Title: SEALING OF A WELLBORE DEVICE IN A TUBULAR ELEMENT

Abstract: A method of operating a wellbore formed in an earth formation is disclosed. The wellbore is provided with a tubular element in which a wellbore device is to be arranged such that the wellbore device is sealed to the inner surface of the tubular element, and whereby an elongate member is to be extended through the tubular element for carrying out a wellbore operation. The method comprises extending the elongate member through the tubular element so as to carry out said wellbore operation, removing the elongate member from the tubular element, providing the wellbore device at the outer surface thereof with a swellable seal susceptible of swelling upon contact with a selected fluid, and installing the wellbore device in the tubular element, and inducing the swellable seal to swell by virtue of contact of the swellable seal with the selected fluid.
DOWNHOLE SWELLABLE SEAL

The present invention relates to a method of operating a wellbore formed in an earth formation, the wellbore being provided with a tubular element in which a wellbore device is to be arranged such that the wellbore device is sealed to the inner surface of the tubular element, and whereby an elongate member is to be extended through the tubular element for carrying out a wellbore operation.

In the production of hydrocarbon fluid from a wellbore it is common practice that the produced hydrocarbon fluid flows from the producing zone in a lower part of the well via a conduit, referred to as the production tubing, to surface. The production tubing can be provided with one or more devices, such as surface-controlled subsurface safety valves, tubing hangers, landing nipples, packers and sliding side-doors. Some of these devices are retrievable and are sealingly installed in the string. The production tubing string is assembled from a plurality of tubular sections, whereby one or more landing nipples are incorporated in the string at each location in the string where such retrievable device is to be installed. To ensure that each retrievable device is arranged at the desired depth in the tubing string, each landing nipple corresponds to the dimensions of a respective one of the retrievable devices. Sealing of the retrievable device to the inner surface of the landing nipple is achieved by suitable seal elements, such as chevron type seals. In order to achieve adequate sealing, the seal surface portions of the landing nipples are
often polished so as to provide a very smooth seal surface.

Another example of a wellbore device which is sealingly received in a tubular element, is a seal assembly of a production tubing. The seal assembly is formed by the lower end part of the production tubing and is received in a polished bore receptacle (PBR) of a production packer arranged near the producing zone of the wellbore. The seal assembly is axially movable relative to the PBR to allow for thermal expansion/contraction of the production tubing.

Tubular elements, like production tubings and PBR's, are also used to convey equipment for conducting downhole operations. For example in a wireline-conveyed operation the downhole equipment can be lowered on a wireline through the production tubing or through the PBR. Such operation involves movement of the wireline (which can be of several kilometres length) at high speed through the production tubing or PBR whereby the wireline scratches along the polished seal surfaces. As a result, the seal surfaces may become damaged so that adequate sealing of the device in the tubular element can no longer be guaranteed. In many instances such situation leads to serious limitations in operating the well, and may even compromise the safety of the well. In the special case of seal surfaces for a surface-controlled subsurface safety valve, damage to the seal surfaces can imply that the well needs to be shut-in. Such situation occurs frequently since the seal surfaces of the safety valve landing nipple are often unprotected during well entries when the safety valve is pulled to allow lowering of maximum-size tools into the well.
Thus, there is a need to provide an improved method of operating a wellbore which overcomes the afore-mentioned drawbacks.

In accordance with the invention there is provided a method of operating a wellbore formed in an earth formation, the wellbore being provided with a tubular element in which a wellbore device is to be arranged such that the wellbore device is sealed to the inner surface of the tubular element, and whereby an elongate member is to be extended through the tubular element for carrying out a wellbore operation, the method comprising:

- extending the elongate member through the tubular element so as to carry out said wellbore operation;
- removing the elongate member from the tubular element;
- providing the wellbore device at the outer surface thereof with a swellable seal susceptible of swelling upon contact with a selected fluid, and installing the wellbore device in the tubular element; and
- inducing the swellable seal to swell by virtue of contact of the swellable seal with the selected fluid.

It is thereby achieved that, by virtue of swelling of the swellable seal upon contact with the selected fluid, the seal expands into any irregularities in the seal surfaces of the tubular element which are attributable to damage caused by the wellbore operations carried out through the tubular element.

