BARRIER VALVE DEVICE

TECHNICAL FIELD

The present disclosure relates to a barrier valve device for use in a completion string within a well pipe.

BACKGROUND

Once a hydrocarbon well has been drilled, a completion phase can begin. The completion phase is where the well is prepared to produce the hydrocarbons. During completion, tubing, which may be referred to as the completion string or production tubing, is installed in the well. Several types of tools may be connected together as part of the completion string. The completion string is used to channel hydrocarbon fluid within the well during extraction.

The hydrocarbon fluid will flow through the completion string at high pressure. To ensure that the completion string can withstand such pressures and that there are no faults along the completion string where hydrocarbon fluid may escape or cause damage, the completion string may be pressure tested. Pressure testing may be performed by increasing the pressure within a closed portion of the completion string. Typically, a barrier valve device is incorporated into the completion string to allow such pressure testing. The barrier valve device may include a plug or barrier that closes off a downstream portion of the completion string, so that pressure testing can be performed on an upstream portion. The barrier valve device includes a mechanism for removing the plug so that fluid flow is permitted between the downstream and upstream portions when the pressure testing is complete.

After the drilling of the well, the well will typically be filled with a liquid. If the upstream portion is filled with air, it will be buoyant within the well, and this can make it difficult to run the completion string into the well. One solution to this problem may be to fill the completion string with fluid from the top, but such a solution is complex to implement and therefore undesirable. Another solution is to have a separate tool as part of the completion string that allows fluid to flow from the well into the completion string. In this case, debris from the well may enter the completion string and may settle on the plug. Such debris may

cause problems when attempting to remove the plug or may even form a sort of plug itself, resulting in difficulty extracting the hydrocarbon fluid. Debris can also prevent certain mechanisms from working effectively, because it may isolate the mechanism from other parts of the completion string. Such a solution can also be undesirably complex because it introduces multiple different mechanisms and tools into the completion string. Different tools may come from different manufacturers and may not have been designed to be compatible.

SUMMARY

According to an aspect, there is provided a barrier valve device for use in a completion string within a well pipe. The barrier valve device comprises: a housing comprising a wall, the wall defining a bore provided longitudinally through the barrier valve device; a circulation system comprising at least one first opening in the wall for fluid flow between at least a first portion of the bore and outside of the housing and a first valve having a first valve closed configuration for preventing fluid flow through the at least one first opening and a first valve open configuration for permitting fluid flow through the at least one first opening; and a barrier system within the bore comprising a second valve having a second valve closed configuration for preventing longitudinal fluid flow through the bore between the first portion of the bore and a second portion of the bore and a second valve open configuration for permitting longitudinal fluid flow through the bore between the first portion and the second portion. The barrier valve device is configurable in an initial state, an intermediate state, and a final state. In the initial state, the first valve is in the first valve open configuration and the second valve is in the second valve closed configuration. In the intermediate state, the first valve is in the first valve closed configuration and the second valve is in the second valve closed configuration. In the final state, the first valve is in the first valve closed configuration and the second valve is in the second valve open configuration.

A barrier valve device having two separate valves, one for selectively opening the bore and one for selectively allowing circulation of fluid between outside of the housing and the bore, is useful for use in a completion string. Such a device can be run into a well without difficulty because fluid is permitted to flow into the bore from outside of the housing via the at least one first opening in the initial state. When the device is being run

into a well pipe, fluid outside of the housing may be fluid within the well pipe, specifically in an annulus between the well pipe and the device. The device subsequently allows pressure testing of the completion string in the intermediate state, because the bore is sealed by the first valve and by the second valve. Next, the device also allows hydrocarbon flow in its final state because hydrocarbon fluid can flow along the bore without flowing out of the bore because the first valve closes the at least one first opening. The barrier system and circulation system therefore cooperate to provide a device that is useful across the completion and production phases.

Providing a circulation system in addition to a barrier system, and having an initial state in which the first valve of the circulation system is in an open configuration to permit fluid flow into the first portion of the bore, avoids the complex task of needing to fill the completion string, and therefore the first portion of the bore, which would be above the barrier system when the device forms part of the completion string, from above. Accordingly, the process of running the completion string into the well is less complex, and fewer pieces of apparatus are required to perform the running in of the completion string.

Such an arrangement of a circulation system and a barrier system in a single device is also useful in enabling improved circulation within the first portion during the initial state. The circulation system being in the same device may lead to increased debris clearance from the second valve, as the at least one first opening may be closer to the second valve than in systems where circulation is achieved in a different device. Because the opening and circulation system is provided above the second valve within the first portion, in use, debris that settles on the second valve may be better cleared by improving circulation withing the first portion.

The fluid in a well may be more likely to deposit debris, because solids may be suspended in the fluid or the fluid may have dissolved in it material likely to form a deposit on the barrier system. An example of this is Barite, which may deposit as a solid. The device described herein therefore provides better debris clearance in such wells.

Because the circulation system and the barrier system are provided in the same device, the operation of each valve may be coordinated. Providing these systems in the same device also reduces the number of tools required to be combined in a completion string, which

may increase the efficiency of the completion phase and which may increase the chances of failure of part of the completion string.

Furthermore, providing the circulation system and barrier system in the same device avoids a requirement for multiple connections between different tools and the tubing of the completion string. If a circulation system and barrier system were to be provided in separate tools, there would be two tools each having two ends for connecting to tubing. Each tool may require a connector for connecting to the tubing, such as a crossover assembly or an end sub. Each connection between a tool and a connector or between a connector and tubing represents a risk for leaking to occur. By combining the systems into a single tool, the number of connectors required is reduced significantly, thereby reducing the risk of leaking.

