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Inventor(s)	Thomas; Micheal Cole et al.

VALVE BODY

Abstract

A valve configured to seal against a valve seat. The valve and valve seat are configured to be installed within a fluid end. A recess is formed within the valve for receiving a seal. A shape of the recess and a shape of the valve are designed to reduce wear to the seal during operation.

Inventors: **Thomas; Micheal Cole (Azle, TX), Barnett; Christopher Todd (Stratford, OK), Son; Nicholas (Davis, OK), Keith; John (Ardmore, OK), Foster; Kelcy Jake (Sulphur, OK)**

Applicant: **Kerr Machine Co.** (Sulphur, OK)

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Background/Summary

SUMMARY

[0001] The present invention is directed to a valve configured to seal against a valve seat. The valve comprises a tapered sealing surface joined to an outer side surface by a recessed surface. The recessed surface forms a recess within the valve and comprises a plurality of straight-line segments: L**1**, L**2**, L**3**, and L**4**, and a plurality of radius segments: R**1**, R**2**, R**3**, and R**4**. L**1** is positioned intermediate the tapered sealing surface and R**1**. L**2** is positioned intermediate R**1** and R**2**, L**3** is positioned intermediate R**2** and R**3**, and L**4** is positioned intermediate R**3** and R**4**. R**4** is positioned intermediate L**4** and the side surface. The valve further comprises a seal installed within the recess and engaging the plurality of straight-line segments and the plurality of radius segments. At least a portion of the tapered sealing surface and at least a portion of the seal are configured to seal against the valve seat.

[0002] The present invention is directed to a valve configured to seal against a valve seat. The valve comprises a tapered sealing surface joined to an outer side surface by a recessed surface. The recessed surface forms a recess within the valve and comprises a plurality of straight-line segments: L**1**, L**2**, and L**3**, and a plurality of radius segments: R**1** and R**2**. L**1** is positioned intermediate the tapered sealing surface and R**1**. L**2** is positioned intermediate R**1** and R**2**, and L**3** is positioned intermediate R**2** and the side surface. The valve further comprises a seal installed within the recess and engaging the plurality of straight-line segments and the plurality of radius segments. At least a portion of the tapered sealing surface and at least a portion of the seal are configured to seal against the valve seat.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. **1** is a perspective view of one embodiment of a fluid end attached to one embodiment of a power end.

[0004] FIG. **2** is a cross-sectional view of the fluid end shown in FIG. **1**, taken along line A-A.

[0005] FIG. **3** is the cross-sectional view shown in FIG. **2**, but another embodiment of an intake and a discharge valve are installed therein.

[0006] FIG. **4** is a perspective view of another embodiment of a fluid end attached to another embodiment of a power end.

[0007] FIG. **5** is a cross-sectional view of the fluid end shown in FIG. **4**, taken along line B-B.

[0008] FIG. **6** is a top perspective view of the intake valve and valve seat shown installed within the fluid end in FIG. **2**. The valve is shown in a closed position.

[0009] FIG. **7** is a side elevational view of the valve and valve seat shown in FIG. **6**.

[0010] FIG. **8** is the top perspective view of the intake valve and valve seat shown in FIG. **6**, but the valve is shown in an open position.

[0011] FIG. **9** is a side elevational view of the valve and valve seat shown in FIG. **8**.

[0012] FIG. **10** is a cross-sectional view of the valve and valve seat shown in FIG. **7**, taken along line C-C, but the valve is not in a fully closed position.

[0013] FIG. **11** is an enlarged view of area D shown in FIG. **10**, but the valve is shown in a fully closed position.

[0014] FIG. **12** is an enlarged view of area E shown in FIG. **10**.

[0015] FIG. **13** is an enlarged view of area G shown in FIG. **12**.
[0016] FIG. **14** is an enlarged view of area J shown in FIG. **15**.
[0017] FIG. **15** is an enlarged view of area D shown in FIG. **10**.
[0018] FIG. **16** is a top perspective view of the intake valve and valve seat shown installed within the fluid end in FIG. **3**. The valve is shown in a closed position.
[0019] FIG. **17** is a side elevational view of the valve and valve seat shown in FIG. **16**.
[0020] FIG. **18** is a cross-sectional view of the valve and valve seat shown in FIG. **17**, taken along line K-K.
[0021] FIG. **19** is the cross-sectional view of the valve and valve seat shown in FIG. **18**, but the valve is shown in an open position.
[0022] FIG. **20** is an enlarged view of area M shown in FIG. **22**.
[0023] FIG. **21** is an enlarged view of area N shown in FIG. **20**.
[0024] FIG. **22** is an enlarged view of area O shown in FIG. **18**.
[0025] FIG. **23** is a top perspective view of another embodiment of a valve and the valve seat. The valve is shown in a closed position.
[0026] FIG. **24** is a side elevational view of the valve and valve seat shown in FIG. **23**.
[0027] FIG. **25** is a cross-sectional view of the valve and valve seat shown in FIG. **24**, taken along line Q-Q.
[0028] FIG. **26** is an enlarged view of area T shown in FIG. **25**.
[0029] FIG. **27** is an enlarged view of area U shown in FIG. **26**.
[0030] FIG. **28** is an enlarged view of area V shown in FIG. **27**.
[0031] FIG. **29** is a cross-sectional view of another embodiment of a valve and the valve seat. The valve is shown in an almost closed position.
[0032] FIG. **30** in an enlarged view of area X shown in FIG. **29**.
[0033] FIG. **31** is a top perspective view of another embodiment of a valve and the valve seat. The valve is shown in a closed position.
[0034] FIG. **32** is a side elevational view of the valve and valve seat shown in FIG. **31**.
[0035] FIG. **33** is a cross-sectional view of the valve and valve seat shown in FIG. **32**, taken along line Y-Y. The valve is shown in an almost closed position.
[0036] FIG. **34** is an exploded view of the valve and valve seat shown in FIG. **31**.
[0037] FIG. **35** is an enlarged view of area Z shown in FIG. **33**.
[0038] FIG. **36** is a cross-sectional view of another embodiment of a valve and the valve seat. The valve is shown in an almost closed position.
[0039] FIG. **37** is an enlarged view of area AA shown in FIG. **36**.
[0040] FIG. **38** is a cross-sectional view of another embodiment of a valve and the valve seat. The valve is shown in an almost closed position.
[0041] FIG. **39** is an enlarged view of area AB shown in FIG. **38**.
[0042] FIG. **40** is a cross-sectional view of another embodiment of a valve and the valve seat. The valve is shown in an almost closed position.
[0043] FIG. **41** is an enlarged view of area AC shown in FIG. **40**.

