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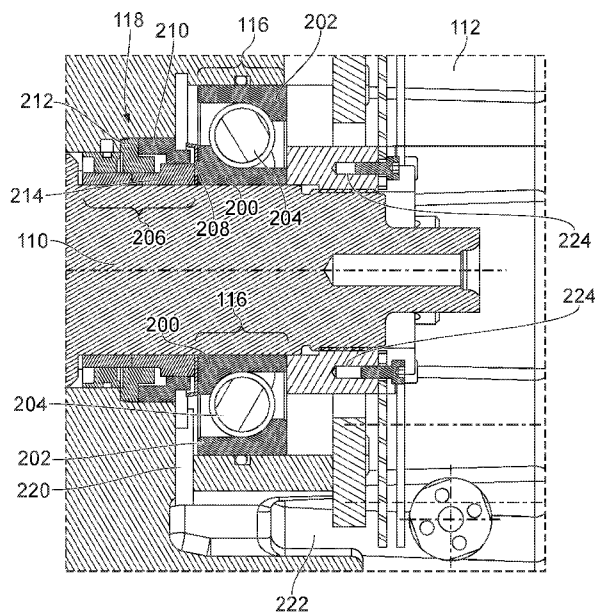


FIG. 2

(57) Abstract: A seal system forming a seal between a housing and a shaft (110), the shaft (110) being rotatable relative to the housing, the seal system comprising: a labyrinth seal (206) comprising: a first labyrinth seal part (210) substantially fixed relative to the housing; and a second labyrinth seal part (214) substantially fixed relative to the shaft (110); wherein the first and second labyrinth seal parts (210, 214) define a tortuous path (302) for a fluid; and the tortuous path (302) comprises an opening (304) at a first side of the labyrinth seal (206); and a member (208) fixed relative to either the housing or the shaft (110); wherein: the member (208) is located adjacent to the labyrinth seal (206) at the first side of the labyrinth seal (206); and the member (208) comprises a fluid deflection portion (301) that extends in a direction away from the opening (304) such that a fluid impinging on a surface of the deflection portion (301) is directed away from the opening (304).

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SEAL SYSTEM FOR FORMING A SEAL BETWEEN A FIXED HOUSING AND A ROTATABLE SHAFT

FIELD OF THE INVENTION

5 The present invention relates to seals between fixed housings and rotatable shafts, especially, but not limited to, seals for use in vacuum pumps, such as dry vacuum pumps.

BACKGROUND

10 In various types of machinery, it is desirable to seal the opening through which a rotatable shaft protrudes.

 For example, in dry vacuum pumps, typically a rotating drive shaft is supported by bearings located at opposite axial ends of the drive shaft. The bearings are located in lubrication chambers located at the opposing axial ends of the drive shaft. A lubricant, such as an oil, is circulated in the lubrication chambers to lubricate the moving parts, including the bearings and the drive shaft, within the lubrication chambers. The lubricant may be circulated by means of a throwing arm, i.e. a thrower, that may be attached to one of the drive shafts. In contrast, no liquids are used in the main pumping stages between the lubrication chambers. It is desirable to seal the lubrication chambers located at the opposing axial ends of the drive shaft from the main pumping stages located therebetween such that no fluid lubricant flows from the lubrication chambers into the main pumping stages.

25 It is known to use labyrinth seals to provide such sealing of the lubrication chambers from the main pumping stages.

 A labyrinth seal is a type of mechanical seal which tends not to be fluid-tight, but that limits fluid leakage by means of a tortuous path. A labyrinth seal typically comprises one or more rings that fit about the rotating shaft with a goal to minimize leakage.

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SUMMARY OF THE INVENTION

The present inventors have realised that there is a need for improved seals and assemblies comprising the same, particularly with respect to minimal leakage, long life expectancy and easy fabrication.

- 5 In a first aspect, there is provided a seal system forming a seal between a housing and a shaft, the shaft being rotatable relative to the housing. The seal system comprises a labyrinth seal comprising a first labyrinth seal part fixed relative to the housing and a second labyrinth seal part fixed relative to the shaft. The first and second labyrinth seal parts define a tortuous path for a fluid.
- 10 The tortuous path comprises an opening at a first side of the labyrinth seal. The seal system further comprises a member fixed relative to either the housing or the shaft. The member is located adjacent to the labyrinth seal at the first side of the labyrinth seal. The member comprises a fluid deflection portion that extends in a direction away from the opening such that a fluid impinging on a
- 15 surface of the deflection portion is directed away from the opening.

- The shaft may define an axial direction and a radial direction. The fluid deflection portion may extend from the opening in a direction that has a component that points in a radially outward direction. The fluid deflection portion may extend from the opening in a direction that has a component that points in
- 20 an axial direction towards the labyrinth seal.

 The fluid deflection portion extends beyond, i.e. over, the opening of tortuous path in the axial direction. The fluid deflection portion may thus be considered as a cover for the opening of tortuous path.

 The member may be fixed relative to the shaft.

- 25 The member may comprise an annular disc positioned around the shaft. The fluid deflection portion may extend from a radially outer edge of the annular disc. The annular disc may comprise one or more radially extending grooves formed therein. The radially extending grooves may be formed in a surface of the annular disc that faces the labyrinth seal.

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The member may be the inner race of a bearing. The bearing may be for supporting the shaft within the housing. The inner race may be fixed relative to the shaft.

In a further aspect, the present invention provides a vacuum pump
5 comprising a housing, a shaft rotatable relative to the housing, and a seal system coupled between the housing and the shaft. The seal system is in accordance with any preceding aspect.

The vacuum pump may further comprise a lubrication chamber in which a fluid lubricant is circulated, and a pumping stage. The seal system may be
10 located between the lubrication chamber and the pumping stage thereby to prevent or oppose a flow of the fluid lubricant from the lubrication chamber into the pumping stage.

The vacuum pump may further comprise a bearing configured to support the shaft within the housing. The member may be located between the labyrinth
15 seal and the bearing.

The vacuum pump may further comprise a bearing configured to support the shaft within the housing. The member may be an inner race of the bearing, the inner race of the bearing being fixed relative to the shaft.

