[0005] After completing the well, it is typically desirable to remove the weighted column of fluid from both the interior of the tubular string, if present, and the annulus above the uppermost packer. This may be achieved through the use of a circulating valve disposed within in the tubular string, which has a primary purpose of selectively permitting fluid flow between the interior of the tubular string and the annulus. For example, when it is desired to remove the weighted column of fluid from the annulus, a lighter fluid may be pumped from the earth's surface down through the tubular string and radially outwardly from the tubular string through the circulating valve into the annulus and then back to the earth's surface up through the annulus. Typically, such tubing conveyed circulating valves have a sliding sleeve that may be longitudinally shifted between circulating and non-circulating positions using wireline or slickline techniques. In the non-circulating position, conventional circulating valves typically utilize resilient materials such as elastomers for sealing between movable metal parts to prevent fluid communication between the interior of the tubular string and the annulus.

[0006] It has been found, however, that resilient sealing materials may deteriorate due to the harsh chemical, physical and thermal environment downhole. When such deterioration occurs, the seals may fail to prevent fluid communication between the interior of the tubular string and the annulus when a conventional circulating valve is in its non-circulating configuration. Accordingly, a need has arisen for an improved circulating valve that is operable to selectively permit fluid flow between the interior of the tubular string and the annulus. In addition, a need has arisen for such an improved circulating valve that does not rely on resilient sealing materials to prevent fluid communication between the interior of the tubular string and the annulus when the circulating valve is in its non-circulating configuration.

SUMMARY OF THE INVENTION

[0007] ~~The~~Embodiments of the present invention disclose~~d herein comprises~~ an improved circulating valve that is operable to selectively permit fluid flow between the interior of a tubular string and the annulus between the tubular string and the wellbore. In addition, the improved circulating valve as per embodiments of the present invention does not rely on resilient sealing materials to prevent fluid communication between the interior of the tubular string and the annulus when the circulating valve is in its non-circulating configuration but instead utilizes a metal-to-metal seal to provide a long lasting, high-pressure seal.

[0008] ~~In one aspect, the present invention is directed to a downhole circulating valve. The downhole circulating valve includes a generally tubular outer housing having a generally axially extending internal passageway. At least one generally longitudinally extending circulating passageway is formed through at least a portion of the housing. At least one exterior port and at least one interior port are in fluid communication with the circulating passageway. At least one seal plug is disposed within the circulating passageway. The seal plug has a first position relative to the housing wherein the seal plug is remote from the exterior port and the interior port, thereby allowing fluid flow between the exterior port and the interior port through the circulating passageway. The seal plug has a second position relative to the housing wherein the seal plug is between the exterior port and the interior port~~

~~and forms at least one metal-to-metal seal with the circulating passageway, thereby preventing fluid flow between the exterior port and the interior port.~~

According to a first aspect, there is provided a downhole circulating valve comprising: a generally tubular outer housing comprising an internal passageway, at least one circulating passageway formed through at least a portion of the housing, at least one exterior port in fluid communication with the circulating passageway and at least one interior port in fluid communication with the circulating passageway and the internal passageway; and at least one seal plug disposed within the circulating passageway, the seal plug comprising a plug shell having at least a seal ring and a plug pin operable to be received within the plug shell to expand the seal ring, the seal plug being actuable between a first position, in which the seal plug is remote from the interior and the exterior ports so that fluid is allowed between the interior and the exterior ports through the circulating passageway, and a second position, in which the seal plug is positioned between the interior and the exterior ports and the plug pin is received within the plug shell so that the seal ring is expanded to form a metal-to-metal seal with the circulating passageway, thereby preventing fluid flow between the interior and the exterior ports.

[0009] In one embodiment, the downhole circulating valve may include a piston that is at least partially disposed within the circulating passageway and is operably associated with the seal plug. In this embodiment, longitudinal shifting of the piston in a first direction operates the seal plug from the first position to the second position. In some embodiments, the seal plug may include at least one seal ring that forms a metal-to-metal seal with the circulating passageway when the seal plug is in the second position. In certain embodiments, the seal plug may form multiple metal-to-metal seals with the circulating passageway when the seal plug is in the second position. For example, in one embodiment, the seal plug may include a plurality of seal rings each forming a metal-to-metal seal with the circulating passageway when the seal plug is in the second position. In another embodiment, the seal plug may include a plug shell having a plurality of seal rings and a plug pin operable to be received within the plug shell to expand the seal rings to form metal-to-metal seals with the circulating passageway when the seal plug is in the second position.

