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(54) Title: PISTON COMPRESSOR WITH GLASS CYLINDER AND GRAPHITE PISTON

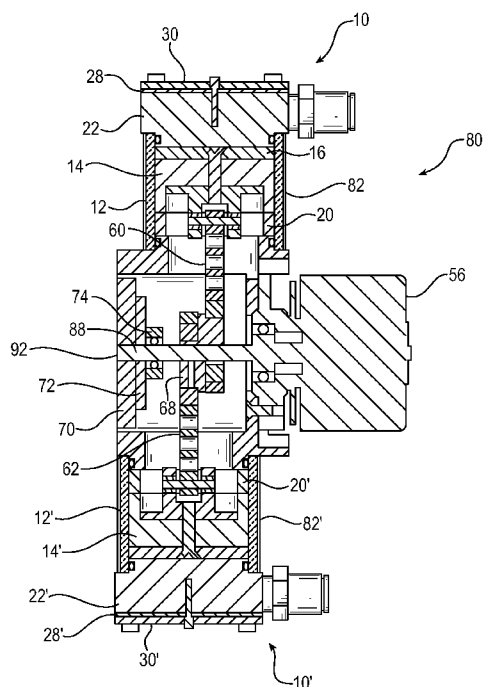


FIG. 5

(57) **Abstract:** A pump/compressor includes at least one piston assembly for pumping a fluid from a fluid inlet to a fluid outlet, a housing configured to support the piston assembly, and an eccentric actuator that is enclosed within the housing. The piston assembly includes a glass cylinder, and a graphite piston that is actuated by the eccentric actuator to move within the glass cylinder, wherein movement of the piston drives the fluid from the fluid inlet to the fluid outlet. A motor drives a drive shaft that in turn drives the eccentric actuator to actuate the graphite piston. A housing cover of the housing receives a motor shaft support bearing that supports an end of the drive shaft opposite from an end that is driven by the motor. The pump/compressor may be a twin head pump/compressor with two oppositely positioned piston assemblies actuated by a split eccentric actuator.



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**TITLE: PISTON COMPRESSOR WITH GLASS CYLINDER
AND GRAPHITE PISTON**

Related Application Data

5 This application claims priority to U.S. Provisional Application Serial No. 61/971,111, filed on March 27, 2014, the contents of which is incorporated here by reference.

Field of Invention

10 The present invention relates generally to fluid pumps and compressors including gas pumps and compressors, and more particularly to piston compressors, piston pumps, and motor driven pumps and compressors and enhanced piston assemblies for use in such pumps and compressors.

Background of the Invention

15 Compact pumps and compressors, including vacuum pumps and air and gas compressors, are utilized in a variety of applications. In medical applications in particular, such pumps and compressors may be used in oxygen concentrator systems that supply oxygen to users as a medical replacement for an oxygen tank.

20 Other uses for such pumps and compressors include nitrogen concentrators for food preservation. Pumps and compressors in such and similar applications typically are battery powered with long-life batteries, and operate at pressures of approximately 20 psi and at flow rates of 30 L/min or less.

 As such, it is important for pumps and compressors in oxygen concentrators and similar devices to be compact for user portability and discreetness of operation.

25 It is also important for such pumps and compressors to be essentially noiseless, and to have efficient air flow through the pump/compressor. It is also important for the pump or compressor to incorporate an efficient cooling mechanism. Configurations of conventional pumps and compressors, however, have proven to be deficient in

30 these aspects.

Summary of the Invention

A need in the art exists for an improved pump or compressor that overcomes the above deficiencies of conventional configurations. A pump/compressor includes an eccentric actuated piston assembly, the piston assembly including a graphite piston that is actuated by an eccentric actuator and moves within a glass cylinder. The fit between the glass cylinder and graphite piston acts as a seal to prevent leakage during the compression or intake stroke, with no other dynamic sealing element being provided. Efficiency is therefore enhanced without the generation of significant heat due to reduced frictional losses, as compared to conventional configurations.

An aspect of the invention, therefore, is a pump/compressor. In exemplary embodiments, the pump/compressor includes at least one piston assembly for pumping a fluid from a fluid inlet to a fluid outlet, a housing configured to support the piston assembly, and an eccentric actuator that is enclosed within the housing. The piston assembly includes a glass cylinder, and a graphite piston that is actuated by the eccentric actuator to move within the glass cylinder, wherein movement of the piston drives the fluid from the fluid inlet to the fluid outlet. A motor drives a drive shaft that in turn drives the eccentric actuator to actuate the graphite piston. The housing may include a motor support face to which the motor is attached, and a housing cover that forms an outer face of the housing opposite to the motor support face. The housing may receive a motor shaft support bearing that supports an end of the drive shaft opposite from an end that is driven by the motor.

In exemplary embodiments, the pump/compressor is a twin head pump compressor. The twin head pump/compressor includes a housing including a first end and a second end opposite the first end. A first piston assembly is attached to the first end of the housing for pumping a fluid from a first fluid inlet to a first fluid outlet, and a second piston assembly is attached to the second end of the housing for pumping a fluid from a second fluid inlet to a second fluid outlet. A split eccentric actuator is enclosed within the housing. Each of the first and second piston assemblies includes a glass cylinder, and a graphite piston that is actuated by the split eccentric actuator to move within the glass cylinder, wherein movement of the pistons drives the fluid from the fluid inlets to the fluid outlets.