In a further aspect, there is provided a fluid flow deflection device for use
20 with a vacuum pump. The device comprises an annular disc for positioning around a shaft of the vacuum pump, and a portion that extends from a radially outer edge of the annular disc in a direction that is oblique to a radial direction.

The annular disc may comprise one or more radially extending grooves.

In a further aspect, there is provided a bearing for supporting a rotatable
25 shaft of a vacuum pump within a fixed housing of the vacuum pump. The bearing comprises a radially inner race, a radially outer race, and a plurality of bearing balls disposed between the inner race and the outer race. The inner race comprises a portion that extends from a side of the inner race in a direction away from the bearing, the direction having a first component that points in an
30 axial direction and a second component that points in a radially outward

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direction, the portion being configured to deflect a flow of a fluid flowing out of the bearing.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Figure 1 is a schematic illustration (not to scale) of a vacuum pump;

Figure 2 is a schematic illustration (not to scale) showing further details of a portion of the vacuum pump, including a seal system and bearing;

Figure 3 is a schematic illustration (not to scale) showing further details of the seal system and bearing;

10 Figure 4 is a schematic illustration (not to scale) showing a deflector plate of the seal system;

Figure 5 is a schematic illustration (not to scale) showing a further deflector plate; and

15 Figure 6 is a schematic illustration (not to scale) showing a further bearing.

DETAILED DESCRIPTION

Figure 1 is a schematic illustration (not to scale) of a vacuum pump 100.

20 In this embodiment, the vacuum pump is a dry pump, such as a positive displacement dry pump.

The vacuum pump 100 comprises a pump inlet 102 and a pump outlet 104. The vacuum pump 100 is configured to pump a fluid (e.g. a gas) from the pump inlet 102 to the pump outlet 104.

25 The vacuum pump 100 comprises a plurality of vacuum pumping stages 106. Although four pumping stages are depicted in Figure 1, it will be appreciated by those skilled in the art that a different number of stages may be implemented. The number of stages may be application dependent. For example, the number of stages of the pump 100 may depend on pumping

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requirements, such as a desired pressure at the pump inlet 102, and a pumping capacity.

Each of the vacuum pumping stages 106 comprises a respective pumping mechanism. Each pumping mechanism comprises a respective
5 intermeshed pair of rotors 108.

In this embodiment, the rotors 108 of the pumping mechanisms are driven by two drive shafts 110. The pumping mechanisms, i.e. the rotors 108, are driven by the drive shafts 110 for pumping fluid in series through the pumping stages 106 from the pump inlet 102 to the pump outlet 104.

10 The vacuum pump 100 further comprises lubrication chambers 112 located at opposing axial ends of the train of pumping stages 106. The lubrication chambers 112 are separated from respective adjacent pumping stages 106 by head plates 114. The lubrication chambers 112 house bearings 116 configured to support the drive shafts 110.

15 The vacuum pump 100 further comprises a motor (not shown) configured to one of the drive shafts 110. A gear assembly (not shown) is coupled between the drive shafts 110 such that rotation of a first drive shaft 110 by the motor drives the other of the drive shafts 110. The gear assembly may be located in a lubrication chamber 112.

20 A lubricant, such as an oil, is provided in sumps of the lubrication chambers 112. In operation, the lubricant is circulated in the lubrication chambers 112 to lubricate the moving parts (including the bearings 116, the gear assembly, and the drive shafts 110) within the lubrication chambers 112. The lubricant may be circulated by means of a throwing arm that may be
25 attached to one of the drive shafts 110.

The vacuum pump 100 further comprises a plurality of seal systems 118 disposed between the head plates 114 and the drive shafts 110. The seal systems 118 are described in more detail later below with reference to Figures 2 and 3. The seal systems are configured to oppose or prevent the flow of fluid
30 (e.g. liquid lubricant) between the lubrication chambers 112 and the pumping stages 106.

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Figure 2 is a schematic illustration (not to scale) showing further details of a portion of the vacuum pump proximate to one axial end of a drive shaft 110. In particular, Figure 2 shows further details of a seal system 118 and its coupling between a head plate 114 and drive shaft 110, and the bearings 116
5 that support that drive shaft.

Figure 3 is a schematic illustration (not to scale) showing further details of a portion of the seal system 118 and bearing 116 of Figure 2.

In this embodiment, the bearing 116 comprises a bearing inner race 200, a bearing outer race 202, and a plurality of bearing balls 204.

10 The bearing inner race 200 is fixed to the drive shaft 110 such that rotation of the drive shaft 110 causes the bearing inner race 200 to be rotated.

The bearing inner race 200 is coupled to the bearing outer race 202 by the plurality of bearing balls 204. The bearing balls 204 are disposed between the bearing inner race 200 and the bearing outer race 202 such that the bearing
15 inner race 200 and the bearing outer race 202 are rotatable relative to one another.

The bearing outer race 202 has restricted movement (e.g. is fixed) relative a housing of the vacuum pump 100, thereby to provide support for the drive shaft 110.

20 The seal system 118 comprises a labyrinth seal 206 and a fluid flow deflection device, hereinafter referred to as “a deflector plate” 208.

The labyrinth seal 206 forms a seal between two components which rotate relative to each other, in particular the head plate 114 and the drive shaft 110. The labyrinth seal 206 may be a conventional labyrinth seal.

25 In this embodiment, the labyrinth seal 206 comprises a first part 210, a second part 212, and a third part 214.

The first and second parts 210, 212 are fixed relative a housing of the vacuum pump 100. More specifically, in this embodiment, the first and second parts 210, 212 are fixedly attached to the head plate 114.

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The third part 214 is fixed to the drive shaft 110 such that rotation of the drive shaft 110 causes the third part 214 to be rotated. Thus, the third part 214 is rotatable relating to the first and second parts 210, 212.

5 The first and second parts 210, 212 are located radially outwards of the third part 214. Radially inner faces (i.e. inwardly facing surfaces) of the first and second parts 210, 212 face a radially outer face (i.e. an outwardly facing surface) of the third part 214.