DETAILED DESCRIPTION

[0044] With reference to FIG. **1**, one embodiment of a fluid end **10** is shown attached to one embodiment of a power end **12**. Fluid ends, like the fluid end **10**, are used in oil and gas operations to deliver highly pressurized corrosive and/or abrasive fluids to piping leading to a wellbore. Power ends, like the power end **12**, are configured to reciprocate plungers, like the plunger **14**, shown in FIG. **2**, within a fluid end to pump fluid throughout the fluid end. Fluid used in high pressure hydraulic fracturing operations is typically pumped through a fluid end at a minimum of 8,000 psi; however, fluid will normally be pumped through a fluid end at pressures around 10,000-15,000 psi during such operations, with spikes up to 22,500 psi.
[0045] With reference to FIG. **2**, the fluid end **10** comprises a housing **16** having a horizontal bore

18 and a vertical bore **20** extending therethrough. The horizontal bore **18** opens on opposed front and rear surfaces **22** and **24** of the housing **16**, and the vertical bore **20** opens on opposed upper and lower surfaces **26** and **28** of the housing **16**. The bores **18** and **20** intersect to form an internal chamber **30**. The plunger **14** is installed within the horizontal bore **18** through the opening on the rear surface **24**. As the plunger **14** reciprocates, it pressurizes fluid contained within the internal chamber **30**. A plurality of horizontal and vertical bore pairs **18** and **20** may be formed within a single fluid end housing **16**.

[0046] Continuing with FIG. **2**, fluid is routed throughout the housing **16** using an intake valve **34** and a discharge valve **36**. The valves **34** and **36** are identical and configured to seal against a valve seat **38**. The intake valve **34** and corresponding valve seat **38** are positioned below the internal chamber **30**, and the discharge valve **36** and corresponding valve seat **38** are positioned above the internal chamber **30**. During operation, the valves **34** and **36** move between open and closed positions. In the open position, the valve **34** or **36** is spaced from the valve seat **38**, allowing fluid to flow around the valve **34** or **36**. The intake valve **34** is shown in the open position in FIG. **2**. In the closed position, the valve **34** or **36** seals against the valve seat **38**, blocking fluid from passing around the valve **34** or **36**. The discharge valve **36** is shown in the closed position in FIG. **2**. The valves **34** and **36** are biased in a closed position by a spring **40** and moved to an open position by fluid pressure.

[0047] Continuing with FIG. **2**, the valves **34** and **36** each comprise a seal **42**. When the valve **34** or **36** is in a closed position, the seal **42** is compressed against the valve seat **38**, forming a tight seal. Seals used with valves, like the valves **34** or **36**, are typically made of urethane and molded to the valve body. In traditional fluid ends, the high fluid pressure within the fluid end has been known to wear and erode the area of the seal contacting the valve seat. Such erosion will cause the valve to fail to seal properly, allowing fluid to leak around the valve. The seal is also known to shear or separate from the valve body, allowing fluid to leak around the valve. This leakage reduces the maximum pressure and flow capabilities of the fluid end. Once the valve fails, it will need to be replaced to ensure proper function of the fluid end. The operation of a fluid end must be stopped in order to replace a valve, costing valuable production time and money.

[0048] The present disclosure describes a plurality of different embodiments of valves, including the valves **34** and **36** shown in FIG. **2**. The various embodiments of valves described herein are each designed to reduce wear and erosion to the valve over time, as well as prevent the seal from shearing or separating from the valve body. Such advantages extend the life of the valves disclosed herein as compared to traditional valves. Extending the life of a valve extends production time between valve replacements, saving valuable time and money.

[0049] Even if not specifically shown in the figures herein, the various embodiments of valves described herein may be configured as leg-guided valves, like the valves **34** and **36** shown in FIG. **2**. In alternative embodiments, the various embodiment of valves described herein may be configured as stem-guided valves, like intake and discharge valves **41** and **44**, shown in FIG. **3**. In further alternative embodiments, the various embodiments of valves described herein may be configured for use in different embodiments of fluid ends, such as the fluid end **50**, shown in FIGS. **4** and **5**.

