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(71) Applicant: **EATON CORPORATION** [US/US]; Eaton Center, 1111 Superior Ave., Cleveland, OH 44114-2584 (US).

(72) Inventor: **HICKS, Aaron, M.**; 1320 Creek Park Lane NE, Fridley, MN 55432 (US).

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(54) **Title:** BI-DIRECTIONAL DISC-VALVE MOTOR AND IMPROVED VALVE-SEATING MECHANISM THEREFOR

(57) **Abstract:** A rotary fluid pressure device (11) has a stationary valve member (17), a rotatable valve member (51), and a valve seating mechanism (73). The valve seating mechanism (73) defines an outer balance ring member (75) having a valve-confronting surface (79) in engagement with an opposite surface (81) of the rotatable valve member (51) and an inner balance ring member (77) having a valve-confronting surface (111) in engagement with the opposite surface (81) of the rotatable valve member (51), with the outer balance ring member (75) and the inner balance ring member (77) being structurally independent from the other. The outer balance ring member (75) and the inner balance ring member (77) define a balance ring passage (71) which provides continuous fluid communication between a fluid inlet (53) or a fluid outlet (53) and the valve passages (61) in the rotatable valve member (51).

TITLE OF INVENTION

[0001] Bi-Directional Disc-Valve Motor and Improved Valve-Seating Mechanism Therefor.

BACKGROUND OF THE DISCLOSURE

[0002] The present invention relates to a bi-directional fluid pressure-operated displacement unit, of the type including a rotary valve member, and more particularly, to an improved valve-seating mechanism for use therein.

[0003] Although the present invention may be used in various pump and motor configurations in which fluid flows axially through a valve member and contact must be maintained between the valve member and a corresponding port plate which communicates with the volume chambers of a fluid displacement mechanism, it is especially advantageous when used in disc-valve gerotor motors. Therefore, the present invention will be discussed in connection with disc-valve gerotor motors without intending to limit the scope of the invention.

[0004] Fluid motors of the type utilizing a gerotor displacement mechanism to convert fluid pressure into a rotary output are widely used in a variety of low speed, high torque commercial applications. Typically, in fluid motors of this type, the gerotor mechanism includes a fixed internally toothed member (ring) and an externally toothed member (star) which is eccentrically disposed within the ring and orbits and rotates relative thereto. In fluid motors of this type there are normally two relatively moveable valve members. One of the valve members is stationary and provides a plurality of fluid passages, each one being in permanent communication with one of the volume chambers defined by the gerotor mechanism, while the other valve member rotates relative to the stationary valve member, in commutating fluid communication therewith, as is now well known to those skilled in the low speed, high torque gerotor motor art.

[0005] Low speed, high torque gerotor motors are illustrated in U.S. Pat. Nos.

3,572,983 and 4,390,329, both of which are assigned to the assignee of the present invention and incorporated herein by reference. Fluid motors made in accordance with the cited patents include, in addition to the previously mentioned stationary valve member and rotatable disc-valve member, a valve-seating mechanism which is now also generally well known in the gerotor motor art. The general function of the valve-seating mechanism is to exert a circumferentially uniform biasing force, biasing the rotatable valve member into sliding, sealing engagement with the stationary valve member.

[0006] One of the problems with fluid motors of the disc-valve type is a condition referred to as "internal leakage." Internal leakage is defined as a volume of fluid communicated between the high-pressure side and the low-pressure side that effectively bypasses the gerotor displacement mechanism. Since such internal leakage effectively bypasses the gerotor displacement mechanism, such leakage reduces the volumetric efficiency of the fluid motor. As is well known to those skilled in the art, internal leakage in a fluid motor varies proportionally to the operating pressure of the fluid. Therefore, as the operating pressure of the inlet fluid increases, the internal leakage in the fluid motor also increases.

[0007] A recent trend in commercial applications which use fluid motors of the disc-valve type is to require increased operating pressure ratings in the fluid motor. In addition to this requirement, the manufacturers of commercial products for those applications have requested improved volumetric efficiencies at these higher operating pressures. However, as previously stated, higher operating pressures result in more internal leakage in the fluid motor and lower volumetric efficiencies. Therefore, in order to meet these requests and requirements, it is necessary to identify, and reduce the effect of any sources of volumetric inefficiency in the fluid motor.

[0008] One location in fluid motors of the disc-valve type where internal leakage is prevalent, especially at high operating fluid pressures, is at the interface between the rotatable valve member and the valve-seating mechanism. At this location, fluid inlet, fluid outlet, and case fluid pressure forces act on the valve-confronting surface of the valve-seating mechanism and cause the valve-seating mechanism to "distort"(or deform or deflect). Such distortion, is referred to by those skilled in the art as "potato chipping." Potato chipping occurs when the outer periphery of the valve-seating mechanism distorts, deforms or deflects more or less than the inner diameter of the valve-seating mechanism, such that the valve-confronting surface and the adjacent surface of the stationary valve member are no longer in a planar, face-to-face relationship. Distortion of the valve-seating mechanism results in a loss of sealing engagement between the valve-seating mechanism and the rotatable valve member. Internal leakage occurs at the location of this loss of sealing engagement. At higher operating pressures, this distortion, deformation or deflection is more pronounced.

[0009] In the disc-valve fluid motor art, there are two primary types of rotatable valve members. The first type is referred to as a "blind-bore" type. In the blind-bore type of disc-valve, as illustrated in the above incorporated U.S. Pat. Nos. 3,572,983 and 4,390,329, the internal cavity, in which internal splines are formed, of the rotatable valve member does not continue along the entire axial length of the valve member, and thus, fluid cannot flow axially throughout the axial length of the valve. The second type is referred to as a "thru-bore" type. In the thru-bore type of disc-valve, an internal bore, in which internal splines are formed, extends the entire axial length of the rotatable valve member. While the present invention can be used with both types of rotatable valve members, it is especially advantageous when used with a motor of the thru-bore type, and will be described in connection therewith, without intending to limit the scope of the invention.

BRIEF SUMMARY OF THE INVENTION

[0010] Accordingly, it is an object of the present invention to provide an improved valve-seating mechanism for a bi-directional disc-valve motor that overcomes the above discussed disadvantages of the prior art.

[0011] It is a more specific object of the present invention to provide an improved valve-seating mechanism for a bi-directional disc-valve motor that achieves less internal leakage than the prior art mechanism at high pressure.

[0012] The above and other objects of the invention are accomplished by the provision of an improved rotary fluid pressure device of the type including a housing that defines a fluid inlet and a fluid outlet, a displacement mechanism that defines expanding and contracting fluid volume chambers, a stationary valve member that defines fluid passages in fluid communication with the expanding and contracting volume chambers in the displacement mechanism, a rotatable valve member that defines valve passages that communicate between the fluid inlet and fluid outlet and the fluid passages in the stationary valve member, a valve surface of the rotatable valve member being in sliding, sealing engagement with the valve surface of the stationary valve member, and the rotatable valve member further having an opposite surface.

[0013] The improved rotary fluid pressure device is characterized by an outer balance ring member having a valve-confronting surface in engagement with the opposite surface of the rotatable valve member, an inner balance ring member having a valve-confronting surface in engagement with the opposite surface of the rotatable valve member, with the outer balance ring member and the inner balance ring member defining a balance ring passage which provides continuous fluid communication between the fluid inlet or the fluid outlet and the valve passages in the rotatable valve member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is an axial cross-section of a bi-directional disc-valve motor made in accordance with the present invention and includes a fragmentary section taken on a different plane.

[0015] FIG. 2 is an enlarged, fragmentary, axial cross-section of an embodiment of a valve-seating mechanism, in accordance with the present invention, as shown in FIG. 1.

[0016] FIG. 3 is a transverse cross-section, taken on line 3-3 of FIG. 1, but showing only the valve-seating mechanism.

[0017] FIG. 4 is a fragmentary axial cross-section of a prior art valve-seating mechanism.

[0018] FIG. 5 is a enlarged axial cross-section of the upper half of a prior art valve-seating mechanism illustrating applied pressure forces.

[0019] FIG. 6 is a fragmentary axial cross-section of the upper half of a prior art valve-seating mechanism, illustrating resulting deflection from applied pressure forces.

[0020] FIG. 7 is a fragmentary axial cross-section of the upper half of a valve-seating mechanism made in accordance with the present invention, illustrating applied pressure forces.

[0021] FIG. 8 is an enlarged, fragmentary, axial cross-section of an alternative embodiment of the interface between a rotatable valve member and a valve-seating mechanism, in accordance with the present invention.

[0022] FIG. 9 is a fragmentary axial cross-section of the upper half of a valve-seating mechanism made in accordance with the present invention, illustrating applied pressure forces resulting from the alternate embodiment of the interface between a rotatable valve member and a valve-seating mechanism.

[0023] FIG. 10 is an enlarged, fragmentary axial cross-section, including the upper half of a valve-seating mechanism made in accordance with the present invention, illustrating the resulting deflection from applied pressure forces.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] Referring now to the drawings, which are not intended to limit the invention, FIG. 1 is an axial cross-section of a bi-directional disc-valve motor of the thru-bore type made in accordance with the present invention. The disc-valve motor, generally designated **11**, includes a mounting plate **13**, a gerotor displacement mechanism **15**, a stationary valve member **17**, also referred to hereinafter as the "port plate", and a valve housing **19**. The sections are held together in tight sealing engagement by means of a plurality of bolts **21**, in threaded engagement with the mounting plate **13**.