[0010] In some embodiments, the downhole circulating valve may have multiple seal plugs disposed within the circulating passageway, each forming at least one metal-to-metal seal with the circulating passageway when the seal plugs are positioned between the exterior port and the interior port. In other embodiments, the downhole circulating valve may have multiple seal plugs disposed within the circulating passageway, each forming multiple metal-to-metal seals with the circulating passageway when the seal plugs are positioned between the exterior port and the interior port. In one embodiment, the downhole circulating valve may include a removable barrier disposed within a fluid flow path between the exterior port and the interior port to initially prevent fluid flow between the exterior port and the interior port.

[0011] ~~In another aspect, the present invention is directed to a downhole circulating valve. The downhole circulating valve includes a generally tubular outer housing having a generally axially extending internal passageway. At least one generally longitudinally extending circulating passageway is formed through at least a portion of the housing. At~~

~~least one exterior port and at least one interior port are in fluid communication with the circulating passageway to form a fluid flow path through the housing. At least one seal plug is disposed within the circulating passageway. The seal plug has a first position relative to the housing wherein the seal plug is remote from the exterior port and the interior port, thereby allowing fluid flow through the fluid flow path. The seal plug has a second position relative to the housing wherein the seal plug is between the exterior port and the interior port and forms at least one metal-to-metal seal with the circulating passageway, thereby preventing fluid flow through the fluid flow path. A piston is at least partially disposed within the circulating passageway and is operably associated with the seal plug. An actuator sleeve is slidably disposed within the internal passageway and is operably associated with the piston such that longitudinal shifting of the actuator sleeve in a first direction longitudinally shifts the piston in the first direction which operates the seal plug from the first position to the second position. A removable barrier is disposed within the fluid flow path to initially prevent fluid flow through the fluid flow path.~~

According to a second aspect, there is provided a downhole circulating valve comprising: a generally tubular outer housing comprising an internal passageway, at least one circulating passageway formed through at least a portion of the housing, at least one exterior port and at least one interior port, the exterior port, the interior port, and at least a potion of the circulating passageway forming a fluid flow path through the housing; at least one seal plug disposed within the circulating passageway, the seal plug comprising a plug shell having at least one seal ring and a plug pin operable to be received within the plug shell to expand the seal ring, the seal plug being actuable between a first position, in which the seal plug is remote from the interior and the exterior ports so that fluid flow is allowed through the fluid flow path, and a second position, in which the seal plug is positioned between the interior and the exterior ports and the plug pin is received within the plug shell so that the seal ring is expanded to form at least one metal-to-metal seal with the circulating passageway, thereby preventing fluid flow through the fluid flow path.

[0012] ~~In a further aspect, the present invention is directed to a method for operating a downhole circulating valve. The method includes providing a circulating valve including a generally tubular outer housing having a generally axially extending internal passageway, at least one generally longitudinally extending circulating passageway formed through at least a portion of the housing, at least one exterior port in fluid communication with the circulating passageway, at least one interior port in fluid communication with the circulating passageway and at least one seal plug disposed within the circulating passageway; running the circulating valve into a wellbore on a tubular string; shifting the seal plug from a first position relative to the housing wherein the seal plug is remote from the exterior port and the interior port thereby allowing fluid flow between the exterior port and the interior port through the circulating passageway to a second position relative to the housing wherein the seal plug is between the exterior port and the interior port; and forming at least one metal-to-metal seal between the seal plug and the circulating passageway, thereby preventing fluid flow between the exterior port and the interior port.~~

According to a third aspect, there is provided a method for operating a downhole circulating valve, the method comprising: providing a circulating valve, the circulating valve comprising: a generally tubular outer housing comprising an internal passageway, at least

one circulating passageway formed through at least a portion of the housing, at least one exterior port in fluid communication with the circulating passageway, and at least one interior port in fluid communication with the circulating passageway and the internal passageway; and at least one seal plug disposed within the circulating passageway, the seal plug comprising a plug shell having at least one seal ring and a plug pin operable to be received within the plug shell to expand the seal ring; running the circulating valve into a wellbore on a tubular string; shifting the seal plug from a first position, in which the seal plug is remote from the interior and the exterior ports so that fluid flow is allowed between the interior and the exterior ports through the circulating passageway, to a second position, in which the seal plug is positioned between the interior and the exterior ports; and receiving the plug pin within the plug shell so that the seal ring is expanded to form at least one metal-to-metal seal with the circulating passageway, thereby preventing fluid flow between the interior and the exterior ports.

