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(54) Title: DUAL DENSITY MUD RETURN SYSTEM

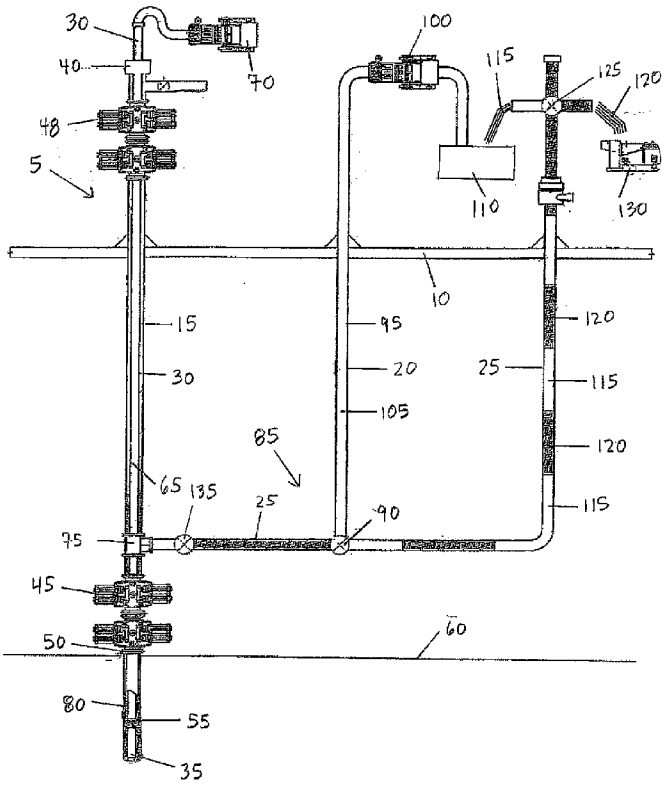

FIG. 1

(57) Abstract: Systems and methods for lifting drilling fluid from a well bore in a subsea formation are disclosed. Some system embodiments include a drill string suspended within a drilling riser to form the well bore, and a drilling fluid source for supplying drilling fluid through the drill string during drilling. A diverter is coupled between the drilling riser and a return line, while a power riser coupled to the return line at an interface. A lift fluid source supplies lift fluid through the power riser into the return line. The lift fluid is intermittently injected from the power riser through the interface into the return line to form one or more slugs of lift fluid positioned between slugs of drilling fluid, such that the combined density of lift fluid and drilling fluid in the return line is less than the density of the drilling fluid alone.

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AMENDED CLAIMS
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What is claimed is:

1. A system for lifting drilling fluid from a well bore in a formation, comprising:

a drilling riser;

a drill string suspended within the drilling riser and adapted to form at least a portion of the well bore;

a drilling fluid source for supplying drilling fluid through the drill string, the drilling fluid exiting from the drill string during drilling and returning up an annulus between the drilling riser and the drill string;

a return line having a first end;

a diverter coupled between the drilling riser and the first end of the return line, the diverter configured to selectably divert drilling fluid from the annulus into the return line;

a power riser coupled to the return line at an interface positioned along the return line, wherein the interface is configured to prevent the drilling fluid from flowing into the power riser from the return line; and

a lift fluid source for supplying lift fluid through the power riser into the return line, wherein the lift fluid is intermittently injected from the power riser through the interface into the return line to form one or more slugs of lift fluid positioned between slugs of drilling fluid;

wherein a combined density of lift fluid and drilling fluid in the return line is less than the density of the drilling fluid alone.

2. The system of claim 1, wherein the interface is one of a group consisting of a check valve, an intermittent diverter, and diverter shuttle valve.

3. The system of claim 1, wherein the drill string is suspended from one of a group consisting of a floating vessel, a floating structure, and a fixed structure.

4. The system of claim 1, further comprising a drilling fluid pump for conveying the drilling fluid from the drilling fluid source down the drill string.

5. The system of claim 4, wherein the drilling fluid pump is operable to maintain a hydrostatic pressure of the drilling fluid in the well bore exceeding a formation pressure.

6. The system of claim 1, further comprising a shut-off valve positioned along the return line between the diverter spool and the interface and actuatable between an open position and a closed position, wherein the open position is configured to permit the drilling fluid to flow through the shut-off valve and wherein the closed position is configured to prevent the drilling fluid from flowing through the shut-off valve.

7. The system of claim 1, wherein the drilling fluid is mud.

8. The system of claim 1, wherein the lift fluid is one of a group consisting of fresh water and sea water.

9. The system of claim 1, further comprising a packer and pressure control means operable to control pressure in the drill string.