Providing a circulation system and barrier system in the same device may also improve testing and/or qualification of the tool, because the testing can be performed together. Accordingly, efficiency is improved during preliminary stages, prior to using the device within a well. Moreover, this can lead to improved reliability because the tools have been tested together, as well as reduced cost and risk.

Fluid flow through the openings may be both from the bore to outside the housing and from outside the housing to the bore. As a result, the device may be used for bullheading as well as for circulation, in which fluid is pumped into the completion tubing when there is an unexpected surge, or ‘kick’, of hydrocarbons into the well. Bullheading involves pumping the fluids out of the openings to outside the housing.

The housing may be a single housing. The wall may comprise a continuous wall. The bore may be defined by a continuous interior surface of the wall. The housing may have an upstream end and a downstream end. The housing may have an upstream connection mechanism at its upstream end for connecting to an upstream portion of a completion string. The housing may have a downstream connection mechanism at its downstream end for connecting to a downstream portion of a completion string.

The terms “upstream”, “upper”, or “above”, and “downstream”, “lower”, or “below” are used herein to define parts of the barrier valve device 10, when the barrier valve device 10 is used in a well. “Upstream”, “upper”, and “above” refer to a position relatively closer to

the well opening and “downstream”, “lower”, and “below” refer to a position relatively further away from the well opening. These terms apply when the well has a vertical orientation, an inclining orientation, or a horizontal orientation.

In use, when the device forms part of a completion string, the first portion of the bore may be an upstream portion and the second portion of the bore may be a downstream portion. In some examples, the first portion of the bore may be a downstream portion and the second portion may be an upstream portion. In these examples, the first valve may be downstream of the second valve. The first and second portions are separated by the second valve, in the second valve closed configuration. The first portion may be to a first side of the second valve. The second portion may be to a second side of the second valve.

In the second valve closed configuration, the second valve may be sealingly engaged with an interior surface of the wall.

The initial state may be referred to as a running or running in state. The intermediate state may be referred to as a pressure testing state. The final state may be referred to as a hydrocarbon production state.

The barrier valve device may be configured to transition from the initial state to the intermediate state in response to a first predetermined pressure change. The barrier valve device may be configured to transition from the intermediate state to the final state in response to a second predetermined pressure change that is different to the first predetermined pressure change.

Utilising two different pressure changes to cause the transitions from state to state ensures that the barrier valve device transitions in the correct way, and that the final state is not reached until it is desired by an operator. Because the circulation system and barrier system are in the same device, the pressure changes can be predetermined and set so that they are not in conflict with one another, making deployment of a completion string more efficient.

The first and second predetermined pressure changes may be referred to as pressure patterns or pressure change patterns.

The first predetermined pressure change may comprise a pressure difference between a fluid in the first portion of the bore and a fluid outside of the housing exceeding a first threshold value.

In other words, the intermediate state may be achieved by increasing a pressure within the bore so that a relative pressure is achieved. The pressure difference may be expressed as being a pressure difference between an interior of the device and an exterior of the device.

The second predetermined pressure change may comprise a predetermined number of pressure cycles within the first portion of the bore, the predetermined number of pressure cycles being greater than 1.

Utilising a pressure difference and pressure cycling for different valves that are desired to operate sequentially reduces the likelihood that the second valve may be accidentally operated. Furthermore, especially where pressure testing is to be performed, the predetermined pressure changes can form part of an overall pressure specification to be performed by an operator, and that can be provided with the device. Such a specification may allow an operator to efficiently transition the device to the intermediate state, perform pressure testing, and subsequently transition to the final state. Accordingly, the device makes such pressure testing more efficient.

Each pressure cycle may include cycling the pressure above and below a second threshold value. The second predetermined threshold value may be equal to the first threshold value or may be greater than the first threshold value.

Alternatively, the second predetermined pressure change may comprise a pressure within the first portion of the bore exceeding a second threshold value, wherein the second threshold value is greater than the first threshold value.

The barrier system may comprise a pressure cycling mechanism configured to transition the second valve from the second valve closed configuration to the second valve open configuration in response to the predetermined number of pressure cycles being performed. The barrier system may comprise an electronic system configured to transition the second valve from the second valve closed configuration to the second valve open configuration. The electronic system may comprise one or more sensors configured to sense the second

predetermined pressure change and one or more actuators that are to be controlled to perform said transition in response to said sensors sensing the second predetermined pressure change.

A pressure cycling mechanism may prevent the second valve from opening unexpectedly for example due to one single intentional or unintentional pressure increase.

The first valve may comprise a piston configured to close the at least one first opening upon the pressure difference exceeding the first predetermined threshold value.

A piston may be defined as a feature that moves in a predetermined way in response to a force differential on two opposing parts or surfaces of the piston. The force differential may be caused by the pressure difference. A force acting on a first part of the piston, within the bore, said force being due to fluid pressure in the bore, may be larger than an opposing force acting on a second part of the piston, said opposing force being due to fluid pressure in the well pipe. Accordingly, the piston may move in the direction of the force from the fluid in the bore.

The piston may be provided at least partially within the bore.

The piston may be configured to move towards the second valve to close the at least one first opening. The piston may be configured to move downwardly to close the at least one first opening.

