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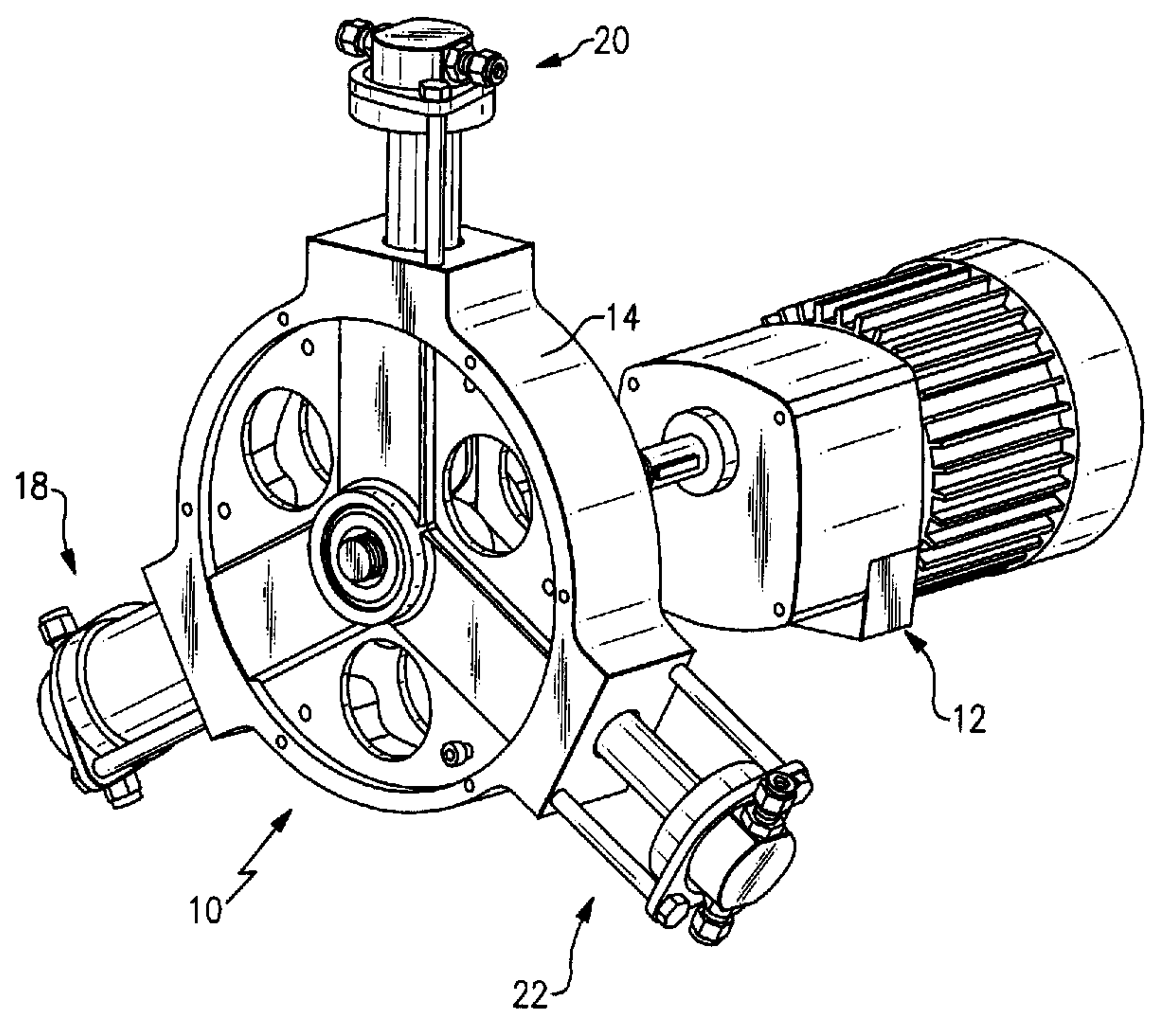
(54) Title: RADIAL CAM-DRIVEN COMPRESSOR AND CAM-DRIVEN COMPRESSOR ASSEMBLIES



(57) Abrégé/Abstract:
A first aspect of the invention includes a multi-stage gas compressor having a central cam with a plurality of pistons operably connected to and radially extending from the central cam. The cam follower assemblies each include a roller element connected to a roller bracket which rides within and along a guide channel defines by facing grooves formed in housing end plates.

ABSTRACT OF THE DISCLOSURE

A first aspect of the invention includes a multi-stage gas compressor having a central cam with a plurality of pistons operably connected to and radially extending from the central cam. The cam follower assemblies each include a roller element connected to a roller bracket which rides within and along a guide channel defines by facing grooves formed in housing end plates.

TITLE: RADIAL CAM-DRIVEN COMPRESSOR AND CAM-DRIVEN COMPRESSOR ASSEMBLIES

BACKGROUND OF THE INVENTION

The present invention relates to compressors and, in a first aspect thereof, more particularly relates to a compressor having a central cam with one or more pistons and respective cam follower assemblies operatively connected to and radially extending from the centrally located cam. In another aspect, the invention relates to a compressor including a filter and filter retainer plate positioned between the compression chamber of the cylinder and outlet port of the cylinder head. In yet another aspect, the invention relates to a compressor including a cam follower assembly having a roller element and guide bracket which is located for reciprocal movement within a respective guide channel defined by a pair of facing grooves formed in compressor housing plates.

Electrically driven compressors must convert rotary motion from a motor into linear motion to actuate a piston or a series of pistons to generate compressed gas. Most gas compressors accomplish this task by means of a crankshaft and connecting rod assembly similar to that found in internal combustion engines. Some advantages to this design are the proven reliability and the high operating efficiency. One major disadvantage is the space required by the connecting rod throughout a complete rotation of the crankshaft. This disadvantage becomes particularly evident in multistage compressors used for compressing gas to high pressures, typically greater than 1000psig. Often, the higher-stage pistons cannot accommodate the connecting rod and the dynamic space it occupies. As a result, many designs limit the piston travel to under 0.5 inches, and used stepped pistons in the higher pressure stages. These actions reduce the compressor efficiency and add components to the assembly.

Other designs for compressors utilize nutating heads to convert rotary motion into linear motion. In these designs, the piston travel is parallel to the axis of rotation. Automotive air conditioning compressors commonly use this type of compressor. An advantage of this style compressor is the low amount of package space required by the compressor. In addition, the connecting rods articulate less than those used with crankshafts. This allows more travel in small diameter pistons than with crankshaft designs. One disadvantage to this style of compressor is the piston reciprocation relies mostly on sliding action than on rolling action. This increases the amount of friction in the system, lowers overall compressor efficiency, and requires continuous lubrication to achieve reliable compressor performance.

