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(54) **PLUNGER PUMP PACKING ASSEMBLY**

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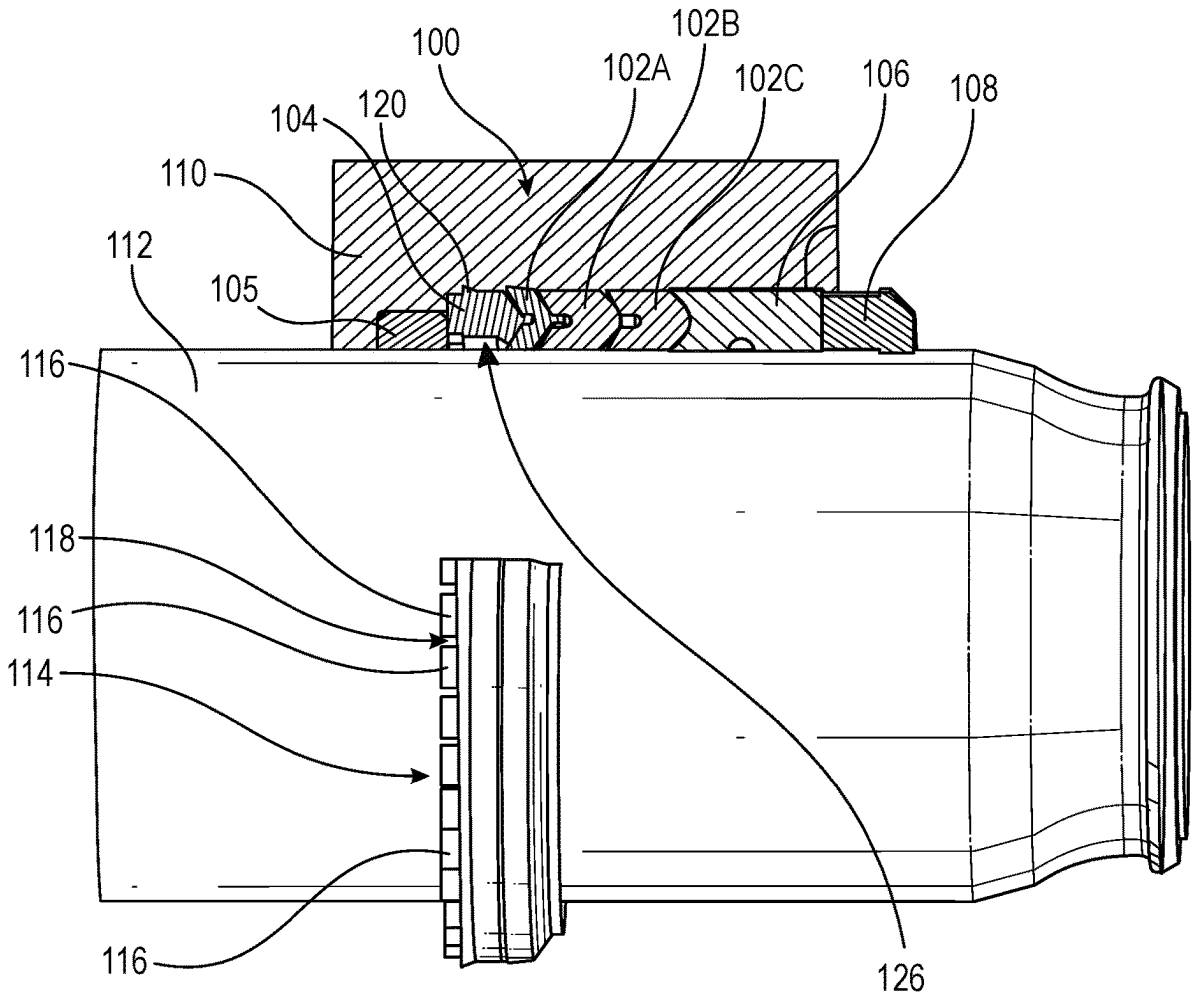
(57) **ABSTRACT**

A plunger pump packing assembly includes a header ring, and one or more seals. The plunger pump packing assembly operates as a seal between a static component and a dynamic component (e.g., reciprocating plunger). The header ring has a vented inside portion to prevent trapping pressure on the outer diameter of the header ring or between the header ring and adjacent seals or packing rings. The vents allow trapped pressure to return when the pumped fluid pressure is lower. A radially protruding edge on the outer diameter of the header ring significantly reduces or prevents migration of abrasive media, such as proppant, between the header ring and the static component. In some examples, the header ring does not contact the dynamic component, thus preventing the trapping of abrasive media particles between the header ring and the surface of the dynamic component.



