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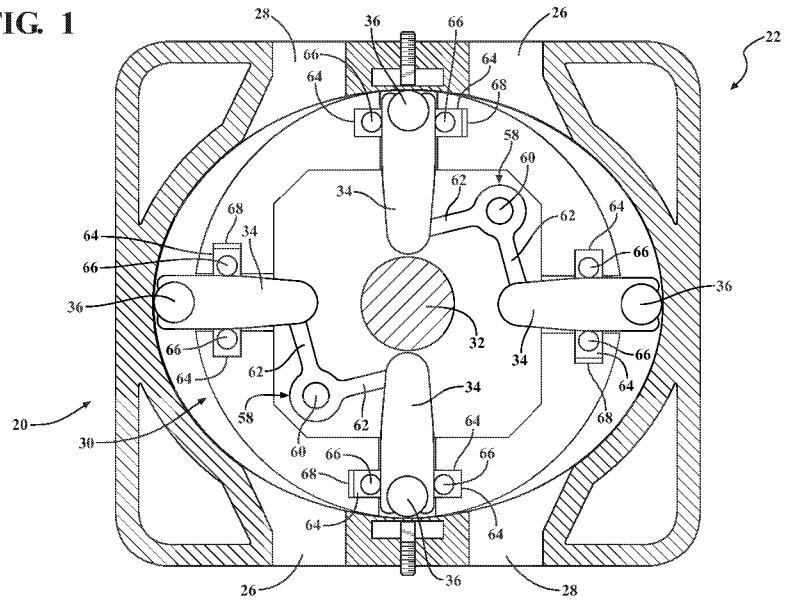
(54) **Title**: VANE PUMP ASSEMBLY

FIG. 1



(57) **Abstract**: The vane pump assembly includes a housing with an inner wall that surrounds an open chamber. A rotor is rotatably disposed in the open chamber and has a circular shape when viewed in cross section. A first pair of vanes are received in the rotor and are operably connected with one another by a first bell crank which is pivotable about a pivot axis such that movement of one vane inwardly into the rotor causes the other vane to move outwardly out of the rotor to maintain both vanes in contact with the inner wall as the rotor rotates relative to the housing during operation of the vane pump assembly.

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VANE PUMP ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This PCT patent application claims the benefit and priority to U.S. Provisional Patent Application No. 62/311,003 filed March 21, 2016, the entire disclosure being considered part of the disclosure of this application and hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention is related, generally, to pneumatic and hydraulic pumps, motors and heat regenerative systems.

2. Related Art

[0003] In general, rotary vane pump assemblies are positive displacement pumps that include one or more vanes that are mounted to a rotor which is rotatable within a housing having an inner wall defining an open chamber. A pressure differential is applied across the vane, which causes the rotor to rotate within the open chamber of the housing. The rotor is coupled with an output shaft which may be attached to any suitable machine including, for example, an electric generator. During operation of such vane pump assemblies, it is important to maintain a fluid-tight seal between the vane and the inner wall of the housing in order to optimize efficiency and maximize power output.

[0001] One approach to maintaining the fluid-tight seal between the vane and the housing is to use springs to bias the vane against the inner wall of the housing. Rotary vane pumps that use this approach generally include two or more vanes, and a spring is disposed between the rotor and each vane to bias the respective vane in a radially outward direction and against this housing. The biasing forces exerted by the springs maintain the vanes in

continuous contact with the housing through a full 360 degrees of rotation of the rotor within the open chamber of the housing.

[0002] Another approach to maintaining the fluid-tight seal between the vane and the housing is to provide open chamber with a non-circular shaped cross-section. The rotor is centered within the non-circular open chamber, and a vane extends through the rotor to engage at either end with an inner wall of the open chamber. The noncircularly shaped cross-section of the open chamber guides the vane through a reciprocating motion back and forth across the rotor to maintain both ends of the vane in contact with the inner wall to establish the fluid tight seals.

[0003] In some rotary vane pumps it is additionally important for the rotor to seal against the inner wall. In general this is accomplished by manufacturing the rotor and housing under tight tolerances in order to achieve a tight fit between the rotor and the inner wall of the housing. However, it is often costly as expensive and time consuming manufacturing and/or machining processes must be employed to achieve such tight tolerances.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0004] One aspect of the present invention is related to a vane pump assembly which includes a housing with an inner wall that surrounds an open chamber. A rotor is rotatably disposed in the open chamber and has a circular shape when viewed in cross section. A first pair of vanes are received in the rotor and are operably connected with one another by a first bell crank which is pivotable about a pivot axis such that movement of one vane inwardly into the rotor causes the other vane to move outwardly out of the rotor to maintain both vanes in contact with the inner wall as the rotor rotates relative to the housing during operation of the vane pump assembly. The vane pump assembly constructed

according to this aspect of the present invention allows for improved efficiency and cost effectiveness as compared to other known vane pump assemblies.

[0005] According to another aspect of the present invention, the bell crank includes a pair of resiliently deflectable arms which are made of a resiliently deflectable material such that the arms elastically deflect while the vanes move into and out of the rotor during operation of the vane pump assembly.

[0006] According to yet another aspect of the present invention, the bell crank is made as a single piece.

[0007] According to still another aspect of the present invention, each of the arms of the bell crank has an end with a socket, and each of the vanes has a ball-shaped end portion that is received in one of the sockets.

[0008] According to a further aspect of the present invention, the vane pump assembly further includes a second pair of vanes that are received in the rotor and are operably connected with one another by a second bell crank.

[0009] According to yet a further aspect of the present invention, the vanes are uniformly spaced from one another around the rotor.

[0010] According to still a further aspect of the present invention, the rotor has a pair of slots on opposite sides of each of the vanes, and sealing elements are disposed in the slots for sealing the vanes with the rotor.

[0011] According to another aspect of the present invention, a bearing block and a bearing pin are received in each of the slots with the bearing pins being rotatable relative to the bearing blocks such that the bearing pins roll in response to movement of the associated one of the vanes into and out of the rotor.

[0012] According to yet another aspect of the present invention, a leaf spring is disposed in one of the slots associated with each of the vanes. The leaf spring biases one of the bearing pins against the associated one of the vanes.

[0013] According to still another aspect of the present invention, pins operably connect the vanes of the first pair of vanes with the first bell crank.

