(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 December 2010 (02.12.2010)

PCT

(10) International Publication Number
WO 2010/138511 A2

(51) International Patent Classification:
F04B 53/14 (2006.01) *F16C 33/02* (2006.01)
F04B 53/18 (2006.01) *F04B 1/04* (2006.01)

(21) International Application Number:
PCT/US2010/036075

(22) International Filing Date:
25 May 2010 (25.05.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/181,929 28 May 2009 (28.05.2009) US

(71) Applicant *(for all designated States except US)*: **CARRIER CORPORATION** [US/US]; 1 Carrier Place, Farmington, CT 06489 (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **FLANIGAN, Paul, J.** [US/US]; 8660 Backstrecth Pth, Cicero, NY 13039 (US).

(74) Agent: **MILLER, Thomas, A.**; Miller, Mathias & Hull, One North Franklin Street, Suite 2350, Chicago, IL 60606 (US).

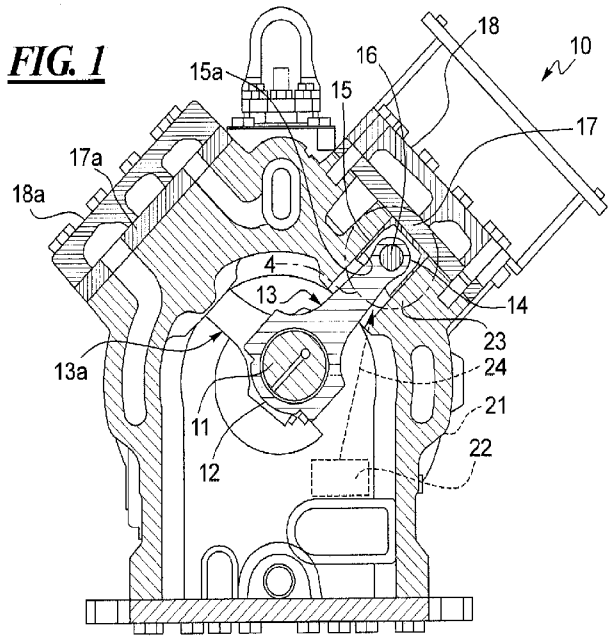
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, 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, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: RECIPROCATING COMPRESSOR WRIST PIN BEARING AND LUBRICATION PASSAGEWAY



(57) **Abstract**: Reciprocating compressors (10) are disclosed that provide enhanced wear characteristics for wrist pins (16) and connecting rods (13) with small pistons (15) such as reciprocating compressors (10) for higher pressure working fluids like CO2. One disclosed compressor (10) includes at least one eccentric (11) and a connecting rod (13) comprising a proximal end (12) and a distal end (14). The proximal end (12) of the connecting rod (13) includes a proximal through opening (26) providing a proximal bearing surface (28, 29) that is connected around the eccentric (11). The distal end (14) of the connecting rod (13) includes a distal through opening (27) forming a distal bearing surface (27a) lined with a bearing insert (37) that is connected around a wrist pin (16). The wrist pin (16) is connected to an interior (15) of the piston (15). The distal end (14) of the connecting rod (13) also includes a lubricant passageway (39, 38) extending through the distal end (14) of the connecting rod (13) and through the bearing insert (37) to the wrist pin (16). The piston (15) is movable within a cylinder (23) to compress a working fluid.

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RECIPROCATING COMPRESSOR WRIST PIN BEARING AND LUBRICATION PASSAGEWAY

BACKGROUND

Cross-Reference to Related Application

[0001] This is a non-provisional patent application claiming priority under 35 USC §119(e) to US Provisional Patent Application Serial No. 61/181,929 filed on May 28, 2009.

Technical Field:

[0002] This disclosure relates to reciprocating compressors and, more specifically, to reciprocating compressors suitable for use with carbon dioxide refrigerant. Still more specifically, this disclosure relates to an improved connecting rod/wrist pin design for more reliable operation of such reciprocating compressors.

Description of the Related Art:

[0003] Compressors are utilized in many applications to compress various fluids. One type of compressor is a reciprocating piston compressor. In a reciprocating piston compressor, a crankshaft rotates at least one eccentric. Each eccentric in turn drives a connecting rod that is connected to a piston by a wrist pin. The connecting rod typically includes a larger proximal end lined with a bearing that receives the eccentric. The connecting rod also includes a smaller distal end, also equipped with a bearing that is typically received on a wrist pin that connects the connecting rod to the piston.