The piston may comprise at least a first piston surface within the first portion of the bore and at least a second piston surface in fluid communication with an exterior of the housing via a fluid inlet in the housing.

Such an arrangement of piston surfaces may enable movement of the piston in response to said pressure difference. The first piston surface may be at an oblique angle relative to a longitudinal axis of the bore.

The housing may comprise a plurality of fluid inlets. The fluid inlet may connect to a chamber within the housing. The chamber may be bounded by the housing, the second piston surface and the piston.

The piston may comprise a piston sleeve having at least one second opening, wherein, in the first valve open configuration, the at least one second opening is aligned with the at least one first opening, and wherein, in the first valve closed configuration, the at least one second opening is misaligned with the at least one first opening. A wall of the piston sleeve may be aligned with the at least one first opening in the first valve closed configuration to form a seal that prevents fluid flow from the bore to outside of the housing through the first opening.

The second opening may match the at least one first opening. In other words, the second opening may have a cross-section that is the same as a cross-section of the first opening. By aligning the first and second opening, fluid may flow through the first and second openings to allow fluid flow between the bore and the well pipe. When the second opening and first opening are misaligned, a portion of the piston sleeve may be aligned with the first opening, and that portion may seal the first opening, preventing fluid flow through it.

The circulation system may comprise a plurality of first openings, and the piston sleeve may comprise a corresponding plurality of second openings. Each second opening may align with a corresponding one of the plurality of first openings in the first valve open configuration.

The first piston surface may be formed by an end surface of the piston sleeve exposed to the pressure of the through bore. The second piston surface may be formed by an edge on the outwardly facing surface of the piston sleeve.

The circulation system may comprise a flow restriction that restricts fluid flow through the at least one first opening from the first portion of the bore to outside of the housing.

Restricting fluid flow may enable a pressure difference to be formed between the bore and outside the housing to cause transition from the initial to the intermediate state. The pressure difference may be achieved using the flow restriction by increasing a fluid flow rate into the bore or within the bore.

The flow restriction may comprise a nozzle. The nozzle may be provided within the at least one first opening. Where the circulation system comprises a plurality of first openings, a plurality of nozzles may be provided, with a nozzle being provided in each first opening.

Alternatively, the nozzle may be provided within a second opening within the piston sleeve.

The flow restriction may restrict fluid flow through the at least one first opening just from the bore to the well pipe. This may allow better circulation of fluid from the well pipe to the bore, for debris clearance. The flow restriction may provide a greater restriction to fluid flow through the at least one first opening from the bore to the well pipe than from the well pipe to the bore.

Alternatively, the flow restriction may be formed by the first and second openings. The flow restriction may be formed by a difference in a diameter of the first and second openings.

The flow restriction may be removeable from outside the housing for replacement by a different flow restriction that restricts the fluid flow through the at least one first opening by a different amount.

Being able to remove and replace a flow restriction, such as a nozzle, enables onsite variation of the properties of the device. It may be desirable to be able to vary the fluid flow rate into the bore that causes the transition from the initial to the intermediate state, and providing a replaceable flow restriction enables this to be performed onsite.

The circulation system may comprise at least one shear mechanism that prevents the first valve transitioning from the first valve open configuration to the first valve closed configuration until the pressure difference exceeds the first predetermined threshold value.

The at least one shear mechanism may comprise a shear pin, a shear screw, or a shear ring. The shear mechanism may be connected to or may support the piston sleeve or piston. The at least one shear mechanism may shear when the first predetermined threshold value is exceeded. The at least one shear mechanism may comprise a dissolvable shear mechanism. The shear mechanism may dissolve when a dissolving fluid is provided within the bore. The shear mechanism may be accessible from outside the device via an aperture in the housing. The shear mechanism may be adjustable to vary the first predetermined threshold value. The shear mechanism may be provided upstream of the first and second openings. The shear mechanism may be supported by the housing and may interface with a part of

the piston sleeve. The shear mechanism may be provided downstream of the first and second openings. The shear mechanism may be provided downstream of the piston sleeve. The shear mechanism may be supported by the housing and interface with part of the piston sleeve or may be connected to the piston sleeve and interface with part of the housing.

The first valve may comprise, within the first portion of the bore, a ball seat for receiving a drop ball.

When a drop ball is dropped into the bore it may travel along the bore to the ball seat. The ball seat may restrict a diameter of the bore. The drop ball may have a diameter that is less than the bore but greater than the ball seat, meaning that it will sit in the ball seat. The drop ball may be used to move the first valve from the first valve open configuration to the first valve closed configuration. A pressure within the bore above the drop ball can be increased. Such an increase in pressure may cause a force to be applied by the drop ball to the ball seat. As the force on the ball seat may exceed a force applied to the first valve elsewhere, the first valve may be moved into the first valve closed configuration. Where the first valve comprises a piston, increasing a pressure above a drop ball may cause a pressure difference between fluid in the bore and fluid in the well pipe, and may therefore cause the piston to close the at least one first opening. Where the piston has a first piston surface and a second piston surface, the force applied to the ball seat may exceed the opposing force applied to the second piston surface by fluid in the well pipe entering the fluid inlet, and the piston may therefore be allowed to move in the direction of the force. The force may be sufficient to shear a shear mechanism to allow movement of the valve.

The first valve may also be moved from the first valve open configuration to the first valve closed configuration using a tool that is lowered down the bore and engages with the first valve. The piston or sleeve may comprise a tool interface for engaging with the tool for moving the first valve from the first valve open configuration to the first valve closed configuration.

