



- (51) **International Patent Classification:**
F04C 18/344 (2006.01) *F04C 28/14* (2006.01)
F04C 29/12 (2006.01)
- (21) **International Application Number:**
PCT/US2016/026120
- (22) **International Filing Date:**
6 April 2016 (06.04.2016)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/146,624 13 April 2015 (13.04.2015) US
- (71) **Applicant:** **CARRIER CORPORATION** [US/US];
17900 Beeline Highway, Jupiter, Florida 33478 (US).
- (72) **Inventors:** **AKEL, Masao**; Carrier Corporation, 6304
Thompson Rd, TR 4, Syracuse, New York 13221 (US).
HOLDEN, Steven J.; Carrier Corporation, 6304
Thompson Rd, TR 4, Syracuse, NY 13221 (US).
- (74) **Agent:** **SLATE, William B.**; Bachman & LaPointe, P.C.,
900 Chapel Street, Suite 1201, New Haven, Connecticut
06510 (US).

(81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) **Title:** ECONOMIZED SPOOL COMPRESSOR

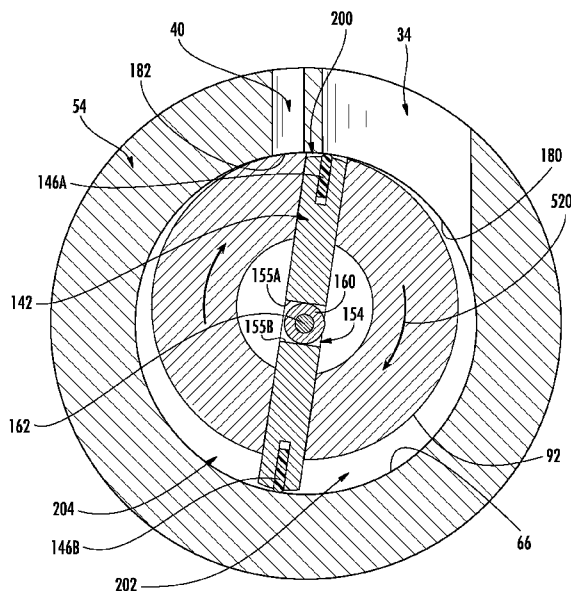


FIG. 8

(57) **Abstract:** A spool compressor (250) comprises a housing (26) comprising an inlet port (34) and an outlet port (40). A spool (78) is mounted for rotation of about a spool axis (500). A first endplate (82) of the spool has a pair of ports (300A, 300B). The housing has at least one port (310, 312) positioned to cyclically communicate with the pair of ports during said rotation.



Published:

— *with international search report (Art. 21(3))*

ECONOMIZED SPOOL COMPRESSOR

CROSS-REFERENCE TO RELATED APPLICATION

5 [0001] Benefit is claimed of U.S. Patent Application No. 62/146,624, filed April 13, 2015, and entitled "Economized Spool Compressor", the disclosure of which is incorporated by reference herein in its entirety as if set forth at length.

BACKGROUND

10 [0002] The disclosure relates to spool compressors. More particularly, the disclosure relates to economized spool compressors.

[0003] Spool compressors are a form of rotary positive displacement compressor disclosed in United States Patent 8,113,805, of Kemp, issued February 14, 2012, and International Application Publication WO 2014/116978 A1, of Torad Engineering, LLC, published July 31, 15 2014.

[0004] FIG. 1 shows an exemplary spool compressor 20 having a motor 22. The exemplary compressor is a hermetic or semi-hermetic compressor wherein the motor falls within a case of the compressor. In this example, the motor falls within an outer case or housing 24 and the 20 compressor further comprises an inner case or housing 26 within the outer case discussed below. The outer case has a suction port or inlet port (inlet) 30 and a discharge port or outlet port (outlet) 32. The exemplary inner case 26 further includes a suction port or inlet port (inlet) 34 which may be connected to the outer case suction port 30 via an inlet conduit 36. The inner case 26 further includes an outlet port. The inner case outlet port 40 (FIG. 3) is 25 closed by a reed valve 42 (FIG. 1). In the exemplary embodiment, the inner case discharge port comprises two side-by-side ports. Although, in various embodiments, the discharge port may be connected to the outer case discharge port via conduit, in the exemplary embodiment, the discharge port 42 is open to the interior of the outer case.

30 [0005] Viewed alternatively, the inner case 26 may be treated as the case of a core compressor 50 including the motor but not including the outer case and inlet conduit. In this example, the ports 34 and 40 would be regarded as inlet and outlet ports of the core compressor 50.

[0006] FIG. 1 further shows a shaft 100 of the compressor extending into and mating with a shaft (not shown) of the motor to allow the motor to drive the compressor. In an exemplary configuration shown in FIG. 1, a central longitudinal axis 500 is shared by the motor, core compressor, and outer case. In the exemplary illustrated embodiment, in the orientation of FIG. 1, the central longitudinal axis 500 is oriented vertically with the outlet port being in a top of the compressor. Other orientations of the compressor are possible.

[0007] FIG. 2 is an exploded view of the core compressor. The inner housing 26 is shown comprising a main case (or housing) 54 and a bearing case (or housing) 56. The bearing case carries a race of bearings (not shown) to rotationally support the shaft 100 for rotation about the axis 500. In the assembled condition and FIG. 1 orientation, the bearing housing 56 is atop the main housing 54 and secured thereto such as via threaded fasteners (e.g., screws, bolts, studs).

[0008] A spool 78 of the core compressor comprises the combination of a rotor hub member 80 and a pair of endplates 82 and 84. The exemplary hub member 80 comprises a central hub portion 86 having respective first and second ends 88 and 90, an outer surface or periphery 92, and a diametric through-slot 94 (having an opposed pair of openings to the periphery 92). Protruding from the end faces 88 and 90 are respective shaft portions 100 and 102. In the exemplary FIG. 1 orientation, the face 88 is an upper face and face 90 is a lower face.

[0009] The exemplary main housing 54 comprises a first end face 60 and a second end face 62. In the exemplary FIG. 1 orientation, the first end face is an upper end face and the second end face is a lower end face. A compartment or chamber (cylinder) 64 is formed by a surface 66 extending axially through to the surfaces 60 and 62. This chamber 64 forms a cylinder of the compressor. The suction port(s) and discharge port(s) are open to the surface 66 at locations discussed further below. In the assembled condition, the length between the rotor hub faces 88 and 90 is essentially the same as between the main housing faces 60 and 62 and accommodated within the main housing. The endplates 82 and 84 are secured against the faces 88 and 90 (e.g., via press fitting or fasteners) so that respective inboard faces 120 and 122 of these two plates are in sealing engagement with the faces 60 and 62 along outboard portions of the plates. The exemplary sealing engagement may be provided by seal material

(seals; not shown) carried by the main housing 54 or the plates. Thus, the plates 82 and 84 form the flanges of the spool.

[0010] FIG. 2 further shows a vane assembly 140 carried in the slot 94. An exemplary vane assembly comprises a structural vane 142 having respective first and second longitudinal edges 144A and 144B. The longitudinal edges may bear features (e.g., slots) for carrying a respective tip seal 146A, 146B. The structural vane extends from a first end 148 to a second end 150. Extending inward from the second end 150 is a stepped slot or compartment 152. A distal end portion 154 of the slot 152 receives a roller 160 to help guide movement of the vane as is discussed below. The exemplary roller 160 is supported for rotation about an axis 510 by a pin 162 received in a central bore of the roller. The pin 162 is held by a shaft 164 of a support 166. The support 166 is mounted to the second face 62 of the main housing (e.g., via fasteners). The exemplary shaft 164 shares the axis 500 and is received in a central bore of the shaft portion 102. This may be in a journal bearing relation. The axis 510 is parallel to and offset from the axis 500 as is discussed further below. At the upper end of the core compressor, the shaft portion 100 extends through the plate 82 and through the bearing with an intermediate portion engaging the bearing inner race and a distal portion engaging the motor shaft.

[0011] The roller 160 rotating about the axis 510 offset from the axis 500 serves the function of the eccentric cam of other exemplary spool compressors to which the teachings below may also be applied.

[0012] FIG. 3 shows the roller 160 in rolling/sliding engagement with opposite walls 155A and 155B of the slot distal end portion 154. FIGS. 4, 5, and 6 show sequence of operational conditions of the baseline compressor. The illustrations are notational views corresponding approximately to a downward sectional view through the main housing of the FIG. 1 compressor but with FIGS. 4-6 showing the upper endplate superimposed. FIGS. 4-6 show an outer periphery 170 of the endplate superimposed so as to extend beyond the inner surface 66 of the cylinder. FIG. 3 also shows the openings 180 and 182 of the respective suction port and discharge port to the surface 66. In this condition, three pockets (volumes or chambers) are formed in the cylinder. The pockets are separated by the two edges of the vane assembly (e.g., provided by the seals) and by close fitting cooperation of the hub periphery 92 and the surface 66 at one location (for reference defined as the twelve o'clock location at the top of

the view). There is increasing clearance between the hub periphery and surface 66 progressively further away from the twelve o'clock position. Thus, a first volume or pocket 200 is seen between the twelve o'clock position and the next adjacent edge of the vane in the direction of rotation 520 of the hub about its axis 500. A second pocket 202 is to the opposite side of the vane from the first volume and from a third pocket 204 between the nearest vane edge approaching the twelve o'clock position.

