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(72) Inventors; and
(71) Applicants : **SAHAM, Gholamali, Kyoumars** [IR/US]; 201 Red Fern Trail, Simpsonville, SC 29681 (US). **LARI, Hassan** [US/US]; 201 Red Fern Trail, Simpsonville, SC 29681 (US).

(74) Agent: **SIGMON, David, M.**; J. Bennett Mullinax, LLC, PO Box 26029, Greenville, SC 29616-1029 (US).

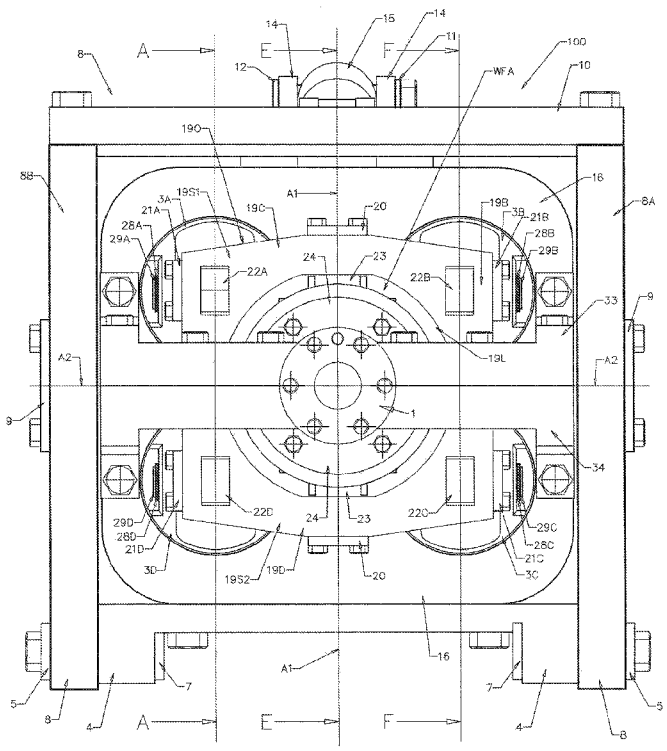
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(54) Title: VARIABLE DISPLACEMENT DEVICES AND RELATED METHODS



(57) Abstract: Variable displacement devices and related methods are provided that can be used to change the amount of volume displaced by pistons within corresponding cylinders. The subject matter disclosed herein can relate to variable displacement devices usable as pumps, combustion engines, air compressors, compressed air engines, hydraulic engines, or the like, that can be used to change the amount of volume displaced by pistons within corresponding cylinders while the compression ratio remains substantially constant or can be variable as well depending on the configuration of the variable displacement devices and their components.

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# DESCRIPTION

# VARIABLE DISPLACEMENT DEVICES AND RELATED METHODS

## TECHNICAL FIELD

The subject matter disclosed herein relates generally to variable displacement devices and related methods that can be used to change the amount of volume displaced by pistons within corresponding cylinders. More specifically, the subject matter disclosed herein relates to variable displacement devices usable as pumps, combustion engines, air compressors, compressed air engines, hydraulic engines or the like, that can be used to change the amount of volume displaced by pistons within corresponding cylinders while the compression ratio can remain substantially constant or can be variable as well depending on the configuration of the variable displacement devices and their components.

## BACKGROUND

As the availability of fossil fuels, such as gasoline, become scarcer, the need for newer and better ways to provide locomotion power to cars increases. One area of potential improvement over current internal combustion engines is in increases in efficiency at which such combustion engines currently operate. It is suspected that currently available combustion engines operate between about 15% and about 30% efficient. On average, it is suspected that automobiles use between about 20% and about 25% of their maximum power when they are running on the road.

Thermal efficiency of all engines, such as internal combustion engines, will be at their maximum efficiency when the cylinders are totally filled with air at ambient pressure (barometric air pressure at sea level). In this case, engines will generate their maximum power output. The above conditions do not happen very often on the road because drivers drive with an almost fixed and defined speed (speed limit) on the roads and usually push the gas pedal lightly in order to keep their desired speed. A light displacement (push) of the gas pedal will drop the manifold air pressure causing the reduction of cylinder air intake pressure. Since this pressure is much lower than ambient pressure, the combustion chamber pressure will drop at top dead center and this will reduce the thermal efficiency of the engine as well as its power output.

Briefly, a study of the above situations shows that there are two main factors that cause a decrease in the economical use of the car's engine (the fuel consumption is not proportional with the delivered power from the engine). In other words, the rate of fuel consumption is not proportional with the driven miles.

A first factor is that reduction of intake air pressure (by partially opening the throttle/light displacement of gas pedal) will cause a drop in the combustion chamber pressure at the time of the compression stroke at top dead center, reducing the thermal efficiency of the engine. A second factor relates to internal friction power. While there is no need for the maximum power of the engine for some driving conditions, a big engine with a large internal friction is still being used and a high internal friction power is generated. For example, when only 20% of the maximum power of a 100 horsepower ("HP") engine is in use, the entire internal friction of the 100 HP engine is being overcome. But if in this situation we were able to use an engine with a lower maximum power output of 20 HP, we would be using the entire power of that engine at the maximum rate of its efficiency and could reduce the power wasted when compared to a 100 HP engine because a smaller horsepower engine has less power lost due to internal friction.

Much research has been done in this area and many solutions have been provided. One of the solutions is to shut down one or more cylinders by disabling the intake and exhaust valves. This method has improved fuel consumption by 8%-25%. However, it causes vibrations, an unequal distribution of heat inside the engine, and also causes step changes in the engine power. Another solution given is to increase the engine's compression ratio in order to improve the pressure at T.D.C. and therefore the thermal efficiency of the engine when the engine is generating less power.

Further, engine designs that use wobbler plate, i.e., swash plates, have been developed that can provide some variable displacement while trying to minimize changes in the compression ratio to keep it substantially constant. Wobbler plate or swash plate engine mechanisms broadly comprise a plurality of piston/cylinders arranged around a crankshaft axis, and coupled to arms of a wobbler, or swash, plate rotatably mounted on a wobbler carrier, which is obliquely mounted on a

crankshaft. As the crankshaft rotates, each piston is forced to reciprocate in its cylinder, and vice versa.

In some swash plate engines, pistons can be positioned at opposing outer perimeter positions of an engine housing which drive respective swash plate assemblies to in turn rotate an output shaft. In these engines, a cylinder head can have threads used to linearly adjust the position of the cylinder head relative to the piston heads to achieve variable compression in a combustion envelope between the piston head and the linearly-adjustable cylinder head. Rotating cam members of respective swash plate assemblies can be supported at equal, but opposite, angles from perpendicular with respect to the power output shaft of the engine. This provides counterbalanced reciprocative travel of the pistons. The rotatable cam members are each understood to be maintained at a fixed angle relative to the output shaft by a structure including a starter gear which interconnects the rotatable members. A pinch plate guide prevents rotation of non-rotatable or pinch plate portions of the swash plate assemblies. The pinch plate guide for each swash plate assembly comprises guide rods extending radially outwardly from the pinch plates into sliding contact with guide slots and guide members attached to the engine housing. These guide rods prevent rotation of the non-rotatable members of the swash plate assemblies. These non-rotatable members are driven by the reciprocating pistons such that the non-rotatable members reciprocate and drive the rotatable members of the swash plate assemblies and thus the output shaft.

Some variable stroke internal combustion engines can include first and second swash plate assemblies with rotatable members that are interconnected by a sliding bar. A crank arm coupled to the sliding bar can shift the position of the sliding bar to adjust the angle of the swash plate assemblies to adjust the engine stroke. The crank is actuated by a link coupled to an actuating mechanism such as a hydraulic piston, a screw or other actuating means. The two swash plate assemblies can be maintained by the sliding bar so as to be substantially parallel positions. A carrier can have a central plate portion which is positioned between and separates the two swash plate assemblies.

In some wobbler plate engines, a wobbler plate can be rotatably mounted on a wobbler carrier which can in turn be mounted at an incline on a crankshaft in a

crankcase. The wobbler plate has a plurality of arms which are coupled to pistons slidably mounted in cylinders arranged around the axis of the crankshaft. As the crankshaft rotates, each arm oscillates laterally relative to its respective piston and a stabilizer mechanism comprising ball races on the wobbler plate and a ball carrier on the crankcase, is included to prevent the oscillations from creating an imbalance in the mechanism. To provide a variable displacement, a shifting mechanism is incorporated that can shift the rotational axis of the wobbler plate along the axis of the crankshaft, and the ball carrier parallel thereto, while simultaneously altering an angle between the crankshaft axis and the wobbler carrier to vary the stroke of the pistons. In such engines, the effective lengths of the ball races can vary to accommodate the alternation of the angle.

In some swash plate engines, a counterbalancing swash plate assembly can be provided. The angle of a first swash plate assembly may be varied to vary the stroke of the engine. The swash plate assemblies may be operable such that during certain operating conditions of the engine a portion of one swash plate assembly passes at least partially through an interior passage provided in another swash plate assembly. In such swash plate engines, the stroke to bore ratio of the engine may be varied from greater than one to less than one depending on a vehicle operating parameter, such as the horsepower and/or torque of the vehicle engine and/or the position of a vehicle throttle pedal. In such swash plate engines, an engine housing is provided with a plurality of cylinders within the engine housing. Each cylinder has a longitudinal cylinder axis extending in a first direction. A piston is positioned within each cylinder for reciprocation therein so that a reciprocative piston is associated with and positioned within each of the respective cylinders. A rotatable output member is rotatably coupled to the housing for rotation about a first axis. Desirably, first and second swash plate assemblies are positioned within the engine housing.

In these swash plate engines, the first swash plate assembly includes a first member and a second member. The first member is rotatably coupled to the second member for rotation relative to the second member and about the first axis. The second member is coupled to the housing such that the second member is restrained against rotation. The first member may be pivotally coupled to the output member for pivoting about a second axis which is transverse to the first axis. A piston rod is pivotally coupled to the piston and also pivotally coupled to the second

member. The piston rod reciprocates with the reciprocal movement of the piston. Reciprocal movement of the piston results in reciprocal movement of the second member and rotation of the first rotatable member and output member about the first axis. The second swash plate assembly also includes a third rotatable member and a fourth member. The third member is rotatably coupled to the fourth member for rotation relative to the fourth member and about the first axis. The fourth member is also coupled to the housing such that the fourth member is restrained against rotation. The third member may also be pivotally coupled to the output member for pivoting about a third axis which is transverse to the first axis. The third member rotates with the rotation of the output member and with the rotation of the first member. Rotational movement of the third member results in reciprocal movement of the fourth member. Desirably, the reciprocal movement of the fourth member counterbalances the reciprocal movement of the second member.

In all these swash plate or wobbler plate engines, the pistons are attached to the swash plate or wobbler plate and the pistons oscillate with the swash plate to which they are attached so that only one piston is at top dead center at any given time and the other pistons are at various retreating or advancing stroke positions with none of the pistons at same stroke position. Thereby, such engine designs generally do not operate in the same manner as a conventional 4-cylinder engine that has two pistons positioned at top dead center when the other two pistons are positioned at bottom dead center.

## SUMMARY

It is an object of the present disclosure to provide variable displacement devices and related methods that can be used to change the amount of volume displaced by pistons within corresponding cylinders. More specifically, the subject matter disclosed herein relates to variable displacement devices usable as pumps, combustion engines, air compressors, or the like, that can be used to change the amount of volume displaced by pistons within corresponding cylinders while, in some embodiments, the compression ratio remains relatively constant.

While a few objects of the presently disclosed subject matter have been stated hereinabove, which can be achieved in whole or in part by the presently disclosed subject matter, other objects will become evident as the description

proceeds when taken in connection with the accompanying drawings as best described hereinbelow.

## BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present subject matter including the best mode thereof to one of ordinary skill in the art is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

Figure 1 illustrates a front view of an embodiment of a variable displacement device according to the subject matter disclosed herein;

Figure 2 illustrates a side view of the embodiment of the variable displacement device according to Figure 1;

Figure 3 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line A-A;

Figure 4 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 2 taken along the line B-B;

Figure 5 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figures 2 and 3 taken along the line C-C;

Figure 6 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figures 2 and 3 taken along the line D-D;

Figure 7 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line E-E;

Figure 8 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line E-E after the main shaft has been rotated 180 degrees relative the cross-sectional view illustrated in Figure 7;

Figure 9 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line E-E when the volume displacement is greater than zero;

Figure 10 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line E-E when the volume displacement is greater than zero, but after the main shaft has been rotated 180 degrees relative the cross-sectional view illustrated in Figure 9;

Figure 11 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line F-F when the volume displacement is equal to zero;

Figure 12 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line F-F when the volume displacement is equal to zero, but after the main shaft has been rotated 180 degrees relative the cross-sectional view illustrated in Figure 11;

Figure 13 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line F-F when the volume displacement is greater than zero;

Figure 14 illustrates a cross-sectional view of the embodiment of the variable displacement device according to Figure 1 taken along the line F-F when the volume displacement is greater than zero, but after the main shaft has been rotated 180 degrees relative the cross-sectional view illustrated in Figure 13;

Figure 15 illustrates perspective view of an embodiment of a variable displacement device according to the subject matter disclosed herein;

Figure 15A illustrates an exploded perspective view of the embodiment of the variable displacement device according to Figure 15;

Figure 16 illustrates perspective view of a portion of the embodiment of the variable displacement device according to Figure 15;

Figure 17 illustrates a side view of another embodiment of the variable displacement device according to the subject matter disclosed herein that uses a different embodiment of a driver in the form of a screw device that can move the adjustment assembly to vary displacement according to the subject matter disclosed herein;

Figure 18 illustrates a front view of an additional embodiment of the variable displacement device according to the subject matter disclosed herein which uses a different embodiment of a driver in the form of two screw devices for varying displacement according to the subject matter disclosed herein;

Figure 19 illustrates a side view of the embodiment of the variable displacement device according to Figure 18 that uses the screw device for varying displacement; and

Figure 19A illustrates a side view of an additional embodiment of the variable displacement device according to the subject matter disclosed herein which uses a different embodiment of a driver in the form of two hydraulic cylinder devices (only one is shown) for varying displacement according to the subject matter disclosed herein with one hydraulic cylinder device on either side of the variable displacement device in a similar position as the screw devices depicted in Figure 18; and

Figures 20-23 illustrate schematic views of embodiments of controllers that can be used to control different embodiments of variable displacement devices that comprise combustion engines according to the subject matter disclosed herein.

## DETAILED DESCRIPTION

Reference will now be made in detail to the description of the present subject matter, one or more examples of which are shown in the figures. Each example is provided to explain the subject matter and not as a limitation. In fact, features illustrated or described as part of one embodiment may be used in another embodiment to yield still a further embodiment. It is intended that the present subject matter cover such modifications and variations.

Although the terms first, second, right, left, front, back, etc. may be used herein to describe various features, elements, components, regions, layers and/or sections, these features, elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one feature, element, component, region, layer or section from another feature, element, component, region, layer or section. Thus, a first feature, element, component, region, layer or section discussed below could be termed a second feature, element,

component, region, layer or section without departing from the teachings of the disclosure herein.