The invention also relates to a wellbore device for use in a wellbore formed in an earth formation whereby the wellbore is provided with a tubular element in which the wellbore device is to be arranged in a manner that the wellbore device is sealed to the inner surface of the tubular element, and whereby an elongate member is to be
extended through the tubular element for carrying out a wellbore operation, the wellbore device being provided at the outer surface thereof with a swelleable seal susceptible of swelling upon contact with a selected fluid.

In a preferred embodiment the tubular element is a production tubing for transporting hydrocarbon fluid produced from the earth formation to surface, or a part thereof such as a landing nipple for the wellbore device. In such application the wellbore device is, for example, a safety valve assembly for selectively controlling flow of hydrocarbon fluid through the production tubing.

Alternatively the tubular element is a polished bore receptacle (PBR), and the wellbore device is a seal assembly of a production tubing for transporting hydrocarbon fluid produced from the earth formation, to surface.

Preferably the swelleable seal swells upon contact with hydrocarbon fluid, and includes a material selected from natural rubber, nitrile rubber, hydrogenated nitrile rubber, acrylate butadiene rubber, poly acrylate rubber, butyl rubber, brominated butyl rubber, chlorinated butyl rubber, chlorinated polyethylene, neoprene rubber, styrene butadiene copolymer rubber, sulphonated polyethylene, ethylene acrylate rubber, epichlorohydrin ethylene oxide copolymer, ethylene-propylene-copolymer (peroxide crosslinked), ethylene-propylene-copolymer (sulphur crosslinked), ethylene-propylene-diene terpolymer rubber, ethylene vinyl acetate copolymer, fluoro rubbers, fluoro silicone rubber, and silicone rubbers.

Said material is suitably selected from EP(D)M rubber (ethylene-propylene-copolymer, either peroxide or sulphur
crosslinked), EPT rubber (ethylene-propylene-diene terpolymer rubber), butyl rubber, brominated butyl rubber, chlorinated butyl rubber, and chlorinated polyethylene.

Instead of, or in addition to, the swelleable seal swelling upon contact with hydrocarbon fluid, the swelleable seal suitably swells upon contact with water, and includes a material selected from NBR, HNBR, XNBR, FKM, FFKM, TFE/P or EPDM base rubber. In order to enhance the swelling capacity of the swelleable member, even for saline water conditions, said material suitably is a matrix material wherein a compound soluble in water is incorporated in the matrix material in a manner that the matrix material substantially prevents or restricts migration of the compound out of the swelleable seal and allows migration of water into the swelleable seal by osmosis so as to induce swelling of the swelleable seal upon migration of said water into the swelleable seal. Said compound suitably comprises a salt, for example at least 20 weight% salt based on the combined weight of the matrix material and the salt, preferably at least 35 weight% salt based on the combined weight of the matrix material and the salt. In order to prevent, or reduce, leaching of the compound out of the matrix material, it is preferred that the matrix material is substantially impermeable to said compound or to ions of said compound. The compound can be present in the matrix material, for example, in the form of a plurality of compound particles dispersed in the matrix material.

The invention will be described hereinafter in more detail and by way of example, with reference to the accompanying drawings in which:
Fig. 1 schematically shows an embodiment of the wellbore device according to the invention;

Fig. 2 schematically shows detail A of the wellbore device of Fig. 1;

Fig. 3 schematically shows a longitudinal section of a tubular element to be used in conjunction with the wellbore device of Fig. 1;

Fig. 4 schematically shows the wellbore device of Fig. 1 when arranged in the tubular element of Fig. 3.

In the Figures, like reference numerals relate to like components.

Referring to Fig. 1 there is shown a surface-controlled subsurface safety valve assembly 1 (hereinafter: safety valve assembly 1) for selectively controlling flow of fluid through a wellbore (not shown) for the production of hydrocarbon fluid. The safety valve assembly 1 includes a tubular conduit 2 having a passage 4 for produced hydrocarbon fluid, the passage 4 being provided with valve 6 for selectively closing the passage 4. The valve 6 is controlled by a hydraulic control system of which only hydraulic control lines 8, 9 and plunger system 10 are schematically shown. The hydraulic lines 8, 9 are in fluid communication with the exterior of the safety valve assembly 1 via a port 11 provided in the wall of the tubular conduit 2. A locking mandrel 12 is provided at an upper portion of the safety valve assembly 1 for supporting and locking the safety valve assembly 1 in a production tubing referred to hereinafter.

