present. The fluid is returned through a return line opposite the injection line, equipped with a choke such that pressure between the sleeves can be controlled. Maintaining this pressure within the cavity decreases the pressure drop across the lower sleeve and enhances the sleeve's longevity as a result. Furthermore, the opposing fluid rates from the return and injection lines can be compared to determine the integrity of the sleeves – i.e. if fluid is either passing through the upper or lower sleeve or if wellbore fluid is entering passing through the lower sleeve. Supplying a lubricating fluid to this cavity may assist in lubricating the drill string as it enters this region and thus ultimately reducing the frictional forces between the sealing faces of the sleeve and the drill pipe. The lubrication fluid does not have to be a special lubricant or oil as for the bearing type systems mentioned earlier. It is sufficient for this to consist of 'clean' drilling fluid i.e. drilling fluid which has had the cuttings removed. Such fluid is in ample supply from the active drilling tank which is the same supply as is pumped down the drill pipe.

This design may also provide a floating fluid seal or hydrodynamic film between the seal sleeve and the drill string that will assist in actively sealing around the tubular, using lubricants such as drilling fluid or hydraulic oil. This may assist in decreasing friction and associated wear rates as the drill pipe is rotated and reciprocated through the energized sleeve.

According to a first aspect of the invention we provide a pressure containment device for containing pressure in an annulus around a tubular body such as a drill string, the device comprising a housing having an axis and a passage extending generally parallel to the housing axis, and a seal assembly comprising a seal located in the housing to surround and enter into sealing engagement with a tubular body extending along the passage, the passage comprising: an upper end for connection to a bell nipple or to a section of a riser pipe, and a lower end for connection to a riser annulus, wherein the housing is provided with a returns outlet port, an injection port, and an overflow outlet port, all of which extend through the housing from the exterior of the

housing into the passage, the injection port being located between the returns outlet port and a first end of the seal, the overflow outlet port being located adjacent a second, opposite end of the seal, and thus being separated from any injection port by the seal and the overflow port outlet is in fluid communication with the upper end of the passage.

The seal may be a generally tubular sleeve.

The seal is preferably adapted to remain substantially stationary in the housing when in sealing engagement with a tubular body which is moving in the housing (for example when the tubular body rotates about its longitudinal axis).

The seal assembly may further comprise an actuator which is operable to urge the seal into sealing engagement with a tubular body extending along the passage in the housing.

The actuator may comprise a piston which is movable generally parallel to the housing axis. In this case, the seal assembly may further comprise an annular packer which is located between the piston and the seal so that the piston is movable against the packer to force the packer to act on the seal, to urge the seal into seal engagement with a tubular body extending along the passage in the housing. The seal may be located in the circular space enclosed by the annular packer.

The seal assembly may comprise a plurality of seals which are spaced along the housing axis.

The seal may be provided in a first housing part.

The returns outlet port may be provided in a second housing part.

The injection port may be provided in a third housing part.

The overflow port may be provided in a fourth housing part.

All these housing parts may be integral so that the housing comprises a single housing unit. Alternatively, one or more of these housing parts may be separate but secured relative to the adjacent housing part or parts. For

The drilling system may be further provided with a returns flow line extending from the returns outlet port.

The returns flow line may be provided which a flow meter which is operable to measure the rate of flow of fluid along the returns flow line.

The return line may be provided with a pressure control valve which is operable to restrict flow of fluid along the returns flow line to a variable degree.

The returns flow line may extend from the returns outlet port to a drilling fluid treatment system.

The drilling system may further include an overflow line which extends from the overflow outlet port.

The overflow line may be provided with a flow meter which is operable to measure the rate of flow of fluid along the overflow line.

According to a third aspect of the invention we provide a method of operating a drilling system, the drilling system including a drill string, a pressure containment device for containing pressure in an annulus around the drill string, the pressure containment device comprising a housing having an axis, a passage extending generally parallel to the housing axis, and a seal assembly comprising a seal located in the housing, the drill string passing through the housing in such way that a portion of the drill string extends along the passage in the housing, wherein the method comprises the steps of pumping drilling fluid into the drill string, allowing the drilling fluid from the drill string to exit the annular space around the drill string via a returns outlet port provided in the housing below the lowermost end of the seal, injecting a further fluid into the passage of the housing via an injection port provided in the housing between the returns outlet port and the lowermost end of the seal, and setting the seal into sealing engagement with a portion of the drill string extending along the passage in the housing such that a proportion of the fluid

injected into the passage via the injection port is intentionally leaked up the passage between the drill string and the seal.

The method may further include the step of removing the fluid that has leaked up between the drill string and the seal via an overflow outlet port provided in the housing adjacent the uppermost end of the seal.

The fluid injected into the housing via the injection port may be clean drilling fluid.