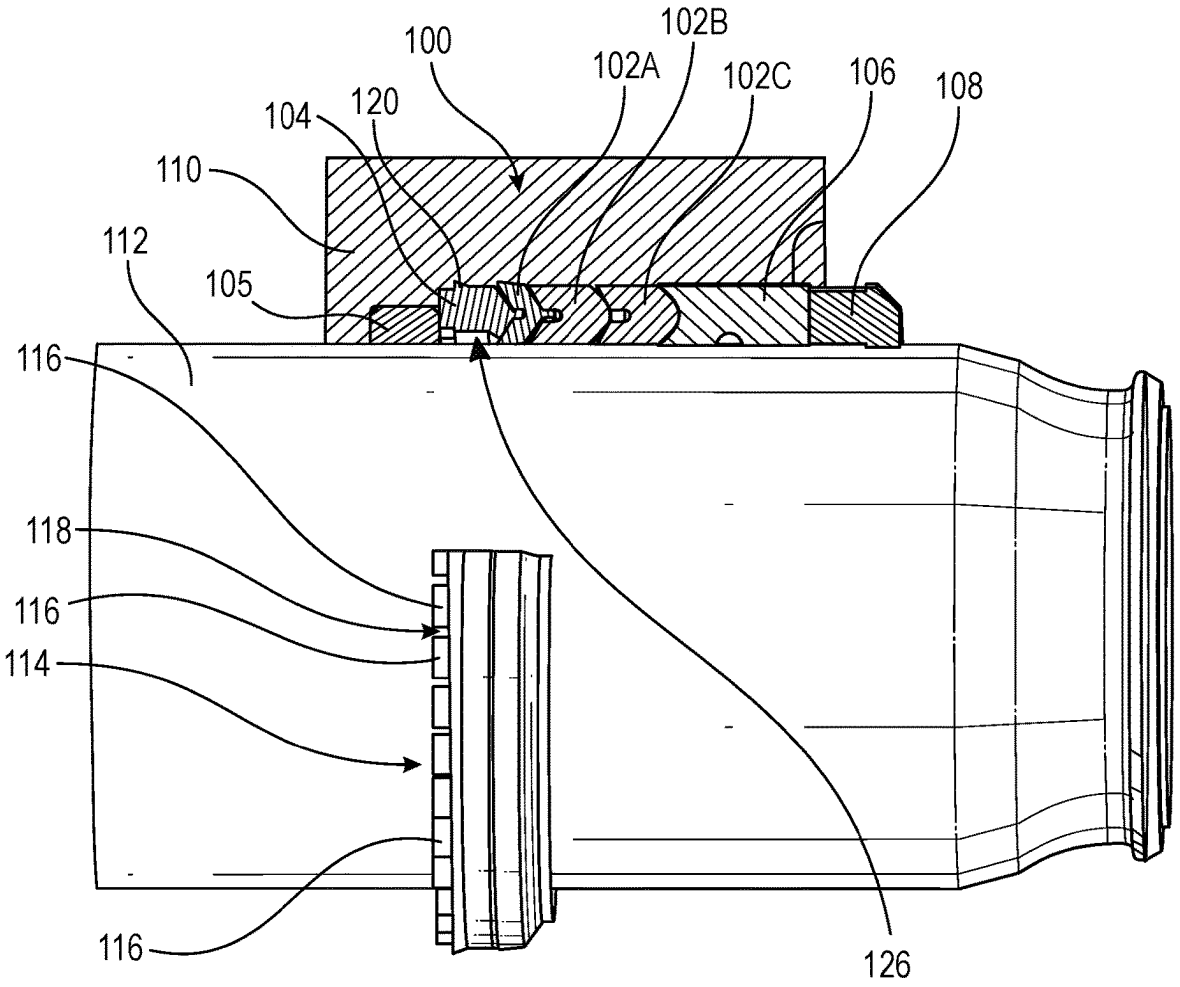

100
102B
102A
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FIG. 1

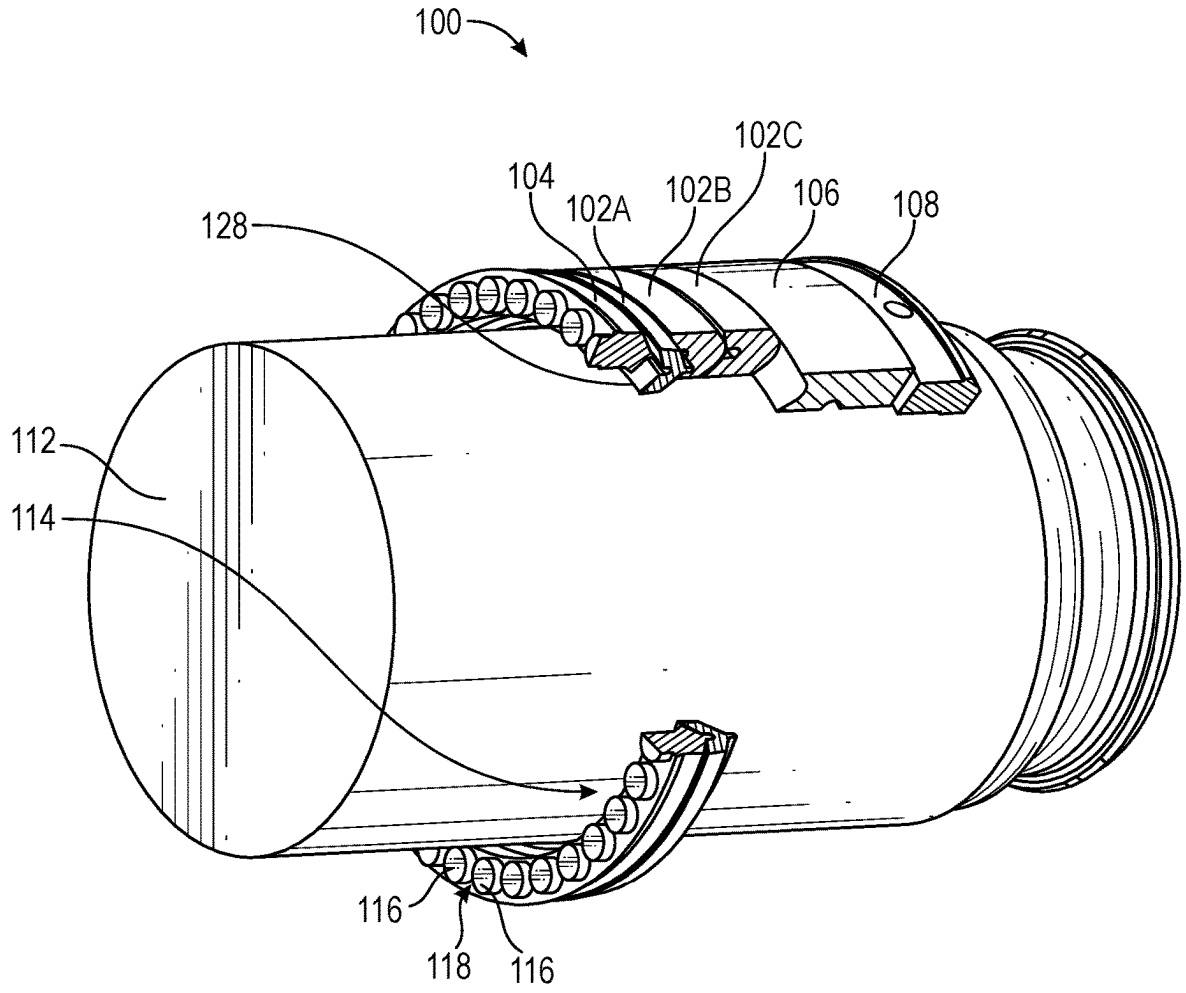

FIG. 2

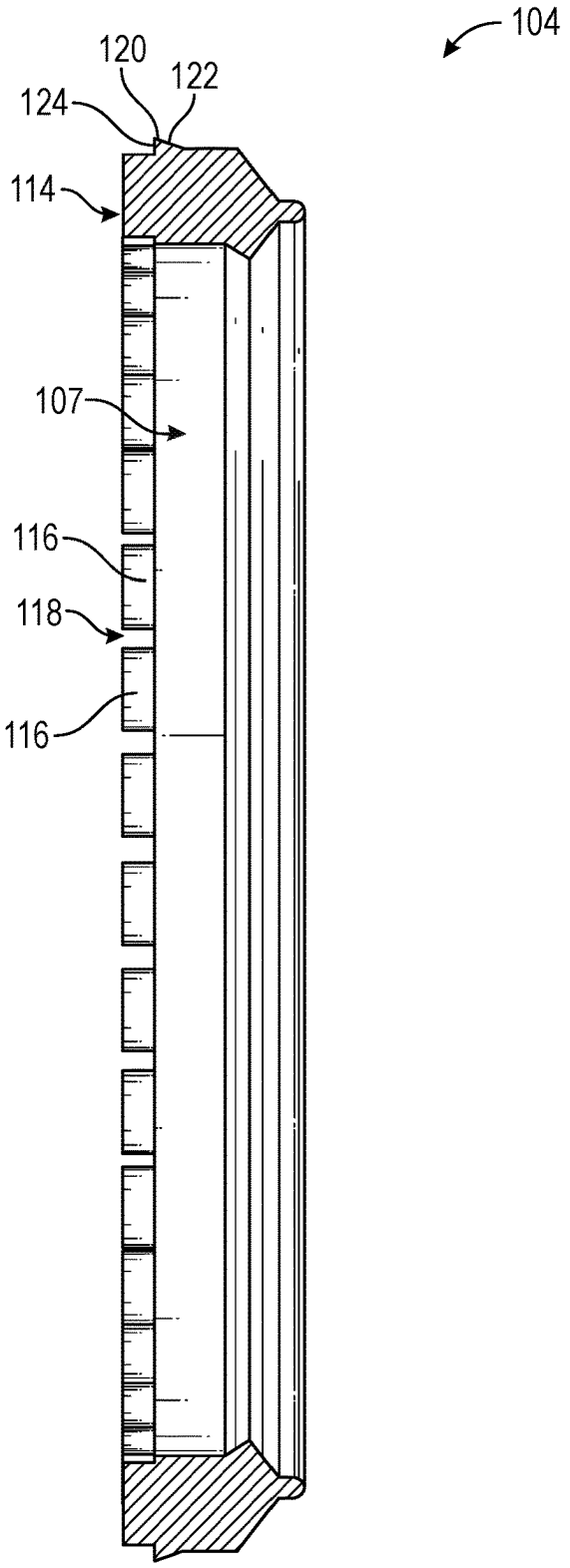

FIG. 3

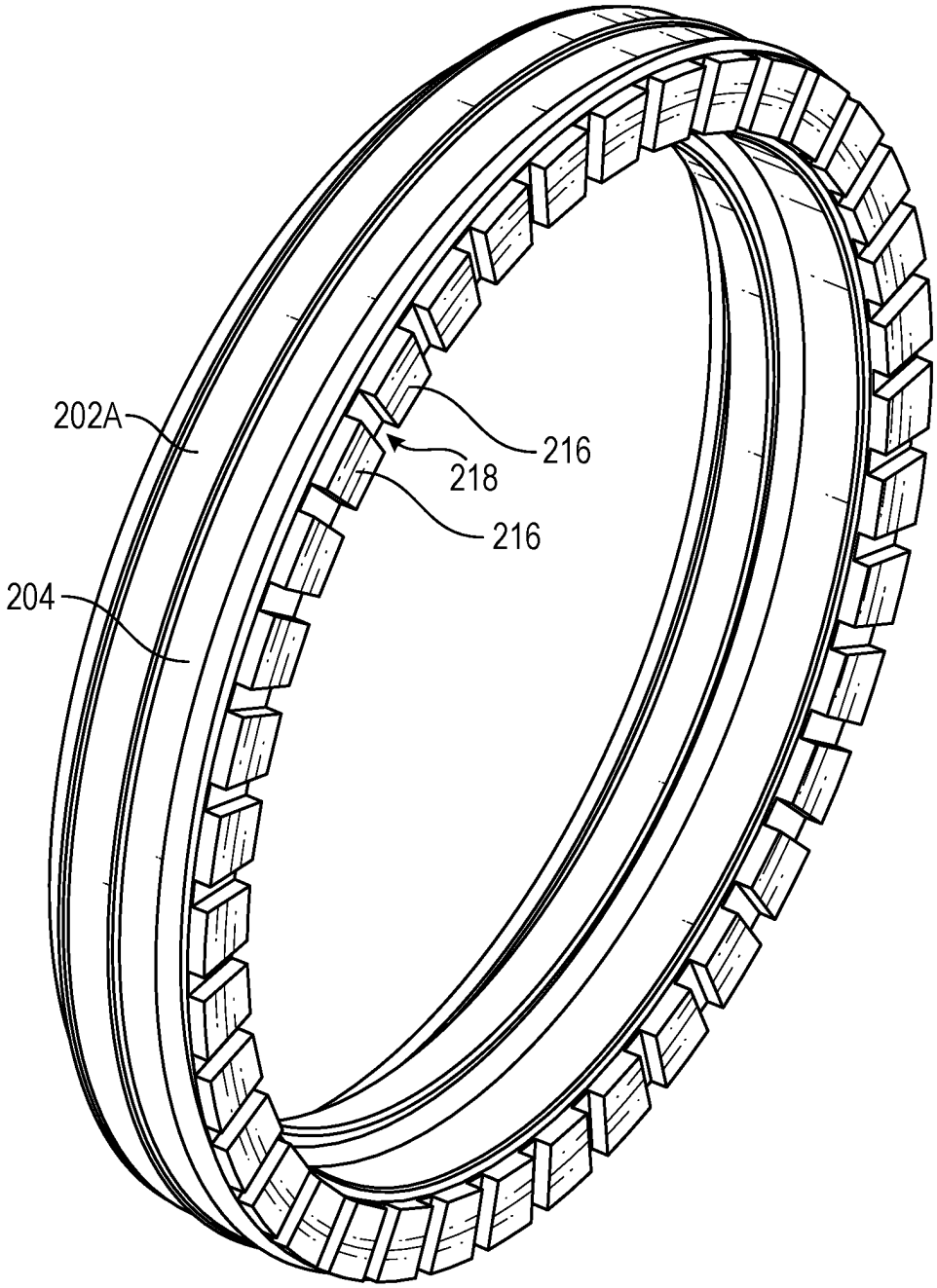

FIG. 4

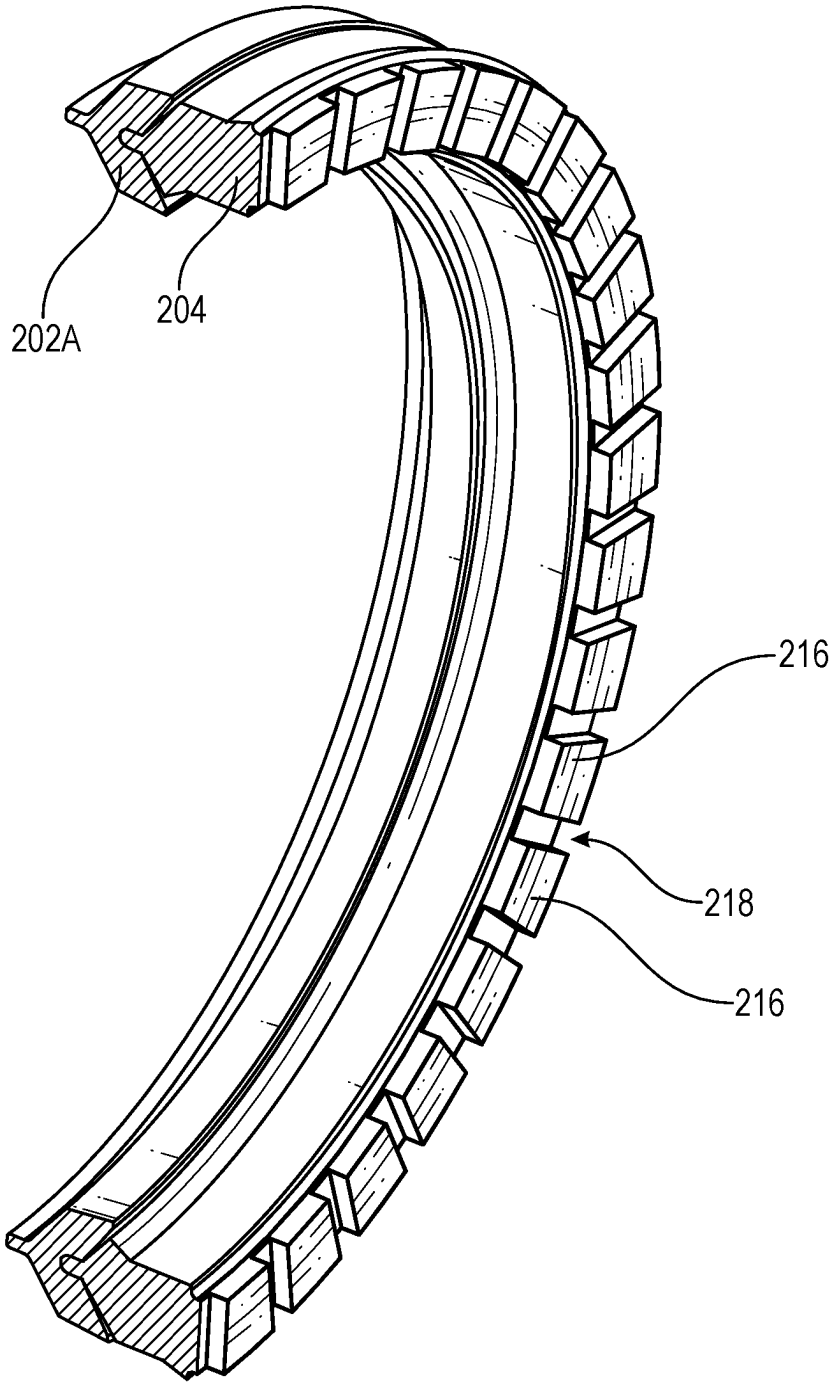

FIG. 5

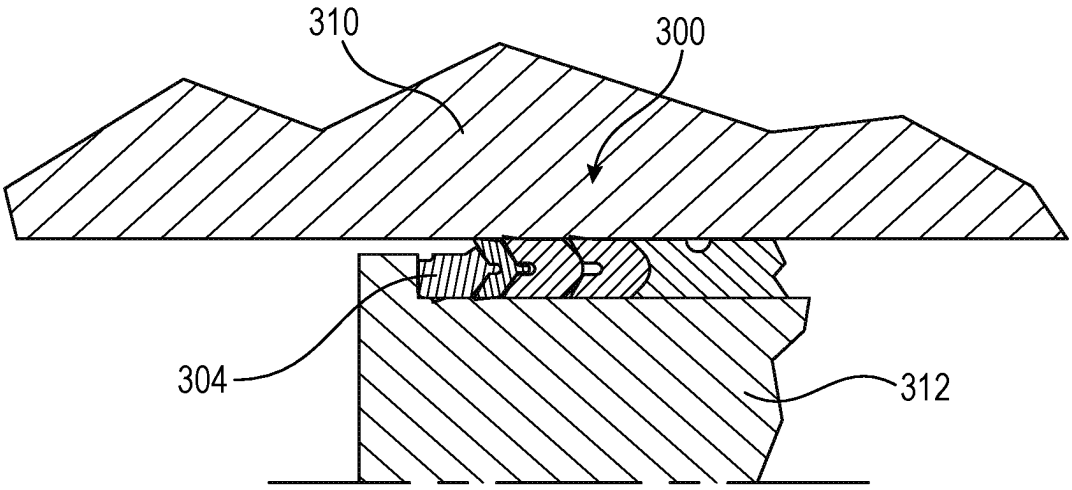

FIG. 6

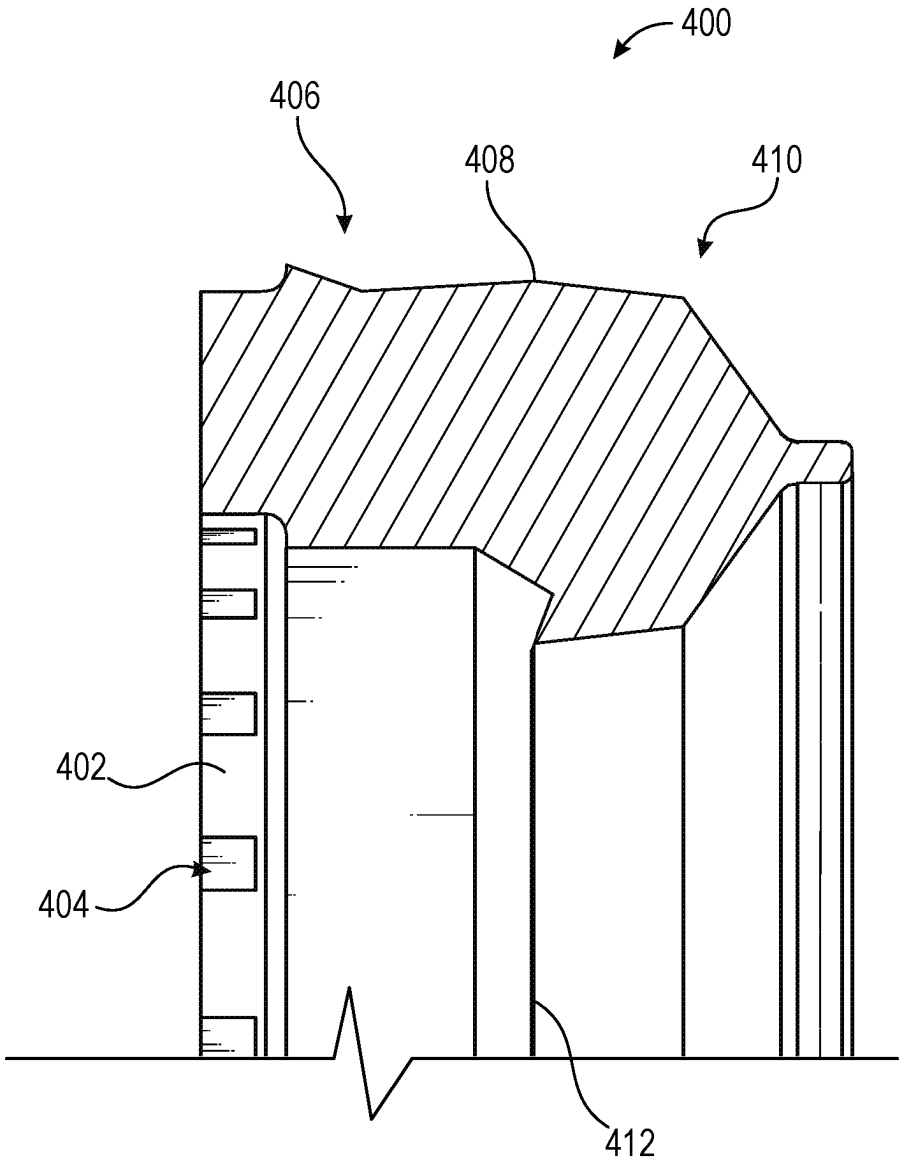

FIG. 7

PLUNGER PUMP PACKING ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 63/369,579, filed on Jul. 27, 2022, which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to plunger pump packing assemblies and other packing assemblies.

BACKGROUND

[0003] Packing assemblies are used in many reciprocating plunger pumps. In the oil and gas industry, large reciprocating pumps are used in well drilling and completions to pump drilling mud, cement, and well stimulation fluids. For operations in hydraulic fracturing, pumps in excess of 3000 HP may be used to pump pressures to 20,000 psi (137.9 MPa) in order to create fractures in rock. The packing set seals around the reciprocating plunger to prevent escape of the pumped fluid. Some pumps in the art include an adjustable space for the packing, referred to as a stuffing box or packing gland, located between a static component and the plunger. A gland/compression nut may be used to adjust the length of the space in which the packing set is assembled. Thus, the