The first valve may comprise a locking mechanism for locking the first valve in the first valve closed configuration when the barrier valve device transitions from the initial state to the intermediate state.

In the first valve open configuration, the first valve may be unlocked by the locking mechanism. The first valve may be maintained in position in the first valve open configuration by the shear mechanism. In the first valve closed configuration, the first valve may be locked by the locking mechanism. When locked by the locking mechanism movement of the first valve from the first valve closed configuration to the first valve open configuration may be prevented. When locked by the locking mechanism any movement of the first valve from the first valve closed configuration may be prevented.

The locking mechanism may comprise a C-ring configured to be received by part of the first valve. Where the first valve comprises a piston sleeve, the C-ring may surround the piston sleeve. The piston sleeve may comprise a corresponding groove, recess, or profile for receiving the C-ring. In the first valve open configuration, the C-ring may be in an expanded state and in the first valve closed configuration, the C-ring may be in a retracted state, in which it is seated in the groove. Alternatively, in the first valve open configuration, the C-ring may be in a retracted or compressed state, in which it is seated in the groove, and in the first valve closed configuration the C-ring may be in an expanded state. The locking mechanism may be provided upstream or downstream of the first and second openings.

The second valve may comprise a frangible barrier. The second valve may comprise a disintegration device for disintegrating the frangible barrier. The disintegration device may comprise one or more knives. The second valve may comprise one or more sealing elements for sealing the frangible barrier against the wall. The sealing elements may comprise O-rings. The second valve may comprise one or more support elements for supporting the frangible barrier within the bore. The second valve may comprise a device for dislodging the frangible barrier towards the disintegration device. The device may be connected to the pressure cycling mechanism.

The at least one first opening may have a first longitudinal position along the device. The second valve may have a second longitudinal position along the device. A distance between the first longitudinal position and the second longitudinal position may be less than 2 metres.

The distance may be less than 1 metre, less than 0.9 metres, less than 0.8 metres, less than 0.7 metres, less than 0.6 metres, or less than 0.5 metres. The first longitudinal position may

be measured as a longitudinal position of a centre of the at least one first opening. The second longitudinal position may be measured as a longitudinal position of an upstream side of the second valve. Having a short distance between the opening and the second valve may provide enhanced circulation of fluid within the bore and therefore enhanced debris clearance from the second valve.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a longitudinal cross-sectional view of a barrier valve device when the barrier valve device is in an initial state within a well pipe.

Fig. 2 is a detail of a circulation system of the barrier valve device when the barrier valve device is in the initial state.

Fig. 3 is a longitudinal cross-sectional view of the barrier valve device when the barrier valve device is in the initial state within the well pipe, the barrier valve device having a ball in a ball seat.

Fig. 4 is a detail of a barrier system of the barrier valve device when the barrier valve device is in the initial state.

Fig. 5 is a longitudinal cross-sectional view of the barrier valve device when the barrier valve device is in an intermediate state within the well pipe.

Fig. 6 is a detail of the circulation system of the barrier valve device when the barrier valve device is in the intermediate state.

Fig. 7 is a longitudinal cross-sectional view of the barrier valve device when the barrier valve device is in a final state within the well pipe.

Fig. 8 is a detail of the barrier system of the barrier valve device when the barrier valve device is in the final state.

Fig. 9 is a longitudinal cross-sectional view of a further barrier valve device.

Fig. 10 is a detail of a circulation system of the further barrier valve device when the further barrier valve device is in the initial state.

DETAILED DESCRIPTION

Fig. 1 shows a barrier valve device 10 in a well pipe WP. The barrier valve device 10 and the well pipe WP are depicted as longitudinal cross sections, so that internal features of the barrier valve device 10 can be seen. The well pipe WP has a larger diameter than the barrier valve device 10 and an annulus WA is defined between the barrier valve device 10 and the well pipe WP.

The barrier valve device 10 includes a housing 11. The housing 11 has a wall 13 that defines a bore 12. The wall 13 may be formed of one or more interconnected sections. The bore 12 extends through the housing 11 and the barrier valve device 10 longitudinally, along a longitudinal axis LA of the barrier valve device 10. Fluid can therefore flow along the barrier valve device 10 through the housing 11 from a first, upstream end 14 of the device 10 to a second, downstream end 15 of the barrier valve device 10. Although not visible in Fig. 1, the upstream end 14 and the downstream end 15 each connect the barrier valve device 10 to other parts of a completion string within the well pipe WP.

The barrier valve device 10 has a circulation system 20 and a barrier system 30. The barrier system 30 is provided to control fluid flow along the bore 12, between a first portion 18 of the bore 12 and a second portion 19 of the bore 12. The circulation system 20 is in the first portion 18 of the bore 12, and is provided to control fluid to flow between outside the housing 11 and the bore 12.When in a well pipe WP, such as in Fig. 1, fluid outside of the housing 11 will be in the annulus WA, and fluid flow will be between the annulus WA and the bore 12.

The circulation system 20, a part A of which can be seen enlarged in Fig. 2, includes a plurality of first openings 21 in the housing 11 for permitting said fluid flow. The first openings 21 are through the wall 13 of the housing 11 and are distributed around a circumference of the housing 11. A flow restriction 40 in the form of a nozzle is provided in each first opening 21. The nozzles restrict fluid flow through their respective first openings 21, specifically for fluid flowing from the bore 12 to outside of the housing 11, i.e. into the annulus WA. The nozzles are removeable from the housing 11 when the barrier valve device 10 is outside the well pipe WP. The nozzles are removeable from outside the housing 11. This may allow for replacement by a different nozzle or flow restriction that restricts the fluid flow through the at least one first opening by a different amount.

