Attorney Docket No. 274-46678-US (D5407-406)

APPLICATION FOR PATENT

Title: Pressure Balanced Piston For Subsurface Safety Valves

Inventors: Dario Casciaro; Ben Lake and Steve Rosenblatt

FIELD OF THE INVENTION

[0001] The field of this invention is control systems for operating subsurface safety valves and more particularly control systems with a piston in pressure balance to the surrounding annulus.

BACKGROUND OF THE INVENTION

[0002] Subsurface safety valves are operated from the surface normally through control lines that run outside the production tubing. These valves are typically of the flapper type where a control system, when pressurized from the surface overcomes a closure spring on a flow tube to push the flapper 90 degrees into the open position behind the shifting flow tube. Removal of pressure from the control system allows the closure spring that had previously been held in a compressed position to then push the flow tube away from the flapper so that a torsion spring can bias it back against its seat to prevent flow from the formation from going up the production string.

[0003] These systems have to deal with issues such as failing in a safe mode if one or more seals in the control system fail. They also have to address offsetting the hydrostatic pressure in the control line. Systems with a single control line down to the subsurface safety valve typically have a pressurized chamber at the valve preset with enough pressure for the expected depth of the valve to offset the control line hydrostatic pressure so that on removal of applied control line pressure from the surface, the closure spring that acts on the flow tube doesn't have to overcome the hydrostatic pressure from the control line. A single control line system that addresses fail safe failure modes of the various seals is USP 6,109,351. Alternatively a closure spring is provided that is strong enough to overcome the control line hydrostatic pressure particularly in shallower wells. Other systems simply cancel out control line hydrostatic pressure with a balance line

from the opposite side of an operating piston than the main control line. One example of such systems is USP 6,173,785. Some two line systems also incorporate pressurized chambers such as USP 6,427,778.

[0004] Some of these designs employ a passage through the piston for the purpose of obtaining a fail safe closure mode if one or more of the system seals malfunction or if a control line is sheared. The prior systems typically separated tubing pressure from control line pressure and made no reference to the surrounding annulus. Typically the operating piston in the control system had to have a mechanical connection to the flow tube to move the flow tube to open the valve. That mechanical connection was exposed to tubing pressure and the operating piston featured a pair of seals in a housing so that a portion of the operating piston in the region that it connected to the flow tube was exposed to tubing pressure but remained in pressure balance from tubing pressure.

[0005] The present invention addresses alternative approaches to the past designs that reference the surrounding annulus. Some embodiments operate differently than others during failure modes and this will be explained in detail when the various embodiments are described in detail. Those skilled in the art will appreciate the various aspects of the invention from the description of the preferred embodiment and associated drawings that appear below with the understanding that the full scope of the invention is measured by the appended claims.

SUMMARY OF THE INVENTION

[0006] A control system for a subsurface safety valve references the surrounding annulus to put the operating piston in pressure balance. Depending on the configuration and which seal in the system fails, the various embodiments can differ in their failure modes. With the lower end of the piston exposed to annulus pressure all failure modes close the flapper. With the lower end of the piston exposed to tubing pressure, failure of any of the seals except one will result in flapper closure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a schematic view of a single line control system with a piston pressure balanced to the annulus;

[0008] FIG. 2 is an alternative embodiment to FIG. 1 and still having a pressure balanced piston to the annulus; and

[0009] FIG. 3 is an alternative to the embodiment in FIG. 2 and having a piston in pressure balance to the annulus; and

[0010] FIG. 4 is a variation of FIG. 1 showing an annular piston rather than a rod piston with a balance control line to the surface.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0011] FIG. 1 is a schematic representation of a subsurface safety valve that those skilled in the art will appreciate can illustrate the various embodiments of the present invention. Typically, a flapper **10** is mounted on a pivot **12** that can combine a torsion spring (not shown) to urge the flapper **10** against the seat **14**. The flapper **10** is pushed to turn 90 degrees and go behind an advancing flow tube **16** that is forced to move against a return bias from closure spring **18**. Passage **20** goes through a housing that is partially shown as **22**. A string from the surface represented by arrow **24** is in flow communication with passage **20** in housing **22** in a known manner. Similarly arrow **26** represents the continuation of a tubing string to the producing zone further down in the well.