[0013] In the exemplary FIG. 4 condition, the first volume 200 is fully exposed to the opening 180 (e.g., as viewed in FIG. 4 a seal has just passed the clockwise-most extreme of the opening 180). With further rotation (e.g., see transition to FIG. 5) the volume of this pocket increases to draw in fluid from the suction port. Accordingly, during this stage this pocket may be referred to as a suction volume or suction port. In the FIGS. 4 and 5 example, the second pocket 202 has already received its charge of fluid and it may be compressing that charge. The third pocket 204 may be discharging through the discharge port. Initially, when a pocket is exposed to the discharge port, back pressure from discharge conditions and from any bias on the discharge valve may prevent discharge until sufficient compression has occurred to overcome these forces.

[0014] FIG. 6 shows a condition wherein the vane has just begun to occlude the opening 182 of the discharge port. Once the seal fully equips as the discharge port, there may be some small volume between the seal and the twelve o'clock position wherein fluid will be compressed. This fluid may end up blowing by the seal back to discharge or blowing between the hub and chamber surface to suction conditions. It is thus seen that a given pocket or volume will sequentially transition between being a suction pocket, a compression pocket, and a discharge pocket. However, depending upon context, the term "compression pocket" may be used to indicate any pocket in any of these conditions.

SUMMARY

[0015] One aspect of the disclosure involves a spool compressor comprising a housing having an inlet port and an outlet port. A spool is mounted for rotation about a spool axis. A first endplate of the spool has a pair of ports. The housing has at least one port positioned to cyclically communicate with the pair of ports during said rotation.

[0016] In one or more embodiments of any of the other embodiments, a leading edge of a cylinder opening (182) to the outlet port commences within 30° of a top-dead-center location along the cylinder.

5 **[0017]** In one or more embodiments of any of the other embodiments, the at least one port comprises: a first port positioned to communicate with a pocket of the spool during a first portion of spool rotation; and a second port positioned to communicate with the pocket during a second portion of spool rotation different from the first portion.

10 **[0018]** In one or more embodiments of any of the other embodiments, the at least one port comprises a port positioned to communicate with a pocket of the spool during a portion of spool rotation after a completion of closing the pocket to the inlet port.

[0019] In one or more embodiments of any of the other embodiments, the port is sized to
15 maintain the communication with the pocket of the spool until volume of the pocket reaches a first predetermined ratio between 0.50 and 1.0 relative to the volume at the completion of closing the pocket to the inlet port.

[0020] In one or more embodiments of any of the other embodiments, the at least one port
20 comprises a port positioned to begin to communicate with a pocket of the spool during a portion of spool rotation after a start of compression of the pocket but before a completion of compression of the pocket.

[0021] In one or more embodiments of any of the other embodiments, the port is sized to
25 begin the communication with the pocket of the spool when the volume of the pocket is in a range between 0.05 and 0.50 relative to a volume of the pocket at a closing the pocket to the inlet port.

[0022] In one or more embodiments of any of the other embodiments, the housing further
30 comprises a cylinder having a central longitudinal axis, a first end, and a second end. The spool has a hub having an outer surface accommodated within the cylinder. The hub has a slot having a first opening to the hub outer surface and a second opening to the hub outer surface. A vane is accommodated in the slot for reciprocal movement relative to the hub and has a first edge and a second edge both in sealing contact or proximity with an inner surface

of the cylinder. The first endplate is at the first cylinder first end and is configured to rotate with the hub as a unit about the spool axis. A first port of the pair of ports is to a first side of the vane and the second port of the pair of ports is to a second side of the vane.

5 **[0023]** In one or more embodiments of any of the other embodiments, the spool has: a second endplate at the cylinder second end and configured to rotate with the hub as a unit about the spool axis.

10 **[0024]** In one or more embodiments of any of the other embodiments, the vane comprises: a vane body; a first tip seal forming the first edge of the first vane; and a second tip seal forming the second edge of the first vane.

15 **[0025]** In one or more embodiments of any of the other embodiments, the spool further comprises one or both of: a motor coupled to the spool to drive said rotation; and a one-way discharge valve.

20 **[0026]** In one or more embodiments of any of the other embodiments, the housing is an inner housing and an outer housing encloses the inner housing and has an inlet port and an outlet port, the outer housing optionally enclosing an electric motor.

25 **[0027]** In one or more embodiments of any of the other embodiments, a vapor compression system comprises the spool compressor and further comprises: a heat rejection heat exchanger coupled to the outlet port along a flowpath extending from the outlet port and returning to the inlet port; and a heat absorption heat exchanger coupled to the inlet port along the flowpath.

30 **[0028]** In one or more embodiments of any of the other embodiments, the system further comprises: a branch flowpath between the at least one port and the flowpath; a shut-off valve coupled to the at least one port along the branch flowpath; and a controller.

35 **[0029]** In one or more embodiments of any of the other embodiments, the branch flowpath is an economizer flowpath and the at least one port is an economizer port.

[0030] In one or more embodiments of any of the other embodiments, the system further comprises an expansion device between the heat rejection heat exchanger and the heat absorption heat exchanger.

5 **[0031]** Another aspect of the disclosure involves a method for operating a spool compressor. The compressor has: a housing having a suction port and a discharge port; and a spool having a hub and an endplate, a first port and a second port. The method comprises: driving rotation of the spool about a spool axis. The rotation cyclically alternatingly brings the first port and the second port into communication with an additional port of the housing.

10

[0032] In one or more embodiments of any of the other embodiments, the rotation brings each port of the first port and the second port into said communication with the additional port after a pocket associated with said each port is closed to the suction port.

15 **[0033]** In one or more embodiments of any of the other embodiments, the rotation brings each port of the first port and the second port into said communication with a first said additional port and a second said additional port. The communication with first said additional port ends before the communication with the second said additional port begins.

20 **[0034]** In one or more embodiments of any of the other embodiments, the rotation brings each port of the first port and the second port into said communication with the additional port overlapping communication of the pocket to the discharge port.

[0035] In one or more embodiments of any of the other embodiments, a controller controls
25 a valve coupled to the additional port to admit flow when a pressure ratio between the discharge port and the suction port reaches a threshold value.

[0036] The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the
30 description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] FIG. 1 is a view of a prior art baseline spool compressor with outer case shown in broken lines.

[0038] FIG. 2 is a partial exploded view of a core compressor of the compressor of FIG. 1.

[0039] FIG. 3 is a partially schematic transverse sectional view of a spool compressor in an
5 instance during a cycle.

[0040] FIG. 4 is a partially schematic transverse sectional view of a spool compressor in
another instance during the cycle.

10 [0041] FIG. 5 is a view of the compressor of FIG. 4 in an instance subsequent to FIG. 4.

[0042] FIG. 6 is a view of the compressor of FIG. 4 in an instance subsequent to FIG. 5.

[0043] FIG. 7 is a partial exploded view of a core compressor modified relative to the FIG.
15 2 configuration.

[0044] FIG. 8 is a partially schematic transverse sectional view of a spool compressor
modified relative to the FIG. 3 configuration in a similar instance during a cycle.

20 [0045] FIG. 9 is a partially schematic transverse sectional view of the modified spool
compressor at an instance during a cycle corresponding to the FIG. 4 baseline.

[0046] FIG. 10 is a view of the compressor of FIG. 9 in an instance subsequent to FIG. 9.

25 [0047] FIG. 11 is a view of the compressor of FIG. 9 in an instance subsequent to FIG. 10.

[0048] FIG. 12 is a view of a further modified compressor in an instance corresponding to
the FIG. 4 baseline.

30 [0049] FIG. 13 is a view of the compressor of FIG. 12 in an instance subsequent to FIG. 12.

[0050] FIG. 14 is a view of the compressor of FIG. 12 in an instance subsequent to FIG. 13.

[0051] FIG. 15 is a view of the compressor of FIG. 12 in an instance subsequent to FIG. 14.

[0052] FIG. 16 is a view of the compressor of FIG. 12 in an instance subsequent to FIG. 15.

[0053] FIG. 17 is a view of the compressor of FIG. 12 in an instance subsequent to FIG. 16.

5

[0054] FIG. 18 is a schematic view of a vapor compression system.

[0055] FIG. 19 is a partially schematic transverse sectional view of a spool compressor modified relative to the FIG. 3 configuration in a top-dead-center instance during a cycle.

10

[0056] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0057] FIG. 7 shows a first modification of the baseline compressor described above and illustrated in FIGS. 1-6. Details not illustrated or described may be the same for this compressor 250 as those of the illustrated baseline or other baseline spool compressor. The basic components of the compressor are described using the same numerals as FIGS. 1-6 with additional numerals for additional features.

[0058] The first modification places a pair of ports 300A and 300B in one of the endplates (the upper endplate 82 in this example). Each of the ports is open to the two opposite faces of the endplate. The ports 300A and 300B are positioned to cooperate with one or more housing ports at one or more instances in the cycle. In the exemplary embodiment, a housing port 310 is formed in the bearing housing having one end (proximal end) open to an inner/lower surface of the housing in sealing engagement with the endplate 82 and another end (distal end) which may be fluidly connected to some other component in order to remove fluid from or introduce fluid to the pockets during the cycle. In the exemplary embodiment, the distal end of the port 310 is connected by a fluid line 320. The fluid line 320 may ultimately be connected to, for example, an economizer line of a vapor compression system (discussed below). Thus, in the hermetic or semi-hermetic compressor configuration of FIG. 1, the line 320 may extend to a port/fitting on the outer case to which an economizer line or other line is connected. A valve 322 (either internal or external to the compressor) may be positioned to control fluid flow through the port 310.

