WHAT IS CLAIMED IS:

1. A drill string valve configured to be attached to a casing for connecting a drill to a rig, the drill string valve comprising:

an elongated housing having an inside cavity, the housing extending along an axis and having a substantially constant outer diameter;

a seal element attached to a first end of the elongated housing, the seal element having an outer diameter smaller than an inner diameter of the elongated housing, and the seal element being disposed within the inside cavity such that a flow of liquid through the inside cavity from the first end to a second end of the elongated housing is allowed;

a sliding valve disposed within the inside cavity and configured to slide to and from the seal element along the axis such that when the sliding valve contacts the seal element the flow of liquid is suppressed;

a biasing cartridge disposed within the inside cavity, between the seal element and the second end of the elongated housing, and configured to apply a first force on the sliding valve such that the sliding valve is contacting the seal element; and

a loading mechanism disposed within the inside cavity, between the biasing cartridge and the second end of the elongated housing, and configured to apply a second force on the biasing cartridge.

2. The drill string valve of Claim 1, wherein the biasing cartridge is disposed inside a biasing chamber configured to be filled with oil.

3. The drill string valve of Claim 2, wherein the biasing cartridge comprises:

a sliding collar configured to slide inside the biasing chamber and to contact the sliding valve, wherein a face of a projection part of the sliding collar extends substantially parallel to a face of the seal element; and

a wave spring provided within the biasing chamber and configured to apply the first force on the sliding collar.

4. The drill string valve of Claim 3, wherein the wave spring is different from a coil spring.

5. The drill string valve of Claim 1, wherein the loading mechanism comprises:

a loading chamber having a pressure port;

a hydraulic piston provided in the loading chamber and configured to act on a spacer element configured to sealingly separate the biasing cartridge from the loading mechanism, the hydraulic piston being configured to move when a fluid under a pressure enters the pressure port; and

a stop element configured to engage and fix the spacer element after the pressure is removed from the loading chamber.

6. The drill string valve of Claim 1, further comprising:

a compensating chamber formed between the loading mechanism and the second end of the elongated housing and configured to communicate with an exterior of the drill string valve; and

a compensating piston provided inside the compensating chamber and configured to receive an annulus pressure from the exterior of the drill string valve.

7. The drill string valve of Claim 1, wherein the sliding element and the seal element are configured, when closed, to withstand pressures between around 5,000 and around 30,000 psi.

8. A method for preparing a drill string valve to be connected to a casing for connecting a drill to a rig, the method comprising:

connecting a power source to a port of a biasing cartridge of the drill string valve, the drill string valve including (i) an elongated housing having an inside cavity, the housing extending along an axis and having a substantially constant outer diameter, (ii) a seal element attached to a first end of the elongated housing, the seal element having an outer diameter smaller than an inner diameter of the elongated housing, and the seal element being disposed within the inside cavity such that a flow of liquid through the inside cavity from the first end to a second end of the elongated housing is allowed, (iii) a sliding valve disposed within the inside cavity and configured to slide to and from the seal element along the axis such that when the sliding valve contacts the seal element the flow of liquid is suppressed, and (iv) a biasing cartridge disposed within the inside

cavity, between the seal element and the second end of the elongated housing and configured to apply a first force on the sliding valve such that the sliding valve is contacting the seal element, and (v) a loading mechanism disposed within the inside cavity, between the biasing cartridge and the second end of the elongated housing, and configured to apply a second force on the biasing cartridge;

applying a pressure to the loading mechanism to generate the second force;

compressing a wave spring of the biasing cartridge;

locking a stop element to maintain the wave spring in a compressed state; and

releasing the applied pressure.

9. A drill string valve configured to be attached to a casing for connecting a drill to a rig, the drill string valve comprising:

an elongated housing having an inside cavity, the housing extending along an axis;

a motor module disposed within the inside cavity;

a seal element connected to the motor module and configured to move within the inside cavity along the axis;

a seat disposed within the inside cavity and configured to receive the seal element to interrupt a fluid flow through the drill string valve when the seat touches the seal element; and

a control element disposed within the inside cavity and configured to control a closing and opening of the seal element.

