Offshore drilling relies on the use of a tubular, known as a drilling riser, which allows the annulus to extend from the seabed to the surface. For floating drilling vessels, a riser section known as a slip joint or telescopic joint is used to allow the free movement of the drilling vessel caused by wave motion.

Managed pressure drilling systems are known which utilise a managed pressure drilling manifold comprising metering, distribution and choke manifolds mounted on a skip on the rig at surface. However, these manifolds are bulky and take up considerable space on a rig or drill ship. The manifolds also require numerous hoses and control lines to be run from the riser to the manifold.

Summary of the invention

Aspects of the invention are defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

It may be possible to obviate or at least mitigate the foregoing disadvantages of prior art well control and managed pressure drilling systems.

It may also be possible to provide a robust, reliable and compact well control system suitable for deployment on riser assemblies used in a variety of drilling.

It may also be possible to provide marine risers with a managed pressure drilling system with improved reliability and accessibility.

It may also be possible to provide a marine riser conversion system for managed pressure drilling operations.

Further aims will become apparent from the following description.

According to a first exemplary arrangement there is provided a well control system for a riser comprising:
a riser assembly; and
at least one flow meter;
wherein the at least one flow meter is configured to be mounted on the riser.

The at least one valve assembly on the riser may be configured to open a pathway between the riser annulus and the distribution assembly, at least one flow meter and/or at least one choke assembly.

The tension ring may be disposed circumferentially about a portion of the riser, a portion of the RID, a portion of slip joint, an outer barrel of a slip joint, a portion of the upper riser disconnect assembly and/or a tension joint.

The upper riser disconnect assembly may comprise an upper connector and a lower connector. The upper and lower connectors may be configured to disconnect from one another. The separated upper and lower connectors may be configured to connect to one another.

The slip joint may be a two-part slip joint. Alternatively, the slip joint may be a three or more part slip joint. The slip joint may comprise at least one sealing assembly. The slip joint may be a telescopic joint. The slip joint may comprise two telescopic members. The slip joint may comprise more than two telescopic members.

According to a second exemplary arrangement there is provided a riser assembly comprising:
a riser; and
a managed pressure drilling manifold mounted on the riser.

The managed pressure drilling manifold may comprise at least one flow meter module, at least one choke module and/or at least one valve assembly.

The managed pressure drilling manifold may comprise an integrated flow spool, choke manifold and/or metering manifold. The managed pressure drilling manifold may be mounted on a retrievable riser slip joint.

The least one flow meter module may comprise at least one flow meter. The at least one flow meter may be an inline flow meter. The at least one flow meter may be configured to be connected to a distribution assembly comprising at least one valve assembly. The distribution assembly may be located on the riser. The at least one flow meter and/or the distribution assembly may be connected to the at least one choke assembly mounted on

the riser. The distribution assembly may comprise at least one spool or hose connecting the at least one flow meter and/or the at least one choke assembly.

The at least one valve assembly on the riser may be configured to open a pathway between the riser annulus and the distribution assembly, at least one flow meter and/or at least one choke assembly.

The riser assembly may be connected to or installed onto a riser system to allow a managed pressure drilling operation without requiring structural modifications to riser. The upper riser assembly comprising a riser isolation device and a managed pressure drilling manifold may be connected to the upper riser disconnect assembly located above the tension ring.

Embodiments of the second exemplary arrangement may include one or more features of the first exemplary arrangement or its embodiments, or vice versa.

According to a third exemplary arrangement there is provided a system for well control comprising:
an upper riser assembly comprising
an upper riser disconnect assembly; and
at least one flow meter assembly, wherein the at least one flow meter assembly is mounted on the upper riser assembly.

The at least one flow meter assembly may be mounted on an outer surface of the upper riser assembly. The upper riser assembly may comprise a riser isolation device. The upper riser assembly may comprise a slip joint. The at least one flow meter assembly may be mounted on an outer surface of the slip joint.