[0025] The gerotor displacement mechanism **15** is well known in the art and will therefore be described only briefly herein. More specifically, in the subject embodiment, the gerotor displacement mechanism **15** is a Geroler ® displacement mechanism comprising an internally toothed assembly **23**. The internally toothed assembly **23** comprises a stationary ring member **25** which defines a plurality of generally semi-cylindrical openings **27**. Rotatably disposed within each of the semi-cylindrical openings **27** is a cylindrical member **29**, as is now well known in the art. Eccentrically disposed within the internally toothed assembly **23** is an externally toothed rotor member **31**, typically having one less external tooth than the number of cylindrical members **29**, thus permitting the externally toothed rotor member **31** to orbit and rotate relative to the internally toothed assembly **23**. The relative orbital and rotational movement between the internally toothed assembly **23** and the externally toothed rotor member **31** defines a plurality of expanding and contracting volume chambers **33**. The externally toothed rotor member **31** defines a set of internal splines **35** formed at the inside diameter of the rotor member **31**. The internal splines **35** of the rotor member **31** are in engagement with a set of external, crowned splines **37** on a main drive shaft **39**. Disposed at the opposite end of the main drive shaft **39** is another set of external, crowned splines **41**, for engagement with a set of internal splines (not shown) in a customer-supplied output device, such as a shaft (not shown).

[0026] Also in engagement with the internal splines **35** of the externally toothed rotor member **31** is a set of external splines **43** formed about one end of a valve drive shaft **45** which has, at its opposite end, another set of external splines **47** in engagement with a set of internal splines **49** formed about the inner periphery of a rotatable valve member **51**. The valve member **51** is rotatably disposed within the valve housing **19**, and the valve drive shaft **45** is splined to both the externally toothed rotor member **31** and the rotatable valve member **51** in order to maintain proper valve timing, as is generally well known in the art.

[0027] The valve housing **19** defines a fluid port **53** which is in open fluid communication with a fluid passage **55**. The fluid passage **55** is in open fluid communication with an annular fluid chamber **57**. The valve housing **19** further defines a second fluid port (not shown) which is in open communication with a second fluid passage (not shown). The second fluid passage is in open fluid communication with an annular valve housing cavity **59**, which is cooperatively defined by an inner annular surface of the valve housing **19** and the rotatable valve member **51**.

[0028] The rotatable valve member **51** defines a plurality of alternating valve passages **61** and **63**. The valve passages **61**, which are disposed in an annular fluid groove **64**, are in continuous fluid communication with the annular fluid chamber **57** in the valve housing **19**, while the valve passages **63** are in continuous fluid communication with the valve housing cavity **59**. In the subject embodiment, and by way of example only, there are eight of the valve passages **61**, and eight of the valve passages **63**, corresponding to the eight external teeth or lobes on the externally toothed rotor member **31**.

[0029] Referring still to FIG. 1, the port plate **17** defines a plurality of fluid passages **65**, each of which is disposed to be in continuous fluid communication with the adjacent volume chamber **33**. The port plate **17** also defines a transverse valve surface **67**, and the rotatable valve member **51** defines a transverse valve surface **69** in sliding, sealing engagement with the valve surface **67**. In operation, pressurized fluid entering the fluid port **53** will flow through the fluid passage **55** and into the annular fluid chamber **57**. The pressurized fluid will then flow through a fluid passage **71**, in a valve-seating mechanism, generally designated **73**, both of which will also be described in greater detail subsequently. Fluid will then flow into the valve passages **61** in the rotatable valve member **51**. The pressurized fluid will then flow through the valve passages **61** in the rotatable valve member **51** which are in commutating fluid communication with the fluid passages **65** in the port plate **17**. The pressurized fluid will enter the expanding volume chambers **33** in the gerotor displacement mechanism **15** through the adjacent fluid passages **65** in the port plate **17** which are in commutating fluid communication with the respective valve passages **61**. As is well known to those skilled in the art, the above described flow will result in orbital and rotational movement of the externally toothed rotor member **31**.

[0030] Exhaust fluid will flow from the contracting volume chambers **33** through the adjacent fluid passages **65** in the port plate **17** which are in commutating fluid communication with the valve passages **63** in the rotatable valve member **51** and into those respective valve passages **63**. The fluid will then flow into the valve housing cavity **59** and to a reservoir (not shown) through the second fluid passage (not shown) and the second fluid port (not shown) in the valve housing **19**.

[0031] Referring now to FIGS. 2 and 3, with reference made to elements introduced in FIG. 1, the valve-seating mechanism **73** includes an outer balance ring member **75** and an inner balance ring member **77**, each of which is structurally independent from the other. The outer balance ring member **75** defines a valve confronting surface **79** which is in sealing engagement with a rearward surface **81** of the rotatable valve member **51**. The outer balance ring member **75** also defines a rearwardly projecting, integral ring portion **83** which is disposed in a mating annular ring groove **85** in the valve housing **19**. The outer balance ring member further defines an axial end surface **86**.

[0032] The rearwardly projecting, integral ring portion **83** of the outer balance ring member **75** defines a circumferential annular groove **87** with a first axial end **89** and a second axial end **91**. The outer diameter **D1** of the first axial end **89** of the circumferential annular groove **87** is larger than the outer diameter **D2** of the second axial end **91** of the circumferential annular groove **87**. The difference between the outer diameter **D1** of the first axial end **89** and the outer diameter **D2** of the second axial end **91** is determined from the amount of axial balancing force required to maintain sealing engagement between the transverse valve surface **69** of the rotatable valve member **51** and the transverse valve surface **67** of the port plate **17**. A sealing member **93** and first and second backup members **95**, **97**, respectively, are disposed in the circumferential annular groove **87** of the outer balance ring member **75** such that the sealing member **93** is located between the first and second back-up members **95**, **97**.

[0033] The outer balance ring member **75** of the valve-seating mechanism **73** further defines a plurality of rotational constraint holes **99** (see FIG. 3), and each of the constraint holes **99** has associated therewith a pin member **100** (shown only in FIG. 1) including a first axial end **101** and a second axial end **102**. The second axial ends **102** are disposed in a plurality of rotational constraint holes **103** defined by the valve housing **19**. The pin members **100** are disposed in the rotation constraint holes **99** of the outer balance ring member **75** and the rotational constraint holes **103** in the valve housing **19** in order to prevent rotation of the outer balance ring member **75** with respect to the valve housing **19**.

[0034] The outer balance ring member **75** of the valve-seating mechanism **73** further defines a spring confronting surface **105** which is in engagement with a plurality of biasing springs **107**. The biasing springs **107** are disposed in a plurality of biasing spring holes **109** in the valve housing **19**. In the absence of pressurized fluid, the biasing springs **107** maintain the engagement of the valve surface **67** of the port plate **17** and the valve surface **69** of the rotatable valve member **51** as well as the valve confronting surface **79** of the outer balance ring member **75** and the rearward surface **81** of the rotatable valve member **51**.

[0035] Referring still primarily to FIGS. 2 and 3, the inner balance ring member **77** of the valve-seating mechanism **73** defines a valve confronting surface **111** which is seated against the rearward surface **81** of the rotatable valve member **51**. The inner balance ring member **77** defines a rearwardly projecting, integral ring portion **113** which is disposed in the annular ring groove **85** in the valve housing **19**. The inner balance ring member **77** further defines an axial end surface **114**. The rearwardly projecting, integral ring portion **113** defines a circumferential step **115**, against which is disposed a backup member **117** and a sealing member **119**.

[0036] Similar to the outer balance ring member **75**, the inner balance ring member **77** of the valve-seating mechanism **73** defines a plurality of rotational constraint holes **121**, each of the constraint holes **121** has associated therewith a pin member **122** including a first axial end **123** and a second axial end **124**. The second axial ends **124** are disposed in a plurality of rotational constraint holes **125** defined by the valve housing **19**. The pin members **122** are disposed in the rotational constraint holes **121** in the inner balance ring member **77** and the rotational constraint holes **125** in the valve housing **99** in order to prevent any rotation of the inner balance ring member **77** with respect to the valve housing **19**.

[0037] The inner balance ring member **77** defines a spring confronting surface **127** which is in engagement with a plurality of biasing springs **129** (shown only in FIG. 1). The biasing springs **129** are disposed in a plurality of biasing spring holes **131** (shown in FIG. 1) in the valve housing **19**. In the absence of pressurized fluid, the biasing springs **129** maintain the engagement of the valve surface **67** of the port plate **17** and the valve surface **69** of the rotatable valve member **51**, as well as the valve confronting surface **111** of the inner balance ring member **77** and the rearward surface **81** of the rotatable valve member **51**.

[0038] Referring still to FIG. 2 and FIG. 3, the inner balance ring member **77** is radially positioned with respect to the outer balance ring member **75** such that the inner balance ring member **77** is concentric or nearly concentric to the outer balance ring member **75**. The fluid passage **71** is formed between the outer diameter of the inner balance ring **77** and the inner diameter of the outer balance ring **75**, and therefore, comprises an annular fluid passage, providing relatively little restriction to flow.

[0039] FIG. 4 illustrates an embodiment ("PRIOR ART") of a prior art valve-seating mechanism **273**. To the extent that elements associated with the prior art design are structurally or functionally equivalent to elements previously introduced in regards to the present invention, the reference numerals assigned to the prior art elements will bear the same reference numerals assigned to the elements of the present invention, plus "200". The prior art embodiment shown in FIG. 4 includes a valve housing **219**, a rotatable valve member **251**, and a prior art valve-seating mechanism **273**. The valve housing **219** defines an annular fluid chamber **257** which is in fluid communication with a fluid port (not shown) and a valve housing cavity **259** which is in fluid communication with a second fluid port (not shown).