The seal assembly may further include an actuator which is operable to urge the seal into engagement with the drill string. In this case, the method may include the steps of operating the actuator to vary the force with which the seal is urged into engagement with the drill string (hereinafter referred to as the sealing force) until a desired rate of leakage of injected fluid between the seal and the drill string is achieved. The method may include the steps of operating the actuator to urge the seal into engagement with the drill string with a relatively high sealing force before commencing injection of fluid into the injection port, and then, after commencing injection of fluid into the injection port, operating the actuator to decrease the sealing force until the desired rate of leakage of injected fluid between the drill string and the seal is achieved.

The method may further comprise the step of monitoring the rate of flow of fluid out of the housing via the returns outlet port (Q3).

The method may further comprise the step of monitoring the rate of flow of fluid out of the housing via the overflow outlet port (Q4). In this case, the measured rate of flow of fluid out of the housing via the overflow outlet may be used to determine if the desired rate of the desired rate of leakage of injected fluid between the drill string and the seal has been achieved.

Claims

1. A pressure containment device for containing pressure in an annulus around a tubular body, the device comprising:

a housing having an axis and a passage extending generally parallel to the housing axis, and

a seal assembly comprising a seal located in the housing to surround and enter into sealing engagement with a tubular body extending along the passage, the passage comprising:

an upper end for connection to a bell nipple or to a section of a riser pipe, and

a lower end for connection to a riser annulus,

wherein the housing is provided with a returns outlet port, an injection port, and an overflow outlet port, all of which extend through the housing from the exterior of the housing into the passage,

the injection port being located between the returns outlet port and a first end of the seal,

the overflow outlet port being located adjacent a second, opposite end of the seal, and thus being separated from the injection port by the seal, and

the overflow port outlet is in fluid communication with the upper end of the passage.

2. A pressure containment device according to claim 1 wherein the seal is a generally tubular sleeve.

3. A pressure containment device according to claim 1 or 2 wherein the seal is adapted to remain substantially stationary in the housing when in sealing engagement with a tubular body which is moving in the housing.

4. A pressure containment device according to any preceding claim wherein the seal assembly further comprises an actuator which is operable to urge the seal into sealing engagement with a tubular body extending along the passage in the housing.

5. A pressure containment device according to claim 4 wherein the actuator comprises a piston which is movable generally parallel to the housing axis.

6. A pressure containment device according to claim 5 wherein the seal assembly further comprises an annular packer which is located between the piston and the seal so that the piston is movable against the packer to force the packer to act on the seal, to urge the seal into seal engagement with a tubular body extending along the passage in the housing.

7. A pressure containment device according to claim 6 wherein the seal is located in the circular space enclosed by the annular packer.

8. A pressure containment device according to any preceding claim wherein the seal assembly comprises a plurality of seals which are spaced along the housing axis.

9. A pressure containment device according to any preceding claim wherein the seal is provided in a first housing part, the returns outlet port is provided in a second housing part, the injection port is provided in a third housing part, and the overflow port is provided in a fourth housing part.

10. A pressure containment device according to claim 9 wherein the first, second, third and fourth housing parts are integral so that the housing comprises a single housing unit.

11. A pressure containment device according to claim 9 wherein one or more of these housing parts is separate but secured relative to the adjacent housing part or parts.

12. A pressure containment device according to claim 9 wherein the first housing part is integral with the fourth housing part, and the second housing part is integral with the third housing part.

13. A pressure containment device according to any preceding claim wherein the pressure containment device further includes at least one locking element which may be used to retain the seal in the housing, but which is operable to release the seal so that the seal can be removed from the housing.

14. A pressure containment device according to claim 13 wherein the locking element comprises a locking dog which is a generally cylindrical element mounted in an aperture in the housing, and which is movable between an extended position in which it extends from the housing into the passage, and retracted position in which it does not extend into the passage at all or to such an extent.

15. A pressure containment device according to claim 13 or 14 wherein the device includes a further locking element, or two sets of the locking elements, which are spaced along the housing axis so that the seal is, in use, retained between the two locking elements or sets of locking elements.

16. A pressure containment device according to any one of claims 13, 14 or 15 wherein at least one locking element is located between the injection port and the seal.

17. A pressure containment device according to any one of claims 13-16 wherein at least one locking element is located between the overflow port and the seal.

18. A pressure containment device according to any preceding claim wherein the injection port comprises a plurality of injection ports which are spaced around the housing between the returns outlet port and the seal.

19. A drilling system including a pressure containment device according to any preceding claim, and a pump which is connected to the injection port via an injection flow line.

20. A drilling system according to claim 19 wherein the injection flow line is provided with a flow meter is operable to measure the rate of flow of fluid along the injection flow line.

21. A drilling system according to claim 19 or 20 wherein the drilling system is further provided with a returns flow line extending from the returns outlet port.