10. The system of claim 9, wherein the pressure control means is one of a group consisting of an accumulator and a valve.

11. The system of claim 9, wherein the packer is a rotating packer.

12. The system of claim 1, further comprising a blowout preventer.

13. The system of claim 12, wherein the blowout preventer is positioned on the structure.

14. A method for lifting drilling fluid from a well bore in a formation, comprising:
injecting a drilling fluid through a drill string;
diverting the drilling fluid from the well bore into a return line; and
injecting a lift fluid through a conduit and into the return line;
wherein a combined density of the lift fluid and the drilling fluid in the return line is less than the density of the drilling fluid alone.

15. The method of claim 14, further comprising creating in the return line one or more slugs of lift fluid between slugs of drilling fluid.

16. The method of claim 15, further comprising diverting the one or more slugs of lift fluid into a lift fluid pit after exiting the return line and re-injecting the lift fluid diverted to the lift fluid pit into the conduit.

17. The method of claim 15, further comprising diverting the slugs of drilling fluid into a return shaker.

18. The method of claim 17, further comprising re-injecting the drilling fluid diverted to the return shaker into the drill string.

19. A return system for lifting fluid from a well bore in a formation, comprising:

a return line having a first end;

a diverter spool positioned at the first end of the return line, the diverter spool configured to selectably divert well bore fluid from the well bore into the return line;

a power riser coupled to the return line at an interface positioned along the return line, wherein the interface is configured to prevent the well bore fluid inside the return line from flowing into the power riser; and

a lift fluid source for supplying lift fluid through the power riser into the return line, wherein the lift fluid is injected from the power riser through the interface into the return line;

wherein a combined density of lift fluid and well bore fluid in the return line is less than the density of the well bore fluid alone.

20. The return system of claim 19, wherein the return line has a second end, and further comprising a return shaker configured to receive the well bore fluid emerging from the second end of the return line.

21. The return system of claim 19, wherein the return line has a second end, and further comprising a lift fluid pit configured to receive the lift fluid emerging from the second end of the return line.

22. The return system of claim 21, wherein the lift fluid source is the lift fluid pit.

23. The return system of claim 19, wherein the interface is one of a group consisting of a check valve, an intermittent diverter, and diverter shuttle valve.

24. The return system of claim 19, further comprising a lift fluid pump for injecting the lift fluid from the lift fluid source into the power riser.

25. The return system of claim 19, further comprising a shut-off valve positioned along the return line between the diverter spool and the interface and actuatable between an open position and a closed position, wherein the open position is configured to permit the well bore fluid to flow through the shut-off valve and wherein the closed position is configured to prevent the well bore fluid from flowing through the shut-off valve.

26. The return system of claim 19, wherein the well bore fluid is drilling mud.

27. The return system of claim 19, wherein the lift fluid is one of a group consisting of fresh water and sea water.

28. The return system of claim 19, wherein the power riser is positioned concentrically within the return line.

29. The return system of claim 19, wherein the return line is positioned concentrically within the power riser.

30. A method of killing a well bore in a formation, comprising:
suspending a drill string into the well bore;
coupling a return line to the drill string using a diverter spool configured to divert fluid from the return line into the well bore;
injecting a heavy fluid through the return line and the diverter spool into the well bore;
wherein the hydrostatic pressure of the heavy fluid injected into the well bore exceeds the pressure of fluid in the formation.

31. A system for lifting drilling fluid from a well bore in a formation, comprising:
a tubular member extending between a packer and the well bore;

a drill string suspended within the tubular member and adapted to form at least a portion of the well bore;

29 30 31 32

a drilling fluid source for supplying drilling fluid through the drill string, the drilling fluid exiting from the drill string during drilling and returning up an annulus between the tubular member and the drill string;

a supply line having a first end and a second end;

a diverter coupled between the drilling riser and the first end of the supply line, the diverter configured to selectably divert drilling fluid from the annulus into the supply line;

an enclosure coupled to the second end of the supply line, the enclosure configured to receive and contain drilling fluid from the supply line;

a power riser having a first end disposed within the enclosure;

a return line having a first end disposed within the enclosure;

an interface coupled between the power riser and the return line, wherein the interface is configured to prevent the drilling fluid from flowing into the power riser from the return line; and

a lift fluid source for supplying lift fluid through the power riser, wherein the lift fluid is intermittently injected from the power riser through the interface into the return line to form one or more slugs of lift fluid positioned between slugs of drilling fluid;

wherein a combined density of lift fluid and drilling fluid in the return line is less than the density of the drilling fluid alone.