The slip joint and/or the riser isolation device may be mounted to the upper riser disconnect assembly above the upper riser disconnect assembly.
The upper riser assembly may be connectable to a lower riser. The upper riser assembly may be connected to a lower riser by connecting the upper riser disconnect assembly to the riser. The upper riser assembly may be connected to a riser above a riser tension ring.

The system may comprise at least one choke assembly. The at least one choke assembly may be mounted on the upper riser assembly. The at least one choke assembly may be mounted on the slip joint. The upper riser assembly may be a self-contained well control system.

The at least one flow meter and/or at least one choke assembly may be integrated with a flow spool. The integrated at least one flow meter, at least one choke assembly and integrated flow spool system may be mounted on a retrievable slip joint.

The riser assembly may comprise a rotating control device. The rotating control device may be located in the system between the slip joint and the RID.

The at least one choke assembly and/or at least one flow meter assembly may form part of a managed pressure drilling manifold. The managed pressure drilling manifold may be mounted on the upper riser assembly and/or slip joint.

Embodiments of the third exemplary arrangement may include one or more features of the first or second exemplary arrangements or their embodiments, or vice versa.

According to a fourth exemplary arrangement there is provided a system for managed pressure drilling in a riser comprising:
an upper riser assembly comprising:
an upper riser disconnect assembly;
a rotating control device; and
at least one flow meter assembly, wherein the at least one flow meter assembly is mounted on the upper riser assembly.

The upper riser assembly may comprise a slip joint. The upper riser assembly may comprise riser isolation device. The riser isolation device may be mounted to the upper riser disconnect assembly above the upper riser disconnect assembly.

The upper riser assembly may be connectable to a lower riser. The upper riser assembly may be connected to a lower riser by connecting the upper riser disconnect assembly to a riser. The upper riser assembly may be connected to a riser above a riser tension ring.

The system may comprise at least one choke assembly. The at least one choke assembly may be mounted on the upper riser assembly. The at least one choke assembly may be mounted on the slip joint.

The at least one choke assembly and/or at least one flow meter assembly may form part of a managed pressure drilling manifold. The managed pressure drilling manifold may be mounted on the upper riser assembly and/or slip joint.

The upper riser assembly and/or the slip joint may comprise a self-contained well control system. The self-contained well control system may comprise at least one flow meter, at least one choke assembly and/or an integrated flow spool.

The riser isolation device, at least one flow meter, at least one choke assembly, rotating control device and/or the managed pressure drilling manifold may be located above the upper riser disconnect assembly.

Providing at least flow meter and/or at least one choke assembly and RCD on the upper riser assembly avoids the requirement for surface MPD flow meter and choke manifolds.

The at least one flow meter assembly may form part of a managed pressure drilling manifold. The managed pressure drilling manifold may comprise at least one flow meter module, at least one choke module and/or at least one valve assembly. The at least one flow meter module, at least one choke module and/or at least one valve assembly are mounted on the upper riser assembly.

The at least one flow meter assembly, valve manifold and/or at least one valve may be mounted on an outer surface of the slip joint on the upper riser assembly.

Embodiments of the fourth exemplary arrangement may include one or more features of the first, second or third exemplary arrangements or their embodiments, or vice versa.

According to a fifth exemplary arrangement there is provided a system for managed pressure drilling in a riser comprising:
a riser assembly comprising
a rotating control device; and

at least one flow meter assembly, wherein the at least one flow meter assembly is mounted on the riser.

The riser assembly may comprise a slip joint. The at least one flow meter may be mounted on the slip joint. The riser assembly may comprise riser isolation device. The riser may comprise an upper riser disconnect assembly. The slip joint may be a retrievable slip joint.

The system may comprise at least one choke assembly. The at least one choke assembly may be mounted on the riser. The at least one choke assembly may be mounted on the slip joint.

The system may comprise an integrated flow spool, choke manifold and/or metering manifold on the slip joint.

The at least one choke assembly and/or at least one flow meter assembly may form part of a managed pressure drilling manifold. The managed pressure drilling manifold may be mounted on the upper riser assembly and/or slip joint.