[0040] Referring still to FIG. 4, the prior art valve-seating mechanism **273** is a single piece structure which defines a valve confronting surface **279**, a rearwardly projecting, integral ring portion **283**, and an axial end surface **286**. The rearwardly projecting, integral ring portion **283** defines a circumferential annular groove **287** disposed in the outer diameter of the integral ring portion **283** with a first axial end **289** and a second axial end **291**. The prior art valve-seating mechanism **273** further defines a plurality of fluid passages **271** that extend from the axial end surface **286** through to the valve confronting surface **279**.

[0041] Referring still to FIG. 4, the valve housing **219** defines a circumferential annular groove **315** which comprises a first axial end **316** and a second axial end **318**. Disposed in the circumferential annular groove **315** is a sealing member **319** that prohibits the flow of fluid along the inner diameter of the prior art valve-seating mechanism **273**.

[0042] Referring now to FIG. 5, with reference to elements introduced in FIG. 4, the prior art valve-seating mechanism **273** is subjected to pressure forces from pressurized fluid. FIG. 5 illustrates these pressure forces acting on the prior art valve-seating mechanism **273** when inlet fluid flows through the annular fluid chamber **257** in the valve housing **219** and return fluid flows through the valve housing cavity **259**. The inlet pressure forces acting on the prior art valve-seating mechanism **273** are designated with arrows accompanied by the letter "**A**" in FIG. 5. The return pressure forces acting on the prior art valve-seating mechanism **273**, as illustrated in FIG. 5, result from pressurized return fluid in the valve housing cavity **259** which flows to the second fluid port (not shown) through the second fluid passage (not shown). The return pressure forces acting on the valve-seating mechanism **273** are designated using smaller arrows and the letter "**B**". Case pressure forces acting on the prior art valve-seating mechanism **273** are designated with small arrows accompanied by the letter "**C**".

[0043] Referring still to FIG. 5 with reference made to elements introduced in FIG. 4, inlet pressure forces "**A**" act on the inner diameter of the plurality of fluid passages **271** between the valve confronting surface **279** and the axial end surface **286**. Inlet pressure forces "**A**" also act on the surfaces of the rearwardly projecting, integral ring portion **283** of the prior art valve-seating mechanism **273** from the first axial end **289** of the circumferential annular groove **287** over the entire surface of the axial end surface **286** of the prior art valve-seating mechanism **273**. Inlet pressure forces "**A**" act on the surface of the inner diameter of the prior art valve-seating mechanism **273** from the axial end surface **286** to an axial location along the inner diameter of the valve-seating mechanism **273** where the inlet pressure forces "**A**" are approximately aligned with the first axial end **316** of the annular groove **315** in the valve housing **219**.

[0044] Referring still to FIG. 5, return pressure forces "**B**" act on the outer diameter surfaces of the prior art valve-seating mechanism **273** between the valve confronting surface **279** and the first axial end **289** of the circumferential annular groove **287**. The valve confronting surface **279** of the prior art valve-seating mechanism **273** is subjected to a pressure force gradient with inlet pressure force "**A**" located on a diameter surrounding the plurality of fluid passages **271** and return pressure force "**B**" at a location on the valve confronting surface **279** aligned with the outer diameter of the rotatable valve member **251**. Return pressure force "**B**" acts on the valve confronting surface **279** between the location aligned with the outer diameter of the rotatable valve member **251** and the outer diameter of the valve confronting surface **279**.

[0045] Referring still to FIG. 5, case pressure forces "**C**" act on the surface of the inner diameter of the prior art valve-seating mechanism **273** from the valve confronting surface **279** to the axial location along the inner diameter of the prior art valve-seating mechanism **273** where the case pressure forces "**C**" are approximately aligned with the first axial end **316** of the annular groove **315** in the valve housing **219**. Case pressure and inlet pressure are maintained separate along the inner diameter of the prior art valve-seating mechanism **273** by the sealing member **319** which is disposed in the annular groove **315** in the valve housing **219**.

[0046] FIG. 6 illustrates the distortion, as predicted by finite element analysis, of the prior art valve-seating mechanism **273** when the prior art valve-seating mechanism **273** is subjected to the previously described inlet, return and case pressure forces "**A**", "**B**", "**C**", respectively, as shown in FIG. 5. It should be understood by those skilled in the art that the relative amounts of distortion represented in FIG. 6 are greatly exaggerated, to facilitate illustration of the invention. As illustrated in FIG. 6, these pressure forces result in "potato chipping" of the prior art valve-seating mechanism **273**, with a greater amount of deflection at the outer diameter of the valve confronting surface **279** than at the radially inner diameter of the valve confronting surface **279** of the prior art valve-seating mechanism **273**. The inner diameter of the valve confronting surface **279** of the prior art valve-seating mechanism **273** maintains contact with the rearward surface **281** of the rotatable valve member **251**, but the "potato chipping" of the prior art valve-seating mechanism **273** results in separation of the outer diameter of the valve confronting surface **279** of the prior art valve-seating mechanism **273** and the rearward surface **281** of the rotatable valve member **251**. This separation allows for fluid communication between the plurality of fluid passages **271** in the prior art valve-seating mechanism **273** and the valve housing cavity **259**. Since the fluid passages **271** are in open communication with the annular fluid chamber **257** in the valve housing **219**, this separation then allows for an amount of fluid entering the motor through the fluid port **253**, which is in open fluid communication with the annular fluid chamber **257**, to flow to the second fluid port (not shown) which is in open fluid communication with the valve housing cavity **259**, thereby bypassing the gerotor displacement unit **215**. As discussed in the BACKGROUND OF THE INVENTION, the above-described "internal leakage" through the separation formed between the valve confronting surface **279** and the rearward surface **281** of the rotatable valve member **251** adversely affects the volumetric efficiency of the motor.

[0047] Referring now to FIG. 7 with reference made to elements introduced in FIGS. 1 and 2, the valve-seating mechanism **73** of the present invention is subjected to pressure forces from pressurized fluid in the disc-valve motor **11**. FIG. 7 illustrates the pressure forces acting on the valve-seating mechanism **73** when inlet fluid flows from the fluid port **53** through the fluid passage **55** of the motor **11** and to the annular fluid chamber **57** in the valve housing **19**. The inlet pressure forces acting on the valve-seating mechanism **73** are designated with arrows accompanied by the letter "**A**" in FIG. 7. The return fluid pressure forces acting on the valve-seating mechanism **73** in the motor **11**, as illustrated in FIG. 7, result from pressurized return fluid in the valve housing cavity **59** which flows to the second fluid port (not shown) through the second fluid passage (not shown). The return pressure forces acting on the valve-seating mechanism **73** are designated by smaller arrows accompanied by the letter "**B**". Case pressure forces acting on the valve-seating mechanism **73** are designated with small arrows accompanied by the letter "**C**".

[0048] Referring still to FIG. 7, inlet pressure forces "**A**" act on the inner diameter of the outer balance ring member **75** between the valve confronting surface **79** and the axial end surface **86**, as well as on the surfaces of the rearwardly projecting, integral ring portion **83** of the outer balance ring member **75** between and including the axial end surface **86** and the first axial end **89** of the circumferential annular groove **87**. Return pressure forces "**B**" act on the outer diameter surfaces of the outer balance ring member **75** between the valve confronting surface **79** and the first axial end **89** of the circumferential annular groove **87**. The valve confronting surface **79** of the outer balance ring member **75** is subjected to a pressure force gradient with inlet pressure force "**A**" at the inner diameter of the valve confronting surface **79** and return pressure force "**B**" acting at a location on the valve confronting surface **79** aligned with the outer diameter of the rotatable valve member **51**, and with the forces gradually decreasing in the radially outward direction, as is represented by the arrows of decreasing length and the angled dashed line. Return pressure force "**B**" also acts on the valve confronting surface **79** between the location aligned with the outer diameter of the rotatable valve member **51** and the outer diameter of the outer balance ring member **75**.

[0049] Referring still to FIG. 7, inlet pressure forces "**A**" act on the outer diameter surfaces of the inner balance ring member **77** between the valve confronting surface **111** and the axial end surface **114**, as well as on the surfaces of the rearwardly projecting, integral ring portion **113** of the inner balance ring member **77** between and including the axial end surface **114** and the circumferential step **115**. Case pressure forces "**C**" act on the inner diameter surfaces of the inner balance ring member **77** between the valve confronting surface **111** and the circumferential step **115**. The valve confronting surface **111** of the inner balance ring member **77** is subjected to a pressure force gradient with inlet pressure force "**A**" acting on the outer diameter of the valve confronting surface **111** and case pressure force "**C**" acting on the inner diameter of the valve confronting surface **111**. Again, the forces gradually decrease, but this time, in the radially inward direction, as is represented by the arrows of decreasing length and the angled dashed line.

[0050] Referring now to FIG. 8, an alternate embodiment of the interface between a rotatable valve member **351** and the valve-seating mechanism **73** is shown. To the extent that elements associated with the alternate embodiment of the interface between the rotatable valve member **351** and the valve-seating mechanism **73** are structurally or functionally equivalent to elements previously introduced, the reference numerals assigned to the alternate embodiment elements will bear the same reference numerals assigned to the elements of the subject embodiment, plus "300".