These and further features of the present invention will be apparent with reference to the following description and attached drawings. In the description and drawings, particular embodiments of the invention have been disclosed in detail as being indicative of some of the ways in which the principles of the invention may be employed, but it is understood that the invention is not limited correspondingly in scope. Rather, the invention includes all changes, modifications and equivalents coming within the spirit and terms of the claims appended hereto. Features that are described and/or illustrated with respect to one embodiment may be used in the same way or in a similar way in one or more other embodiments and/or in combination with or instead of the features of the other embodiments.

Brief Description of the Drawings

Fig. 1 is a schematic diagram depicting a perspective and exploded view of an exemplary piston assembly for use in a pump or compressor in accordance with embodiments of the present invention.

Fig. 2 is a schematic diagram depicting a perspective and exploded view of an exemplary pump housing and motor assembly for use in a pump or compressor in accordance with embodiments of the present invention.

Fig. 3 is a schematic diagram depicting a motor side perspective view of an exemplary pump or compressor system in accordance with embodiments of the present invention.

Fig. 4 is a schematic diagram depicting a housing side perspective view of the exemplary pump or compressor system of Fig. 3.

Fig. 5 is a schematic diagram depicting a side cross-sectional view of the exemplary pump or compressor system of Figs. 3 and 4.

Detailed Description

Embodiments of the present invention will now be described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. It will be understood that the figures are not necessarily to scale.

Generally, a pump/compressor includes at least one piston assembly for pumping a fluid from a fluid inlet to a fluid outlet, a housing configured to support the piston assembly, and an eccentric actuator that is enclosed within the housing. The piston assembly includes a glass cylinder, and a graphite piston that is actuated by the eccentric actuator to move within the glass cylinder, wherein movement of the piston drives the fluid from the fluid inlet to the fluid outlet.

Fig. 1 is a schematic diagram depicting a perspective and exploded view of an exemplary piston assembly 10 for use in a pump or compressor in accordance with embodiments of the present invention. The piston assembly 10 includes a cylinder 12 that houses a piston 14 that is moveable within the cylinder. In accordance with embodiments of the present invention, the cylinder 12 may be a glass cylinder. For example, the glass cylinder may be formed of a borosilicate glass, although other suitable glass materials may be employed. The piston 14 may be a carbon graphite piston. As further described below, the graphite piston is actuated by an eccentric actuator to move within the glass cylinder, wherein movement of the piston drives the fluid from the fluid inlet to the fluid outlet.

The use of a glass cylinder with a graphite piston reduces friction, which improves the overall efficiency of the pump or compressor in which such a piston assembly is employed. Other advantages of the reduced friction include longer life, reduced noise, reduced size, and reduced friction heating as compared to conventional configurations. The configuration of a glass cylinder and graphite piston creates a dynamic "seal-less" pump or compressor. The fit between the glass cylinder and graphite piston acts as a seal to prevent leakage during the compression or intake stroke, with no other dynamic sealing element being provided. Efficiency is therefore enhanced without the generation of significant heat due to reduced frictional losses, as compared to conventional configurations.

Referring again to Fig. 1, the graphite piston 14 is topped by a support washer 16 that is held in place by a fastener 18, such as for example a machine screw. A first or inner sealing gasket 20 may seal the piston assembly relative to a pump housing (not shown in Fig. 1). A compression head 22 acts as a pump chamber that receives fluid through a fluid inlet 24, and expels fluid via actuation of the piston through a fluid outlet 26. In typical applications, such as for example oxygen concentrators or nitrogen generators referenced above, the fluid may be a

compressed gas, although any suitable fluid may be employed. A second or outer sealing gasket 28 may be provided on an outer face of the compression head for sealing the compression head on the side opposite the piston. As referenced above, however, an additional dynamic sealing element is not required between the graphite
5 piston and the pump head, as the fit between the glass cylinder and graphite piston acts as a seal to prevent leakage during the compression or intake stroke. The piston assembly further may be secured with an outer cover plate 30.

Fig. 2 is a schematic diagram depicting a perspective and exploded view of an exemplary pump or compressor housing and motor assembly 40 for use in a pump
10 or compressor in accordance with embodiments of the present invention. A housing and motor assembly 40 may include a housing 42 that is configured to support at least one piston assembly as described with respect to Fig. 1. In particular, the embodiment depicted in Fig. 2 is configured as a twin head system such that two piston assemblies may be provided, with one piston assembly respectively
15 supported on each of two housing ends on opposite sides of the housing 42. It will be appreciated, however, that a single head configuration also may be employed, in which only one piston assembly is supported on one of the housing ends.

As seen in Fig. 2, the housing 42 may include a first end 44 for supporting a first piston assembly as described in Fig. 1. The first end 44 may include a first
20 recess 46 defined by an outer face 48 and a ridge 50. The recess 46 is configured to receive the inner gasket 20 referenced above, and otherwise operates to align and support the glass cylinder and associated graphite piston relative to the housing. The housing 42 has a second end 52. In twin head embodiments, the second end 52 may have comparable features as the first end 44, including a second recess that
25 receives a second inner gasket, so as to support and align a second piston assembly relative to the housing.