In the present disclosure, when a feature, element, component, region, layer and/or section is being described as "top", "bottom," "front," "rear," "side," etc., it should be understood that such terms are relative and not absolute. Thus, something that is described with the adjective of "top" may also be considered on a side or a bottom depending on the orientation of the larger subject being described. Additionally, when a feature, element, component, region, layer and/or section is being described as "under," "on," or "over" another feature, element, component, region, layer and/or section, it is to be understood that the features, elements, components, regions, layers and/or sections can either be directly contacting each other or have another feature, element, component, region, layer and/or section between the them, unless expressly stated to the contrary. Similarly, directional movement, such as "back and forth," "forward," "backward," "up," "down," or the like are to be understood as relative descriptions that can change depending on the orientation of the subject matter relative to the viewer. Thus, these terms are simply describing the relative position of the features, elements, components, regions, layers and/or sections to each other and do not necessarily mean an absolute position or direction since the relative position above or below depends upon the orientation of the subject matter to the viewer.

Embodiments of the subject matter of the disclosure are described herein with reference to schematic illustrations of embodiments that may be idealized. As such, variations from the shapes and/or positions of features, elements or components within the illustrations as a result of, for example but not limited to, user preferences, manufacturing techniques and/or tolerances are expected. Shapes, sizes and/or positions of features, elements or components illustrated in the figures may also be magnified, minimized, exaggerated, shifted or simplified to facilitate explanation of the subject matter disclosed herein. Thus, the features, elements or components illustrated in the figures are schematic in nature and their shapes and/or positions are not intended to illustrate the precise configuration of a leg protector and are not intended to limit the scope of the subject matter disclosed herein.

"Top dead center" as used herein means the dead-center position of a piston and its connecting rod within a cylinder in a volume displacement device at the top of the piston's stroke when the piston has reached its uppermost position within the cylinder and the volume within the cylinder is at its smallest.

"Bottom dead center" as used herein means the dead-center position of a piston and its connecting rod within a cylinder in a volume displacement device at the bottom of the piston's stroke when the piston has reached its lowermost position within the cylinder and the volume within the cylinder is at its largest.

"Piston stroke length" or "stroke length" as used herein means the distance a piston travels in a cylinder between top dead center and bottom dead center. For example, the piston stroke length can be the measurement of the distance from top dead center to bottom dead center as during an induction stroke or power stroke or the distance from bottom dead center to top dead center. "Piston stroke length" and "stroke length" are used herein interchangeably.

"Compression ratio" as used herein means the value that represents the ratio of the volumes of a cylinder within a volume displacement device based on the volume of the cylinder at the largest capacity of the cylinder when the piston within the cylinder is at bottom dead center compared to the volume of the cylinder at the smallest capacity of the cylinder when the piston within the cylinder is at top dead center. The compression ratio of a volume displacement device can be obtained by dividing the volume of a cylinder when the piston therein is bottom dead center by the volume of a cylinder when the piston therein is top dead center.

"Volume displacement" as used herein means the amount of volume within a cylinder that is displaced when the piston within the cylinder travels the piston stroke length from bottom dead center to top dead center.

Multiple stroke cylinder-piston variable displacement devices are provided herein. Such variable displacement devices as disclosed herein can include a rotatable main shaft, a cylinder block, one or more pistons that can travel within cylinders in the cylinder block, a wobbler carrier connected to and rotatable with the main shaft, a wobbler that resides in the wobbler carrier but does not rotate, a wobbler follower secured to the wobbler and an adjustment assembly that is secured

to the wobbler follower. The adjustment assembly can be used to adjust an angle of the wobbler carrier relative to the axis of the main shaft to adjust the stroke length of the pistons and change the volume that is displaced within the cylinder by the piston. The adjustment assembly, wobbler follower, wobbler, main shaft, and/or wobbler carrier can be in operable communication together and can be movable in relation to each other. The dimensions and the connections of the components, such as the wobbler, the wobbler carrier, a main link between the wobbler carrier and the main shaft, and the wobbler follower, as well as components of the adjustment assembly, for example, can be such that the adjustments made to the piston stroke lengths can keep the compression ratio nearly constant regardless of the volume displaced by the pistons within the cylinder.

Depending on how the variable displacement device is to be used, the pistons can be used to drive the shaft or, conversely, the shaft can be used to drive the pistons. For example, the variable displacement devices disclosed herein can comprise engines, such as internal combustion engines, pumps for pumping fluids, compressors used to compress gases, compressed air engines, hydraulic engines, etc. For example, in embodiments where the variable displacement device comprises a combustion engine, the pistons within the cylinders can interact with valves that provide air and fuel and take away exhaust and with spark plugs that ignite the fuel to drive the shaft. Conversely, the shaft in some embodiments of the variable displacement device can be engaged by and driven by a motor to drive the shaft. The shaft can then in turn cause the pistons to oscillate within the cylinder. Such embodiments of the variable displacement device can comprise an air compressor or a pump. While the shaft can be used to drive the pistons in some embodiments of the variable displacement device disclosed herein, most illustrated examples provided herein relate to variable displacement devices where the pistons are used to drive the shaft, such as in internal combustion engines.

As shown in the Figures, an embodiment of a four stroke, cylinder-piston, reciprocating type variable displacement device, such as a four-stroke engine, is provided. In such embodiments, the variable displacement device can vary displacement of the engine steplessly (i.e., continuously) from zero to a maximum when the engine is generating different levels of power. With this variability, power that is wasted due to internal friction within these variable displacement devices can

be reduced when the displacement (via the piston stroke) of the respective variable displacement device is reduced. Further, each piston's lateral pressure to the cylinder walls can be very low; and, therefore, less internal friction will be generated by the pistons. At the same time, the compression ratio can be close to constant in all displacement situations for either high or low power output. For example, the volume of the combustion chamber will change according to changes in displacement. Therefore, air pressure at the time of ignition when the given piston is at top dead center can remain nearly fixed and can be equal to a desired value so that the thermal efficiency of the engine remains at or near a maximum value. Additionally, due to the arrangement and configuration of the components mentioned above and described in more detail below, an engine's balance can remain the same when there are changes in the piston's displacement. Further, an engine's power output can change consistently and can be adjustable from at or near zero to a maximum power. Engine cooling and lubrication can also be done easily. In embodiments used as engines, the thermal efficiency of the engine can stay at or near maximum levels and remain nearly fixed at all times whether there is low power, high power, or anything in between being generated.

With the variable displacement devices disclosed herein, the changing of the power of the engine is consistent and done by changes in displacement of the piston's stroke which can be varied in a continuous manner. In all situations, intake air pressure into the cylinders can be nearly equal to ambient pressure. In all situations, thermal efficiency of an engine employing the variable displacement devices disclosed herein can be substantially maintained at its maximum rate. In such engines, by controlling the amount of the stroke of the pistons, the amount of input air to the engine can be controlled and the power delivered by the engine can be changed. For example, in situations of less power, the piston's stroke can be reduced. Thereby, the engine's internal friction can also be reduced accordingly. Control of the engine output can thus be accomplished by utilizing the systems that adjust the piston's stroke, instead of opening and closing the throttle air inlet. Therefore, the air inlet can be open at all times. Further, in such embodiments, pistons can stay motionless when there is zero power. Thus, there will not be any friction created that can harm the pistons and its connecting joints in such configurations. Accordingly, engines that employ the variable displacement devices

disclosed herein can be economical than conventional engines and can reduce the fuel consumption. A "super charger" can also be attached to such engines, especially in high altitude areas.

It should be mentioned that in certain situations (when the road is sloped) where the engine is used to reduce the speed of the vehicle, this action can be done by closing the fuel injection system and maximizing the piston's stroke at the same time.

The variable displacement devices disclosed herein has a main oscillating plate (wobbler follower) which pivots on a wobbler by two pins, and provides its piston's oscillating movement. The wobbler is held within a wobbler carrier, and the wobbler carrier can freely rotate within the wobbler and the wobbler follower. The wobbler carrier can be connected to the main shaft. The rotation of the wobbler carrier can be related to the rotation of the main shaft. In such embodiments, when the main shaft rotates, so does the wobbler carrier. The wobbler carrier can be connected to the main shaft via a main link. The rotation of the wobbler carrier/main shaft can bring about the "wobbling" movement of the wobbler. The wobbler follower can be connected to the wobbler via two pins. The "wobbling" movement of the wobbler causes the oscillating movement of the wobbler follower. From one end, the main link can be connected to the main shaft via a connecting pin. From the other end, the main link can be connected to the wobbler carrier via a wobbler carrier pin. Both of the aforementioned connections via the two different pins are not rigid and are able to pivot/move within a small angle.

The wobbler follower can comprise two wobbler follower shafts connected to a wobbler follower body. The two wobbler follower shafts can hold the wobbler follower in place and allow it to oscillate. The wobbler follower can oscillate about the same rotational axis as the two wobbler follower shafts. The variable displacement device can have one or more pistons. The pistons can be arranged around the main shaft axis (the axes of the cylinders can be parallel to the axis of the main shaft). The pistons can be connected to the wobbler follower via connecting rods. The movement of the pistons can be dependent upon the movement of the wobbler follower and vice versa (that is, if the piston oscillates, the wobbler follower will oscillate and vice versa). The pistons can be attached to the connecting rods via

Gudgeon pins. Also, the connecting rods can be connected to and can be pivoted about the wobbler follower via connecting rod pins. Based on the aforementioned information, the rotation of the main shaft can causes the reciprocating movement of the pistons which signifies a completed cycle.

The wobbler follower can also comprise two main wobbler follower shaft housings. The wobbler follower shafts can be located within main wobbler follower shaft housings. Each wobbler follower shaft can partially rotate within the respective main wobbler follower shaft housing. Each wobbler follower shaft can be located in a space/slot within main shaft cases that can encase the main shaft. The spaces or slots can be parallel to the main shaft. The wobbler follower shafts can move parallel with the main shaft within the spaces/slots in main shaft cases in forward and backward movements. Each wobbler follower shaft can be positioned and moved within the respective slot of the main shaft cases by various methods (when volume displacement is needed within the variable displacement device). In order to adjust the position of the wobbler follower shafts, one or more drivers can be used that are part of the adjustment assembly. Examples of such drivers can include screw devices and hydraulic cylinders. In some embodiments, the adjustment assembly can comprise two drivers positioned on opposing sides of the cylinder block. Each driver can be directly or indirectly connected to a respective wobbler follower shaft. These drivers, for example, can work in tandem to move the wobbler follower.

In some embodiments, the adjustment assembly can comprise a variety of components that work together when moving the wobbler follower, for example, via the wobbler follower shafts, and thus, the wobbler and wobbler carrier. For example, in some embodiments, the adjustment assembly can comprise two arm members with a connecting beam between the two arm members on one end of the two arm members and an arm base. The arm members can also be attached to the arm base in a pivotal manner. As stated above, the adjustment assembly can comprise one or more drivers that can be connected to the arm base and/or the connecting beam. The configurations of the adjustment assembly as shown in Figures1-17 allow the adjustment assembly to have angular motions. In such embodiments, the movement of the driver causes a movement in the connecting beam which in turn can cause the adjustment assembly to move. The movement of the adjustment assembly can be transferred to the wobbler follower shaft housings. Finally, this

movement can be then passes along to the wobbler follower shafts which place the wobbler follower in the desired position. The change in the position of the wobbler follower shafts, and thereby the main oscillating axis of the wobbler follower, can cause a variation in the volume displacement of the variable displacement device.

The parts of the variable displacement devices can be designed in such a way that when the main oscillating axis of the wobbler follower is changed that causes a variation of the stroke length of the piston, the compression ratio of the mechanism can remain at or near a constant level. Therefore, when such variable displacement devices are being used in an internal combustion engine, the thermal efficiency of the engine can remain approximately at maximum levels at or near a constant rate.

The position of the wobbler follower shafts, and thereby the position of the oscillating axis of the wobbler follower, can be determined and set by a controller, such as a computer system, computer, mini-computer, programmer logic controller, microprocessor, or the like, that is in communication with at least one driver on the adjustment assembly. Commands that can be given by the controller can be related to the needed displacement within the cylinders of the volume displacement device for the desired power. These commands can be generated by the controller based on different conditions and parameters that can be set by the controller or by instructions input into the controller. Once sent, these commands can be executed by the one or more drivers of the adjustment assembly. In some embodiments, one or more drivers can be used, such as one or more hydraulic cylinders or one or more screw devices. Such drivers can be used to move the connecting beam and/or arm base integral with the arm members of the adjustment assembly. Thus, the movement of the connecting beam and/or arm base in turn causes the movement of the adjustment assembly, the wobbler follower shaft housings, and wobbler follower shafts, and thereby the main oscillating axis of the wobbler follower.

It should be noted that the parts of the mechanism can also be designed in such a way so that the compression ratio is variable. For example, in many embodiments of variable displacement devices, the remaining volume in the top dead center remains almost constant. Such embodiments can be utilized as pumps, gas compressors, compressed air engines, hydraulic motors, and apparatuses of that nature.

It is noted that, because the cylinder head of different embodiments of the variable displacement device (as well as its associated parts) changes with different uses (pumps, internal combustion engine, etc.), the cylinder heads do not appear in the given figures. It is further noted that, in the given figures, the bearings and secondary parts of the variable displacement devices are not shown (for example: the pistons' rings, the lubrication mechanism, the cooling system, and features of that nature). The purpose of this is to show the main parts of the variable displacement devices clearly and effectively. It should be noted that for the parts of the variable displacement devices that slide on each other and/or rotate about each other, anti-friction and anti-wear materials can be used. In the following descriptions, the abovementioned parts are no longer mentioned.

As shown in Figures 1-16, an embodiment of a variable displacement device **100** is provide that can comprise a cylinder block **16** having one or more cylinders and a main shaft **1**. As shown in Figures 1-16, cylinder block **16** has four cylinders in which individual pistons **3A**, **3B**, **3C**, **3D** can oscillate. The main shaft **1** can have a first end **1A** and a second end **1B** (see Figures 7-10). The first end **1A** of the main shaft **1** can be located in and/or extend through the cylinder block **16** and the second end **1B** of the main shaft **1** can be located in and/or extend through a main shaft case (body) comprising two portions **33** and **34**. The main shaft **1** can rotate about its axis, main shaft axis $A_S$, which can also correspond with the axis of symmetry for the variable displacement device **100**. The variable displacement device **100** can also comprise a wobbler carrier represented by **24** and **32** that is connected to and rotatable with the shaft **1** and a wobbler **23** can be held by the wobbler carrier **24** and **32** but does not rotate with the wobbler carrier **24** and **32**. While the wobbler carrier **24** and **32** is shown in the figures as two separate pieces that are secured together, the wobbler carrier in other embodiments can be a single unitary piece that has a different configuration.