[0051] The rotatable valve member **351** defines an outer annular groove **433** disposed on a rearward surface **381** of the rotatable valve member **351** between the outer diameter of the rearward surface **381** and an annular fluid groove **364**. The outer annular groove **433** is in open fluid communication with the cavity **59**

in the valve housing **19** through a fluid passage **435** (shown in FIG. 8 with a dashed line and dashed lead line for the reference numeral). The rotatable valve member **351** further defines an inner annular groove **437** disposed on the rearward surface **381** between the inner diameter of the rearward surface **381** and the annular fluid groove **364**. The inner annular groove **437** is in open fluid communication with the interior of the rotatable valve member **351** through a fluid passage **439** (shown in FIG. 8 with a dashed line and a dashed lead line for the reference numeral).

[0052] FIG. 9 illustrates the pressure forces acting on the valve-seating mechanism **73** resulting from the alternate embodiment of the interface between the rotatable valve member **351** and the valve-seating mechanism **73** when inlet fluid flows from the fluid port **53** through the fluid passage **55** of the motor **11** and to the annular fluid chamber **57** in the valve housing **19**. The designations of the pressure forces used in FIG. 9 are the same as those used in FIGS. 5 and 7.

[0053] Referring still to FIG. 9, inlet pressure forces "**A**" act on the inner diameter of the outer balance ring member **75** between the valve confronting surface **79** and the axial end surface **86**, as well as on the surfaces of the rearwardly projecting, integral ring portion **83** of the outer balance ring member **75** between and including the axial end surface **86** and the first axial end **89** of the circumferential annular groove **87**. Return pressure forces "**B**" act on the outer diameter surfaces of the outer balance ring member **75** between the valve confronting surface **79** and the first axial end **89** of the circumferential annular groove **87**. Since the outer annular groove **433** of the rotatable valve member **351** is in open fluid communication with the cavity **59**, the pressure forces in the outer annular groove **433** would be substantially similar to the pressure forces in the cavity **59** of the valve housing **19**, which in the present example would be return pressure force "**B**". The valve confronting surface **79** of the outer balance ring member **75** is subjected to a pressure force gradient with inlet pressure force "**A**" acting at the inner diameter of the valve confronting surface **79** and return pressure force "**B**" acting at the location on the valve confronting surface **79** approximately aligned with the inner diameter of the outer annular groove **433** in the rotatable valve member **351** with the forces gradually decreasing in the radially outward direction. This force gradient is represented in FIG. 9 by arrows decreasing in length and an angled dashed line. Since the pressure forces in the outer annular groove **433** are substantially equal to the pressure forces in the cavity **59** in the valve housing **19**, return pressure force "**B**" would act on the valve confronting surface **79** from a location approximately aligned with the inner diameter of the outer annular groove **433** radially outward to the outer diameter of the valve confronting surface **79**.

[0054] Referring still to FIG. 9, inlet pressure forces "**A**" act on the outer diameter surfaces of the inner balance ring member **77** between the valve confronting surface **111** and the axial end surface **114**, as well as on the surfaces of the rearwardly projecting, integral ring portion **113** of the inner balance ring member **77** between and including the axial end surface **114** and the circumferential step **115**. Case pressure forces "**C**" act on the inner diameter surfaces of the inner balance ring member **77** between the valve confronting surface **111** and the circumferential step **115**. Since the inner annular groove **437** of the rotatable valve member **351** is in open fluid communication with the interior of the rotatable valve member **351**, the pressure forces in the inner annular groove **437** would be substantially similar to the pressure forces in the interior of the rotatable valve member **351**, which in the present example would be case pressure forces "**C**". Therefore, the valve confronting surface **111** of the inner balance ring member **77** is subjected to a pressure force gradient with inlet pressure force "**A**" acting at the outer diameter of the valve confronting surface **111** and case pressure force "**C**" acting at the location on the valve confronting surface **111** approximately aligned with the outer diameter of the inner annular groove **437** in the rotatable valve member **351**. Again, the forces gradually decrease, but this time, in the radially inward direction, as is represented by arrows of decreasing length and an angled dashed line. Since the pressure forces in the inner annular groove **437** are substantially equal to the pressure forces in the interior of the rotatable valve member **351**, case pressure force "**C**" would act on the valve confronting surface **111** from a location approximately aligned with the outer diameter of the inner annular groove **437** radially inward to the inner diameter of the valve confronting surface **111**.

[0055] FIG. 10 illustrates the distortion, deformation, or deflection, as predicted by finite element analysis, of the present invention when the valve-seating mechanism **73** is subjected to the previously defined inlet, return and case pressure forces "**A**", "**B**", "**C**", respectively, shown in FIGS. 7 and 9. It should be understood by those skilled in the art that the relative amounts of distortion represented in FIG. 10 are greatly exaggerated, to facilitate illustration of the invention. In the present invention, both the outer balance ring member **75** and the inner balance ring member **77** are subjected to a "potato chipping" effect resulting from the previously defined pressure forces. However, the "potato chipping" effect of the outer balance ring member **75** and the inner balance ring member **77** is substantially less than the "potato chipping" effect of the prior art valve-seating mechanism **273**. As shown in FIG. 10, the inner diameter of the valve confronting surface **111** of the inner balance ring member **77** maintains contact with the rearward surface **81** of the rotatable valve member **51**. But, the deflection of the inner balance ring member **77** results in separation of the outer diameter of the valve confronting surface **111** of the inner balance ring member **77** and the rearward surface **81** of the rotatable valve member **51**.

[0056] Referring still to FIG. 10, the deflection of the outer balance ring member **75** results in separation of the outer diameter of the valve confronting surface **79** of the outer balance ring member **75** and the rearward surface **81** of the rotatable valve member **51**. But the inner diameter of the valve confronting surface **79** of the outer balance ring member **75** maintains contact with the rearward surface **81** of the rotatable valve member **51**. Therefore, unlike the prior art valve-seating mechanism **273**, the outer balance ring member **75** maintains sealing engagement with the rearward surface **81** of the rotatable valve member **51** between the fluid passage **71** and the valve housing cavity **59**. Thus, the amount of leakage resulting from the deformation of the valve-seating mechanism **73** is significantly reduced as compared to the leakage resulting from the deformation of the prior art valve-seating mechanism **273**.

[0057] The invention has been described in great detail in the foregoing specification, and it is believed that various alterations and modifications of the invention will become apparent to those skilled in the art from a reading and understanding of the specification. It is intended that all such alterations and modifications are included in the invention, insofar as they come within the scope of the appended claims.

What is claimed is:

1. A rotary fluid pressure device (11) of the type having a housing means (19) defining a fluid inlet (53) and a fluid outlet (53), a fluid energy-translating displacement means (15) defining expanding and contracting fluid volume chambers (33), a stationary valve means (17) defining fluid passage means (65) in communication with said expanding and contracting fluid volume chambers (33) and having a valve surface (67), a rotary valve member (51) defining valve passage means (61,63) providing commutating fluid communication between said fluid inlet (53) and said fluid outlet and said fluid passage means (65) and having a valve surface (69) in sliding, sealing engagement with said valve surface (67) of said stationary valve member (17), said rotary valve member (51) further having an opposite surface (81); characterized by:
   (a) an outer balance ring member (75) having a valve-confronting surface (79) in engagement with said opposite surface (81);
   (b) an inner balance ring member (77) having a valve-confronting surface (111) in engagement with said opposite surface (81); and
   (c) said outer balance ring member (75) and said inner balance ring member (77) cooperating to define a fluid passage (71) providing continuous fluid communication between said fluid inlet (53) and said fluid outlet and said valve passage means (61).

2. A rotary fluid pressure device (11) as claimed in claim 1, characterized by said outer balance ring member (75) including a retainer member (100) preventing rotation of said outer balance ring member (75) relative to said rotary valve member (51).

3. A rotary fluid pressure device as claimed in claim 2, characterized by a pin member (100) inserted in an outer balance ring pin cavity (99) and a first housing means pin cavity (103) preventing rotation of said outer balance ring member (75) relative to said rotary valve member (51).

4. A rotary fluid pressure device as claimed in claim 1, characterized by said inner balance ring member (77) including a retainer member (122) preventing rotation of said inner balance ring member (77) relative to said rotary valve member (51).

5. A rotary fluid pressure device as claimed in claim 4, characterized by a pin member (122) inserted in an inner balance ring pin cavity (121) and a second housing means pin cavity (125) preventing rotation of said inner balance ring member (77) relative to said rotary valve member (51).

6. A rotary fluid pressure device as claimed in claim 1, characterized by said outer balance ring member (75) defining an annular groove (87) with a first axial end (89) having an outer diameter D1 and a second axial end (91) having an outer diameter D2.

7. A rotary fluid pressure device as claimed in claim 6, characterized by diameter D1 of said first axial end (89) of said annular groove (87) being larger than diameter D2 of said second axial end (91) of said annular groove (87).

8. A rotary fluid pressure device as claimed in claim 6, characterized by a sealing member (93) disposed within said annular groove (87) in the

outer balance ring member (75) that substantially prevent fluid flow between said fluid inlet (53) and said fluid outlet (53).