22. A drilling system according to claim 21 wherein the returns flow line is provided with a flow meter which is operable to measure the rate of flow of fluid along the returns flow line.

23. A drilling system according to claim 21 or 22 wherein the return line is provided with a pressure control valve which is operable to restrict flow of fluid along the returns flow line to a variable degree.

24. A drilling system according to any one of claims 21, 22, or 23 wherein the returns flow line extends from the returns outlet port to a drilling fluid treatment system.

25. A drilling system according to any one of claims 19 to 24 wherein the drilling system further includes an overflow line which extends from the overflow outlet port.

26. A drilling system according to claim 25 wherein the overflow line is provided with a flow meter which is operable to measure the rate of flow of fluid along the overflow line.

27. A method of operating a drilling system, the drilling system including:

a drill string,

a pressure containment device for containing pressure in an annulus around the drill string, the pressure containment device comprising a housing having an axis, a passage extending generally parallel to the housing axis, and a seal assembly comprising a seal located in the housing, the drill string

passing through the housing in such way that a portion of the drill string extends along the passage in the housing,

wherein the method comprises the steps of:

pumping drilling fluid into the drill string,

allowing the drilling fluid from the drill string to exit the annular space around the drill string via a returns outlet port provided in the housing below the lowermost end of the seal,

injecting a further fluid into the passage of the housing via an injection port provided in the housing between the returns outlet port and the lowermost end of the seal, and

setting the seal into sealing engagement with a portion of the drill string extending along the passage in the housing such that a proportion of the fluid injected into the passage via the injection port is intentionally leaked up the passage between the drill string and the seal.

28. The method of operating a drilling system according to claim 27 wherein the method further includes the step of removing the fluid that has leaked up between the drill string and the seal via an overflow outlet port provided in the housing adjacent the uppermost end of the seal.

29. The method of operating a drilling system according to claim 27 or 28 wherein the fluid injected into the housing via the injection port is clean drilling fluid.

30. The method of operating a drilling system according to any one of claims 27, 28 or 29 wherein the seal assembly further includes an actuator which is operable to urge the seal into engagement with the drill string.

31. The method of operating a drilling system according to claim 30 wherein the method includes the step of operating the actuator to vary the force with which the seal is urged into engagement with the drill string (hereinafter

referred to as the sealing force) until a desired rate of leakage of injected fluid between the seal and the drill string is achieved.

32. The method of operating a drilling system according to claim 31 wherein the method includes the steps of operating the actuator to urge the seal into engagement with the drill string with a relatively high sealing force before commencing injection of fluid into the injection port, and then, after commencing injection of fluid into the injection port, operating the actuator to decrease the sealing force until the desired rate of leakage of injected fluid between the drill string and the seal is achieved.

33. The method of operating a drilling system according to any one of claims 27 to 32 wherein the method further comprises the step of monitoring the rate of flow of fluid out of the housing via the returns outlet port (Q3).

34. The method of operating a drilling system according to any one of claims 27 to 33 wherein the method further comprises the step of monitoring the rate of flow of fluid out of the housing via the overflow outlet port (Q4).

35. The method of operating a drilling system according to claim 34 wherein the measured rate of flow of fluid out of the housing via the overflow outlet is used to determine if the desired rate of the desired rate of leakage of injected fluid between the drill string and the seal has been achieved.

36. The method of operating a drilling system according to claims 33 and 34 wherein the method further includes the step of commencing drilling once the rate of flow of fluid through the returns outlet port and the rate of flow of fluid thought the overflow outlet port are substantially constant.

37. The method of operating a drilling system according to any one of claims 27 to 26 wherein the method may further include monitoring the rate of flow of fluid into the housing via the injection port (Q1).

38. The method of operating a drilling system according to any one of claims 27 – 37 wherein the method further includes monitoring the rate of flow of drilling fluid into the drill string (Q5) and / or the rate of return of drilling fluid into the passage of the housing around the drill string (Q2).

39. The method of operating a drilling system according to claims 33, 34, 37 and 38 wherein the method includes commencing a well control procedure if $Q3 \neq Q5 + (Q1-Q4)$ whilst Q1 and Q4 are substantially constant.

40. The method of operating a drilling system according to claims 33, 34, 37 and 38 wherein the method includes using the measure values of Q1, Q3, Q4 and Q5 to determine if the seal has worn and might need replacing.

41. The method of operating a drilling system according to claim 40 wherein the method includes commencing a procedure to replace the seal if Q4 increases and Q3 decreases in direct proportion whilst Q1 and Q5 are substantially constant.

42. The method of operating a drilling system according to any one of claims 27 to 41 wherein the method further includes the step of increasing the rate of injection of fluid into the housing via the injection port in the event of an influx of gas into the drilling fluid from a formation into which the drill string is drilling.