seal can be adjusted by tightening the gland nut, which is typically threaded into the fluid end. A typical packing has one or more vee packing elements, which expand or press radially toward the plunger by reacting to the force in the axial direction from the gland nut and fluid pressure.

[0004] These vee packing elements may be the main pressure seal in the packing—typically rubber or polytetrafluoroethylene (PTFE) and may be reinforced with various fabrics, granular fillers, or randomly oriented fibers. The header ring is typically rubber or another elastomer that may also be reinforced.

[0005] When used in the drilling and completion of wells, these pumps may be used at high pressures pumping aggressive fluids and abrasive media (e.g., proppant). Improper function of these seals can cause damage to the pump housing and plunger. Failure of the packing set can lead to the unintended leakage of fluids laden with abrasive media, which can quickly erode metal parts of the pump, requiring costly replacement. Frequent adjustment or replacement of these packing sets to avoid failure result in high maintenance costs and additional staff working at the well site.

[0006] Accordingly, there is a need to prevent abrasive media from migrating between the packing and the plunger and from the packing and the first component. There is a further need to prevent trapping of pressure on the outer diameter of the header ring, and/or between the header ring and subsequent seals, such as vee packing ring(s). The present disclosure seeks to solve these and other problems.

SUMMARY OF EXAMPLE EMBODIMENTS

[0007] In some embodiments, a packing assembly comprises a header ring that provides axial compression force to adjacent seals or packing rings, such as vee packing rings. The header ring comprises a vented inside portion to prevent trapping pressure on the outer diameter of the header ring or between the header ring and adjacent seals or packing rings. The vent allows trapped pressure to return when the pumped fluid pressure is lower (typically on each pump intake stroke).

[0008] In some embodiments, a radially protruding edge on the outer diameter of the header ring prevents migration of particles between the header ring and the static component. In a preferred embodiment, the header ring does not contact the dynamic component (e.g., reciprocating plunger), thus preventing the trapping of abrasive media particles between the header ring and the dynamic component surface. Adjacent seals or packing rings can be configured with abrupt edges to prevent the abrasive media particles from migrating further between the seals or packing components and the dynamic component.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** illustrates a partial cut-away, side elevation view of a packing assembly;

[0010] FIG. **2** illustrates a partial cut-away, front, side perspective view of a packing assembly;

[0011] FIG. **3** illustrates a cross-section of a side elevation view of a header ring;

[0012] FIG. **4** illustrates a front perspective view of a header ring and seal of a packing assembly;

[0013] FIG. **5** illustrates a cross-section of a front perspective view of a header ring and seal of a packing assembly;

[0014] FIG. **6** illustrates a partial cross-section of a packing assembly in an alternate embodiment; And

[0015] FIG. **7** illustrates a partial cross-section of a header ring and seal combined into a single item of manufacture.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0016] The following descriptions depict only example embodiments and are not to be considered limiting in scope. Any reference herein to "the invention" is not intended to restrict or limit the invention to exact features or steps of any one or more of the exemplary embodiments disclosed in the present specification. References to "one embodiment," "an embodiment," "various embodiments," and the like, may indicate that the embodiment(s) so described may include a particular feature, structure, or characteristic, but not every embodiment necessarily includes the particular feature, structure, or characteristic. Further, repeated use of the phrase "in one embodiment," or "in an embodiment," do not necessarily refer to the same embodiment, although they may.

