

Title: Riser Pressure Relief Apparatus

Description of Invention

5 The present invention relates to a pressure relief apparatus for use in relation to the drilling of a subterranean borehole for oil and/or gas production.

When drilling a subsea subterranean borehole for oil and/or gas production, it is known to use a tubular drill string which extends down from a drilling rig at the ocean surface into the borehole through a wellhead mounted at the ocean floor. The drill string has a drill bit mounted at its lowermost end and drilling
10 may be achieved by rotating the drill string using a top drive mounted on the drilling rig, or by rotating the drill bit using a downhole motor at the remote end of the drill string. A tubular riser is mounted on a blowout preventer (BOP) provided at the top of the wellhead, and extends generally vertically upwardly to the ocean surface, whilst the drill string extends down the riser into the
15 borehole.

During drilling, a fluid (known as drilling mud) is pumped down the inside of the tubular drill string, through the drill bit, and circulated continuously back to surface via the drilled space between the borehole and the drill string (referred to as the wellbore annulus), and between the riser and the drill string (referred
20 to as the riser annulus). The riser thus provides a flow conduit for the drilling fluid and cuttings returns to be returned to the surface to the rig's fluid treatment system.

Traditionally deepwater drilling risers were designed as a conduit for transporting well bore returns to the rig during conventional drilling operations
25 or for diverting returns overboard during conventional well control in the event of a shallow gas kick or an influx escaping past the subsea BOP. In such

systems, the riser is designed as a flow conduit that is open to atmospheric pressure and is not a pressure containment system.

Since the development of riser flow control drilling systems, a drilling operation is now able to apply a safe amount of back pressure to the riser for the purposes of managed pressure drilling or reducing peak gas flow rates in a riser gas event. A riser flow control system consists of a pressure control manifold on the rig and a riser sealing device that diverts returns to the pressure control manifold. Where the riser is used in this way, there is a need to include a continuously available pressure relief system which provides an alternative flow path out of the riser for drilling returns so that the weakest link in the riser system is not over-pressured in the event of a control system failure, an operational error or a blockage in the conduit normally transporting riser returns to the rig.

Electrically operated pressure relief systems which use a PLC and pressure transducer to signal the actuator of the pressure relief valve are known, and disclosed in US4,636,934 and US 2011/0098946, for example. In the event of an umbilical failure, or a failure of the electronic control system, the electrical communication required to operate such a system may be lost, and this can cause the system to be unavailable when needed or result in an unintended actuation (opening) of the pressure relief valve. An unintended actuation can cause an environmental hazard by diverting oil based drilling mud overboard unnecessarily (because there was no over-pressure event to begin with). Alternatively, a lack of system availability during a riser over-pressure event can cause the riser to burst through resulting in danger to the rig crew as well as an environmental hazard. To avoid this, the system must be provided with full redundancy, which involves providing multiple umbilicals, PLCs, pressure transducers, etc at significant cost.

The present invention relates to an improved apparatus for automatically relieving excessive fluid pressure in the riser annulus in the event that the pressure of fluid in the riser exceeds a predetermined amount.

According to the invention we provide a riser pressure relief apparatus comprising a tubular riser having a main body enclosing a main passage and a side port extending through the main body to connect the main passage with the exterior of the riser, a pressure relief valve including a valve member which is movable between a first position in which the valve member substantially prevents flow of fluid through the side port and a second position in which flow of fluid through the side port is permitted, an actuator which is operable to move the valve member from the first position to the second position by the supply of pressurised fluid to an open port of the actuator, a source of pressurised fluid, and a pilot valve assembly, the pilot valve assembly being connected to the source of pressurised fluid and being movable between a first configuration in which flow of fluid from the source of pressurised fluid to open port of the actuator is substantially prevented and a second configuration in which flow of fluid from the source of pressurised fluid to the open port of the actuator is permitted, wherein the pilot valve assembly includes a valve part which is fluidly connected to the main passage of the riser and moves from a first position to a second position when the fluid pressure in the main passage of the riser exceeds a predetermined amount, movement of the valve part from the first position to the second position causing the pilot valve assembly to move from the first configuration to the second configuration, or vice versa, i.e. in the alternative, movement of the valve part from the first position to the second position causing the pilot valve assembly to move from the second configuration to the first configuration.

Advantageously, movement of the valve part from the first position to the second position causes the pilot valve assembly to move from the first configuration to the second configuration.

In one embodiment the valve member of the pressure relief valve is rotatable between the first position and the second position.

In one embodiment, the pressure relief valve is a ball valve.