The wobbler carrier **24** and **32** can have a wobbler carrier aperture **WCA** therethrough (see Figure 5). The main shaft **1** can extend through the wobbler carrier aperture **WCA** and thus the wobbler carrier **24** and **32**. In some embodiments, the wobbler carrier aperture **WCA** can be a circular aperture and the wobbler carrier **24** and **32** can be annular. In some embodiments, a center point of the wobbler carrier aperture **WCA** can align with the main shaft axis $A_S$. Similarly,

the wobbler **23** can have a wobbler aperture **WA** therethrough. The wobbler carrier aperture **WCA** can be alignable with the wobbler aperture **WA** with the main shaft **1** extending through both the wobbler carrier aperture **WCA** and the wobbler aperture **WA** (see Figure 5). For example, in some embodiments, the wobbler **23** and the wobbler carrier **24** and **32** can be aligned so that the wobbler carrier aperture **WCA** and the wobbler aperture **WA** are concentric. For example, in some embodiments, the wobbler **23** can reside in the wobbler carrier **24** and **32**. In some embodiments, as shown in Figures 7-10, the wobbler carrier **24** and **32** can form a groove **24G** along its outer periphery **24P**. The wobbler **23** can reside in the groove **24G** in the wobbler carrier **24** and **32** with an outer perimeter **23P** of the wobbler **23** extending outside of the groove **24G**.

Additionally, the variable displacement device **100** can also comprise a wobbler follower **19** that can be secured to the wobbler **23** and an adjustment assembly **8** that is secured to the wobbler follower **19**. The pistons **3A**, **3B**, **3C**, **3D** can be pivotably attached to the wobbler follower **19**. The wobbler follower **19** can also have an aperture **WFA** therethrough (see Figure 1 and 5). An inner periphery **19L** of the wobbler follower **19** can form the aperture **WFA** (see Figure 1 and 5). The aperture **WFA** can be of any suitable cross-sectional shape, but can be larger than the wobbler **23**. For example, the wobbler **23** can at least partially reside within the aperture **WFA** of the wobbler follower **23** and can move freely in any direction. In some embodiments, the outer perimeter **23P** of the wobbler **23** can be rotatably secured to the inner periphery **19L** of the wobbler follower **19** (see Figures 5). For example, the outer perimeter **23P** of the wobbler **23** can be rotatably secured to the inner periphery **19L** of the wobbler follower **19** along an axis of the wobbler $A_1$.

The wobbler follower **19** can have a body with an outer periphery **19O** that can be connected to the adjustment assembly **8**. For example, in some embodiments, the wobbler follower **19** can comprise wobbler follower shafts **18** that can be connected to the body of the wobbler follower **19**. The wobbler follower shafts **18** can be attached to opposing sides of the wobbler follower **19** at the outer periphery **19O** along an axis of oscillation $A_2$ as is explained in more detail below (see Figure 5). Further, the wobbler follower shafts **18** can be connected to the adjustment assembly **8** on ends opposite from the ends connected to the outer periphery **19O**.

As the shaft **1** rotates, wobbler carrier **24** and **32** rotates with the shaft **1**. While the wobbler **23** does not rotate with the wobbler carrier **24** and **32**, the wobbler **23** can oscillate as the wobbler carrier **24** and **32** is at an angle to the main shaft axis $A_S$ and the wobbler carrier **24** and **32** rotates with the main shaft **1**. Conversely, as the wobbler **23** is oscillated by the wobbler follower **19** as the pistons move within the cylinders, the wobbler **23** can rotate the wobbler carrier **24** and **32**, which, in turn, can rotate the main shaft **1**. Depending on the angle of the wobbler carrier **24** and **32** relative to the main shaft axis $A_S$, the stroke length of the pistons **3A**, **3B**, **3C**, **3D** can be varied causing the volume displaced in the cylinders in the cylinder block **16** to be varied.

The adjustment assembly **8** can be used to adjust the angle of the wobbler carrier **24** and **32** relative to the axis $A_S$ of the shaft **1** to adjust the stroke length of the pistons **3A**, **3B**, **3C**, **3D** and change the volume that is displaced within each cylinder by the respective piston **3A**, **3B**, **3C**, **3D**. In particular, the changing of the angle of the wobbler carrier **24** and **32** relative to the main shaft axis $A_S$ can result from the movement of the wobbler follower **19** by the adjustment assembly **8** to adjust the stroke length of the one or more pistons **3A**, **3B**, **3C**, **3D**. The movement of the wobbler follower **19** and the resulting adjusted stroke lengths change the volume that is displaced within the cylinders by the respective pistons **3A**, **3B**, **3C**, **3D** as the respective pistons **3A**, **3B**, **3C**, **3D** oscillate within their corresponding cylinders. Varying the position of the adjustment assembly **8** can vary the volume displaced by the pistons **3A**, **3B**, **3C**, **3D** within the cylinders while maintaining a substantially constant compression ratio for the pistons **3A**, **3B**, **3C**, **3D** within the cylinders. For example, the compression ratio can be maintained at or near a specific level even as the volume displaced within the cylinders varies. In some embodiments of the variable displacement devices, however, the compression ratio may vary in the same or different manner as the volume displacement varies.

A main link **26** is provided to secure the wobbler carrier **24** and **32** to the shaft **1**. As shown in Figures 6, 7, 8, and 16, the main link **26** is connected at one end to the main shaft **1** by a connecting pin **2**, while the main link **26** is connected at the other end to the wobbler carrier **24** and **32** by wobbler carrier pin **31**. Thereby, the main shaft **1**, the main link **26**, and wobbler carrier **24** and **32** all rotate together. The main link **26** can be configured to aid in maintaining a spatial relationship between

the wobbler carrier **24** and **32** and the main shaft **1** as the angle of the wobbler carrier **24** and **32** relative to the main shaft **1** is changed so that the pistons **3A**, **3B**, **3C**, **3D** remain aligned with the respective cylinders without hindering the oscillation of the pistons **3A**, **3B**, **3C**, **3D** within the respective cylinders.

The wobbler carrier **24** and **32** can hold the wobbler **23** in a groove that can be formed, or defined, in an outer perimeter of the wobbler carrier **24** and **32** so that the wobbler **23** can be exposed on the outer perimeter of the wobbler carrier **24** and **32** as seen in Figures 1, 3, 4, and 7-10. The wobbler carrier **24** and **32** is able to rotate with the main shaft **1** around an inside portion without the wobbler **23** rotating.

The wobbler **23** can be connected to the wobbler follower **19** by wobbler follower pins **20**. The wobbler follower pins **20** can connect the wobbler **23** to the wobbler follower **19** along the axis of the wobbler $A_1$. In particular, the wobbler follower **19** can have a central aperture therein through which the main shaft **1** passes and in which the wobbler carrier **24** and **32** and the wobbler **23** are positioned. The wobbler follower pins **20** can connect the wobbler **23** residing in the aperture of the wobbler follower **19** to a first side **19C** and an opposing second side **19D** of the wobbler follower **19** at points in intersecting alignment with the main shaft **1** so that the axis of the wobbler $A_1$ passes through, for example, intersects with, the main shaft **1**. The wobbler follower **19** can, in turn, be attached to the adjustment assembly **8**, which can be moved back and forth to adjust the angle of the wobbler carrier **24** and **32** relative to the main shaft **1**. In particular, the wobbler follower **19** can be attached to the adjustment assembly **8** by wobbler follower shafts **18**. For example, in some embodiments as shown in the figures, the wobbler follower **19** can also comprise wobbler follower shaft housings **17**. The wobbler follower shafts **18** can be located within wobbler follower shaft housings **17** that can be secured to the adjustment assembly **8**. Each wobbler follower shaft **18** can partially rotate within the respective wobbler follower shaft housing **17**.

The adjustment assembly **8** as shown in the Figures 1-5, 15, and 15A can comprise various components that work together when moving the wobbler follower **19**, and thus, the wobbler **23** and wobbler carrier **24** and **32**. For example, the adjustment assembly **8** can comprise two arm members **8A** and **8B** with a connecting beam **10** between the two arm members **8A** and **8B** on one end of the

two arm members **8A** and **8B** and an arm base **4**. The arm members **8A** and **8B** can also be attached to the arm base **4**, for example, by one or more hinge pins **7** that in some instances can be a bolt on an opposing end of the arm members **8A** and **8B**. The arm base can, in turn, be attached to the cylinder block **16**. The adjustment assembly **8** can further comprise a driver **15** that can be secured to the cylinder block **16** by a driver base **14** and movably attached to the connecting beam **10**. For example, in the embodiment shown, the driver **15** can be secured to the base **14** in different manners, including, for example, at one end by a hinge pin **13** that can permit the movement of the driver **15** as the adjustment assembly **8** is moved. At an opposing end, the driver **15** can be movable attached to the connecting beam **10** by a hinge pin **12**. Hinge pins, like the pins **7**, **12**, can comprise other components such as washers **5**, **11** as shown in Figures 1-5 that can facilitate the pins **7**, **12** serving as hinges. The arm members **8A** and **8B** of the adjustment assembly **8** can have apertures therein for receiving the respective wobbler follower shaft housings **17** as shown in Figure 15A. Covers **9** can be provided for covering the apertures on the sides of the arm members **8A** and **8B** that face outward.

The configuration of the adjustment assembly **8** as shown in the Figures 1-6 allows the adjustment assembly **8** to have an angular motion. The movement of the driver **15** can cause a movement in the connecting beam **10** which in turn causes the adjustment assembly **8** to move. The movement of the adjustment assembly **8** can transferred to the wobbler follower shaft housings **17**. Finally, this movement is then passed along to the wobbler follower shafts **18** which place the wobbler follower **19** in the desired position.

Thus, the adjustment assembly **8** as shown in Figures 1-5, through the arm members **8A** and **8B**, the adjustment arm base **4**, hinge pins **7**, **12**, and **13**, connecting beam **10**, and the one or more drivers, such as a hydraulic cylinder **15**, can indirectly move the wobbler carrier **24** and **32** relative to the cylinder block **16** and the main shaft **1** to change its angle relative to the main shaft **1**. As the adjustment assembly **8** moves, the arm members **8A** and **8B** in which the wobbler follower shaft housings **17** reside move the wobbler follower **19** through the wobbler follower shaft housings **17** and the wobbler follower shafts **18**. Thereby, the wobbler follower **19** can move the wobbler **23** through the connection made between them with the wobbler follower pins **20**. The wobbler **23** can, in turn, move the wobbler

carrier **24** and **32**. The main link **26** rotates around the connecting pin **2** to help maintain the wobbler carrier **24** and **32** in a concentric relationship with the main shaft **1**.

Since the main link **26** is connected to the rotatable main shaft **1**, a counterbalance to the main link **26** is needed to keep the main shaft **1** in balance during rotation. In particular, a balancing weight **27** having a similar weight, length and weight distribution as the main link **26** can be connected to the main shaft **1** by a connecting pin **2** as shown in Figures 3 and 6-10. The main link **26** and the balancing weight **27** can be situated opposite one another along the main shaft **1** and can be fitted together with a small section of gears **A** and **B** (see Figure 3) such that, when the main link **26** moves angularly, the balancing weight **27** moves by an equal angular amount.

As stated above, to facilitate the operation of the variable displacement device **100**, the wobbler follower shafts **18** can be pivotally secured on a third side **19A** and an opposing fourth side **19B** along the axis of oscillation $A_2$. The wobbler follower shafts **18** can be aligned so that the axis of oscillation $A_2$ is generally perpendicular to the axis of the wobbler $A_1$. Further, the wobbler follower shafts **18** can be aligned with the main shaft **1** so that the axis $A_2$ passes through the main shaft axis $A_S$. For example, the axis of oscillation $A_2$ can be perpendicular to the axis $A_S$ of the main shaft **1**. The wobbler follower shafts **18** can be centrally located on the sides **19A**, **19B**. This configuration can aid in holding the wobbler follower **19** at these central points of connection along the oscillation axis $A_2$ and aligned with the rotatable main shaft **1** whether the main shaft **1** is rotating in a driving manner or being rotated in a driven manner.

Thus, as explained above, the wobbler follower **19** does not have a full rotating motion, but does have an oscillating motion about the axis of oscillation $A_2$ created by the wobbler follower shafts **18**. By the connection of the adjustment assembly **8** to the wobbler follower **19** through the wobbler follower shafts **18** that are generally centrally located on the sides **19A**, **19B**, the axis of oscillation $A_2$ (see Figure 5) serves as a fulcrum to allow the sides **19C**, **19D** of the wobbler follower **19** to rock back and forth like a see-saw so that the sides **19C**, **19D** oscillate an equal amount. Thus, the variable displacement devices **100** that comprise a the wobbler

follower **19** as disclosed herein differs from the displacement devices that only use a wobbler plate or swash plate by having more of a see-saw effect where only two sides travel back and forth in the full oscillation distance instead of having a swash plate effect where generally all the side oscillate the same distance.

The axis of oscillation $A_2$ can bisects the wobbler follower **19** with a first wobbler follower portion $19S_1$ on one side of the axis of oscillation $A_2$ and a second wobbler follower portion $19S_2$ on the other side of the axis of oscillation $A_2$. Additionally, the axis of oscillation $A_2$ can be aligned with and perpendicular to the main shaft axis $A_S$. As shown in the figures, the axis of oscillation $A_2$ can intersect the main shaft axis $A_S$. As the angle of the wobbler carrier **24** and **32** changes relative to the main shaft axis $A_S$, the axis of oscillation $A_2$ moves forward or backward relative to the main shaft axis $A_S$ in the embodiment shown in Figures 1-16. Depending on the embodiment of the variable displacement device, first and second wobbler follower portions $19S_1$ and $19S_2$ may or may not be of equal size and proportions.

In some embodiments, the pistons **3A**, **3B** can be pivotably attached to the first wobbler follower portion $19S_1$ and the pistons **3C**, **3D** can be pivotably attached to the second wobbler follower portion $19S_2$. In operation, the first wobbler follower portion $19S_1$ and the second wobbler follower portion $19S_2$ of the wobbler follower **19** can oscillate back and forth about the axis of oscillation $A_2$. Thereby, the pistons **3A**, **3B** on the first wobbler follower portion $19S_1$ oscillate together with the first wobbler follower portion $19S_1$ and the pistons **3C**, **3D** on the second wobbler follower portion $19S_2$ oscillate together with the second wobbler follower portion $19S_2$ that can be 180° difference in phase.

Thus, the pistons **3A**, **3B**, **3C**, **3D** can be connected proximal to sides **19C**, **19D** of the wobbler follower **19** in proximity of the peripheries of the sides **19C**, **19D** to more fully take advantage of the oscillation motion of the sides **19C**, **19D**. For example, pistons **3A**, **3B** can be movably connected to the wobbler follower **19** on side **19C** and pistons **3C**, **3D** can be movably connected to the wobbler follower **19** on side **19D** so that the pistons **3A**, **3B** oscillate back and forth as side **19C** oscillates back and forth and the pistons **3C**, **3D** oscillate back and forth as side **19D** oscillates back and forth.