10. The drill string valve of Claim 9, wherein the motor module comprises:

a motor; and

a connection element configured to connect the motor to the seal element and configured to extend or retract under an action of the motor such that the seal element closes or opens.

11. The drill string valve of Claim 10, wherein the connection element comprises:

a ball screw connected to the motor, the ball screw being configured to translate rotational motion from the motor to linear motion of a ball nut; and

an actuation rod connected between the ball screw and the seal element and configured to apply the linear motion to the seal element.

12. The drill string valve of Claim 10, wherein a pressure around the connection element is maintained substantially equal to an annulus pressure outside the drill string valve.

13. The drill string valve of Claim 9, wherein the control element comprises:

first and second pressure sensors disposed within the inside cavity and configured to measure first and second pressures, the first pressure sensor being disposed on one side of the seal element and the second pressure sensor being disposed on another side of the seal element; and

a microprocessor connected to the first and second pressure sensors and the motor and configured to receive pressure data from the first and second pressure sensors and to control the motor based on the received pressure data.

14. The drill string valve of Claim 13, wherein the control element further comprises:

a position sensor connected to the microprocessor and configured to determine a position of the seal element.

15. The drill string valve of Claim 13, wherein the control element further comprises:

a power source connected to the microprocessor and configured to furnish electrical power to the microprocessor and the first and second pressure sensors.

16. The drill string valve of Claim 9, wherein the control element comprises:

a flow meter unit configured to measure a flow rate of the fluid flow;

a position unit configured to measure a position of the seal element;

a memory configured to store a look-up table describing a relation between the flow rate and the position of the seal element; and

a processor connected to the flow meter unit, the position unit, and the memory and configured to instruct the motor module to close and open the seal element based on the flow rate, the position of the seal element, and the look-up table.

17. The drill string valve of Claim 16, wherein look-up table includes a flow rate threshold and, for any measured flow rate above the threshold, the processor is configured to close the seal element to suppress the fluid flow.

18. The drill string valve of Claim 9, wherein the seal element and the seat are configured, when closed, to withstand pressures between around 5,000 and around 30,000 psi.

19. A method for controlling a drill string valve, the method comprising:

receiving from a flow meter unit a flow rate of a fluid through the drill string valve;

determining in a processor a position of a seal element that is configured to move to and from a seat to suppress a fluid flow through the drill string valve; and

searching a look-up table stored in memory connected to the processor for determining whether a motor has to be activated to close or open the seal element.

20. The method of Claim 19, further comprising:

instructing, based on a result of the searching step, the motor to move the seal element, wherein the look-up table includes a flow rate threshold, and for any measured flow rate above the threshold, the processor is configured to close the seal element to suppress the fluid flow.

Claims

1. A drill string valve, comprising:

a tubular housing having an axis and threaded upper and lower ends for connection into a drill string;

an axially movable valve element mounted in the housing, the valve element having a closed position and an open position that allows drilling fluid to be pumped downward through the housing;

a spring in cooperative engagement with the valve element for biasing the valve element to the closed position;

a compensating piston movably carried in the housing, defining a compensating chamber, and being in cooperative engagement with the valve element;

an annulus fluid port extending through the housing into the compensating chamber for admitting into the compensating chamber drilling fluid from an annulus surrounding a well and causing the compensating piston to exert an annulus force to the valve element corresponding to an annulus pressure of the drilling fluid in the annulus immediately surrounding the housing, the annulus force urging the valve element to the closed position; and

a preload piston carried in the housing defining a preload fluid chamber between the preload piston and the compensating piston for receiving a preload fluid to preload the spring, the compensating piston transmitting the annulus pressure within the compensating chamber to the preload fluid chamber, the preload piston being in cooperative engagement with an end of the spring to apply the annulus force to the end of the spring in response to the annulus pressure being applied to the preload fluid chamber.