SUMMARY OF THE INVENTION

The present invention addresses the shortcomings of the prior art by providing in a first aspect a compressor having a central cam to actuate pistons arranged in a radial fashion about the cam. The compressor assembly includes a housing comprising an annular block having annularly spaced cylinder mounting surfaces. A cam 16 is positioned near or at the center of housing and connects to motor and speed reducer via a central shaft extending along an axis. First, second and third stage cylinder and piston assemblies radially extend from and are operably connected via respective cam follower assemblies to the cam.

In one embodiment, the invention provides a radial cam-driven compressor comprising:

a) a housing having a central opening and a plurality of radially extending bore holes formed in annularly spaced relation about and through said housing;

b) a cam rotatably mounted on a camshaft extending through said housing central opening;

c) a plurality of cylinder and piston assemblies with each said piston located and movable within a respective said cylinder; and

d) a plurality of cam follower assemblies each including a roller element rotatably connected to a roller bracket and a connecting rod having first and second ends, each said connecting rod extending along a respective radial axis through a respective said bore hole in said housing, each said connecting rod first end connected to a respective said roller bracket located within said housing central opening, each said connecting rod second end connected to a respective said piston located outside said housing central opening, said roller element of each of said cam follower assemblies being in rolling contact with said cam,

whereby rotation of said cam is operable to sequentially reciprocate each of said rollers and respective connecting rods and piston and cylinder assemblies positioned in annularly spaced relation about said housing.

The radial cam-driven compressor may be a three-stage compressor comprising first, second and third cylinder and piston assemblies sequentially compressing air through low, medium and high relative compressions, respectively.

The radial cam-driven compressor may further comprise first and second housing plates positioned in spaced, parallel relation about the housing central opening with the cam positioned between the first and second housing plates, the plates each having an aligned central opening wherethrough the cam shaft extends along an axis extending substantially perpendicular to each of the radially extending axes of the connecting rods of the cam follower assemblies.

The first and second housing plates may each further include a plurality of annularly spaced, radially extending grooves with the channels in the first plate aligned in facing relation to the grooves in the second plate, each pair of facing grooves forming a guide channel wherein a respective one of the cam follower assemblies is located for reciprocal, sliding movement therein.

The cam follower assemblies may each further include a pair of end plates attached on opposite sides of a respective roller bracket, the pair of end plates received in closely fitting, sliding engagement within the guide channel of a respective pair of facing grooves.

In a second aspect of the invention, a cam-driven compressor is provided including a housing, a cam and a plurality of cylinder and piston assemblies with said piston located and movable within a respective cylinder, wherein the improvement comprises:

a) a plurality of cam follower assemblies each including a roller element rotatably connected to a roller bracket having first and second, spaced end plates, and a connecting rod having first and second ends, each connecting rod first end connected to a respective roller bracket, each connecting rod second end connected to a respective piston, the roller element of each cam follower assembly being in rolling contact with the cam, and first and second housing plates positioned in spaced, parallel relation to the housing with the first and second housing plates each including a plurality of grooves aligned in facing relation to each other, each pair of facing grooves defining a guide channel, whereby a pair of end plates are received in closely fitting, sliding engagement within a respective guide channel whereby rotation of the cam is operable to reciprocate each of the cam follower assemblies in a respective said guide channel. This aspect of the invention may be part of a radial compressor as described above in the first aspect of the invention, or in a linear compressor

In a third aspect of the invention, a cam-driven compressor including a plurality of cylinder and piston assemblies is provided with each piston located and movable within a respective cylinder, each piston and cylinder pair defining a gas compression chamber within a respective cylinder, and a cylinder head for mounting to each cylinder, each cylinder head including a gas inlet port and gas outlet port, wherein the improvement comprises a filter and filter retainer plate positioned between the gas compression chamber and gas outlet port. The filter retainer plate advantageously also serves to reduce dead space between the piston and the outlet port of the cylinder head which increases the operating efficiency of the compressor. As with the second aspect of the invention, this aspect of the invention may be part of a radial compressor as described above in the first aspect of the invention, or in a linear compressor such as described in co-pending application serial number 11/997,970.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a perspective view of one embodiment of a compressor assembly of the invention;

Figure 2 is an exploded view of a portion thereof;

Figure 3 is an exploded view of a cylinder and piston assembly thereof;

Figure 4 is a cross-sectional view of a cylinder and head assembly;

Figure 5 is a perspective view of a piston;

Figure 6 A is plan view of a compressor assembly with the front end plate removed and having an alternate embodiment of the cylinder head and air line connection; and

Figure 6B is an enlarged, plan view of one of the cam and cam followers shown in Figure 6A.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to the drawing, there is seen in Figures 1 and 2 one embodiment of the inventive compressor assembly designated generally by the reference numeral 10. Compressor assembly 10 is configured to connect to a motor and speed reducer 12. As seen best in Figure 2, compressor assembly 10 includes a housing 14 comprising an annular block having annularly spaced mounting surfaces 14a-c. A cam 16 is positioned near or at the center of housing 14 and connects to motor and speed reducer 12 via central shaft 17 extending along axis X-X. First, second and third stage cylinder and piston assemblies 18, 20 and 22, respectively, are spaced 120° apart and radially extend along respective axes Y-Y_{1-3} from and are operably connected via respective cam follower assemblies 18a, 20a and 22a to cam 16 as described more fully below. Cam axis X-X extends substantially perpendicular to axes $Y\text{-}Y_{1\text{-}3}$ along which the respective cam follower assemblies 18a, 20a and 22a extend.

Each cam follower assembly includes a respective roller element 18b, 20b and 22b rotatably connected between respective roller brackets 18b', 20b' and 22b' and associated end plates 18b",18b"', 20b",20b"' and 22b",22b"'. In the preferred embodiment, the roller elements 18b, 20b and 22b are constructed from advanced polymers. These materials have demonstrated the ability to carry high loads without needing continuous lubrication to prevent surface wear. Where prior art designs used a fixed support pin and cam follower bearing as the roller element, the present invention preferably uses side bearings (see parts 21 in Fig. 2) in the follower body to support the rotating pin 23 used to locate the respective roller element.

Each cam follower assembly further includes a respective connecting rod 18c, 20c and 22c connected to a respective roller element 18b, 20b and 22b via a respective roller bracket at a first end thereof, and to a respective piston 18d, 20d and 22d at a second end thereof. Each connecting rod telescopes within a respective linear bearing 18g, 20g and 22g. Each piston 18d, 20d and 22d is reciprocally located in a respective cylinder 18e, 20e and 22e. A compressor head 18f, 20f and 22f mounts to the end of a respective cylinder opposite the end from which the respective connecting rod extends. Although not individually labeled, appropriate sub-components (e.g., seals, bushings, bearings and washers, etc.), are provided within the completed assembly.