In particular, the pistons **3A**, **3B**, **3C**, **3D** can be connected to the first wobbler follower portion $19S_1$ and the second wobbler follower portion $19S_2$ of the wobbler follower **19** by connecting rods **22A**, **22B**, **22C**, **22D** that are rotatably connected at one end by connecting rod pins **21A**, **21B**, **21C**, **21D** to the respective the first wobbler follower portion $19S_1$ and the second wobbler follower portion $19S_2$ of the wobbler follower **19** and pivotally connected at one end by piston pins **29A**, **29B**, **29C**, **29D**, such as Gudgeon pins, and locking rings **28A**, **28B**, **28C**, **28D** to the respective pistons **3A**, **3B**, **3C**, **3D**. Through the connections of components as described above, the wobbling motion of the wobbler **23** causes the wobbler follower **19** to oscillate. The oscillation of the first wobbler follower portion $19S_1$ and the second wobbler follower portion $19S_2$ of the wobbler follower **19** is passed on to the connecting rods **22A, 22B, 22C, 22D**. Finally, this movement is transferred to the pistons **3A**, **3B**, **3C**, **3D** and causes the reciprocating movement of the pistons **3A**, **3B**, **3C**, **3D**.

To hold the wobbler follower **19**, as described above, the wobbler follower shafts **18** can be located in slots **35** in the main shaft case portions **33** and **34** with axis $A_2$ of the wobbler follower shafts **18** being the main axis of oscillation of the wobbler follower **19**. In particular, each wobbler follower shaft **18** can be located in a slot **35** by the respective wobbler shaft housing **17** within main shaft case portions **33**, **34** as shown in Figures 2 and 11. The slots **35** can be parallel to the main shaft **1**. The wobbler follower shafts **18** can move parallel with the main shaft **1** within the slots **35** in main shaft case portions **33**, **34** in forward and backward movements. Each wobbler follower shaft **18** can be positioned and moved within the respective slot **35** by various methods when volume displacement is needed within the variable displacement device **100**.

Through the movement of the arm members **8A** and **8B** by the adjustment assembly **8**, movements of the wobbler follower shaft **18** within the slots **35** in the main shaft case portions **33** and **34** can run generally parallel to the axis $A_S$ of the main shaft **1**. In particular, this movement can be generated by a driver, such as the hydraulic cylinder **15** in embodiments similar to that shown in Figures 1-16. This movement causes the variation in the amount of volume displacement in the cylinders of the variable displacement device **100**. The wobbler follower shafts **18** can be maintained perpendicular to axis $A_S$ of the main shaft **1** during the movement

of the adjustment assembly **8**, while the wobbler follower shafts **18** can be moved back and forth by the adjustment assembly **8** up to a distance **L**. The wobbler follower shafts **18** can absorb and tolerate the torque of the wobbler follower **19** and transfers it to the main shaft case portions **33** and **34**. In all positions of the wobbler follower shafts **18**, the wobbler follower **19** can be held in its place by the cylindrical parts of the wobbler follower shafts **18**. The wobbler follower shafts **18** can thus facilitate an oscillating motion (See Figures 1-3, 5, and 7-16).

The wobbler follower shafts **18** can be held within the wobbler follower shaft housings **17** and the hydraulic cylinder **15** causes the movement of the adjustment assembly **8**. This movement can be transferred to the wobbler follower shaft housings **17** which can transfer the movement to the wobbler follower shafts **18**. As stated above, the components of the adjustment assembly **8** can vary, adjust, and fix the oscillating axis $A_2$ of the variable displacement device **100** shown in Figures 1-16 with respect to the desired operating condition. The components can include the connecting beams **10**, the hydraulic cylinder **15**, the arm members **8A** and **8B**, and adjustment arm base **4** that can work with the wobbler follower shafts **18** and the wobbler follower shaft housings **17** of the wobbler follower **19**.

As stated above, the wobbler follower shafts **18** can be maintained by the movement of the adjustment assembly **8** in a position that is about perpendicular to the axis $A_S$ of the main shaft **1**, while the wobbler follower shafts **18** can be also moved along the distance **L** by the adjustment assembly **8** through the wobbler follower shaft housings **17**. Thus, the adjustment assembly **8** can move the wobbler follower shafts **18**, the wobbler follower **19**, the wobbler **23**, and the wobbler carrier **24** and **32** back and forth in an angular motion in directions $M_A$ (see Figure 3) so that the wobbler follower shafts **18** can be positioned to any point desired along the distance L in a smooth, continuous fashion. The indirect movement of the wobbler carrier **24** and **32** in this manner will change its angle relative to the axis $A_S$ of the main shaft **1** due to the connection of the wobbler carrier **24** and **32** to the main link **26**. In particular, the main link and the connections among the wobbler carrier, the wobbler, the wobbler follower, and the adjustment assembly, as well as the connection between the adjustment assembly and the cylinder block, can help maintain the respective components in positions that also maintain the positions of the pistons relative to the cylinder block and their respective cylinders as the axis of

oscillation is moved backward or forward in parallel with and along the main shaft axis. In this manner, the main link **26** can aid in maintaining the spatial relationship between the wobbler carrier **24** and **32** and the main shaft **1** even as the angle of the wobbler carrier **24** and **32** relative to the main shaft **1** is changed.

The movement of the adjustment assembly **8** to its upper position when the hydraulic cylinder **15** is compressed as shown in Figures 7, 8, 11, and 12 causes the wobbler follower shafts **18**, the wobbler follower **19**, the wobbler **23**, and the wobbler carrier **24** and **32** to move upward as well. At the same time, this movement causes the acute angle and its complementary obtuse angle of the wobbler carrier **24** and **32** relative to the main shaft axis $A_S$ to both approach 90°. In this upper position, the oscillation amplitudes $M_{CL}$, $M_{DL}$ of the first wobbler follower portion $19S_1$ and the second wobbler follower portion $19S_2$ and the sides **19C**, **19D** of the wobbler follower **19** are very small and can approach being non-existent. Thereby, in this position, all of the pistons **3A**, **3B**, **3C**, **3D** are at or near the top of the cylinder and their reciprocating movements are minimal so that the top dead center positions of the pistons **3A**, **3B**, **3C**, **3D** is extremely close to the bottom dead center positions of the pistons **3A**, **3B**, **3C**, **3D**.

Conversely, the movement of the adjustment assembly **8** to its lower position when the hydraulic cylinder **15** is extended as shown in Figures 9, 10, 13, and 14 causes the wobbler follower shafts **18**, the wobbler follower **19**, the wobbler **23**, and the wobbler carrier **24** and **32** to move downward as well. At the same time, this movement causes the acute angle of the wobbler carrier **24** and **32** relative to the main shaft **1** to become much smaller, while its complementary obtuse angle of the wobbler carrier **24** and **32** relative to the main shaft **1** to become much larger. In this lower position, the oscillation amplitudes $M_{CB}$, $M_{DB}$ of the first wobbler follower portion $19S_1$ and the second wobbler follower portion $19S_2$ and the sides **19C**, **19D** of the wobbler follower **19** are much larger. Thereby, in this lower position, the pistons **3A**, **3B**, **3C**, **3D** have much larger reciprocating movements with each stroke being much longer so that the top dead center positions of the pistons **3A**, **3B**, **3C**, **3D** is much farther away from the bottom dead center positions of the pistons **3A**, **3B**, **3C**, **3D** than when the arrangement is in the upper position described above. Thereby, the stroke length of the pistons when the angle of the wobbler carrier **24** and **32** relative to the main shaft axis $A_S$ is more acute and its complimentary angle

is more obtuse is much larger than the stroke length of the piston when the angle of the wobbler carrier **24** and **32** relative to the main shaft axis $A_S$ and its complimentary angle approach 90°. As stated above, the movement of the adjustment assembly **8** to any point between the extremes shown in Figures 7-14, will change the angle of the wobbler carrier **24** and **32** relative to the main shaft axis $A_S$, the oscillations of the first wobbler follower portion **19S**$_1$ and the second wobbler follower portion **19S**$_2$ and the sides **19C**, **19D** of the wobbler follower **19** and the reciprocating movements of the pistons **3A**, **3B**, **3C**, **3D** in a relative manner. In this manner a desired output can be maintained even as that desired output changes over time.

Thus, when the hydraulic cylinder **15** is compressed as shown in Figures 7, 8, 11, 12 and 15, the main oscillating axis, axis $A_2$, is in a position such that the volume displacement of the variable displacement device **100** is zero and the pistons **3A**, **3B**, **3C**, **3D** are generally motionless. In such a configuration, the internal friction of the variable displacement device **100** is decreased to a minimum. With the expansion of the hydraulic cylinder **15**, the main oscillating axis, axis $A_2$, is in a position such that volume displacement of the variable displacement device **100** increases as the motion of the pistons **3A**, **3B**, **3C**, **3D** increases. Thereby, the volume displacement of the variable displacement device **100** increases at a rate related to the expansion of the hydraulic cylinder **15** and vice versa.

In Figures 7, 8, 11 and 12, the location of the pistons **3A**, **3B**, **3C**, **3D** are shown with minimum volume displacement $V_0$ which in some embodiments can be equal to or about 0. Figures 7 and 11 illustrate the variable displacement device **100** in cross-sectional views along the respective line E-E and line F-F in Figure 1, while Figures 8 and 12 show the variable displacement device **100** after a 180 degree rotation of the main shaft **1** from its position in Figures 7 and 11. As stated above, Figures 9 and 13 show the conditions of the variable displacement device **100** with a volume displacement $V_g$ that is greater than zero. Figures 10 and 14 show the same conditions of the variable displacement device **100** as presented in Figures 9 and 13 after a 180 degree rotation of the main shaft **1**. In Figures 9 and 13 and Figures 10 and 14, it can also be seen that with an increase in the volume displacement of the variable displacement device **100**, the top dead center of the pistons **3A**, **3B**, **3C**, **3D** is varied by a distance **m** related to Figures 7 and 11, 8 and 12. The purpose of the

change of the top dead center of the pistons **3A**, **3B**, **3C**, **3D** by the distance **m** is to keep the compression ratio of the variable displacement device **100** nearly, i.e., substantially, constant and the design of the components of the variable displacement device **100** and their interactions are responsible for this change. The distance **m** is dependent upon the position of the wobbler follower shaft **18**, which is the position of the main oscillating axis of the wobbler follower **19** relative to the axis $A_S$ of the shaft **1**. When the volume displacement is increased, the amount m is also increases relative to the increase in the volume displacement. This means that when the distance **L** is equal to about zero, the distance **m** is also equal to about zero. By increasing the distance **L**, the distance **m** increases by a relative, or related, amount.

As further explanation and referring to Figure 13, the cylinders can have different volumes depending on the position of the pistons within the cylinders. For example, a volume within each cylinder can be a smaller volume, represented by $V_m$, when the respective piston within the cylinder is at the top dead center. Similar, a volume within each cylinder can be a larger volume, represented by $V_b$, when the pistons within the cylinders are at the bottom dead center. The changing of the distance **m** can change the volume $V_m$ (see Figure 13) when the pistons within the cylinders are at the top dead center. In particular, by varying the volume $V_m$ as the stroke length and the volume $V_b$ (see Figure 13) are varied, the constancy of the compression ratio can be increased. Thereby, a substantially constant compression ratio can be obtained as the volume displacement within the cylinders is changed. For example, by varying the distance **m**, the volume $V_m$ when the piston stroke length is longer and the displaced volume **Vg** is larger can be greater than the volume $V_m$ when the piston stroke length is shorter and the volume **Vg** displaced is smaller. Conversely, the volume $V_m$ when the piston stroke length is shorter and the displaced volume **Vg** is smaller can be less than that the volume $V_m$ when the piston stroke length is longer and the displaced volume **Vg** is larger. This shift in where the pistons are at top dead center to create a variable volume $V_m$ is done in relation to the change in a volume $V_b$ when the pistons are at bottom dead center as well as the change in the stroke length. The movement of the position of the axis of oscillation $A_2$ makes this possible.

Thus, the variation in volume displacement in the variable displacement device **100** can be obtained by varying, or moving, the position of the axis of oscillation $A_2$, as well as the variation of the volume $V_m$ of the cylinder with the pistons at top dead center to help maintain a more constant compression ratio. The variation of the position of the axis of oscillation $A_2$ while keeping the axis of oscillation $A_2$ about perpendicular to and generally intersecting with the main shaft axis $A_S$ can be created through the movement of the adjustment assembly **8**. The adjustment assembly **8** can be moved in various ways. For example, as provided above, one or more drivers can be used. For example, as provided above, the driver can comprise a hydraulic cylinder. In some embodiments, the adjustment assembly **8** can comprise two drivers as explained in further detail below.

In some embodiments, the one or more drivers can be one or more screw devices. For example, in Figure 17, a variable displacement device that comprises a different embodiment of an adjustment assembly **8**. As above, the adjustment assembly **8** can comprise the arm members **8A** and **8B** (not shown in Figure 17), the adjustment arm base **4**, one or more pins **7**, **12**, **13**, the cover **9**, and the connecting beam **10**. The driver of the adjustment assembly **8** can comprise a screw device **38**. The screw device **38** can comprise a screw **48** that screwably engages a nut **46** secured to the beam **10**. The screw device **38** also can comprise a screw base **40A** with a servo motor base plate **40B** attached thereto, a servo motor **40** attached to the motor base plate **40B** and a pulley system secured to the motor **40** and the screw **48**. The screw base can be attached to a side of the cylinder block **16** and the adjustment arm base **4** can be attached to an opposing side of the cylinder block in a similar manner as the embodiment described above. The motor **40** has a pulley **44** attached to its shaft and the screw **48** has a pulley **42** attached to its head with a belt or chain that engages both pulleys. As the motor **40** turns its shaft in one direction or another, the pulley **44** drives the belt to rotate the pulley **42** on the head of the screw **48**. The rotation of the pulley **42** rotates the screw **48** in an appropriate direction to move the adjustment assembly **8** as the nut **46** moves back and forth on the screw **48**.

Figures 18 and 19 show a variable displacement device **100** that comprises a similar configuration of the cylinder block **16**, the wobbler carrier **24** and **32**, the wobbler **23**, the wobbler follower **19** and pistons, but a different embodiment of an

adjustment assembly **8**. The adjustment assembly **8** in Figures 18 and 19 can comprise a screw and motor configuration for the driver. In particular, the adjustment assembly **8** can comprise two screw devices **38** secured on opposing side of the cylinder block **16** which can operate in tandem to move the wobbler carrier **24** and **32** into different angular positions relative to the main shaft **1**. For example, each screw device **38** can be secured to the cylinder block **16** on one end of the respective screw device **38** and can be secured to a respective wobbler follower shaft (not shown) of the wobbler follower **19** on an opposing end of the respective screw device **38**.

Each screw device **38** can comprise a screw **48** that screwably engages a nut **46** that is secured to a respective wobbler follower shaft (not shown) of the wobbler follower **19**. Each screw device **38** can also comprise a motor base **40A** secured to the cylinder block **16** and a servo motor **40** attached to the motor base **40A**. Each screw device **38** can further comprises coupling **40C** (see Figure 19) that can directly connect the shaft of the respective motor **40** to the respective screw **48**. As the motors **40** of the respective screw devices **38** turn their motor shafts in one direction or another, the couplings **40C** rotate the screws **48** in an appropriate direction to move the respective wobbler follower shafts (not shown) of the wobbler follower **19** as the nuts **46** move backward and forward on the screws **48**. As the wobbler follower shafts of the wobbler follower **19** are moved, the wobbler follower **19** can move the wobbler **23** through the connection made between them with the wobbler follower pins (not shown in Figures 18 and 19). The wobbler **23** can, in turn, move the wobbler carrier **24** and **32** secured at one location to the main link **26** to the desired angle relative to the main shaft **1** and/or its axis in a manner similar to the embodiments described above.

