Title: RETRIEVING A SAMPLE OF FORMATION FLUID IN A CASED HOLE

Abstract: Retrieving a sample of formation fluid from a formation layer traversed by a cased borehole comprising making a plurality of perforation sets through the casing wall into the formation layer, wherein the orientation of the perforation sets is so selected that the angle between adjacent perforation sets equals 360° divided by the number of perforation sets; lowering a sampling tool into the borehole to the first perforation set; taking a sample from the formation and storing the sample in the first fluid sample container; positioning the sampling tool near the next perforation set, taking a sample from the formation and storing the sample in the next fluid sample container; and repeating the latter step until samples from all perforation sets have been taken, and retrieving the sampling tool.
RETRIEVING A SAMPLE OF FORMATION FLUID IN A CASED HOLE

The present invention relates to retrieving a sample of formation fluid from a formation layer traversed by a cased borehole. The formation layer is a hydrocarbon-bearing formation layer or a formation layer that is expected to contain hydrocarbons.

A cased borehole is a borehole lined with a casing that has been cemented in the borehole so that the annulus between the outer surface of the casing and the inner surface of the borehole is filled with set cement. The casing is filled with liquid used to displace the cement out of the casing and into the annulus, before the cement sets. The liquid in the casing is so dense that fluids are prevented from entering into the casing.

In order to obtain a sample of the formation fluid from the formation layer, the casing wall is perforated in a predetermined interval within that formation layer. The tool used to create the perforations, is a perforating gun. This is an elongated body provided with a plurality of outwardly directed charges. The charges are arranged at different locations along the body oriented in different directions, and they can be activated electrically or mechanically. The charges are so designed that each charge on activation produces a perforation including a perforation tunnel that extends through the wall of the casing into the formation surrounding the borehole. The perforating gun can be lowered into the cased borehole by means of for example a wireline.

In order to obtain a fluid sample, the perforating gun is lowered to the predetermined depth and the charges are activated to create a plurality of perforations. The
liquid present in the casing prevents formation fluid from entering into the casing.

Then a sampling tool is lowered into the cased borehole by means of for example a wireline. The sampling tool comprises a central conduit having an inlet and a discharge, a fluid sample container opening into the central conduit, and a system for discharging fluids from the central conduit and for moving fluids into the fluid sample container. The sampling tool is further provided with an upper and a lower packer arranged at either side of the inlet of the central conduit, wherein the discharge opens below the lower packer. The distance between the upper and the lower packer is greater than the height of the perforations.

The sampling tool is so positioned that the upper packer is located above the perforations and the lower packer below the perforations. Then the packers are set to seal off a sampling space between the packers into which all the perforations open.

The system for discharging fluids from the central conduit and for moving fluids into the fluid sample container includes a pump. The pump is activated to remove the liquid from the sampling space. The time required to remove the liquid from the sampling space is substantially equal to the volume of the sampling space divided by the pump rate.

The pump is further activated and the fluid that enters into the central conduit is now moved into the sample container. Once the sample container is filled, it is sealed off and the sampling tool is retrieved from the borehole.

At surface the sample container is brought to a laboratory for further analysis. This analysis is important because it can give an answer to the question
whether or not the formation fluid is a valuable hydrocarbon.

Unfortunately, the sampled fluid need not always represent the formation fluid. For example when the cement in the annulus does not completely fill the annulus, there is a channel with a low resistance to fluid flow. Thus fluids from the channel will preferentially be drawn into the sampling space.

It is an object of the present invention to overcome this drawback and to provide a method to obtain a fluid sample correctly representing the formation fluid.

To this end the method of retrieving a sample of formation fluid from a formation layer traversed by a cased borehole according to the present invention comprises the steps of:

a) making a plurality of perforation sets through the casing wall into the formation layer, wherein the orientation of the perforation sets is so selected that the angle between adjacent perforation sets equals 360° divided by the number of perforation sets;

b) lowering a sampling tool into the borehole to the first perforation set, which sampling tool comprises a central conduit having an inlet and a discharge, several fluid sample containers opening into the central conduit, and a system for discharging fluids from the central conduit and for moving fluids into the fluid sample containers, which sampling tool is provided with an upper and a lower packer arranged at either side of the inlet of the central conduit, wherein the discharge opens above the upper packer or below the lower packer, wherein the distance between the upper and the lower packer is larger than the height of a perforation set, wherein the length of the longest packer is smaller than the spacing between adjacent perforation sets;
c) setting the packers so that the perforation set is straddled between the packers, taking a sample from the formation, storing the sample in the first fluid sample container and shutting off the first fluid sample container;

5 d) positioning the sampling tool near the next perforation set, setting the packers so that the perforation set is straddled between the packers, taking a sample from the formation, storing the sample in the next fluid sample container and shutting off the next fluid sample container; and

e) repeating step d) until samples from at most all perforation sets have been taken, and retrieving the sampling tool.

15 In the specification and the claims the expression a perforation set refers to at least one perforation, wherein, when the set contains two or more perforations, these perforations have the same orientation.

The method of retrieving a sample of formation fluid from a formation layer traversed by a cased borehole according to the invention will now be described in more detail.

