magnitude of the differential across the sealing assembly is decreased, and a negative differential of 500 psi would result across the lower sealing element.

The circuit described in patent applications WO2012127227 and WO2011128690 is now referred to as the Seal Integrity Circuit (SIC), and the inventive system and method introduces further aspects of such a system which may enhance the efficiency and safety of its operation.

According to a first aspect of the invention we provide a method of operating a drilling system for drilling a subterranean bore hole, the drilling system including a drill string and a sealing device which is operable to provide a substantially fluid tight seal around the drill string whilst the drill string is rotating during drilling, wherein the method includes the steps of:

a) injecting fluid into the annular volume around the drill string directly above the sealing device, and

b) controlling the fluid pressure in the annular volume around the drill string above the sealing device so that this pressure is greater than the fluid pressure in the annular volume around the drill string directly below the lowermost sealing device.

In one embodiment, the drilling system includes two sealing devices which are operable to provide a substantially fluid tight seal around the drill string whilst the drill string is rotating during drilling, and the method includes the steps of:

a) injecting fluid into the annular volume around the drill string between the two sealing devices, and

b) controlling the fluid pressure in the annular volume around the drill string between the two sealing devices so that this pressure is greater than the fluid pressure in the annular volume around the drill string directly below the lowermost sealing device,

wherein the or each sealing device is configured such that the sealing pressure it exerts on the drill string when operated to seal against the drill string can be varied; and

wherein the method further includes the step of varying the sealing pressure exerted by the, one of the, or each sealing device on the drill string to establish leakage of injected fluid between the sealing device and the drill string at a desired rate.

In one embodiment, a return pressure sensor is provided to measure the fluid pressure in the return line. In this case, the return pressure sensor is preferably located upstream of the back pressure valve.

The pressure measured by a pressure sensor located in one or both of the injection line and/or return line may be used in controlling the fluid pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices.

According to the first aspect, the or each sealing device is configured such that the sealing pressure it exerts on the drill string when operated to seal against the drill string can be varied. In this case, the method further includes the step of varying the sealing pressure exerted by the or each sealing device on the drill string to establish leakage of injected fluid between the sealing device and the drill string at a desired rate. In this case, the method may further include the step of controlling the fluid pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices by controlling the sealing pressure of the or each sealing device.

A flow meter may be provided in the return line upstream of the back pressure valve, and a flow meter may be provided in the injection line. In this case, the method may further include monitoring the inflow rate of flow of fluid into the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices, and the outflow rate of flow of fluid out of the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices, comparing the inflow rate and outflow rate, and using this comparison to detect a loss of sealing integrity of

that the packer pushes the seal into engagement with a drill string extending along the main passage of the housing.

According to a second aspect of the invention we provide a tangible computer readable medium having installed thereon instructions which when executed by a processing device cause a drilling system including a drill string and a sealing device which is operable to provide a substantially fluid tight seal around the drill string whilst the drill string is rotating during drilling, to:

a) inject fluid into the annular volume around the drill string directly above the sealing device, and

b) control the fluid pressure in the annular volume around the drill string above the sealing device so that this pressure is greater than the fluid pressure in the annular volume around the drill string directly below the lowermost sealing device,

wherein the or each sealing device is configured such that the sealing pressure it exerts on the drill string when operated to seal against the drill string can be varied; and

wherein the method further includes the step of varying the sealing pressure exerted by the, one of the, or each sealing device on the drill string to establish leakage of injected fluid between the sealing device and the drill string at a desired rate.

An embodiment of the invention will now be described, by way of example only, with reference to the following figures of which,

FIGURE 1 shows a schematic illustration of a drilling system according to the first aspect of the invention,

FIGURE 2 shows a flow chart illustrating a method of using the drilling system shown in Figure 1, and according to the second aspect of the invention.

Referring now to Figure 1, there is shown a drilling system 10 including two sealing devices 12a, 12b, and a drill string 14, the sealing devices 12a, 12b being operable to seal around drill string 14 to contain fluid pressure in the annular space around the drill string 14, whilst allowing the drill string 14 to rotate about its longitudinal axis A.