[0013] The method may also include initially preventing fluid flow between the exterior port and the interior port with a removable barrier, initially preventing fluid flow between the exterior port and the interior port with a rupture disk and increasing a pressure signal acting on the rupture disk to burst the rupture disk and allow fluid flow between the exterior port and the interior port, forming multiple metal-to-metal seals between the seal plug and the circulating passageway, forming at least one metal-to-metal seal with each of a plurality of seal plugs and the circulating passageway, forming multiple metal-to-metal seals between each of a plurality of seal plugs and the circulating passageway and/or shifting the seal plug by one of mechanical actuation, electromechanical actuation and pressure actuation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0015] Figure 1 is a schematic illustration of a well system operating a downhole circulating valve according to an embodiment of the present invention;

[0016] Figures 2A-2B are cross sectional views of a downhole circulating valve according to an embodiment of the present invention in its circulating configuration and its non-circulating configuration, respectively;

[0017] Figure 2C is an enlarged view of a seal plug positioned in a downhole circulating valve in its circulating configuration according to an embodiment of the present invention;

[0018] Figure 2D is an enlarged view of a seal plug forming a metal-to-metal seal in a downhole circulating valve in its non-circulating configuration according to an embodiment of the present invention;

[0019] Figures 3A-3B are cross sectional views of a downhole circulating valve according to an embodiment of the present invention in its circulating configuration and its non-circulating configuration, respectively;

~~What is claimed is:~~ CLAIMS

1. A downhole circulating valve comprising:

a generally tubular outer housing ~~having a generally axially extending~~ comprising an internal passageway, at least one ~~generally longitudinally extending~~ circulating passageway formed through at least a portion of the housing, at least one exterior port in fluid communication with the circulating passageway and at least one interior port in fluid communication with the circulating passageway and the internal passageway; and

at least one seal plug disposed within the circulating passageway, the seal plug ~~having~~ comprising a plug shell having at least a seal ring and a plug pin operable to be received within the plug shell to expand the seal ring, the seal plug being actuable between a first position ~~relative to the housing wherein~~, in which the seal plug is remote from the ~~exterior port and the~~ interior and the exterior ports ~~thereby allowing fluid flow~~ so that fluid is allowed between the ~~exterior port and the~~ interior and the exterior ports through the circulating passageway, and a second position ~~relative to the housing wherein~~, in which the seal plug is positioned between the ~~exterior port and the~~ interior and the exterior ports and ~~wherein the seal plug forms at least one~~ the plug pin is received within the plug shell so that the seal ring is expanded to form a metal-to-metal seal with the circulating passageway, thereby preventing fluid flow between the ~~exterior port and the~~ interior and the exterior ports.

2. The downhole circulating valve as recited in claim 1 further comprising a piston at least partially disposed within the circulating passageway and operably associated with the seal plug, wherein longitudinal shifting of the piston in a first direction operates the seal plug from the first position to the second position.

~~3. The downhole circulating valve as recited in claim 1 wherein the seal plug further comprises at least one seal ring that forms a metal-to-metal seal with the circulating passageway when the seal plug is in the second position.~~

43. The downhole circulating valve as recited in claim 1 wherein the seal plug further comprises a plurality of seal rings each forming a metal-to-metal seal with the circulating passageway when the seal plug is in the second position.

~~5. The downhole circulating valve as recited in claim 1 wherein the seal plug further comprises plug shell having a plurality of seal rings and a plug pin operable to be received within the plug shell to expand the seal rings to form metal-to-metal seals with the circulating passageway when the seal plug is in the second position.~~

~~6~~4. The downhole circulating valve as recited in claim 1 wherein the seal plug forms multiple metal-to-metal seals with the circulating passageway when the seal plug is in the second position.

~~7~~5. The downhole circulating valve as recited in claim 1 further comprising multiple seal plugs disposed within the circulating passageway wherein each of the seal plugs forms at least one metal-to-metal seal with the circulating passageway when the seal plugs are positioned between the exterior port and the interior port.

~~8~~6. The downhole circulating valve as recited in claim 1 further comprising multiple seal plugs disposed within the circulating passageway wherein each of the seal plugs forms multiple metal-to-metal seals with the circulating passageway when the seal plugs are positioned between the exterior port and the interior port.

~~9~~7. The downhole circulating valve as recited in claim 1 further comprising a removable barrier disposed within a fluid flow path between the exterior port and the interior port to initially prevent~~ing~~ fluid flow between the exterior port and the interior port.

~~10~~8. A downhole circulating valve comprising:

a generally tubular outer housing ~~having a generally axially extending~~ comprising an internal passageway, at least one ~~generally longitudinally extending~~ circulating passageway formed through at least a portion of the housing, at least one exterior port and at least one interior port, the exterior port, the interior port, and at least a potion of the circulating passageway forming a fluid flow path through the housing;

at least one seal plug disposed within the circulating passageway, the seal plug ~~having~~ comprising a plug shell having at least one seal ring and a plug pin operable to be received within the plug shell to expand the seal ring, the seal plug being actuable between a first position ~~relative to the housing wherein~~, in which the seal plug is remote from the ~~exterior~~

~~port and the~~ interior and the exterior ports ~~thereby allowing~~ so that fluid flow is allowed through the fluid flow path, and a second position ~~relative to the housing wherein~~, in which the seal plug is positioned between the ~~exterior port and the~~ interior and the exterior ports and ~~wherein the seal plug forms~~ the plug pin is received within the plug shell so that the seal ring is expanded to form at least one metal-to-metal seal with the circulating passageway, thereby preventing fluid flow through the fluid flow path~~;~~.