The housing 42 further may have a motor support face 54 to which a motor 56 is attached. In exemplary embodiments, the motor 56 may be a brushless direct current (DC) motor powered by a long-life battery, although any suitable motor may
30 be employed. Lead wires 58 may be provided that couple the motor to a suitable controller, such as an external driver or integrated electronics.

The housing 42 encloses the components that are configured to actuate the one or two piston assemblies when driven by a motor drive shaft (not shown specifically in Fig. 2). A first connecting rod 60 actuates a first piston assembly supported by the first end 44 of the housing, and in the case of a twin head configuration as depicted in Fig. 2, a second connecting rod 62 actuates a second piston assembly supported by the second end 52 of the housing. The first and second connecting rods each respectively may have a support bearing 64 and 66 for supporting the motor drive shaft. A split eccentric 68 may be provided between the connecting rods through which the piston assemblies are actuated when the split eccentric rotates commensurately with the motor drive shaft.

A housing cover 70 may form an outer face of the housing 42 opposite to the motor support face 54. The housing cover 70 may include a motor shaft bearing support 72 that may receive a drive shaft support bearing 74. When fully assembled, the motor shaft support bearing 74 supports an end of the drive shaft opposite from an end that is received by the motor 56.

One or more piston assemblies as described with respect to Fig. 1, and the housing and motor assembly as described with respect to Fig. 2, may be combined into a pump or compressor system. Fig. 3 is a schematic diagram depicting a motor side perspective view of an exemplary pump or compressor system 80 in accordance with embodiments of the present invention. Fig. 4 is a schematic diagram depicting a housing side perspective view of the exemplary pump or compressor system 80 of Fig. 3. Fig. 5 is a schematic diagram depicting a side cross-sectional view of the exemplary pump or compressor system of Figs. 3 and 4. Because the pump or compressor system 80 includes the components of Figs. 1 and 2, components in Figs. 3-5 are afforded common references numerals as like components of Figs. 1 and 2.

Similarly as above, the embodiment depicted in Figs. 3-5 is configured as a twin head system such that two piston assemblies may be provided, with one piston assembly respectively supported on each of two housing ends on opposite sides of the pump housing. It will be appreciated, however, that a single head configuration also may be employed, in which only one piston assembly is supported on one of the housing ends.

Accordingly, a twin head pump/compressor includes a housing including a first end and a second end opposite the first end. A first piston assembly is attached to the first end of the housing for pumping a fluid from a first fluid inlet to a first fluid outlet, and a second piston assembly is attached to the second end of the housing for pumping a fluid from a second fluid inlet to a second fluid outlet. A split eccentric actuator is enclosed within the housing. Each of the first and second piston assemblies includes a glass cylinder, and a graphite piston that is actuated by the split eccentric actuator to move within the glass cylinder, wherein movement of the pistons drives the fluid from the fluid inlets to the fluid outlets.

Referring initially to Figs. 3 and 4, the pump or compressor system 80 includes the housing 42 to which is attached the motor 56. The motor 56 may be a brushless direct current (DC) motor powered by a long-life battery, although any suitable motor may be employed, and lead wires 58 may be provided that couple the motor to a suitable controller, such as an external driver or integrated electronics. A first piston assembly 10 is attached to the first end 44 of the housing, and a second piston assembly 10' is attached to the second end 52 of the housing. The piston assemblies are comparably configured. As described above, the first piston assembly 10 includes a glass cylinder 12 that houses a graphite piston 14. The glass cylinder is seated against an inner sealing gasket 20 within the first end 44 of the housing. The piston assembly 10 further includes the first compression head 22 including the first fluid inlet 24 and first fluid outlet 26. The first compression head 22 is sealed at its outer surface by an outer sealing gasket 28 and outer cover plate 30. The pump or compressor system further may include supports plates 82 for attaching the first piston assembly 10 to the first end 44 of the housing 42. Fasteners 84 may extend through the cover plate 30 and supports plates 82, which secure the piston assembly 10 to the housing in a manner that permits up and down movement of the piston 14 within the glass cylinder 12.

Similarly, the second piston assembly 10' includes a glass cylinder 12' that houses a graphite piston 14'. The glass cylinder is seated against an inner sealing gasket 20' within the second end 52 of the housing. The second piston assembly 10' further includes a second compression head 22' including a second fluid inlet 24' and a second fluid outlet 26'. The second compression head 22' is sealed at its outer surface by an outer sealing gasket 28' and outer cover plate 30'. The pump or

compressor system 80 further may include supports plates 82' for attaching the second piston assembly 10' to the second end 52 of the housing 42. Fasteners may extend through the cover plate 30' and supports plates 82', which secure the piston assembly 10' to the housing in a manner that permits up and down movement of the piston 14' within the glass cylinder 12'.

Fig. 4 depicting the housing side view further shows the housing cover 70 as attached to the housing 42 via additional fastening elements 86. The motor shaft support bearing 74 supports a drive shaft 88 at a second end 92 that is opposite to a first end received within the motor 56.