[0017] Reference to the drawings is done throughout the disclosure using various numbers. The numbers used are for the convenience of the drafter only and the absence of numbers in an apparent sequence should not be considered limiting and does not imply that additional parts of that particular embodiment exist. Numbering patterns from one embodiment to the other need not imply that each embodiment has similar parts, although it may.

[0018] Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of the invention, which is to be given the full breadth of the appended claims and any and all equivalents thereof. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation. Unless otherwise expressly defined herein, such terms are intended to be given their broad, ordinary,

and customary meaning not inconsistent with that applicable in the relevant industry and without restriction to any specific embodiment hereinafter described.

[0019] As used herein, the article "a" is intended to include one or more items. When used herein to join a list of items, the term "or" denotes at least one of the items, but does not exclude a plurality of items of the list. For exemplary methods or processes, the sequence and/or arrangement of steps described herein are illustrative and not restrictive.

[0020] It should be understood that the steps of any such processes or methods are not limited to being carried out in any particular sequence, arrangement, or with any particular graphics or interface. Indeed, the steps of the disclosed processes or methods generally may be carried out in various sequences and arrangements while still falling within the scope of the present invention.

[0021] The term "coupled" may mean that two or more elements are in direct physical contact. However, "coupled" may also mean that two or more elements are not in direct contact with each other, but yet still cooperate or interact with each other.

[0022] The terms "comprising," "including," "having," and the like, as used with respect to embodiments, are synonymous, and are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including, but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes, but is not limited to," etc.).

[0023] As previously discussed, there is a need for plunger pump packing that prevents abrasive media from migrating between the packing and the plunger, to prevent abrasive media from migrating between the packing and the static component, and to prevent trapping of pressure on the outer diameter of the header ring and/or between the header ring and subsequent seals. The packing assembly disclosed herein solves these and other problems.

[0024] In some embodiments, as shown in FIGS. **1-3**, a packing assembly **100** comprises one or more seals **102**A-C (e.g., vee packing rings, U-cups, etc.), a header ring **104**, a spacer **106**, and a lantern ring **108**. The packing assembly **100** may be constrained axially to provide a pre-load on the header ring **104** and seals **102**A-C. For example, a compression nut (not shown) may abut the lantern ring **108** and adjustably impart axial force on the lantern ring **108**. The plunger pump packing assembly **100** may operate as a seal between a static component **110** and a dynamic component **112** (e.g., reciprocating plunger or other shaft). For example, the seals **102**A-C may comprise one or more of rubber, PTFE, polyurethane, UHMWPE, fabrics, granular fillers, fibers, etc. In some embodiments, each seal **102**A-C may comprise the same materials, but may also comprise different materials. For example, the first seal **102**A may comprise polyurethane while a second seal **102**B may comprise fabric-reinforced rubber. The header ring **104** may comprise rubber or other elastomer, which may or may not be reinforced. While FIGS. **1** and **2** illustrate cutaways for ease of understanding, it will be appreciated that the seals **102**A-C, header ring **104**, spacer **106**, and lantern ring **108** each encircle the dynamic component **112**.

[0025] In some embodiments, the header ring **104** comprises a vented inside portion **114** to prevent trapping pressure on the outer diameter of the header ring **104** or between the header ring **104** and adjacent seals or seals **102**A-C. The vented inside portion **114** may be formed from a plurality of protrusions **116** and apertures **118** on a first side of the header ring **104**. The plurality of protrusions **116** are sized and shaped so as to form an aperture **118** between each protrusion **116**. In some embodiments, the protrusions **116** are cylindrical. However, it will be appreciated that the protrusions **116** may comprise other formfactors without departing herefrom (e.g., cubed, triangular, hexagonal, etc.).

[0026] For example, FIGS. **4-5** illustrate a header ring **204** coupled to a seal **202**A (e.g., vee packing ring), the header ring **204** comprising a plurality of cube-shaped protrusions **216** and apertures **218** therebetween. Returning to FIG. **3**, the apertures **118** function as vents, allowing trapped pressure to return when the pumped fluid pressure is lower (typically on each pump intake stroke). By reducing trapped pressure, the packing assembly **100** is less subject to deformation and wear, preventing media from wearing down the seals **102**A-C (e.g., vee packing rings **102**A-C) and extending the life of the assembly **100** and the pump.

[0027] By utilizing a plurality of spaced protrusions **116**, the apertures **118** remain even when the header ring **104** is subjected to axial pressure, deforming the protrusions **116**. Wider apertures **118** (i.e., distance between adjacent protrusions), allow for greater axial compression without blocking the apertures **118** due to deformation of the protrusions **116**. Apertures **118** of sufficient width, depth, and number provide space for axial compression of protrusions **116** by allowing space for deformation of the protrusion **116** into the apertures **118**, thereby allowing axial deformation pre-load force to be adequate over a greater tolerance of axial constraint distance. For example, apertures **118** with a depth of 1 mm (face of protrusion **116** is 1 mm distance from surface) remove about 10% of the material volume to that 1 mm depth (i.e., 10% of the vented portion) as compared to a continuous annulus. However, the depth and percentages may change, depending on the number of apertures **118** as well. For example, a depth of 0.75 mm may still result in 20% removal of material volume to that 0.75 mm depth. If the vented portion **114** were mostly a solid annulus with, for example, four small apertures **118** to vent (meaning a smaller percentage (e.g., less than 10%) of material volume removed) to the depth of the apertures, the axial compression of the packing assembly **100** would reach a high axial force in a very small distance. As a result, adjusting the axial force, which in turn adjusts the seals' **102**A-C contact force on the dynamic component **112** and static component **110**, would be very sensitive and require skilled labor. In contrast, by increasing the number of apertures **118** and/or their size, and thereby the material volume to be reduced (e.g., 10% or more), there is increased space for deformation (adequate apertures volume), which makes the axial force build up over a longer distance of axial compression. Thus, the adjustment of seals force is less sensitive. As another example, in some embodiments, a plurality of apertures having a depth of 2 mm removes 25% of the volume to the 2 mm depth of the apertures (i.e., 25% of the vented portion **114**). With at least a 10% reduction in volume, and preferably 25%, of the vented portion **114**, the header ring **104** has greater compressibility, making it a more effective axial spring to load the seals, which overcomes limitations in the art.