[0050] With reference to FIGS. **4** and **5**, the fluid end **50** is shown attached to another embodiment of a power end **52**. In contrast to the fluid end **10**, the fluid end **50** comprises a plurality of fluid end sections **54** positioned in a side-by-side relationship. Each fluid end section **54** has a single horizontal bore **56** formed therein, as shown in FIG. **5**. Fluid is routed throughout the horizontal bore **56** using a fluid routing plug **58**. Fluid enters the horizontal bore **56** through one or more intake or suction conduits **60** and discharges from the horizontal bore **56** through one or more discharge conduits **62**, as shown in FIG. **5**.

[0051] Continuing with FIG. **5**, fluid flow throughout the fluid routing plug **58** is controlled by an intake or suction valve **64** and a discharge valve **66**. The valves **64** and **66** engage opposite sides of the fluid routing plug **58** such that the fluid routing plug **58** functions as a valve seat. The valves **64** and **66** shown in FIG. **5** are stem-guided valves, like the valves **41** and **44** shown in FIG. **3**. The valves **64** and **66** are generally identical to the valves **41** and **44** but may vary in size. The fluid end **50** is described in more detail in U.S. patent application Ser. No. 17/884,712, authored by Cole et al., the entire contents of which are incorporated herein by reference.

[0052] Turning to FIGS. **6-15**, the valve **34** is shown in more detail. Because the valves **34** and **36** are identical, only the valve **34** will be described in detail herein. The valve **34** is shown in the closed position, engaging the valve seat **38** in FIGS. **6** and **7**, and is shown in the open position, spaced from the valve seat **38** in FIGS. **8** and **9**.

[0053] Continuing with FIG. **10**, the valve **34** comprises a valve body **70** having a tapered sealing surface **72** joined to a side surface **74** by a recessed surface **76**. The side surface **74** is further joined to an upper surface **78** of the valve body **70**. A nose **80** projects from the upper surface **78** and is configured to engage the spring **40**, as shown in FIG. **2**. The tapered sealing surface **72** is further joined to a lower surface **82** of the valve body **70**. A plurality of legs **84** extend from the lower surface **82** in a downward direction. The plurality of legs **84** are configured to center the valve **34** within a flow passage **86** formed in the valve seat **38**. The legs **84** ensure the valve **34** is properly aligned with the valve seat **38** during operation.

[0054] Continuing with FIGS. **10** and **11**, the recessed surface **76** forms a recess **88** within the valve body **70**. The seal **42** is installed within the recess **88** and engages the recessed surface **76**. As mentioned, the seal **42** is made of urethane and molded to the valve body **70** to form the valve **34**. When the valve **34** is in the closed position, the tapered sealing surface **72** and a portion of the seal **42** engage a tapered strike face **90** formed at the top of the valve seat **38**, as shown in FIG. **11**.

[0055] Turning to FIGS. **12** and **13**, a profile of the recessed surface **76** comprises a plurality of straight-line segments and a plurality of radius segments. The straight-line segments comprise: L**1**, L**2**, L**3**, and L**4**. The radius segments comprise: R**1**, R**2**, R**3**, and R**4**. L**1** starts at the end of the tapered sealing surface **72** as shown in FIG. **13**. L**1** extends a short distance and transitions into R**1**. R**1** transitions into L**2**, L**2** transitions into R**2**, R**2** transitions in L**3**, L**3** transitions into R**3**, R**3** transitions into L**4**, and L**4** transitions into R**4**, as shown in FIG. **12**. R**4** transitions into the side surface **74**. Put another way, L**1** is positioned intermediate the tapered sealing surface **72** and R**1**, L**2** is positioned intermediate R**1** and R**2**, L**3** is positioned intermediate R**2** and R**3**, L**4** is positioned intermediate R**3** and R**4**, and R**4** is positioned intermediate L**4** and the side surface **74**.

[0056] Continuing with FIGS. **12** and **13**, L**1** extends at a 0-10-degree angle counterclockwise from vertical, preferably 5-degrees, as shown in FIG. **13**. L**2** may be at a 25-35-degree angle counterclockwise from vertical, preferably 30-degrees, as shown in FIG. **12**. L**3** may be at a 17-27-degree angle counterclockwise from horizontal, preferably 22-degrees, and L**4** is generally horizontal, as shown in FIG. **12**. While the specific values of L**1**, L**2**, L**3**, and L**4** may vary depending on the size of the valve **34**, the relationship between the plurality of line segments are preferably: L**2**>L**4**>L**3**>L**1**. Likewise, while the specific values of R**1**, R**2**, R**3**, and R**4** may vary depending on the size of the valve **34**, the relationship between the plurality of radius segments are preferably: R**1**>R**3**>R**2**>R**4**.

[0057] Continuing with FIG. **12**, the side surface **74** comprises a straight-line segment, L**5** and a radius segment, R**5**. L**5** is generally vertical and is positioned intermediate R**4** and R**5**. R**5** transitions into the upper surface **78**. L**5** is preferably less than L**3**, but greater than L**1**. R**5** is generally equal in size to R**4**. The seal **42** is installed within the recess **88** such that the seal **42** engages L**1**, L**2**, L**3**, L**4**, L**5**, R**1**, R**2**, R**3**, R**4**, and R**5**. When installed therein, the seal **42** covers the side surface **74** and an edge **92** of the seal **42** meets the upper surface **78** of the valve body **70**.