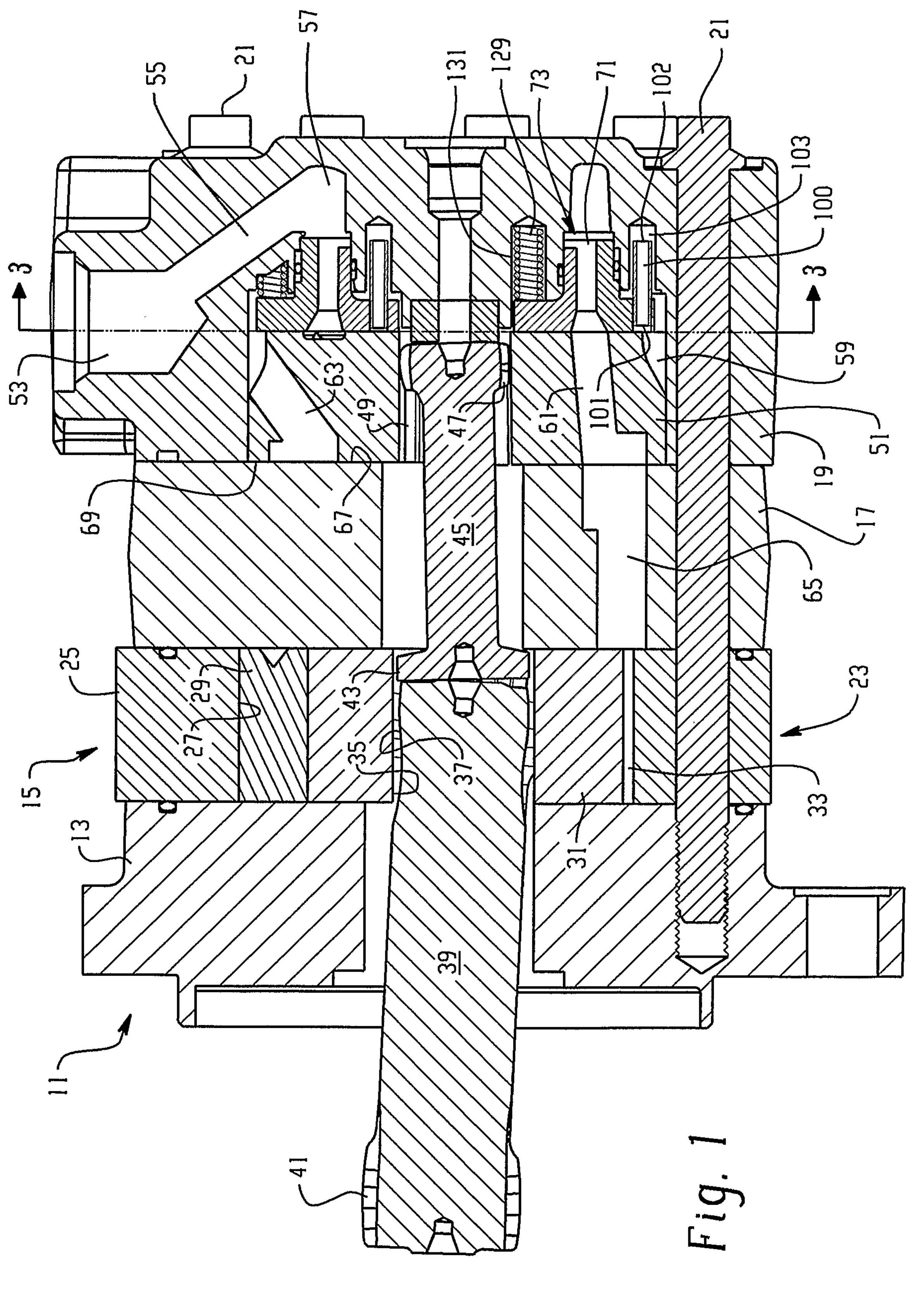
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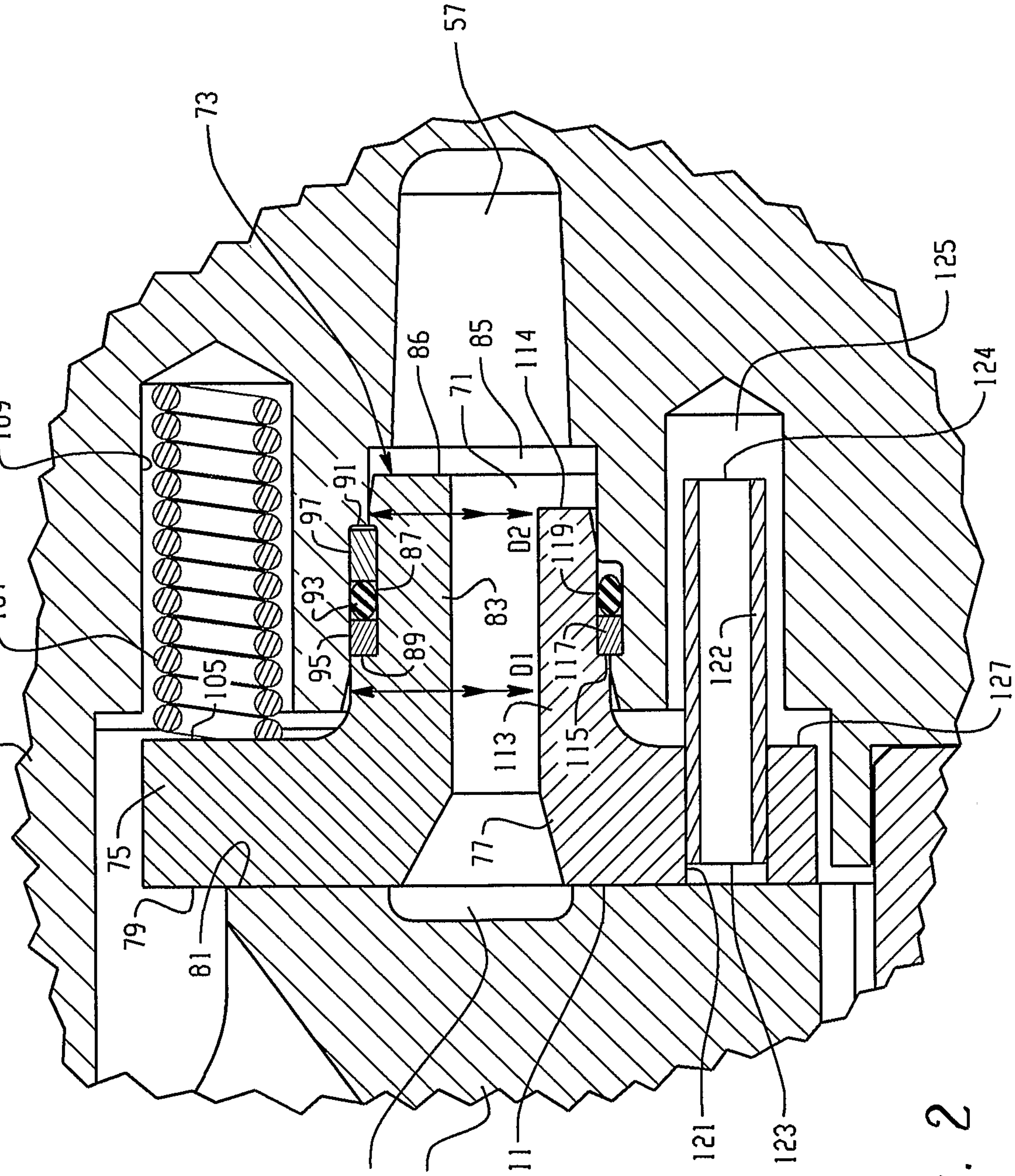
Fig. 1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19
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121
123