The first and second parts 210, 212 are spaced apart in a radial direction from the third part 214. Thus, there exists a gap 302 between the opposing
10 surfaces of the first and second parts 210, 212 and the third part 214 (i.e. the radially inner faces of the first and second parts 210, 212 and the radially outer face of the third part 214). This gap 302 defines a labyrinthine or tortuous path through which the migration of lubricating fluid or contaminants (e.g. from the lubrication chamber 112 into a pumping stage 106) is difficult.

15 In this embodiment, the tortuous path defined by the gap 302 extends from a first end 304 of the tortuous path to a second end 306 of the tortuous path. The first, second, and third parts 210, 212, 214 may comprise various features (e.g. protrusions, grooves, notches, ribs, flanges, etc.) to define the tortuous path and thereby make it more difficult for fluid to flow along that path.

20 The first end 304 of the tortuous path may be considered to be a first opening or inlet to the tortuous path through which a fluid, for example a lubricating fluid, may flow. The first end 304 of the tortuous path is located at or proximate to the side of the labyrinth seal 206 at which the lubrication chamber 112 is located. The first end 304 of the tortuous path may be proximate to the
25 bearing 116.

The second end 306 of the tortuous path may be considered to be a second opening or outlet to the tortuous path. The second end 306 of the tortuous path is located at or proximate to the side of the labyrinth seal 206 at which a pumping stage 106 is located.

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In this embodiment, the deflector plate 208 is fixed to the drive shaft 110 such that rotation of the drive shaft 110 causes the deflector plate 208 to be rotated.

Figure 4 is a schematic illustration (not to scale) showing the deflector plate 208 in this embodiment.

The deflector plate 208 may be formed from any appropriate material or materials. The material(s) used may be application dependent. Example materials include, but are not limited to, metal, such as steel, stainless steel or aluminium, or a plastic. The deflector plate 208 may be formed from the same material as the drive shaft 110.

The deflector plate 208 comprises a disc portion 300 and an edge portion 301. The disc portion 300 and the edge portion 301 may be integrally formed.

The disc portion 300 comprises a hole 303 through its centre. Thus, the disc portion 300 is an annulus, annular disc, annular member, or ring-shaped member.

In this embodiment, the disc portion 300 is fixed to the drive shaft 110. More specially, the drive shaft 100 is positioned through the central hole 303 of the disc portion 300 and the disc portion 300 and drive shaft fixedly attached together. Thus, the disc portion 300 may be considered to be a rotor disc that radially extends from the drive shaft 110.

The edge portion 301 is an annular structure. The edge portion 301 of the deflector plate 208 is located at the radially outer edge of the disc portion 300. The edge portion 301 is oblique to the disc portion 300. The edge portion 301 extends from the radially outer edge of the disc portion 300 in a direction that points radially outward and along an axial direction of the drive shaft 110.

In this embodiment, a diameter of the central hole 303, i.e. an inner diameter of the disc portion 300 may be approximately 50-60mm, or more preferably approximately 54-56mm, or more preferably approximately 55.00mm to 55.20mm, or more preferably approximately 55.07mm. An outer diameter of the disc portion 300 may be approximately 70-85mm, or more preferably

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approximately 75-80mm, or more preferably approximately 77.0mm to 78.2mm, or more preferably approximately 77.6mm. An outer diameter of the edge portion 301, i.e. the outer diameter of the deflector plate 208, may be approximately 75-85mm, or more preferably approximately 79-81mm, or more preferably approximately 79.9-80.1mm or more preferably approximately 80.0mm. An angle between the disc portion 300 and the edge portion 301 may be approximately 95°-105°, or more preferably approximately 97°-103°, or more preferably approximately 99°-101°, or more preferably approximately 100°. The length of the edge portion 301 in the axial direction may be approximately 3.0-4.0mm, or more preferably approximately 3.3-3.8mm, or more preferably approximately 3.4-3.6mm, or more preferably approximately 3.5mm. The thickness of the disc portion 300 may be approximately 1mm. The thickness of the edge portion 301 may be approximately 1mm.

Referring back to Figures 2 and 3, in this embodiment, the deflector plate 208 is located on the drive shaft 110 between the bearing 116 and the labyrinth seal 206.

In this embodiment, a first side of the disc portion 300 of the deflector plate 208 abuts, and indeed may be fixed to, an adjacent surface of the bearing inner race 200. The disc portion 300 extends from the shaft 110 in the radial direction, approximately to the same extent as the portion of the bearing inner race 200 against which it abuts. In some embodiments, the radially outer surfaces of the deflector plate 208 and the bearing inner race 200 form a continuous surface with no large steps or gaps, e.g. they may be substantially flush.

In this embodiment, a second side of the disc portion 300 of the deflector plate 208 (the second side being opposite to the first side) abuts, and indeed may be fixed to, an adjacent surface of the third part 214 of the labyrinth seal 206. In this embodiment, the second side of the disc portion 300 of the deflector plate 208 is spaced apart from the first part 210 of the labyrinth seal 206, thereby to define the opening (or first end 304) of the tortuous path of the labyrinth seal 206.

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The edge portion 301 of the deflector plate 208 extends away from the disc portion 300 in a direction that points radially outwards and also in a direction away from the bearing 116 and towards the labyrinth seal. The edge portion 301 may point in a direction towards the head plate 114. Thus, the edge
5 portion 301 overhangs (i.e. extends over, or protrudes over) the opening (or first end 304) of the tortuous path of the labyrinth seal 206.

The edge portion 301 may be considered to provide a cover for the opening (or first end 304) of the tortuous path of the labyrinth seal 206.

In this embodiment, the vacuum pump further comprises a bearing drain
10 220, a sump 222, and a clamp 224.

The bearing drain 220 is a channel that fluidly connects a space within the lubrication chamber 112 with the sump 222. In this embodiment, the bearing drain 220 couples the space that is proximate to the bearing 116, the deflector plate 208, and the labyrinth seal 206, with the sump 222. As described in more
15 detail later below, the bearing drain 220 allows lubrication fluid that has been ejected from the dynamic components within the lubrication chamber 112 (e.g. the bearing 116) to flow into the sump 222.

