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PACKING SEAL ASSEMBLY

Abstract

A fluid end assembly comprising a plurality of fluid end sections positioned in a side-by-side relationship. Each fluid end section comprises a housing having a bore formed therein for housing a reciprocating plunger. Fluid is prevented from leaking around the plunger by a packing seal assembly. The packing seal assembly comprises one and only one packing seal.

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Background/Summary

SUMMARY

[0001] The present invention is directed to a fluid end comprising a housing having a longitudinal axis and opposed front and rear surfaces joined by an outer intermediate surface, and a bore formed within the housing and interconnecting the front and rear surfaces. The bore extends along the longitudinal axis of the housing. The housing further comprises a retainer attached to the rear surface of the housing by a plurality of fasteners, a reciprocating plunger disposed within the bore and the retainer, and one and only one packing seal installed within the housing and engaged an outer surface of the plunger.

[0002] The present invention is also directed to an apparatus comprising a packing seal assembly. The packing seal assembly is configured to be installed within a housing having a horizontal bore formed therein. The packing seal assembly comprises one and only one packing seal configured to surround and engage an outer surface of a reciprocating plunger. The one and only one packing seal has opposed front and rear surfaces joined by inner and outer surfaces and comprising an energizing component. The energizing component is installed within the seal and is configured to expand the inner and outer intermediate surfaces during operation. The packing seal assembly further comprises a wear ring surrounding the one and only one packing seal, and an annular component installed within the housing and comprising a projecting portion, the projecting portion engaging the energizing component.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. **1** is a perspective view of one embodiment of a high pressure pump.

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

[0005] FIG. **3** is the cross-sectional view of the fluid end assembly shown in FIG. **2**, but the plunger has been removed.

[0006] FIG. **3**A is the cross-sectional view of the fluid end assembly shown in FIG. **3**, but the cross-section is taken along a different axis.

[0007] FIG. **4** is an enlarged view of area B shown in FIG. **3**.

[0008] FIG. **5** is a front perspective view of the packing seal shown in FIGS. **2**-**4** and **18**-**20**.

[0009] FIG. **6** is a rear perspective view of the packing seal shown in FIG. **5**.
[0010] FIG. **7** is a rear elevational view of the packing seal shown in FIG. **5**.
[0011] FIG. **8** is a cross-sectional view of the packing seal shown in FIG. **7**, taken along line C-C.
[0012] FIG. **9** is an enlarged view of area D shown in FIG. **8**.
[0013] FIG. **10** is a front perspective view of the support element shown in FIGS. **2-4** and **18-20**.
[0014] FIG. **11** is a rear perspective view of the support element shown in FIG. **10**.
[0015] FIG. **12** is a side elevational view of the support element shown in FIG. **10**.
[0016] FIG. **13** is a cross-sectional view of the support element shown in FIG. **12**, taken along line E-E.
[0017] FIG. **14** is an enlarged view of area F shown in FIG. **13**.
[0018] FIG. **15** is a front perspective view of the support element shown in FIG. **10** engaged with the packing seal shown in FIG. **5**.
[0019] FIG. **16** is a cross-sectional view of the support element and packing seal shown in FIG. **15**, taken along line G-G.
[0020] FIG. **17** is an enlarged view of area H shown in FIG. **15**.
[0021] FIG. **18** is a front perspective and partially exploded view of one of the fluid end sections shown in FIG. **1**.
[0022] FIG. **19** is a rear perspective and partially exploded view of the fluid end section shown in FIG. **18**.
[0023] FIG. **20** is the rear perspective and partially exploded view of the fluid end section shown in FIG. **19**, but fewer components are shown exploded.
[0024] FIG. **21** is a front perspective view of the rear retainer shown in FIGS. **2-4** and **18-20**.
[0025] FIG. **22** is a rear perspective view of the rear retainer shown in FIG. **21**.
[0026] FIG. **23** is a front elevational view of the rear retainer shown in FIG. **21**.
[0027] FIG. **24** is a cross-sectional view of the rear retainer shown in FIG. **23**, taken along line I-I.
[0028] FIG. **25** is a front perspective view of the metal ring shown in FIGS. **2-4** and **18-20**.
[0029] FIG. **26** is a rear perspective view of the metal ring shown in FIG. **25**.
[0030] FIG. **27** is a rear elevational view of the metal ring shown in FIG. **25**.
[0031] FIG. **28** is a cross-sectional view of the metal ring shown in FIG. **27**, taken along line J-J.
[0032] FIG. **29** is a front perspective view of the packing nut shown in FIGS. **2-4** and **18-20**.
[0033] FIG. **30** is a rear perspective view of the packing nut shown in FIG. **29**.
[0034] FIG. **31** is a front elevational view of the packing nut shown in FIG. **29**.
[0035] FIG. **32** is a cross-sectional view of the packing nut shown in FIG. **31**, taken along line **32**.
[0036] FIG. **33** is a cross-sectional and enlarged view of another embodiment of a packing seal assembly.