[0004] A good deal of friction is encountered in these connecting rod bearings from transmitting the force of actuation to the piston. Thus, it is known in the art to provide lubricant to the various moving surfaces in a compressor to facilitate the movement of the piston and the connecting rod. Typically, a lubricant is driven into a lubricant path inside the crankshaft where it is distributed to the feedholes for each eccentric and the main

bearings. Lubricant may also be communicated up through the connecting rod to the distal end or wrist pin bearing to lubricate the wrist pin and corresponding bearing in the piston.

[0005] In a reciprocating compressor, the wrist pin carries the load for compressing the gas. The wrist pin has to fit inside the piston so the area for the bearing surface is limited by the size of the piston bore that receives the wrist pin. Further, the wrist pin requires lubrication to maintain an oil film to reliably carry the load.

[0006] In CO_2 compressors, for example, the piston bore is small compared to other compressors so the wrist pin bearing surface area is small relative to the high loads required for a CO_2 compressor. The space inside the piston is also small which inhibits designs relying upon splash-feed lubrication to the wrist pin. Because of the problems associated with getting lubricant delivered to the wrist pin, the typical materials such as aluminum for the connecting rod and steel for the wrist pin are not sufficiently reliable.

[0007] U.S. Patent No. 7,128,528 discloses a two-stage CO_2 compressor and a scroll-type CO_2 compressor that relies upon special materials for its bearings, such as graphite, but does not address the problems associated with stress on wrist pins and delivering lubricant to wrist pins of reciprocating CO_2 compressors or similar reciprocating compressors. U.S. Publication 2006/0171824 discloses a circuitous lubricant delivery route through the central portion of the connecting rod to the wrist pin. However, this design does not permit inclusion of a bearing surrounding the wrist pin and therefore does not completely address the problem of premature wear or failure of a steel wrist pin.

[0008] Thus, there is a need for an improved reciprocating compressor wrist pin/bearing/connecting rod design that provides reliable lubricant delivery to the wrist pin and reliable, long-term operation of the wrist pin and connecting rod.

SUMMARY OF THE DISCLOSURE

[0009] Improved compressors are disclosed that provide better wear characteristics for wrist pins and connecting rods of reciprocating compressors with small pistons, such as reciprocating compressors for higher pressure working fluids like CO_2.

[0010] One disclosed compressor comprises at least one eccentric and a connecting rod comprising a proximal end and a distal end. The proximal end of the connecting rod comprises a proximal through opening forming a proximal bearing surface that is connected around the eccentric. The distal end of the connecting rod comprises a distal through opening that forms a distal bearing surface that may be lined with a bearing insert that may, in turn, be lined with a bearing material that may comprise carbon, e.g., graphite. The bearing insert is connected around a wrist pin. The wrist pin is connected to an interior of the piston. The piston is movable within a cylinder to compress a working fluid.

[0011] The distal end of the connecting rod may further comprise a lubricant passageway extending through the distal end of the connecting rod and through the lined bearing insert to provide fluid communication to the wrist pin. A lubricant supply system may be provided for supplying lubricant, or splash feeding lubricant, to the interior of the piston and the wrist pin through the lubricant passageway.

[0012] Other advantages and features will be apparent from the following detailed description when read in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] For a more complete understanding of the disclosed methods and apparatuses, reference should be made to the embodiments illustrated in greater detail in the accompanying drawings, wherein:

[0014] FIG. 1 is a sectional view of a compressor made in accordance with this disclosure;

[0015] FIG. 2 is a side sectional view of a connecting rod of the compressor shown in FIG. 1;

[0016] FIG. 3 is an exploded view of the connecting rod shown in FIGS. 1-2;

[0017] FIG. 4 is an enlarged view of the area labeled 4 of FIG. 1, particularly illustrating the distal end of the connecting rod, bearing, wrist pin and piston;

[0018] FIG. 5 is a partial exploded view of two bearing rods, wrist pins, pistons and seals of the compressor shown in FIG. 1; and

[0019] FIG. 6 is an enlarged sectional view of the bearing insert, wrist pin and lubricant passageway.