Additional features of the pump or compressor system 80 are illustrated in the cross-sectional view of Fig. 5. Fig. 5 depicts the configuration of the drive shaft 88 extending from a first end 90 received by the motor 56, to a second end 92 supported by the motor shaft support bearing 74. The drive shaft 88 thereby extends through the respective bearings 64 and 66 of the first and second connecting rods 60 and 62, and through the split eccentric 68. The piston assemblies are actuated via the connecting rods when the split eccentric rotates commensurately as driven by the motor drive shaft. In particular, the graphite pistons may be driven cyclically up and down to pump fluid (e.g., compressed gas or other suitable fluid) from the fluid inlet through the fluid outlets.

An aspect of the invention, therefore, is a pump/compressor. In exemplary embodiments, the pump/compressor includes at least one piston assembly for pumping a fluid from a fluid inlet to a fluid outlet, a housing configured to support the piston assembly, and an eccentric actuator that is enclosed within the housing. The piston assembly includes a glass cylinder, and a graphite piston that is actuated by the eccentric actuator to move within the glass cylinder, wherein movement of the piston drives the fluid from the fluid inlet to the fluid outlet.

In an exemplary embodiment of the pump/compressor, the piston assembly further comprises a compression head that acts as a pump chamber that receives fluid through the fluid inlet and expels fluid through the fluid outlet via actuation of the graphite piston.

In an exemplary embodiment of the pump/compressor, the housing has a recess for aligning the glass cylinder relative to the housing.

In an exemplary embodiment of the pump/compressor, the pump/compressor further includes a gasket that is located in the recess for sealing the glass cylinder relative to the housing.

5 In an exemplary embodiment of the pump/compressor, the pump/compressor further includes a motor and a drive shaft that is driven by a motor, wherein the drive shaft in turn drives the eccentric actuator to actuate the graphite piston.

In an exemplary embodiment of the pump/compressor, the motor is a brushless direct current (DC) motor.

10 In an exemplary embodiment of the pump/compressor, the pump/compressor further includes a connecting rod located between the eccentric actuator and the graphite piston, wherein the eccentric actuator actuates the graphite piston via the connecting rod.

15 In an exemplary embodiment of the pump/compressor, the housing includes a motor support face to which the motor is attached, and a housing cover that forms an outer face of the housing opposite to the motor support face.

In an exemplary embodiment of the pump/compressor, the housing cover receives a motor shaft support bearing that supports an end of the drive shaft opposite from an end that is driven by the motor.

20 In an exemplary embodiment of the pump/compressor, the glass cylinder is made of a borosilicate glass.

Another aspect of the invention is a twin head pump/compressor. In exemplary embodiments, the twin head pump/compressor includes a housing including a first end and a second end opposite the first end, a first piston assembly
25 attached to the first end of the housing for pumping a fluid from a first fluid inlet to a first fluid outlet, a second piston assembly attached to the second end of the housing for pumping a fluid from a second fluid inlet to a second fluid outlet, and a split eccentric actuator that is enclosed within the housing. Each of the first and second piston assemblies includes a glass cylinder, and a graphite piston that is actuated by
30 the split eccentric actuator to move within the glass cylinder, wherein movement of the pistons drives the fluid from the fluid inlets to the fluid outlets.

In an exemplary embodiment of the twin head pump/compressor, the first piston assembly further includes a first compression head that acts as a pump chamber that receives fluid through the first fluid inlet and expels fluid through the first fluid outlet via actuation of the graphite piston of the first piston assembly, and
5 the second piston assembly further includes a second compression head that acts as a pump chamber that receives fluid through the second fluid inlet and expels fluid through the second fluid outlet via actuation of the graphite piston of the second piston assembly.

In an exemplary embodiment of the twin head pump/compressor, the housing
10 has a first recess for aligning the glass cylinder of the first piston assembly relative to the first end housing, and a second recess for aligning the glass cylinder of the second piston assembly relative to the second end of the housing.

In an exemplary embodiment of the twin head pump/compressor, the twin head pump/compressor further includes a first gasket that is located in the first
15 recess for sealing the glass cylinder of the first piston assembly relative to the housing, and a second gasket that is located in the second recess for sealing the glass cylinder of the second piston assembly relative to the housing..

In an exemplary embodiment of the twin head pump/compressor, the twin head pump/compressor further includes a motor and a drive shaft that is driven by a
20 motor, wherein the drive shaft in turn drives the split eccentric actuator to actuate the graphite pistons.

In an exemplary embodiment of the twin head pump/compressor, the motor is a brushless direct current (DC) motor.

In an exemplary embodiment of the twin head pump/compressor, the twin
25 head pump/compressor further includes a first connecting rod located between the split eccentric actuator and the graphite piston of the first piston assembly, and a second connecting rod located between the split eccentric actuator and the graphite piston of the second piston assembly, wherein the split eccentric actuator actuates the graphite pistons via the connecting rods.

In an exemplary embodiment of the twin head pump/compressor, the housing
30 includes a motor support face to which the motor is attached, and a housing cover that forms an outer face of the housing opposite to the motor support face.

In an exemplary embodiment of the twin head pump/compressor, the housing cover receives a motor shaft support bearing that supports an end of the drive shaft opposite from an end that is driven by the motor.

5 In an exemplary embodiment of the twin head pump/compressor, the glass cylinders of the piston assemblies are made of a borosilicate glass.