[0059] A further optional modification (FIG. 8) shifts the positioning of the ports, namely the circumferential positioning and/or span of the openings 180 and 182. The beginning (leading edge) of the opening 180 is shifted to earlier in the cycle, thus increasing the circumferential span of the opening 180. The entire opening 182 is shifted to later in the cycle, thus leaving a very small gap between the end of the opening and 182 and the beginning of the opening 180 (e.g., the gap is just at the closest proximity location of hub and cylinder (i.e. the twelve o'clock position in the views)).

[0060] As viewed in FIG. 8, the leading edge of the opening 180 is the left (counterclockwise) edge and is shifted to within a few degrees (about the roller axis 510 or other central axis of the bore in a non-roller embodiment) of the twelve o'clock or "top-dead-center" position or location (e.g., within 10° or within 5°).

[0061] As viewed in FIG. 8, the trailing edge of the opening 182 is the right (clockwise) edge and is shifted to within a few degrees of the twelve o'clock or "top-dead-center" position or location (e.g., within 10° or within 5°). As viewed in FIG. 8, the leading edge of the opening 182 is the left (counterclockwise) edge and is shifted to within about thirty degrees of the twelve o'clock or "top-dead-center" position or location (e.g., within 25° or within 20° or within 15°).

[0062] To avoid blow-by the circumferential span of the discharge port may be less than the circumferential span of the seals 146A, 146B or vane edge (even if larger than the seal, if smaller than the vane edge only small gaps will briefly open. In this way, at most one pocket is exposed to discharge at a given time. For ease of illustrating the discharge port, it is, however, shown with a larger opening circumferential span than the seal.

[0063] FIGS. 9-11 are views corresponding to vane positions (orientations during the cycle) of FIGS. 4-6 but also showing positions of the ports 300A, 300B, and 310. In the FIG. 9 condition, the ports 300A and 300B are blocked by the upper housing and the port 310 is blocked by the upper endplate. However, in FIG. 10, the rotation has brought the port 300A into full communication with the port 310. As noted previously, this communication may be used to either inject further fluid into the pocket 202 or withdraw fluid from that pocket. In the exemplary embodiment, the positioning is shown relatively early in compression and, therefore, likely associated with an economizer injection. In the FIG. 11 condition, the port 300A has just rotated out of communication with the port 310 and is again blocked by the upper housing. Continued rotation will bring the port 300B into communication with the port 310 as was described for the port 300A.

[0064] FIGS. 12-17 show an alternate configuration wherein an additional port 312 is provided in the housing for communication with the ports 300A and 300B. The exemplary embodiment shows port 312 in addition to the port 310. However, a similar port could be used alone or in combination with yet other ports. In the FIG. 15 condition, the port 300B passes into communication with the port 312. In one example, the port 312 is connected to the discharge port. The registry/communication between ports 300A and 300B and the port 312 has the effect of increasing an effective discharge port cross-sectional area, thereby improving flow. This may help in facilitating the shift of the discharge port relative to the

FIG. 3 illustration. It also may help in keeping the circumferential span of the discharge port opening low and thus keeping seal circumferential span low to improve efficiency and capacity.

5 **[0065]** FIG. 18 shows a vapor compression system 900 containing an exemplary modified compressor 250. In this example, the line 320 of FIG. 7 is an internal line connecting to an economizer port 330 on the outer case. A main refrigerant flowpath 902 includes a leg formed by a discharge line 904 extending from the compressor outlet or discharge port 32 to the inlet of a heat rejection heat exchanger (e.g., condenser) 906. The exemplary main
10 flowpath 902 proceeds downstream from the outlet of the heat rejection heat exchanger 906 with an economizer branch 908 branching off at a junction 910 to return to the economizer port 330. The main refrigerant flowpath 902 proceeds downstream from the junction 910 to the compressor suction port 30. The main flowpath passes from the junction 910 through an expansion device (e.g., expansion valve) 912 and a heat absorption heat exchanger 914 to a
15 suction line 916. The exemplary heat exchangers 906 and 914 are refrigerant-air heat exchangers with fan-forced airflows. Alternative heat exchangers include refrigerant-water heat exchangers (e.g., in chiller use).

[0066] An exemplary economizer 920 includes an economizer heat exchanger 922 having a
20 first leg 924 along the main flowpath 902 upstream of the expansion device 912 and a second leg 926 in heat exchange with the first leg. The second leg is along the economizer flowpath 908 downstream of an economizer expansion device (e.g., expansion valve) 928. Alternative economizers include flash tank economizers. In economizer operation, refrigerant is bypassed through the economizer line (e.g., via control of valves 322 and/or 928) 930 passing along the
25 economizer flowpath. The refrigerant flowing along the economizer flowpath is expanded by the expansion device 928 reducing its temperature. The reduced temperature refrigerant in the economizer leg 926 cools refrigerant in the main flowpath leg 924 prior to the expansion of that main flowpath leg refrigerant in the expansion device 912.

30 **[0067]** FIG. 18 further shows a controller 950. The controller may receive user inputs from an input device (e.g., switches, keyboard, or the like) and sensors (not shown, e.g., pressure sensors and temperature sensors at various system locations). The controller may be coupled to the sensors and controllable system components (e.g., valves, the bearings, the compressor motor, vane actuators, and the like) via control lines (e.g., hardwired or wireless

communication paths). The controller may include one or more: processors; memory (e.g., for storing program information for execution by the processor to perform the operational methods and for storing data used or generated by the program(s)); and hardware interface devices (e.g., ports) for interfacing with input/output devices and controllable system components.

[0068] One possible control modification involves control of flow through the port 310. With a simple reed valve as the discharge valve, the discharge valve opens early when the compressor discharge pressure (condenser temperature) is low, and opens late when the discharge pressure (condenser temperature) is high. The controller may close the valve when the discharge pressure is low. This will prevent the discharge gas flowing back into the port 310 when the reed valve opens early. This configuration allows the port 310 to be made bigger (to maintain more overlapping time with the ports 300A, 300B) so that it can introduce more economized gas to the compression volume.

[0069] In one example, the system may be operated in the economized mode when a ratio between the discharge pressure ($P_{\text{discharge}}$) and the suction pressure (P_{suction}) reaches a threshold value. The threshold value may be calculated via a formula using the maximum pocket volume (V_{max}) and pocket volume at the time of closing of the pocket to the economizer port 310 (V_{later}). Thus, the calculation may be performed during engineering of the system and its result configured into the system (e.g., via programming into the controller).

[0070] An exemplary formula may be:

$$\frac{P_{\text{discharge}}}{P_{\text{suction}}} = \left(\frac{V_{\text{max}}}{V_{\text{later}}} \right)^K$$

where K is a polytropic exponent of a refrigerant ranging from 1.1 to 1.4.

[0071] FIG. 19 shows a further variation where one or both ports 310, 312 are circumferentially elongated as arcuate obounded slots having respective circumferential ends 310-1, 310-2 and 312-1 and 312-2. FIG. 19 also shows zones 610 and 612 that the two ports may occupy. The exemplary port 310 is essentially the full circumferential extent of the zone

610; the port 312 is slightly smaller than the circumferential extent 612 with its leading (opening) end 312-1 somewhat recessed relative to the corresponding end of the zone 612.

[0072] The exemplary FIG. 19 port 310 is exposed to a pocket via the associated port 300A, 300B at the start of compression when pocket volume is maximum ($V_{\max}$).

Communication ends sometime later (e.g., when the pocket has compressed to half its maximum volume: V_{later}). FIG 19 shows a reference dot on the vane merely to distinguish one end or side from the other. The dot is initially at top dead center, prior to opening to suction of the pocket trailing the dot. After approximately 270° of rotation the pocket will open to the port 310 via the associated port 300A or 300B. After approximately 360° of rotation the pocket will close to the port 310. In general, the port 310 may be positioned and sized so that the port remains in communication with the pocket from after opening of communication until pocket volume reaches a predetermined value. The value may be expressed as a ratio of pocket volume to the pocket volume at closing of the pocket to the suction port. An exemplary ratio is between 0.50 and 1.0, more narrowly between 0.50 and 0.95, or between 0.50 and 0.75.

[0073] The exemplary FIG. 19 port 312 is exposed to that pocket via the associated port 300A, 300B at some time after closing to the port 310 (e.g., after approximately 360° of rotation, with about 45° thereafter for the illustrated end 312-1). Communication ends sometime later (e.g., when the pocket closes to discharge at bit shy of 540°). In general, the port 312 may be positioned and sized so that the port begins communication with the pocket only after compression of the pocket volume to a predetermined value. The value may be expressed as a ratio of pocket volume to the pocket volume at closing of the pocket to the suction port. An exemplary ratio is between 0.05 and 0.50, more narrowly between 0.10 and 0.50, or between 0.20 and 0.50.

[0074] The use of “first”, “second”, and the like in the description and following claims is for differentiation within the claim only and does not necessarily indicate relative or absolute importance or temporal order. Similarly, the identification in a claim of one element as “first” (or the like) does not preclude such “first” element from identifying an element that is referred to as “second” (or the like) in another claim or in the description.