5 In one embodiment, the actuator is configured such that the valve member of the pressure relief valve is movable from the second position to the first position by the supply of pressurised fluid to a close port of the actuator. In this case, the actuator may be configured such that if the fluid pressure at the open port exceeds the fluid pressure at the close port by a predetermined amount the actuator moves the valve member from the first position to the
10 second position, whilst if the fluid pressure at the close port exceeds the fluid pressure at the open port by a predetermined amount, the actuator moves the valve member from the second position to the first position.

In one embodiment, the source of pressurised fluid is an accumulator bottle.

15 In one embodiment, the source of pressurised fluid and pilot valve are provided adjacent to the pressure relief valve.

In one embodiment, the source of pressurised fluid and pilot valve are provided downstream of a connector whereby the source of pressurised fluid may be connected to an umbilical. As such, in the event of an umbilical failure, the pilot valve and source of pressurised fluid are available to operate
20 the pressure relief valve.

In one embodiment, the fluid in the source of pressurised fluid is hydraulic fluid.

25 In one embodiment, the valve part of the pilot valve assembly may be a piston which has a face which is exposed to the fluid pressure in the main passage of the riser.

In one embodiment, the pilot valve assembly is provided with a resilient biasing element which exerts a force on the valve part urging it into the first position.

5 In one embodiment, the source of pressurised fluid is a local source of pressurised fluid and the pressure relief apparatus further comprises a fluid flow line for connection to a remote source of pressurised fluid. In this case, the fluid flow line may extend to the local source of pressurised fluid.

10 There may be a non-return valve provided in the fluid flow line, the non-return valve valve being operable to permit flow of fluid along the fluid flow line towards the local source of pressurised fluid whilst preventing flow of fluid along the fluid flow line in the opposite direction.

15 The pilot valve assembly may include a control inlet for an external control signal, and be operable to move from the first configuration to the second configuration when the valve part is on the first position on receipt of an external control signal at the control inlet.

The control inlet may be for an electrical control signal or for a fluid pressure control signal.

The pilot valve assembly may include a pilot valve having the valve part.

20 The pilot valve assembly may include a control valve which moves from a rest position in which flow of fluid from the source of pressurised fluid to the open port of the actuator is substantially prevented to an active position in which flow of fluid from the source of pressurised fluid to the open port of the actuator is permitted on receipt of the external control signal.

25 The control valve may be provided with a first port which is connected to the source of pressurised fluid via a flow line which does not contain the pilot valve, and a second port which is connected to the open chamber via a flow line which does not contain the pilot valve, and a valve member which is

movable between a first position in which flow of fluid between the first port and the second port is permitted, and a second position in which flow of fluid between the first port and the second port is substantially prevented.

5 The control valve may be provided with an electrically operable actuator which moves it from its rest position to its open position when an electrical control signal is supplied to the actuator.

Alternatively, the control valve may be a pilot operated valve with an actuator to which the control inlet is connected, the control valve being configured such that it moves from its rest position to its active position when the fluid pressure
10 at the control inlet exceeds a predetermined level.

The control valve may be operable to connect the open chamber of the actuator to a low pressure region.

The control valve may connect the open chamber of the actuator to a low pressure region when the control valve is in its rest position.

15 The actuator may be configured such that the valve member of the pressure relief valve is movable from the second position to the first position by the supply of pressurised fluid to a close port of the actuator.

The actuator may be configured such that if the fluid pressure at the open port exceeds the fluid pressure at the close port by a predetermined amount the
20 actuator moves the valve member from the first position to the second position, whilst if the fluid pressure at the close port exceeds the fluid pressure at the open port by a predetermined amount, the actuator moves the valve member from the second position to the first position.

The pilot valve assembly may be configured to allow flow of fluid from the
25 source of pressurised fluid to the close port and to connect the open port of the actuator to a low pressure region when the pilot valve assembly is in the first configuration.

The control valve may be movable to a close position in which the close port of the actuator is connected to the source of pressurised fluid whilst the open port of the actuator is connected to a low pressure region.

5 The control valve may be provided with an electrically operable actuator which moves it from its rest position to its close position when electrical power is supplied to the actuator.

Embodiments of the invention are described, by way of example only, with reference to the accompanying figures of which,

10 FIGURE 1 shows a schematic illustration of a first embodiment of riser pressure relief apparatus according to the invention in the normal closed position,

FIGURE 2 shows a schematic illustration of the embodiment of riser pressure relief apparatus illustrated in Figure 1 in the automatic open position,

15 FIGURE 3 shows a schematic illustration of the embodiment of riser pressure relief apparatus illustrated in Figure 1 in the electronically initiated open position,

FIGURE 4 shows a schematic illustration of the embodiment of riser pressure relief apparatus illustrated in Figure 1 in the return to close position,

20 FIGURE 5 shows a schematic illustration of a second, alternative embodiment of riser pressure relief apparatus according to the invention, in the normal closed configuration,

FIGURE 6 shows a schematic illustration of the embodiment of riser pressure relief apparatus illustrated in Figure 5 in the open position under surface control,

FIGURE 7 shows a schematic illustration of the embodiment of riser pressure relief apparatus illustrated in Figure 5 in the open position,

FIGURE 8 shows a schematic illustration of a redundant system including the first embodiment of pressure relief apparatus,

- 5 FIGURE 9 shows a schematic illustration of a redundant system including the second embodiment of pressure relief apparatus.