[0014] According to a further aspect of the present invention, an end plate body is secured with the housing.

[0015] According to yet a further aspect of the present invention, a stabilizer plate contacts and seals against an end face of the rotor.

[0016] According to still another aspect of the present invention, a biasing mechanism biases the stabilizer plate against the end face of the rotor.

[0017] According to another aspect of the present invention, the biasing mechanism includes a plurality of set screws which are moveable into and out of the end plate body.

[0018] According to yet another aspect of the present invention, the biasing mechanism further includes a plurality of springs between the set screws and the stabilizer plate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] These and other features and advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0020] Figure 1 is a cross-sectional view of a first exemplary embodiment of a vane pump assembly constructed according to one aspect of the present invention;

[0021] Figure 2 is a perspective view of a rotor of the vane pump of Figure 1;

[0022] Figure 3 is a perspective view of the components that are inserted into the rotor of Figure 2;

[0023] Figure 4 is a sectional and fragmentary view of the vane pump assembly of Figure 1;

[0024] Figure 5 is another sectional and fragmentary view of the vane pump assembly of Figure 2;

[0025] Figure 6 is a sectional view of a second exemplary embodiment of the vane pump assembly; and

[0026] Figure 7 is a sectional view of a third exemplary embodiment of the vane pump assembly.

DETAILED DESCRIPTION OF THE ENABLING EMBODIMENTS

[0027] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a first exemplary embodiment of an improved vane pump assembly **20** is generally shown in Figures 1-4. The vane pump assembly **20** includes a housing **22** with an inner wall **24** which defines an open chamber that is generally elliptical, or oval, in shape when viewed in cross-section. The exemplary housing **22** has a total of four ports **26, 28** with two of them being fluid inlet ports **26** for conveying a fluid, such as steam, into the open chamber and two of them being fluid outlet ports **28** for dispensing the fluid out of the open chamber. Although two of each are shown in the exemplary embodiment, it should be appreciated that the housing **22** could be configured with any suitable number of inlet and outlet ports **26, 28**.

[0028] The vane pump assembly **20** further includes a rotor **30** which is generally circular in shape and is centered within the elliptical open chamber of the housing **22**. The rotor **30** is rotatable within the open chamber about an axis **A**, which is centrally located within the elliptical open chamber and the circular rotor **30**. The rotor **30** is coupled with an

axially extending input/output shaft **32** which may be fixed with the rotor **30** through any suitable means such that rotation of the rotor **30** relative to the housing **22** drives rotation of the shaft **32** and vice versa. The shaft **32** may be attached to any suitable power receiving device (not shown) for operating the vane pump assembly **20** to generate power. Alternately, the shaft **32** may be attached to a power source for operating the vane pump assembly **20** as a fluid compressor.

[0029] The exemplary embodiment of the rotor **30** has a total of four radially extending passages which are generally evenly spaced from one around the rotor **30**. A vane **34** is received in each of the passages and is movable radially into and out of the respective passage for sealing against the inner wall **24** of the housing **22** to establish a total of four evenly distributed, circumferentially spaced and fluid-tight seals between the rotor **30** and the housing **22**.

[0030] Each of the vanes **34** has an end with a first U-shaped opening which opens in a radially outward direction (away from the axis **A**) and within which a primary roller **36** is positioned. The primary rollers **36** have outer diameters which are similar to the widths of the first U-shaped openings. During operation of the vane pump assembly **20**, rotation of the rotor **30** relative to the housing **22** generates a circumferential force which biases the vanes **34** and the primary rollers **36** in a radially outward direction to maintain the primary rollers **36** in contact with the inner wall **24** of the housing **22**. The eccentric shape of the inner wall **24** drives the radial movement of the vanes **34** into and out of the passages of the rotor **30**. Because the primary rollers **36** roll rather than slide along the inner wall **24** of the housing **22**, friction losses during operation of the vane pump assembly **20** are minimized.

[0031] The housing **22** presents a pair of axially extending openings **38** which are diametrically opposed with one another and are located circumferentially between the inlet ports **26** and the outlet ports **28**. The axially extending openings **38** are separated from the

inner passage by thin and flexible portions **40** of the inner wall **24**. A bar **42** is positioned in one or both of the openings **38**, and the bar **42** is in contact with a plurality of set screws **44** which are accessible from outside of the housing **22**. The radial position of the bar **42** is adjustable by threading the set screws **44** into and out of the housing **22** to manually increase or decrease a biasing force of the thin portion **40** of the inner wall **24** against the rotor **30**. This allows for easy adjustment to optimize the seal between the inner wall **24** of the housing **22** and the rotor **30** and the friction between the rotor **30** and the inner wall **24** of the housing **22**.

[0032] The vane pump assembly **20** further includes a pair of pressure balanced end plate assemblies which are joined with opposite axial ends of the housing **22** to seal the housing **22** against axial end faces of the rotor **30**. Each of the end plate assemblies includes an end plate body **46** with an axially extending shaft opening that has a shaft bearing **48** disposed therein for receiving the input/output shaft **32**. A shaft seal **50** is also disposed in the shaft opening for establishing a fluid tight seal between the end plate body **46** and the shaft **32**. The end plate assemblies also include a plurality of circumferentially spaced bolts for fixing the end plate body **46** with the axial end faces of the housing **22**. Each end plate assembly further includes a rigid stabilizer plate **52** with an annular shape which extends around the shaft opening. The stabilizer plate **52** is disposed in a groove of the end plate body **46** and has a thin and flexible membrane which faces away from the end plate body **46** for sealing against an axial end face of the rotor **30**.

[0033] Each end plate assembly additionally includes an adjustable biasing mechanism for applying a biasing force against the stabilizer plate **52** to bias the membrane against the axial end face of the rotor **30** and establish a fluid-tight seal therebetween. The biasing mechanism includes a plurality of circumferentially spaced set screws **54** which are threadedly disposed in holes within the end plate body **46** and are movable in the axial

direction by threading the set screws **54** into or out of the holes. A compression spring **56** is positioned between each set screw **54** and the stabilizer plate **52** for applying a biasing force against the stabilizer plate **52**. The magnitude of the biasing force is adjustable by threading and unthreading the set screws **54** into and out of the holes. The adjustability of the biasing force allows for the optimization of the fluid tight seal and friction between the stabilizing plate **52** and the rotor **30**.