Housing plates 24, 26 are provided which mount to opposite sides of housing 14 and include aligned centrally located holes 24', 26' through which cam shaft 17 extends. Plates 24, 26 each further include a plurality of grooves 24a-c and 26a-c which align and face each other in spaced relation in the assembled condition to form guide channels in which the respective cam followers and connecting rods/linear bearings reciprocate.

It is noted that prior art axial cam designs used a ball bearing mounted on the outside of the follower body. These bearings were guided by linear slots machined into the compressor housing. The linear cam design utilized guide rings mounted on the follower body that were guided by large bores machined into the compressor body. Each of these approaches resulted in high contact stresses and non-optimal support of the follower body.

The present invention utilizes roller brackets 18b', 20b' and 22b' and associated end plates 18b",18b"', 20b",20b"' and 22b",22b"' which are supported by large paired grooves 24a-c and 26a-c, respectively, machined into housing plates 24, 26, respectively. These brackets distribute the cam side loading over a large area. In addition, the guide brackets are centered over the cam roller centerline. The combined effect of the larger contact area and centered location result in lower contact stresses and better follower support. Follower support is also less sensitive to roller bracket and manufacturing tolerances. It will furthermore be appreciated that the low friction design of the cam follower assemblies of the present invention reduces the need for lubricating agents which in turn reduces cost and the potential for particulate contamination.

In the embodiment of Figure 2, each connecting rod and respective piston are not rigidly connected to each other (i.e., one simply abuts the other). As such, secondary support for the followers may be provided by linear bushings 18g, 20g, 22g mounted in the compressor housing. These bushings contact the outer surface of their respective connecting rods and ensure the connecting rod remains centered in the respective cylinder. This is particularly important for the third stage piston assembly 22 where the amount of clearance between the connecting rod and the cylinder is low. Advantages of using linear bearings include piston side load reduction which can extend seal life, more design options and lower sensitivity to manufacturing tolerances.

While linear bearings provide a number of advantages as explained above, they may not be desirable from a cost perspective. In an alternate embodiment seen in Figure 3, linear bearings are not used. In this embodiment, a solid connection (e.g., threaded) is provided between the connecting rod and respective piston whereby the piston helps support and guide the respective follower assembly. As such, linear bearings are not necessary in this embodiment.

The cylinder heads 18f, 20f and 22f of Figures 1 and 2 include respective fittings 18e, 20e and 22e for attaching air lines (not shown in Figures 1 and 2) using a compression type fitting. Figure 3 illustrates an alternate embodiment of cylinder head 42 having inlet and outlet ports 38, 40 to which air tubing 30, 32 is connected via respective flanges 34, 36 and bolts 34', 36'. It is understood the embodiment of cylinder head 42 and air tubing of Figure 3 may be incorporated at the other two cylinder and piston assemblies 18, 22.

Still referring to Figure 3, check valves 44, 46 and associated O-rings 44', 46' mount within inlet and outlet ports 38, 40 to ensure air flow through the cylinder and piston assembly in the correct direction, i.e., from air tube 30 to air tube 32. A filter element 48 may be mounted with a filter retainer plate 50 and O-ring 52 within head 42 to prevent seal wear particles from reaching the check valves 44, 46 which could cause leaks (see also Figure 4). It is noted filter retainer plate 50 also reduces the dead space between the piston and cylinder head at the top of the piston stroke. Reducing piston/cylinder dead space is beneficial in that it improves compressor efficiency and reduces internal loads in the compressor.

A guide ring 54 and seal 56 may also be provided for mounting to piston 20d (see also Figure 5). A shim washer 58 may also be provided to adjust the clearance between the piston and cylinder head to, for example, between about 0.010 and 0.025 inches.

Referring to Figures 6A and 6B, an embodiment of compressor 10 is illustrated in the assembled condition with the front end plate 26 removed. Low pressure gas enters via an air tube 60 into first stage cylinder and piston assembly 18 via inlet port 19a thereof and enters cylinder 18e. When the highest lobe point 16a of cam 16 reaches assembly 18, roller 18b rides along lobe point 16a resulting in a piston upstroke (toward head 18f) and a first stage compression of the gas within cylinder 18e. During the upstroke, end plates 18", 18"' ride within and along the guide channel defined by facing grooves 24c and 26c (plate 26 not shown in Figure 6A). The compressed gas exits head 18 at outlet port 19b and is directed through air tube 30 until it reaches head 20f wherein the first stage compressed gas enters through inlet port 21a into cylinder 20e. At this time, piston 20d begins a downstroke position as the gas enters its respective compression chamber. As cam 16 continues to rotate in the counter-clockwise direction, the medium point of cam 16 approaches cam follower assembly 20 which then begins its upstroke. High lobe point 16a next approaches assembly 20 which completes the second stage compression of the gas within cylinder 20e. During the upstroke, end plates 20", 20"' ride along and within the guide channel defined by facing grooves 24a, 26a. The compressed gas exits at outlet port 21b and is directed through air tube 32 until it reaches head 22f wherein the second stage compressed air enters through inlet port 25a into cylinder 22e. As cam 16 continues to rotate in the counter-clockwise direction, the medium lobe point of cam 16 approaches roller assembly 22 which begins its upstroke. Roller 22b then rides along lobe high point 16a resulting in a full piston upstroke and a third stage compression of the gas within cylinder 22e. During the upstroke, end plates 22b", 22b"' ride along and within the guide channel defined by facing grooves 24b, 26b. The compressed gas exits as high pressure air (e.g., up to or exceeding 1000 psi), via outlet port 25b through air tube 62 which may be connected to an appropriate high pressure gas collection (e.g., air cylinder, not shown). As rotation of cam 16 continues, this cycle is repeated providing a continuous stream of high pressure gas at outlet port 25b.

It will thus be appreciated the present invention provides a cam driven radial compressor. Although three stages of compression are shown, it is understood that any number of compression stages including one may be used in accordance with the teachings of the present invention. It is further understood that variations may be made to the present invention as understood by those skilled in the art without departing from the full spirit and scope of the invention.

What Is Claimed Is:

1. A cam-driven compressor including a housing, a cam and a plurality of cylinder and piston assemblies wherein each of said cylinder and piston assemblies comprises a piston located and movable within a respective cylinder, and wherein:

a) a plurality of cam follower assemblies each including a roller element rotatably connected to a roller bracket which is mounted between generally rectangular first and second, spaced end plates, and a connecting rod having first and second ends, wherein each of said connecting rod first end is connected to a respective said roller bracket, each of said connecting rod second end is connected to a respective said piston, said roller element of each of said cam follower assemblies being in rolling contact with said cam; and

b) first and second housing plates positioned in spaced, parallel relation to said housing with said first and second housing plates each including a plurality of integral grooves aligned in facing relation to each other, each pair of integral facing grooves defining a linear guide channel, whereby the entirety of each respective cam follower assembly is contained within a respective linear guide channel and each of said generally rectangular first and second end plates of each respective cam follower assembly are received in closely fitting, sliding engagement within said respective linear guide channel.