Although the invention has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to
10 the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally
15 equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be
20 desired and advantageous for any given or particular application.

Claims

What is claimed is:

- 5 1. A pump/compressor comprising:
at least one piston assembly for pumping a fluid from a fluid inlet to a fluid
outlet;
a housing configured to support the piston assembly; and
an eccentric actuator that is enclosed within the housing;
- 10 the piston assembly comprising a glass cylinder, and a graphite piston that is
actuated by the eccentric actuator to move within the glass cylinder, wherein
movement of the piston drives the fluid from the fluid inlet to the fluid outlet.
- 15 2. The pump/compressor of claim 1, wherein the piston assembly further
comprises a compression head that acts as a pump chamber that receives fluid
through the fluid inlet and expels fluid through the fluid outlet via actuation of the
graphite piston.
- 20 3 The pump/compressor of any of claims 1-2, wherein the housing has a
recess for aligning the glass cylinder relative to the housing.
4. The pump/compressor of claim 3, further comprising a gasket that is
located in the recess for sealing the glass cylinder relative to the housing.
- 25 5. The pump/compressor of any of claims 1-4, further comprising a motor
and a drive shaft that is driven by a motor, wherein the drive shaft in turn drives the
eccentric actuator to actuate the graphite piston.
- 30 6. The pump/compressor of claim 5, wherein the motor is a brushless
direct current (DC) motor.

7. The pump/compressor of any of claims 1-6, further comprising a connecting rod located between the eccentric actuator and the graphite piston, wherein the eccentric actuator actuates the graphite piston via the connecting rod.

5 8. The pump/compressor of any of claims 4-7, wherein the housing includes a motor support face to which the motor is attached, and a housing cover that forms an outer face of the housing opposite to the motor support face.

9. The pump/compressor of claim 8, wherein the housing cover receives
10 a motor shaft support bearing that supports an end of the drive shaft opposite from an end that is driven by the motor.

10. The pump/compressor of any of claims 1-9, wherein the glass cylinder is made of a borosilicate glass.

15 11. A twin head pump/compressor comprising:
a housing including a first end and a second end opposite the first end;
a first piston assembly attached to the first end of the housing for pumping a fluid from a first fluid inlet to a first fluid outlet, and a second piston assembly
20 attached to the second end of the housing for pumping a fluid from a second fluid inlet to a second fluid outlet; and
a split eccentric actuator that is enclosed within the housing;
each of the first and second piston assemblies comprising a glass cylinder, and a graphite piston that is actuated by the split eccentric actuator to move within
25 the glass cylinder, wherein movement of the pistons drives the fluid from the fluid inlets to the fluid outlets.

12. The twin head pump/compressor of claim 11, wherein:
the first piston assembly further comprises a first compression head that acts
30 as a pump chamber that receives fluid through the first fluid inlet and expels fluid through the first fluid outlet via actuation of the graphite piston of the first piston assembly; and

the second piston assembly further comprises a second compression head that acts as a pump chamber that receives fluid through the second fluid inlet and

expels fluid through the second fluid outlet via actuation of the graphite piston of the second piston assembly.

13 The twin head pump/compressor of any of claims 11-12, wherein the
5 housing has a first recess for aligning the glass cylinder of the first piston assembly relative to the first end housing, and a second recess for aligning the glass cylinder of the second piston assembly relative to the second end of the housing.

14. The twin head pump/compressor of claim 13, further comprising a first
10 gasket that is located in the first recess for sealing the glass cylinder of the first piston assembly relative to the housing, and a second gasket that is located in the second recess for sealing the glass cylinder of the second piston assembly relative to the housing..

15 15. The twin head pump/compressor of any of claims 11-14, further
comprising a motor and a drive shaft that is driven by a motor, wherein the drive shaft in turn drives the split eccentric actuator to actuate the graphite pistons.