The figures illustrate embodiments of riser pressure relief apparatus which are intended to be used in connection with a tubular riser for use in drilling a subsea wellbore for oil and/or gas production. The riser has a main body
10 enclosing a main passage and a side port extending through the main body to connect the main passage to the exterior of the riser.

Referring now to Figure 1 there is shown a schematic illustration of a first embodiment of riser pressure relief apparatus in a normal closed position. The pressure relief apparatus includes a pressure relief valve 10 which is, in use,
15 mounted on the riser, and which is a valve member which is movable between a first position in which the valve member substantially prevents flow of fluid through the side port and a second position in which flow of fluid through the side port is permitted. The pressure relief valve may be mounted directly on the riser, or in a fluid flow passage which extends from the side port. The
20 pressure relief valve further includes an actuator which is operable to move the valve member from the first position to the second position by the supply of pressurised fluid to an open port 10a in the actuator.

In one embodiment, the valve rotates between the first position and second position.

- 25 In a preferred embodiment of the invention, the pressure relief valve 10 is a ball valve. It should be appreciated, however, that any other suitable configuration of valve could be used.

The pressure relief apparatus further includes a source of pressurised fluid for supply to the open port of the pressure relief valve. In this embodiment of the invention, the source of pressurised fluid is an accumulator bottle 12, but may equally be any other form of pressure vessel. Advantageously, the
 5 accumulator bottle is located as close as possible to the actuator of the pressure relief valve 10 to minimise the response time of the pressure relief valve 10.

The accumulator bottle 12 is connected to the open port of the pressure relief valve 10 via a pressure operated spring biased pilot valve 14. The pilot valve
 10 14 includes a resilient biasing element (spring) which biases the pilot valve 14 to a closed position in which flow of fluid from the accumulator bottle 12 to the open port of the pressure relief valve 10. The pilot valve 14 is movable against the biasing force of the spring to an open position in which the accumulator
 15 bottle 12 is connected to the open chamber 10a of the pressure relief valve actuator. The pilot valve 14 has an actuator with a face which is, in use, in pressure communication with the fluid in the main passage of the riser, the fluid pressure in the riser acting to urge the actuator against the biasing force of the spring. When the fluid pressure in the riser exceeds a predetermined
 20 value, the actuator can overcome the biasing force of the spring to move the pilot valve 14 to the open position. In one embodiment of the invention, the actuator comprises a piston movably mounted in a cylinder.

The resilient biasing element may comprise a replaceable spring cartridge, and so the pressure at which the pilot valve 14 moves from the closed position to the open position may be adjusted by replacing the spring cartridge with a
 25 spring rated to withstand the desired pressure before compressing.

The pressure relief system is also provided with a control valve 16. The control valve 16 is a three position valve which has a first port 16a which is connected to a fluid reservoir 18, a second port 16b which is connected to a line to the accumulator bottle 18, a third port 16c which is connected to the line

between the pilot valve 14 and the open port 10a of the pressure relief valve actuator, and a fourth port 16d which is connected to the close port 10b of the pressure relief valve actuator 10. The fluid reservoir 18 may be a tank located at surface. Alternatively, the first port 16a may simply vent into the sea.

- 5 The control valve 16 is biased to a rest position in which the second port 16b and third port 16c are closed, whilst the first port 16a is connected to the fourth port 16d. As such, when the control valve 16 is in the rest position the close port 10b of the pressure relief valve actuator is connected to the fluid reservoir 18.
- 10 Whilst the control valve 16 may be hydraulically (or pilot) operated, in this embodiment it is an electrically operated valve. The control valve 16 is provided with a first electrically operated actuator such as a solenoid or piezoelectric element which, when charged, moves the control valve 16 from the rest position to an open position in which the second port 16b is connected
15 to the third port 16c, and the first port 16a is connected to the fourth port 16d. As such, when the control valve 16 is in the open position the close port 10b of the pressure relief valve 10 is connected to the fluid reservoir 18 whilst the open port 10a is connected to the accumulator bottle 12. The control valve 16 is also provided with a second electrically operated actuator such as a
20 solenoid or piezoelectric element which, when charged, moves the control valve 16 from the rest configuration to an close position in which the first port 16a is connected to the third port 16c and the second port 16b is connected to the fourth port 16d. As such, when the control valve 16 is in the close position, the close port 10b of the pressure relief valve actuator is connected to the
25 accumulator bottle 12 whilst the open port 10a is connected to the fluid reservoir 18.