[0012] A single control line **28** connects into housing **22** into chamber **30** above the operating piston **32**. Chamber **34** is on the other side of piston **32** from chamber **30** and it communicates to the surrounding annulus around housing **22** through passage **36**.

[0013] Piston **32** is preferably a rod piston with seals **40**, a lower seal, and seal **42** an upper seal. There is a through passage **44** going from lower end **46** to upper end **48** of piston **32**. Above upper end **48** is a chamber **50** in housing **22** that gets tubing pressure communicated to it through the passage **44** from inlet **52**. Link **53** connects piston **32** to flow tube **16**.

[0014] In operation, applied pressure from control line **28** raises the pressure in chamber **30** to the point that spring **18** is compressed and the flapper **10** goes open. Removal of pressure from the control line **28** allows the spring **18** to overcome the net difference between hydrostatic pressure in line **28** and the surrounding annulus pressure. The spring **18** is sized to overcome the net pressure on piston **32** between control line hydrostatic and annulus pressure apart from seal friction at seals **40** and **42** when piston **32** moves. Piston **32** is mechanically coupled to flow tube **16** below seal **40** which is exposed to tubing pressure on one side and annulus pressure on the other side. Seal **39**, the piston seal, separates chambers **30** and **34**. Seal **42** is on one side of piston seal **39** and seal **40** is on the opposite side of seal **39** from seal **40**. In most cases a net closing force acts on piston **32** from tubing pressure pushing up on seal **40** and annulus pressure pushing down on seal **42**.

[0015] If seal **40** fails, the pressure in the tubing will communicate to the surrounding annulus and pressurize chamber **34** forcing the piston **32** up and the flapper **10** will go closed. If seal **39** fails in any illustrated embodiment, there cannot be a pressure differential across the piston **32** from control line **28** and the closure spring **18** will make the flapper **10** close. However if seal **42** fails then tubing pressure will get into chamber **30** and prevent spring **18** from closing the flapper **10** since spring **18** is not sized for overcoming tubing pressure because the flow tube **16** is in pressure balance to tubing pressure. Hence in this embodiment, failure of seal **42** makes the valve stay open.

[0016] FIG. 2 is a modified design of FIG. 1. The difference is that a second lower seal **38** is added and the lower **46'** end of piston **32'** is now exposed to annulus pressure rather than tubing pressure. Annulus pressure also goes through inlet **52'** to chamber **50'**. The piston **32'** is in pressure balance from annulus pressure acting up on lower seal **38** and down on upper seal **42'** through chamber **50'**. Piston **32'** is also in pressure balance from tubing pressure pushing up at seal **40'** and down at seal **38** because those seals straddle the link **53'** that connects the piston **32'** to the flow tube **16'**.

[0017] If seal **40'** fails tubing pressure enters chamber **34'** and the annulus through passage **36'** pushing the piston **32'** up and the flapper **10'** will close. If seal **38**

fails tubing pressure will leak into the annulus and get into chamber **34'** and again the flapper **10'** will close. If seal **42'** breaks pressure in the control line **28'** will pass into the annulus through chamber **50'** and passage **44'** and the closure spring **18'** will be able to close the flapper **10'**. The design of FIG. 2 fails closed if any seal **38, 40'** and **42'** fails.

[0018] FIG. 3 is virtually the same as FIG. 2 with the difference being that piston **32''** is solid and the passage through it has been eliminated. However, a connection **60** to the annulus has been added to chamber **50"** so that the top **48"** of the piston **32"** is again in communication with the annulus despite there being no passage through piston **32"**. Inlet **52"** exposes the lower end **46"** of piston **32"** to annulus pressure present in chamber **62**. In all other respects, the FIG. 3 design functions and fails the same way as the FIG. 2 design.

[0019] FIG. 4 is similar to FIG. 1 except the piston has an annular shape rather than a rod shape as illustrated in FIG. 1 and is pressure balanced with a balance line that runs to the surface. The flow tube **100** has a piston **102** integrated into it with a seal **104** to separate compartments **106** and **108**. Tubing pressure is in passage **110**. Downward movement of the flow tube **100** rotates the flapper **112** and compresses the spring **114**. Compartment **106** is connected to a first control line represented schematically by arrow **116** and compartment **108** is connected to another control line running back to the surface and schematically represented by arrow **118**. Seals **120** and **122** are preferably the same size so that piston **102** is in pressure balance from the equal hydrostatic pressure in lines **116** and **118** when no pressure is being applied to either line from the surface. Seals **120** and **122** have tubing pressure in passage **110** acting on one side and control line pressure **116** acting on the other side of seal **120** and balance line pressure **118** acting on the other side of seal **122**.