In order to obtain samples from the formation fluid, first the casing is perforated. According to the present invention, perforating the casing involves making a plurality of perforation sets through the casing wall into the formation layer. The height of each perforation set is less than the distance between the upper and the lower packer of the sampling tool and the spacing between adjacent perforation sets is at least equal to the length of the longest packer of the sampling tool. This ensures that, with the sampling tool in place a sampling volume between the packers can cover one and only one perforation set. Moreover, the orientation of the perforation sets is so selected that the angle between
adjacent perforation sets equals 360° divided by the number of perforation sets. In this way it is obtained that samples are along the circumference of the casing, but a single sample can be taken from a particular direction and at a different level. Thus the likelihood that all samples are contaminated is negligible. This would for example occur if there is no cement behind the casing.

Then a sampling tool is lowered into the cased borehole to the first, lowermost, perforation set. The sampling tool comprises a central conduit having an inlet and a discharge, several fluid sample containers opening into the central conduit, and a system for discharging fluids from the central conduit and for moving fluids into the fluid sample containers. Furthermore the sampling tool is provided with an upper and a lower packer arranged at either side of the inlet of the central conduit. The discharge of the central conduit opens above the upper packer or below the lower packer. The location of the discharge depends on the design of the tool, but it should be located outside the sampling space between the packers.

The sampling tool can be for example by lowered by means of for example a wireline.

The packers are set so that the perforation set is straddled between the upper and lower packer. In this way the sampling space between the packers is isolated from the remainder of the casing. Fluids are sucked into the central conduit and discharged until the volume of the sampling space had been displaced. Then a sample is taken from the formation and it is stored in the first fluid sample container. When the sample is stored, the first fluid sample container is shut off. Taking a sample can be preceded by discharging the contents of the sampling space to the space below the lower packer.
When the first sample is taken, the sampling tool is positioned near the next higher perforation set. The packers are set so that the perforation set is straddled between the packers. A sample is taken from the formation and it is stored in the next fluid sample container, which next fluid sample container is thereafter shut-off. The latter step is repeated until samples have been taken from at most all perforation sets. The sampling tool is retrieved from the cased borehole.

At surface the fluid sample containers are removed from the sampling tool and their contents are analysed in a laboratory to obtain the relevant information.

Suitably, the step of taking a sample from a next perforation set is repeated until samples from all perforation sets have been taken.

In an alternative embodiment of the invention, the sampling tool further comprises a fluid analyser. Then the step of taking a sample from a next perforation set is repeated until formation fluid is detected.

For example, samples are to be taken from a sand layer having a thickness of 40 m through a cased borehole traversing the sand layer. The height of the perforation set is 0.5 m and the spacing between adjacent perforation sets is 1.5 m. Therefore the number of perforation sets is 20 (=40/(0.5+1.5)) and the angle between two adjacent perforation sets is 18° (=360°/20). The length of the packer on the sampling tool is about 0.5 m, which is smaller than the spacing of 1.5 m, and the distance between the nearest ends of the packers is 1.5 m. The sampling tool in this case must have at most 20 fluid sample containers.

Suitably, the lowermost perforation is marked, and the sampling tool comprises a device for detecting the marker. The marker is suitably a radioactive tracer, and the sampling tool suitably comprises a nuclear tool for
detecting the radioactive tracer. The nuclear tool is suitably a gamma ray detector.

The invention provides a simple way to ensure that at least one of the samples taken correctly represents the formation fluid.
1. A method of retrieving a sample of formation fluid from a formation layer traversed by a cased borehole comprising the steps of:
   a) making a plurality of perforation sets through the casing wall into the formation layer, wherein the orientation of the perforation sets is so selected that the angle between adjacent perforation sets equals 360° divided by the number of perforation sets;
   b) lowering a sampling tool into the borehole to the first perforation set, which sampling tool comprises a central conduit having an inlet and a discharge, several fluid sample containers opening into the central conduit, and a system for discharging fluids from the central conduit and for moving fluids into the fluid sample containers, which sampling tool is provided with an upper and a lower packer arranged at either side of the inlet of the central conduit, wherein the discharge opens above the upper packer or below the lower packer, wherein the distance between the upper and the lower packer is larger than the height of a perforation set, wherein the length of the longest packer is smaller than the spacing between adjacent perforation sets;
   c) setting the packers so that the perforation set is straddled between the packers, taking a sample from the formation, storing the sample in the first fluid sample container and shutting off the first fluid sample container;
   d) positioning the sampling tool near the next perforation set, setting the packers so that the perforation set is straddled between the packers, taking a sample from the formation, storing the sample in the
next fluid sample container and shutting off the next fluid sample container; and

e) repeating step d) until samples from at most all perforation sets have been taken, and retrieving the sampling tool.

2. The method according to claim 1, wherein step d) is repeated until samples from all perforation sets have been taken.

3. The method according to claim 1, wherein the sampling tool further comprises a fluid analyser, and wherein step d) is repeated until formation fluid is detected.

4. The method according to any one of the claims 1-3, wherein the lowermost perforation is marked, and the sampling tool comprises a device for detecting the marker.

5. The method according to claim 4, wherein the marker is a radioactive tracer, and wherein the sampling tool comprises a nuclear tool for detecting the radioactive tracer.

6. The method according to claim 5, wherein the nuclear tool is a gamma ray detector.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B49/08

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

B. FIELDS SEARCHED

Minimal 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

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