Fig. 2

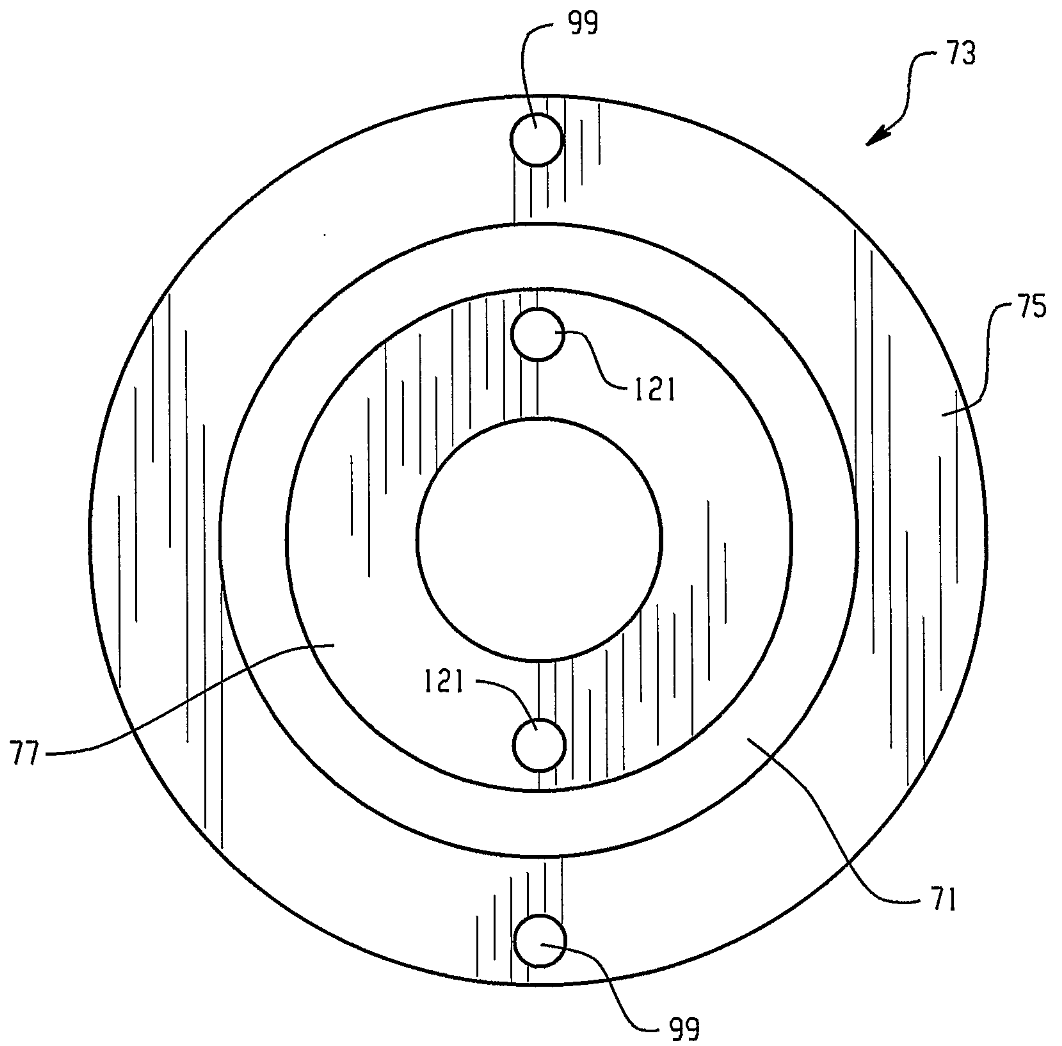


Fig. 3

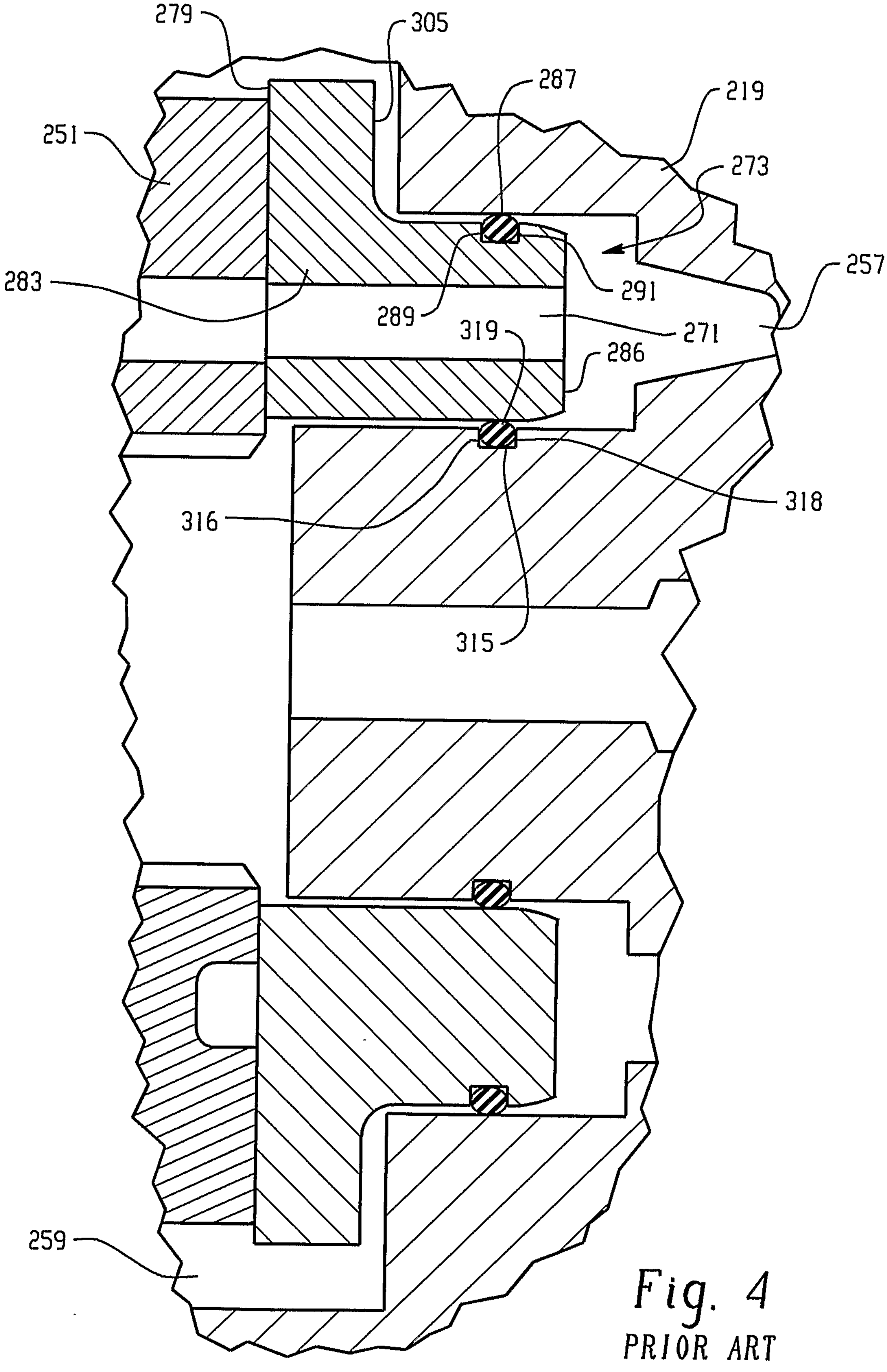


Fig. 4
PRIOR ART

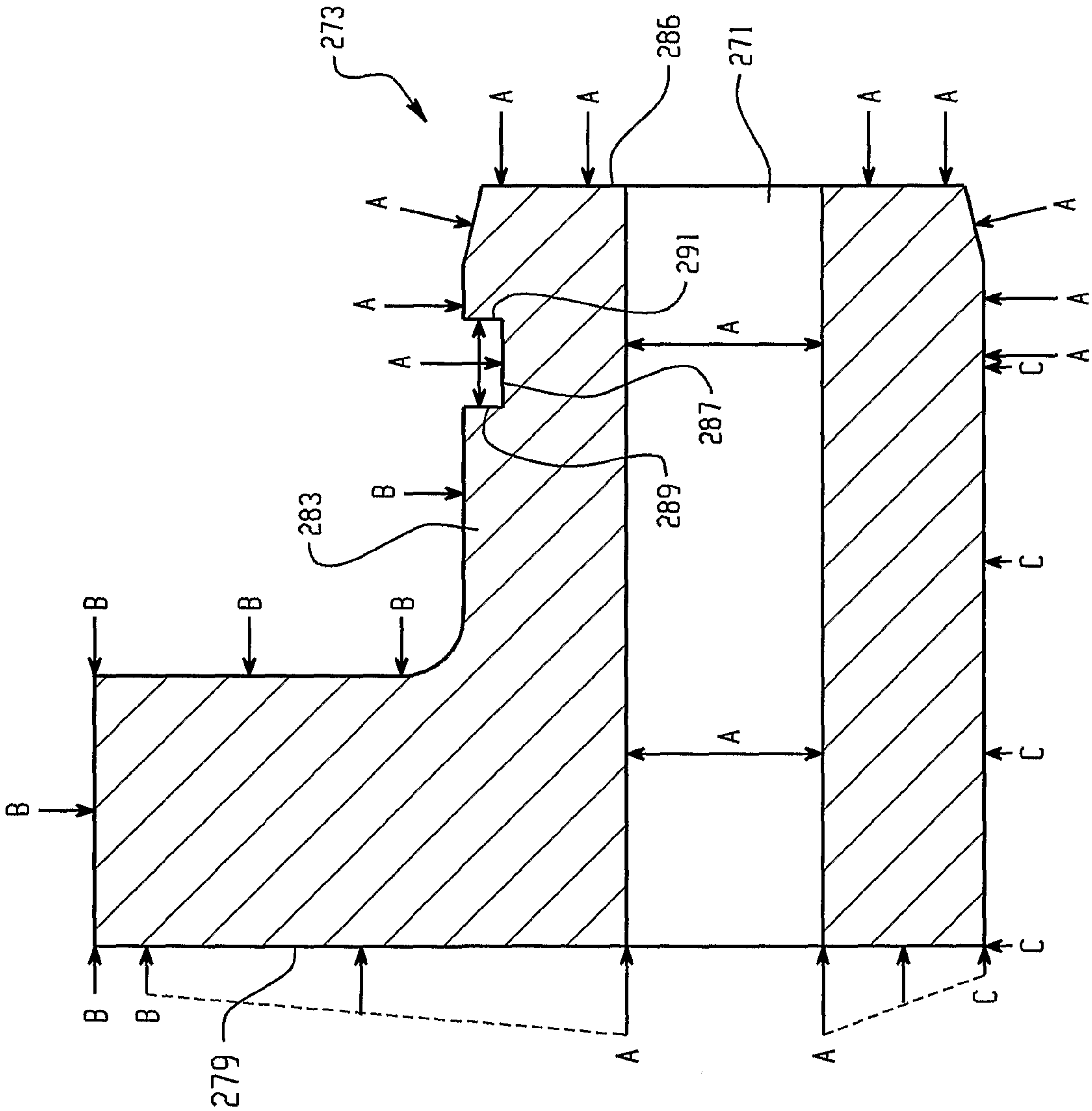


Fig. 5
PRIOR ART