In other embodiments of the variable displacement device **100** as partially shown in Figure 19A, an adjustment assembly **8** can comprise two hydraulic cylinders **91** in similar positions on the cylinder block **16** as the screw devices 38 in the embodiment of the variable displacement device **100** shown in Figures 18 and 19. For example, each hydraulic cylinder **91** can be secured to the cylinder block **16** on one end of the respective hydraulic cylinder **91** and can be secured to a respective wobbler follower shaft (not shown) of the wobbler follower **19** on an opposing end of the hydraulic cylinder **91**. In particular, each hydraulic cylinder **91**

can comprise a hydraulic cylinder base **92** secured to the cylinder block **16** and a cylinder hook **90** that is attached to the distal end of the extendable and retractable cylinder rod of the hydraulic cylinder **91**. Each cylinder hook **90** of the hydraulic cylinder **91** can be secured to a respective wobbler follower shaft (not shown) of the wobbler follower **19**. As the cylinder rods of the hydraulic cylinder **91** extend or retract the cylinder hooks **90** in an appropriate amount and an appropriate direction, the respective wobbler follower shafts (not shown) of the wobbler follower **19** move forward or backward relative to the cylinder block **16**. As the wobbler follower shafts of the wobbler follower **19** are moved, the wobbler follower **19** can move the wobbler **23** through the connection made between them with the wobbler follower pins (not shown in Figure 19A). The wobbler **23** can, in turn, move the wobbler carrier **24** and **32** secured at one location to the main link **26** to the desired angle relative to the main shaft **1** and/or its axis in a manner similar to the embodiments described above.

One or more controllers can be in operable communication with the adjustment assembly **8** to move the adjustment assembly **8** to vary volume displacement of the pistons within the cylinders while maintaining a substantially constant compression ratio for the pistons **3A**, **3B**, **3C**, **3D** within the cylinders. Such controllers can comprise computers, computer systems, microprocessors, minicomputers, smart devices, programmable logic controllers or the like. The controller can be in communication with one or more sensors to collect information from the sensors. The sensors can provide information to the controller that the controller processes to determine the movement to be made to the adjustment assembly **8** to properly adjust the position of the axis of oscillation $A_2$ to appropriately change the angle of the wobbler carrier **24** and **32** relative to the main shaft axis $A_S$ to obtain the desired stroke length for the pistons **3A**, **3B**, **3C**, **3D**.

The type of sensors used and the type of information collect can depend on the type of variable displacement device **100**. For example, a pump may have sensors appropriately located thereon to measure the pressure created by the pump of the fluid being pumped, the revolutions per minute (rpm's) of the main shaft, the displacement of the adjustment assembly, and the flow rate of the fluid being pumped. Likewise, sensors can be provided that can measure the temperature and viscosity of the fluid being pumped. Based on the information collect by the sensors associated with the pump, the controller can determine and can provide commands

for the movement to be made to the adjustment assembly to properly adjust the position of the axis of oscillation to appropriately change the angle of the wobbler carrier relative to the main shaft to obtain the desired stroke length for the one or more pistons so that the pump provides the desired output. By changing the stroke length of the one or more pistons on the pump, for example, energy used to pump the fluid can be conserved, such as decreased fuel or electricity consumption, and the wear on the components of the pump, such as the pistons and cylinder block, can be decreased. The controller can have a user interface, such as touch screen or keypad, that permits a user to enter data such as the desired flow rate or other output or the parameters for changing the stroke length for the pistons based on the information collected by the sensors.

Similarly, as another example, an air compressor may have sensors appropriately located thereon to measure the pressure created by the compressor, the displacement of the adjustment assembly, the compression generated within the cylinders with each stroke of the pistons, the rpm's of the main shaft, or the like. Likewise, sensors can be provided that can measure the dew point temperature of the gas being compressed before (dew point) and after (pressure dew point) compression. As with the pump, the controller can have a user interface, such as touch screen or keypad, that can permit a user to enter data such as the desired pressure or other output or the parameters for changing the stroke length for the pistons based on the information collected by the sensors. Based on the information collect by the sensors and/or the user interface associated with the compressor, the controller can determine and provide commands for the movement to be made to the adjustment assembly to properly adjust the position of the axis of oscillation to appropriately change the angle of the wobbler carrier relative to the main shaft to obtain the desired stroke length for the pistons so that the air compressor provides the desired output.

Figures 20-23 illustrate controllers **50**, which can be computers, microprocessors, minicomputers, smart devices, programmable logic controllers or the like, that can be used to operate drivers, such as the motors for the screw devices or the valves of the hydraulic cylinders described above, to move the adjustment assembly that can vary the displacement within variable displacement devices. While such controllers **50** can be used with pumps, air compressors,

hydraulic engines or the like, as described above, Figures 20-23 herein relate to the controllers use as a combustion engine for illustration purposes. Each controller **50** can be, for example, a computer system or a part of a computer system for or in a vehicle.

Controller **50** can receive inputs from various components or sensors to provide outputs to control the components of the variable displacement devices disclosed herein to make the proper adjustments to the variable displacement devices. For example, a schematic embodiment of a controller **50** is shown in Figure 20. The controller **50** can be part of a variable displacement device, which comprises a variable displacement combustion engine, that uses an adjustment assembly comprising a hydraulic cylinder on a single side of a cylinder block of the variable displacement device and arm members that can directly or indirectly engage wobbler follower shafts as described above. The controller **50** can have an input **52** that transmits information from a sensor or a computer of a vehicle about the use of the throttle therein to the controller **50**. For example, the sensor or computer can measure the displacement of the vehicle's throttle pedal, monitor the displacement of a throttle valve or monitor fluid flow through the throttle. Also, information about the motor's rpm's (i.e., the rpm's of the main shaft) can be provided by an input **54** into controller **50**. Further, in the embodiment shown in Figure 20, the controller **50** can be in communication with a hydraulic cylinder displacement gage input through **56** to provide information related thereto. Such a sensor as the hydraulic cylinder displacement gage can monitor and provide information the displacement of the driver. Based on the information received, the controller **50** can determine the needed action by the hydraulic cylinder and can communicate with hydraulic solenoid valves through outputs **60**, **62** to drive the hydraulic cylinder to properly move the adjustment assembly. The controller **50** can communicate with the fuel injection system through an output **64** to facilitate the optimization of air and fuel mixture rate which can increase fuel efficiency.

Additionally, in some embodiments, the controller **50** can have or be in communication with a user interface (not shown) through which a user can input information such as parameter setting to be used. For example, the user interface can be a touch screen, a keypad, a keyboard or other buttons. For instance, in some embodiments, a vehicle can be equipped with a touch screen or buttons that

can be on the dashboard or steering wheel. In such embodiments, for example, buttons can be provided for selecting fuel conservation, maximum power, or normal operating conditions. Each different button can provide different parameters under which the controller **50** will operate the variable displacement combustion engine.

Figures 21-23 provide similar examples of controllers **50**. For example, in Figure 21, a controller **50** for an embodiment of an adjustment assembly that uses a servo motor to drive or move the adjustment assembly of a variable displacement device. The controller **50** can have input **52A** for receiving information from a sensor or computer about the use of a throttle pedal and an input **54A** for receiving information about the rpm's for the motor. Further, the controller **50** can have an input feedback **56A** from the servo motor. The controller **50** can process the information received from the inputs **54A**, **54A**, and **56A** and provide information to control the servo motor through output **60A** and the fuel injection system through output **64A**. The controller **50** also can have or be in communication with a user interface (not shown) through which user can input information such as parameter setting to be used.

Figure 22 illustrates a schematic view of a controller **50** that is used to control the movement of an adjustment assembly that has hydraulic cylinders on two opposing sides of a variable displacement device. The controller **50** includes inputs **76** and **78** for receiving information from the two hydraulic cylinders and input **72** for receiving information about throttle use as well as an input **74** for receiving information about the motor's rpm's. The controller **50** can provide information for controlling the hydraulic cylinders through outputs **80**, **82**, **84**, and **86** and information to the fuel inject system through output **88**. Similarly, the embodiment of a controller **50** in Figure 23 is provided to control the movement of an adjustment assembly that has two servo motor. The controller **50** can include similar inputs **52**, **54** for receiving information about throttle use and the rpm's of the variable displacement engine on which the adjustment assembly is secured. The controller **50** can be used to communicate through outputs **60A**, **62A**, **64A** with the servo motors and the fuel injection system. Additionally, in both embodiments shown in Figures 22 and 23, the controller **50** can have a user interface (not shown) or be in communication with a user interface.

As previously stated, the variable displacement devices disclosed herein can be used for such machines as internal combustion engines, external combustion engines, pumps, compressed air engines, hydraulic engines, and other things of that nature. Referring to the figures, the given design of the variable displacement devices shown in the figures are more configured for use in an internal combustion engine. Therefore, the parts of the mechanism are designed in such a way that with an increase in the volume displacement of the mechanism, the position of the top dead center changes slightly. This change in the position is in such a way that the volume of the top dead center position will increase by the appropriate amount so that the compression ratio remains fairly constant.

The minimum volume displacement of the variable displacement devices disclosed herein can be near or equal to zero (when the main shaft is rotating, the pistons remain in an almost fixed position). An increase in the volume displacement of the variable displacement devices from at or near zero to the desired amount is achieved in an approximately constantly linear manner. Such a variation can be achieved while the variable displacement device is running. An advantage of the variable displacement devices disclosed herein lies in its ability to change its volume displacement while the respective variable displacement device is running. For example, when the variable displacement devices disclosed herein are used in an internal combustion engine, a noticeable conservation in fuel consumption can likely be realized. Another advantage of the variable displacement devices disclosed herein can be a decrease in internal friction such that when the volume displacement decreases, the internal friction also decreases.

Thus, as disclosed above, embodiments of variable displacement devices are provided herein. The variable displacement device can comprise a main shaft having a main shaft axis. The main shaft can have a first end and a second end and can be configured to be rotatable about the main shaft axis. The variable displacement device can comprise a cylinder block that can have one or more cylinders therein. A portion of the main shaft can be positioned within the cylinder block. The variable displacement device can also comprise a wobbler carrier that can be movably connected to and rotatable with the main shaft. Additionally, the variable displacement device can comprise a wobbler and a wobbler follower. The wobbler can be operatively engaged by the wobbler carrier but does not have to

rotate with the wobbler carrier and the main shaft. The wobbler follower can be secured to the wobbler and one or more pistons corresponding to the one or more cylinders can be pivotably attached to the wobbler follower with each piston being movable within the corresponding cylinder. Further, the variable displacement device can comprise an adjustment assembly secured to the wobbler follower. The adjustment assembly can be configured to be adjustable to change the angle of the wobbler carrier relative to the main shaft axis by the adjustment assembly moving the wobbler follower.

For example, the adjustment assembly can be configured to adjust a stroke length of the one or more pistons and thereby can change the volume that is displaced within each cylinder by the respective piston as the respective piston oscillates within the corresponding cylinder by the changing of the angle of the wobbler carrier relative to the main shaft axis resulting from the movement of the wobbler follower. The adjustment assembly can thus vary the volume displacement of the pistons within the cylinders while maintaining a substantially constant compression ratio for the pistons within the cylinders.

In some embodiments, the wobbler follower can comprise wobbler follower shafts that can be connected the wobbler follower to the adjustment assembly. The wobbler follower shafts can be rotatably attached to opposing sides of the wobbler follower. In particular, in some embodiments, the wobbler follower shafts can be aligned along an axis of oscillation. Additionally, the axis of oscillation can be aligned with and perpendicular to the main shaft axis. As shown in the figures, the axis of oscillation can intersect the main shaft axis. With the movement of the wobbler follower shafts by the adjustment assembly, the axis of oscillation can be moved forward and/or backward in parallel with and along the main shaft axis to change the angle of the wobbler carrier relative to the main shaft axis. Thereby, the volume within each cylinder when the respective piston therein is at top dead center can be variable as the axis of oscillation is moved forward or backward in parallel with and along the main shaft axis to increase the constancy of a compression ratio.

The axis of oscillation can bisect the wobbler follower with a first wobbler follower portion on one side of the axis of oscillation and a second wobbler follower portion on the other side of the axis of oscillation. Thereby, the first wobbler follower

portion and the second wobbler follower portion of the wobbler follower can be configured to oscillate back and forth about the axis of oscillation. In some embodiments, at least one of the pistons can be pivotably attached to the first wobbler follower portion and at least one of the pistons can be pivotably attached to the second wobbler follower portion. In operation, the first wobbler follower portion and the second wobbler follower portion of the wobbler follower can oscillate back and forth about the axis of oscillation. Thereby, the pistons on the first wobbler follower portion oscillate together with the first wobbler follower portion and the pistons on the second wobbler follower portion oscillate together with the second wobbler follower portion.

To change the angle of the wobbler carrier relative to the main shaft axis, the wobbler follower can be connected to an outer perimeter of the wobbler on the first wobbler follower portion and on the second wobbler follower portion along an axis of the wobbler. The axis of the wobbler can be perpendicular to the axis of oscillation. The axis of the wobbler can also intersect the main shaft axis. In particular, the wobbler follower can be connected to the outer perimeter of the wobbler on opposing sides of the wobbler follower along the axis of the wobbler. As the adjustment assembly moves the wobbler follower, the wobbler moves with the wobbler follower and the wobbler causes the wobbler carrier to move so that the angle of the wobbler carrier relative to the main shaft changes as explained above.

To facilitate this movement, the wobbler carrier can operatively engage the wobbler in different ways. In some embodiments, the wobbler carrier can have a groove in which at least a portion of the wobbler can reside. For example, in some embodiments, the wobbler carrier can have a groove along its outer periphery. The wobbler can reside in the groove in the wobbler carrier with the outer perimeter of the wobbler extending outside of the groove. Alternatively, in some embodiments, the wobbler can have a groove in which at least a portion of the wobbler carrier can reside and rotate. In some embodiments, the wobbler and wobbler carrier can both have grooves and projections, with the groove of one engaging the projection of the other while permitting the wobbler carrier to rotate with the main shaft.

The variable displacement device can comprise a main link that can connect the wobbler carrier to the main shaft and can rotatable with the wobbler carrier and

the main shaft. The main link can be configured to aid in maintaining a spatial relationship between the wobbler carrier and the main shaft as the angle of the wobbler carrier relative to the main shaft is changed so that the one or more pistons remain aligned with the respective cylinders without hindering the oscillation of the pistons within the respective cylinders. As explained above, the main link and the connections among the wobbler carrier, the wobbler, the wobbler follower, the adjustment assembly and the cylinder block can help maintain the respective components in positions that also maintain the positions of the pistons relative to the cylinder block and their respective cylinders during movement of the axis of oscillation.