[0028] Some pumps have non-adjustable axial constrained packing housings (e.g., bolted together). In those instances, the greater axial deformation to reach a specific axial com-

pression force makes the packing assembly less sensitive to packing housing fixed lengths (and manufacturing tolerances). Furthermore, for any packing housing axial constraint length, whether fixed or initially adjusted, the wear and relaxation of packing assembly components results in less reduction in sealing force over time due to the increase axial compression and resilience of the protrusions **116** which were deformed.

[0029] In some embodiments, the protrusions **116** may abut a junk ring **105**, the junk ring **105** applying pressure to the protrusions **116** as discussed above. As the header ring **104** cause wear on the junk ring **105**, the junk ring **105** may be replaced. However, it will be appreciated that while the packing assembly **100** shown in the Figs. includes a junk ring **105**, spacer **106** (which may act as a guide to center a plunger), multiple seals **102**A-C, and a lantern ring **108** (typically included for distribution of lubrication), not each of those components is required, depending on the pump and desired configuration by the user. In other configurations, some components are combined into a single component, such as the spacer **106** and lantern ring **108**, or as described later herein, the header ring **104** and a seal.

[0030] In some embodiments, as best seen in FIGS. **1** and **3**, a radially protruding edge **120** on the outer diameter of the header ring **104** significantly reduces or prevents migration of abrasive media, such as proppant, between the header ring **104** and the static component **110**. This radially protruding edge **120** abuts the static component **110** and may function as a one-way valve, allowing fluid or built-up pressure to pass from the direction of the first seal **102**A, over a sloped face **122** (FIG. **3**) of the protruding edge **120** and to the vented portion **114**, as pressure trapped between the first seal **102**A and protruding edge **120** may force the material of header ring **104** radially inward toward a channel **126**, thereby reducing the contact force of protruding edge **120**. However, because pressure acting inside the header ring **104** increases the contact force of the protruding edge **120** to the static component **110**, fluid and pressure is significantly reduced or prevented from going from the vented portion **114** to the first seal **102**A. Because abrasive media and pressure is prevented from passing past the front side **124** of the protruding edge **120**, the life of the seals or packings **102**A-C is extended, overcoming limitations in the prior art. In some embodiments, the radially protruding edge **120** may comprise a substantially perpendicular face on a first side and a sloped face on a second side. However, other formfactors may be used without departing herefrom. Additionally, while a protruding edge **120** is described as extending radially from the header ring **104**, alternate means of achieving a similar result may be used without departing herefrom. For example, rather than a protruding edge, the header ring **104** may comprise an outer diameter greater than the inner diameter of the static component **110**, thereby providing similar functionality as the protruding edge **120**.

[0031] Further, in some embodiments, the header ring **104** does not contact the reciprocating plunger **112** (or other dynamic surface), thus preventing the trapping of abrasive media particles between the header ring **104** and the surface of the plunger **112**. For example, referring to FIG. **3**, the header ring **104** may comprise a formfactor, such as a contour **107** on a first portion of the inner diameter, forming channel **126** between the outer surface of the plunger **112** and at least a portion of the inner diameter of the header ring **104**. The header ring **104** may maintain its relative position by being coupled to the adjacent seal **102**A (or other first component), such as by tongue and groove or other shape or interference fit, adhesives, or other methods of coupling the header ring **104** to the seal **102**A. As a result, the channel **126** is maintained and the first component to engage the plunger **112** is the first seal **102**A. In this and other embodiments, the seals **102**A-C may comprise an abrupt edge **128** (FIG. **2**) to prevent abrasive media particles from migrating further between the seals (e.g., seals **102**A-C) and the plunger **112**. It will be appreciated that one or more seals **102**A-C may comprise abrupt edges to thereby prevent any abrasive media from continuing to migrate should it succeed in passing a first seal **102**A. In some embodiments, the abrupt edge **128** may be a first portion of the seal **102**A to contact the outer surface of the plunger **112**, the abrupt edge **128** being at an angle of 30 degrees or more in relation to the outer surface of the plunger **112**. Because there is no contact between the inner diameter surface of the header ring **104** and the plunger **112**, and due to the vented portion **114**, pressure is able to be released and not build up on the outer diameter of the header ring **104**, overcoming the prior art.

[0032] It will be appreciated that while three seals **102**A-C are shown, more or fewer may be used without departing herefrom. Additionally, it will be appreciated that while the packing assembly **100** is shown on the outer circumference of the plunger **112**, it is not limited to such placement. In some embodiments, as shown in FIG. **6**, the packing assembly **300** may be inverted for use on an inner diameter of a surface. In other words, the header ring **304** encircles a piston **312** which, together with the packing assembly **300**, is dynamic in relation to a cylindrical bore **310**. Lastly, while an example of a plunger **112** was used, it will be appreciated that any dynamic (i.e., moving) component may be used without departing herefrom.

[0033] In some embodiments, as shown in FIG. **7**, the header ring and the first seal may be combined into a single item of manufacture, rather than two separate items that are coupled together. In other words, the header ring **400** may comprise a plurality of protrusions **402** and apertures **404** on a first portion **406** and a seal **408** on the second portion **410**, the second portion **410** comprising the abrupt edge **412**.

[0034] Accordingly, the header ring **104**, **204**, **304**, **400** of the packing assembly **100**, **300** solves the need to 1) prevent abrasive media from migrating between the packing assembly **100** and the plunger **112**; 2) prevent abrasive media from migrating from the packing assembly **100** and the static component **110**; and 3) prevent trapping of pressure on the outer diameter of the header ring **104**, **204**, **304**, **400**, and/or between the header ring **104**, **204**, **304**, **400** and subsequent seals **102**A-C.