[0075] Where a measure is given in English units followed by a parenthetical containing SI or other units, the parenthetical's units are a conversion and should not imply a degree of precision not found in the English units.

- 5 **[0076]** One or more embodiments have been described. Nevertheless, it will be understood that various modifications may be made. For example, when applied to an existing basic system, details of such configuration or its associated use may influence details of particular implementations. Accordingly, other embodiments are within the scope of the following claims.

10

CLAIMS

What is claimed is:

1. A spool compressor (250) comprising:
 - 5 a housing (26) comprising:
 - an inlet port (34); and
 - an outlet port (40); and
 - a spool (78) mounted for rotation about a spool axis (500),wherein:
 - 10 a first endplate (82) of the spool has a pair of ports (300A, 300B); and
 - the housing has at least one port (310, 312) positioned to cyclically communicate with the pair of ports during said rotation.
2. The spool compressor of claim 1 wherein:
 - 15 a leading edge of a cylinder opening (182) to the outlet port commences within 30° of a top-dead-center location along the cylinder.
3. The spool compressor of claim 1 wherein:
 - the at least one port comprises:
 - 20 a first port (310) positioned to communicate with a pocket of the spool during a first portion of spool rotation; and
 - a second port (312) positioned to communicate with the pocket during a second portion of spool rotation different from the first portion.
- 25 4. The spool compressor of claim 1 wherein:
 - the at least one port comprises: a port (310,312) positioned to communicate with a pocket of the spool during a portion of spool rotation after a completion of closing the pocket to the inlet port.
- 30 5. The spool compressor of claim 4 wherein:
 - the port (310) is sized to maintain the communication with the pocket of the spool until volume of the pocket reaches a first predetermined ratio between 0.50 and 1.0 relative to the volume at the completion of closing the pocket to the inlet port.

6. The spool compressor of claim 1 wherein:

the at least one port comprises:

a port (310,312) positioned to begin to communicate with a pocket of the spool during a portion of spool rotation after a start of compression of the pocket but before a completion of compression of the pocket.

7. The spool compressor of claim 6 wherein:

the port (312) is sized to begin the communication with the pocket of the spool when the volume of the pocket is in a range between 0.05 and 0.50 relative to a volume of the pocket at a closing the pocket to the inlet port.

8. The spool compressor of claim 1 wherein:

the housing further comprises:

a cylinder (64) having a central longitudinal axis, a first end, and a second end;

the spool has:

a hub (80) having:

an outer surface (92) accommodated within the cylinder; and

a slot (94) having a first opening to the hub outer surface and a second opening to the hub outer surface;

a vane (140) accommodated in the slot for reciprocal movement relative to the hub and having:

a first edge and a second edge both in sealing contact or proximity with an inner surface (66) of the cylinder; and

said first endplate at the first cylinder first end and configured to rotate with the hub as a unit about the spool axis; and

a first port (300A) of the pair of ports is to a first side of the vane and the second port (300B) of the pair of ports is to a second side of the vane.

9. The spool compressor of claim 8 wherein:

the spool has:

a second endplate (84) at the cylinder second end and configured to rotate with the hub as a unit about the spool axis.

10. The spool compressor of claim 8 wherein:

the vane comprises:

- a vane body (142);
- a first tip seal (146A) forming the first edge of the first vane; and
- a second tip seal (146B) forming the second edge of the first vane.

5

11. The spool compressor of claim 1 further comprising one or both of:
- a motor (22) coupled to the spool to drive said rotation; and
 - a one-way discharge valve (42).

- 10 12. The spool compressor of claim 1 wherein:
- the housing is an inner housing; and
 - an outer housing (24) encloses the inner housing and has an inlet port (30) and an outlet port (32), the outer housing optionally enclosing an electric motor (22).

- 15 13. A vapor compression system (900) comprising the spool compressor of claim 1 and further comprising:
- a heat rejection heat exchanger (906) coupled to the outlet port along a flowpath (902) extending from the outlet port and returning to the inlet port; and
 - a heat absorption heat exchanger (914) coupled to the inlet port along the flowpath.

20

14. The system of claim 13 further comprising:
- a branch flowpath (908) between the at least one port and the flowpath;
 - a shut-off valve (322) coupled to the at least one port along the branch flowpath; and
 - a controller (950).

25

15. The system of claim 14 wherein:
- the branch flowpath is an economizer flowpath and the at least one port is an economizer port (310).

- 30 16. The system of claim 13 further comprising:
- an expansion device (912) between the heat rejection heat exchanger and the heat absorption heat exchanger.

17. A method for operating a spool compressor (250), the compressor having:

a housing (26) having a suction port (34) and a discharge port (40); and
a spool (78) having a hub (80) and an endplate (82), a first port (300A) and a second port (300B),

the method comprising:

- 5 driving rotation of the spool about a spool axis (500); and
the rotation cyclically alternatingly bringing the first port and the second port into
communication with an additional port (310, 312) of the housing.

18. The method of claim 17 wherein:

- 10 the rotation brings each port of the first port and the second port into said communication
with the additional port (310, 312) after a pocket associated with said each port is
closed to the suction port.

19. The method of claim 17 wherein:

- 15 the rotation brings each port of the first port and the second port into said communication
with a first said additional port (310) and a second said additional port (312), the
communication with first said additional port ending before the communication with
the second said additional port begins.

20 20. The method of claim 17 wherein:

- the rotation brings each port of the first port and the second port into said communication
with the additional port (312) overlapping communication of the pocket to the
discharge port.

25 21. The method of claim 17 wherein:

- a controller controls a valve (322) coupled to the additional port (310) to admit flow when
a pressure ratio between the discharge port and the suction port reaches a threshold
value.

1/10

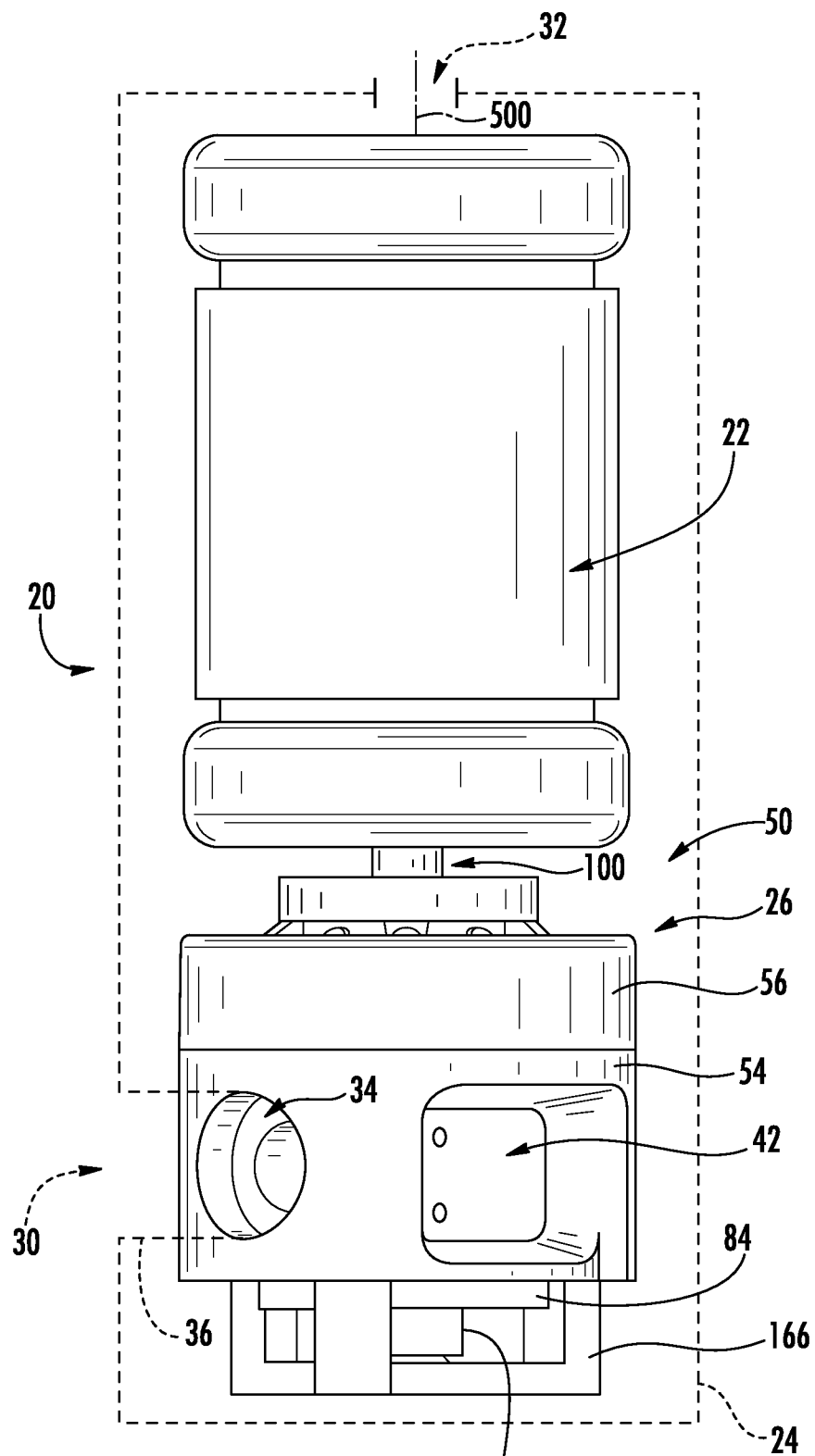


FIG. 1
(PRIOR ART)