[0058] Continuing with FIG. **12**, the combination of the plurality of straight-line segments and the plurality of radius segments forms a double dovetail with the seal **42** when the seal **42** is installed within the recess **88**. Such configuration helps retain the seal **42** within the recess **88** as well as transfers high stress areas of the seal **42** to areas better suited to withstand high stress during operation. The configuration of L**4**, R**4**, L**5**, and R**5** forms a flange **94** at the upper end of the valve body **70**. The horizontal orientation of the flange **94** further aids in keeping the seal **42** contained within the recess **88** during operation. The flange **94** also forces the seal **42** in a specific direction rather than allowing the pressure imposed on the seal **42** by the valve seat **38** to dictate the seal's movement when compressed. Forcing the seal **42** in a specific direction helps prevent the seal **42** from wrapping around an edge **96** of the valve seat **38** during operation. Such action is known to cause damage to traditional seals.

[0059] With reference to FIGS. **11** and **14**, the seal **42** comprises a strike face **98** joined to an outer face **100**. The strike face **98** engages the valve seat **38** in addition to the tapered sealing surface **72** during operation, as shown in FIG. **11**. The strike face **98** comprises a first section **102** joined to a second section **104**, as shown in FIG. **14**. The first section **102** contacts the tapered sealing surface **72** while the second section **104** transitions into the outer face **100**.

[0060] Continuing with FIG. **14**, in traditional valves, the strike face of the seal is generally coplanar with the tapered sealing surface of the valve body. In the valve **34**, the first section **102** is coplanar with the tapered sealing surface **72** at the point of direct contact with the tapered sealing surface **72**, but transitions to have a concave shape. The first section **102** of the strike face **98** transitions into the second section **104** of the strike face **98** at an inflection point, I. The second section **104** has a convex shape and extends vertically downwards past the plane containing the tapered sealing surface **72** to a point, P. When the valve **34** moves from an open to a closed position, point P contacts the tapered strike face **90** of the valve seat **38** before the rest of the seal strike face **98** and the tapered sealing surface **72**.

[0061] With reference to FIGS. **13** and **14**, upon contact of point P with the strike face **98** of the valve seat **38**, a space or standoff, S exists between the tapered strike face **90** and the first section **102** of the seal **42**, as shown in FIG. **13**. The standoff, S may be in the range of 0.015 to 0.035 inches. The standoff, S creates a cushion, slowing the valve **34** down before the entirety of the seal strike face **98** and the tapered sealing surface **72** impact valve seat **38**. Such action helps to decrease wear on the seal **42** and the tapered sealing surface **72** during operation, thereby increasing the life of the valve **34**.

[0062] Continuing with FIG. **14**, a profile of the area of contact between the strike face **98** of the seal **42** and the tapered strike face **90** of the valve seat **38** has a length, F. F starts at F**1**, which is a point that aligns with the point of contact between the tapered sealing surface **72** and the first section **102** of the strike face **98**. F ends at F**2**, which is a point that aligns with the end of the second section **104** of the strike face **98** or the point where the second section **104** transitions into the outer face **100** of the seal **42**.

[0063] Point, P may be positioned anywhere between 60-80% of the total length of F, measured from F**1**. Preferably, point, P is located at 74% of the total length of F. For example, if F is 0.430 inches, point, P will be located anywhere between 0.258-0.344 inches or 0.6F-0.8F, along F. Preferably the distance is 0.218 inches, or 0.74F. The inflection point, I may be located anywhere between 30-50% of the total length of F, measured from F**1**. For example, if F is 0.430 inches, the inflection point, I is located anywhere between 0.129-0.215 inches or 0.3F-0.5F.

[0064] Turning back to FIGS. **11** and **12**, the strike face **98** and the outer face **100** of the seal **42** are formed as one continuous curve. There are no straight sections. This gradual curve provides a smoother, less turbulent fluid flow around the seal **42** with lower velocities. The continuous curve of the outer face **100** also prevents the seal **42** from wrapping around the edge **96** of the valve seat **38** during operation. The one continuous curve may be a splined curve. In alternative embodiments, the one continuous curve may be other types of curves known in the art as long as there are no straight sections in the curve. Because the outer face **100** is shaped from one continuous curve, the outer face **100** does not include any bulbous protrusions or channels, like those shown in U.S. Pat. No. 9,631,739, issued to Belshan, and U.S. Pat. Nos. 10,221,848 and 11,111,915, both issued to Bayyouk.

[0065] Turning to FIG. **15**, the height, H of the seal **42** is measured perpendicular from the strike face **98** to the maximum diametric extension of radius segment, R**5**. The width, W of the seal **42** is measured from straight-line segment, L**2** to the same maximum diametric extension of radius segment, R**5**. The ratio of the height, H of the seal **42** to the width, W of the seal **42**, H:W, may range from 4.5:6 to 5.5:6. Preferably, the ratio is 5:6. Such ratio has been found to optimally reduce stress and strain on the seal **42** during operation.

[0066] With reference to FIGS. **16-22**, the intake valve **41** shown in FIG. **3** is shown in more detail. The intake valve **41** is identical to the discharge valve **44** so only the valve **41** will be described in more detail herein. The valve **41** comprises a valve body **112** having a tapered sealing surface **114** joined to a side surface **116** by a recessed surface **118**. The side surface **116** is further joined to an upper surface **120** of the valve body **112**. The tapered sealing surface **114** is further joined to a lower surface **122** of the valve body **112**.