The at least one flow meter assembly, valve manifold and/or at least one valve may be mounted on an outer surface of the slip joint on the riser .

The riser isolation device, rotating control device and/or the managed pressure drilling manifold may be located on a riser above a riser tension ring.

The upper riser disconnect assembly may be configured to be connected to a tension joint above the tension ring.

Preferably the upper riser assembly which comprise the riser isolation device, rotating control device and the managed pressure drilling manifold may be releasably connected to the lower riser assembly via the upper riser disconnect assembly.

Embodiments of the fifth exemplary arrangement may include one or more features of the first to fourth exemplary arrangements or their embodiments, or vice versa.

According to a sixth exemplary arrangement there is provided a metering manifold for use on a riser comprising:
at least one flow meter;
wherein the metering manifold is mountable on the riser.

The metering manifold may be mountable on the slip joint. The metering manifold may be connected to at least one choke assembly which is mountable on the riser and/or slip joint. The metering manifold may be connected to at least one flow spool. The metering manifold, at least one choke assembly and at least one flow spool may be an integrated unit. The integrated unit mountable on the riser and/or slip joint.

Embodiments of the sixth exemplary arrangement may include one or more features of the first to fifth exemplary arrangements or their embodiments, or vice versa.

According to a seventh exemplary arrangement there is provided a managed pressure manifold for managed pressure drilling comprising:
at least one flow meter;
wherein the managed pressure manifold is mounted on the riser.

The managed pressure manifold may comprise at least one choke assembly. The managed pressure manifold may comprise least one flow spool. The at least one choke assembly, at least one flow meter and at least one flow spool may be an integrated unit.

The managed pressure manifold may be mounted on the slip joint. The integrated flow spool, choke assembly and flow meter manifold may be mounted on a slip joint.

Embodiments of the seventh exemplary arrangement may include one or more features of the first to sixth exemplary arrangements or their embodiments, or vice versa.

According to an eighth exemplary arrangement there is provided a method of installing a riser well control system in a subsea riser comprising:
providing a riser assembly and
installing at least one flow meter assembly on the riser.
The method may comprise installing at least one choke assembly on the riser.

The method may comprise installing a riser isolation device above a tension ring on the riser. The method may comprise installing a riser isolation device on the riser string above the tension ring.

The method may comprise providing a valve assembly and/or a distribution assembly. The method may comprise making up a tension ring. The method may comprise connecting the tension ring to the riser, riser isolation device, slip joint and/or the upper riser disconnect assembly.

The method may comprise mounting the at least one flow meter assembly and the at least one choke assembly on at least one component of the upper riser assembly. The method may comprise installing the upper riser assembly with connected at least one flow meter assembly and/or at least one choke assembly on the riser.

The method may comprise mounting the at least one flow meter assembly and the at least one choke assembly on the slip joint.

The method may comprise installing the upper riser disconnect assembly on the riser string above the tension ring.

Embodiments of the eighth exemplary arrangement may include one or more features of the first to seventh exemplary arrangements or their embodiments, or vice versa.

According to a ninth exemplary arrangement there is provided a method of installing a managed pressure drilling system on a subsea riser comprising:
providing a riser assembly;
installing a rotary control device; and
installing at least one flow meter assembly on the riser.

The method may comprise installing an upper riser disconnect assembly above the tension ring. The method may comprise installing the rotary control device and the at least one flow meter assembly above the upper riser disconnect assembly.
The method may comprise installing a riser isolation device above the tension ring.

The method may comprise installing at least one a choke assembly, at least one valve assembly and/or a distribution assembly. The method may comprise installing an integrated at least one flow meter, at least one a choke assembly and a flow spool on the riser or slip joint. The method may comprise making up the tension ring. The method may comprise connecting the tension ring to the riser below the upper riser disconnect assembly.

The method may comprise installing the upper riser disconnect assembly on the riser string and then installing the rotary control device onto the upper riser disconnect assembly.