In this example, a pressure transducer 20 is provided to measure the fluid pressure in the line between the accumulator bottle 12 and the pilot valve 14. This may be used for monitoring of the system pressure, and periodic system

integrity checks. It will be appreciated, however, that the pressure relief valve 10 can be actuated without the availability of pressure transducers.

In this example a non-return valve 22 is provided in the line between the fluid reservoir 18 and the first port 16a of the control valve 16.

- 5 Pressurised fluid is supplied to the accumulator bottle 12 by means of an umbilical connection to a fluid pump, which is typically mounted on the drilling rig. A further non-return valve 24 is provided in the umbilical (or a line connecting the accumulator bottle 12 to the umbilical). This is intended to prevent the back flow of fluid from the accumulator bottle 12 in the event that
 10 the umbilical is damaged and loses pressure. As a result, the pressure relief apparatus does not lose pressure, and continues to function in the event of an umbilical failure.

- In this example, the further non-return valve 24 is provided which is an electrically operated 2 position valve which is movable between a first position
 15 in which flow of fluid from the accumulator bottle 12 to the umbilical is substantially prevented whilst flow of fluid from the umbilical to the accumulator bottle is permitted, and a second position in which flow of fluid is permitted in both those directions. The non-return valve 24 will normally be in its first position, but may be moved to its second position in order to de-pressurise the
 20 pressure relief valve system before retrieving it from under the sea.

The system may be provided with a filter 26 in the feed line from the umbilical into the accumulator bottle 12 to ensure the cleanliness of the fluid entering the control system.

The pressure relief apparatus operates as follows.

- 25 Normally, the pressure relief apparatus is configured as illustrated in Figure 1. The pilot valve 14 is in the closed position, and the control valve 16 is in the rest position. As such, the line to the open port 10a of the pressure relief valve 10 is closed, and the close port 10b is connected to the reservoir 18.

If the fluid pressure in the riser exceeds the predetermined level, the pilot valve 14 moves to the open position, whilst the control valve 16 is maintained in its rest position, as illustrated in Figure 2. Fluid flows from the accumulator bottle 12 through the pilot valve 14 to the open port 10a of the pressure relief valve 10, and causes the actuator to move the pressure relief valve from the closed position to the open position. The fluid pressure in the riser may then be relieved by the flow of fluid out of the riser through the side port. Fluid flowing through the side port is typically vented to a safe location away from the drilling rig. Fluid is typically vented overboard via port or starboard diverter lines as done with traditional overboard lines. Another option would be to route the flow to a mud gas separator on the drilling rig.

When the pressure in the riser drops to below the predetermined level, the pilot valve 14 returns to its closed position. The open port 10a is therefore closed, with the fluid pressure from the accumulator bottle 12 maintained within the actuator. The pressure relief valve 10 therefore remains in its open position.

The pressure relief valve 10 may also be opened by a user even if the pressure in the riser has not exceeded the predetermined level required to move the piston actuator of the pilot valve 14. To achieve this, electrical power is supplied to the first electrically operated actuator of the control valve 16 to move the control valve 16 to its open position in which the close port 10b of the pressure relief valve 10 remains connected to the reservoir 18 whilst the open port 10a is connected to the accumulator bottle 12 via the control valve 16. This is illustrated in Figure 3. Pressurised fluid from the accumulator bottle 12 thus flows to the open port 10a and operates the actuator to open the pressure relief valve 10.

In order to close the pressure relief valve 10 after either automatic operation in an overpressure event, or after electronic opening using control valve 16, it is necessary to energise the control valve 16, by supply of power to the second electrically operated actuator, to move it to the close position, as illustrated in Figure 4. The open port 10a of the pressure relief valve 10 is connected to the reservoir 18, thus relieving the fluid pressure at the open port 10a, whilst the close port 10b is connected to the accumulator bottle 12. The supply of pressurised fluid from the accumulator bottle 12 to the close port 10b of the pressure relief valve 10 operates the actuator to move the pressure relief valve 10 to the closed position, thus sealing

the riser once more. Once the pressure relief valve 10 is closed, the supply of electrical power to the control valve 16 can cease, so that the control valve 16 returns to its rest position.

An alternative embodiment of pressure relief apparatus is illustrated in Figures 5 and 6

This embodiment of pressure relief apparatus has many features in common with the pressure relief apparatus illustrated in Figures 1 to 4, and the same reference numerals have been used in relation to these common parts. The information set out in the description relating to Figures 1 to 4 about these common parts applies equally to the equivalent parts in the embodiment illustrated in Figures 5 and 6.