DETAILED DESCRIPTION

[0037] High pressure reciprocating pumps typically comprise a power end assembly attached to a fluid end assembly. Fluid end assemblies are typically used in oil and gas operations to deliver highly pressurized corrosive and/or abrasive fluids to piping leading to the wellbore. Fluid end assemblies are attached to power ends typically run by engines. The power end comprises a crankshaft configured to reciprocate a plurality of plungers within the fluid end assembly to pump fluid throughout the fluid end.
[0038] Fluid may be pumped throughout the fluid end assembly at pressures that range from 5,000-15,000 pounds per square inch (psi). However, the pressure may reach up to 22,500 psi. Power ends typically have a power output of at least 2,250 horsepower during hydraulic fracturing operations. A single fluid end typically delivers a fluid volume of about 185-690 gallons per minute or 4-16 barrels per minute during a fracking operation. When a plurality of fluid ends are used together, the fluid ends collectively deliver about 4,200 gallons per minute or 100 barrels per minute to the wellbore. The present invention improves the performance and life of the various components included in the fluid end assembly.

[0039] Turning now to FIG. **1**, one embodiment of a high pressure pump **10** is shown. The pump **10** comprises a fluid end assembly **12** joined to a power end assembly **14**. The power end assembly **14** is described in more detail in U.S. patent application Ser. No. 17/884,691, authored by Keith, et al., and filed on Aug. 10, 2022, the entire contents of which are incorporated herein by reference. In alternative embodiments, the fluid end assembly **12** may be attached to other power end designs known in the art.
[0040] Continuing with FIG. **1**, the fluid end assembly **12** comprises a plurality of individual fluid ends, or fluid end sections **16** positioned in a side-by-side relationship. Each fluid end section **16** is attached to the power end assembly **14** using a plurality of stay rods **18**.
[0041] Turning to FIGS. **18**-**20**, each fluid end section **16** comprises a housing **20** having a longitudinal axis **22** and opposed front and rear surfaces **24** and **26** joined by an outer intermediate surface **28** and a horizontal bore **30** formed therein, as shown in FIG. **19**. The horizontal bore **30** interconnects the front and rear surfaces **24** and **26** of the housing **20**. The housing **20** comprises multiple pieces joined together by the stay rods **18**, as shown in FIG. **1**.
[0042] Turning to FIGS. **2**-**3**A, another embodiment of a housing **20**A is shown. Like the housing **20**, the housing **20**A comprises a longitudinal axis **22** and opposed front and rear surfaces **24** and **26** joined by an outer intermediate surface **28** and a horizontal bore **30** formed therein. In contrast to the housing **20**, the housing **20**A comprises multiple sections joined together by fasteners **32**. In alternative embodiments, the housing **20** or **20**A may be of single-piece construction.
[0043] Continuing with FIGS. **2**-**3**A, fluid enters the housing **20**A through upper and lower suction bores **34** and **36**. Fluid exits the housing **20**A through upper and lower discharge bores **38** and **40**. Fluid is routed throughout the housing **20**A by a fluid routing plug **42** and suction and discharge valves **44** and **46**. Movement of the valves **44** and **46** is guided by a suction valve guide **48** and a discharge plug **50**. The front surface **24** of the housing **20**A is sealed by a front retainer **52**.
[0044] Continuing with FIG. **2**, a reciprocating plunger **54** is installed within the horizontal bore **30** and projects from the rear surface **26** of the housing **20**A. As the plunger **54** retracts from the housing **20**A, fluid is pulled from the suction bores **34** and **36** into the horizontal bore **30**. As the plunger **54** extends into the housing **20**A, the plunger **54** forces fluid towards the discharge bores **38** and **40**. While not specifically shown herein, the housing **20**, shown in FIGS. **1** and **18**-**20**, uses the same inner components as the housing **20**A and operates in the same manner as the housing **20**A. The construction of the housing **20** and **20**A and their above mentioned inner components are described in more detail in U.S. patent application Ser. No. 17/844,712, authored by Thomas et al., and filed on Aug. 10, 2022, the entire contents of which are incorporated herein by reference.
[0045] In traditional fluid ends, fluid is prevented from leaking from the rear surface of the housing by a plunger packing installed within the housing and surrounding the plunger. The plunger packing comprises a plurality of packing seals stacked on top of one another. A tight seal is created by compressing the plurality of stacked seals together longitudinally. During operation, the packing seals require continuous maintenance to make sure they are adequately compressed and sealing against the plunger. Over time, the components of the plunger packing wear against the walls of the housing, causing erosion and eventual failure of the housing.
[0046] Continuing with FIGS. **2**-**4**, and **18**-**20**, the present application discloses a packing seal assembly **60** that comprises one and only one packing seal **62**. By using one and only packing seal **62**, a much smaller surface area of the housing **20**A or **20** is subject to potential wear from the seal **62**. Further, the single packing seal **62** is much easier to install than a plurality of packing seals used with a traditional plunger packing. As will be described in more detail herein, only one packing seal **62** is needed because the packing seal **62** comprises an energizing component **66**. The energizing component **66** expands the packing seal **62** during operation, ensuring a tight seal against an outer surface of the plunger **54**.
[0047] Turning to FIGS. **5**-**9**, traditional packing seals are solid and comprise only an elastomeric body. The packing seal **62** comprises the energizing component **66** installed within an elastomeric