2. A cam-driven compressor according to claim 1, wherein each said cylinder and piston assembly define a gas compression chamber within the cylinder and including a cylinder head for mounting to each cylinder, each cylinder head including a gas inlet port and gas outlet port, wherein a filter and filter retainer plate are positioned between the gas compression chamber and the gas outlet port of the cylinder head of each cylinder and piston assembly.

3. A cam-driven compressor according to claim 2 wherein said cylinder and piston assemblies are arranged in radially spaced fashion about a centrally located cam.

4. A cam-driven compressor according to claim 1 wherein each cylinder and piston assembly includes a cylinder head which mounts to the cylinder, each said cylinder head including a gas inlet port and gas outlet port, and a gas compression chamber defined with each of said cylinder and piston assemblies and wherein a filter and filter retainer plate are positioned between the gas compression chamber and gas outlet port wherein said filter retainer plate is positioned between the cylinder and the cylinder head of each said cylinder and piston assembly and thereby reducing dead space between said piston and said cylinder head.

5. A cam-driven compressor according to claim 1 or claim 4 wherein rotation of said cam is such that each of said cam follower assemblies reciprocate within said respective linear guide channel.

6. A cam-driven compressor according to claim 5 wherein said cylinder and piston assemblies are arranged in radially spaced fashion about a centrally located cam.

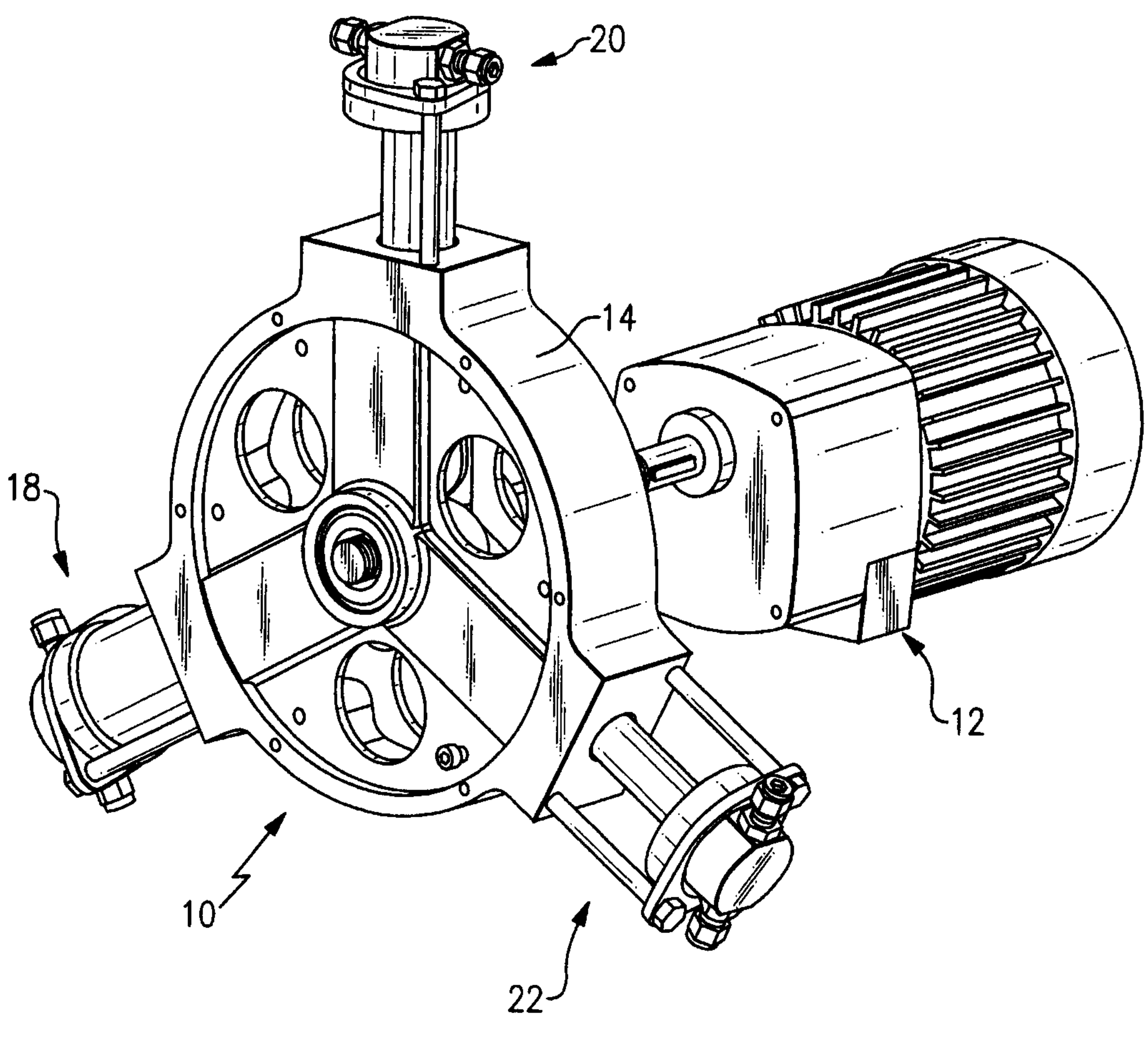
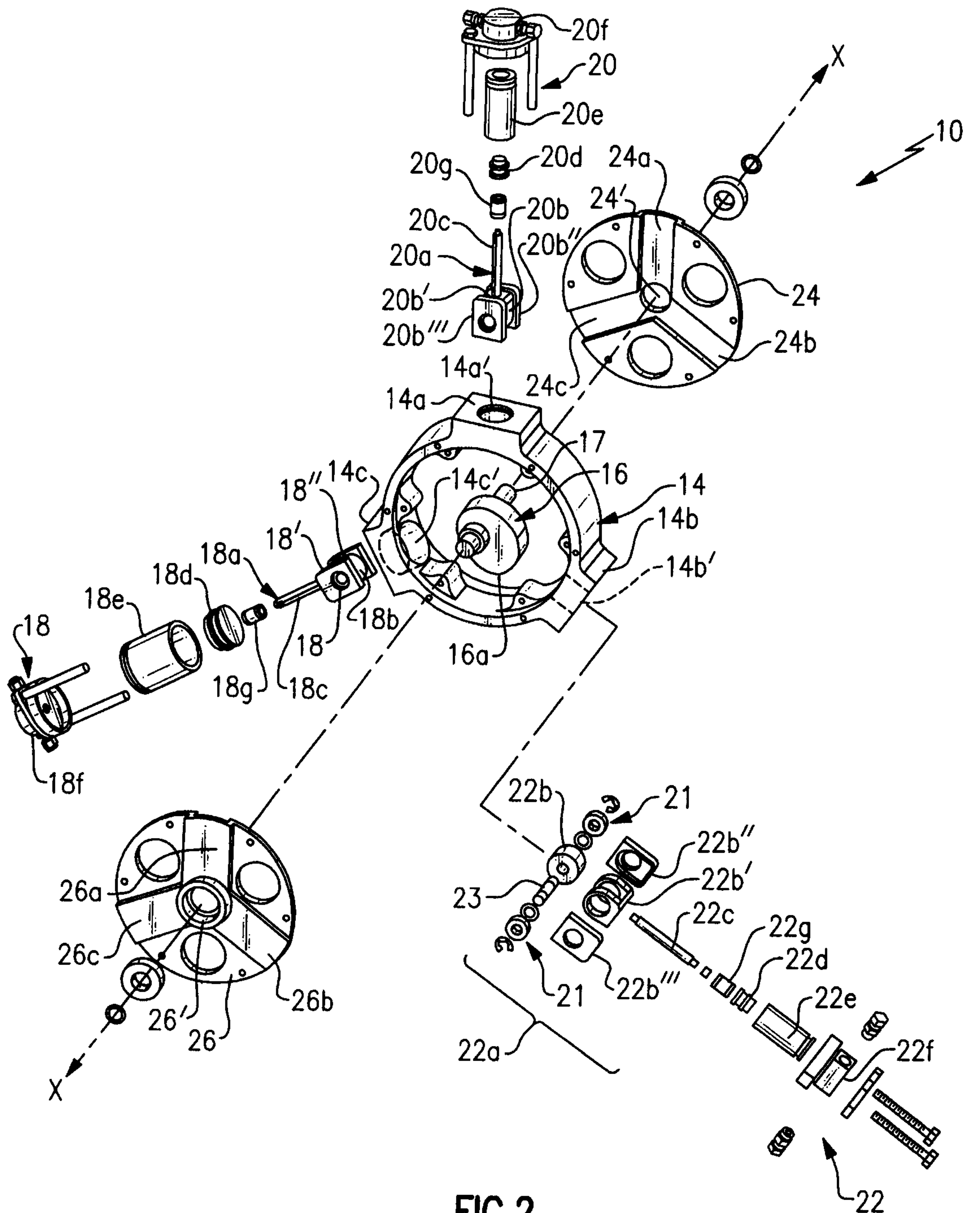