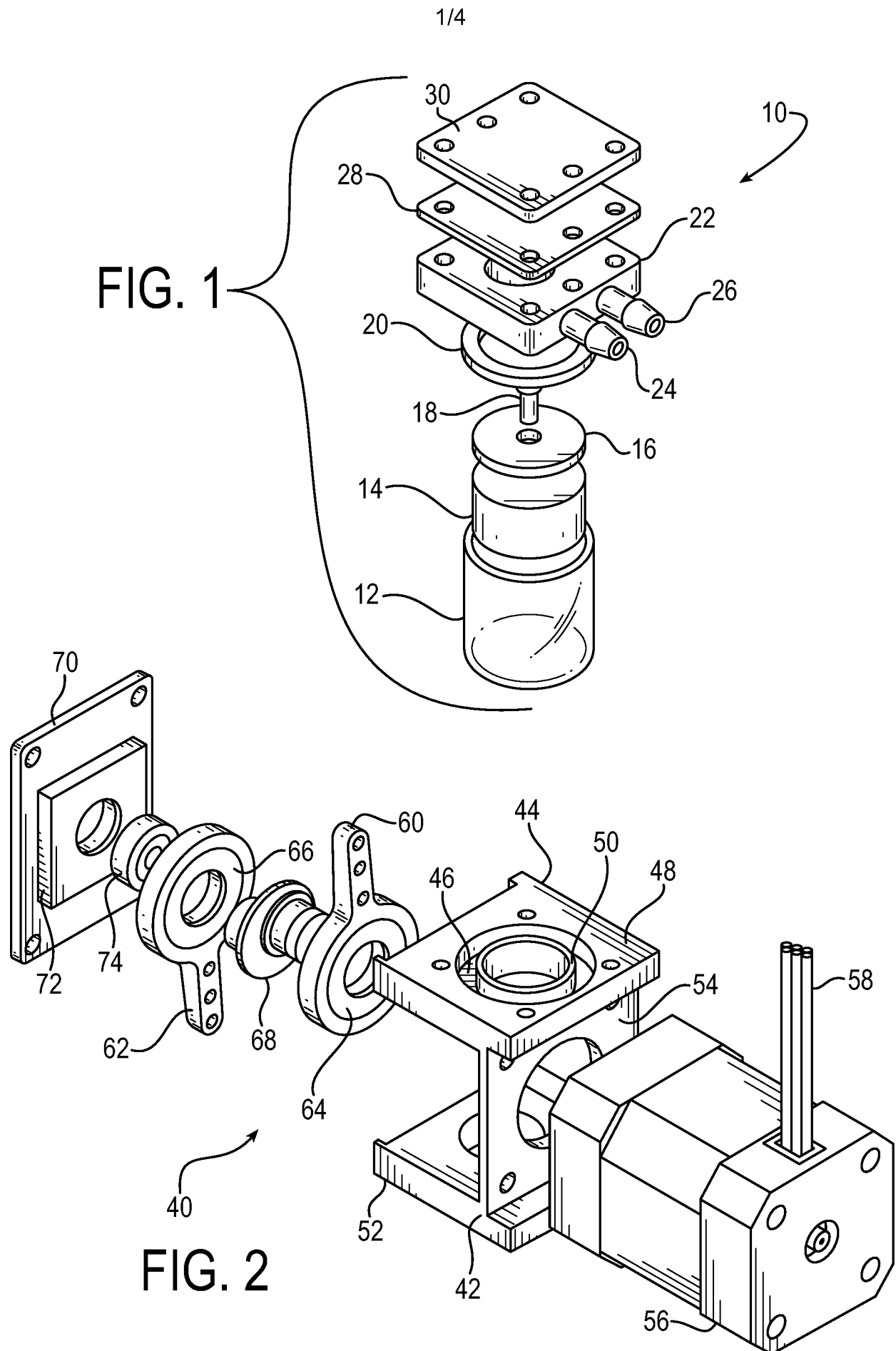
16. The twin head pump/compressor of claim 15, wherein the motor is a
20 brushless direct current (DC) motor.

17. The twin head pump/compressor of any of claims 11-16, further
comprising a first connecting rod located between the split eccentric actuator and the graphite piston of the first piston assembly, and a second connecting rod located
25 between the split eccentric actuator and the graphite piston of the second piston assembly, wherein the split eccentric actuator actuates the graphite pistons via the connecting rods.

18. The twin head pump/compressor of any of claims 14-17, wherein the
30 housing includes a motor support face to which the motor is attached, and a housing cover that forms an outer face of the housing opposite to the motor support face.

19. The twin head pump/compressor of claim 18, wherein the housing cover receives a motor shaft support bearing that supports an end of the drive shaft opposite from an end that is driven by the motor.

- 5 20. The twin head pump/compressor of any of claims 11-19, wherein the glass cylinders of the piston assemblies are made of a borosilicate glass.