~~a piston at least partially disposed within the circulating passageway and operably associated with the seal plug;~~

~~an actuator sleeve slidably disposed within the internal passageway and operably associated with the piston, wherein longitudinal shifting of the actuator sleeve in a first direction longitudinally shifts the piston in the first direction which operates the seal plug from the first position to the second position; and~~

~~a removable barrier disposed within the fluid flow path to initially preventing fluid flow through the fluid flow path.~~

~~11~~9. The downhole circulating valve as recited in claim ~~10~~8 wherein the seal plug forms multiple metal-to-metal seals with the circulating passageway when the seal plug is in the second position.

~~12~~10. The downhole circulating valve as recited in claim ~~10~~8 further comprising multiple seal plugs disposed within the circulating passageway wherein each of the seal plugs forms at least one metal-to-metal seal with the circulating passageway when the seal plugs are positioned between the exterior port and the interior port.

~~13~~11. The downhole circulating valve as recited in claim ~~10~~8 further comprising multiple seal plugs disposed within the circulating passageway wherein each of the seal plugs forms multiple metal-to-metal seals with the circulating passageway when the seal plugs are positioned between the exterior port and the interior port.

~~14~~12. The downhole circulating valve as recited in claim ~~10~~8 wherein the removable barrier further comprises a rupture disk.

~~15~~13. A method for operating a downhole circulating valve, the method comprising:

providing a circulating valve ~~including~~, the circulating valve comprising:

a generally tubular outer housing ~~having~~ comprising an ~~a generally axially extending~~ internal passageway, at least one ~~generally longitudinally extending~~ circulating passageway formed through at least a portion of the housing, at least one exterior port in fluid communication with the circulating passageway, and at least one interior port in fluid communication with the circulating passageway and the internal passageway; and

at least one seal plug disposed within the circulating passageway, the seal plug comprising a plug shell having at least one seal ring and a plug pin operable to be received within the plug shell to expand the seal ring;

running the circulating valve into a wellbore on a tubular string;

shifting the seal plug from a first position ~~relative to the housing wherein~~, in which the seal plug is remote from the ~~exterior port and the~~ interior and the exterior ports ~~thereby allowing~~ so that fluid flow is allowed between the ~~exterior port and the~~ interior and the exterior ports through the circulating passageway, to a second position ~~relative to the housing wherein~~, in which the seal plug is positioned between the ~~exterior port and the~~ interior and the exterior ports; and

receiving the plug pin within the plug shell so that the seal ring is expanded to ~~forming~~ form at least one metal-to-metal seal ~~between the seal plug and~~ with the circulating passageway, thereby preventing fluid flow between the ~~exterior port and the~~ interior and the exterior ports.

~~16~~14. The method as recited in claim ~~15~~13 further comprising initially preventing fluid flow between the exterior port and the interior port with a removable barrier.

~~17~~15. The method as recited in claim ~~15~~13 further comprising initially preventing fluid flow between the exterior port and the interior port with a rupture disk and increasing a pressure signal acting on the rupture disk to burst the rupture disk and allow fluid flow between the exterior port and the interior port.

~~18~~16. The method as recited in claim ~~15~~13 wherein receiving the plug pin within the plug shell so that the seal ring is expanded to form at least one metal-to-metal seal with the circulating passageway ~~forming at least one metal-to-metal seal between the seal plug and the circulating passageway~~ further comprises forming multiple metal-to-metal seals ~~between the seal plug and~~ with the circulating passageway.

~~19~~17. The method as recited in claim ~~15~~13 wherein shifting the seal plug from the first position to the second position further comprises shifting multiple seal plugs; and

wherein receiving the plug pin within the plug shell so that the seal ring is expanded to form at least one metal-to-metal seal with the circulating passageway ~~forming at least one metal-to-metal seal~~ further comprises forming at least one metal-to-metal seal with each of the seal plugs and the circulating passageway.

~~20~~18. The method as recited in claim ~~15~~13 wherein shifting the seal plug from the first position to the second position further comprises shifting multiple seal plugs; and

wherein receiving the plug pin within the plug shell so that the seal ring is expanded to form at least one metal-to-metal seal with the circulating passageway ~~forming at least one metal-to-metal seal~~ further comprises forming multiple metal-to-metal seals between each seal plug and the circulating passageway.

~~21. The method as recited in claim 15 wherein shifting the seal plug further comprises one of mechanical actuation, electromechanical actuation and pressure actuation.~~