The pressure relief apparatus illustrated in Figures 5 and 6 includes a pressure relief valve 10 which is, in use, mounted on the riser, and which is a valve member which is movable between a first position in which the valve member substantially prevents flow of fluid through the side port and a second position in which flow of fluid through the side port is permitted. The pressure relief valve 10 further includes an actuator which is operable to move the valve member from the first position to the second position by the supply of pressurised fluid to an open port 10a in the actuator.

The pressure relief apparatus further includes a source of pressurised fluid for supply to the open port of the pressure relief valve, which, in this embodiment of the invention, is an accumulator bottle 12. The pressure relief system also includes a pressure operated spring biased pilot valve 14' with a resilient biasing element (spring) which biases the pilot valve 14' to a closed position.

The pilot valve 14 has a piston actuator with a face which is, in use, in pressure communication with the fluid in the main passage of the riser, the fluid pressure in the riser acting to urge the piston against the biasing force of the spring. When the fluid pressure in the riser exceeds a predetermined

value, the piston actuator can overcome the biasing force of the spring to move the pilot valve 14' to an open position.

The configuration of the pilot valve 14' is, however, slightly different to the configuration of the pilot valve 14 in the embodiment of the invention described in relation to Figures 1 to 4. Specifically, the pilot valve 14' has a first port 14a' which is connected to the accumulator bottle 12, a second port 14b' which is connected to the control actuators 28, 30 of two 2 position 3 way pilot operated valves 32, 34 (hereinafter referred to as the auxiliary pilot valves 32, 34), and a third port 14c' which is blocked. When the pilot valve 14' is in the closed position, the first port 14a' is closed whilst the second port 14b' is connected to the third port 14c'. When the pilot valve 14' is in the open position, the first port 14a' is connected to the second port 14b', and the third port 14c' is closed.

The auxiliary pilot valves 32, 34 are each biased to a rest position by means of a resilient biasing element such as a spring, and are movable from the rest position to an active position by the supply of pressurised fluid to their respective actuator 28, 30. The auxiliary pilot valves 32, 34 each have a first port 32a, 34a which is connected to the accumulator bottle 12, a second port 32b, 34b which is connected to the actuator of the pressure relief valve 10, and a third port 32c, 34c which is connected to a drain line A which extends to either a pressurised fluid reservoir via the umbilical, or to an overboard vent point. The second port 32b of the first auxiliary pilot valve 32 is connected to the open port 10a of the pressure relief valve actuator, whilst the second port 34b of the second auxiliary pilot valve 34 is connected to the close port 10b of the pressure relief valve actuator.

When the first auxiliary pilot valve 32 is in the rest position, the third port 32c is connected to the second port 32b whilst the first port 32a is closed, whilst when it is in the active position, the first port 32a is connected to the second port 32b, and the third port 32c is closed. In contrast, when the second

auxiliary pilot valve 34 is in the rest position, the first port 34a is connected to the second port 34b whilst the third port 34c is closed, whilst when it is in the active position, the first port 32a is closed and the third port 34c is connected to the second port 34b.

- 5 In this example, a pressure transducer 20 is provided to measure the fluid pressure in the line between the accumulator bottle 12 and the pilot valve 14'.

Pressurised fluid is supplied to the accumulator bottle 12 by means of an umbilical connection to a source of high pressure fluid – typically a fluid pump, which is mounted on the drilling rig. A non-return valve 24 is provided in the
 10 line B connecting the accumulator bottle 12 to the high pressure line of the umbilical). This is intended to prevent the back flow of fluid from the accumulator bottle 12 in the event that the umbilical is damaged and loses pressure. As a result, the pressure relief apparatus does not lose pressure, and continues to function, in the event of an umbilical failure.

- 15 In this example, the non-return valve 24 is a pilot operated 2 position valve which is movable between a first position in which flow of fluid from the accumulator bottle 12 to the umbilical is substantially prevented whilst flow of fluid from the umbilical to the accumulator bottle 12 is permitted, and a second position in which flow of fluid is permitted in both those directions. This non-
 20 return valve 24 is normally in the first position, but it includes a fluid pressure operated actuator and may be moved from the first position to the second position by the supply of pressurised fluid to the actuator to de-pressurise the system prior to its retrieval from beneath the sea. It will be appreciated, however, that this valve 24' could equally be electrically operated.

- 25 As with the embodiment of the invention described in relation to Figures 1 to 4, the system may be provided with a filter in the feed line from the umbilical into the accumulator bottle 12 to ensure the cleanliness of the fluid entering the control system.