The upper riser assembly including slip joint, managed pressure drilling manifold, RCD and RID may be installed on the lower riser by releasably latching onto the upper riser disconnect assembly.

Embodiments of the ninth exemplary arrangement may include one or more features of the first to eighth exemplary arrangements or their embodiments, or vice versa.

According to a tenth exemplary arrangement there is provided a method of converting a marine riser for well control operations comprising:
providing a riser assembly and installing at least one flow meter assembly on the riser.

The method may comprise installing at least one choke assembly on the riser. The method may comprise installing an upper riser assembly on the riser with the at least one flow meter assembly and/or the at least one choke assembly mounted on upper riser assembly.

The method may comprise installing a slip joint on the riser with the at least one flow meter assembly, the at least one choke assembly and/or an integrated flow spool mounted on the outer surface of the slip joint. The method may comprise removing an existing slip joint and/or an existing slip joint inner barrel on the subsea riser.

Embodiments of the tenth exemplary arrangement may include one or more features of the first to ninth exemplary arrangements or their embodiments, or vice versa.

According to an eleventh exemplary arrangement there is provided a method of converting a marine riser for MPD operations which enables managed pressure subsea drilling operations comprising:
installing a rotary control device; and
at least one flow meter assembly on the riser.

The method may comprise installing at least one choke assembly on the riser and/or the slip joint.

The method may comprise installing at least one choke assembly on the riser. The method may comprise installing an upper riser assembly on the riser with the at least one flow meter assembly and/or the at least one choke assembly mounted on upper riser assembly.

The method may comprise installing a slip joint on the riser with the at least one flow meter assembly, the at least one choke assembly and/or an integrated flow spool mounted on the outer surface of the slip joint.

The method may comprise removing an existing slip joint and/or an existing slip joint inner barrel on the subsea riser.

Embodiments of the eleventh exemplary arrangement may include one or more features of any of the first to tenth exemplary arrangements or their embodiments, or vice versa.

According to a twelfth exemplary arrangement there is provided a method of measuring at least one parameter or property of drill fluid in subsea riser comprising:
providing a riser assembly comprising:
at least one flow meter assembly;
wherein the at least one flow meter assembly is mounted on the riser;
measuring at least one parameter or at least one property of the drill fluid in the riser.
The method may comprise generating a measurement signal to a control unit. The method may comprise analysing the measurement signal in the control unit to compare the at least one parameter with a desired range of operating parameters.
The method may comprise generating a control signal from the control unit when the at least one parameter is determined to be outside of the desired range of operating parameters.

The method may comprise measuring at least one parameter or at least one property of the fluid using two or more flow meters. The method may comprise switching between a first flow meter having a first flow measurement range to a second flow meter having a second flow measurement range.

The method may comprise using knowledge of the geometry of the riser, geometry of the at least one flow meter, geometry of pipes or tubing, previous knowledge discharge coefficient as function of friction factor and/or Reynolds number to calculate or estimate information on the drilling fluid. The method may include estimating or calculating the friction factor, Reynolds number, Discharge coefficient, density, viscosity and corrected flowrate.

Embodiments of the twelfth exemplary arrangement may include one or more features of any of the first to eleventh exemplary arrangements or their embodiments, or vice versa.

According to a thirteenth exemplary arrangement there is provided a method of measuring a property of the drill fluid in a subsea drilling operation comprising:
providing a riser assembly comprising;
a riser isolation device;
a rotary control device;
at least one flow meter mounted on the riser; and
diverting drill fluid from the riser to the at least one flow meter.

The method may comprise diverting drill fluid from the riser beneath the rotary control device. The method may comprise diverting, measuring and/or choking drilling fluid returns from the riser beneath the rotary control device back into the riser via the at least one flow meter.

The method may comprise utilising existing mud return system. The method may comprise using the existing divert system and flow lines to reach the shakers.

Embodiments of the thirteenth exemplary arrangement may include one or more features of any of the first to twelfth exemplary arrangements or their embodiments, or vice versa.