[0034] During operation of the vane pump assembly **20** as a motor, a high pressure fluid enters the inner chamber through the inlet ports **26**. Pressure differentials within the inner chamber of the housing **22** and across the vanes **34** has the effect of rotating the rotor **30** and driving rotation of the shaft **32**. During operation of the vane pump assembly **20** as a fluid pump, the shaft **32** is driven by an external source to rotate the rotor **30** relative to the housing **22**. The movement of the vanes **34** creates a pressure differential such that the pressure which leaves the inner chamber through the outlet ports **28** has a greater pressure than the fluid which enters the inner chamber through the inlet ports **26**.

[0035] Pairs of the vanes **34** are operably connected with one another by a bell crank **58** which is pivotable about a fulcrum pin **60** that is attached with the rotor **30**. Each of the bell cranks **58** is made as a single piece and is generally V-shaped with a pair of arms **62** that extend away from the fulcrum pin **60** to engage the pair of vanes **34**. The arms **62** are angled relative to one another by approximately ninety degrees (90°). During operation, as one of the vanes **34** is pushed inwardly into the rotor **30** due to the eccentric shape of the inner wall **24**, the bell crank **58** pivots about the fulcrum pin **60** to urge the other vane **34** radially outwardly to maintain contact with the inner wall **24**. The bell cranks **58** are made of a resiliently deflectable material, such as an aluminum alloy or spring steel, such that the arms **62** deflect resiliently while the vanes **34** move in and out of the rotor **30** during operation of the vane pump assembly **20**. The bell cranks **58** function to connect and

influence the movement of the vanes **34** by harnessing a radially inward force from one vane **34** and transforming that force into a radially outward force on the other vane **34**. In this embodiment, the ends of the arms **62** are connected with the ends of the vanes **34** via cylindrically-shaped pins to establish a pivoting relationship between each vane **34** and the associated arm **62**.

[0036] The rotor **30** also presents a pair of axially extending slots on opposite sides of each vane **34** and which support a pair of bearing assemblies. Each of the slots contains a bearing block **64** with a semi-circular cutout and a cylindrically shaped bearing pin **66** that is rolls within the bearing block **64**. The bearing pins **66** are in contact with the opposite sides of the respective vane **34** to provide a low friction interface to allow the vane **34** to move in and out of the rotor **30** during operation of the vane pump assembly **20**.

[0037] One of the slots associated with each of the vanes **34** is wider than the associated bearing block **64** and bearing pin **66** such that there is a gap between the bearing block **64** and an inner surface of the rotor **30**. A spring **68**, such as a leaf spring, is inserted into this slot to bias the associated bearing block **64** and bearing pin **66** against the associated vane **34** thereby affirming a firm contact seal between the rotor **30** and both sides of the vane **34**.

[0038] As shown, in the first exemplary embodiment, no mechanical fasteners are required to connect the vanes **34**, primary rollers **36**, bell cranks **58**, etc. with the rotor **30**. As such, the rotor assembly can be extremely quickly and efficiently assembled and inserted as a completed unit into the housing **22** during manufacture of the vane pump assembly **20**. Also, most of these components can be made through extrusion, thereby allowing the rotor and the rotor components to be very cost effectively produced.

[0039] Referring now to Figure 5, an alternate embodiment of the vane pump assembly **120** is generally shown with like numerals, separated by a prefix of "1" indicating

corresponding parts with the above described embodiments. In this embodiment, each of the arms **162** extends away from the fulcrum pin **160** to an end with a socket, and the vanes **134** have ball-shaped ends that are received in the sockets at the ends of the arms **162**. These ball and socket attachments allows the vane **134** to articulate relative to the arms **162** of the bell cranks **158** during operation of the vane pump assembly **120**.

[0040] Referring now to Figure 6, yet another alternate embodiment of the vane pump assembly **220** is generally shown with like numerals, separated by a prefix of "2" indicating corresponding parts with the above-described embodiments. In this embodiment, four total vanes **234** are disposed in the rotor **230**, and each of the vanes **234** includes a second U-shaped opening **270** which opens in a radially inward direction (towards the axis **A**) and within which a guide roller **272** is located. The guide rollers **272** are fixed with the rotor **230** for guiding the radial movements of the vanes **234** into and out of the rotor **230** during operation of the vane pump assembly **220**. Also, in this embodiment, the vanes **234** and the walls of the rotor **230** present a pair of aligned channels which receive sealing pins **274** that within the channels as the vanes **234** move into and out of the rotor **230**. The sealing pins **274** also perform a sealing function to seal the sides of the vanes **234** with the rotor **230**.

[0041] Referring now to Figure 7, still another exemplary embodiment of the vane pump assembly **320** is generally shown with like numerals, separated by a prefix of "3" indicating corresponding parts with the above-described embodiments. In this embodiment, only a single vane **324** is provided, and that vane **324** extends diametrically across the rotor **330** and has a central opening through which the input/output shaft **332** extends. Also, a wedge **376** is disposed in one of the sets of aligned channels between the rotor **330** and the associated sealing pin **374**. The wedge **376** is slidable within the associated respective

channel for biasing the sealing pin **374** against the vane **334** and maintaining the fluid tight seals between the sealing pin **374** and the vane **334** and rotor **330**.

[0042] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims.

CLAIMS

What is claimed is:

Claim 1. A vane pump assembly, comprising:

a housing having an inner wall which surrounds an open chamber;

a rotor rotatably disposed in said open chamber of said housing, said rotor being circular in shape when viewed in cross-section; and

a first pair of vanes received in said rotor and being operably connected with one another by a first bell crank which is pivotable about a pivot axis such that movement of one vane inwardly into said rotor causes the other vane to move outwardly out of said rotor to maintain both vanes in contact with said inner wall as said rotor rotates relative to said housing during operation of said vane pump assembly.

Claim 2. The vane pump assembly as set forth in claim 1 wherein said bell crank includes a pair of resiliently deflectable arms which are made of a resiliently deflectable material such that said arms elastically deflect while said vanes move into and out of said rotor during operation of said vane pump assembly.

Claim 3. The vane pump assembly as set forth in claim 1 wherein said bell crank is made as a single piece.

Claim 4. The vane pump assembly as set forth in claim 1 wherein each of said arms has an end with a socket and wherein each of said vanes has a ball shaped end portion that is received in one of said sockets.