Further, as explained above, the variable displacement device can comprise a controller, such as a computer, a programmable logic controller, a mini-computer, a microprocessor, or the like in operable communication with the adjustment assembly. The controller can be used to move the wobbler follower with the adjustment assembly to vary volume displacement of the pistons within the cylinders while maintaining a substantially constant compression ratio for the pistons within the cylinders. For example, the adjustment assembly can comprise at least one driver for moving the wobbler follower with the adjustment assembly. In particular, the one or more drivers can be used to move or change the position of the axis of oscillation as described above. The one or more drivers can be in communication with the controller to control such movement. In some embodiments, two or more drivers can be used on move the wobbler follower with the adjustment assembly. The drivers can comprise one or more hydraulic cylinders or one or more screw devices. Depending on the configuration of the adjustment assembly, the one or more drivers can be directly or indirectly secured to the cylinder block and the wobbler follower shafts or a movable portion of the adjustment assembly. For example, a driver can be secured to the cylinder block on one end and a portion of the adjustment assembly connected to two movable arm members.

To determine how much the adjustment assembly needs to change the angle of the wobbler carrier relative to the main shaft, the controller can be in communication with one or more sensors to collect information from the sensors. The sensors can provide information to the controller. The controller can then

process the information to determine the amount of movement to be made to the one or more drivers to adjust the adjustment assembly.

For example, when the variable displacement device comprises an internal combustion engine that includes a throttle and a fuel injection system, the sensors can be configured to monitor revolutions per minute of the main shaft, displacement of the driver(s), and an air flow rate through the throttle. In turn, the controller can be configured to receive information from the sensors about the revolutions per minute of the main shaft, the displacement of the driver(s), and the air flow rate through the throttle. The controller can then provide direction for movement to the one or more drivers of the adjustment assembly and direction to the fuel injection system regarding the rate of fluid flow based on the rate of air flow through the throttle which can be based on the change in the volume to be displaced within each cylinder by the stroke of the respective piston. The controller can control the one or more drivers and/or the fuel injection system directly. Additionally or alternatively, the directions can be transmitted from the controller as signals such as electric or light pulses to a receiver of the driver and a receiver of the fuel injection system. Such receivers can be a transceiver for receiving and transmitting signals and can be internal or external to the respective driver or fuel injection system. Further, such receivers can comprise a computer, a programmable logic controller, a mini-computer, a microprocessor, or the like, in operable communication with the controller.

As shown in the figures, the main shaft can extend through the wobbler carrier, the wobbler and the wobbler follower. For example, the wobbler follower can have an aperture therethrough with an inner periphery of the wobbler follower forming the aperture. Similarly, the wobbler carrier can have a wobbler carrier aperture therethrough and the wobbler can have a wobbler aperture therethrough. The wobbler can at least partially reside within the wobbler follower aperture with the outer perimeter of the wobbler rotatably secured to the inner periphery of the wobbler follower along the axis of the wobbler described above. The wobbler carrier aperture can be alignable with the wobbler aperture with the main shaft extending through both the wobbler carrier aperture and the wobbler aperture. As shown in the figures, the wobbler follower can have a body with an outer periphery and the wobbler follower can comprise wobbler follower shafts that can connect the wobbler follower

to the adjustment assembly. The wobbler follower shafts can be attached to and partially rotatably within opposing sides of the wobbler follower at the outer periphery. The wobbler follower can also comprise wobbler follower shaft housings in which ends of the wobbler follower shafts that are distal from the outer periphery can reside and in which the wobbler follower shafts can at least partially pivot or rotate. The wobbler follower shaft housings, for example, can reside in arm members of the adjustment assembly.

Thus, in some embodiments, a variable displacement device can comprise a main shaft having a main shaft axis. The main shaft can have a first end and a second end and configured to be rotatable about the main shaft axis. The variable displacement device can comprise a cylinder block having a plurality of cylinders therein with a first end of the main shaft positioned within the cylinder block. The variable displacement device can comprise a wobbler carrier movably connected to and rotatable with the main shaft and a wobbler having an outer perimeter. The wobbler can reside in a groove in the wobbler carrier with the wobbler not being rotatable with the wobbler carrier and the main shaft. Additionally, the variable displacement device can comprise a wobbler follower having a first side and an opposing second side connected to the outer perimeter of the wobbler so that the connections on the opposing first and second sides reside along an axis of the wobbler. The wobbler follower can comprise wobbler follower shafts that extend outward from the wobbler follower. The variable displacement device can also comprise adjustment assembly secured to the wobbler follower shafts of the wobbler follower along an axis of oscillation about which the wobbler follower is at least partially pivotable so that the first side and opposing second side of the wobbler follower are oscillatable. Further, the variable displacement device can comprise one or more pistons pivotably connected to the wobbler follower on one side of the axis of oscillation and one or more pistons pivotably connected to the wobbler follower on an opposite side of the axis of oscillation. The number of pistons corresponds to the plurality of cylinders with each piston being movable within its corresponding cylinder. The adjustment assembly can be configured to be adjustable to change the angle of the wobbler carrier relative to the main shaft axis by the adjustment assembly moving the wobbler follower to vary the displacement of pistons within the cylinders.

Additionally, as explained above, methods of using a variable displacement device are also provided. The methods can include providing a variable displacement device. The variable displacement device can comprise a wobbler carrier that can be movably connected to and can rotate with a main shaft. The variable displacement device can comprise a wobbler that can be operatively engaged by the wobbler carrier and a wobbler follower that can be secured to the wobbler. The variable displacement device can also comprise an adjustment assembly secured to the wobbler follower to form an axis of oscillation. For example, the wobbler follower can comprise wobbler follower shafts that can be secured to and/or engage the adjustment assembly. For instance, the wobbler follower shafts can be secured to and/or engage the adjustment assembly by or through the wobbler follower shaft housing. Further, the variable displacement device can comprise one or more pistons that can be pivotably connected to the wobbler follower on one side of the axis of oscillation and one or more pistons that can be pivotably connected to the wobbler follower on an opposite side of the axis of oscillation with each piston being movable with a corresponding cylinder. For example, the pistons can be pivotably connected to the wobbler follower by connecting rods. The pistons can be oscillated within their corresponding cylinders over a stroke length with the pistons on the one side of the axis of oscillation rising and falling together and the pistons on the other side of the axis of oscillation falling and rising together. The adjustment assembly can be adjusted to change the angle of the wobbler carrier relative to the main shaft axis to change the stroke lengths of the pistons. The adjustment to the adjustment assembly can be performed before using the variable displacement device or during the use of the variable displacement device.

Depending on how the variable displacement devices are used, the rotation of the main shaft can be driven through the oscillation of the pistons to oscillate the wobbler follower to move the wobbler and rotate the wobbler carrier as in an engine such as an internal combustion engine, an external combustion engine, a compressed air engine, a hydraulic engine, or the like. Alternatively, the oscillation of the pistons can be driven through the rotation of the main shaft to rotate the wobbler carrier to move the wobbler and oscillate the wobbler follower as in a pump or gas compressor, such as an air compressor, or the like.

To adjust of the adjustment assembly, the wobbler follower can be moved with the adjustment assembly to move the wobbler that moves the wobbler carrier relative to the main shaft. The spatial relationship between the wobbler carrier and the main shaft can be maintained as the angle of the wobbler carrier relative to the main shaft axis is changed so that the pistons remain aligned with the respective cylinders without hindering the oscillation of the pistons within the respective cylinders.

The methods of operation of the variable displacement device can also include moving the axis of oscillation forward or backward in parallel with and along the main shaft axis to change the angle of the wobbler carrier relative to the main shaft axis. In some embodiments, the axis of the wobbler can intersect the main shaft axis and can be perpendicular to the axis of oscillation. In some embodiments, the axis of oscillation can intersect the main shaft axis and can maintain that intersection as the angle of the wobbler carrier changes relative to the main shaft axis. As stated above, the volume within each cylinder when the respective piston therein is at top dead center can be varied as the axis of oscillation is moved forward or backward in parallel with and along the main shaft axis. At the same time, the volume within each cylinder when the respective piston therein is at bottom dead center can also be varied as the axis of oscillation is moved in parallel with and along the main shaft axis. By varying the volumes within each cylinder when the respective piston therein is at top dead center and when the respective piston therein is at bottom dead center as the axis of oscillation is moved in parallel with and along the main shaft axis, the constancy of the compression ratio within all cylinders can be increased. Thereby, the change in volume within each cylinder when the respective piston therein is at top dead center and the change in volume within each cylinder when the respective piston therein is at bottom dead center can be related or can be proportional to help maintain a substantially constant compression ratio.

Embodiments of the present disclosure shown in the Figures and described above are exemplary of numerous embodiments that can be made within the scope of the present subject matter. It is contemplated that the configurations of the variable displacement devices and related methods can comprise numerous configurations other than those specifically disclosed. Thus, the scope of the

present subject matter in this disclosure and the appended claims should be interpreted broadly.

What is claimed is:

1. A variable displacement device comprising:

a main shaft having a main shaft axis, the main shaft configured to be rotatable about the main shaft axis;

a cylinder block having one or more cylinders therein;

a wobbler carrier movably connected to and rotatable with the main shaft;

a wobbler being operatively engaged by the wobbler carrier but the wobbler not being rotatable with the wobbler carrier and the main shaft as the main shaft rotates;

a wobbler follower secured to the wobbler;

one or more pistons corresponding to the one or more cylinders with each piston being movable within the corresponding cylinder, the one or more pistons being pivotably attached to the wobbler follower; and

an adjustment assembly secured to the wobbler follower, the adjustment assembly configured to be adjustable to change the angle of the wobbler carrier relative to the main shaft axis by the adjustment assembly moving the wobbler follower.

2. The variable displacement device according to claim 1, wherein the adjustment assembly is configured to adjust a stroke length of the one or more pistons and changes the volume that is displaced within each cylinder by the respective piston as the respective piston oscillates within the corresponding cylinder by the changing of the angle of the wobbler carrier relative to the main shaft axis resulting from the movement of the wobbler follower.

3. The variable displacement device according to claim 1, wherein the adjustment assembly is configured to vary volume displacement of the pistons within the cylinders while maintaining a substantially constant compression ratio for the pistons within the cylinders.

4. The variable displacement device according to claim 1, wherein the wobbler follower comprises wobbler follower shafts connected to the adjustment assembly, the wobbler follower shafts attached to and partially rotatable within opposing sides of the wobbler follower, the wobbler follower shafts being aligned along an axis of oscillation.

5. The variable displacement device according to claim 4, wherein the axis of oscillation is aligned with and perpendicular to the main shaft axis, the axis of oscillation being movable forward and backward in parallel with and along the main shaft axis to change the angle of the wobbler carrier relative to the main shaft axis.

6. The variable displacement device according to claim 5, wherein the volume within each cylinder when the respective piston therein is at top dead center is variable as the axis of oscillation is moved forward or backward in parallel with and along the main shaft axis to increase the constancy of a compression ratio.

7. The variable displacement device according to claim 5, wherein the axis of oscillation bisects the wobbler follower with a first wobbler follower portion on one side of the axis of oscillation and a second wobbler follower portion on the other side of the axis of oscillation, the wobbler follower configured to oscillate back and forth about the axis of oscillation with at least one of the one or more pistons being pivotably attached to the first wobbler follower portion and at least one of the one or more pistons being pivotably attached to the second wobbler follower portion.

8. The variable displacement device according to claim 5, wherein the wobbler follower is connected to an outer perimeter of the wobbler on opposing sides of the wobbler follower along an axis of the wobbler that is perpendicular to the axis of oscillation and that intersects the main shaft axis, the wobbler residing in a groove in the wobbler carrier with the outer perimeter of the wobbler extending outside the groove and wherein the opposing sides of the wobbler follower connected to the wobbler oscillate back and forth about the axis of oscillation.

9. The variable displacement device according to claim 1, further comprising a main link that connects the wobbler carrier to the main shaft, the main link being configured to aid in maintaining a spatial relationship between the wobbler carrier and the main shaft as the angle of the wobbler carrier relative to the main shaft is

changed so that the one or more pistons remain aligned with the respective cylinders without hindering the oscillation of the pistons within the respective cylinders.

10. The variable displacement device according to claim 1, wherein the variable displacement device comprises one of an air compressor, a pump, an internal combustion engine, an external combustion engine, a hydraulic engine, or a compressed air engine.

11. The variable displacement device according to claim 1, further comprising a controller in operable communication with the adjustment assembly to move the wobbler follower with the adjustment assembly to vary volume displacement of the pistons within the cylinders while maintaining a substantially constant compression ratio for the pistons within the cylinders.

12. The variable displacement device according to claim 11, wherein the controller is in communication with one or more sensors to collect information from the one or more sensors and the adjustment assembly comprises at least one driver for moving the wobbler follower with the controller being in communication with the at least one driver to move the wobbler follower with the adjustment assembly, the one or more sensors providing information to the controller that the controller processes to determine an adjustment to be made to the at least one driver to adjust the adjustment assembly.

13. The variable displacement device according to claim 12, wherein the variable displacement device comprises an internal combustion engine that further comprises a throttle and a fuel injection system, the controller being configured to receive information from the sensors about the revolutions per minute of the main shaft, the displacement of the driver, and the air flow rate through the throttle and configured to provide commands for operation of the driver of the adjustment assembly and direction to the fuel injection system regarding the rate of fluid flow based on the air flow rate through the throttle.

14. The variable displacement device according to claim 1, wherein the wobbler follower has a body with an outer periphery and the wobbler follower further comprises wobbler follower shafts attached to opposing sides of the wobbler follower at the outer periphery and wobbler follower shaft housings in which ends of the

wobbler follower shafts that are distal from the outer periphery pivotally reside, the wobbler follower shaft housings residing in arm members of the adjustment assembly and the wobbler follower shafts being aligned along an axis of oscillation that bisects the wobbler follower.

15. A variable displacement device comprising:

a main shaft having a main shaft axis, the main shaft configured to be rotatable about the main shaft axis;

a cylinder block having a plurality of cylinders therein;

a wobbler carrier movably connected to and rotatable with the main shaft;

a wobbler having an outer perimeter, the wobbler residing in a groove in the wobbler carrier, the wobbler not being rotatable with the wobbler carrier and the main shaft;

a wobbler follower having a first side and an opposing second side connected to the outer perimeter of the wobbler so that the connections on the opposing first and second sides reside along an axis of the wobbler, the wobbler follower comprising wobbler follower shafts that extend outward from the wobbler follower;

an adjustment assembly secured to the wobbler follower shafts of the wobbler follower along an axis of oscillation about which the wobbler follower is at least partially pivotable so that the first side and opposing second side of the wobbler follower are oscillatable; and

one or more pistons pivotably connected to the wobbler follower on one side of the axis of oscillation and one or more pistons pivotably connected to the wobbler follower on an opposite side of the axis of oscillation, the number of pistons corresponding to the plurality of cylinders with each piston being movable within the corresponding cylinder; and

the adjustment assembly being configured to be adjustable to change the angle of the wobbler carrier relative to the main shaft axis by the adjustment assembly moving the wobbler follower to vary the displacement of pistons within the cylinders.