The sump 222 is a container for collecting lubrication fluid that has been ejected from the dynamic components within the lubrication chamber 112 (e.g.
20 the bearing 116). Lubrication fluid contained within the sump 22 may be recirculated and reused to provide lubrication to dynamic components within the lubrication chamber 112.

In this embodiment, the clamp 224 clamps together the bearing inner race 200, the deflector plate 208, and the third part 214 of the labyrinth seal
25 206. The clamp 224 clamps the bearing inner race 200, the deflector plate 208, and the third part 214 onto the drive shaft 110.

In operation, the drive shaft 110 is rotated. Thus, the bearing inner race 200 is rotated relative to the bearing outer race 204. The bearing balls 204 rotate relative to the inner and outer races 200, 202 thereby to permit relative
30 rotation of the inner and outer races 200, 202. Liquid lubricant is supplied to the bearing 116 to facilitate this relative movement of the inner and outer races 200,

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202 and the bearing balls 204. The movement of the inner and outer races 200, 202 and the bearing balls 204 tends to cause the liquid lubricant to be expelled from the bearing.

The edge portion 301 of the deflector plate 208 tends to direct liquid lubricant that is expelled from the bearing 116 (or other dynamic components within the lubrication chamber 112) in a radially outwards direction, as indicated in Figure 3 by an arrow and the reference numeral 310. Thus, advantageously the edge portion 301 tends to direct the liquid lubricant in a direction 310 away from the opening 304 of the tortuous path of the labyrinth seal 206. This liquid lubricant may contact a face of the head plate 114 or other non-rotating component. This liquid lubricant tends to flow, or drain, along the bearing drain 220 to the sump 222.

Thus, the edge portion 301 may be considered to be a fluid deflection portion that extends in a direction away from the opening 304 and is configured to direct or deflect a fluid that impinges on a surface of the edge portion 301 away from the opening 304.

Furthermore, when the vacuum pump 100 is stopped, i.e. when the drive shaft 110 is not being rotated, lubrication liquid may collect, or pool, within or proximate to the opening 304 of the tortuous path of the labyrinth seal 206. Advantageously, the deflector plate 208 tends to provide that, when the vacuum pump 100 is restarted, i.e. when the drive shaft 110 is rotated, this lubrication fluid that has collected proximate to the opening 304 of the tortuous path is expelled outwards and away from the opening 304, as indicated in Figure 3 by an arrow and the reference numeral 312.

Thus, the amount of liquid lubricant that enters the tortuous path of the labyrinth seal 206 tends to be reduced. Sealing between the pumping stages and the lubrication chambers 106 tends to be improved.

Advantageously, the above-described deflector plate tends to be easy to fabricate.

Advantageously, the above-described deflector plate tends to be easy to retrofit into existing vacuum pumps to provide improved sealing.

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Advantageously, use of a deflector plate tends to improve sealing without use of a thrower for distributing lubrication fluid within the vacuum pump. Thus, use of a thrower can be avoided.

In the above embodiments, the seal system is implemented in a vacuum pump. However, in other embodiments, the seal is implemented in a different type of apparatus or system other than a vacuum pump, and forms a seal between a fixed housing and a rotatable shaft.

In the above embodiments, the vacuum pump is a positive displacement dry pump, and in particular a roots type pump. However, in other embodiments, the vacuum pump is a different type of pump. For example, in other embodiments, the vacuum pump is a different type of positive displacement pump, for example a claw or screw type pump.

In the above embodiments, the vacuum pump comprises two drive shafts. However, in other embodiments, the vacuum pump comprises a different number of drive shafts, e.g. only one drive shaft, or more than two drive shafts.

In the above embodiments, the vacuum pump comprises four pumping stages. However, in other embodiments, the vacuum pump comprises a different number of pumping stages, e.g. less than four pumping stages or more than four pumping stages.

In the above embodiments, the labyrinth seal comprises three parts, namely a first part, a second part, and a third part. However, in other embodiments, the labyrinth seal comprises a different number of parts, for example more than three or less than three.

In the above embodiments, the third part of the labyrinth seal, the deflector plate, and the bearing inner race are held on the shaft by means of a clamp. However, in other embodiments, one or more of the third part of the labyrinth seal, the deflector plate, and the bearing inner race are held on the shaft by means other than a clamp. For example, the deflector plate may be weld onto or integrally formed with the shaft.

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In the above embodiments, the deflector plate comprises an annular disc and an edge portion that extends from the radially outer edge of the annular disc portion, in a direction that is oblique to the annular disc portion (i.e. oblique to the radial direction). In some embodiments, the deflector plate may
5 additionally comprise other features.

By way of example, Figure 5 is a schematic illustration (not to scale) showing a further deflector plate 313, in accordance with a further embodiment.

In this embodiment, the further deflector plate 313 comprises the disc portion 300 and the edge portion 301, which may be configured as described in
10 more detail earlier above with reference to Figures 2 to 4.

In addition, in this embodiment, the disc portion 300 comprises a plurality of radially extending grooves 314 formed in one of its surfaces. In some embodiments, the grooves can follow a curved or meandering path across the surface of the disc portion 300. Although eight grooves 314 are depicted in
15 Figure 5, it will be appreciated that any number of grooves may be implemented. In this embodiment, the grooves are substantially equally spaced-apart, i.e. by an angular spacing of 45°. In some embodiments, the angular spacings between adjacent grooves may be a different value, and/or the spacing may be uneven. The depths of the grooves may be approximately
20 0.3mm.

In this embodiment, each groove extends from the central hole 303 to the edge portion 301. In some embodiments, one or more of the grooves start at a position radially outwards of the central hole 303. Optionally, the grooves 314 may continue into the edge portion 301, i.e. at least a part of a groove may be
25 formed in the edge portion 301.

In this embodiment, the grooves 314 are formed in the surface of the disc portion 300 that, in use, faces, is adjacent to, or abuts, the labyrinth seal 206.

As described above, when the vacuum pump 100 is stopped, i.e. when the drive shaft 110 is not being rotated, lubrication liquid may collect, or pool,
30 within or proximate to the opening 304 of the tortuous path of the labyrinth seal 206. Advantageously, the grooves 314 of the deflector plate 313 provide

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channels along which the pooled liquid may flow. Thus, when the vacuum pump 100 is restarted, i.e. when the drive shaft 110 is rotated, the lubrication fluid that has collected proximate to the opening 304 of the tortuous path is channelled in a radially outward direction by the grooves 314. Thus, the grooves facilitate
5 expulsion of the pooled lubrication liquid out of the opening 304 of the tortuous path.