[0020] It should be understood that the drawings are not necessarily to scale and that the disclosed embodiments are sometimes illustrated diagrammatically and in partial views. In certain instances, details which are not necessary for an understanding of the disclosed methods and apparatuses or which render other details difficult to perceive may have been omitted. It should be understood, of course, that this disclosure is not limited to the particular embodiments illustrated herein.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

[0021] A compressor 10 is illustrated in FIG. 1 with a motor (not shown) that drives the crankshaft (not shown) that rotates the eccentric 11 received within the proximal ends 12 of the connecting rod 13. The connecting rod 13 includes a distal end 14 that is connected to a piston 15 by a wrist pin 16, as best seen in FIGS. 4-5. While only a single connecting rod 13 is illustrated in FIG. 1, compressors such as those shown at 10 in FIG. 1 typically include four connecting rods 13 or two pairs of connecting rods 13, one such pair of parallel connecting rods 13 being illustrated in FIG. 5. Another connecting rod 13a is also illustrated in FIG. 1 and is disposed in a parallel relationship with an additional connecting rod 13a (not shown). The connecting rods 13, 13a may be fabricated from aluminum, an aluminum alloy, various steels, cast irons or magnesium alloys.

[0022] The pistons 15 shown in FIGS. 1 and 5 move towards and away from the valve plate 17 and head 18 to compress a gas, such as a refrigerant, while a corresponding pair of pistons (not shown) associated with a corresponding pair of connecting rods 13a move towards and away from the valve plate 17a and head 18a.

[0023] The compressor 10 includes the casing 21 which, in combination with a lubricant supply reservoir shown schematically at 22, provides a lubricant distribution network 24 that feeds a lubricant to the required areas, such as within each cylinder 23 defined by the casing 21. Only one cylinder 23 is shown in FIGS. 1 and 5 but a typical compressor 10 will include four cylinders 23. In the embodiment illustrated, the lubricant delivery to the cylinder 23 through various passageways, only one of which is shown schematically at 24, is typically referred to as a "splash-feed" system.

[0024] Turning to FIGS. 2-3, the connecting rods 13 include a proximal through opening 26 and a distal through opening 27. The proximal through opening 26 provides bearing

surfaces 26a, 26b for the eccentric 11 but is preferably lined by a bearing or bearing assembly, such as a pair of connecting semi-cylindrical rod bearings 28, 29. In the embodiment illustrated in FIGS. 1-3, the connecting rod 13 is not a unitary structure but, instead, includes a lower semi-cylindrical portion 31 that defines the proximal end 12 and that is connected to the upper portion 32 that defines the distal end 14 and the distal through opening 27 of the connecting rod 13. The lower portion 31 may be connected to the upper portion 32 by a variety of means, such as the fastening elements 33, locating pins 34 and washers 35 as shown in FIG. 3. Of course, the connecting rods 13, 13a may also be a unitary structure, depending upon the design of the compressor 10.

[0025] FIG. 3 also provides a perspective view of the bearing insert 37 disposed within the distal through opening 27 and which receives or is connected around the wrist pin 16. The bearing insert 37 is preferably fabricated with a metal backing, such as a steel backing layer, lined with a carbon containing bearing material, such as a graphite containing bearing material. A sintering layer, such as a bronze sintering layer may be used to adhere the graphite containing later to the steel backing. The bearing material containing carbon and/or graphite may also include silica and a resin. The function of the bearing insert 37 is to reduce friction and wear on the wrist pin 16. By employing a bearing insert 37 lined with a carbon or graphite bearing material for the distal through opening 27 and wrist pin 16, a lubricant delivery hole or aperture 38 may be provided in the insert 37 to provide lubricant delivery to the wrist pin 16. FIG. 3 also illustrates a hole or aperture 39 passing through the surface 41 of the distal end 14 of the connecting rod 13. As illustrated in FIG. 4, the aligned holes 39, 38 provide a lubricant passageway to the wrist pin 16. The hole 38 may be machined or drilled into the bearing insert 37 initially, or the hole 38 may be machined/drilled through the insert 37 after the bearing insert 37 is pressed into the distal

through opening 27 of the connecting rod 13. The latter procedure would, of course, eliminate alignment problems during assembly. In FIG. 4, the lubricant passageway provided by the holes 39, 38 is disposed more or less diametrically opposite the wrist pin 16 from the eccentric 11. An alternative lubricant passageway 39a, 38a is also illustrated in phantom in FIG. 4 which is disposed at an angle θ with respect to the intersection of line 45 that bisects the wrist pin 16 and eccentric 11 and a central axis 16a of the wrist pin 16. The combination of the hole 38 in the bearing insert 37 and the hole 39 in the distal end 14 of the connecting rod 13 provides a means for delivering lubricant to the wrist pin 16 while still providing a bearing insert 37 for the wrist pin 16. Thus, the design illustrated in FIGS. 3-4 provides a unique combination of splash-feed lubricant delivery to the wrist pin 16 as well as reduced frictional bearing support for the wrist pin 16 in the form of the bearing insert 37.