16. A method of using a variable displacement device, the method comprising:

providing a variable displacement device comprising:

a wobbler carrier movably connected to and rotatable with a main shaft having a main shaft axis;

a wobbler having an outer perimeter, the wobbler being operatively engaged by the wobbler carrier;

a wobbler follower secured to the wobbler;

an adjustment assembly secured to the wobbler follower and forming an axis of oscillation; and

one or more pistons pivotably connected to the wobbler follower on one side of the axis of oscillation and one or more pistons pivotably connected to the wobbler follower on an opposite side of the axis of oscillation with each piston being movable within a corresponding cylinder of a cylinder block;

oscillating the pistons within their corresponding cylinders over a stroke length with the pistons on the one side of the axis of oscillation rising and falling together and the pistons on the other side of the axis of oscillation falling and rising together; and

adjusting the adjustment assembly to change the angle of the wobbler carrier relative to the main shaft axis to change the stroke lengths of the pistons.

17. The method according to claim 16, further comprising driving the rotation of the main shaft through the oscillation of the pistons to oscillate the wobbler follower to move the wobbler and rotate the wobbler carrier.

18. The method according to claim 16, further comprising driving the oscillation of the pistons through the rotation of the main shaft to rotate the wobbler carrier to move the wobbler and oscillate the wobbler follower.

19. The method according to claim 16, further comprising maintaining a spatial relationship between the wobbler carrier and the main shaft as the angle of the

wobbler carrier relative to the main shaft axis is changed so that the pistons remain aligned with the respective cylinders without hindering the oscillation of the pistons within the respective cylinders.

20. The method according to claim 16, further comprising moving the axis of oscillation forward or backward in parallel with and along the main shaft axis to change the angle of the wobbler carrier relative to the main shaft axis.

21. The variable displacement device according to claim 20, further comprising varying the volume within each cylinder when the respective piston therein is at top dead center as the axis of oscillation is moved forward or backward in parallel with and along the main shaft axis to increase the constancy of a compression ratio.

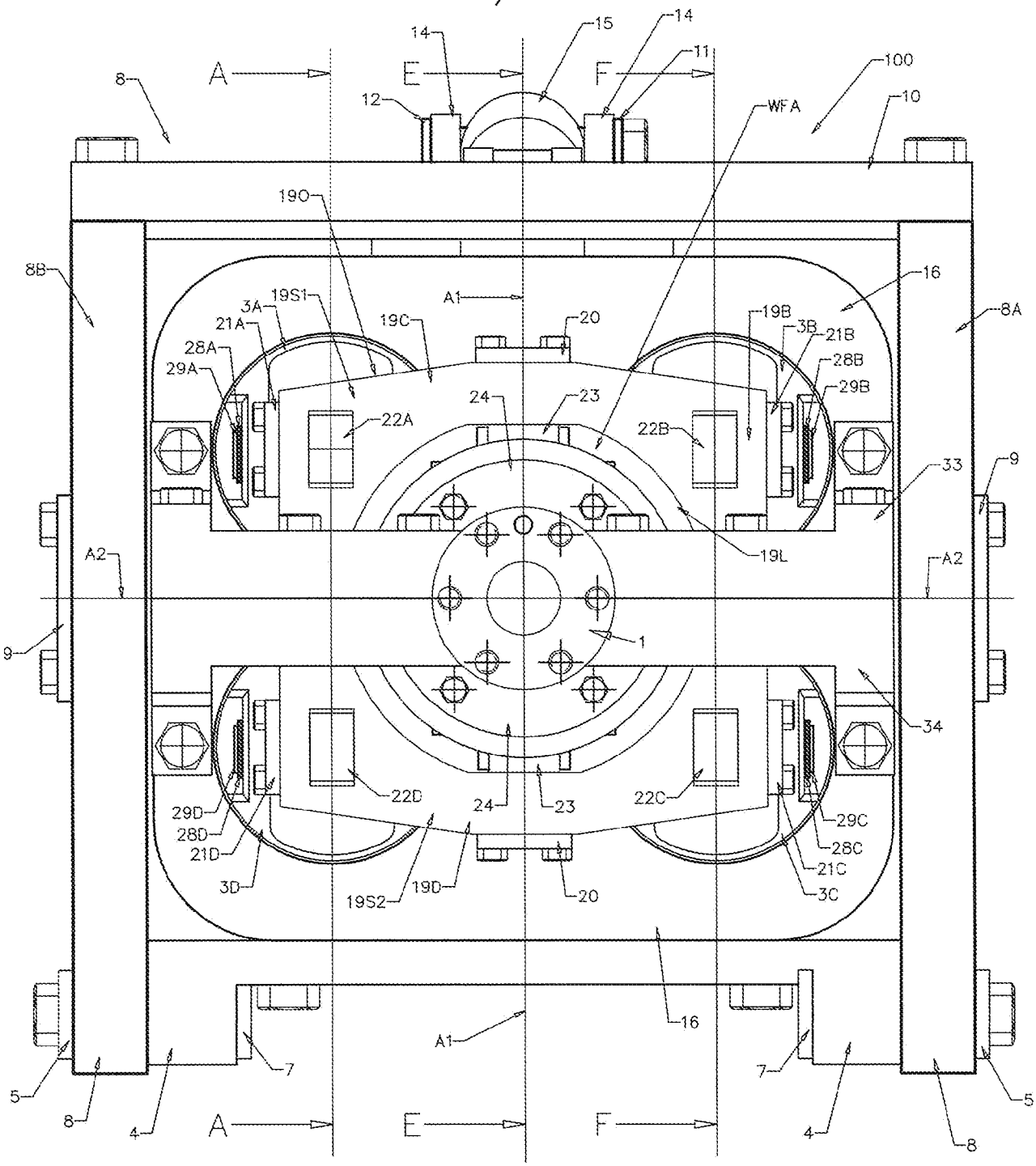

A
E
F
14
15
14
11
12
100
10
WFA
8
8B
8A
16
19O
19S1
3A
21A
28A
29A
19C
A1
20
19B
3B
21B
28B
29B
22A
24
23
22B
33
9
19L
A2
1
34
22D
22C
29D
28D
21D
3D
19S2
19D
29C
28C
21C
3C
5
7
4

FIG 1

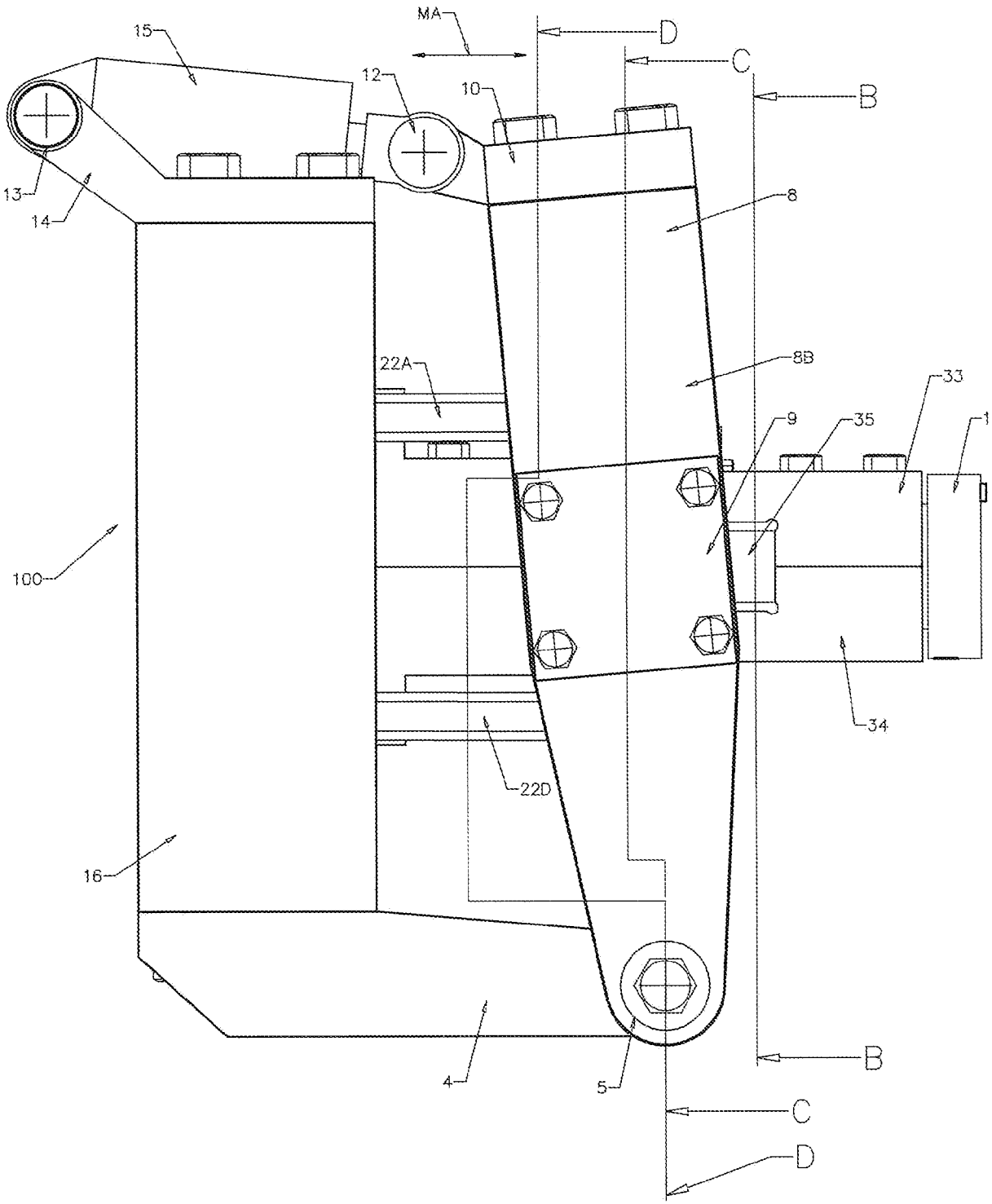
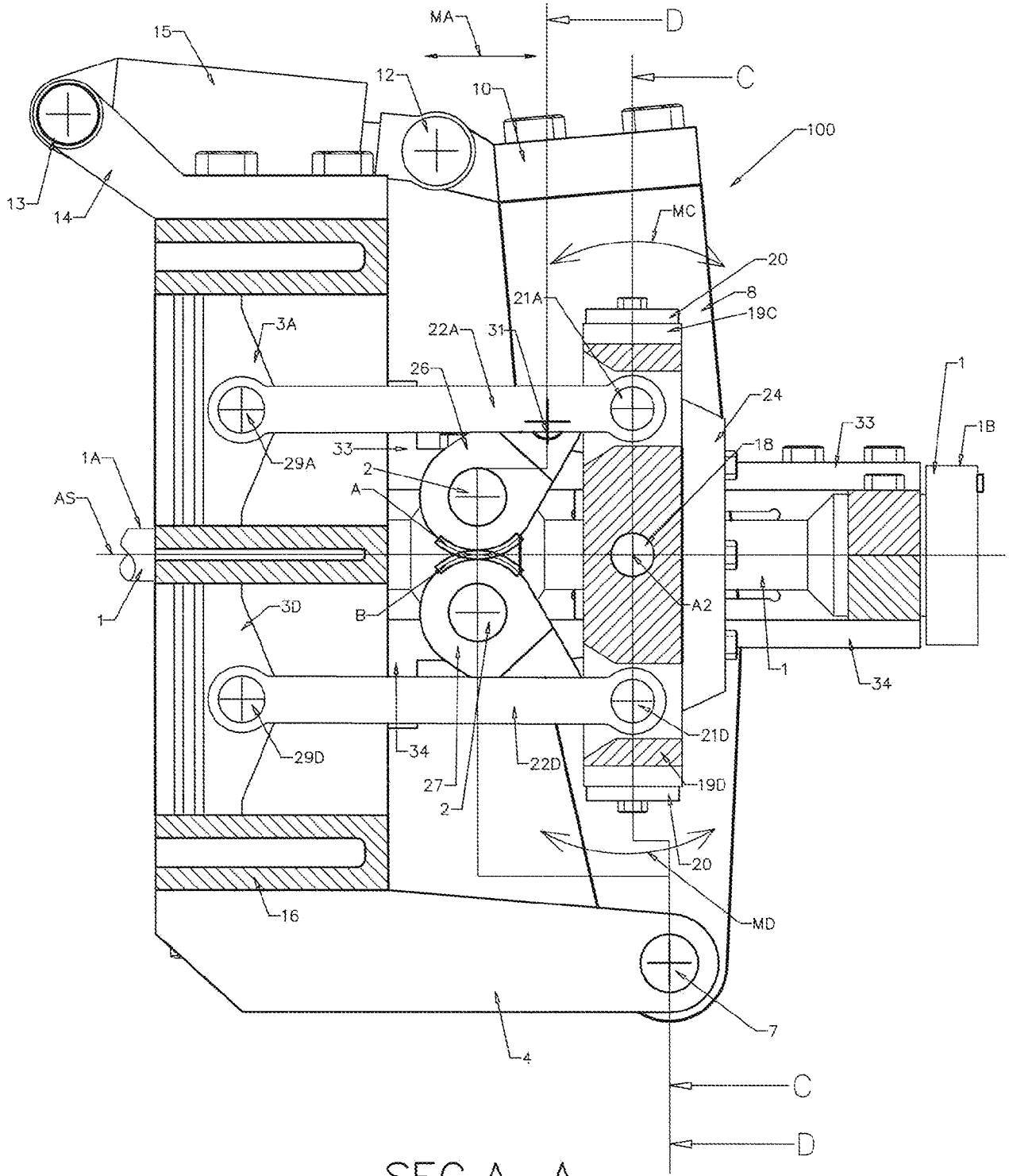
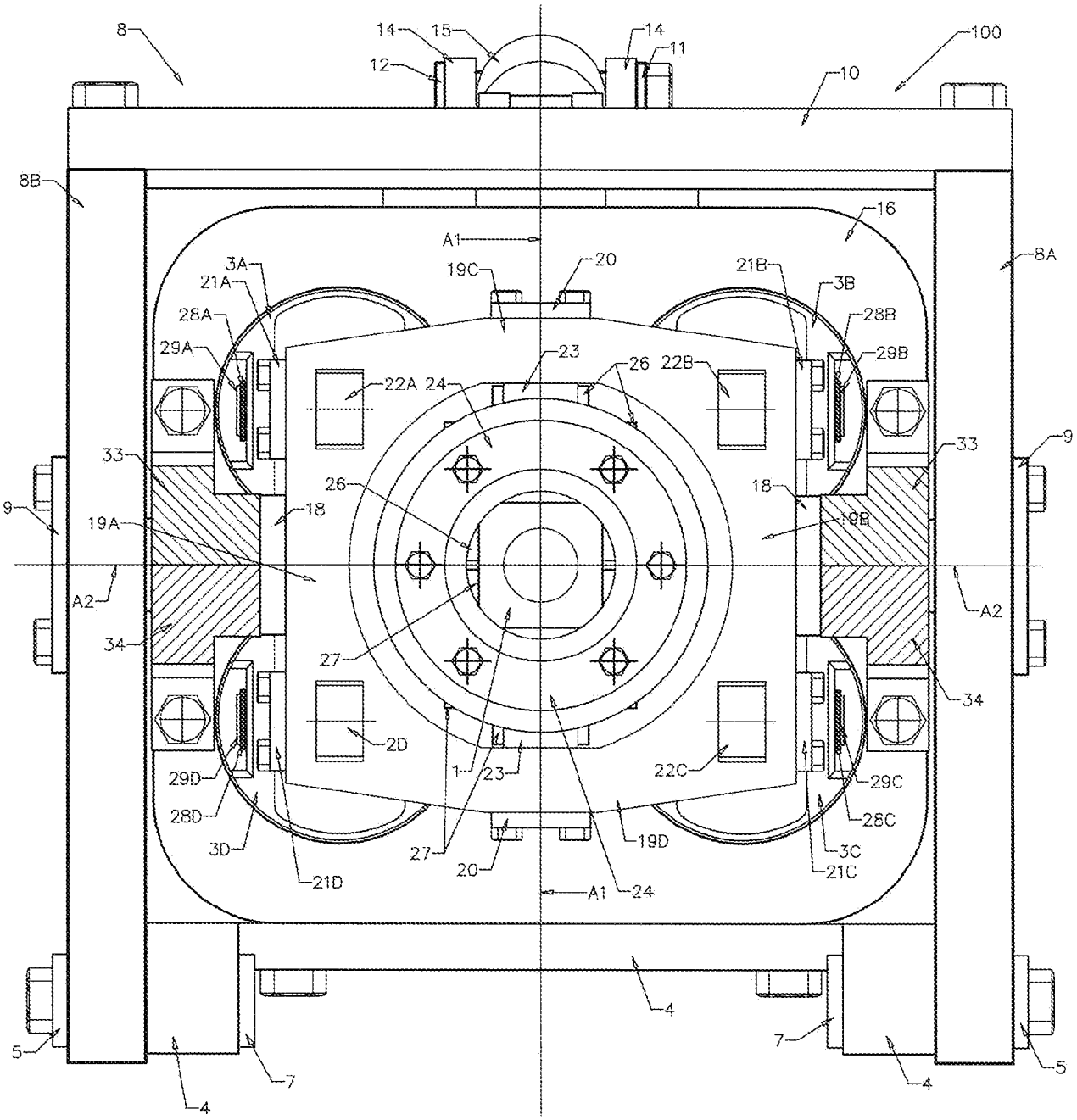