[0020] In operation, the flapper **112** is opened with pressure applied in line **116** that compresses spring **114** and drives the flow tube **100** down against the flapper **112**. Removal of pressure on line **116** allows the spring **114** to drive the flow tube **100** up so that the flapper **114** closes. Since there is a balance of hydrostatic forces on piston **102**

the spring **114** does not have to be sized to oppose any hydrostatic force acting on piston **102** since there is no such force acting on it in this embodiment.

[0021] If seal **104** breaks then the flapper **112** will close under the force of spring **114**. Failure of seal **122** will allow tubing pressure from passage **110** into chamber **108** forcing the flow tube **100** up and the flapper **112** will close. Failure of seal **120** will send tubing pressure from passage **110** to chamber **106** and will likely overpower spring **114** to hold the flapper **112** open unless pressure is applied to the control line **118**.

[0022] Those skilled in the art will appreciate that a variety of control systems are disclosed that use a single control line and a pressure balanced piston with respect to the annulus. The designs that fail safe closed are also pressure balanced to tubing pressure as well. Pressure balance to the annulus can occur at opposed ends with bore through the piston or with separate exposure of opposed ends of the piston to annulus pressure. In the preferred embodiment the piston can be one or more rod pistons but other piston shapes are contemplated. Pressurized chambers or offsets for control line hydrostatic pressure are not needed. The annulus pressure is used to at least in part offset the control line hydrostatic pressure and the closure spring **18** is sized to overcome net force on the piston from the net difference in pressure acting on it from the control line trying to push it down and the annulus pressure trying to push it back up.

[0023] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below.

CLAIMS

1. A control system for operating a downhole tool from the surface, comprising:

a tool housing having a movable member in a passage connected to a piston and a control line connection on said housing to allow pressure to be delivered to a first chamber defined by said piston for tandem movement of said piston and movable member against a bias force, said movement of said piston reducing the volume of a second chamber in said housing and isolated from said passage that is in communication with pressure downhole in an annulus around said housing

a third chamber in said housing defined by a first end of said piston, said third chamber communicating to a second end of said piston by a passage through said piston, said second end of said piston isolated in said housing from said second chamber and exposed to either pressure in said passage in said housing or in said annulus.

2. The system of claim 1, wherein:

the opposed ends of said piston communicate with pressure in said passage in said housing.

3. The system of claim 1, wherein:

the opposed ends of said piston communicate with pressure downhole in an annulus around said housing.

4. The system of claim 3, wherein:

the opposed ends of said piston communicate with pressure downhole in the annulus around said housing through discrete annulus connections in said housing.

5. The system of claim 1, wherein:

said movable member comprises a flow tube movable against a closure spring to turn a flapper to an open position for flow through a said passage through said housing;

said piston is linked to said flow tube in a manner where said link and a portion of said piston adjacent to it are exposed to pressure in said passage.

6. The system of claim 5, wherein:

said piston comprises a plurality of spaced seals where the failure of all but one of said seals allows the closure spring to move said flow tube to let said flapper go to a closed position.

7. The system of claim 6, wherein:

said piston comprises a piston seal, an upper seal on one side of said piston seal and a lower seal on the opposite side of said piston seal from said upper seal;

said lower seal is exposed to pressure in said passage.

8. A control system for operating a downhole tool from the surface, comprising:

a tool housing having a movable member in a passage connected to a piston and a control line connection on said housing to allow pressure to be delivered to a first chamber defined by said piston for tandem movement of said piston and movable member against a bias force, said movement of said piston reducing the volume of a second chamber in said housing that is in communication with pressure downhole in an annulus around said housing;

said movable member comprises a flow tube movable against a closure spring to turn a flapper to an open position for flow through a passage through said housing;

said piston is linked to said flow tube in a manner where said link and a portion of said piston adjacent to it are exposed to pressure in said passage;

said piston comprises a plurality of spaced seals where the failure of all but one of said seals allows the closure spring to move said flow tube to let said flapper go to a closed position;

said piston comprises a piston seal, an upper seal on one side of said piston seal and a lower seal on the opposite side of said piston seal from said upper seal;

said lower seal is exposed to pressure in said passage;

said piston seal is exposed to said control line connection on one side and the annulus pressure surrounding said housing on its opposite side;

said lower seal is exposed to annulus pressure on the side opposite from which it is exposed to passage pressure.