[0026] The bearing insert 37 may be a steel or metal backing lined with a carbon or graphite containing bearing material with an optional sintering layer disposed between the backing and the carbon or graphite containing bearing material. One suitable insert includes a steel backing, a bronze sintering layer and a graphite resin bearing material layer that includes graphite, silica and resin. Such inserts are available from Taiho Kogyo Co., Ltd. of Japan.

[0027] The lubricant passageway 39, 38 to the wrist pin 16 provided by the holes or apertures 38, 39 enables lubricant to be delivered to the wrist pin 16 through a simple splash-feed system illustrated schematically at 22, 24 and the directional arrows in FIG. 4. Intricate passageways through the upper portions 32 of the connecting rods 13 are avoided, thereby reducing the cost of the connecting rods 13. Because lubricant is delivered to the interiors 15a of the pistons 15 anyway, the lubricant delivery system of the compressor 10

need not be modified to accommodate the modified connecting rods 13 and bearing inserts 37 disclosed herein.

[0028] FIG. 5 provides a perspective view of a pair of connecting rods 13 that illustrates the relative size of the wrist pins 16 and pistons 15. The O-rings or seals for the pistons are shown at 41, 42.

[0029] The working fluid is CO_2. Also, the working fluid may be R410A (http://www51.honeywell.com/sm/410a/index.html) or another environmentally-friendly refrigerants or working fluids.

[0030] FIG. 6 schematically illustrates the flow of lubricant through the opening 38 of the insert to the wrist pin 16 as a result of the oscillating vertical movement of the outer surface 16b of the wrist pin 16 towards and away from the inner surface 37a of the bearing insert 37 as the piston 15 moves up and down during operation of the compressor 10. The oil film 49 between the surfaces 16b, 37a is formed by the pumping action of the load on the wrist pin 16 in the direction of the arrow 50, which forces oil through the opening 38 in the top 37b of the insert 37 towards the bottom 37c of the insert 37 once per stroke. While not shown in FIG. 6, the inner surface 37a may be lined with a carbon or graphite containing bearing material with an optional sintering layer disposed between the backing and the carbon or graphite containing bearing material as described above.

Industrial Applicability

[0031] Reciprocating compressors 10 are disclosed that provide better wear characteristics for wrist pins 16 and connecting rods 13 designed for higher pressure working fluids like CO_2, R410A and other environmentally friendly higher pressure

working fluids that will be apparent to those skilled in the art. The distal end 14 of the connecting rod 13 comprises a distal through opening 27 forming a distal bearing surface 27a lined with a lined bearing insert 37 that slidably and frictionally receives the wrist pin 16. The wrist pin 16 is press-fit into an interior 15a of the piston 15, but the wrist pin 16 can rotate within the bearing insert 37. The bearing insert may include a metal backing lined with a carbon or graphite containing bearing material. The piston 15 is movable within a cylinder 23 to compress a working fluid, such as CO_2 or R410A. Other higher pressure working fluids will be apparent to those skilled in the art. The lined bearing insert 37 may be combined with a splash-feed lubricant delivery system provided by a hole 39 through the distal end 14 of the connecting rod 13 and a corresponding hole 38 through the bearing insert 37. Thus, an improved bearing insert 37 for the wrist pin 16 is disclosed. An improved splash-feed lubricant delivery system 22, 24, 39 for the wrist pins 16 is also disclosed. Finally, these two developments may be practiced separately or combined in a single embodiment.

[0032] While only certain embodiments have been set forth, alternatives and modifications will be apparent from the above description to those skilled in the art. These and other alternatives are considered equivalents and within the spirit and scope of this disclosure and the appended claims.