2. The drill string valve according to claim 1, wherein the cooperative engagement of the compensating piston causes the annulus force to be applied to the spring, which in turn applies the annulus force to the valve element.

3. The drill string valve according to claim 1, further comprising:

a preload piston carried in the housing, defining a preload fluid chamber;

a preload port for injecting a preload fluid into the preload fluid chamber prior to lowering the housing into the well at a pressure sufficient to cause the preload piston to move a first end of the spring to a selected preload position relative to a second end of the spring; and

a threaded valve stop that is axially movable in response to rotation relative to the housing into engagement with the first end of the spring while the first end spring is in the preload position, to prevent the first end of the spring from moving back away from the preload position, allowing the pressure of the preload fluid to be removed before lowering the housing into the well.

4. The drill string valve according to claim 1, further comprising:

a conduit extending axially through the housing for the passage of the drilling fluid;

a valve seat fixedly mounted adjacent an upper end of the conduit;

wherein the valve element comprises a valve sleeve surrounding the conduit and axially movable into engagement with the valve seat while in the closed position; and

wherein the compensating piston has an inner diameter in sliding and sealing engagement with the conduit.

5. The drill string valve according to claim 4, further comprising:

an annular preload piston carried in the housing, defining a preload fluid chamber between the preload piston and the compensating piston for receiving a preload fluid at a pressure sufficient to cause the preload piston to move a lower end of the spring toward an upper end of the spring to a selected preload position prior to lowering the housing into the well, the preload piston having an inner diameter that is in

sliding and sealing engagement with the conduit; and wherein while disposed in the well,

the compensating piston transmits the annulus pressure within the compensating chamber to the preload chamber, the preload piston having an upper end that in response applies the upward annulus force to the lower end of the spring.

6. The drill string valve according to claim 5, further comprising:

a threaded valve stop that is axially movable in response to rotation relative to the housing into engagement with the lower end of the spring while the lower end spring is in the preload position, to prevent the lower end of the spring from moving back downward from the preload position to enable the pressure of the preload fluid to be removed prior to lowering the housing into the well.

7. The drill string valve according to claim 1, wherein:

the housing has an upper section and a lower section connected by a connection member;

a preload piston carried in the upper section of the housing, defining a preload fluid chamber in the upper section of the housing;

a preload port in the upper section of the housing for injecting a preload fluid into the preload fluid chamber prior to lowering the housing into the well at a pressure sufficient to cause the preload piston to move the lower end of the spring upward to a selected preload position relative to an upper end of the spring; and

a threaded valve stop within the connection member and having a lower end extending downward past the connection member for grasping and rotating the valve stop upward into engagement with the lower end of the spring while the lower end spring is in the preload position, to prevent the lower end of the spring from moving back downward from the preload position, allowing the pressure applied to the preload fluid chamber to be removed.

8. A drill string valve, comprising:

a tubular housing having an axis and threaded upper and lower ends for connection into a drill string;

an axially movable valve element carried in the housing, the valve element having a closed position and an open position that allows drilling fluid to be pumped downward through the housing;

a spring having an upper end in cooperative engagement with the valve element for biasing the valve element to the closed position;

a preload piston carried in the housing, defining a preload fluid chamber;

a preload port for injecting a preload fluid into the preload fluid chamber prior to lowering the housing into the well at a pressure sufficient to cause the preload piston to move a first end of the spring to a selected preload position relative to a second end of the spring; and

a threaded valve stop that is axially movable relative to the housing in response to rotation into engagement with the first end of the spring while the first end spring is held in the preload position by the preload piston, to enable the pressure applied to the preload fluid to be removed without the first end of the spring moving back away from the second end of the spring.