In this example, the drilling system is an offshore system which includes an offshore marine riser 15, with a section of riser 15a above and a section of riser 15b below the sealing devices 12a, 12b. The drill string 14 extends from the surface, down the riser 15, through the sealing devices 12a, 12b, and into the wellbore below. The annular space around the drill string 14 below the lowest sealing device 12b contains the returned fluid stream from the wellbore being drilled at pressure P_{WB}, and may contain fluids, solids, and entrained gas. The annular space around the drill string 14 above the upper sealing device 12a contains a column of drilling fluid at atmospheric pressure with a hydrostatic pressure P_{HP} acting downwards on the sealing device 12a at the

CLAIMS

1. A method of operating a drilling system for drilling a subterranean bore hole, the drilling system including a drill string and a sealing device which is operable to provide a substantially fluid tight seal around the drill string whilst the drill string is rotating during drilling, wherein the method includes the steps of:

a) injecting fluid into the annular volume around the drill string directly above the sealing device, and

b) controlling the fluid pressure in the annular volume around the drill string above the sealing device so that this pressure is greater than the fluid pressure in the annular volume around the drill string directly below the lowermost sealing device,

wherein the or each sealing device is configured such that the sealing pressure it exerts on the drill string when operated to seal against the drill string can be varied; and

wherein the method further includes the step of varying the sealing pressure exerted by the, one of the, or each sealing device on the drill string to establish leakage of injected fluid between the sealing device and the drill string at a desired rate.

2. A method according to claim 1 wherein the drilling system includes two sealing devices which are operable to provide a substantially fluid tight seal around the drill string whilst the drill string is rotating during drilling, and step a of the method includes injecting fluid into the annular volume around the drill string between the two sealing devices, and step b of the method includes controlling the fluid pressure in the annular volume around the drill string between the two sealing devices so that this pressure is greater than the fluid

pressure in the annular volume around the drill string directly below the lowermost sealing device.

3. A method according to claim 2 wherein the fluid pressure in the annular volume around the drill string between the two sealing devices is also controlled so that this pressure is greater than the fluid pressure in the annular volume around the drill string directly above the uppermost sealing device.

4. A method according to any preceding claim wherein the drilling system is provided with an injection line which connects the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices, with an injection pump which is operable to pump fluid from a fluid reservoir into the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices.

5. A method according to any preceding claim wherein the drilling system is provided with a return line which connects the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices, with a fluid reservoir, there being a back pressure valve provided in the return line, the back pressure valve being adjustable to restrict the flow of fluid along the return line to a greater or lesser extent.

6. A method according to claim 5 wherein the method further includes the step of controlling the fluid pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices by controlling the back pressure valve to vary to the extent to which it restricts flow of fluid along the return line.

7. A method according to claim 4 and 5 wherein the return line is connected to the same fluid reservoir as the injection pump.

8. A method according to claim 4 wherein an injection pressure sensor is provided to measure the fluid pressure in the injection line.

9. A method according to claim 5, 6 or 7 wherein a return pressure sensor is provided to measure the fluid pressure in the return line.

10. A method according to claim 9 wherein the return pressure sensor is located upstream of the back pressure valve.

11. A method according to claim 4 or 5 wherein the pressure measured by a pressure sensor located in one or both of the injection line and/or return line is used in controlling the fluid pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices.

12. A method according to any preceding claim wherein the method further includes the step of controlling the fluid pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices by controlling the sealing pressure of the or each sealing device.

13. A method according to claim 4 wherein a flow meter is provided in the return line upstream of the back pressure valve, and a flow meter is provided in the injection line.

14. A method according to claim 13 wherein the method further includes monitoring the inflow rate of flow of fluid into the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing

devices, and the outflow rate of flow of fluid out of the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices, comparing the inflow rate and outflow rate, and using this comparison to detect a loss of sealing integrity of the sealing device, or, where two sealing devices are provided, one or both of the sealing devices.