CLAIMS:

1. A compressor (10) comprising:

at least one eccentric (11),

a connecting rod (13) comprising a proximal end (12) and a distal end (14),

the proximal end (12) of the connecting rod (13) comprising a proximal through opening (26) forming a proximal bearing surface (28, 29) connected around the eccentric (11),

the distal end (14) of the connecting rod (13) comprising a distal through opening (27) forming a distal bearing surface lined with a bearing insert (37) that is lined with a bearing material, the bearing insert (37) connected around a wrist pin (16),

the distal end (14) of the connecting rod (13) further comprises a lubricant passageway (39, 38) extending through the distal end (14) of the connecting rod (13) and through the bearing insert (37) to the wrist pin (16),

the wrist pin (16) connected to an interior (15) of the piston (15), the piston (15) being movable within a cylinder (23) to compress a working fluid.

2. The compressor (10) of claim 1 wherein the connecting rod (13) is fabricated from aluminum or an aluminum alloy.

3. The compressor (10) of claim 1 further comprising a lubricant supply system (22, 24) for supplying lubricant to the interior (15) of the piston (15) and the wrist pin (16) through the lubricant passageway (39, 38).

4. The compressor (10) of claim 1 further comprising a plurality of said eccentrics (11), a plurality of said connecting rods (13, 13a), a plurality of said wrist pins (16), a plurality of lined bearing inserts (37), and a plurality of said pistons (15).

5. The compressor (10) of claim 1 wherein the lubricant passageway (39, 38) through surface of the distal end (14) of the connecting rod (13) and the bearing insert (37) is disposed opposite the wrist pin (16) from the eccentric (11).

6. The compressor (10) of claim 1 wherein the working fluid is CO_2 or R410A.

7. The compressor (10) of claim 1 wherein the bearing material comprises carbon.

8. The compressor (10) of claim 7 wherein the carbon is graphite.

9. The compressor (10) of claim 7 wherein the bearing material comprises graphite, silica and resin.

10. A compressor (10) comprising:

at least one eccentric (11),

a connecting rod (13) comprising a proximal end (12) and a distal end (14),

the proximal end (12) of the connecting rod (13) comprising a proximal through opening (26) forming a proximal bearing surface (28, 29) connected around the eccentric (11),

the distal end (14) of the connecting rod (13) comprising a distal through opening (27) forming a distal bearing surface lined with a bearing insert (37) that is lined with a bearing material comprising carbon, the bearing insert (37) connected around a wrist pin (16),

the wrist pin (16) connected to an interior (15) of the piston (15), the piston (15) being movable within a cylinder (23) to compress a working fluid.

11. The compressor (10) of claim 10 wherein the distal end (14) of the connecting rod (13) further comprises a lubricant passageway (39, 38) extending through the distal end (14) of the connecting rod (13) and through the bearing insert (37) to the wrist pin (16),

the compressor further comprising a lubricant supply system (22, 24) for supplying lubricant to the interior (15) of the piston (15) and the wrist pin (16) through the lubricant passageway (39, 38).