The line between the actuators 28, 30 of the auxiliary pilot valves 32, 34 and the second port 14b' of the pilot valve 14' is also connected to a control line C via a further non-return valve 36. The control line C is connected to a surface control line in the umbilical. The further non-return valve 36 is a pilot operated
 5 2 position valve which is movable between a first position in which flow of fluid along the control line from the line between the actuators 28, 30 and the pilot valve 14' to the umbilical is substantially prevented whilst flow of fluid along the control line from the umbilical to the line between the actuators 28, 30 and the pilot valve 14' is permitted, and a second position in which flow of fluid is
 10 permitted in both those directions.

The pilot non-return valve 36 has an actuator which is connected to the line B from the umbilical to the accumulator bottle 12 upstream of the non-return valve 24 (i.e. between the non-return valve 24 and the connection to the umbilical). The pilot non-return valve 36 includes a resilient biasing element which biases it to the first position.
 15 Its actuator is configured such that when the pressurised fluid is supplied to the actuator of the pilot non-return valve 36, i.e. when the line from the umbilical to the accumulator bottle 12 is pressurised, the pilot non-return valve 36 is maintained in its second position (two way flow permitted), and returns to its first position when the fluid pressure in the line from the umbilical to the accumulator bottle 12 falls to a level
 20 which is insufficient to overcome the biasing force of the resilient biasing element.

A pressure release line D connects the control line C to a fluid reservoir (or other low pressure region) via an ROV-operable drain valve 38. This valve is normally closed to contain fluid in the control line C, but may be opened by an ROV to allow flow of fluid from the control line C to the fluid reservoir.

25 The embodiment of pressure relief apparatus illustrated in Figures 5 and 6 may be operated as follows.

Normally, the pressure relief apparatus is configured as illustrated in Figure 5. The actuator of the umbilical non-return valve 24 is not pressurised so this valve is in its first position, and therefore permits flow in one direction only. The pilot valve 14 is in
 30 the closed position, and as such the lines to the actuators 28, 30 of the auxiliary pilot

valves 32, 34 are closed at the pilot valve 14'. Whilst the connection between line B and the high pressure line in the umbilical is present, the further non-return valve is in its second position (two way flow), as illustrated in Figure 5. If, however, the connection to the umbilical is damaged or lost with the result that the supply of high pressure fluid to line B is lost, the further non-return valve 36 will move to its first position. In either case, as the control line C is not pressurised, there is no supply of pressurised fluid to the actuators 28, 30 of the auxiliary pilot valves 32, 34. As a result, the auxiliary pilot valves 32, 34 are in their rest positions, and the open port 10a of the pressure relief valve actuator is connected to the drain line A by the first auxiliary pilot valve 32 and the close port 10b of the pressure relief valve actuator is connected to the accumulator 12 via the second auxiliary pilot valve 34. The pressure relief valve 10 is therefore in its closed position.

Surface control of the pressure relief valve 10 via the umbilical, in the absence of excess pressure in the riser, can be achieved as follows. With the connection to the umbilical in tact, line B is pressurised, and so the further non-return valve is in its second position (two way flow). The pilot valve 14 remains in its closed position, but pressurised fluid is supplied to actuators 28, 30 of the auxiliary pilot valves 32, 34 via the control line C and the umbilical control line. This fluid is pressurised to such an extent that the auxiliary pilot valves 32, 34 move from their rest positions to their active positions in which the open port 10a of the pressure relief valve actuator is connected to the accumulator bottle 12 by the first auxiliary pilot valve 32 and the close port 10b of the pressure relief valve actuator is connected to the drain line A via the second auxiliary pilot valve 34. The pressure relief valve 10 therefore moves to its open position. This is illustrated in Figure 6. The pressure relief valve 10 can be returned to its closed position by exhausting the control line C via the umbilical control line.

If, whilst the control line C is pressurised, the pressure in the riser continues to rise, and rises to such an extent that the pilot valve 14' is moved to its open position, the pressure supplied to the actuators 28, 30 of the auxiliary pilot valves 32, 34 is maintained, and the pressure relief valve 10 remains open.

If the connection to the umbilical (and hence the possibility of surface control) is lost, the pressure relief valve will be opened automatically in the event of riser over-pressure by means of the pilot valve 14'.

In this case, as the pressure in line B upstream of the non-return valve 24 is lost, the further non-return valve 36 moves to its first position in which return flow through the valve 36 is prevented. If the fluid pressure in the riser exceeds the predetermined level, the pilot valve 14' moves to the open position. Fluid flows from the accumulator bottle 12 through the pilot valve 14' to the actuators 28, 30 of the auxiliary pilot valves 32, 34 causing them to move from their rest positions to their active positions. As described above, the further non-return valve 36 is in its first position, and thus retains the pressure in the actuators 28, 30 of the auxiliary pilot valves 32, 34. This fluid is pressurised to such an extent that the auxiliary pilot valves 32, 34 move from their rest positions to their active positions in which the open port 10a of the pressure relief valve actuator is connected to the accumulator bottle 12 by the first auxiliary pilot valve 32 and the close port 10b of the pressure relief valve actuator is connected to the drain line A via the second auxiliary pilot valve 34. This is illustrated in Figure 7. The resulting flow of fluid from the accumulator bottle 12 to the open port 10a and concomitant exhausting of fluid from the close port 10b causes the actuator to move the pressure relief valve from the closed position to the open position. The fluid pressure in the riser may then be relieved by the flow of fluid out of the riser through the side port. Fluid flowing through the side port is typically vented to a safe location away from the drilling rig as described in relation to the embodiment shown in Figures 1 – 4.