The circulation system 20 also includes a first valve 22. The first valve 22 is provided to selectively allow fluid to flow through the first openings 21. The first valve 22 includes a piston 23. The piston 23 has a piston sleeve 24 provided within the bore 12. The piston sleeve 24 has a plurality of second openings 25, which are aligned with corresponding openings of the plurality of first openings 21 in Figs. 1 and 2. The second openings 25 allow fluid flow through the first openings 21 between the bore 12 and the annulus WA.

The first valve 22 can have one of two configurations. In Figs. 1 and 2, the first valve 22 has a first valve open configuration. This may be referred to as the first valve 22 being open. In the first valve open configuration, the second openings 25 are aligned with corresponding first openings 21, to allow fluid to flow between the bore 12 and the annulus WA. The first valve 22 may be moved into a first valve closed configuration, which is shown and described in relation to Figs. 5 to 7 below. This may be described as the first valve 22 being closed. In the first valve closed configuration, the piston sleeve 24 is positioned further along the bore 12 than in the first valve open configuration, so that the second openings 25 do not align with the first openings 21. Because the second openings 25 are misaligned with the first openings 21, fluid is prevented from flowing through the first openings 21 and into the bore 12 or from the bore 12 to the annulus WA.

To move the first valve 22 from its first valve open configuration to its first valve closed configuration, the piston sleeve 24 is moved along the bore 12 so that the second openings 25 no longer align with the first openings 21. In the example shown in the Figures, this can be achieved by one of three mechanisms. In other examples only a subset of these mechanisms may be used or more mechanisms may be provided.

In a first mechanism, the piston 23 may be activated to move the piston sleeve 24 along the bore 12 based on a first predetermined pressure change. The piston 23 includes the piston sleeve 24 as well as a fluid inlet 29 that is in fluid communication with outside of the housing 11. The piston sleeve 24 has a first piston surface 27 and a second piston surface 28.

The first piston surface 27 is provided within the first portion 18 of the bore 12 at an upper, interior edge of the piston sleeve 24. As can be best seen in Fig. 2, the first piston surface 27 is slanted or tapered towards the wall 13, and faces upwardly towards the upstream end 14. The first piston surface 27 is therefore in fluid communication with fluid in the bore

12. By the orientation and position of the first piston surface 27, pressure within the bore 12 creates a force acting downwardly on the first piston surface 27 and therefore on the piston sleeve 24.

The second piston surface 28 is provided on an outside of the piston sleeve 24 and faces downstream towards the downstream end 15 of the barrier valve device 10. The second piston surface 28 is provided within a volume 16 that receives fluid from outside of the housing 11 via the fluid inlet 29. The volume 16 extends downwardly away from the second piston surface 28 and is long enough that the piston sleeve 24 can move downwardly to misalign the second openings 25 with the first openings 21. Accordingly, by the position of the second piston surface 28 in the volume 16 and the orientation of the second piston surface 28 down towards the volume 16, pressure from the annulus WA, outside the housing 11, and therefore in the fluid inlet 29 and the volume 16, creates a force acting upwardly on the second piston surface 28 and therefore the piston sleeve 24.

When there is a difference in the forces acting on the first piston surface 27 and the second piston surface 28, a net force acts on the piston sleeve 24. Force on the first piston surface 27 and the second piston surface 28 is dependent on a pressure of fluid acting on those surfaces and a surface area of those surfaces. As the respective surface areas of the first piston surface 27 and the second piston surface 28 are constant, relative changes in the pressures within and outside the housing 11 can cause changes in the net force acting on the piston sleeve 24.

The circulation system 20 also includes a shear mechanism 70, in the form of a shear pin 71. The shear mechanism 70 is connected to or provided beneath the piston sleeve 24. When a predetermined downward net force is acting on the piston sleeve 24, the shear mechanism 70 shears and the piston sleeve 24 is allowed to move downwardly in the bore 12 under the action of the force. The predetermined force can be achieved by creating a predetermine pressure difference between pressures inside and outside the housing 11. A difference in pressures can be achieved by increasing a fluid flow rate within the bore 12, because the nozzles restrict flow out of the first openings 21, and therefore pressure within the bore 12 rises, increasing the force on the first piston surface 27 at a different rate to an increase in force on the second piston surface 28.

The circulation system 20 also includes a locking mechanism 80, in the form of a C-ring 81 that is expanded when the first valve 22 is in its first valve open configuration, and that is unexpanded and fits into a recess 82 of the piston sleeve 24 when the piston sleeve 24 is moved downwardly into the first valve closed configuration. The C-ring 81 prevents further movement of the piston sleeve 24 along the bore 12, thereby locking it in place.

According to a second mechanism, the first valve 22 may be moved between its configurations by dropping a drop ball 61 that is dropped into a ball seat 60. The ball seat 60 is connected to the piston sleeve 24, and comprises a ring within the bore 12. The ring has a diameter that is smaller than that of the drop ball 61, so that the drop ball 61 cannot progress beyond it when travelling along the bore 12. The drop ball 61 engages with the ball seat 60 and creates a seal or partial seal. Increasing a pressure of fluid above the drop ball 61 creates a pressure differential between the ball seat 60 and another part of the first valve 22, in this case the second piston surface 28. Accordingly, a net force is achieved, and once, the force required to shear the shear mechanism 70 is reached, the piston sleeve 24 will move downwardly.