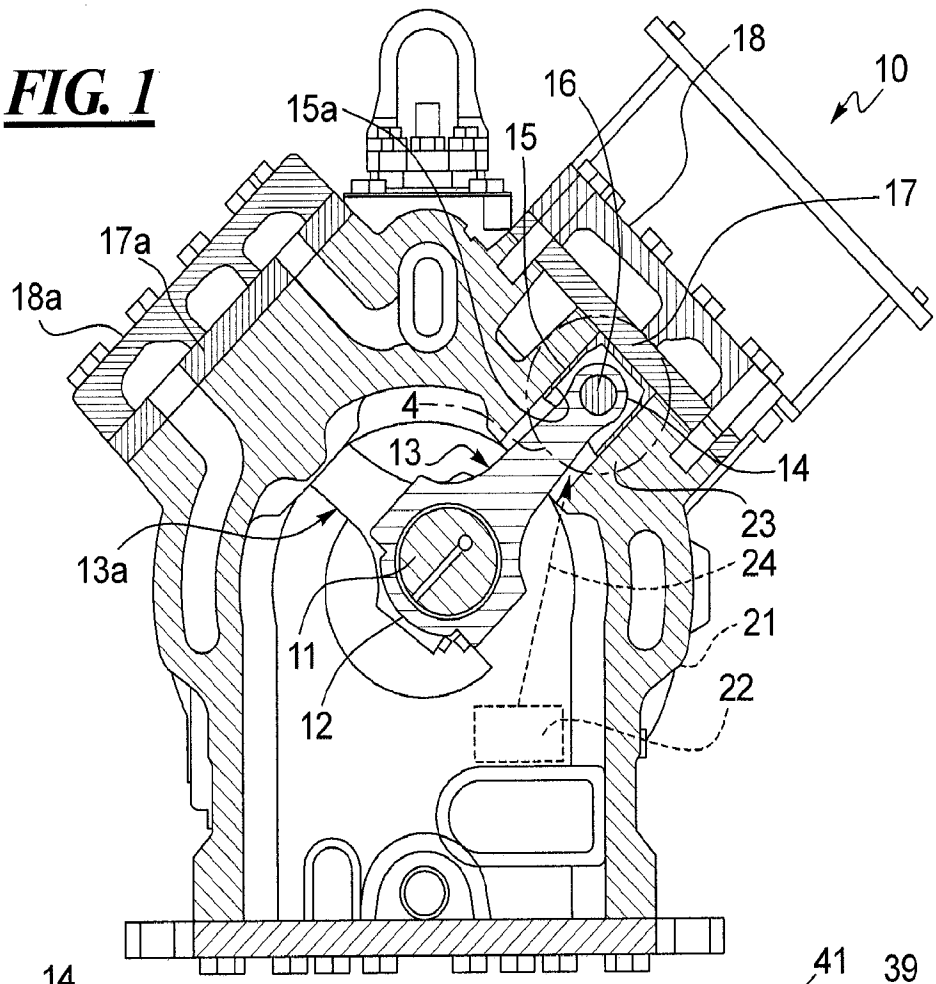
12. The compressor (10) of claim 11 wherein lubricant passageway (39, 38) through surface of the distal end (14) of the connecting rod (13) and the bearing insert (37) is disposed opposite the wrist pin (16) from the eccentric (11).