[0067] Continuing with FIGS. **18** and **19**, in contrast to the valve **34**, the lower surface **122** of the valve **41** does not include any legs for centering the valve **41** on the valve seat **38**. Instead, a stem **124** projects from the upper surface **120** of the valve **41** and is configured to reciprocate within a bore **126** formed within a valve retainer **128**, as shown in FIG. **3**. The combination of the stem **124** and valve retainer **128** maintains the valve **41** in proper alignment on the valve seat **38** during operation. In the case of the discharge valve **44**, the stem **124** reciprocates within a bore **127** formed in a discharge plug **129**, as shown in FIG. **3**.

[0068] Continuing with FIGS. **18** and **19**, the upper surface **120** of the valve **41** comprises an outer rim **117** joined to a base **115**. A spring **119** used with the valve **41** engages the valve **41** on the outer rim **117**, as shown in FIG. **3**. The spring **119** has a conical shape in order to extend between the outer rim **117** and the valve retainer **128** or discharge plug **129**. The stem **124** projects from the base **115** of the upper surface **120**. The outer rim **117** and the base **115** are shaped such that an annular void **121** surrounds a portion of the stem **124**. The annular void **121** reduces the weight of the valve **41** and helps orient the valve's center of gravity during operation.

[0069] Continuing with FIG. **20**, the recessed surface **118** forms a recess **130** within the valve body **112** for receiving a seal **132**. The seal **132** comprises a strike face **134** joined to an outer face **136**. The strike face **134** and the outer face **136** are identical to the strike face **98** and the outer face **100** of the seal **42**. However, the recessed surface **118** the seal **132** engages is different from the recessed surface **76** formed in the valve body **70**.

[0070] Continuing with FIGS. **20** and **21**, a profile of the recessed surface **118** comprises a plurality of straight-line segments and a plurality of radius segments. The straight-line segments comprise: L**1**, L**2**, and L**3**. The radius segments comprise: R**1** and R**2**. L**1** starts at the end of the tapered sealing surface **114** as shown in FIG. **21**. L**1** extends a short distance and transitions into R**1**. R**1** transitions into L**2**, L**2** transitions into R**2**, R**2** transitions in L**3**, and L**3** transitions into the side surface **116**. Put another way, L**1** is positioned intermediate the tapered sealing surface **114** and R**1**, L**2** is positioned intermediate R**1** and R**2**, L**3** is positioned intermediate R**2** and the side surface **116**.

[0071] Continuing with FIG. **20**, the side surface **116** of the valve body **112** comprises a radius segment, R**3**. R**3** transitions into the upper surface **120** of the valve body **112**. Thus, R**3** is positioned intermediate L**3** and the upper surface **120**. The shape of L**3** and R**3** forms a flange **138** at a top end of the valve **41**. The flange **138** provides the same advantages as the flange **94** formed on the valve **34**.

[0072] Continuing with FIGS. **20** and **21**, straight-line segment, L**1** extends at a 0-10-degree angle counterclockwise from vertical, preferably 5-degrees, as shown in FIG. **21**. Straight-line segment, L**2** may be at a 25-35-degree angle counter-clockwise from vertical, preferably 30-degrees. Straight-line segment, L**3** may be at a 10-20-degree angle counterclockwise from horizontal, preferably 15-degrees. While the specific values of L**1**, L**2**, and L**3** may vary depending on the size of the valve **41**, the relationship between the plurality of line segments are preferably: L**3**>L**2**>L**1**.