body **63**. The body **63** is annular and has opposed front and rear surfaces **68** and **70** joined by inner and outer intermediate surfaces **72** and **74**. The energizing component **66** is installed within the front surface **68** of the packing seal **62** and is configured to expand radially when compressed longitudinally. Such expansion causes the inner intermediate surface **72** of the packing seal **62** to tightly seal against the outer surface of the plunger **54**, and the outer intermediate surface **74** to tightly seal against the walls of the housing **20**A or **20** or another component installed therein, as shown for example in FIG. **2**.

[0048] Continuing with FIGS. **2**-**4**, **18**, and **19**, one example of another component installed within the housing **20**A or **20** is a wear ring **64**. The wear ring **64** is shown installed within the housing **20**A and surrounding the packing seal **62** in FIGS. **2**-**4**. The wear ring **64** is positioned between the walls of the housing **20**A or **20** and the packing seal **62** and is configured to protect the walls of the housing **20**A or **20** from wear from the packing seal **62** during operation. The wear ring **64** is annular and is made of a harder and more wear resistant material than the housing **20**A or **20**. For example, if the housing **20**A or **20** is made of steel, the wear ring **64** may be made of tungsten carbide. Another example of another component installed within the housing **20**A or **20** may be a stuffing box or sleeve known in the art. The stuffing box or sleeve may be installed within the housing **20**A or **20** and the packing seal **62** installed within the stuffing box or sleeve.

[0049] Continuing with FIG. **9**, the energizing component **66** comprises a plurality of stacked metal pieces **80** having a V-shaped cross-section that function as a spring. Specifically, the packing seal **62** is known in the art as a multi-contact V-nested spring seal. In alternative embodiments, the energizing component may comprise other components known in the art that expand radially when compressed longitudinally. In further alternative embodiments, the energizing component may comprise one or more coiled springs configured to expand the seal regardless of any longitudinal compression.

[0050] Continuing with FIG. **9**, the inner and outer surfaces **72** and **74** of the packing seal **62** comprise a plurality of seal lips **82**. The seal lips **82** help effectuate sealing during operation. As the seal lips **82** wear over time, the energizing component **66** expands, pushing the lips **82** tighter against the plunger **54** and the wear ring **64**.