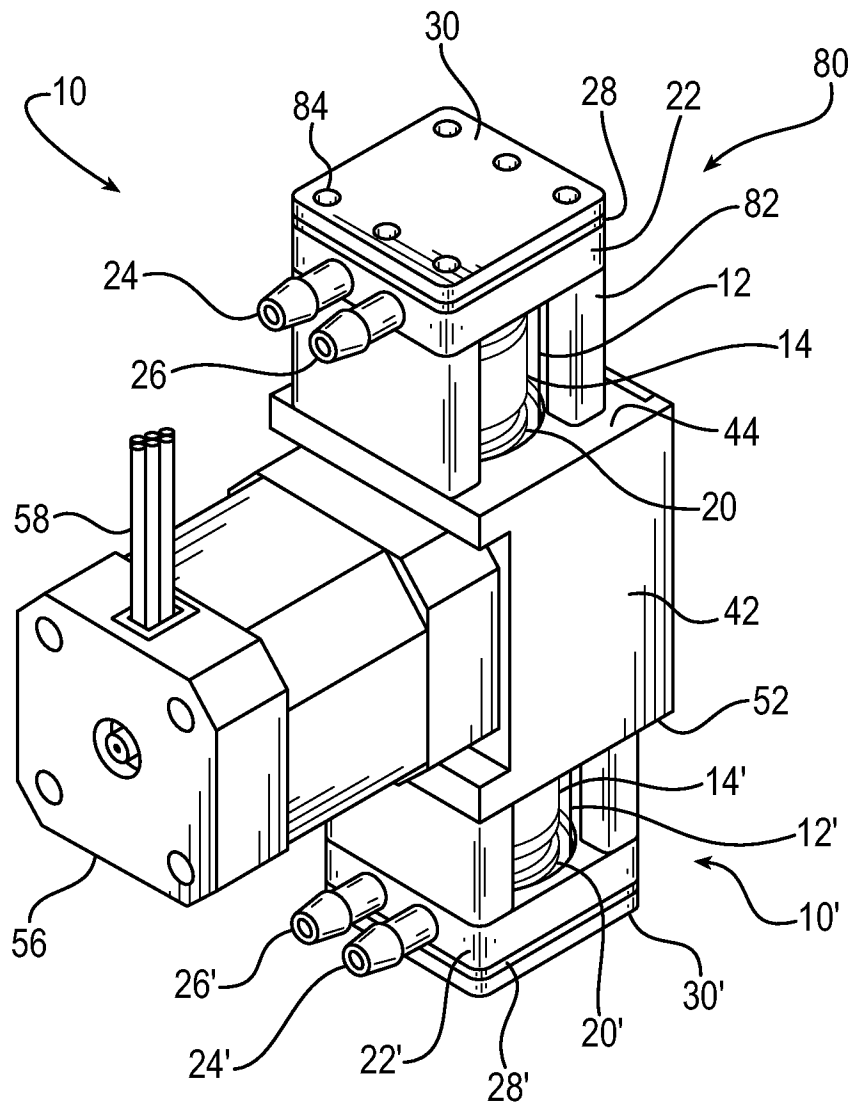


FIG. 3

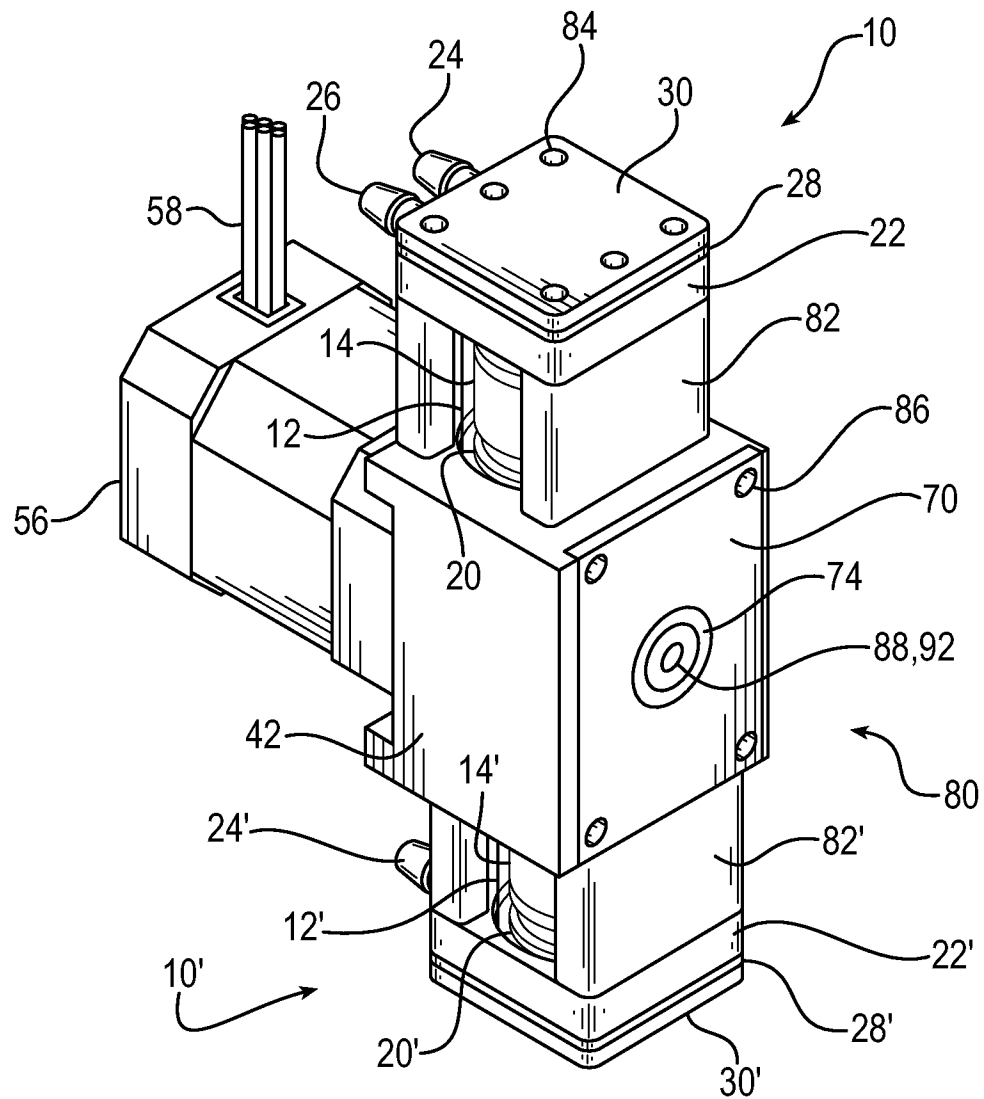


FIG. 4

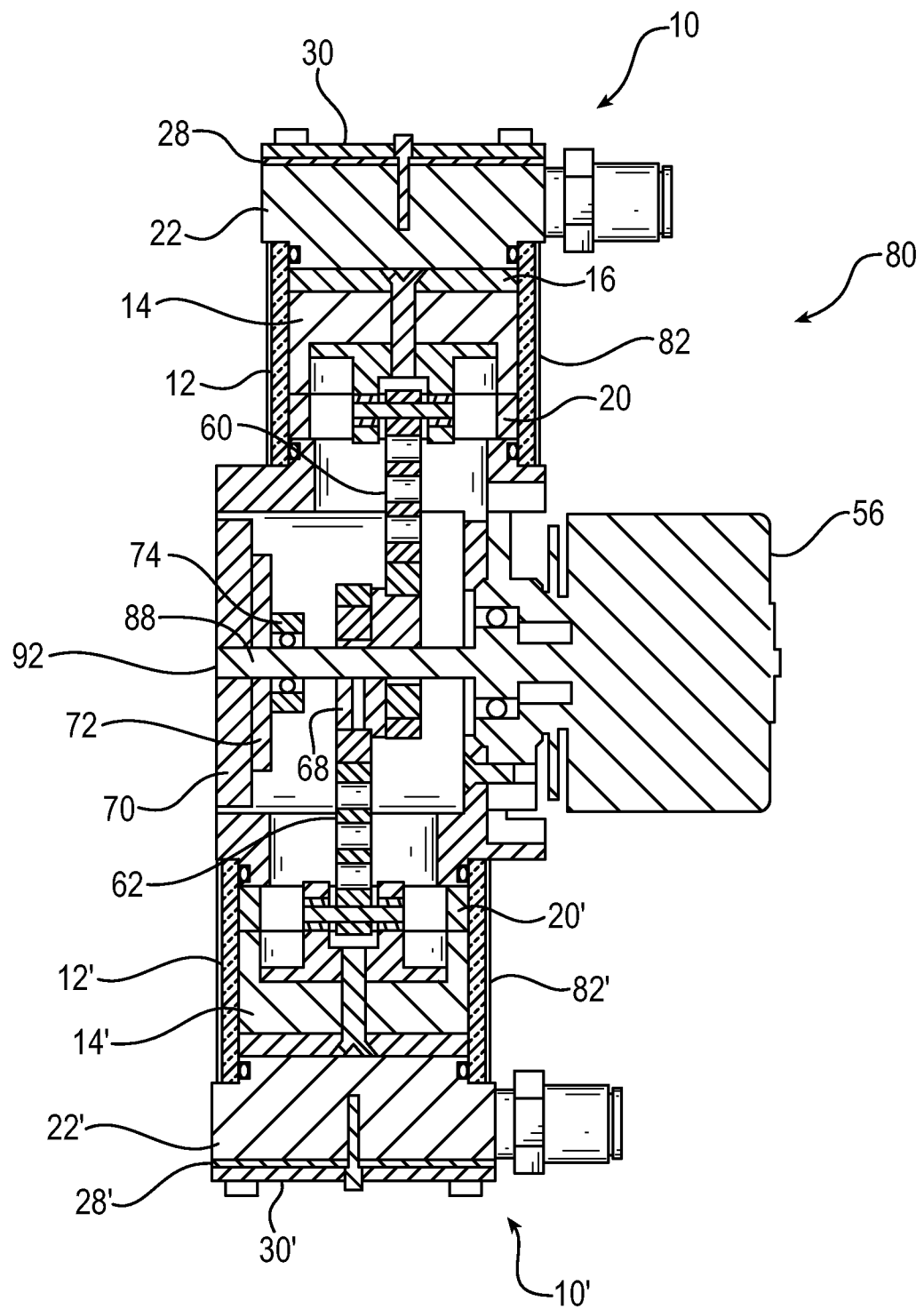


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/011721

A. CLASSIFICATION OF SUBJECT MATTER

INV. F04B1/04 F04B9/04 F04B39/12 F04B53/14 F04B53/16
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/148016 A1 (CRAWFORD RICHARD W JR [US] ET AL CRAWFORD JR RICHARD WILLIAM [US] ET AL) 28 June 2007 (2007-06-28) abstract paragraph 36; figures -----	1-20
X	US 5 163 818 A (BETSILL HARRY E [US] ET AL) 17 November 1992 (1992-11-17)	1-10
Y	abstract; figures column 3, lines 2-28; claims 3,6,9 -----	11-20
X	US 2013/081536 A1 (CRAWFORD JR RICHARD WILLIAM [US] ET AL) 4 April 2013 (2013-04-04) abstract; figures paragraphs [0018], [0019], [0022], [0027], [0028] ----- -/--	1,11



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

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/020143 A1 (VAN BRUNT NICHOLAS P [US] ET AL) 27 January 2011 (2011-01-27) abstractparagraph 14; figures -----	11-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/011721

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007148016 A1	28-06-2007	US 2007148016 A1	28-06-2007
		WO 2007076326 A2	05-07-2007

US 5163818 A	17-11-1992	NONE	

US 2013081536 A1	04-04-2013	NONE	

US 2011020143 A1	27-01-2011	EP 2456977 A2	30-05-2012
		EP 2456982 A2	30-05-2012
		US 2011020143 A1	27-01-2011
		US 2011020156 A1	27-01-2011
		WO 2011011434 A2	27-01-2011
		WO 2011011440 A2	27-01-2011