A third mechanism is provided in which the piston sleeve 24 comprises a tool interface 26 for receiving a tool (not shown) that is lowered down the bore 12. The tool engages with the tool interface 26 to apply a force that moves the piston sleeve 24 downwardly within the bore, thereby moving the first valve 22 from the first valve open configuration to the first valve closed configuration.

Now consulting Fig. 1 and Fig. 4, which shows a part B of the barrier valve device 10 enlarged, the barrier system 30 comprises a second valve 32. The second valve 32 is provided within the bore 12, and separates the bore 12 into the first portion 18, which is to an upstream side of the second valve 32, and the second portion 19, which is to a downstream side of the second valve 32. The second valve 32, like the first valve 22, has two configurations. In a second valve closed configuration, which is shown in Figs. 1 and 4, fluid flow between the first portion 18 and the second portion 19 longitudinally along the bore 12 is prevented by the second valve 32. This may be referred to as the second valve 32 being closed, or the bore 12 being closed by the second valve 32. In a second valve open configuration, described in relation to Figures 5 and 7 to 8, fluid flow longitudinally along the bore 12 between the first portion 18 and the second portion 19 is

permitted by the second valve 32. This may be referred to as the second valve 32 being open, or the bore 12 being opened by the second valve 32.

The second valve 32 includes a frangible barrier 33, here provided in the form of a glass plug. The frangible barrier 33 is surrounded by sealing rings 35 to sealingly engage the wall 13, thereby preventing fluid flow. The frangible barrier 33 is supported between an upper support 36 and a lower support 37. The barrier system includes a pressure cycling mechanism 39. When a second predetermined pressure change is achieved, which is different to the first predetermined pressure change used for moving the piston sleeve 24, the pressure cycling mechanism 39 activates to open the second valve 32. The frangible barrier 33 is dislodged from its sealing engagement by removing the lower support 37 by the pressure cycling mechanism 39, and the frangible barrier 33 therefore moves downwardly within the bore 12. The downward movement of the frangible barrier 33 brings it towards a disintegration device 34, which may be in the form of one or more knives. When the frangible barrier 33 comes into contact with the disintegration device 34, it disintegrates, thereby allowing fluid flow along the bore 12.

The second predetermined pressure change is a predetermined number of pressure cycles greater than 1, in which a pressure in the first portion 18 of the bore 12 exceeds a threshold value.

In Fig. 1, the barrier valve device 10 is shown in a first or initial state. The initial state is the state the barrier valve device 10 is in when it is run into the well pipe WP as part of a completion string. In the initial state, the first valve 22 is in the first valve open configuration and the second valve 32 is in the second valve closed configuration. Accordingly, fluid can flow between the annulus WA and the first portion 18, but is prevented from flowing between the first portion 18 and the second portion 19.

Fig. 5 shows the barrier valve device 10, again in a longitudinal cross-section and within the well pipe WP, in a second or intermediate state. The barrier valve device 10 has been transitioned from the initial state to the intermediate state. The barrier valve device 10 is transitioned from the initial state to the intermediate state to allow for testing of the completion string once it is in the correct place within the well pipe WP, and specifically pressure testing of the completion string.

In the intermediate state, the first valve 22 is in the first valve closed configuration and the second valve 32 is in the second valve closed configuration. As can be seen in Fig. 5, and Fig. 6, which shows the part A of the barrier valve device 10 to provide more detail of the first valve 22 in its first valve closed configuration, the piston sleeve 24 has moved longitudinally downwardly within the bore 12 from its position in the initial state shown in Figs. 1 and 2. As a result, the second openings 25 no longer align with the first openings 21, and instead the first openings 21 are blocked by the piston sleeve 24, thereby preventing fluid flow between the annulus WA and the bore 12.

As can be best seen in Fig. 6, by movement of the piston sleeve 24 downwardly, the C-ring 81 has engaged the recess 82, thereby locking it in place. The C-ring 81 abuts the recess 82 and a corresponding groove 83 in the housing 11, to prevent the piston sleeve 24 from moving relative to the groove 83.

The second valve 32 remains closed, as in the initial state, so that longitudinal fluid flow along the bore 12 between the first portion 18 and the second portion 19 is still prevented.

Fig. 7 shows the barrier valve device 10, again in a longitudinal cross-section and within the well pipe WP, in a third or final state. The barrier valve device 10 has been transitioned from the intermediate state to the final state. The barrier valve device 10 is transitioned from the intermediate state to the final state to allow for hydrocarbon fluid to be extracted from the well.

In the final state, the first valve 22 is in the first valve open configuration and the second valve 32 is in the second valve closed configuration. The first valve 22 is locked into its first valve open configuration in the intermediate state, and so cannot transition back to the first valve closed configuration. Accordingly, the first valve 22 is in the same state in Fig. 7 as it was in Figs. 5 and 6.

The second valve 32 has been moved from the second valve open configuration in the intermediate state to the second valve closed configuration in the final state. The second valve closed configuration is achieved by activating the pressure cycling mechanism 39 to remove the lower support 37 from supporting the frangible barrier 33, resulting in the frangible barrier 33 moving into engagement with a disintegration device 34 and

disintegrating. Fig. 8 illustrates the part B of the barrier valve device 10 enlarged, so that the open second valve 32 can be seen in greater detail.