[0051] With reference to FIGS. **10**-**17**, the packing seal assembly **60** further comprises a support element **86**. The support element **86** comprises an annular base **88** joined to an annular protrusion **90**. The base **88** comprises opposed front and rear surfaces **92** and **94** joined by a tapered outer surface **96** and a cylindrical inner surface **98**. The protrusion **90** projects from the rear surface **94** and has a tapered outer surface **100**, as shown in FIG. **14**. The rear surface **94** of the support element **86** is configured to engage the front surface **68** of the packing seal **62** such that the protrusion **90** projects into the energizing component **66**, as shown in FIG. **17**. In operation, the protrusion **90** helps keep the energizing component **66** expanded so as to maintain a tight seal against the plunger **54**. However, the packing seal assembly **60** may be used without the support element **86**, if desired.

[0052] Turning back to FIGS. **3** and **4**, the horizontal bore **30** comprises a counterbore **84** that opens on the rear surface **26** of the housing **20**A. The counterbore **84** joins a uniform diameter section **102** of the horizontal bore **30** by a tapered surface **104**, as shown in FIG. **4**. The support element **86** is installed within the housing **20**A such that the tapered outer surface **96** engages the tapered surface **104** of the housing **20**A. The packing seal **62** and the wear ring **64** are installed within the counterbore **84** such that the wear ring **64** engages the walls of the counterbore **84** and the packing seal **62** engages the support element **86**. When the components are installed within the housing **20**A, the rear surface **70** of the packing seal **62** and a rear surface **106** of the wear ring **64** are flush with the rear surface **26** of the housing **20**A. The housing **20** also comprises the counterbore **84** for receiving the support element **86**, the wear ring **64** and the packing seal **62**, as shown in FIG. **19**.

[0053] With reference to FIGS. **2**-**4**, **18**, and **19**, the packing seal **62** and wear ring **64** are held

within the housing **20** or **20**A by a rear retainer **108** having a metal ring **110** and a packing nut **112** installed therein. The rear retainer **108** is attached to the rear surface **26** of the housing **20** or **20**A using a plurality of fasteners **114**, as shown in FIGS. **3**A, **18** and **19**.

[0054] With reference to FIGS. **21-24**, the rear retainer **108** comprises opposed front and rear surfaces **116** and **118** joined by an outer intermediate surface **120** and a central passage **122** formed therein. A plurality of passages **124** are formed in the rear retainer **108**. Each passage **124** interconnects the front and rear surfaces **116** and **118**. The retainer **108** is positioned on the rear surface **26** of the housing **20** or **20**A such that the passages **124** align with a plurality of threaded openings **126** formed in the rear surface **26** of the housing **20** and **20**A, as shown in FIGS. **3**A and **19**.

[0055] With reference to FIGS. **3**A and **18-20**, a fastener **114** is received within each pair of aligned openings and passages **126** and **124**. When installed therein, a threaded end **128** of each fastener **114** is positioned within a counterbore **130** formed in each passage **124** adjacent the rear surface **118** of the retainer **108**, as shown in FIGS. **3**A, **20** and **24**. A threaded nut **132** is installed on each threaded end **128** and turned until the retainer **108** is held firmly against the rear surface **26** of the housing **20** or **20**A. The nuts **132** are each fully disposed within each counterbore **130**, such that no nut projects from the rear surface **118** of the retainer **108**, as shown in FIGS. **3**A and **20**. In alternative embodiments, the passages **122** may not include the counterbore **130** and the nuts **132** may instead engage the rear surface **118** of the retainer **108**.

[0056] Turning back to FIG. **24**, the central passage **122** of the rear retainer **108** comprises a first section **134** joined to a second section **136**. The first section **134** opens on the front surface **116** of the rear retainer **108**, and the second section **136** opens on the rear surface **118** of the rear retainer **108**. One or more lube ports **138** are also formed in the retainer **108**. The lube port **138** interconnects the outer intermediate surface **120** and the first section **134** of the central passage **122**, as shown in FIG. **4**.

[0057] Continuing with FIGS. **4** and **24**, internal threads **140** are formed in the walls of the second section **136** for receiving the packing nut **112**. The walls surrounding the first section **134** of the central passage **122** are flat and configured to receive the metal ring **110**. When the retainer **108** is attached to the housing **20**, the central passage **122** aligns with the counterbore **84** formed in the housing **20**A or **20**, exposing the wear ring **64** and packing seal **62**, as shown in FIG. **4**.