Likewise, while the specific values of R**1**, R**2**, and R**3** may vary depending on the size of the valve **41**, the relationship between the plurality of radius segments are preferably: R**1**>R**2**>R**3**. For example, a 4-inch valve **41** may have a L**1** value that is 50% of the L**2** value, but a 6-inch valve may have a L**1** value that is 30% of the L**2** value. In both cases, L**2** is greater than L**1**.
[0073] Continuing with FIG. **20**, the plurality of straight-line segments and the plurality of radius segments together form a reservoir **139** on the internal portion of the seal **132** that absorbs energy caused by the compression and pressure loads encountered during operation. Like the valve body **70**, the angle of straight-line segment, L**2** further minimizes bulging on the outer face **136** of the seal **132**, thereby reducing stress and strain on the seal **132**.
[0074] Continuing with FIG. **22**, the height, H and width, W of the seal **132** are measured in the same general manner as the seal **42**, shown in FIG. **15**. The seal **132** preferably uses the same height and width ratios as the seal **42**.
[0075] Turning to FIGS. **23-28**, another embodiment of a valve **150** is shown. The valve **150** may be used as a discharge or an intake valve. The valve **150** comprises a valve body **152** having a tapered sealing surface **154** joined to an upper surface **156** by an intermediate surface **158**, as shown in FIGS. **25** and **26**. The tapered sealing surface **154** further joins a lower surface **159**. In the embodiment shown in FIGS. **23-28**, a plurality of legs **161** project from the lower surface **159**, making the valve **150** a leg-guided valve.
[0076] Continuing with FIGS. **25** and **26**, in contrast to the valves **34** and **42**, the valve body **152** does not comprise a recessed surface or a recess for receiving a seal. Nor does the valve body **152** comprise a flange, like the flanges **94** or **138** shown in FIGS. **12** and **20**. Instead, a seal **160** engages the intermediate surface **158** of the valve body **152**. No part of the valve body **152** extends over any part of the seal **160**.
[0077] With reference to FIGS. **27** and **28**, a profile of the intermediate surface **158** of the valve body **152** comprises a plurality of straight-line segments: L**1** and L**2**, and a plurality of radius segments: R**1** and R**2**. L**1** joins the tapered sealing surface **154** and transitions into R**1**, as shown in FIG. **28**. R**1** transitions into L**2**, L**2** transitions into R**2**, and R**2** joins the upper surface **156** of the valve body **152**, as shown in FIG. **27**. Put another way, L**1** is positioned intermediate the tapered sealing surface **154** and R**1**, L**2** is positioned intermediate R**1** and R**2**, and R**2** is positioned intermediate L**2** and the upper surface **156**.
[0078] Continuing with FIGS. **27** and **28**, L**1** extends at a 0-10-degree angle counterclockwise from vertical, preferably 5-degrees, as shown in FIG. **28**. L**2** may be at a 25-35-degree angle counterclockwise from vertical, preferably 30-degrees, as shown in FIG. **27**. While the specific values of L**1** and L**2** may vary depending on the size of the valve **150**, the relationship between the plurality of line segments are preferably: L**2**>L**1**. Likewise, while the specific values of R**1** and R**2** may vary depending on the size of the valve **150**, the relationship between the plurality of radius segments are preferably: R**1**>R**2**.
[0079] Continuing with FIG. **27**, the seal **160** is typically made of urethane and is molded to the valve body **152** such that the seal **160** engages L**1**, R**1**, L**2**, and R**2** of the intermediate surface **158** and an edge **162** of the seal **160** joins the upper surface **156**. The seal **160** comprises a strike face **164** joined to an outer face **166**. The strike face **164** is identical to the strike face **98** shown in FIG. **14**. Like the seals **42** and **132**, the outer face **166** is one continuous curve, with no straight sections. Preferably, the curve is a splined curve. The curve of the outer face **166**, however, has a different shape than the outer faces **100** and **136**.
[0080] Continuing with FIGS. **26** and **27**, the outer face **166** has an even more gradual curve than the outer faces **100** and **136** such that it has a less rounded shape. Instead, an upper portion of the outer face **166** has a more sloped shape, such that the edge **162** of the seal is positioned farther away from an outer edge **96** of the valve seat **38** than the seals **42** and **132**. Such construction of the seal **160** helps prevent the seal **160** from wrapping around the edge **96** of the valve seat **38** during operation because no portion of the seal extends past the outermost diameter of the tapered strike

face **90**. Like the seals **42** and **132**, the outer face **166** does not include any bulbous protrusions or channels.

[0081] Continuing with FIGS. **26** and **27**, the shape of the intermediate surface **158** and the shape of the attached seal **160** exposes the entire outer face **166** of the seal **160** to the fluid pressure within the fluid end. The pressure applies a force perpendicular to the surface of the outer face **166** of the seal **160** at every point along the outer face **166**. The resultant force presses the seal **160** into the valve body **152**, thereby reducing the shearing effect of the fluid flow as it exits the valve **150**.

[0082] Turning back to FIGS. **23-25**, the valve **150** is shown with another embodiment of a valve spring **168**. The spring **168** is identical to the spring **40**, but a bottom end **170** of the spring **168** is squared and ground to provide a more even force application to the upper surface **156** of the valve body **152**, as shown in FIG. **26**. Likewise, a top end **172** of the spring **168** is ground so as to better engage a valve retainer, as shown in FIGS. **23** and **24**. Such modifications or like modifications may be made to any of the springs used with the various embodiments of valves disclosed herein so as to provide a more even force application to the corresponding surfaces.

[0083] Turning to FIGS. **29** and **30**, another embodiment of a valve **180** is shown. The valve **180** may be used as a discharge or an intake valve. The valve **180** comprises the valve body **152** used with the valve **150**, but the valve **180** uses a different embodiment of a seal **182**. The seal **182** comprises a strike face **184** joined to an outer face **186**, as shown in FIG. **30**. The strike face **184** is identical to the strike face **164** of the seal **160**, but the seal **182** has another embodiment of an outer face **186**.

[0084] Continuing with FIG. **30**, in contrast to the outer face **166** of the seal **160**, the outer face **186** of the seal **182** is not a splined curve. Instead, the outer face **186** comprises two straight-line segments: L**3** and L**4**, and a radius segment: R**3**. L**3** joins a transition section **190** to the outer face **186**. The transition section **190** joins the strike face **184** to the outer face **186**. L**3** transitions into L**4**, and L**4** transitions into R**3**. R**3** is joined to the upper surface **156** of the valve body **152**. Put another way, L**3** is positioned intermediate the strike face **184** and L**4**. More specifically, L**3** is positioned intermediate the transition section **190** and L**4**. L**4** is positioned intermediate L**3** and R**3**, and R**3** is positioned intermediate L**4** and the upper surface **156**.

[0085] Continuing with FIG. **30**, L**3** extends perpendicular to the tapered strike face **90** of the valve seat **38** and is parallel to L**2** of the intermediate surface **158** of the valve body **152**. L**3** preferably extends at an angle that is 30-degrees counterclockwise from vertical. The angle may have a range of plus or minus 5-degrees, with the intent that L**3** maintains the desired perpendicular and parallel relationships with the valve seat **38** and valve body **152**.