Referring further to Fig. 2, the safety valve assembly 1 is provided with two annular seals 14, 16 arranged at an axial distance from each other, whereby the port 11 is located between the annular seals 14, 16.
Each annular seal 14, 16 includes a plurality of chevron type seals 18 and a swelleable seal 20 made of EPDM rubber which is susceptible of swelling upon contact with hydraulic oil to be used in the hydraulic control system for controlling the valve 6.

Referring further to Fig. 3, there is shown a tubular element in the form of a landing nipple 22 incorporated in a production tubing (not shown) for transporting produced hydrocarbon fluid through the wellbore to surface. The inner diameter of the landing nipple 22 is slightly larger than the outer diameter of the safety valve assembly 1 so as to allow axial movement of the safety valve assembly 1 through the landing nipple 22. The landing nipple 22 is internally provided with a locking profile 24 which is complementary to, and cooperates with, the profile of the locking mandrel 12 so as to allow the safety valve assembly 1 to be supported and locked in the landing nipple 22. Furthermore, the inner surface of the landing nipple 22 is provided with two polished annular surface portions 26, 28 of slightly smaller diameter than the remainder of the inner surface of the landing nipple 22. The polished surface portions 26, 28 are arranged such that annular seal 14 is located opposite polished surface portion 26, and annular seal 16 is located opposite polished surface portion 28 when the safety valve assembly 1 is locked in the landing nipple 22 by the cooperating locking mandrel 12 and locking profile 24.

A port 30 is provided in the wall of the landing nipple 22 at a location between the polished surface portions 26, 28, the port 30 being in fluid communication with a hydraulic control unit (not shown) at surface via a hydraulic control line 32 extending along the outer
surface of the production tubing. It is to be understood that the hydraulic control unit at surface, the control line 32, the port 30, the port 11, the hydraulic control lines 8, 9, and the plunger system 10 are all part of the hydraulic control system for controlling the valve 6.

Referring further to Fig. 4, during normal use the safety valve assembly 1 is arranged in the landing nipple 22 of the production tubing. Hydrocarbon fluid is produced from the earth formation surrounding the wellbore and transported to surface via the production tubing. The produced hydrocarbon fluid thereby flows through the passage 4 of the safety valve assembly 1. If it is required to shut the well in, for example in case of an emergency situation, the valve 6 is induced to close under control of the hydraulic control system operated at surface. Leakage of hydrocarbon fluid along the outside of the safety valve assembly 1 is prevented by the annular seals 14, 16 which seal against the polished surface portions 26, 28 of the production tubing 22.

After some time of continued hydrocarbon fluid production from the wellbore it may be required to suspend the wellbore and to remove the safety valve assembly 1 from the production tubing in order to conduct a downhole workover operation using a wireline (not shown) extending from surface through the production tubing. During such workover operation, the wireline moves at high speed through the production tubing, and hence through the landing nipple 22. The wireline thereby scratches against the protruding polished surface portion 26, 28 of the landing nipple 22. As a result the polished surface portions 26, 28 can easily become damaged so that the chevron type seals 18 of the annular
seals 14, 16 no longer adequately seal against these surface portions after the safety valve assembly 1 has been reinstalled in the landing nipple 22. However, the sealing function of the annular seals 14, 16 is still guaranteed by the swelleable seals 20 which swell by virtue of contact with the hydraulic oil present in the annular chamber defined by the outer surface of the safety valve assembly 1, the inner surface of the landing nipple 22, and the annular seals 14, 16. Thus, the seals 20, after swelling, extend into the irregularities formed at the damaged surface portions 26, 28 and thereby adequately seal the safety valve assembly 1 against the landing nipple 22.