[0058] With reference to FIGS. **25-28**, the metal ring **110** comprises opposed front and rear surfaces **142** and **144** joined by inner and outer surfaces **146** and **148**. A plurality of passages **150** are formed in the metal ring **110** that interconnect the inner and outer surfaces **146** and **148**. The passages **150** open into an annular channel **152** formed in the outer surface **148** of the metal ring **110**.

[0059] Continuing with FIG. **4**, when the metal ring **110** is installed within the central passage **122**, the front surface **142** of the metal ring **110** engages the rear surface **70** of the packing seal **62** and the rear surface **106** of the wear ring **64**, and the outer surface **148** engages the first section **134** of the central passage **122**. The lube port **138** formed in the retainer **108** aligns with the annular channel **152**. During operation, lubricant is supplied to the fluid end section **16** through the lube port **138**. Lubricant passes through the lube port **138** and into the annular channel **152** and eventually through the passages **150**. Lubricant flowing through the passages **150** contacts and lubricates an outer surface of the reciprocating plunger **54**.

[0060] With reference to FIGS. **2-4**, **18-20**, and **29-32**, the metal ring **110** is held within the retainer **108** by the packing nut **112**. The packing nut **112** comprises opposed front and rear surfaces **154** and **156** joined by an outer intermediate surface **158** and a central passage **160** formed therein. The intermediate surface **158** comprises a threaded section **162** joined to a flange **164**. The threaded section **162** is configured to mate with the internal threads **140** formed in the second section **136** of the central passage **122** of the rear retainer **108**, as shown in FIG. **4**.

[0061] Continuing with FIGS. **4** and **32**, a plurality of openings **166** are formed in the flange **164** of

the packing nut **112**. Each opening **166** interconnects the outer intermediate surface **158** and the central passage **160**. The openings **166** are configured to receive a tool used to turn the packing nut **112** within the retainer **108**. The packing nut **112** is turned within the central passage **122** until the front surface **154** of the packing nut **112** tightly engages the rear surface **144** of the metal ring **110** and the flange **164** abuts the rear surface **118** of the retainer **108**, as shown in FIG. **4**. When tightly engaged, the front surface **142** of the metal ring **110** likewise tightly engages the rear surface **70** of the packing seal **62** and the rear surface **106** of the wear ring **64**, thereby retaining the packing seal **62** and wear ring **64** within the housing **20** or **20**A.

[0062] Continuing with FIGS. **2**, **4**, and **32**, a first groove **170** is formed within the walls of the central passage **160** of the packing nut **112** for housing a first seal **172**, as shown in FIG. **2**. The first seal **172** engages an outer surface of the plunger **54** and prevents fluid from leaking between the components, as shown in FIG. **2**. A second groove **174** is formed in a front surface **176** of the flange **164** of the packing nut **112** for housing a second seal **178**, as shown in FIG. **4**. When the flange **164** abuts the rear surface **118** of the retainer **108**, the second seal **178** engages the rear surface **118** of the retainer **108**. The second seal **178** provides friction between the retainer **108** and the packing nut **112** to help prevent the packing nut **112** from backing out of the retainer **108** during operation.

[0063] Similarly, a groove **180** is formed in the rear surface **144** of the metal ring **110** for housing a seal **182**, as shown in FIGS. **4** and **28**. The seal **182** prevents fluid from leaking between the metal ring **110** and packing nut **112** during operation. The seal **182** further provides friction between the metal ring **110** and the packing nut **112** to help prevent the packing nut **112** from backing off during operation.

[0064] Turning to FIG. **33**, another embodiment of a support element **184** and housing **186** are shown. The housing **186** is identical to the housing **20**A, but it does not include the tapered surface **104**, shown in FIG. **4**. Instead, the walls surrounding a horizontal bore **188** of the housing **186** comprise a first counterbore **190** joined to a uniform diameter section **192** by a second counterbore **194**. The support element **184** is identical to the support element **86**, but a base **196** of the element **184** has a rectangular shaped outer surface **198** configured to be installed within the second counterbore **194** formed in the housing **186**. Additionally, a protrusion **200** projecting from the base **196** of the support element **184** has a generally rectangular or uniform diameter outer surface **202**, instead of the tapered outer surface **100**, shown in FIG. **14**. The support element **184** functions in the same manner as the support element **86**.