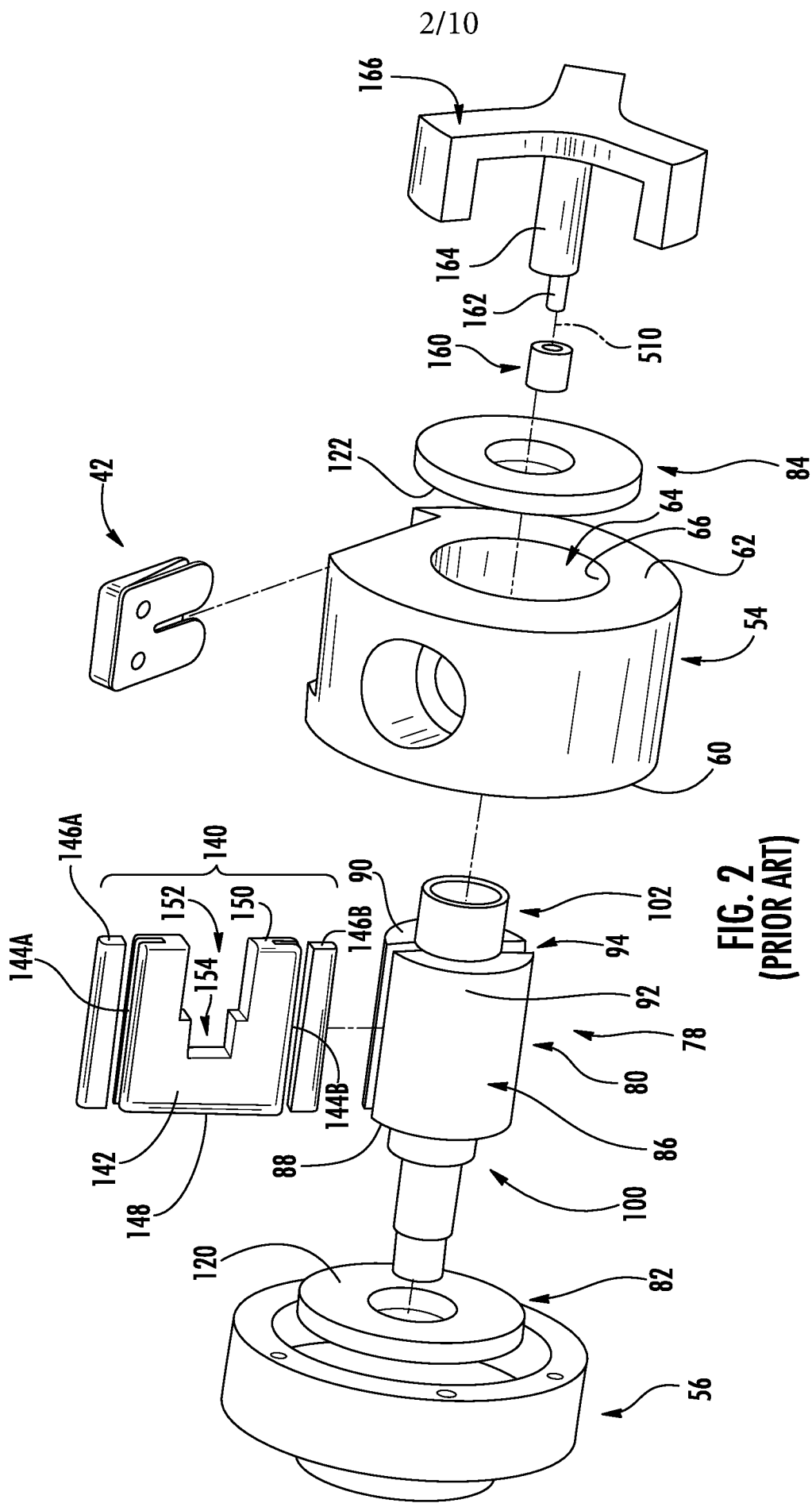


FIG. 2
(PRIOR ART)

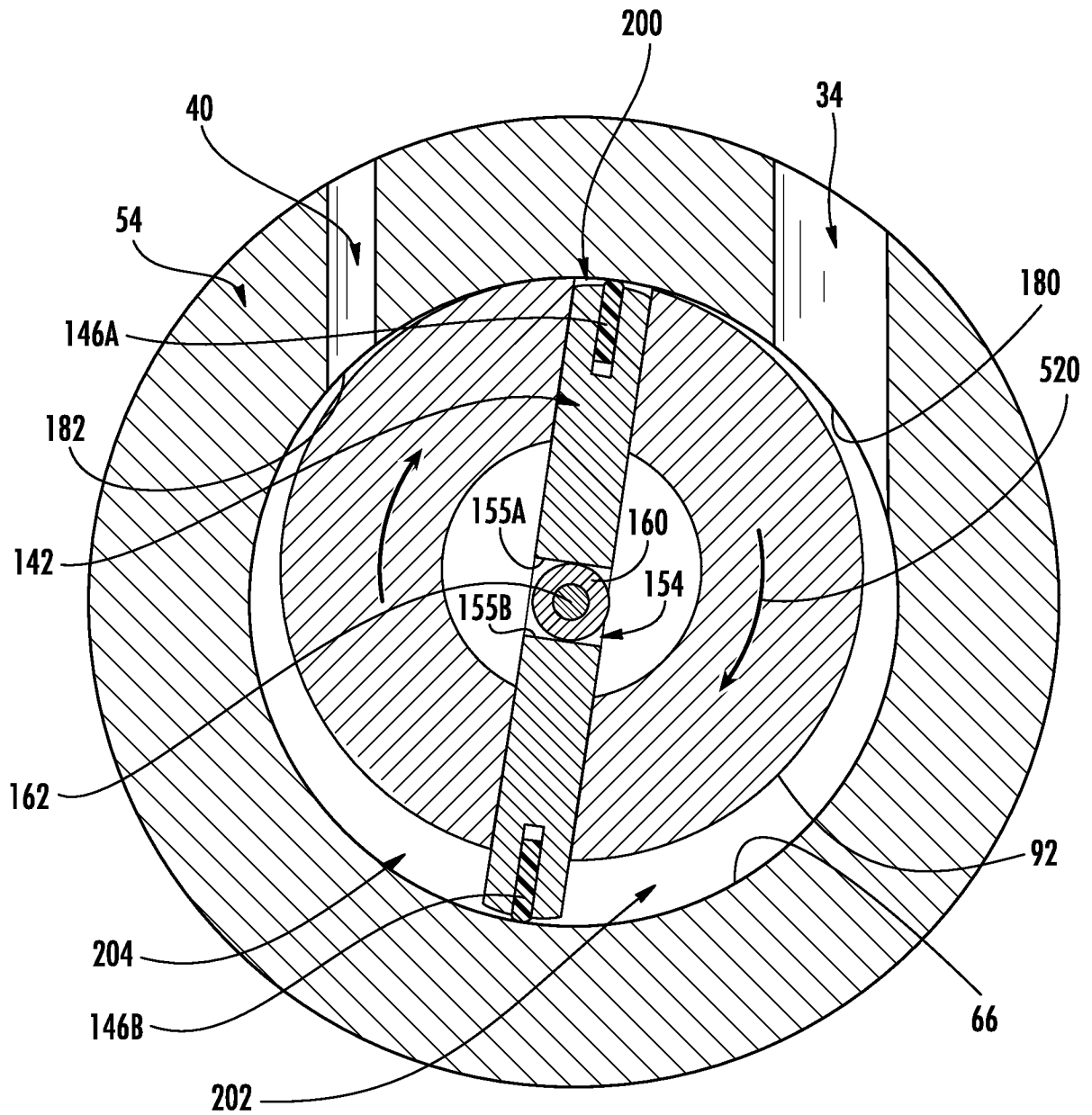


FIG. 3
(PRIOR ART)

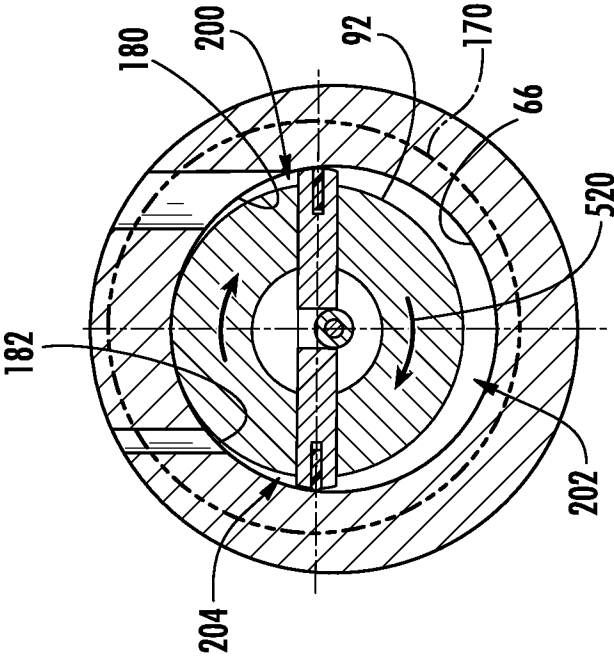


FIG. 4
(PRIOR ART)