Claim 5. The vane pump assembly as set forth in claim 1 further including a second pair of vanes received in said rotor and wherein said second pair of vanes are operably connected with one another by a second bell crank.

Claim 6. The vane pump assembly as set forth in claim 5 wherein said vanes are uniformly spaced from one another around said rotor.

Claim 7. The vane pump assembly as set forth in claim 1 wherein said rotor presents a pair of slots on opposite sides of each of said vanes and wherein sealing elements are disposed in said slots for sealing said vanes with said rotor.

Claim 8. The vane pump assembly as set forth in claim 7 wherein a bearing block and a bearing pin are received in each of said slots with said bearing pins being rotatable relative to said bearing blocks such that said bearing pins roll in response to movement of the associated one of said vanes into and out of said rotor.

Claim 9. The vane pump assembly as set forth in claim 8 further including a leaf spring disposed in one of said slots associated with each of said vanes and biasing one of said bearing pins against the associated one of said vanes.

Claim 10. The vane pump assembly as set forth in claim 1 wherein pins operably connect said vanes of said first pair of vanes with said first bell crank.

Claim 11. The vane pump assembly as set forth in claim 1 further including an end plate body which is secured with said housing.

Claim 12. The vane pump assembly as set forth in claim 11 further including a stabilizer plate which contacts and seals against an end face of said rotor.

Claim 13. The vane pump assembly as set forth in claim 12 further including a biasing mechanism for biasing said stabilizer plate against said end face of said rotor.

Claim 14. The vane pump assembly as set forth in claim 13 wherein said biasing mechanism includes a plurality of set screws which are moveable into and out of said end plate body.

Claim 15. The vane pump assembly as set forth in claim 14 wherein said biasing mechanism includes a plurality of springs between said set screws and said stabilizer plate.