According to a fourteenth exemplary arrangement there is provided a method of managed pressure drilling in a subsea drilling operation comprising:
providing a riser assembly comprising;
a riser isolation device;
a rotary control device;
at least one flow meter mounted on the riser;
at least one choke assembly mounted on the riser;
measuring properties of the flow and
actuating the choke to control flow.

The method may comprise diverting drill fluid from beneath the rotary control device. The method may comprise diverting, measuring and/or choking the drill fluid returns from the riser beneath the rotary control device and back into the riser (low pressure) via external low lines including the at least one flow meter and the at least one choke assembly.

The method may comprise utilising existing mud return system. The method may comprise using the existing divert system and flow lines to reach the shakers. The method may comprise diverting high pressure MPD returns from beneath the RCD back into the riser (low pressure) via flow lines including the at least one flow meter and at least one choke assemblies. The method may utilise existing mud return lines to shakers.

Embodiments of the fourteenth exemplary arrangement may include one or more features of any of the first to thirteenth exemplary arrangements or their embodiments, or vice versa.

According to a fifteenth exemplary arrangement there is provided a method of measuring at least one parameter or property of drilling fluid in a subsea riser comprising:
providing a well control system for a riser comprising a riser assembly;
at least one flow meter;
wherein the at least one flow meter is located on an outer surface of the riser assembly above a riser tension ring; and
measuring at least one parameter or at least one property of the drilling fluid in the riser.

Embodiments of the fifteenth exemplary arrangement may include one or more features of any of the first to fourteenth exemplary arrangements or their embodiments, or vice versa.

According to a sixteenth exemplary arrangement there is provided method of managed pressure drilling in a subsea drilling operation
comprising providing a well control system for a riser assembly comprising
a riser assembly;
at least one flow meter;
wherein the at least one flow meter is located on an outer surface of the riser assembly above a riser tension ring; and
providing a rotating control device; and
measuring at least one property of drilling fluid flow using the at least one flow meter.

Embodiments of the sixteenth exemplary arrangement may include one or more features of any of the first to fifteenth exemplary arrangements or their embodiments, or vice versa.

Brief description of the drawings

There will now be described, by way of example only, various embodiments of the invention with reference to the drawings, of which:

Figure 1 is a representation of a managed pressure drilling (MPD) riser assembly according to the prior art;

Figure 2 is a schematic representation of a riser system for MPD according to a first embodiment of the invention;

Figure 3A to 3F are schematic representations of an upper riser assembly for the riser system shown in Figure 2;

Figure 4 is a cross-sectional schematic view of a flow meter used in the riser assembly of Figure 2;

Figure 5 is a flow diagram of the process of measuring and monitoring mud flow according to an embodiment of the invention; and

Figure 6 is a flow diagram of the process of measuring different parameters of mud flow according to an embodiment of the invention.

installed on, attached to or located on a surface thereof. The terms “manifold” and “assembly” may be interchangeable.

The disclosure provides a well control system for a riser comprising a riser assembly and at least one flow meter, wherein the flow meter manifold is mounted on the riser.

The disclosure may facilitate the conversion of marine riser assemblies for MPD operations which enable conventional and/or managed pressure drilling operations.

The disclosure provides a complete self-contained managed pressure drilling system for connection on the riser. It avoids the requirement for MPD surface equipment and major drilling riser equipment modifications. It also mitigates the requirement for any flow return hoses from riser back to the rig/surface.

The disclosure mitigates the requirement for independent pipework upgrades for MPD mudflow and utilises existing rig mud return / fluid circulation system and well control procedures.

By providing a self-contained MPD system on an upper riser string and an upper riser disconnect assembly above the tension ring, components of the MPD drilling, flow meter, choke and distribution manifolds may quickly, safely and easily installed and/or removed from the riser assembly without requiring the BOP to be disconnected and the riser string pulled to surface. This configuration may allow components of a riser assembly and MPD drilling system to be installed only when they are required.