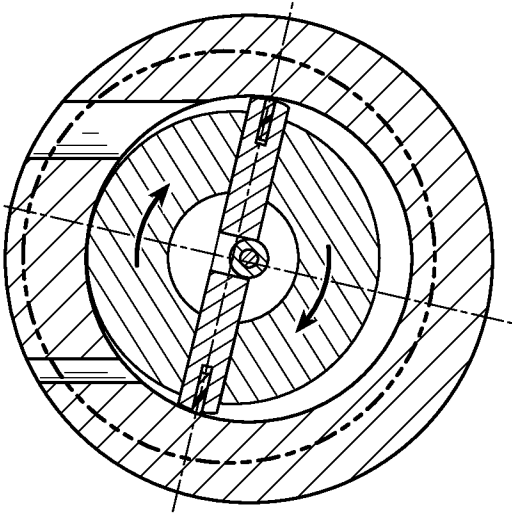


FIG. 5
(PRIOR ART)

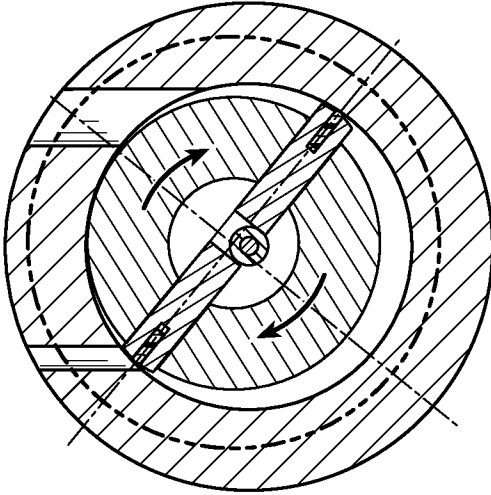


FIG. 6
(PRIOR ART)