FIG.1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20
20e
X
10
20d
20g
24a
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20c
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14a'
24c
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14c
18''
14c'
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FIG.2

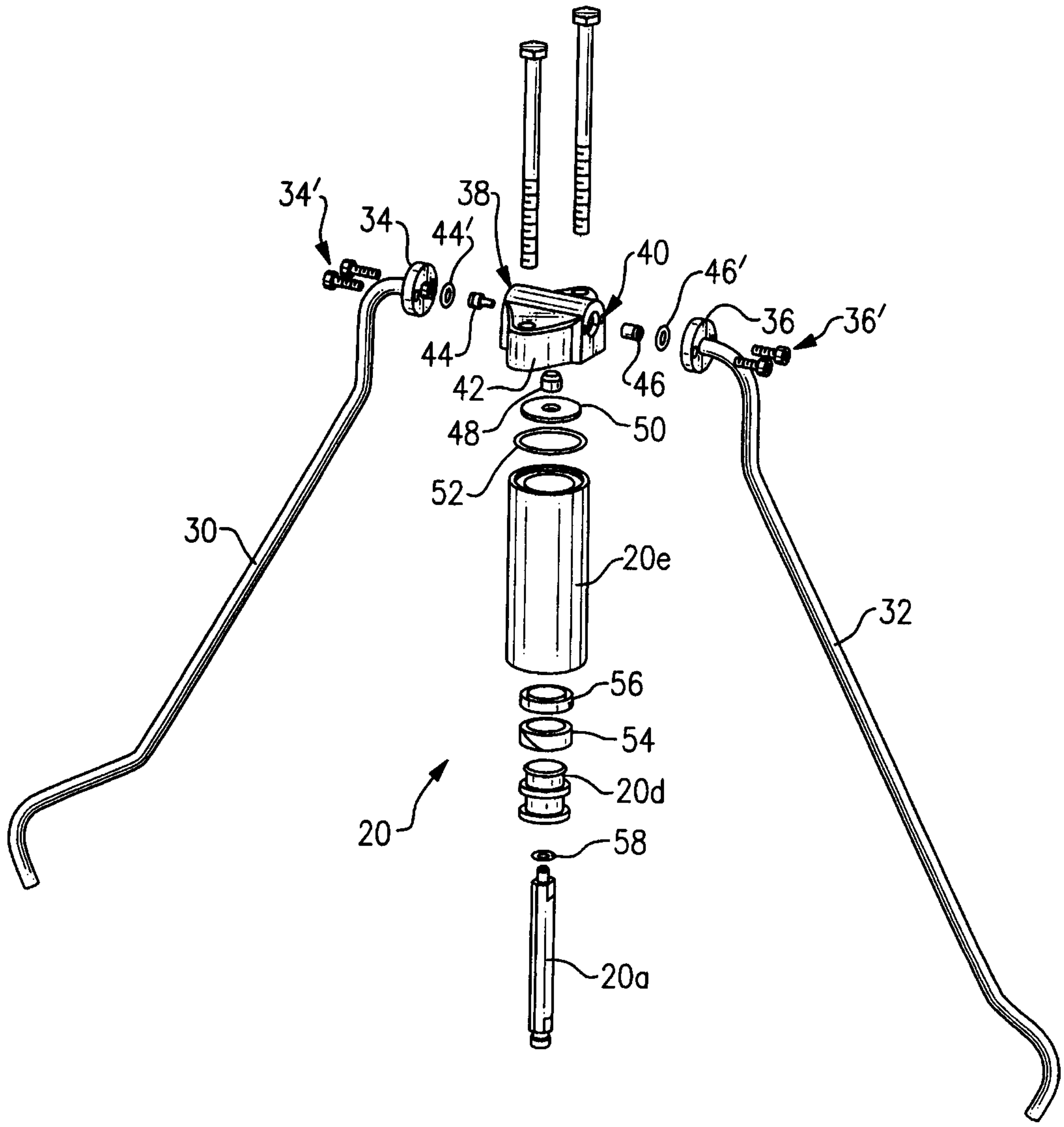
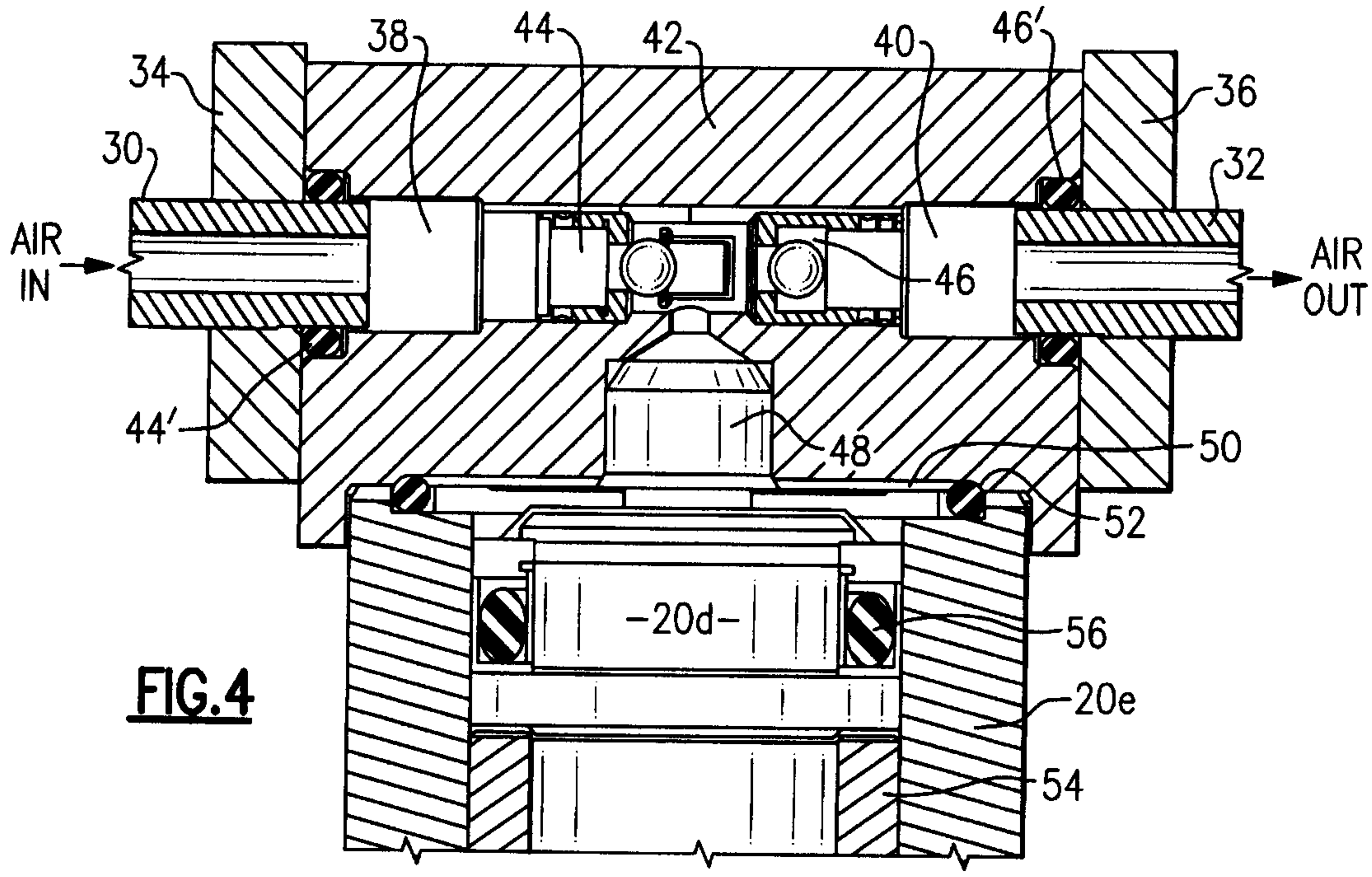


FIG.3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44
42
40
46′
34
36
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32
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OUT
46
44′
48
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56
20e
54