15. A method according to claims 8 and 9 wherein the injection flow meter and return flow meter are both mass flow meters, and the method further includes the step of comparing the inflow rate and outflow rate, and using this comparison to detect an influx of gas into the injected fluid.

16. A method according to claim 9 wherein the drilling system further includes a mud gas separator, and the method further includes directing fluid from the return line to the mud gas separator if gas is detected in the injected fluid, and returning degasified liquid from the mud gas separator to the fluid reservoir.

17. A method according to claim 16 wherein the return line includes a main returns flow line which extends directly to the fluid reservoir and an emergency returns flow line which extends to the mud gas separator, and a valve assembly which is operable to control flow of fluid along the main returns flow line and emergency returns flow line.

18. A method according to claim 17 wherein the method includes the step of operating the valve assembly to close the main returns flow line and open the emergency returns flow line if gas is detected in the injected fluid.

19. A method according to any preceding claim wherein the drilling system further includes a pressure relief system which is operable to direct fluid from the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices, to the fluid reservoir if the pressure in

the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices exceeds a predetermined level.

20. A method according to claim 19 wherein the pressure relief system includes a pressure relief valve which is located in a pressure relief line between the return line and the fluid reservoir, and is configured to allow flow of fluid along the pressure relief line if the pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices exceeds a predetermined level.

21. A method according to claim 20 wherein the pressure relief line extends from the pressure relief valve to the fluid reservoir via the mud gas separator.

22. A method according to claim 4 wherein the drilling systems is configured to switch off the injection pump automatically if the pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices, exceeds a predetermined level.

23. A method according to any preceding claim wherein the method further includes adjusting the sealing pressure of the or each sealing device to reduce the pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing devices are provided, the annular volume around the drill string between the two sealing devices to below the predetermined level.

24. A method according to any preceding claim wherein the pressure relief system includes a pressure relief valve which is located in a pressure relief line between the injection line and the fluid reservoir, and is configured to allow flow of fluid along the pressure relief line if the pressure in the annular volume around the drill string directly above the sealing device, or, where two sealing

devices are provided, the annular volume around the drill string between the two sealing devices exceeds a predetermined level.

25. A method according to any preceding claim wherein the sealing device or one or both of the sealing devices preferably includes a tubular seal which is mounted around the drill string.

26. A method according to claim 25 wherein the sealing device or one or both of the sealing devices may further include housing with a main passage, and an actuator which is operable to urge the seal into sealing engagement with the drill string.

27. A method according to claim 26 wherein the actuator comprises a piston which is movable generally parallel to the longitudinal axis of the main passage in the housing.

28. A method according to claim 26 wherein the sealing device or one or both of the sealing devices, may further include an annular packer which has a central aperture in which the seal is mounted, the actuator being operable to act on the packer so that the packer pushes the seal into engagement with a drill string extending along the main passage of the housing.

29. A method according to any preceding claim wherein the sealing device is mounted in a riser which extends around the drill string to enclose an annular space around the drill string.

30. A method according to any of the claims 1 to 28 wherein the sealing device is installed on top of a land-based blowout preventer.

31. A tangible computer readable medium having installed thereon instructions which when executed by a processing device cause a drilling system including a drill string and a sealing device which is operable to provide a substantially fluid tight seal around the drill string whilst the drill string is rotating during drilling, to:

a) inject fluid into the annular volume around the drill string directly above the sealing device, and

b) control the fluid pressure in the annular volume around the drill string above the sealing device so that this pressure is greater than the fluid pressure in the annular volume around the drill string directly below the lowermost sealing device,

wherein the or each sealing device is configured such that the sealing pressure it exerts on the drill string when operated to seal against the drill string can be varied; and

wherein the method further includes the step of varying the sealing pressure exerted by the, one of the, or each sealing device on the drill string to establish leakage of injected fluid between the sealing device and the drill string at a desired rate.