In the above embodiments, the deflector plate comprises the fluid deflection portion (i.e. the edge portion 301) that extends in a direction away from the opening of the tortuous path and is configured to direct or deflect a
10 fluid that impinges on one of its surfaces in a direction away from the opening of the tortuous path. However, in other embodiments, the fluid deflection portion for direct or deflect a fluid away from the opening of the tortuous path is comprises in a different component of the vacuum pump.

By way of example, Figure 6 is a schematic illustration (not to scale)
15 showing a further bearing 316 that may be used in place of the bearing 116 and the deflector plate 208/313 described above.

In this embodiment, the further bearing 316 comprises the bearing inner race 200, the bearing outer race 202, and the plurality of bearing balls 204, which may be configured as described in more detail earlier above with
20 reference to Figures 2 to 4.

In addition, in this embodiment, the bearing inner race 200 comprises a fluid deflection portion 318 that extends from a side of the inner race 200 in a direction away from the bearing 316 in a direction that has a first component that points in an axial direction and a second component that points in a radially
25 outward direction. The fluid deflection portion 318 is configured to deflect a flow of a fluid flowing out of the bearing 316 in the same way as that described in more detail above for the edge portion 301 of the defector plate 208. The fluid deflection portion 318 may be considered to be a protrusion or flange that extends from the bearing inner race 200.

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Reference numerals

- 100 – vacuum pump
- 102 – pump inlet
- 104 – pump outlet
- 5 106 - pumping stage
- 108 – rotor
- 110 - drive shaft
- 112 - lubrication chambers
- 114 - head plates
- 10 116 - bearing
- 118 – seal system
- 200 – bearing inner race
- 202 – bearing inner race
- 204 – bearing ball
- 15 206 – labyrinth seal
- 208 – deflector plate
- 210 - first part
- 212 - second part
- 214 - third part
- 20 220 - bearing drain
- 222 – sump
- 224 – clamp
- 300 - disc portion
- 301 – edge portion
- 25 302 - gap

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303 - hole

304 – first end

306 – second end

310 – flow direction

5 312 – flow direction

313 – further deflector plate

314 – groove

316 – further bearing

318 - fluid deflection portion

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CLAIMS

1. A seal system forming a seal between a housing and a shaft, the shaft being rotatable relative to the housing, the seal system comprising:

a labyrinth seal comprising:

5 a first labyrinth seal part substantially fixed relative to the housing;
and

a second labyrinth seal part substantially fixed relative to the shaft;
wherein

10 the first and second labyrinth seal parts define a tortuous path for
a fluid; and

the tortuous path comprises an opening at a first side of the
labyrinth seal; and

a member substantially fixed relative to either the housing or the shaft;
wherein:

15 the member is located adjacent to the labyrinth seal at the first side of the
labyrinth seal; and

the member comprises a fluid deflection portion that extends in a
direction away from the opening such that a fluid impinging on a surface of the
deflection portion is directed away from the opening.

20

2. The seal system of claim 1, wherein:

the shaft defines an axial direction and a radial direction; and

the fluid deflection portion extends from the opening in a direction that
has a component that points in a radially outward direction.

25

3. The seal system of claim 1 or 2, wherein:

the shaft defines an axial direction and a radial direction; and

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the fluid deflection portion extends from the opening in a direction that has a component that points in an axial direction towards the labyrinth seal.

4. The seal system of any of claims 1 to 3, wherein the member is
5 substantially fixed relative to the shaft.

5. The seal system of any of claims 1 to 4, wherein:
the member comprises an annular disc positioned around the shaft; and
the fluid deflection portion extends from a radially outer edge of the
10 annular disc.

6. The seal system of claim 5, wherein the annular disc comprises one or more radially extending grooves formed therein.

15 7. The seal system of claim 6, wherein the radially extending grooves are formed in a surface of the annular disc that faces the labyrinth seal.

8. The seal system of any of claims 1 to 4, wherein the member is the inner race of a bearing, the bearing being for supporting the shaft within the housing,
20 the inner race being substantially fixed relative to the shaft.

9. A vacuum pump comprising:
a housing;
a shaft rotatable relative to the housing; and
25 a seal system coupled between the housing and the shaft, the seal system being in accordance with any of claims 1 to 8.

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10. The vacuum pump of claim 9, wherein:

the vacuum pump further comprises:

a lubrication chamber in which a fluid lubricant is circulated; and

a pumping stage; and

5 the seal system is located between the lubrication chamber and the pumping stage thereby to prevent or oppose a flow of the fluid lubricant from the lubrication chamber into the pumping stage.

11. The vacuum pump of claim 9 or 10, wherein:

10 the vacuum pump further comprises a bearing configured to support the shaft within the housing: and

the member is located between the labyrinth seal and the bearing.

12. The vacuum pump of claim 9 or 10, wherein:

15 the vacuum pump further comprises a bearing configured to support the shaft within the housing: and

the member is an inner race of the bearing, the inner race of the bearing being substantially fixed relative to the shaft.

20 13. A fluid flow deflection device for use with a vacuum pump, the device comprising:

an annular disc for positioning around a shaft of the vacuum pump; and

a portion that extends from a radially outer edge of the annular disc in a direction that is oblique to a radial direction.

25

14. The fluid flow deflection device of claim 13, wherein the annular disc comprises one or more radially extending grooves.

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15. A bearing for supporting a rotatable shaft of a vacuum pump within a fixed housing of the vacuum pump, the bearing comprising:

a radially inner race;

5 a radially outer race; and

a plurality of bearing balls disposed between the inner race and the outer race; wherein

the inner race comprises a portion that extends from a side of the inner race in a direction away from the bearing, the direction having a first component
10 that points in an axial direction and a second component that points in a radially outward direction, the portion being configured to deflect a flow of a fluid flowing out of the bearing.