9. The system of claim 8, wherein:

said upper seal is exposed to said control line connection on one side and annulus pressure on the side opposite from which it is exposed to said control line connection.

10. The system of claim 9, wherein:

annulus pressure is communicated to said upper seal through a passage through said piston.

11. The system of claim 9, wherein:

annulus pressure is communicated directly through said housing to said upper seal.

12. The system of claim 10, wherein:

failure of said piston seal or said lower seal causes said flapper to close.

13. The system of claim 5, further comprising:

a single control line connected to said control line connection to communicate surface pressure to open said flapper and upon removal of applied pressure in said control line said closure spring moves said flow tube to let said flapper close.

14. The system of claim 5, wherein:

said piston comprises a plurality of spaced seals where the failure of all of said seals allows the closure spring to move said flow tube to let said flapper go to a closed position.

15. A control system for operating a downhole tool from the surface, comprising:

a tool housing having a movable member in a passage connected to a piston and a control line connection on said housing to allow pressure to be delivered to a first chamber defined by said piston for tandem movement of said piston and movable member against a bias force, said movement of said piston reducing the volume of a second chamber in said housing and isolated from said passage that is in communication with pressure downhole in an annulus around said housing;

said movable member comprises a flow tube movable against a closure spring to turn a flapper to an open position for flow through said passage through said housing;

said piston is linked to said flow tube in a manner where said link and a portion of said piston adjacent to it are exposed to pressure in said passage;

said piston comprises a plurality of spaced seals where the failure of all of said seals allows the closure spring to move said flow tube to let said flapper go to a closed position;

said piston comprises a piston seal, an upper seal on one side of said piston seal and a first and second lower seals on the opposite side of said piston seal from said upper seal with said first lower seal disposed on an opposite side of said link from said second lower seal;

both said lower seals are exposed to pressure in said passage on their respective sides closest to said link.

16. A control system for operating a downhole tool from the surface, comprising:

a tool housing having a movable member in a passage connected to a piston and a control line connection on said housing to allow pressure to be delivered to a first chamber defined by said piston for tandem movement of said piston and movable member against a bias force, said movement of said piston reducing the volume of a second chamber in said housing that is in communication with pressure downhole in an annulus around said housing;

said movable member comprises a flow tube movable against a closure spring to turn a flapper to an open position for flow through ~~a~~ said passage through said housing;

said piston is linked to said flow tube in a manner where said link and a portion of said piston adjacent to it are exposed to pressure in said passage;

said piston comprises a plurality of spaced seals where the failure of all of said seals allows the closure spring to move said flow tube to let said flapper go to a closed position;

said piston comprises a piston seal, an upper seal on one side of said piston seal and a first and second lower seals on the opposite side of said piston seal from said upper seal with said first lower seal disposed on an opposite side of said link from said second lower seal;

both said lower seals are exposed to pressure in said passage on their respective sides closest to said link;

both said first and second lower seals are exposed to annulus pressure on the side opposite to where they are exposed to pressure in said passage.

17. The system of claim 16, wherein:

said upper seal is exposed to said control line connection on one side and annulus pressure on the side opposite from which it is exposed to said control line connection.

18. The system of claim 17, wherein:

annulus pressure is communicated to said upper seal through a passage through said piston.

19. The system of claim 17, wherein:

annulus pressure is communicated directly through said housing to said upper seal.

20. The system of claim 17, wherein:

a single control line connected to said control line connection to communicate surface pressure to open said flapper and upon removal of applied pressure in said control line said closure spring moves said flow tube to let said flapper close.

21. A control system for operating a downhole tool from the surface, comprising:

a tool housing having a movable member in a passage connected to a piston and a control line connection on said housing to allow pressure to be delivered to a first chamber defined by said piston for tandem movement of said piston and movable member against a bias force, said movement of said piston reducing the volume of a second chamber in said housing and isolated from said passage that is in communication with pressure downhole in an annulus around said housing;

the opposed ends of said piston communicate with pressure in said passage in said housing;

pressure in said passage is communicated to opposed ends of said piston through a passage in said piston.