[0065] The packing seal assembly **60** disclosed herein may be used with other embodiments of fluid end sections not specifically disclosed herein. For example, the packing seal assembly **60** may be used with the fluid end sections disclosed in U.S. patent application Ser. No. 17/884,712, previously incorporated herein by reference, and U.S. patent application Ser. No. 17/550,552, authored by Thomas et al., the entire contents of which are incorporated herein by reference. Alternatively, the packing seal assembly **60** may be used with traditional block fluid ends known in the art, such as those disclosed in U.S. Pat. No. 10,941,765, issued to Nowell et al., the entire contents of which are incorporated herein by reference. In further embodiments, the packing seal assembly **60** may be used with other embodiments of retaining systems, such as those disclosed in U.S. patent Ser. No. 17/685,936, authored by Foster et al., the entire contents of which are incorporated herein by reference.

[0066] 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. A packing seal assembly configured to surround at least a portion of a reciprocating plunger, the packing seal assembly comprising: a packing seal, comprising: a body, comprising: a front surface; an opposed rear surface; and an inner intermediate surface situated joining the front and rear surfaces, the inner intermediate surface configured to engage the portion of the reciprocating plunger; and an energizing component situated within a void formed in the front surface of body; and a support element, comprising: a protrusion situated at least partially within the void; and an annular base situated outside of the void; in which the support element is configured to retain the energizing component within the void.
2. The packing seal assembly of claim 1, in which the packing seal is one and only one seal.
3. The packing seal assembly of claim 1, in which the body is formed from an elastomeric material.
4. The packing seal assembly of claim 1, in which the energizing component comprises a plurality of stacked pieces.
5. The packing seal assembly of claim 4, in which each of the plurality of stacked pieces has a V-shaped cross section.
6. The packing seal assembly of claim 4, in which each of the plurality of stacked pieces is metal.
7. The packing seal assembly of claim 1, in which the annular base comprises opposed front and rear base surfaces; in which the rear base surface abuts the front surface of the body.
8. The packing seal assembly of claim 7, in which the protrusion extrudes from the rear base surface.
9. A packing seal assembly for use within a fluid end, the packing seal assembly comprising: one and only one packing seal, comprising: a front surface defining an opening; a rear surface opposed to the front surface; an inner intermediate surface interconnecting the front and rear surfaces, the inner intermediate surface comprising a plurality of inner lips; and an outer intermediate surface interconnecting the front and rear surfaces, the outer intermediate surface comprising a plurality of outer lips.
10. The packing seal assembly of claim 9, in which the inner intermediate surface is configured to engage at least a portion of a reciprocating plunger.
11. The packing seal assembly of claim 9, in which the outer intermediate surface is configured to engage a wall of a fluid end housing.
12. A fluid end, comprising: a fluid end housing comprising a bore; an annular ring installed within the bore; and the packing seal assembly of claim 9 situated inside the annular ring.
13. The fluid end of claim 12, in which the annular ring is formed of a harder material than a material used to form the fluid end housing.
14. The fluid end of claim 12, in which the annular ring is a stuffing box.
15. The packing seal assembly of claim 9, further comprising: a plurality of energizing components situated within the opening.
16. The packing seal assembly of claim 15, in which each of the plurality of energizing components is a metal piece having a V-shaped cross-section.
17. The packing seal assembly of claim 9, further comprising: a support element, comprising: a base having a first surface configured to engage a wall formed in a fluid end housing; and a protrusion, at least part of the protrusion situated in the opening.
18. A fluid end, comprising: a fluid end housing having a bore formed therein, the bore comprising a counterbore; and the packing seal assembly of claim 9, further comprising: a support element situated at least partially within the counterbore, the support element comprising a protrusion extending at least partially into the opening.

19. The fluid end of claim 18, further comprising a wear ring situated within the bore, the wear ring surrounding at least a portion of the packing seal assembly.

20. The fluid end of claim 19, in which the wear ring is made of a first material and the housing is made of a second material; in which the first material is harder than the second material.