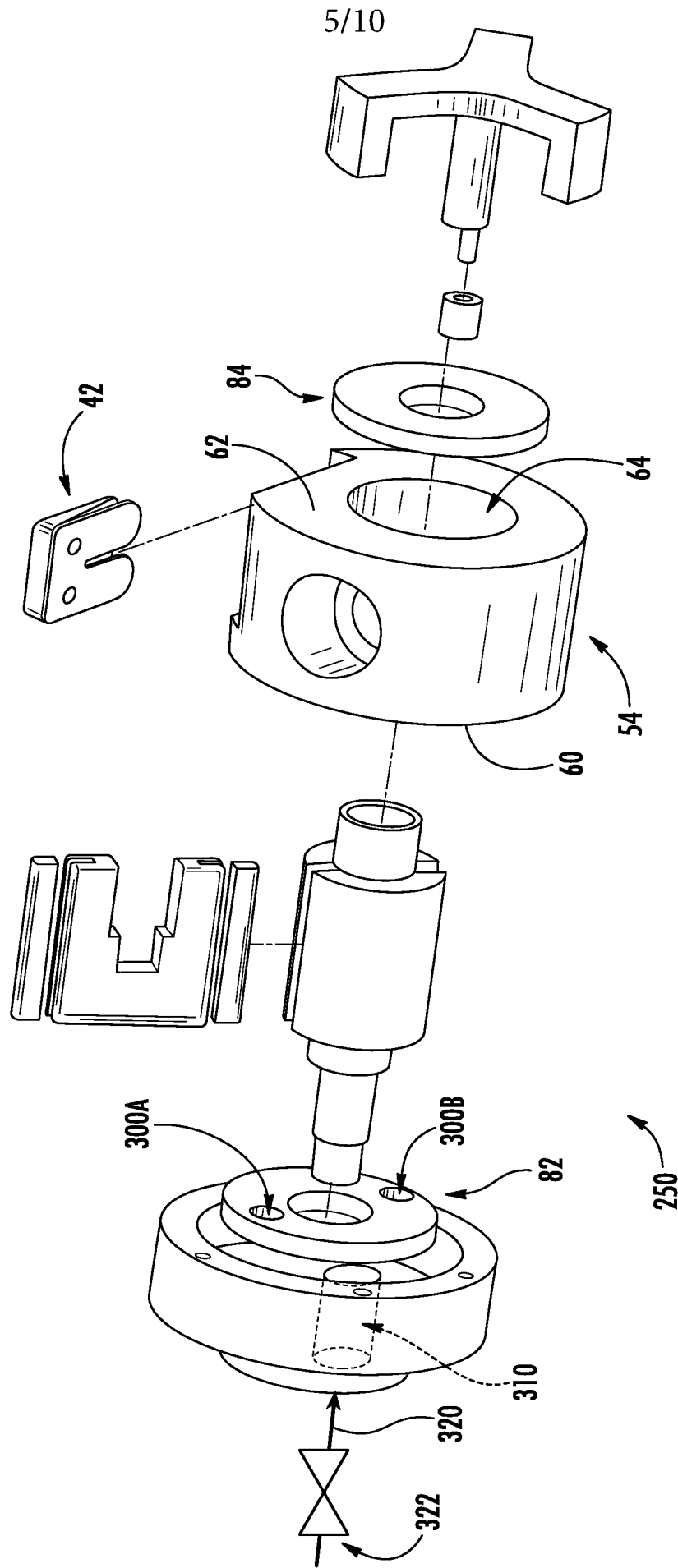


FIG. 7

6/10

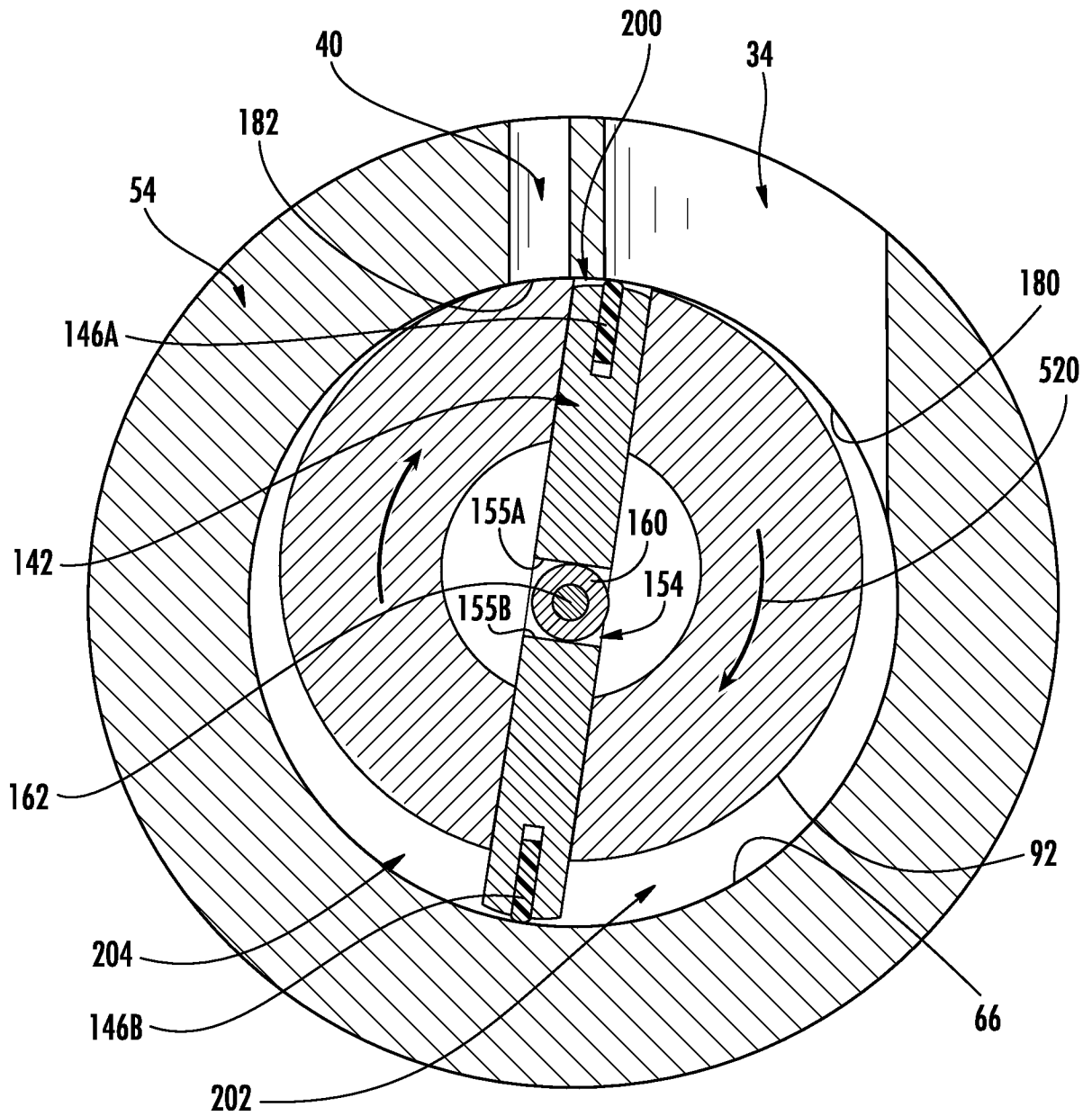


FIG. 8

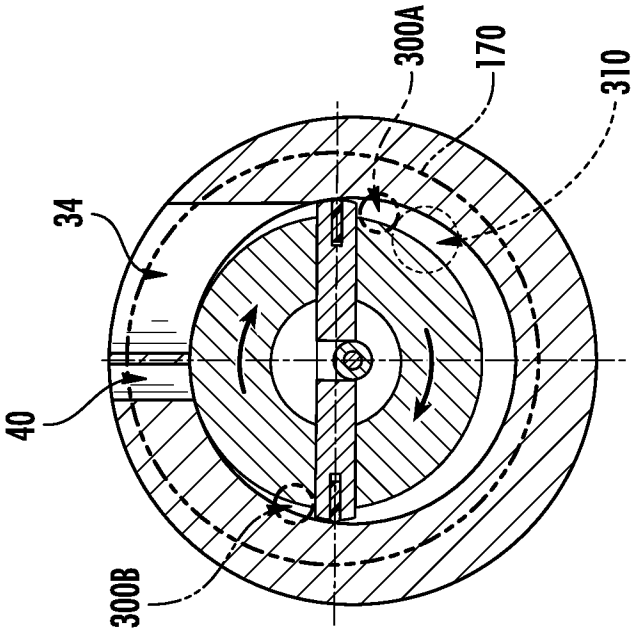


FIG. 9

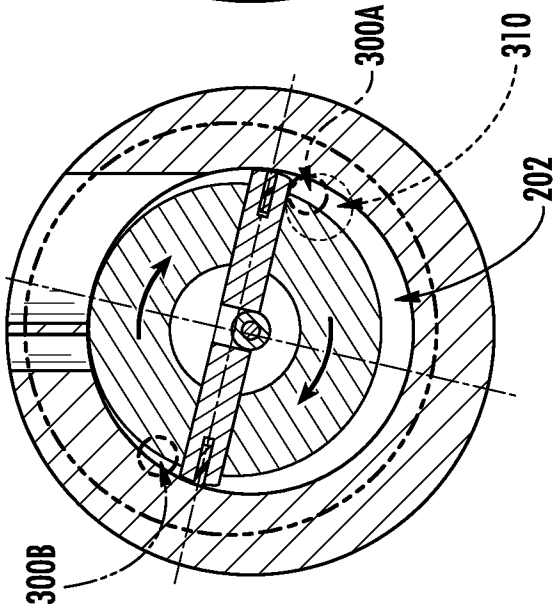


FIG. 10

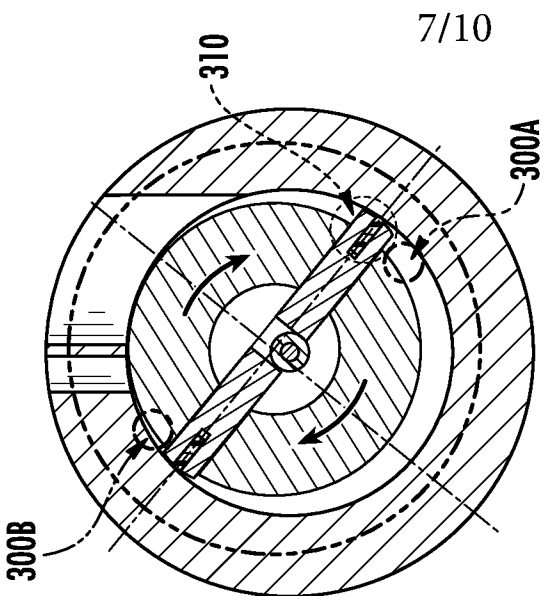


FIG. 11

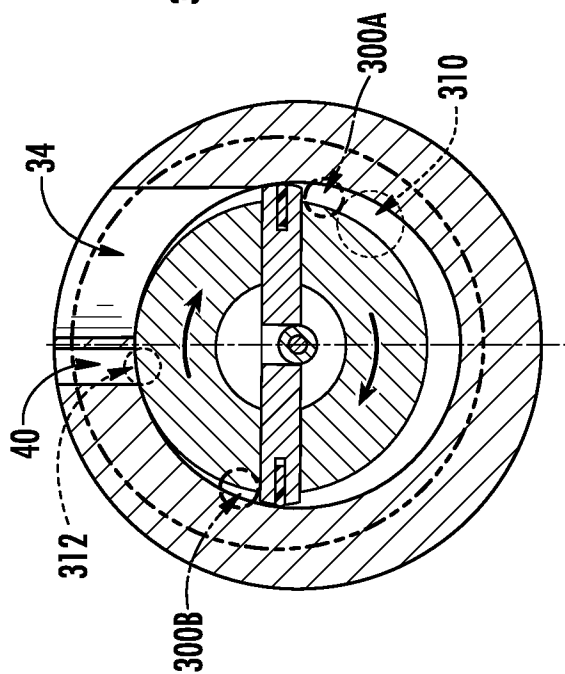


FIG. 12

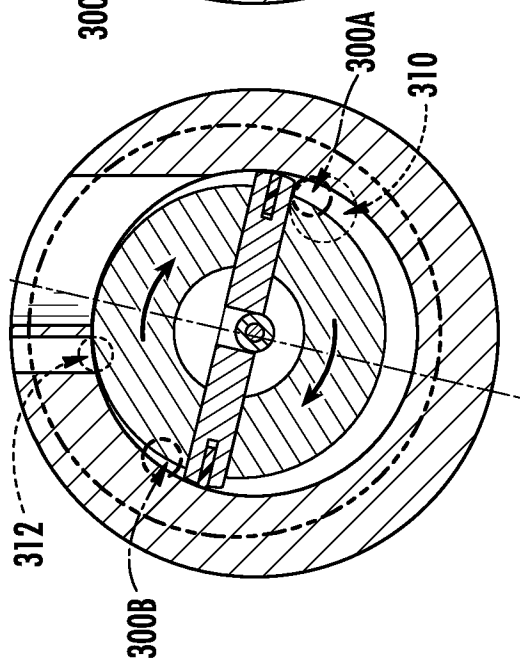


FIG. 13

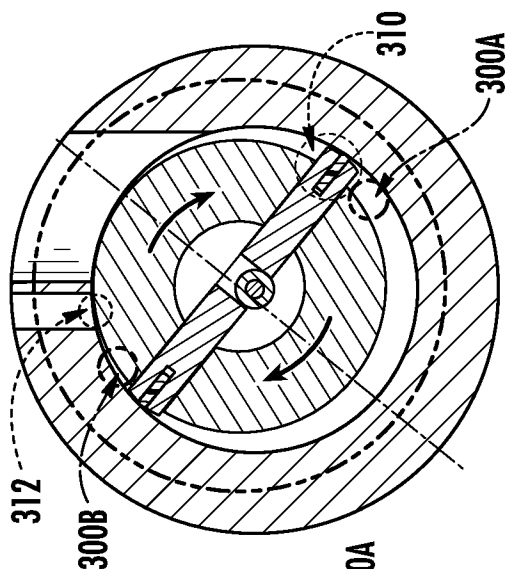


FIG. 14

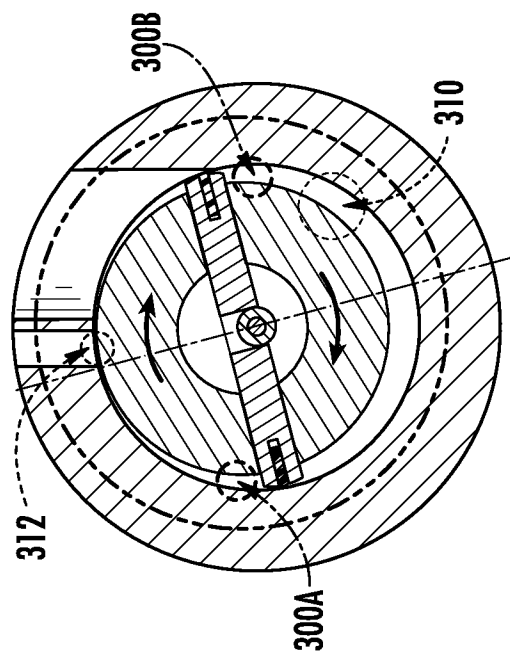


FIG. 17

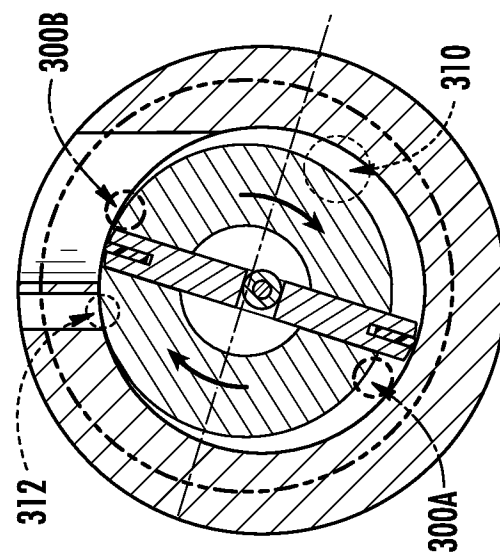


FIG. 16

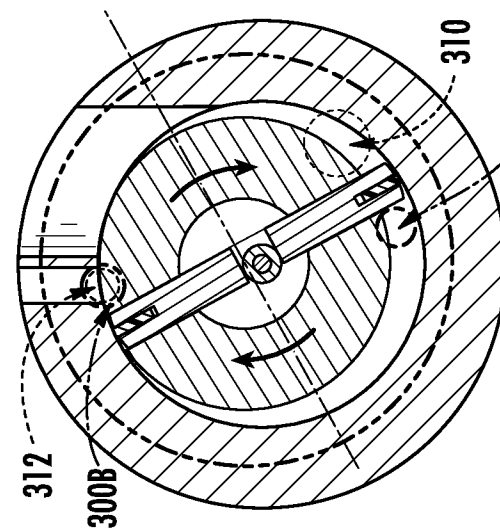


FIG. 15

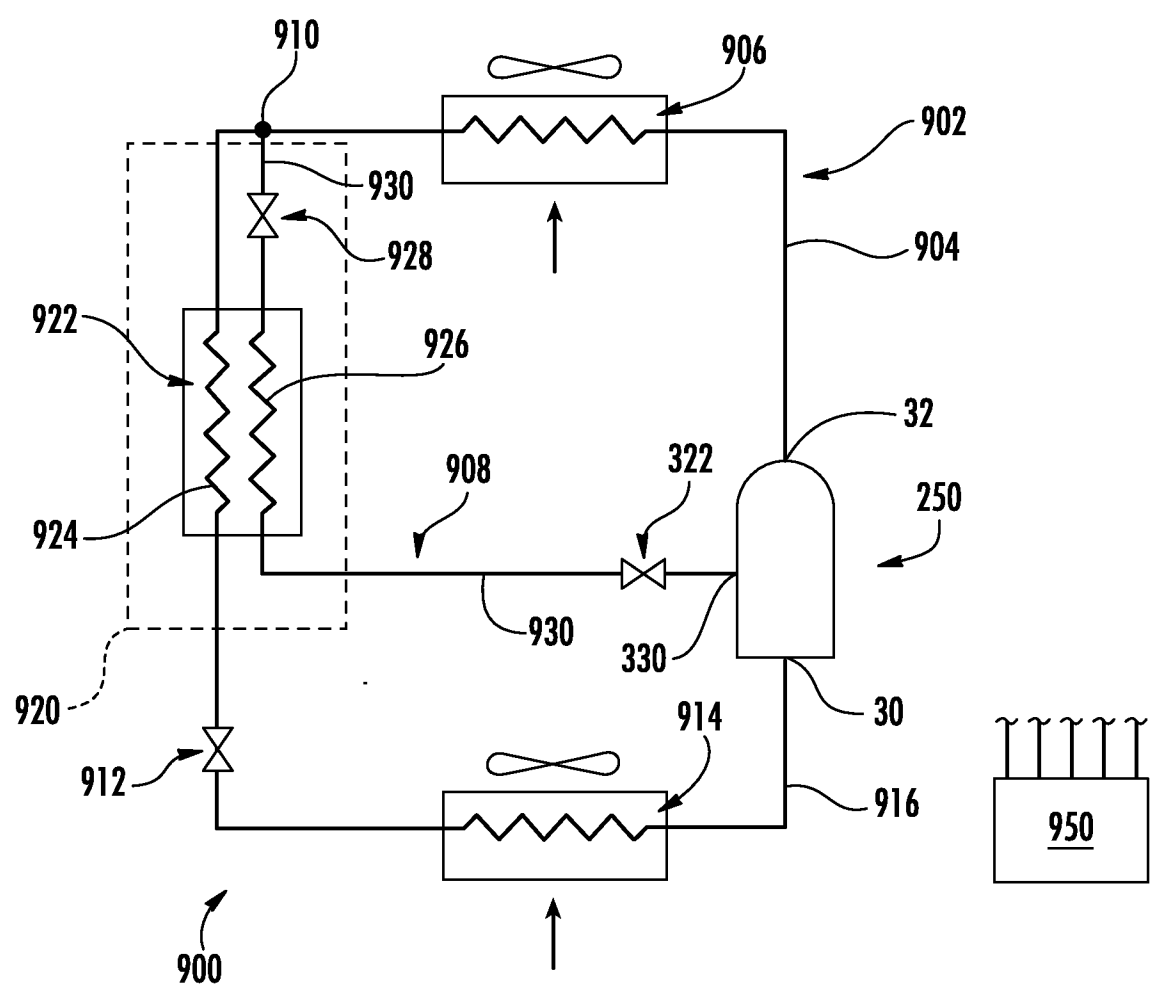
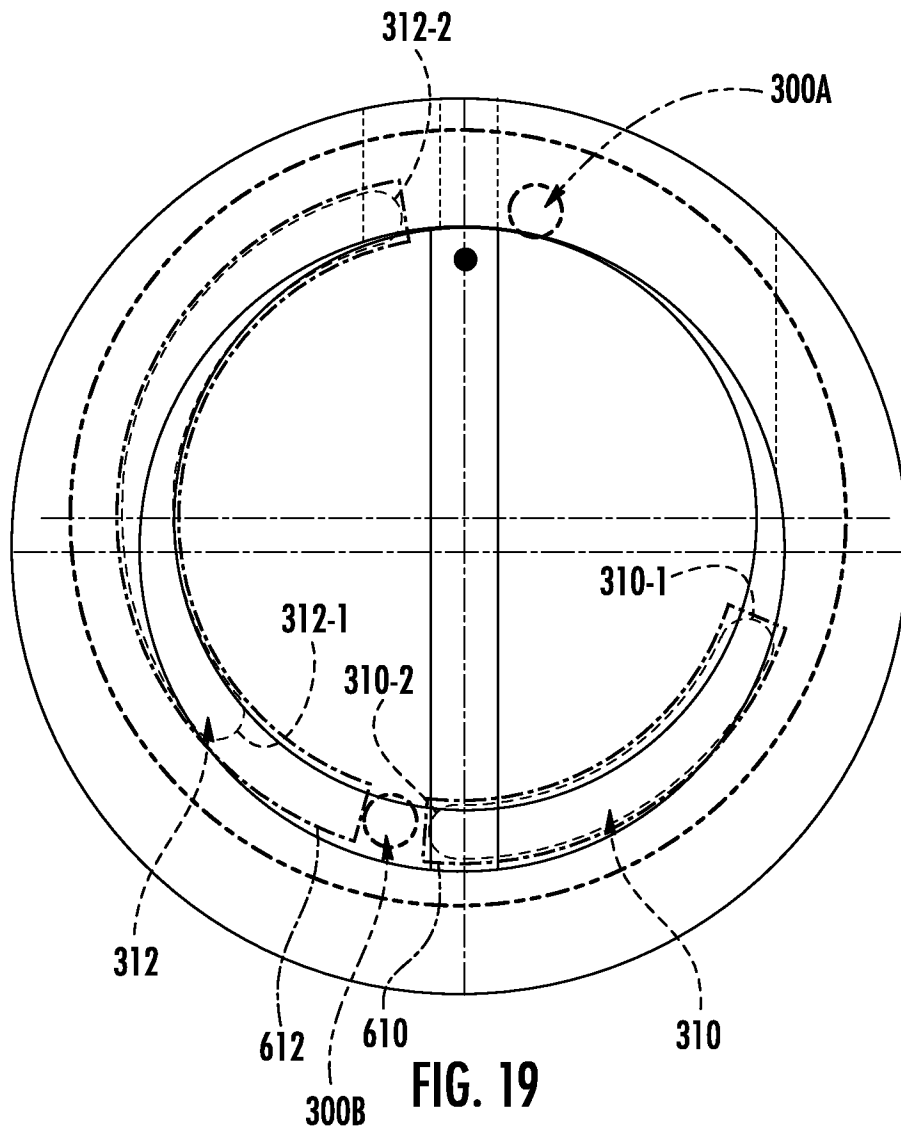


FIG. 18

10/10



INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/026120

A. CLASSIFICATION OF SUBJECT MATTER

INV. F04C18/344 F04C29/12

ADD. F04C28/14

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)

F04C

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	WO 2013/131004 A1 (TORAD ENGINEERING LLC [US]) 6 September 2013 (2013-09-06)	1-4, 8-12, 17-20
Y	figures 2,5,11,12,15c,25,29,30	13-16,21
A	paragraph [0095] - paragraph [0101] paragraph [0136] - paragraph [0139]	5,7
Y	CN 203 432 134 U (GUANGDONG CHANGLING AIR CONDITIONER AIR CONDITIONER MFG CO LTD) 12 February 2014 (2014-02-12) abstract; figure	13-16,21
A	WO 2010/077812 A1 (CARRIER CORP [US]; AWWAD NADER S [US]; STOCKBRIDGE MICHAEL [US]) 8 July 2010 (2010-07-08) paragraphs [0007], [0015] - [0025] abstract; figure 1	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

3 June 2016

Date of mailing of the international search report

13/06/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Bocage, Stéphane

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/026120

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013131004 A1	06-09-2013	CN 104271960 A	07-01-2015
		EP 2820308 A1	07-01-2015
		US 2015064043 A1	05-03-2015
		WO 2013131004 A1	06-09-2013

CN 203432134 U	12-02-2014	NONE	

WO 2010077812 A1	08-07-2010	CN 102272541 A	07-12-2011
		EP 2379959 A1	26-10-2011
		HK 1164989 A1	25-07-2014
		US 2011247350 A1	13-10-2011
		WO 2010077812 A1	08-07-2010