13. The compressor (10) of claim 10 wherein the bearing material comprises graphite.

14. The compressor (10) of claim 12 wherein the bearing material comprises graphite, silica and resin.

15. The compressor (10) of claim 10 wherein the working fluid is CO_2 or R410A.

FIG. 1



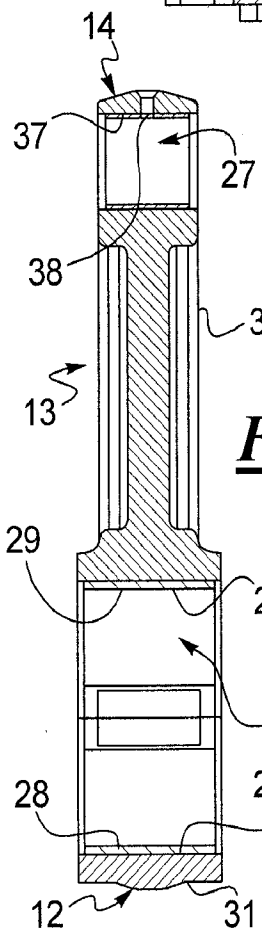


FIG. 2

FIG. 3

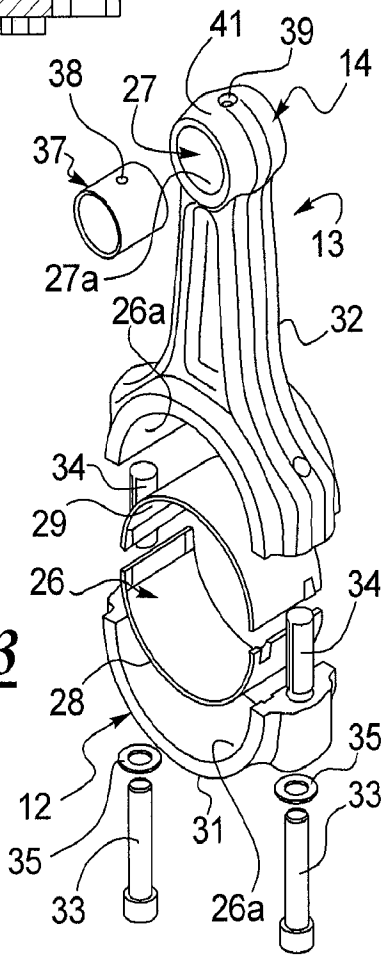


FIG. 4

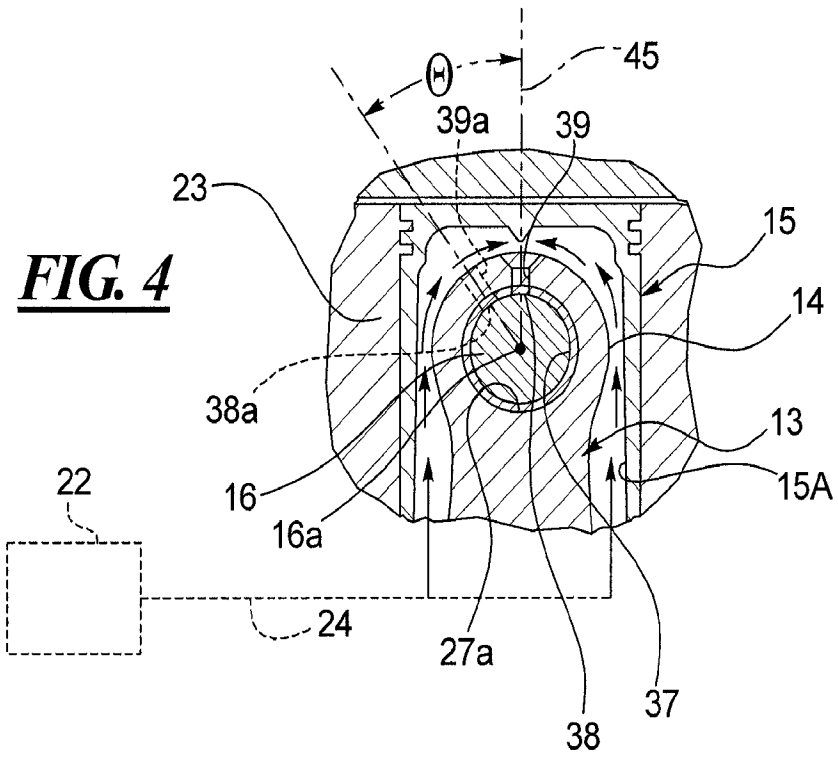


FIG. 5

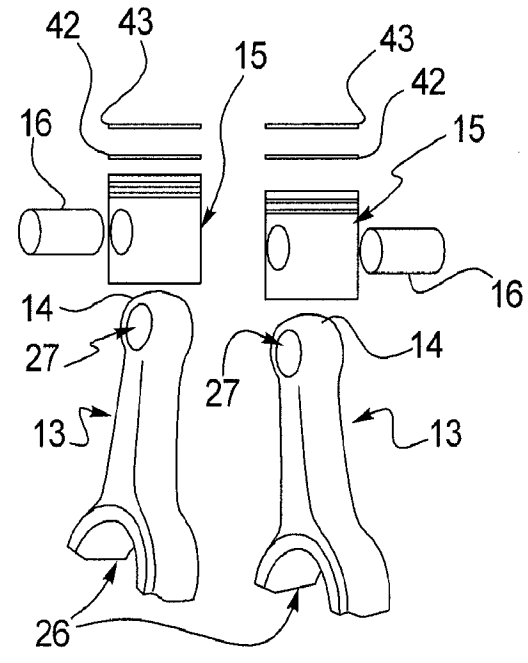
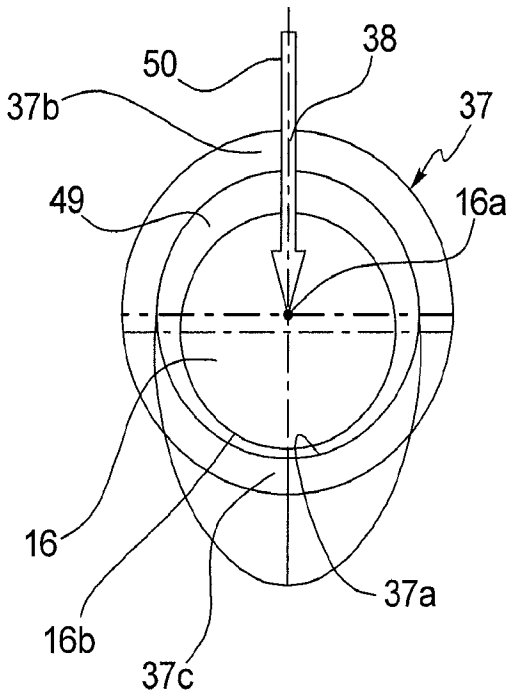



FIG. 6