As a result of the second valve 32 being in its second valve open configuration in the final state of the barrier valve device 10, fluid can flow longitudinally along the bore 12 from the second portion 19 to the first portion 18. Fluid cannot leak into the annulus WA, because the first valve 22 remains in its first valve closed configuration.

Fig. 9 shows a further barrier valve device 110 in a well pipe WP. The further barrier valve device 110 and the well pipe WP are depicted as longitudinal cross sections, so that internal features of the further barrier valve device 110 can be seen. The well pipe WP has a larger diameter than the barrier valve device 110 and an annulus WA is defined between the further barrier valve device 110 and the well pipe WP.

Like the barrier valve device 10 described in relation to Figs. 1 to 8 above, the further barrier valve device 110 includes a circulation system 120, which controls fluid flow between the outside of a housing 111 of the further barrier valve device 110 and a bore 112 within the further barrier valve device 110 as defined by a wall 113 of the housing 111, and a barrier system 30, which controls fluid flow along the bore 112. The barrier system 30 is the same and operates in the same way as the barrier system 30 provided in the barrier valve device 10 of Figs. 1 to 8 and so will not be described further. The circulation system 120 differs by the placement of its shear mechanism and locking mechanism and is described in more detail below in relation to Fig. 10.

Fig. 10 shows an enlargement of a part C of the further barrier valve device 110 as indicated in Fig. 9. The part C shows a longitudinal cross section of part of the circulation system 120 of the further barrier valve device 110. The housing 111 of the further barrier valve device 110 and the wall 113 that defines the bore 112 (not shown in Fig. 10) are shown in Fig. 10.

The circulation system 120 comprises a plurality of first openings 21 in the housing 111 for permitting said fluid flow from outside of the housing 111 into the bore 112. The first openings 21 are through the wall 113 of the housing 111 and are distributed around a circumference of the housing 111. A flow restriction 40 in the form of a nozzle is provided in each first opening 21.

The circulation system 120 also includes a first valve 122 to selectively allow fluid to flow through the first openings 121. The first valve 122 includes a piston 123. The piston 123 has a piston sleeve 124 provided within the bore 112. The piston sleeve 124 has a plurality of second openings 25, which are aligned with corresponding openings of the plurality of first openings 121 in these figures, which show a first valve open configuration, and which allow fluid flow through the first openings 121 between the bore 112 and the annulus WA.

The first valve 122 is configured to move between the first valve open configuration and the first valve closed configuration as described above under one of the mechanisms described. The first valve 122 also has a first piston surface 27, a second piston surface 28, a volume 16 for receiving fluid from outside the housing and a fluid inlet 29. The piston surfaces 27, 28, volume 16, fluid inlet 29, openings 21, 25 and flow restrictions 40 have the same functions and arrangements as in the barrier valve device 10 described above, and hence have the same reference signs.

The circulation system 20 includes a shear mechanism 170 that includes at least one shear screw 171 provided within a shear screw aperture 172. The shear screw 171 interfaces with the piston sleeve 124 at a shear screw interface 173 of the piston sleeve 124. The shear screw 171 is therefore unattached to the piston sleeve 124, and instead is provided within the housing 111. The shear screw 171 can be accessed and adjusted via the shear screw aperture 172 to enable variation of the net downward force required to move the piston sleeve 124 prior to deployment of the device 110.

The shear mechanism 170 in this example differs from the shear mechanism 70 described above as it is provided to interface with part of the piston sleeve 124 rather than being beneath the piston sleeve, it is a shear screw which allows for variation of the shear force required, and it is provided further up within the device 110 and particularly above the openings 21, 25 which may reduce being and compression forces through the sleeve for shearing. Although a shear screw is shown in this example and a shear pin in the previous example, the type of shear mechanism may be varied and does not depend on position. In other words, a shear pin or other shear mechanism may also be used in the position of the shear mechanism 170 and a shear screw or other shear mechanism may be used in the position of the shear mechanism 70.

The circulation system 120 also includes a locking mechanism 180, in the form of a C-ring 181. The C-ring 181 is compressed and fits into a recess 182 in the piston sleeve 124 when the first valve 122 is in its first valve open configuration. When the first valve 122 moves to the first valve closed configuration, the C-ring 181 is also moved downwardly within the recess 182 and expands outwardly to fit beneath a C-ring interface 183 formed by the housing 111. As the C-ring 181 is then expanded, and so prevents further movement of the piston sleeve 124 along the bore 112, thereby locking it in place. Providing the C-ring 181 above the openings 21, 25 again transfers forces differently through the piston sleeve, limiting buckling and compression forces on a majority of the sleeve.

Although not shown in these Figures, in some examples the first valve may be provided below the second valve.