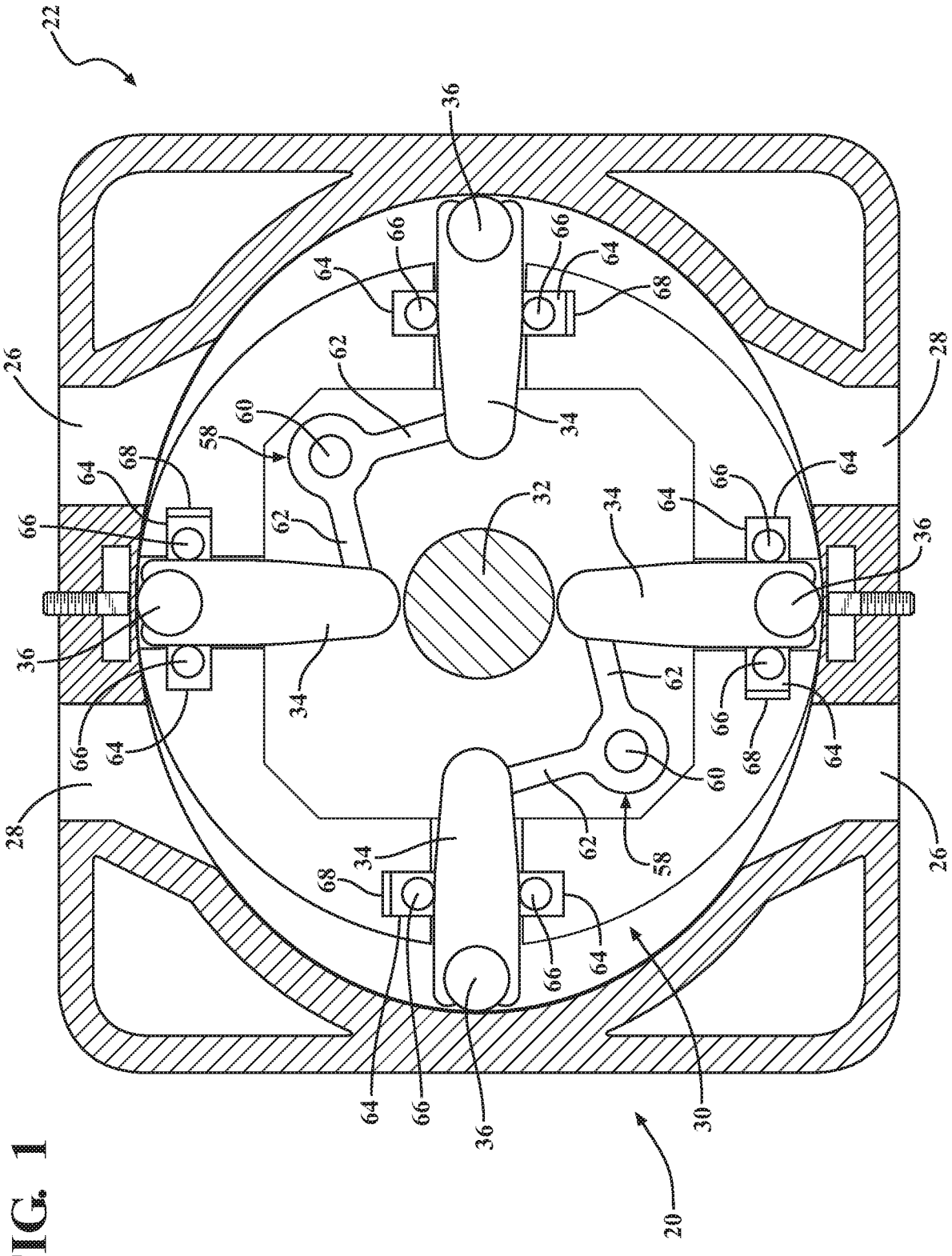

FIG. 1

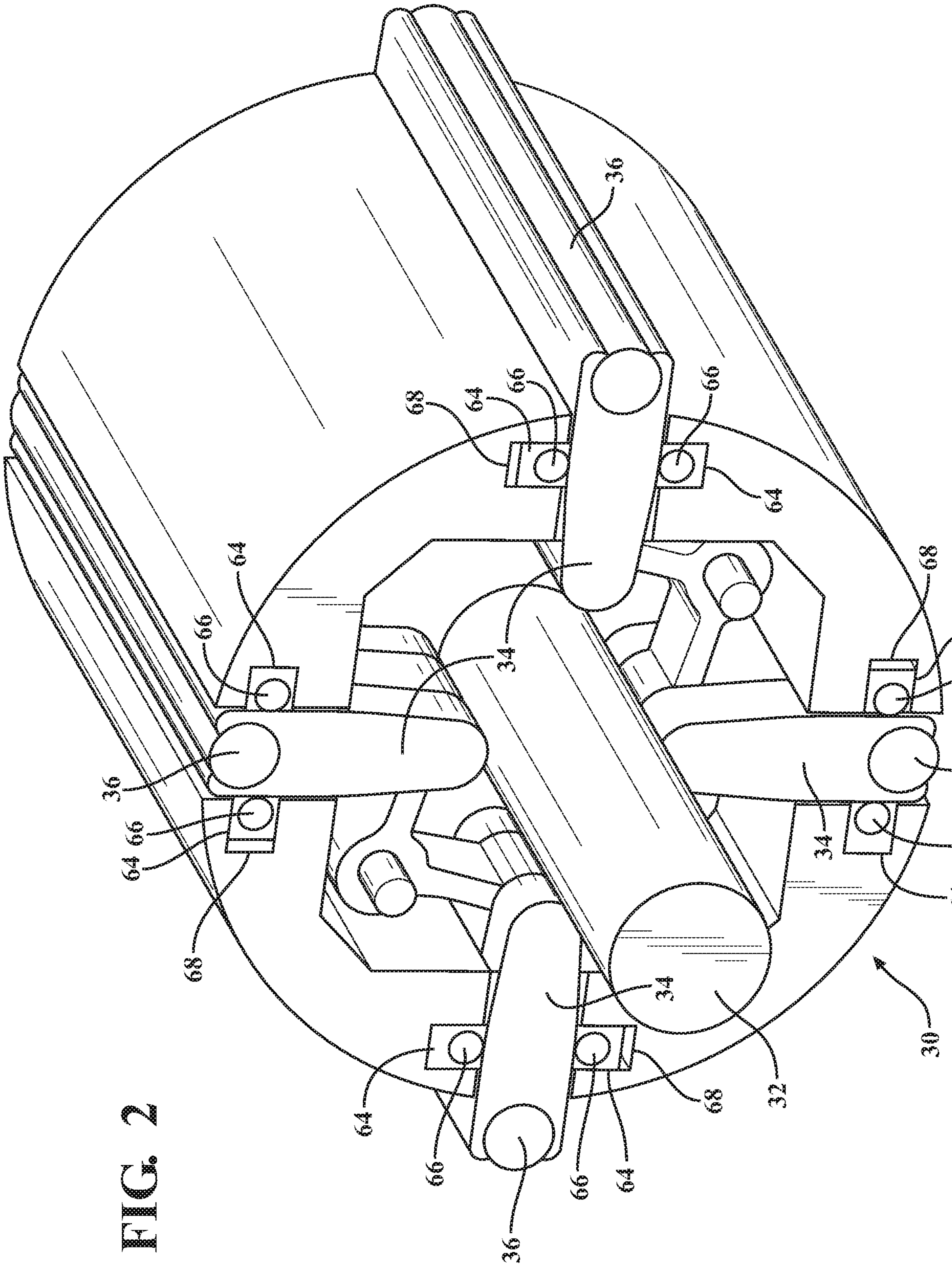
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FIG. 2

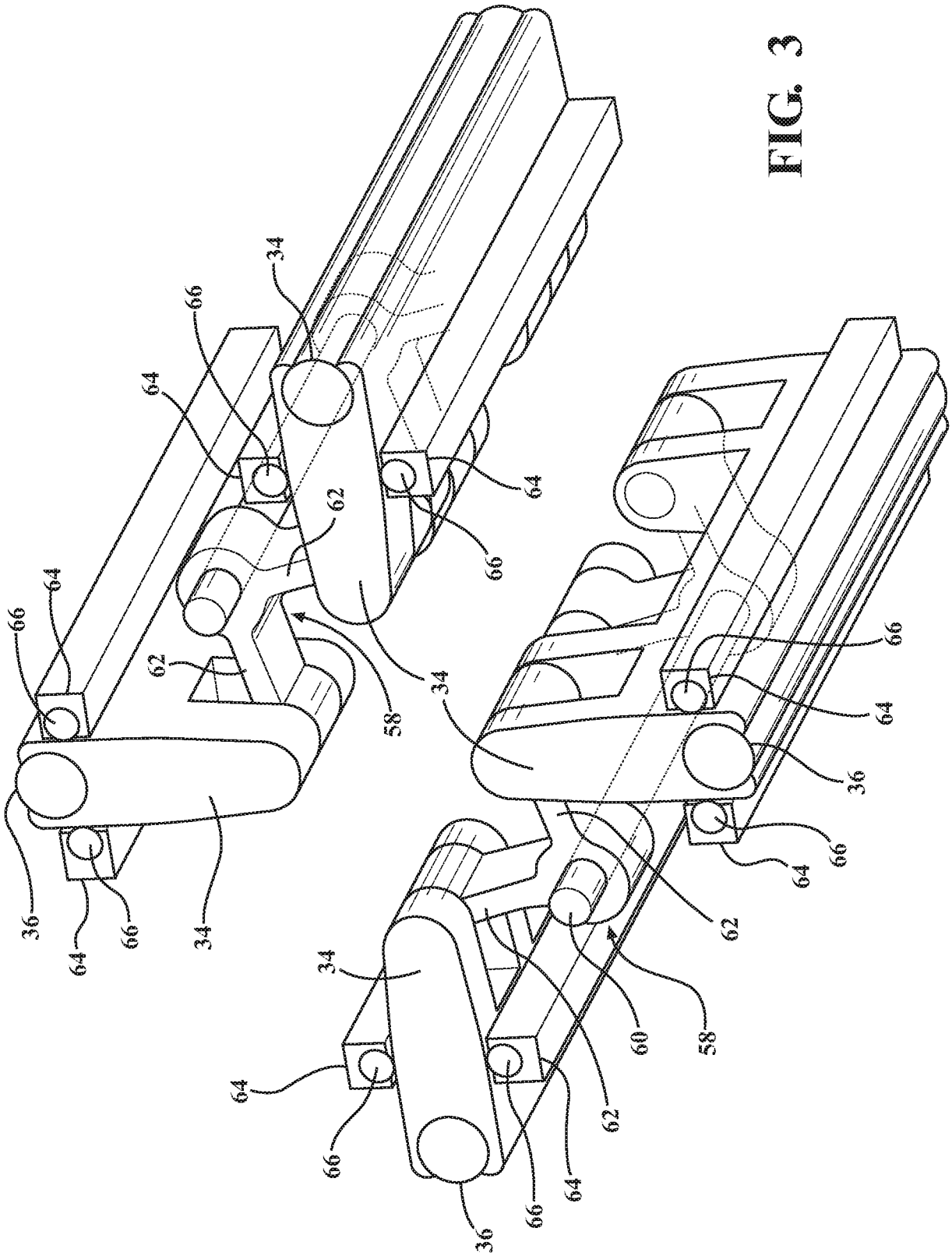
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FIG. 3