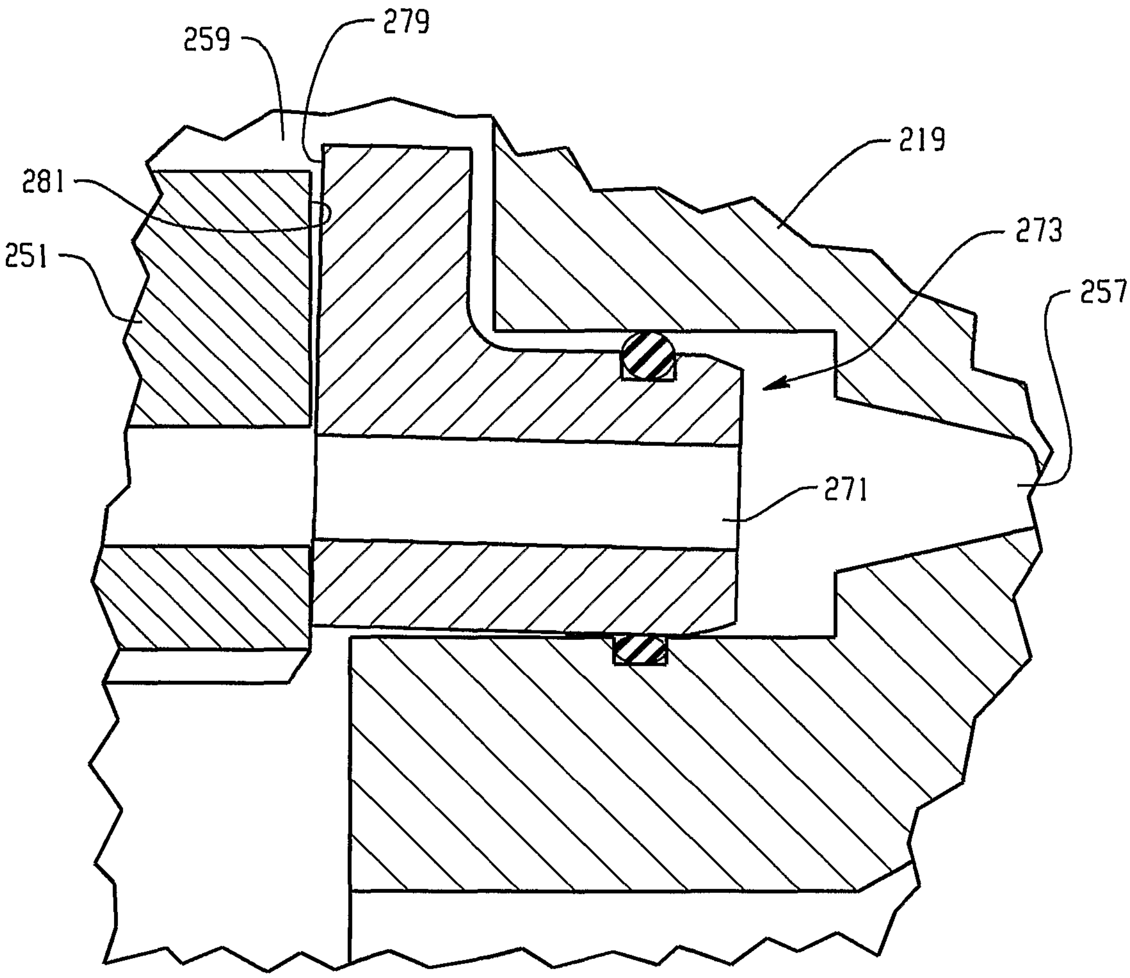
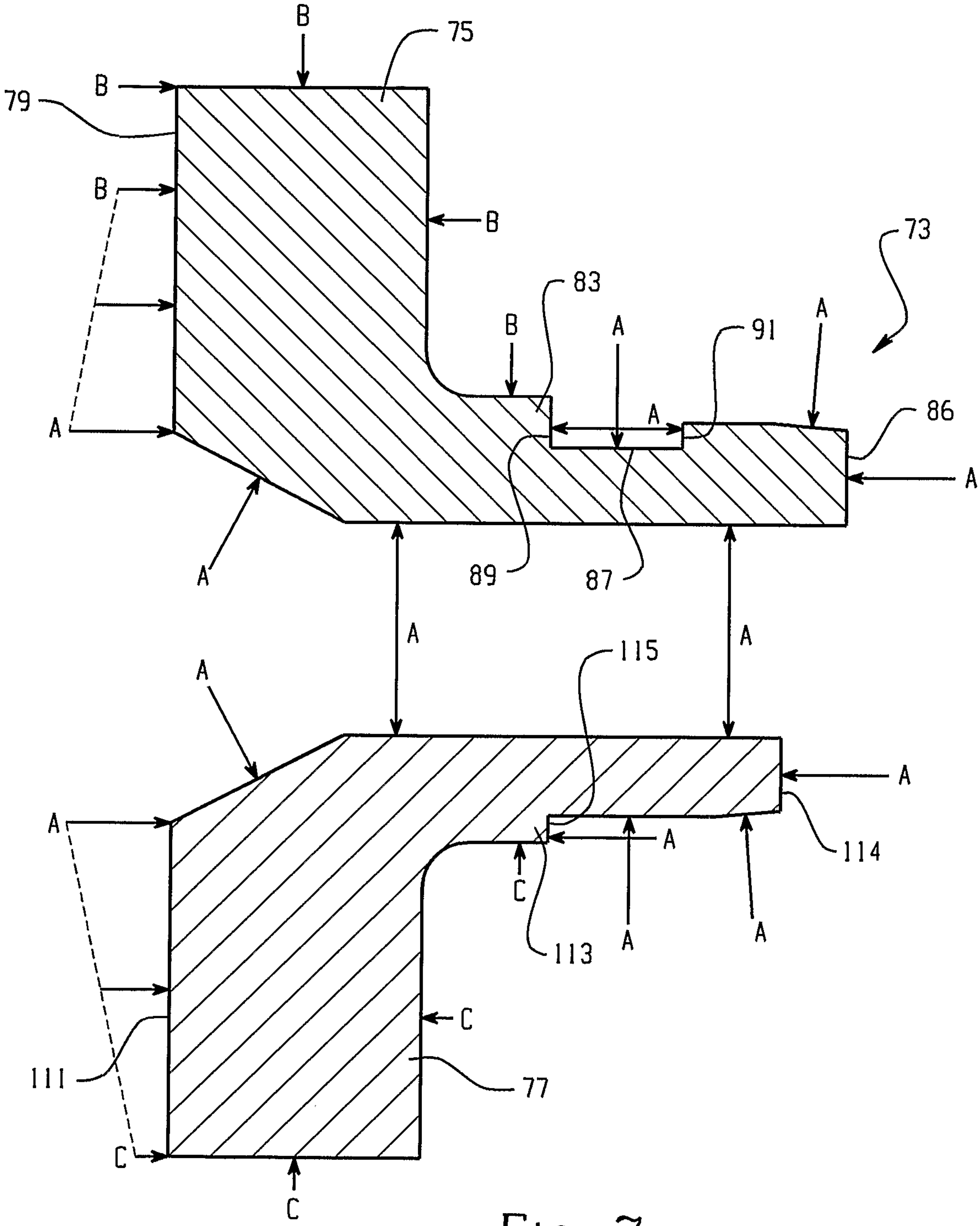


Fig. 6
PRIOR ART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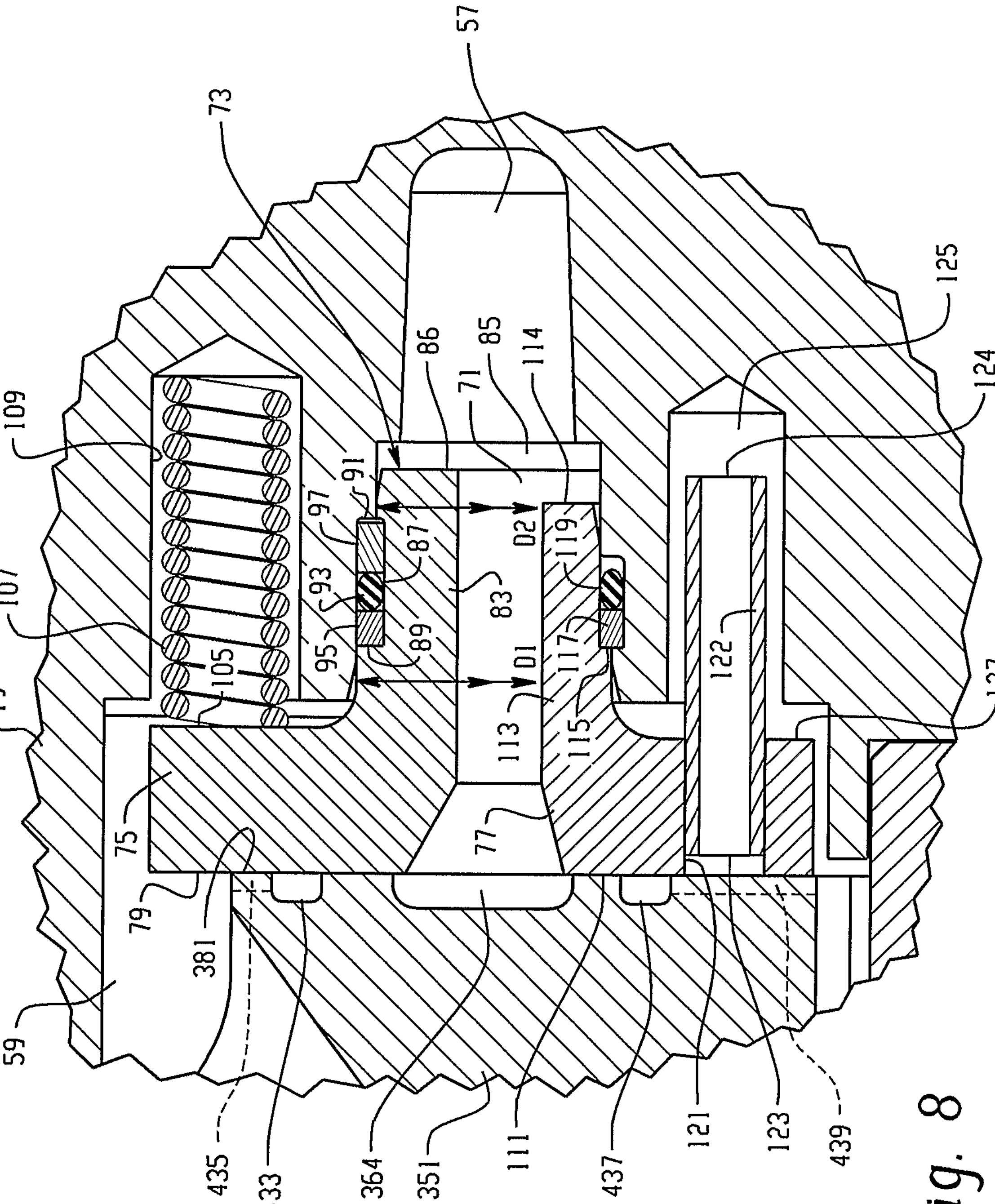
C