9. The drill string valve according to claim 8, wherein:

the housing further comprises an upper section and lower section releasably connected together by a connecting member; and

the valve stop has a lower end that extends below the connecting member to allow the valve stop to be grasped and rotated while the lower section is disconnected from the upper section.

10. The drill string valve according to claim 8, wherein the preload port extends through a side wall of the housing.

11. The drill string valve according to claim 8, further comprising:

a compensating piston carried in the housing, defining a compensating chamber, and being in cooperative engagement with the valve element; and

an annulus fluid port extending through the housing into the compensating chamber for admitting into the compensating chamber drilling fluid from an annulus surrounding a well and causing the compensating piston to exert an annulus force to the valve element corresponding to an annulus pressure of the drilling fluid in the annulus immediately surrounding the housing.

12. The drill string valve according to claim 8, further comprising:

a compensating piston carried in the housing below the preload piston, defining a compensating chamber in the housing;

an annulus fluid port extending through the housing into the compensating chamber for admitting into the compensating chamber drilling fluid from an annulus immediately surrounding the housing;

wherein an upper side of the compensating piston defines a lower end of the preload chamber, such that the compensating piston transmits annulus pressure within the compensating fluid chamber to the preload chamber, and in response, the preload piston applies an annulus force to the spring, which in turn transmits the annulus force from the spring to the valve element.

13. The drill string valve according to claim 8, further comprising:

a conduit extending axially through the housing for the passage of the drilling fluid;

a valve seat fixedly mounted adjacent an upper end of the conduit;

wherein the valve element comprises a valve sleeve surrounding the conduit and axially movable into engagement with the valve seat while in the closed position; and

the preload piston is annular and has an inner diameter that seals and slides on the conduit.

14. A well drilling operation comprising downward pumping drilling fluid through a drill string into the well, discharging the drilling fluid out a drill bit and returning the drilling fluid up an annulus in the well surrounding the drill string, a method of preventing the drilling fluid from continuing to flow downward in the drill string in the event the downward pumping ceases, comprising:

mounting in the drill string a drill string valve having a movable valve element with a closed position and an open position, and a spring that is set to exert a bias force to the valve element toward the closed position;

lowering the drill string into the well and exerting an annulus force against the valve element toward the closed position corresponding to an annulus pressure of the drilling fluid in an annulus immediately surrounding the drill string valve;

applying sufficient downward pumping pressure to exceed the bias force plus the annulus force to cause the valve element to open; and

wherein the spring is set such that if the downward pumping ceases and a downward hydrostatic force on the valve element due to the column of drilling fluid in the drill string above the valve element exceeds the annulus force, the upward bias force plus the upward annulus force will close the spring, and wherein the spring is set prior to lowering the drill string into the well by forcing a first end of the spring toward a second end of the spring to a preload position, and preventing the first end from moving back away from the preload position.

15. The method according to claim 14, wherein exerting the annulus force against the valve element comprises admitting the drilling fluid from the annulus through a port in the drill string valve into fluid communication with a compensating piston provided in the drill string valve, and moving the compensating piston in response to the annulus pressure.

16. The method according to claim 14, wherein forcing the first end of the spring comprises:

injecting a preload fluid into a preload chamber having a preload piston; and

preventing the first end from moving back away from the preload position comprises rotating a threaded stop into engagement with the first end of the spring while in the preload position and while pressure of the preload fluid in the preload chamber is maintained; then

relieving the pressure of the preload fluid in the preload chamber.

17. The method according to claim 14, wherein exerting the annulus force against the valve element comprises:

admitting the drilling fluid from the annulus through a port in the drill string valve into fluid communication with a compensating piston provided in the drill string valve, and moving the compensating piston in response to the annulus pressure;

communicating the annulus pressure with the compensating piston to the preload chamber; and

moving the preload fluid piston in response to the annulus pressure.

18. The method according to claim 14, wherein mounting in the drill string a drill string valve comprises mounting the valve adjacent a lower end of the drill string.