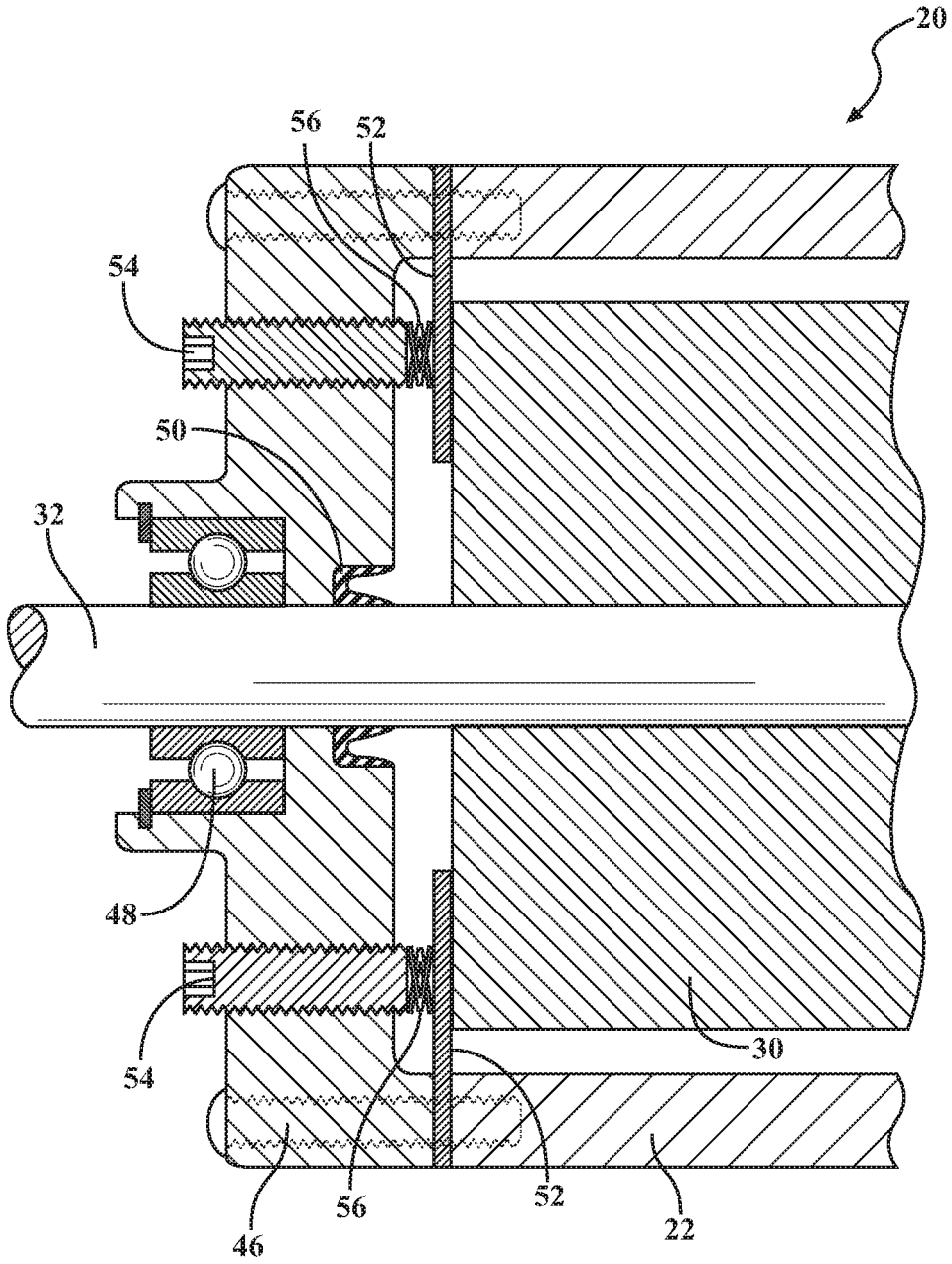

FIG. 4

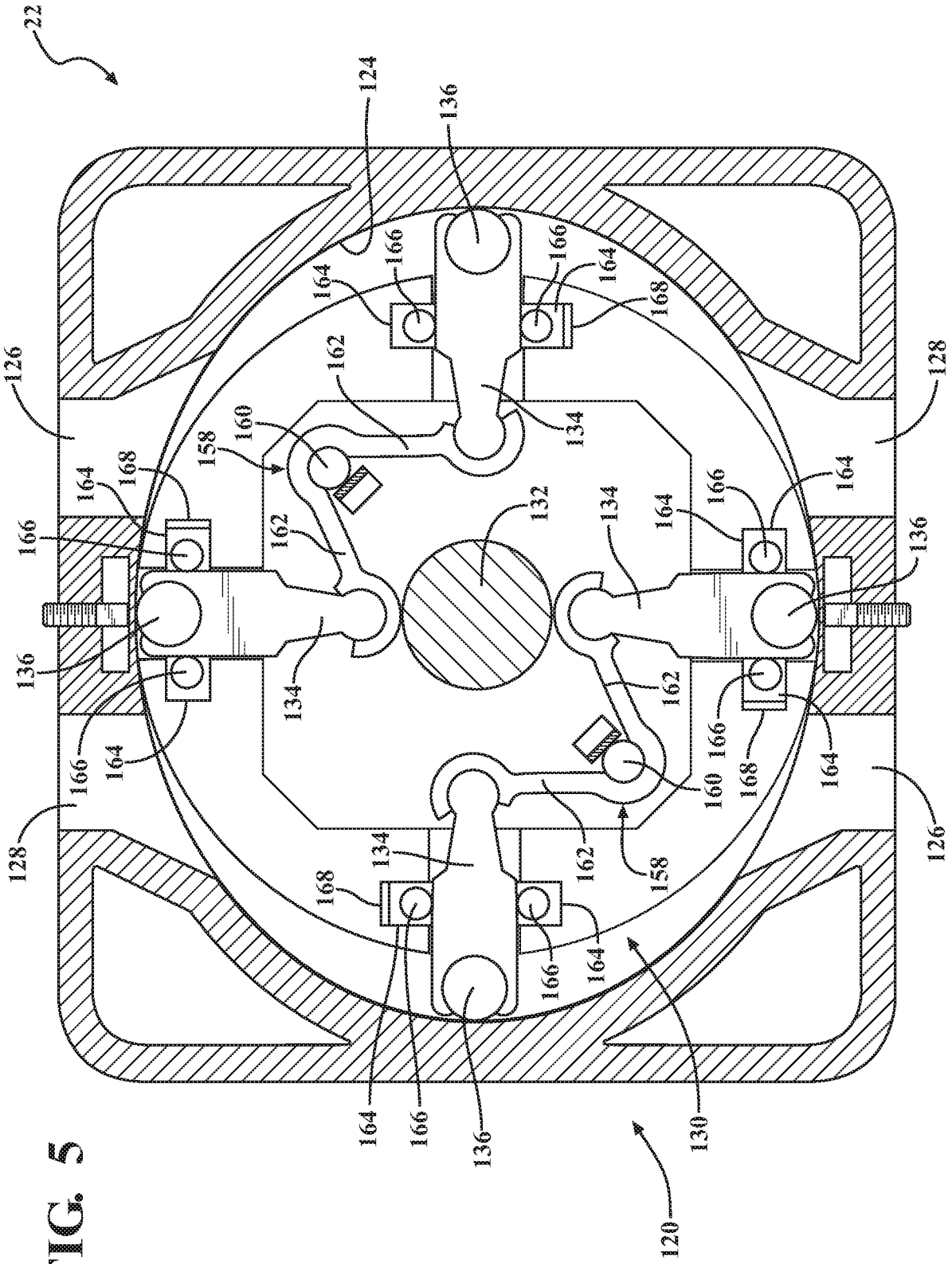

FIG. 5

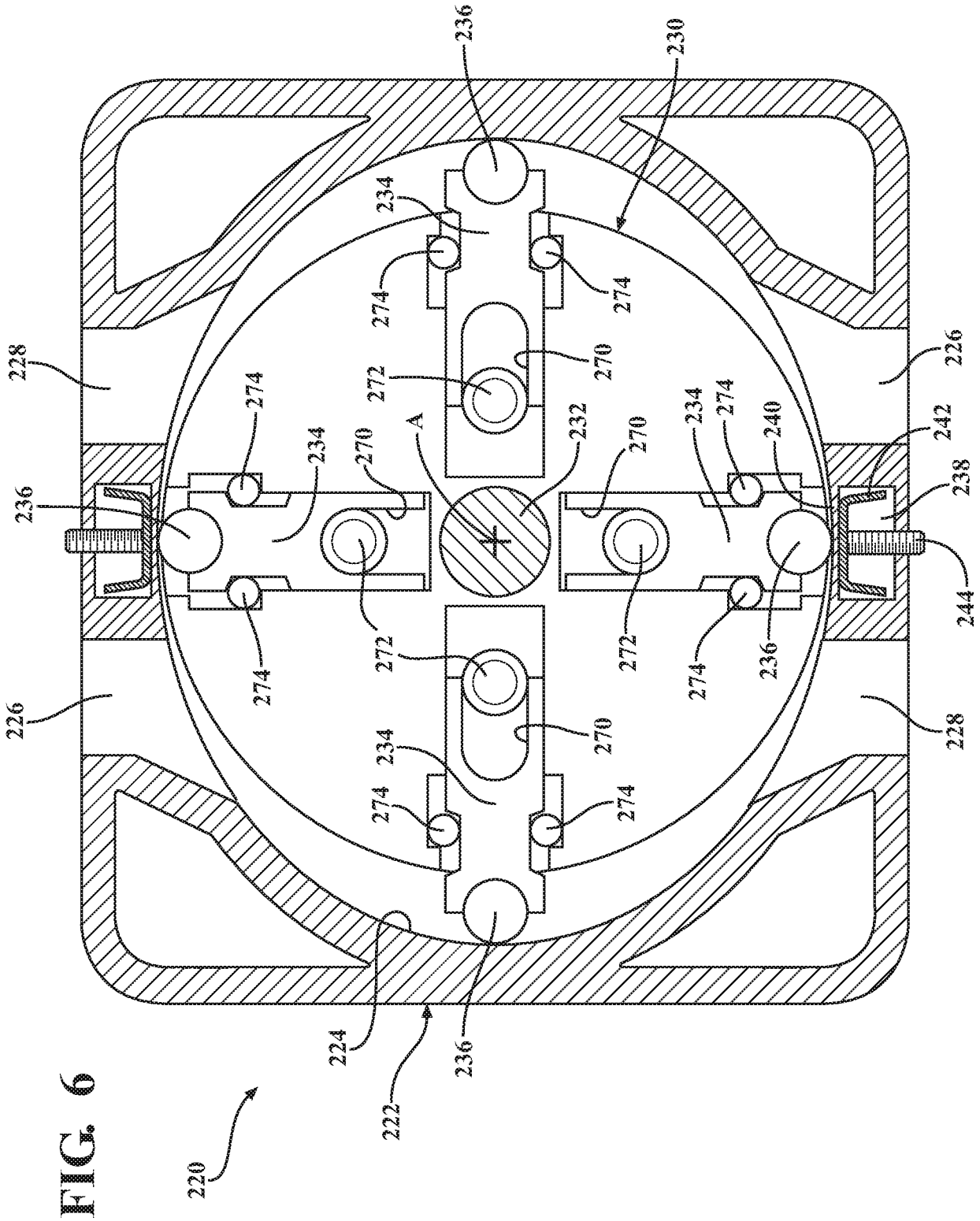

FIG. 6

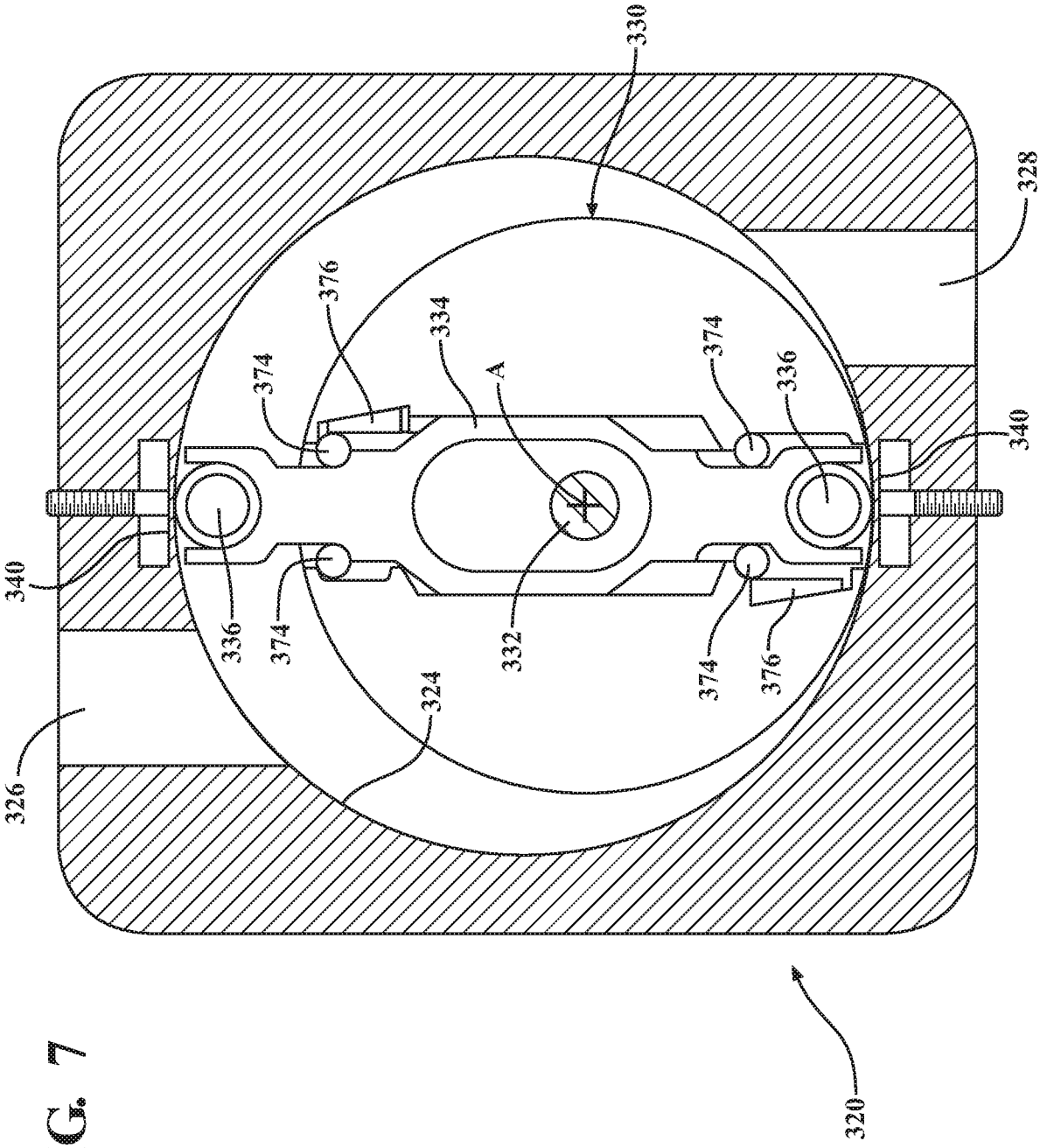
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FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/23471

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F04C 2/00, F04C 15/00, F01C 1/00, F01C 19/00, F01C 19/04 (2017.01)
CPC - F01C 21/0881, F04C 2/00, F04C 29/00, F04C 15/00, F04C 15/0003, F01C 1/00, F01C 1/321, F01C 19/005, F01C 21/08, F01C 21/089

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)
See Search History Document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y -- A	US 2,641,194 A (JONES) 09 June 1953 (09.06.1953) Entire document, especially col 3, ln 29-43, col 3, ln 50-59, col 4, ln 11-36, col 4, ln 50-59 and figs. 1-4.	