[0086] Continuing with FIG. **30**, L**4** extends at angle between L**3** and R**3**. While the angle shown in FIG. **30** is approximately 45-degrees counterclockwise from vertical, it may be any value greater than the angle of L**3**. Such construction of the seal **182** provides a tapering of the outer face **186** towards the upper surface **156** of the valve body **152**. The flat surface provided by L**4** directs the resultant force applied by fluid pressure directly into the valve body **152**, thereby reducing the tensile force attempting to tear the seal **182** away from the valve body **152** during operation.

[0087] Continuing with FIG. **30**, the flat surface of the seal **182** created by L**4** directs the resultant force in two directions. The first direction is into the valve body **152**, and the second direction is perpendicular to the strike face **184**. The direction of such forces counteracts the upward force applied by fluid as it exits the valve **180** and the upward force applied by the closing of the valve **180**, thereby reducing the shear between the seal **182** and the intermediate surface **158** of the valve body **152**.

[0088] Turning to FIGS. **31-35**, another embodiment of a valve **200** is shown. The valve **200** may be used as a discharge or an intake valve. The valve **200** comprises the valve **180** and a conical sleeve **202**. The conical sleeve **202** is shaped to fit over the outer face **186** of the seal **182** and acts as a retaining mechanism for the seal **182** during operation. The conical sleeve **202** also protects the outer face **186** of the seal **182** from erosion during operation. The use of the conical sleeve **202** also requires the valve **200** to use another embodiment of a spring **204**, which will be described in more detail herein.

[0089] Continuing with FIGS. **34** and **35**, the conical sleeve **202** comprises a body **206** having an inner face **208** and an outer face **210**. The body **206** further comprises a lip **212** formed around the outer face **210** and at a bottom end of the body **206**. The lip **212** is sized to receive a bottom end **216** of the spring **204**. The inner face **208** of the sleeve **202** is congruent to straight-line segment, L**4** of the outer face **186** of the seal **182**, as shown in FIG. **35**. The conical sleeve **202** is installed on the valve **180** such that the outer face **186** of the seal **182** engages the inner face **208** of the sleeve **202**. The sleeve **202** is held against the seal **182** by tension applied by the spring **204**. Thus, the sleeve **202** is easily separated from the seal **182**, if needed. The sleeve **202** only contacts the seal **182** and the spring **204**. The sleeve **202** does not contact any portion of the valve body **152**, the valve seat **38**, or the fluid end.

[0090] Turning back to FIGS. **31** and **32**, in order to rest within the lip **212** of the sleeve **202**, the spring **204** has a conical shape, similar to the spring **119** shown in FIG. **3**. The bottom end **216** of the spring **204** has a greater diameter than the springs **40** and **168**, while a top end **218** of the spring **204** has the same diameter as the springs **40** and **168**. The increased diameter at the bottom end **216** of the spring **204** provides stability and leverage to keep the seal **182** contained within the sleeve **202**. The actual diameters of the springs **40**, **119**, **168**, and **204** may vary depending upon the size of the valve used.

[0091] Continuing with FIGS. **31** and **32**, the spring **204** may be squared and/or ground at its ends like the spring **168**, if desired. The spring **204** and the sleeve **202** may be separate pieces that are held together by compression during operation. Alternatively, the spring **204** may be welded to the sleeve **202** or attached by other methods known in the art.

[0092] Turning to FIGS. **36** and **37**, another embodiment of a valve **250** is shown. The valve **250** may be used as a discharge or an intake valve. The valve **250** comprises a valve body **252**. The valve body **252** is identical to the valve body **152**, but the valve body **252** comprises another embodiment of an intermediate surface **254**. The intermediate surface **254** is identical to the intermediate surface **158** but comprises a groove **256** formed within straight-line segment, L**2**. As shown in FIG. **37**, a bottom surface **258** of the groove **256** has a negative slope, as viewed from the center of the valve body **252** toward the outer diameter of the valve body **252**.

[0093] Continuing with FIGS. **36** and **37**, the valve **250** further comprises another embodiment of a seal **260**. The seal **260** is identical to the seal **182**, but an inner surface **262** of the seal **260** comprises a protrusion **264** sized to correspond with the shape of the groove **256**. The protrusion **264** and the groove **256** together act as a locking mechanism **266** between the valve body **252** and the seal **260**, as shown in FIG. **37**. In operation, the locking mechanism **266** provides more surface area for the seal **260** and the intermediate surface **254** to interface, thereby reducing the force per unit area applied to such interface. The locking mechanism **266** also provides varying angles at the interface between the seal **260** and the intermediate surface **254**. The varying angles interrupt the application of the shear force along such interface, thereby increasing the life of the bond between the seal **260** and the valve body **252**.

[0094] Continuing with FIGS. **36** and **37**, the valve **250** also uses the conical sleeve **202** and spring **204** used with the valve **200**. In alternative embodiments, the valve **250** may not use the conical sleeve **202** and instead be used with the spring **40** or **168**, shown in FIGS. **2** and **23**.

[0095] Turning to FIGS. **38** and **39**, another embodiment of a valve **280** is shown. The valve **280** is identical to the valve **250**, but the valve **280** comprises another embodiment of a locking mechanism **282**. Instead of just a single groove formed in an intermediate surface of the valve, the intermediate surface **284** of the valve **280** comprises a plurality of grooves **286** formed along its length. Like the groove **256**, a bottom surface **288** of each groove **286** has a negative slope.