The disclosure enables a convention drilling riser to be converted for managed pressure drilling without requiring significant modification to rigs choke and kill and standpipe manifolds. It also avoids installing additional return hoses and numerous control lines in the moonpool or locating bulky distribution, choke and metering manifolds on the rig. The system also enables high pressure MPD returns to be diverted from beneath an RCD back into the riser (low pressure) via flow lines and the flow meter and choke assembly.

The disclosure provides an integrated flow spool, choke manifold and metering manifold on a retrievable riser slip joint which can be easily installed and/or removed from a riser assembly

The foregoing description of the invention has been presented for the purposes of illustration and description and is not intended to be exhaustive or to limit the invention to the precise form disclosed. The described embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilise the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Therefore, further modifications or improvements may be incorporated without departing from the scope of the invention herein intended.

Claims

1. A well control system for a riser which, when assembled, comprises:
a riser assembly; and
a managed pressure drilling manifold comprising:
at least one flow meter; and
at least one choke assembly;
wherein the at least one flow meter of the managed pressure drilling manifold is located on an outer surface of the riser assembly.

2. The well control system according to claim 1, wherein the at least one choke assembly is located on the riser assembly.

3. The well control system according to claim 1 or claim 2, wherein the riser assembly comprises at least one valve assembly located on the riser assembly.

4. The well control system according to any preceding claim, wherein the riser assembly comprises a rotating control device.

5. The well control system according to any preceding claim, wherein the at least one flow meter and the at least one choke assembly are integrated with a flow spool on a riser slip joint.

6. The well control system according to any preceding claim, wherein the at least one flow meter is selected from the group comprising orifice plate, wedge, venturi, Coriolis, Pitot tubes, differential pressure flow meter and/or variable area flow meters.

7. The well control system according to any preceding claim, comprising a control unit configured to receive at least one measurement signal from the at least one flow meter to measure at least one parameter or at least one property of drilling fluid or drilling fluid flow in the riser and/or in at least one mud return line.

8. The well control system according to claim 7, wherein the control unit is configured to monitor the drilling fluid flow in the riser and/or in the at least one mud return line.

9. The well control system according to claim 7 or claim 8, wherein the control unit is configured to calculate, estimate or predict the density and/or viscosity of the flowing drill fluid.

10. The well control system according to any preceding claim, wherein the at least one flow meter has a flow measurement range of 10 to 2000 USG/min.

11. The well control system according to any preceding claim, wherein the system comprises two or more flow meters.

12. A method of measuring at least one parameter or property of drilling fluid in a subsea riser using a well control system according to any preceding claim.

13. The method according to claim 12, comprising comparing the at least one parameter or at least one property of the drilling fluid with a desired range of drilling fluid operating parameters or properties.

14. The method according to claim 13 comprising generating a control signal when the at least one parameter or at least one property of the drilling fluid is determined to be outside of the desired range of operating parameters or properties.

15. The method according to any of claims 12 to 14, comprising measuring a pressure differential across a differential pressure flow meter ΔP.

16. The method according to any of claims 12 to 15, comprising determining or calculating a friction factor, a discharge coefficient of the flow, Reynolds number, density, viscosity and/or a flow rate of the drilling fluid.

17. The method according to any of claims 12 to 16, comprising measuring the at least one parameter or at least one property of the drilling fluid using two or more flow meters.

18. The method according to any of claims 12 to 17, comprising switching between a first flow meter having a first flow measurement range and a second flow meter having a second flow measurement range.

19. A method of managed pressure drilling in a subsea drilling operation using a well control system according to any one of claims 1 to 11 and
a rotating control device; the method comprising measuring at least one property of drilling fluid flow using the at least one flow meter.

20. The method according to claim 19, comprising providing the at least one choke assembly located on an outer surface of the riser assembly; and
actuating the at least one choke assembly to control flow.

21. The method according to claim 19 or claim 20, comprising diverting managed pressure drilling fluid returns from beneath the rotating control device back into the riser via the at least one flow meter.