1-3, 5-6, 11-13 ---------- 4, 7, 10 ---------- 8-9, 14-15
Y	US 2007/0240674 A1 (PEITZKE et al.) 18 October 2007 (18.10.2007) Entire document, especially para [0033], para [0061], para [0059] and figs. 1 and 10b.	4
Y -- A	US 3,322,335 A (PARTAIN) 30 May 1967 (30.05.1967) Entire document, especially col 1, ln 65-69, col 2, ln 2, col 2, ln 21-29, col 2, ln 34-37, col 2, ln 63-64, col 3, ln 9-10 and figs. 1-5.	7 -- 8-9
Y	US 2,146,877 A (APPLETON) 14 February 1939 (14.02.1939) Entire document, especially col 2, ln 12-16, col 3, ln 25-35 and figs. 1-2 and 7.	10
A	US 2010/0008806 A1 (KOLLER et al.) 14 January 2010 (14.01.2010) Entire document, especially para [0044], para [0051]-[0052] and fig. 1.	14-15
A	US 6,120,271 A (MALLEN) 19 September 2000 (19.09.2000) Entire document, especially col 4, ln 39-42, col 6, ln 46-49, col 7, ln 42-55 and figs. 2 and 4a.	8-9

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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10 May 2017	16 JUN 2017
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/23471

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 699,669 A (VICKERS INC.) 11 November 1953 (11.11.1953) Entire document.	1-15
A	US 2,641,193 A (KLESSIG) 09 June 1953 (09.06.1953) Entire document.	1-15
A	US 5,571,004 A (MASTERS et al.) 05 November 1996 (05.11.1996) Entire document.	1-15
A	US 3,185,102 A (PARTAIN et al.) 25 May 1965 (25.05.1965) Entire document.	1-15