FIG.4

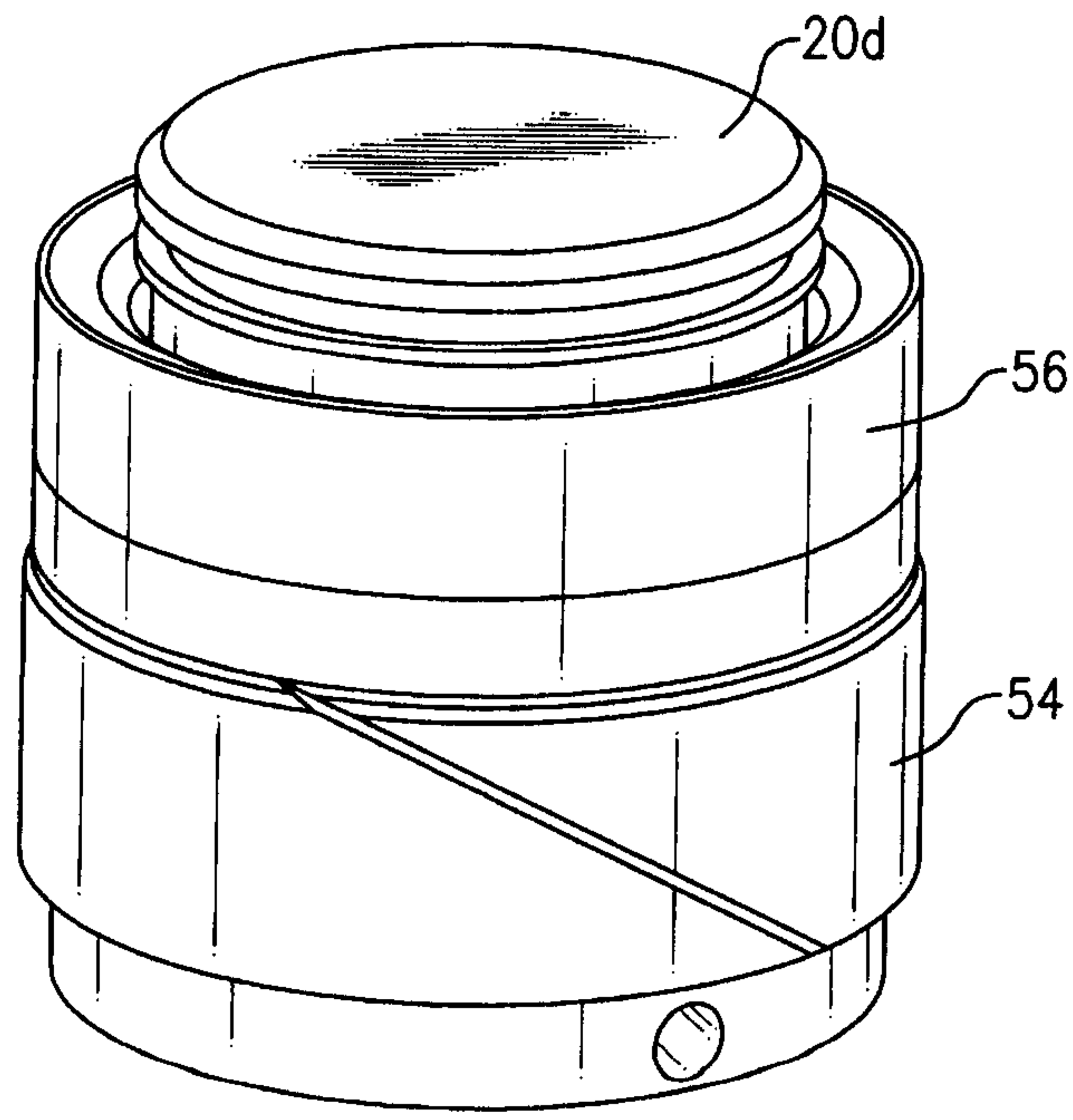
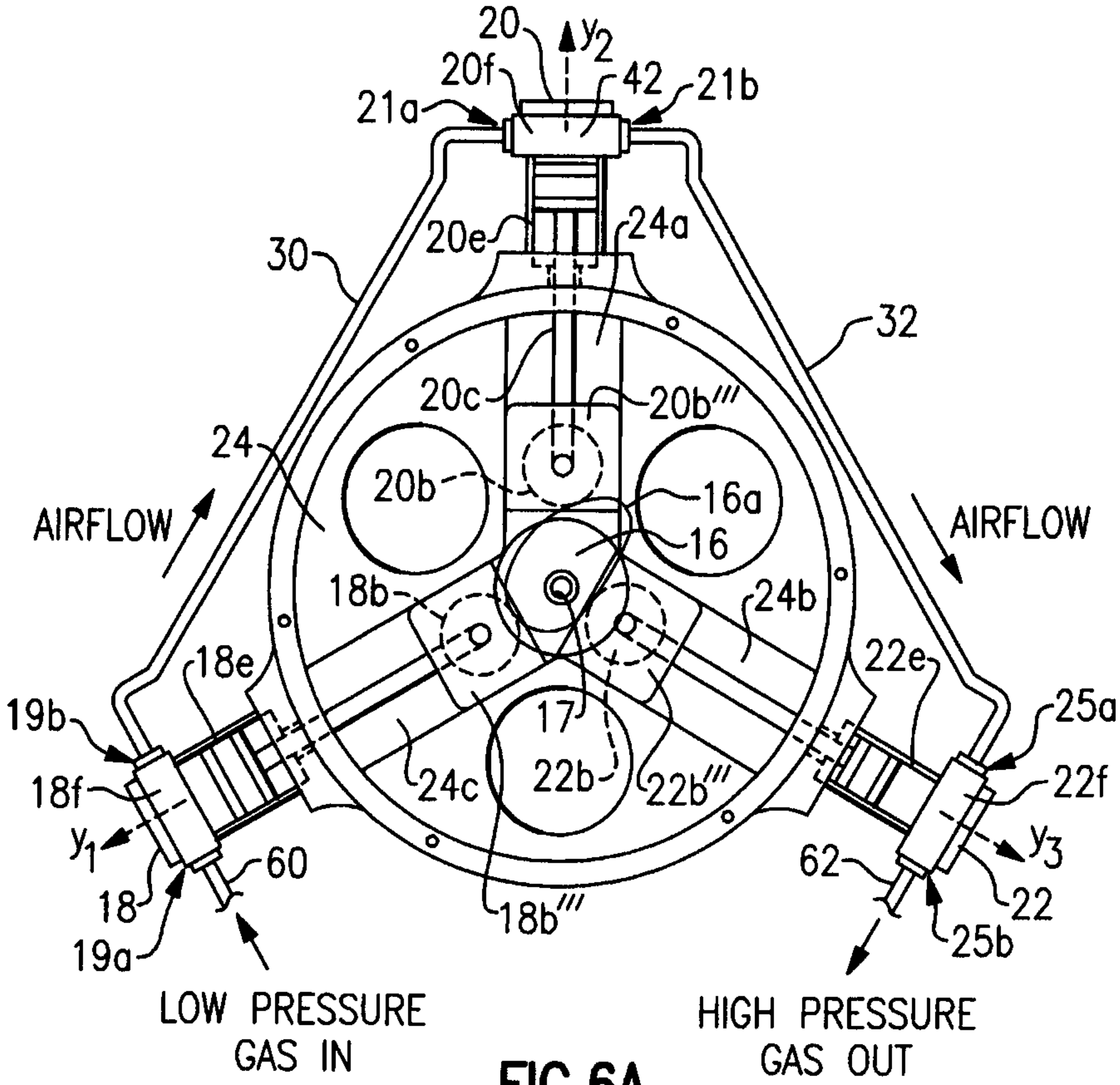

20d
56
54

FIG.5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20c
20b'''
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20b
16a
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22e
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19b
22b
22b'''
24c
22f
18f
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62
18
22
19a
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25b
LOW PRESSURE GAS IN
HIGH PRESSURE GAS OUT