[0035] It will be appreciated that systems and methods according to certain embodiments of the present disclosure may include, incorporate, or otherwise comprise properties or features (e.g., components, members, elements, parts, and/or portions) described in other embodiments. Accordingly, the various features of certain embodiments can be compatible with, combined with, included in, and/or incorporated into other embodiments of the present disclosure. Thus, disclosure of certain features relative to a specific embodiment of the present disclosure should not be construed as limiting application or inclusion of said features to the specific embodiment unless so stated. Rather, it will be appreciated that other embodiments can also include said

features, members, elements, parts, and/or portions without necessarily departing from the scope of the present disclosure.

[0036] Moreover, unless a feature is described as requiring another feature in combination therewith, any feature herein may be combined with any other feature of a same or different embodiment disclosed herein. Furthermore, various well-known aspects of illustrative systems, methods, apparatus, and the like are not described herein in particular detail in order to avoid obscuring aspects of the example embodiments. Such aspects are, however, also contemplated herein.

[0037] Exemplary embodiments are described above. No element, act, or instruction used in this description should be construed as important, necessary, critical, or essential unless explicitly described as such. Although only a few of the exemplary embodiments have been described in detail herein, those skilled in the art will readily appreciate that many modifications are possible in these exemplary embodiments without materially departing from the novel teachings and advantages herein. Accordingly, all such modifications are intended to be included within the scope of this invention.

What is claimed is:

1. A packing assembly, comprising:
- a header ring comprising a vented portion on a first side and configured to couple to at least one seal on a second, opposite side, the header ring and at least one seal configured to encircle an outer surface of a dynamic component;
- wherein a channel is formed between an inner diameter of the header ring and the outer surface of the dynamic component, and
- wherein at least an abrupt edge of the at least one seal contacts the outer surface of the dynamic component.

2. The packing assembly of claim **1**, wherein the header ring further comprises a radially protruding edge configured to abut an inner surface of a static component.

3. The packing assembly of claim **2**, wherein the radially protruding edge comprises a substantially perpendicular face on a first side and a sloped face on a second side.

4. The packing assembly of claim **1**, wherein the vented portion comprises a plurality of protrusions, each protrusion separated from the next via an aperture.

5. The packing assembly of claim **4**, wherein each protrusion is cylindrical.

6. The packing assembly of claim **4**, wherein each protrusion is cubed.

7. The packing assembly of claim **4**, wherein each protrusion is formed by removing portions of the header ring, forming the aperture between each, the apertures removing at least 10 percent of a material volume of the vented portion.

8. The packing assembly of claim **1**, further comprising a compression nut, wherein the at least one seal is a vee packing ring, the vee packing ring interposed between the compression nut and the header ring.

9. The packing assembly of claim **1**, wherein the abrupt edge is at least at a 30-degree angle in relation to the dynamic component.

10. A packing assembly, comprising:
- a header ring, comprising:
  - a first side comprising a plurality of protrusions and apertures forming a vented portion,
  - a second side configured to couple to a vee packing ring,
  - wherein the header ring and vee packing ring are configured to encircle an outer surface of a dynamic component,
- the vee packing ring comprising an abrupt edge on a first side;
- wherein a channel is formed between an inner diameter of the header ring and the outer surface of the dynamic component, and
- wherein at least the abrupt edge of the vee packing ring contacts the outer surface of the dynamic component.

11. The plunger pump packing assembly of claim **10**, wherein the plurality of protrusions on the first side of the header ring are cylindrical.

12. The packing assembly of claim **10**, wherein the header ring further comprises a radially protruding edge configured to abut an inner surface of a static component.

13. The packing assembly of claim **12**, wherein the radially protruding edge comprises a substantially perpendicular face on a first side and a sloped face on a second side.

14. The packing assembly of claim **10**, wherein the apertures comprise a volume of at least 10 percent of the vented portion.

15. A packing assembly, comprising:
- a header ring, comprising:
  - a first side comprising a plurality of protrusions and apertures forming a vented portion,
  - a second side configured to couple to at least one seal,
  - a radially protruding edge configured to abut an inner surface of a static component, and
  - a contour on at least a portion of the inner diameter,
- a first seal of the at least one seal comprising an abrupt edge on a first side for contacting an outer surface of a dynamic component;
- wherein the contour of the inner diameter forms a channel between at least a portion of the inner diameter of the header ring and the outer surface of the dynamic component, and
- wherein the header ring and the at least one seal are each configured to encircle the outer surface of the dynamic component, the packing assembly functioning as a seal between the static component and the dynamic component.

16. The packing assembly of claim **15**, wherein the radially protruding edge comprises a substantially perpendicular face on a first side and a sloped face on a second side.

17. The packing assembly of claim **15**, wherein each protrusion is cylindrical.

18. The packing assembly of claim **15**, wherein each protrusion is cubed.

19. The packing assembly of claim **15**, wherein the apertures collectively remove at least 10 percent of a material volume of the header ring to the depth of the apertures.

20. The packing assembly of claim **15**, wherein the at least one seal is a vee packing ring.

21. The packing assembly of claim **15**, wherein the abrupt edge is at least at a 30-degree angle in relation to the dynamic component.

22. A packing assembly, comprising:
- a header ring, comprising:
  - a first side comprising a plurality of protrusions and apertures forming a vented portion,

a second side comprising a seal, the seal comprising an abrupt edge configured to contact the outer surface of the dynamic component,

wherein the header ring is configured to encircle an outer surface of a dynamic component,

wherein an aperture is formed between a first portion of the header ring and the outer surface of the dynamic component.

23. The packing assembly of claim **22**, wherein the abrupt edge is at least at a 30-degree angle in relation to the dynamic component.

24. The packing assembly of claim **22**, wherein the apertures collectively comprise at least 10 percent by volume of the vented portion.

25. A header ring for use in a packing assembly, comprising:

a first side comprising a plurality of protrusions each separated by an aperture to form a vented portion;

a second side;

a radially protruding edge configured to abut an inner surface of a static component; and

a contour on a portion of an inner diameter;

wherein when the header ring is coupled to a dynamic component, the contour is configured to form a channel between the portion of the inner diameter of the header ring and the outer surface of the dynamic component.

26. The header ring of claim **25**, wherein the radially protruding edge comprises a substantially perpendicular face on a first side and a sloped face on a second side, the sloped face configured to allow pressure to pass over the sloped face and toward the vented portion.

27. The header ring of claim **25**, wherein the apertures collectively comprise at least 10 percent by volume of the vented portion.

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