LIST OF REFERENCE NUMBERS

10	Barrier valve device
11	Housing
12	Bore
13	Wall, of the housing
14	Upstream end of the barrier valve device
15	Downstream end of the barrier valve device
16	Volume, in housing, for receiving fluid from outside of housing
18	First portion of the bore
19	Second portion of the bore
20	Circulation system
21	First opening, in the housing
22	First valve
23	Piston
24	Piston sleeve
25	Second opening, in the piston sleeve
26	Tool interface
27	First piston surface
28	Second piston surface
29	Fluid inlet

30	Barrier system
32	Second valve
33	Frangible barrier
34	Disintegration device
35	Sealing rings
36	Upper support, for the frangible barrier
37	Lower support, for the frangible barrier
39	Pressure cycling mechanism
40	Flow restriction
60	Ball seat
61	Drop ball
70	Shear mechanism
71	Shear pin
80	Locking mechanism
81	C-ring, of locking mechanism
82	Recess for the C-ring, in the piston sleeve,
83	Groove for the C-ring, in the housing
110	Further barrier valve device
111	Housing
112	Bore
113	Wall, of the housing
116	Volume, in housing, for receiving fluid from outside of housing
120	Circulation system
121	First opening, in the housing
122	First valve
124	Piston sleeve
125	Second opening, in the piston sleeve
127	First piston surface
128	Second piston surface
129	Fluid inlet
140	Flow restriction
170	Shear mechanism
171	Shear screws

172	Shear screw aperture
173	Shear screw interface
180	Locking mechanism
181	C-ring, of locking mechanism
182	Recess for the C-ring, in the piston-sleeve
183	C-ring interface
LA	Longitudinal axis of the barrier valve device
WP	Well pipe
WA	Annulus

CLAIMS

1. A barrier valve device (10) for use in a completion string within a well pipe (WP), the barrier valve device (10) comprising:

a housing (11) comprising a wall (13), the wall (13) defining a bore (12) provided longitudinally through the barrier valve device (10);

a circulation system (20) comprising at least one first opening (21) in the wall (13) for fluid flow between at least a first portion (18) of the bore (12) and outside of the housing (11) and a first valve (22) having a first valve closed configuration for preventing fluid flow through the at least one first opening (21) and a first valve open configuration for permitting fluid flow through the at least one first opening (21);

a barrier system (30) within the bore (12) comprising a second valve (32) having a second valve closed configuration for preventing longitudinal fluid flow through the bore (12) between the first portion (18) of the bore (12) and a second portion (19) of the bore (12) and a second valve open configuration for permitting longitudinal fluid flow through the bore (12) between the first portion (18) and the second portion (19); and

wherein the barrier valve device (10) is configurable in an initial state, an intermediate state, and a final state, wherein:

in the initial state, the first valve (22) is in the first valve open configuration and the second valve (32) is in the second valve closed configuration;

in the intermediate state, the first valve (22) is in the first valve closed configuration and the second valve (32) is in the second valve closed configuration; and

in the final state, the first valve (22) is in the first valve closed configuration and the second valve (32) is in the second valve open configuration.

2. The barrier valve device (10) of claim 1, wherein the barrier valve device (10) is configured to transition from the initial state to the intermediate state in response to a first predetermined pressure change, and wherein the barrier valve device (10) is configured to transition from the intermediate state to the final state in response to a second predetermined pressure change that is different to the first predetermined pressure change.

3. The barrier valve device (10) of claim 2, wherein the first predetermined pressure change comprises a pressure difference between a fluid in the first portion (18) of the bore (12) and a fluid outside of the housing (11) exceeding a first threshold value.

4. The barrier valve device (10) of claim 3, wherein the second predetermined pressure change comprises a predetermined number of pressure cycles within the first portion (18) of the bore (12), the predetermined number of pressure cycles being greater than 1.

5. The barrier valve device (10) of claim 3 or claim 4, wherein the first valve (22) comprises a piston (23) configured to close the at least one first opening (21) upon the pressure difference exceeding the first predetermined threshold value.

6. The barrier valve device (10) of claim 5, wherein the piston (23) comprises at least a first piston surface (27) within the first portion (18) of the bore (12) and at least a second piston surface (28) in fluid communication with an exterior of the housing (11) via a fluid inlet (29) in the housing (11).

7. The barrier valve device (10) of claim 5 or claim 6, wherein the piston (23) comprises a piston sleeve (24) having at least one second opening (25), wherein, in the first valve open configuration, the at least one second opening (25) is aligned with the at least one first opening (21), and wherein, in the first valve closed configuration, the at least one second opening (25) is misaligned with the at least one first opening (21).

8. The barrier valve device (10) of any of claims 3 to 7, wherein the circulation system (20) comprises a flow restriction (40) that restricts fluid flow through the at least one first opening (21) from the first portion (18) of the bore (12) to outside of the housing (11).

9. The barrier valve device of claim 8, wherein the flow restriction (40) is removeable from outside the housing (11) for replacement by a different flow restriction (40) that restricts the fluid flow through the at least one first opening (21) by a different amount.

10. The barrier valve device (10) of any of claims 3 to 9, wherein the circulation system (20) comprises at least one shear mechanism (70) that prevents the first valve (22) transitioning from the first valve open configuration to the first valve closed configuration until the pressure difference exceeds the first predetermined threshold value.

11. The barrier valve device (10) of any preceding claim, wherein the first valve (22) comprises, within the first portion (18) of the bore (12), a ball seat (60) for receiving a drop ball (61).

12. The barrier valve device (10) of any preceding claim, wherein the first valve (22) comprises a locking mechanism (80) for locking the first valve (22) in the first valve closed configuration when the barrier valve device (10) transitions from the initial state to the intermediate state.

13. The barrier valve device (10) of any preceding claim, wherein the second valve (32) comprises a frangible barrier (33).

14. The barrier valve device (10) of any preceding claim, wherein the at least one first opening (21) has a first longitudinal position along the barrier valve device (10) and the second valve (32) has a second longitudinal position along the barrier valve device (10), and wherein a distance between the first longitudinal position and the second longitudinal position is less than 2 metres.