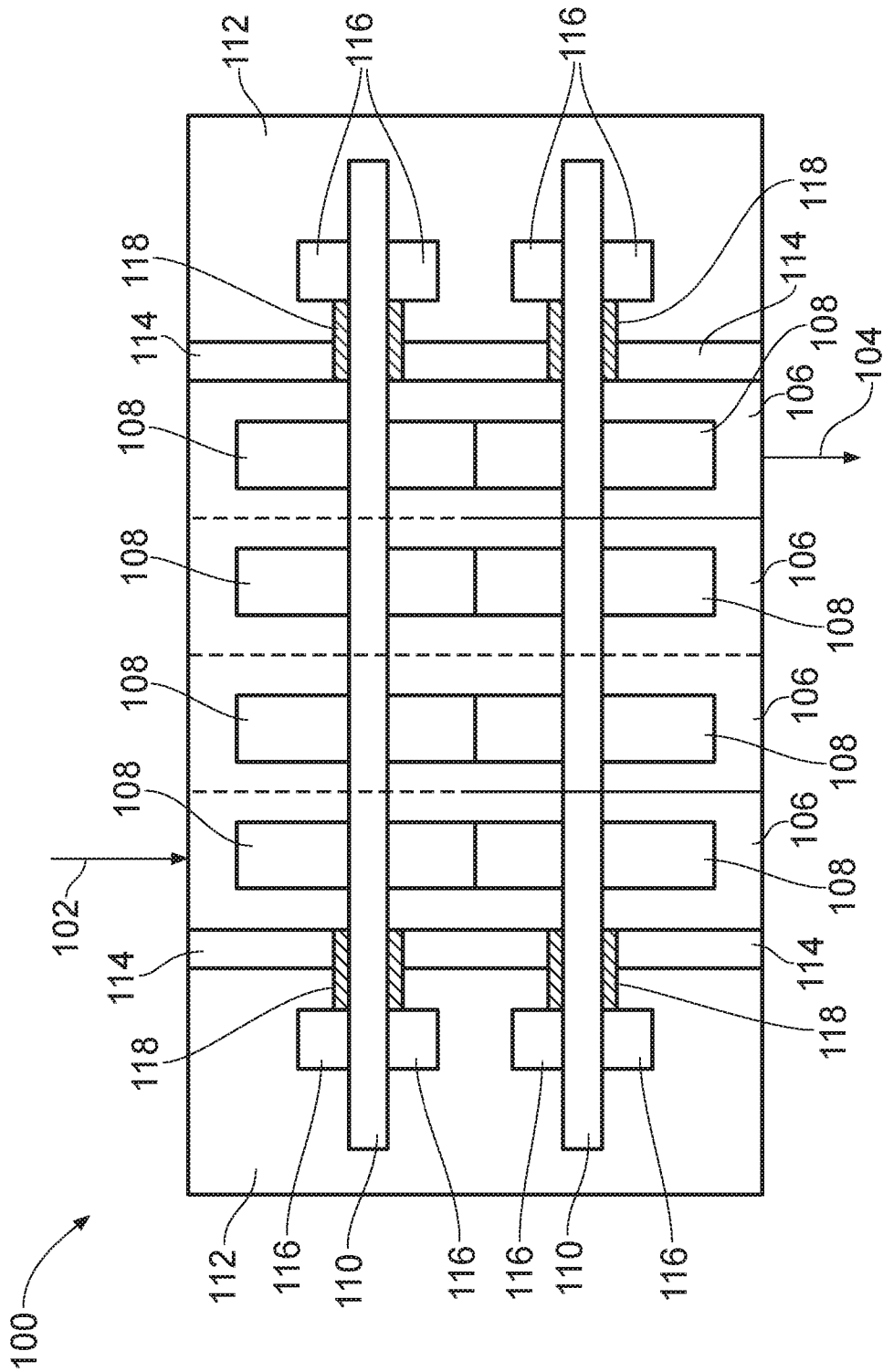


FIG. 1

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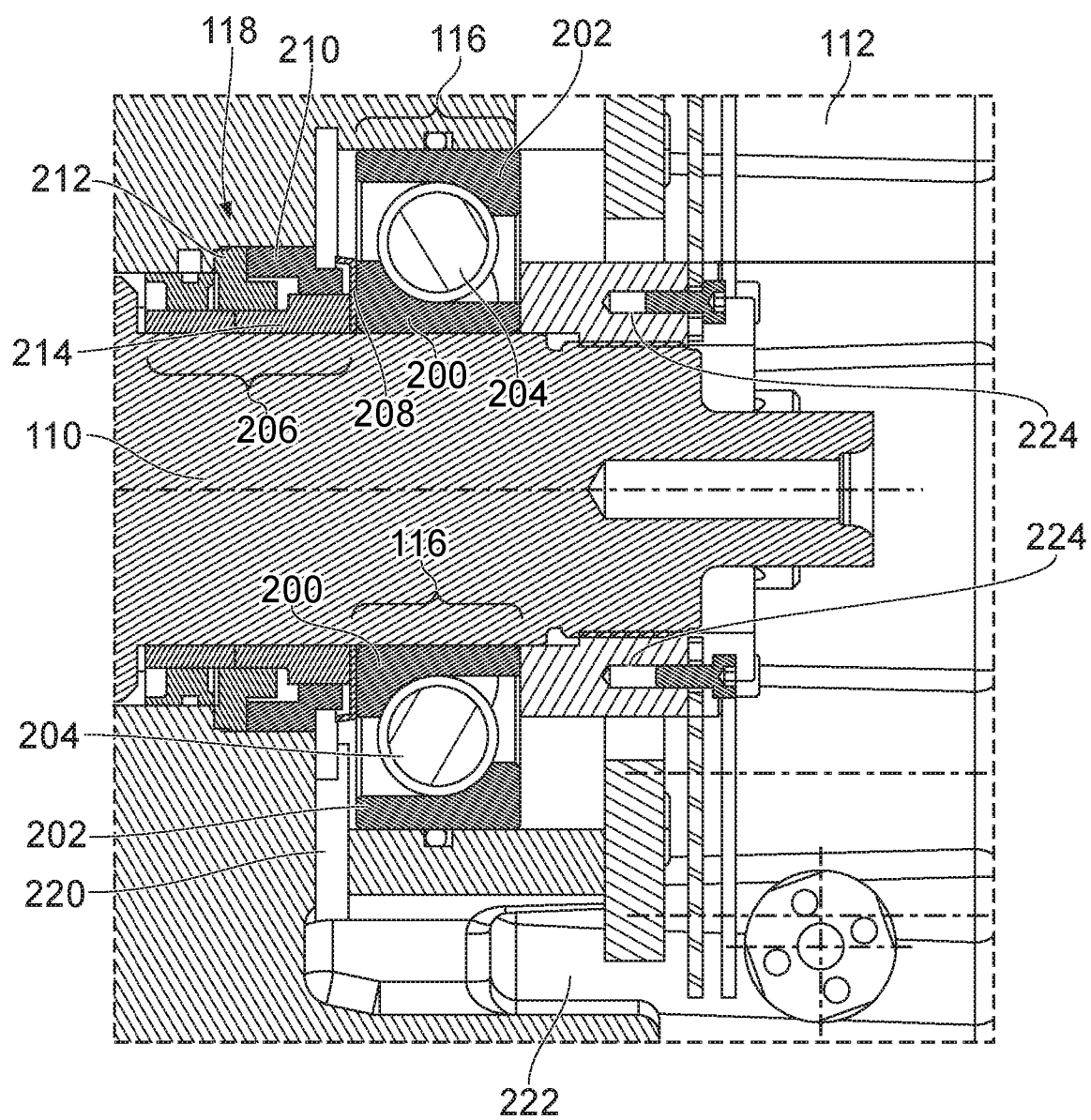


