US</td>
<td>20030066650 A</td>
<td>10/04/2003</td>
</tr>
<tr>
<td>US</td>
<td>20030066650 A1</td>
<td>10/04/2003</td>
<td>GB</td>
<td>0305720 D</td>
<td>00/00/0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GB</td>
<td>2389130 A,B</td>
<td>03/12/2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NO</td>
<td>20031087 A</td>
<td>08/05/2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WO</td>
<td>0306778 A</td>
<td>23/01/2003</td>
</tr>
<tr>
<td>US</td>
<td>4063602 A</td>
<td>20/12/1977</td>
<td>NONE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WO</td>
<td>2004085788 A2</td>
<td>07/10/2004</td>
<td>NO</td>
<td>318220 B</td>
<td>21/02/2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NO</td>
<td>20031168 D</td>
<td>00/00/0000</td>
</tr>
<tr>
<td>GB</td>
<td>2273948 A</td>
<td>06/07/1994</td>
<td>AU</td>
<td>2552792 A</td>
<td>27/04/1993</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GB</td>
<td>9119563 D</td>
<td>00/00/0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GB</td>
<td>9403480 D</td>
<td>00/00/0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WO</td>
<td>9306335 A</td>
<td>01/04/1993</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GB</td>
<td>9201673 D</td>
<td>00/00/0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FR</td>
<td>2787827 A,B</td>
<td>30/06/2000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NO</td>
<td>20013227 A</td>
<td>27/08/2001</td>
</tr>
</tbody>
</table>