[0096] Continuing with FIG. **39**, the valve **280** further uses another embodiment of a seal **290**. The seal **290** is identical to the seal **260** but comprises a plurality of protrusions **292**. Each protrusion

292 is sized to mate with a corresponding one of the grooves **286**. The mating protrusions **292** and grooves **286** together form the locking mechanism **282**. The locking mechanism **282** provides even more surface area for the seal **290** to interface with the intermediate surface **284**. The locking mechanism **282** also provides more interruption points in case the seal **290** begins to separate from the intermediate surface **284**.

[0097] Continuing with FIGS. **38** and **39**, the valve **280** also uses the conical sleeve **202** and the spring **204** used with the valve **200**. In alternative embodiments, the valve **280** may not use the conical sleeve **202** and instead be used with the spring **40** or **168**, shown in FIGS. **2** and **23**.

[0098] Turning to FIGS. **40** and **41**, another embodiment of a valve **300** is shown. The valve **300** is identical to the valve **280**, but the valve **300** comprises another embodiment of a locking mechanism **302**. The locking mechanism **302** is identical to the locking mechanism **282**, but a bottom surface **304** of each groove **306** has a positive slope instead of a negative slope. A seal **308** used with the valve **300** comprises a plurality of protrusions **310**. The protrusions **310** are identical to the protrusions **292**, but the protrusions **310** are shaped to mate with the positively sloped bottom surface **304** of the grooves **306**. Forming the grooves **306** with a positively sloped bottom surface **304** provides a more sharply angled bottom surface **304**. The corresponding shape of the protrusions **310** is harder to tear during operation. The grooves **306** also have a smoother transition between adjacent grooves **306**. The smoother transition creates more surface area for the seal **308** to compress before tearing.

[0099] Continuing with FIGS. **40** and **41**, the valve **300** also uses the conical sleeve **202** and spring **204** used with the valve **200**. In alternative embodiments, the valve **300** may not use the conical sleeve **202** and instead be used with the spring **40** or **168**, shown in FIGS. **2** and **23**.

[0100] A plurality of kits may be useful with the various embodiments of valves disclosed herein. One embodiment of a kit may comprise a valve, a conical sleeve, and/or a spring. Another embodiment of a kit may further comprise a valve seat.

[0101] The various features and alternative details of construction of the apparatuses described herein for the practice of the present technology will readily occur to the skilled artisan in view of the foregoing discussion, and it is to be understood that even though numerous characteristics and advantages of various embodiments of the present technology have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the technology, this detailed description is illustrative only, and changes may be made in detail, especially in matters of structure and arrangements of parts within the principles of the present technology to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

Claims

1. An apparatus, comprising: a valve body configured to seal against a valve seat, the valve body comprising: an upper surface; a tapered sealing surface; a side surface; and a recessed surface situated between the tapered sealing surface and the side surface, the recessed surface comprising: a first straight segment extending from the side surface; a first concave segment; a second straight segment; and a second concave segment situated between the second straight segment and the tapered sealing surface; in which the first concave segment is situated between the first straight segment and the second straight segment; and in which the first concave segment has a different radius than the second concave segment.

2. The apparatus of claim 1, in which the recessed surface forms a recess within the valve body.

3. The apparatus of claim 2, in which the recess is configured to receive a seal.

4. The apparatus of claim 1, in which the first concave segment has a radius value, R**1**; and in which the second concave segment has a radius value, R**2**; in which R**1** is greater than R**2**.

5. The apparatus of claim 1, in which the first straight segment has a length, L**1**; and in which the

second straight segment has a length, L**2**; in which L**1** is greater than L**2**.
6. The apparatus of claim 1, in which the first straight segment is parallel to the upper surface.
7. The apparatus of claim 6, in which the second straight segment is formed at a non-zero angle relative to the first straight segment.
8. The apparatus of claim 7, in which the non-zero angle is between 17 and 27 degrees.
9. The apparatus of claim 1, in which the recessed surface of the valve body further comprises: a third straight segment situated intermediate the second concave segment and the tapered sealing surface.
10. The apparatus of claim 9, in which the side surface is perpendicular to the upper surface, in which the third straight segment is formed at an angle between 25 and 35 degrees relative to the side surface.
11. The apparatus of claim 9, in which the recessed surface of the valve body further comprises: a convex segment situated intermediate the third straight segment and the tapered sealing surface.
12. The apparatus of claim 11, in which the recessed surface of the valve body further comprises: a fourth straight segment situated between the convex segment and the tapered sealing surface.
13. The apparatus of claim 12, in which the fourth straight segment is formed at an angle between 0 and 10 degrees relative to the side surface.
14. The apparatus of claim 1, in which the tapered sealing surface is formed at an angle between 55 and 65 degrees to the side surface.
15. An apparatus, comprising: a valve body, comprising: an upper surface; a tapered sealing surface; and a recessed surface situated intermediate the upper surface and the tapered sealing surface, in which the recessed surface forms a recess in the valve body, in which the recessed surface comprises: a first straight segment; a second straight segment; and a concave segment between the first straight segment and the second straight segment; in which the second straight segment is formed at an angle greater than 90 degrees relative to the first straight segment.
16. The apparatus of claim 15, in which the angle is between 153 and 163 degrees.
17. The apparatus of claim 15, in which the recessed surface further comprises a second concave segment situated between the second straight segment and the tapered sealing surface.
18. The apparatus of claim 17, in which the recessed surface further comprises a convex segment situated between the second concave segment and the tapered sealing surface.
19. The apparatus of claim 15, further comprising a seal situated within the recess of the valve body.
20. A method of assembling the apparatus of claim 19, in which the seal is molded to the valve body.