FIG. 2

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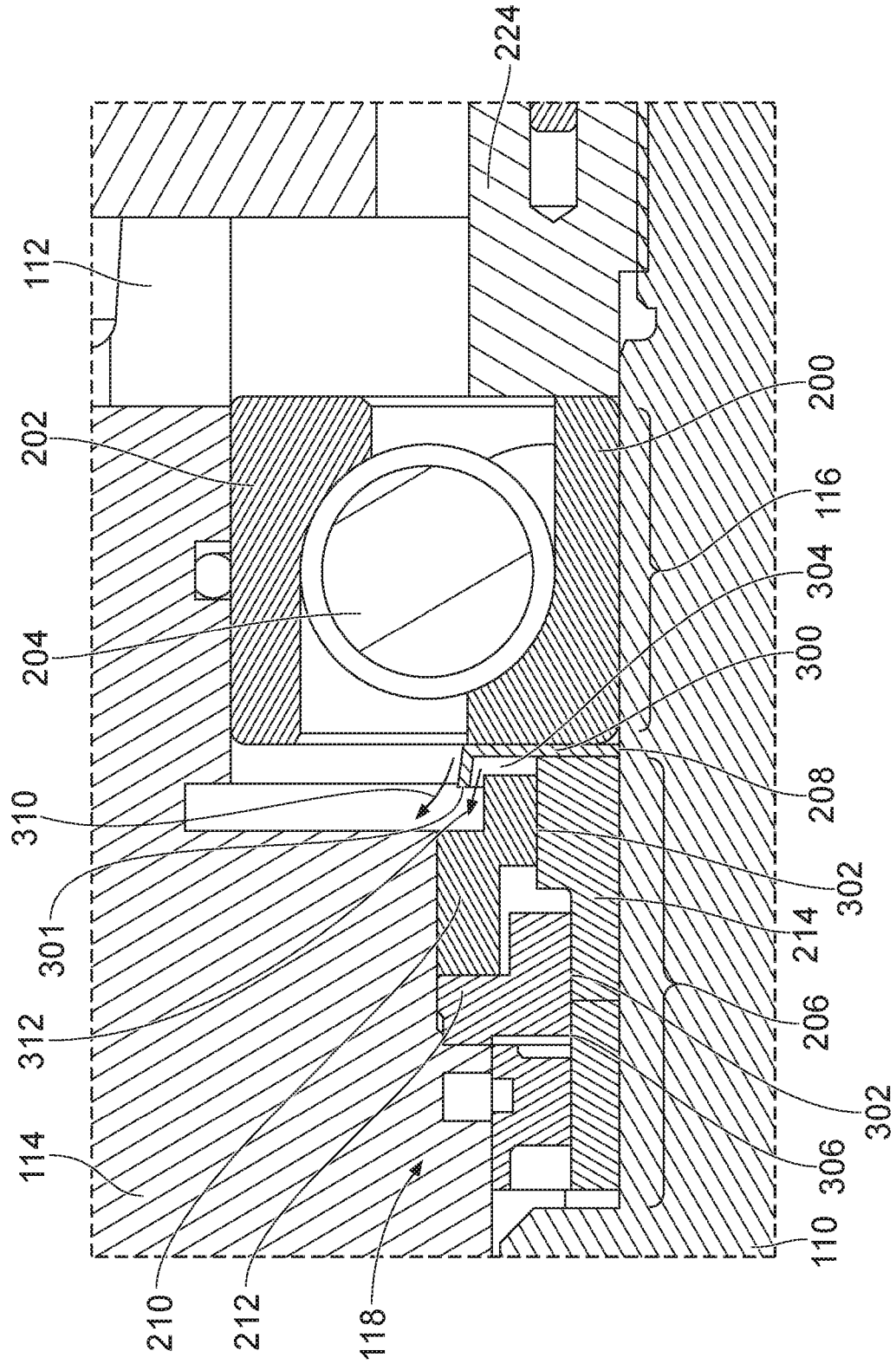