FIG.6A

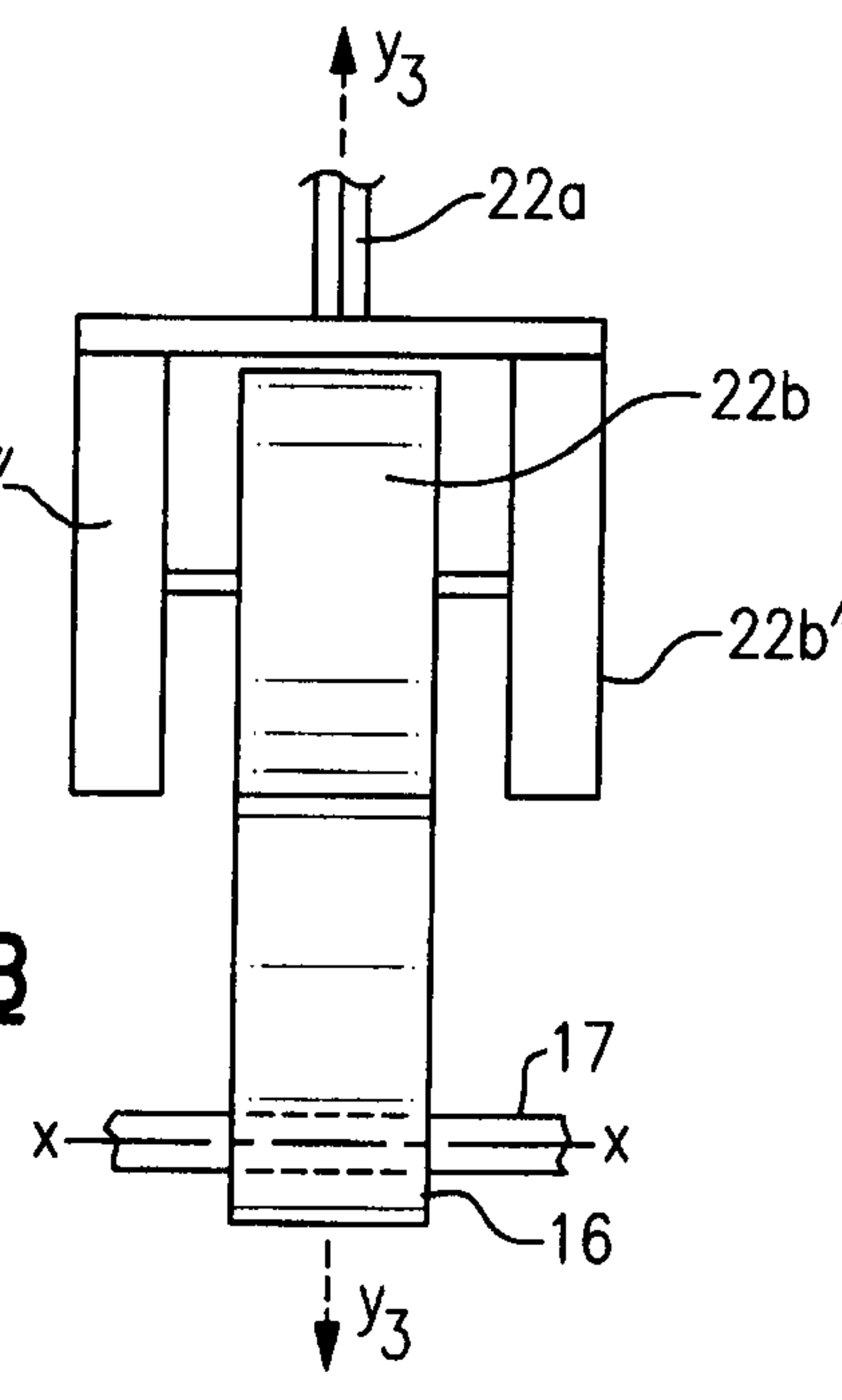
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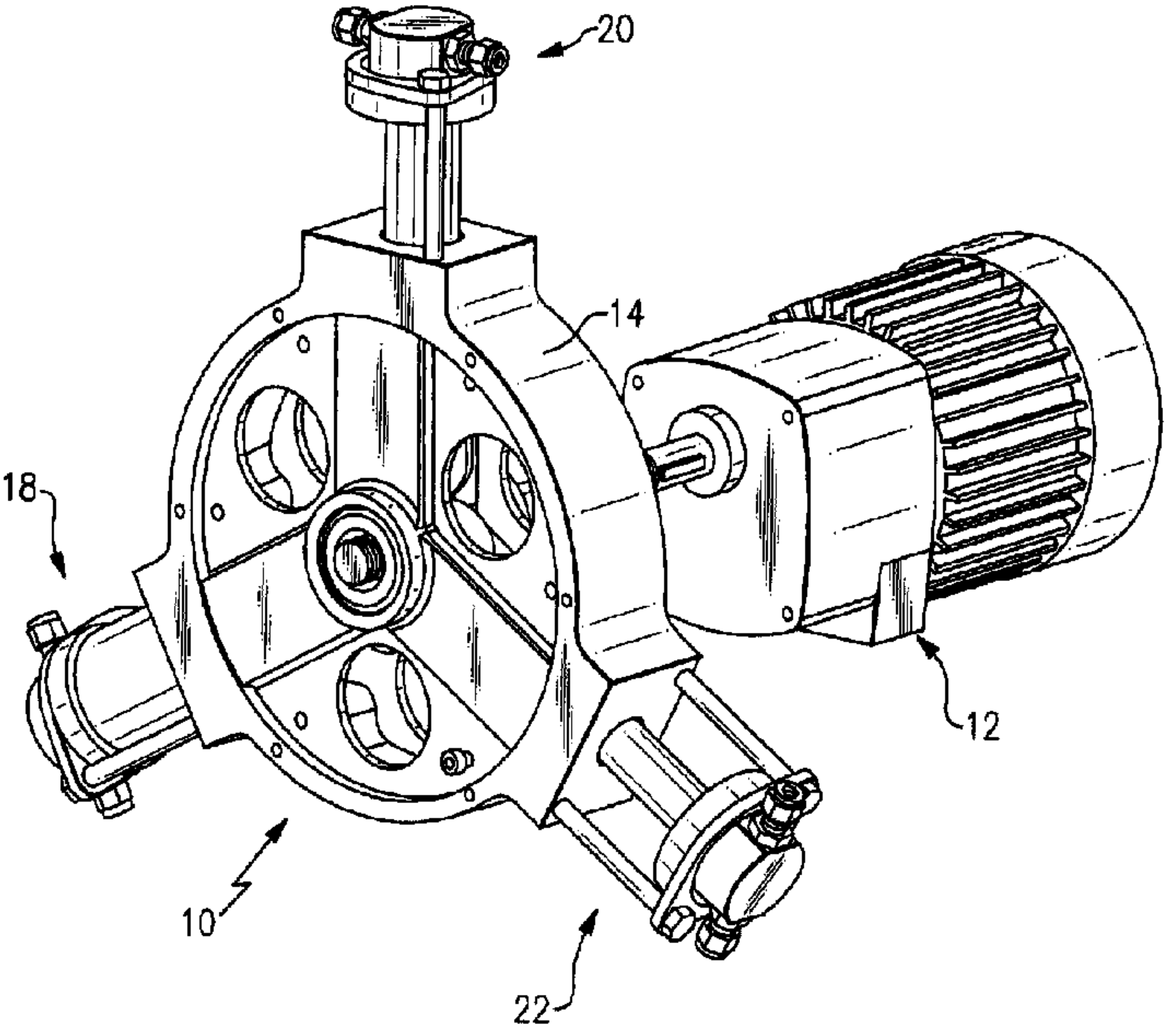
FIG.6B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