Fig. 7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113
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Fig. 8

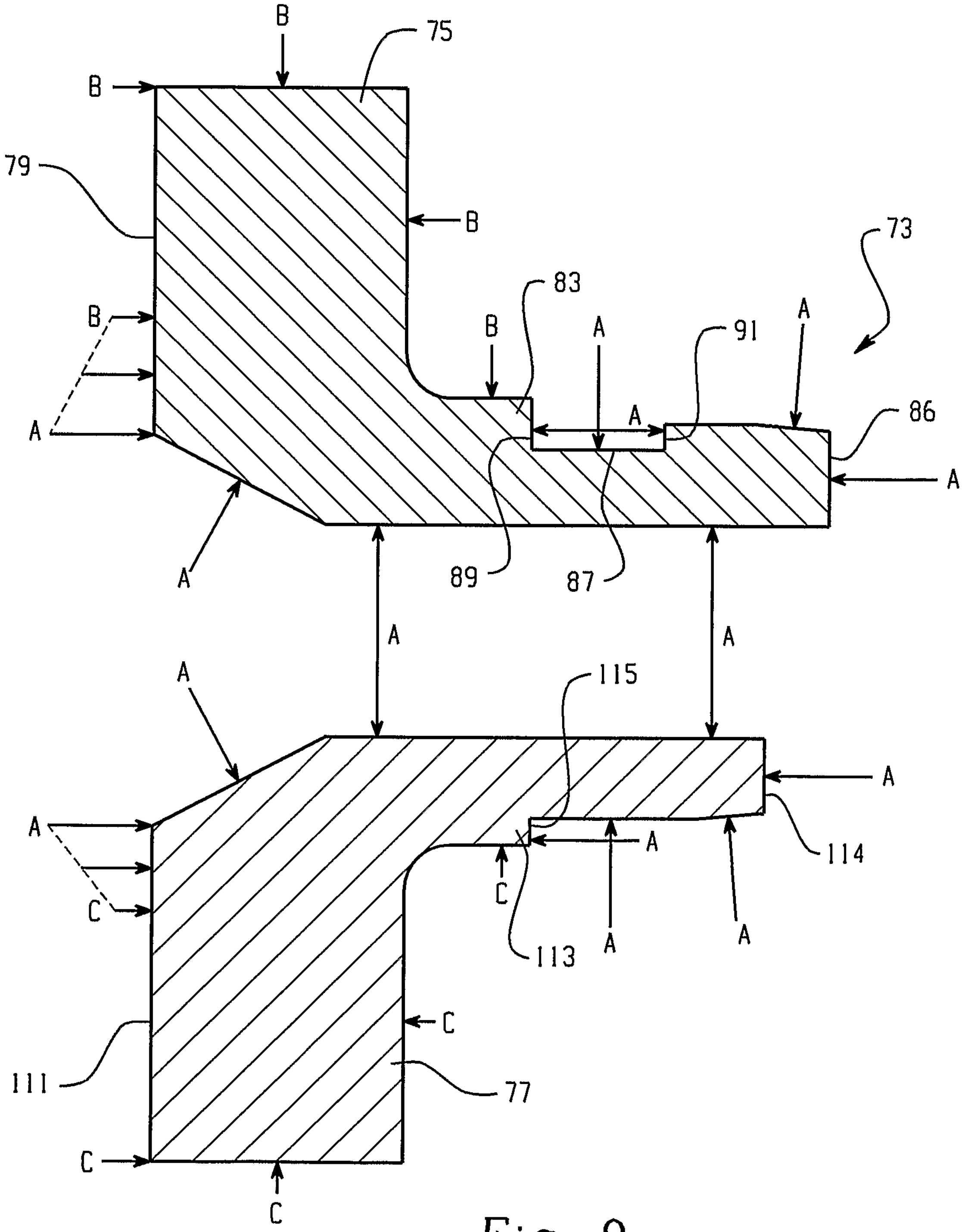
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Fig. 9

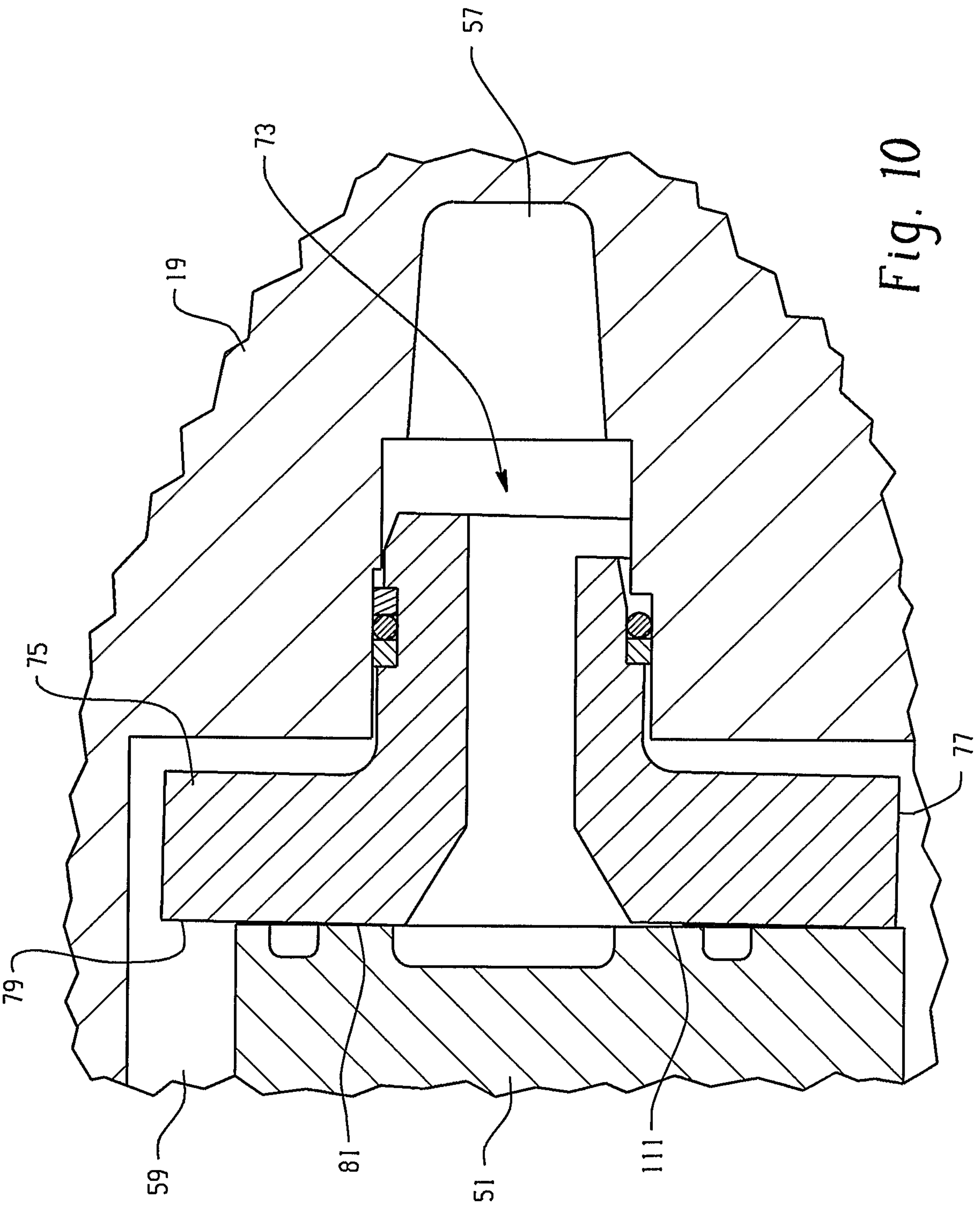

Fig. 10