It is to be understood that the invention is not limited to applications whereby the tubular element is a production tubing or a portion thereof, such as a landing nipple. Other useful applications include, for example, tubing hangers, packers, polished bore receptacles and sliding side-doors.
1. A method of operating a wellbore formed in an earth formation, the wellbore being provided with a tubular element in which a wellbore device is to be arranged such that the wellbore device is sealed to the inner surface of the tubular element, and whereby an elongate member is to be extended through the tubular element for carrying out a wellbore operation, the method comprising:
   - extending the elongate member through the tubular element so as to carry out said wellbore operation;
   - removing the elongate member from the tubular element;
   - providing the wellbore device at the outer surface thereof with a swelleable seal susceptible of swelling upon contact with a selected fluid, and installing the wellbore device in the tubular element; and
   - inducing the swelleable seal to swell by virtue of contact of the swelleable seal with the selected fluid.
2. The method of claim 1, wherein the tubular element is a production tubing for transporting hydrocarbon fluid produced from the earth formation, to surface.
3. The method of claim 2, wherein the tubular element includes a landing nipple for receiving said wellbore device, and wherein the step of installing the wellbore device in the tubular element comprises installing the wellbore device in the landing nipple.
4. The method of claim 3, wherein the wellbore device is a safety valve assembly for selectively controlling flow of hydrocarbon fluid through the production tubing.
5. The method of claim 1, wherein the tubular element is a polished bore receptacle (PBR), and the wellbore device is a seal assembly of a production tubing for transporting hydrocarbon fluid produced from the earth formation, to surface.

6. The method of any one of claims 1-5, wherein the selected fluid is hydrocarbon fluid, and wherein the swelleable seal includes a material selected from natural rubber, nitrile rubber, hydrogenated nitrile rubber, acrylate butadiene rubber, poly acrylate rubber, butyl rubber, brominated butyl rubber, chlorinated butyl rubber, chlorinated polyethylene, neoprene rubber, styrene butadiene copolymer rubber, sulphonated polyethylene, ethylene acrylate rubber, epichlorohydrin ethylene oxide copolymer, ethylene-propylene-copolymer (peroxide crosslinked), ethylene-propylene-copolymer (sulphur crosslinked), ethylene-propylene-diene terpolymer rubber, ethylene vinyl acetate copolymer, fluoro rubbers, fluoro silicone rubber, and silicone rubbers.

7. The method of claim 6, wherein said material is selected from EP(D)M rubber (ethylene-propylene-copolymer, either peroxide or sulphur crosslinked), EPT rubber (ethylene-propylene-diene terpolymer rubber), butyl rubber, brominated butyl rubber, chlorinated butyl rubber, and chlorinated polyethylene.

8. The method of any one of claims 1-5, wherein the selected fluid is water, and wherein the swelleable seal includes a material selected from NBR, HNBR, XNBR, FKM, FFKM, TFE/P or EPDM base rubber.

9. The method of claim 8, wherein said material is a matrix material, and wherein a compound soluble in water is incorporated in the matrix material in a manner that
the matrix material substantially prevents or restricts migration of the compound out of the swelleable seal and allows migration of water into the swelleable seal by osmosis so as to induce swelling of the swelleable seal upon migration of said water into the swelleable seal.

10. The method of claim 9, wherein said compound comprises a salt.

11. The method of claim 10, wherein the swelleable seal contains at least 20 weight% salt based on the combined weight of the matrix material and the salt, preferably at least 35 weight% salt based on the combined weight of the matrix material and the salt.

12. The method of any one of claims 9-11, wherein said matrix material is substantially impermeable to said compound or to ions of said compound.

13. The method of any one of claims 9-12, wherein the compound is present in the matrix material in the form of a plurality of compound particles dispersed in the matrix material.

14. The method of any one of claims 1-5, wherein the selected fluid is hydraulic fluid and the wellbore device is controllable by a hydraulic control system operated by a stream of said hydraulic fluid which is in contact with the swelleable seal, and wherein the step of inducing the swelleable seal to swell comprises supplying the stream of hydraulic fluid to the hydraulic control system.

15. A wellbore device for use in a wellbore formed in an earth formation whereby the wellbore is provided with a tubular element in which the wellbore device is to be arranged in a manner that the wellbore device is sealed to the inner surface of the tubular element, and whereby an elongate member is to be extended through the tubular element for carrying out a wellbore operation, the
wellbore device being provided at the outer surface thereof with a swelleable seal susceptible of swelling upon contact with a selected fluid.

16. The wellbore device of claim 15, wherein the wellbore device is arranged in the tubular element, the tubular element having an inner surface which is damaged due to carrying out a wellbore operation whereby an elongate member has been extended through the tubular element, and wherein the swelleable seal is swollen due to contact with the selected fluid so as to seal the wellbore device to the inner surface of the tubular element.

17. The method substantially as described hereinbefore with reference to the accompanying drawings.

18. The wellbore device substantially as described hereinbefore with reference to the accompanying drawings.