When the pressure in the riser drops to below the predetermined level, the pilot valve 14' returns to its closed position. The pilot pressure acting on the actuators 28, 30 of the auxiliary pilot valves 32, 34 is trapped by the further non-return valve 36, however. To release this pilot pressure, an ROV is employed to open the drain valve 38, thus allowing the pilot pressure to drain from the control line C via the pressure release line D. As a result, the auxiliary pilot valves 32, 34 return their rest positions, and the open port 10a of the pressure relief valve actuator is connected to the drain line A by the first auxiliary pilot valve 32 and the close port 10b of the pressure relief valve actuator is connected to the accumulator 12 via the second auxiliary pilot valve 34. Flow of

fluid from the accumulator bottle 12 to the close port 10b of the pressure relief valve actuator moves the pressure relief valve 10 from the open position to the closed position. It will be appreciated from the above description that an advantage of the proposed systems is that opening of the pressure relief valve is completely automatic
5 in the event of riser over-pressure. It does not rely on the correct functioning of any electrical or electronic equipment (compared with systems which utilise electrical valves operating based on the reading of an electronic pressure sensor), and cannot be electronically deactivated or overridden by a user accidentally altering the pressure relief set point to a dangerously high level. Even if the system is set up such that the
10 set point for pressure relief can be set electronically (for example, in the embodiment illustrated in Figures 1 to 4, by providing for automatic, electronic opening using the electrical control valve 16 based on a reading from a pressure transducer in the riser), the pilot valve 14 will always open at the pressure determined by the compressibility of its spring, irrespective of what set-point has been set electronically, or, indeed, if
15 the electronic control system is functioning correctly. As such, there is no need to set the system to automatically open the pressure relief valve 10 in the event of an electronic systems failure.

The use of a ball valve as the pressure relief valve may be advantageous as such valves can reseal in a reliable fashion without maintenance, parts replacement or
20 retrieval.

Advantageously, the riser will be provided with two identical pressure relief valves 10 and associated control apparatus to provide redundancy should one of the systems fail. Examples of how such redundant systems may be configured are illustrated in Figures 7 and 8. Figure 7 shows a redundant riser pressure relief system including
25 two of the apparatus described above in relation to Figures 1 to 4, whilst the system shown in Figure 8 includes the embodiments described in relation to Figures 5 and 6.

When used in this specification and claims, the terms "comprises" and "comprising" and variations thereof mean that the specified features, steps or integers are included. The terms are not to be interpreted to exclude the
30 presence of other features, steps or components.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any
5 combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS

1. A riser pressure relief apparatus comprising a tubular riser having a main body enclosing a main passage and a side port extending through the main body to connect the main passage with the exterior of the riser, a
5 pressure relief valve including a valve member which is movable between a first position in which the valve member substantially prevents flow of fluid through the side port and a second position in which flow of fluid through the side port is permitted, an actuator which is operable to move the valve member from the first position to the second position by the supply of
10 pressurised fluid to an open port of the actuator, a source of pressurised fluid, and a pilot valve assembly, the pilot valve assembly being connected to the source of pressurised fluid and being movable between a first configuration in which flow of fluid from the source of pressurised fluid to open port of the actuator is substantially prevented and a second configuration in which flow of
15 fluid from the source of pressurised fluid to the open port of the actuator is permitted, wherein the pilot valve assembly includes a valve part which is fluidly connected to the main passage of the riser and moves from a first position to a second position when the fluid pressure in the main passage of the riser exceeds a predetermined amount, movement of the valve part from
20 the first position to the second position causing the pilot valve assembly to move either from the first configuration to the second configuration or the second configuration to the first configuration.
2. A riser pressure relief apparatus according to claim 1 wherein the valve member of the pressure relief valve is rotatable between the first position and
25 the second position.
3. A riser pressure relief apparatus according to claim 1 or 2 wherein the pressure relief valve is a ball valve.