FIG. 3

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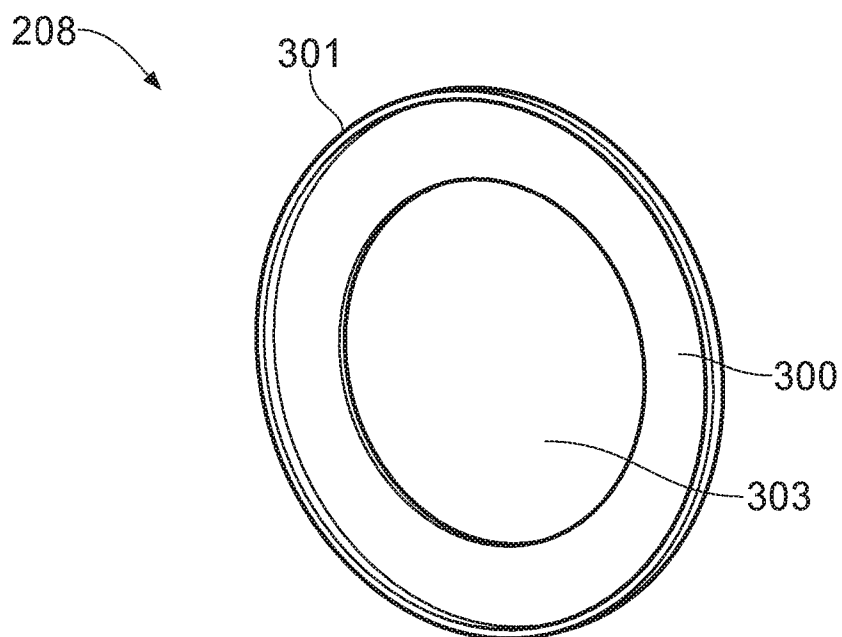


FIG. 4

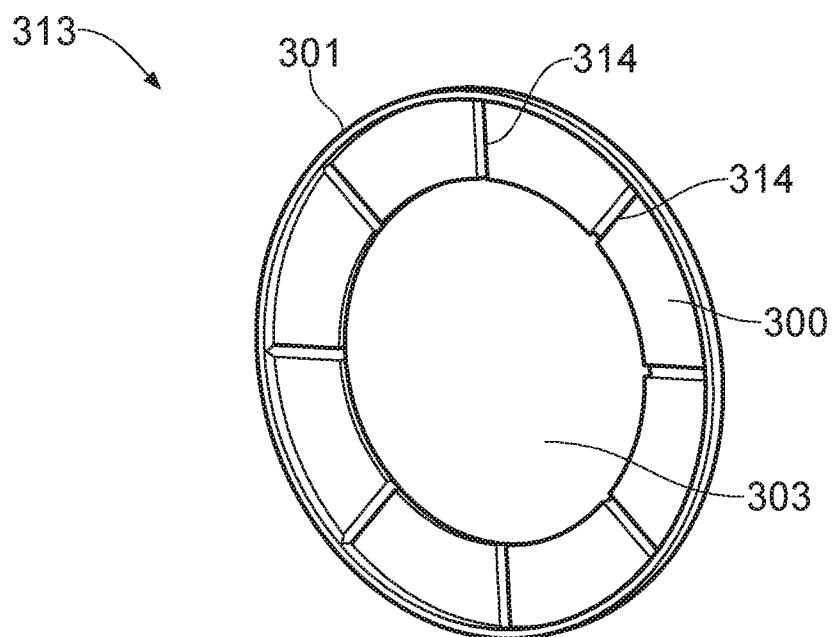


FIG. 5

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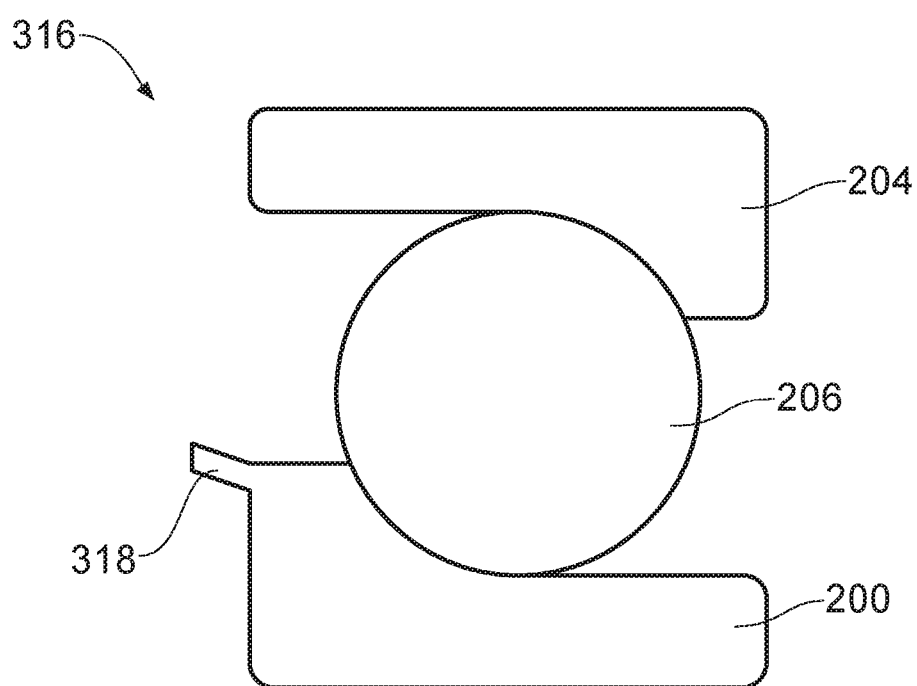


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2021/051894

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16J15/44 B65G39/09 F16C19/36 F16C33/00 F16J15/447
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16J F16C B65G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AT 208 666 B (VOITH GMBH J M [DE]) 25 April 1960 (1960-04-25)	1-5, 8-13,15
Y	figure 2	6,7,14
X	US 9 488 061 B2 (ELECTRO-MOTIVE DIESEL INC [US]) 8 November 2016 (2016-11-08)	1-5, 8-13,15
A	figure 3	6,7,14
Y	US 5 664 644 A (REICKS ALLEN V [US] ET AL) 9 September 1997 (1997-09-09)	6,7,14
A	figure 6	1-5, 8-13,15
A	GB 1 599 114 A (DRESSER IND) 30 September 1981 (1981-09-30) figures 3-4	1-15
	-/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

27 October 2021

Date of mailing of the international search report

08/11/2021

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2021/051894

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 945 730 A (MURRAY ALFRED S ET AL) 19 July 1960 (1960-07-19) figures 1, 3 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2021/051894

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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