32. The system of claim 31, wherein the interface is one of a group consisting of a check valve, an intermittent diverter, and diverter shuttle valve.

33. The system of claim 31, wherein the drill string is suspended from one of a group consisting of a floating vessel, a floating structure, and a fixed structure.

34. The system of claim 31, further comprising a drilling fluid pump for conveying the drilling fluid from the drilling fluid source down the drill string.

35. The system of claim 34, wherein the drilling fluid pump is operable to maintain a hydrostatic pressure of the drilling fluid in the well bore exceeding a formation pressure.

36. The system of claim 31, further comprising a shut-off valve positioned along the supply line between the diverter spool and the enclosure and actuatable between an open position and a closed position, wherein the open position is configured to permit the drilling fluid to flow through the shut-off valve and wherein the closed position is configured to prevent the drilling fluid from flowing through the shut-off valve.

37. The system of claim 31, wherein the drilling fluid is mud.

38. The system of claim 31, wherein the lift fluid is one of a group consisting of fresh water and sea water.

39. The system of claim 31, further comprising a check valve positioned along the return line and actuatable between an open position and a closed position, wherein the open position is configured to permit the drilling fluid to flow through the check valve and wherein the closed position is configured to prevent the drilling fluid from flowing through the check valve.

40. The system of claim 31, further comprising a check valve positioned along the power riser between the interface and the enclosure and actuatable between an open position and a closed position, wherein the open position is configured to permit the lift fluid to flow through the check valve and wherein the closed position is configured to prevent the lift fluid from flowing through the check valve.

41. The system of claim 31, wherein the power riser is positioned concentrically within the return line.

42. The system of claim 31, wherein the return line is positioned concentrically within the power riser.

43. A method for lifting drilling fluid from a well bore in a formation, comprising:
injecting a drilling fluid through a drill string;
diverting the drilling fluid from the well bore into an enclosure;
injecting a lift fluid through a conduit and into the enclosure; and
forcing the drilling fluid from the enclosure through a return line;

wherein the density of the lift fluid is less than the density of the drilling fluid.

44. The method of claim 43, further comprising injecting the lift fluid from the conduit into the return line.

45. The method of claim 44, further comprising creating in the return line one or more slugs of lift fluid between slugs of drilling fluid.

46. The method of claim 45, further comprising diverting the one or more slugs of lift fluid into a lift fluid pit after exiting the return line and re-injecting the lift fluid diverted to the lift fluid pit into the conduit.

47. The method of claim 45, further comprising diverting the slugs of drilling fluid into a return shaker.

48. The method of claim 47, further comprising re-injecting the drilling fluid diverted to the return shaker into the drill string.

49. A system for lifting drilling fluid from a well bore in a formation, comprising:

a drilling riser;

a drill string suspended within the drilling riser and adapted to form at least a portion of the well bore;

a drilling fluid source for supplying drilling fluid through the drill string, the drilling fluid exiting from the drill string during drilling and returning up an annulus between the drilling riser and the drill string;

a return line having a first end;

a diverter coupled between the drilling riser and the first end of the return line, the diverter configured to selectably divert drilling fluid from the annulus into the return line;

a power riser coupled to the return line at an interface positioned along the return line, wherein the interface is configured to prevent the drilling fluid from flowing into the power riser from the return line; and

a lift fluid source for supplying lift fluid through the power riser into the return line, wherein the lift fluid is intermittently injected from the power riser through the

interface into the return line to form one or more slugs of lift fluid positioned between slugs of drilling fluid;

wherein a combined density of lift fluid and drilling fluid in the return line is less than the density of the drilling fluid alone; and

wherein the interface is a diverter shuttle valve comprising:

an outer housing having a cavity therein, the outer housing further having a first end and a plurality of openings; and

an inner housing having a flowbore therethrough, the inner housing having a first end and a plurality of openings;

wherein the inner housing is free to translate within the cavity of the outer housing; and

wherein a flowpath is established between the openings of the inner housing and the openings of the outer housing when the openings of the inner housing are aligned with the openings of the outer housing.

50. The diverter shuttle valve of claim 49, wherein the outer housing further comprises a second end, and wherein the openings of the inner housing are aligned with the openings of the outer housing when the first end of the inner housing abuts the second end of the outer housing.

51. The diverter shuttle valve of claim 50, further comprises a plurality of fins positioned circumferentially disposed proximate the second end of the inner housing thereabout.