4. A riser pressure relief apparatus according to any preceding claim wherein the source of pressurised fluid is an accumulator bottle.
5. A riser pressure relief apparatus according to any preceding claim wherein the source of pressurised fluid and pilot valve assembly are provided adjacent to the pressure relief valve.
6. A riser pressure relief apparatus according to any preceding claim wherein the source of pressurised fluid and pilot valve assembly are provided downstream of a connector whereby the source of pressurised fluid may be connected to an umbilical.
- 10 7. A riser pressure relief apparatus according to any preceding claim wherein the fluid supplied by the source of pressurised fluid is hydraulic fluid.
8. A riser pressure relief apparatus according to any preceding claim wherein the valve part of the pilot valve assembly comprises a piston which has a face which is exposed to the fluid pressure in the main passage of the riser.
- 15 9. A riser pressure relief apparatus according to any preceding claim wherein the pilot valve assembly is provided with a resilient biasing element which exerts a force on the valve part urging it into the first position.
10. A riser pressure relief apparatus according to any preceding claim wherein the source of pressurised fluid is a local source of pressurised fluid and the pressure relief apparatus further comprises a fluid flow line for connection to a remote source of pressurised fluid.
- 20 11. A riser pressure relief apparatus according to claim 10 wherein the fluid flow line extends to the local source of pressurised fluid.
- 25 12. A riser pressure relief apparatus according to claim 11 wherein there is a non-return valve provided in the fluid flow line, the non-return valve being

operable to permit flow of fluid along the fluid flow line towards the local source of pressurised fluid whilst preventing flow of fluid along the fluid flow line in the opposite direction.

13. A riser pressure relief apparatus according to any preceding claim
5 wherein the pilot valve assembly includes a control inlet for an external control signal, and is operable to move from the first configuration to the second configuration on receipt of an external control signal at the control inlet.

14. A riser pressure relief apparatus according to claim 13 wherein the control inlet is for an electrical control signal.

10 15. A riser pressure relief apparatus according to claim 13 wherein the control inlet is for a fluid pressure control signal.

16. A riser pressure relief apparatus according to any preceding claim wherein the pilot valve assembly includes a pilot valve, the pilot valve having the valve part.

15 17. A riser pressure relief apparatus according to claim 16 and any one of claims 13 to 15 wherein the pilot valve assembly further includes a control valve which moves from a rest position in which flow of fluid from the source of pressurised fluid to the open port of the actuator is substantially prevented to an active position in which flow of fluid from the source of pressurised fluid to
20 the open port of the actuator is permitted on receipt of the external control signal.

18. A riser pressure relief apparatus according to claim 17 wherein the control valve is provided with a first port which is connected to the source of pressurised fluid via a flow line which does not contain the pilot valve, and a
25 second port which is connected to the open chamber via a flow line which does not contain the pilot valve, and a valve member which is movable between a first position in which flow of fluid between the first port and the

second port is permitted, and a second position in which flow of fluid between the first port and the second port is substantially prevented.

19. A riser pressure relief apparatus according to claim 17 or 18 wherein the control valve is provided with an electrically operable actuator which
5 moves it from its rest position to its active position when an electrical control signal is supplied to the actuator.

20. A riser pressure relief apparatus according to claim 17 or 18 wherein the control valve is a pilot operated valve with an actuator to which the control inlet is connected, the control valve being configured such that it moves from
10 its rest position to its active position when the fluid pressure at the control inlet exceeds a predetermined level.

21. A riser pressure relief apparatus according to any one of claims 17 to 20 wherein the control valve is operable to connect the open chamber of the actuator to a low pressure region.

15 22. A riser pressure relief apparatus according to claim 21 wherein the control valve connects the open chamber of the actuator to a low pressure region when the control valve is in its rest position.

23. A riser pressure relief apparatus according to any preceding claim wherein the actuator is configured such that the valve member of the pressure
20 relief valve is movable from the second position to the first position by the supply of pressurised fluid to a close port of the actuator.

24. A riser pressure relief apparatus according to claim 23 wherein the actuator is configured such that if the fluid pressure at the open port exceeds the fluid pressure at the close port by a predetermined amount the actuator
25 moves the valve member from the first position to the second position, whilst if the fluid pressure at the close port exceeds the fluid pressure at the open port

by a predetermined amount, the actuator moves the valve member from the second position to the first position.

25. A riser pressure relief apparatus according to claim 23 or 24 wherein the pilot valve assembly is configured to allow flow of fluid from the source of pressurised fluid to the close port and to connect the open port of the actuator to a low pressure region when the pilot valve assembly is in the first configuration.

26. A riser pressure relief apparatus according to either claims 23 or 24 where dependent on claims 17 to 19 wherein the control valve is movable to a close position in which the close port of the actuator is connected to the source of pressurised fluid whilst the open port of the actuator is connected to a low pressure region.

27. A riser pressure relief apparatus according to claim 26 wherein the control valve is provided with an electrically operable actuator which moves it from its rest position to its close position when electrical power is supplied to the actuator.