FIG 2


MA
D
C
15
12
10
100
13
14
MC
20
8
21A
19C
3A
22A
31
26
24
1
33
1B
18
1A
29A
33
2
A
AS
1
3D
B
A2
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34
29D
34
22D
21D
27
19D
2
20
16
MD
7
4
C
D

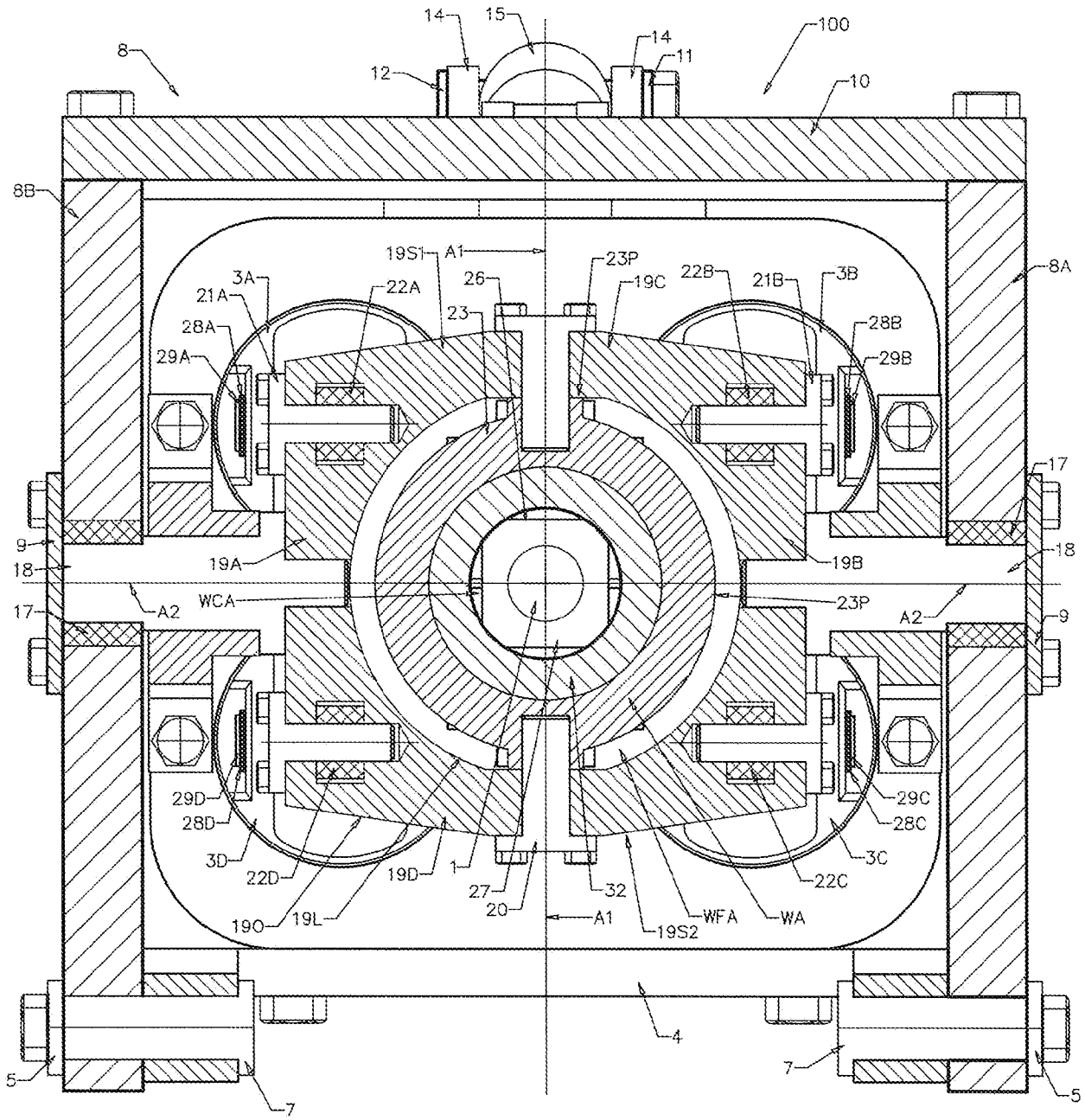
SEC. A—A

FIG 3


8
14
15
14
11
12
10
100
8B
16
A1
19C
20
21B
3B
8A
3A
21A
28A
28B
29A
29B
23
26
22B
22A
24
33
9
18
19A
19B
A2
34
27
2D
22C
29D
28D
3D
21D
1
23
29C
28C
3C
21C
19D
20
A1
24
4
7
5

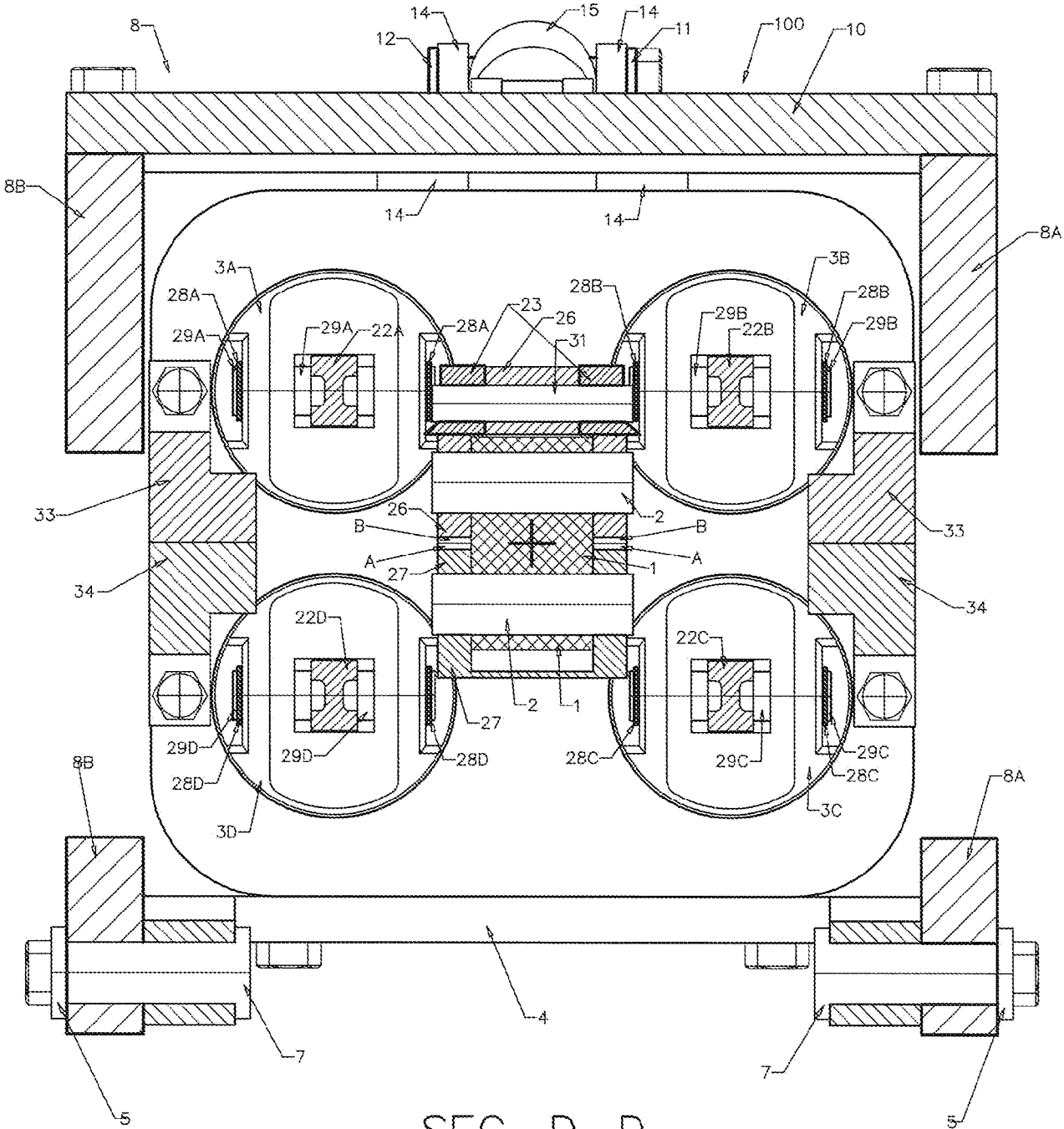
SEC.B–B

FIG 4


14
15
14
11
100
8
12
10
8B
8A
19S1
A1
23P
3A
21A
22A
26
19C
22B
21B
3B
23
28A
28B
29A
29B
17
9
18
19A
19B
18
WCA
23P
A2
A2
17
9
29D
28D
3D
22D
19D
1
27
20
32
A1
19S2
WFA
WA
22C
3C
29C
28C
19O
19L
4
5
7
7
5

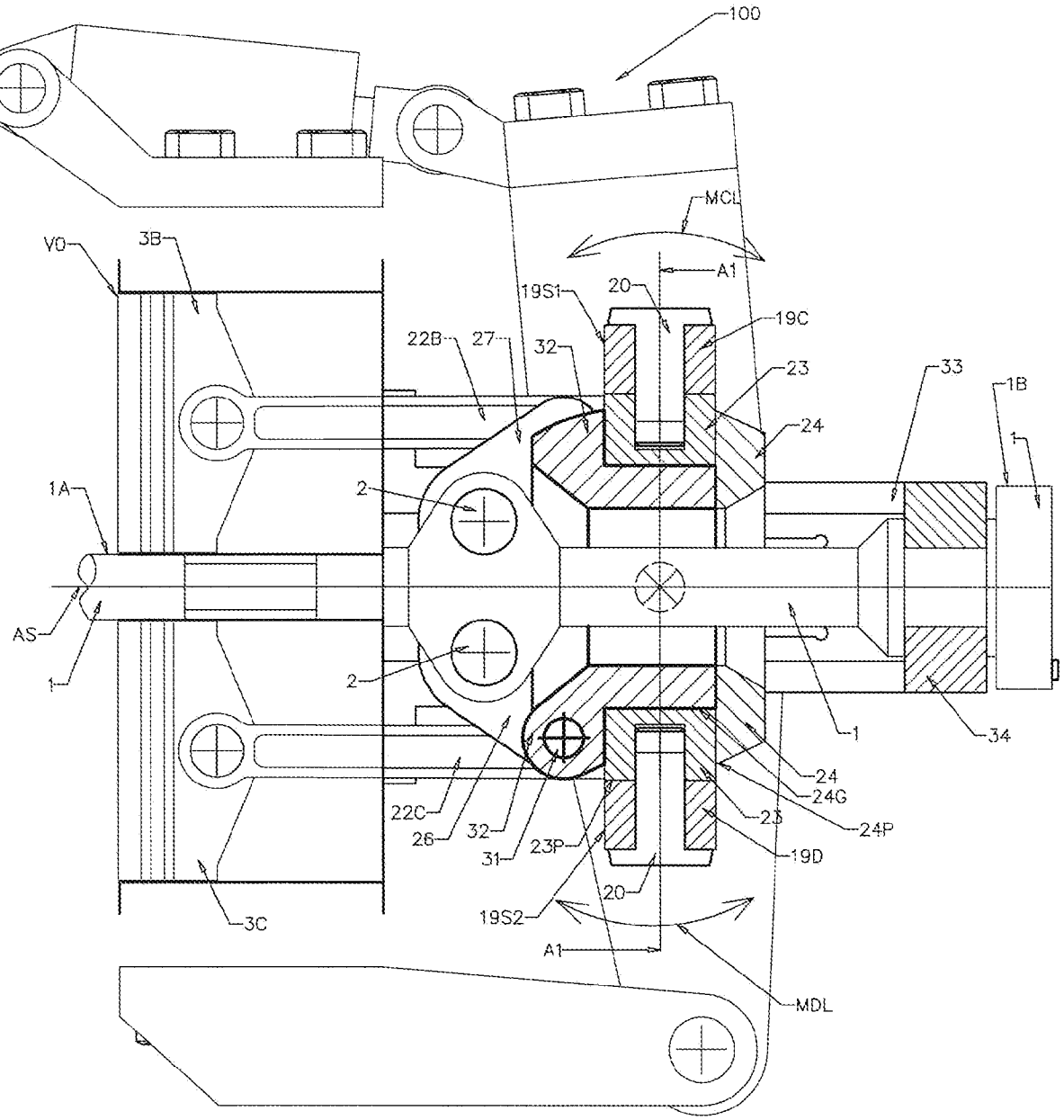
SEC. C–C

FIG 5


8
14
15
14
12
11
100
10
8B
14
14
8A
3A
3B
28A
28B
23
26
31
28B
29A
22A
28A
29B
22B
29B
29A
33
26
2
B
B
A
A
27
1
33
34
34
22D
22C
2
1
27
29D
29D
28D
28D
28C
29C
29C
28C
3C
3D
8B
8A
4
7
7
5
5

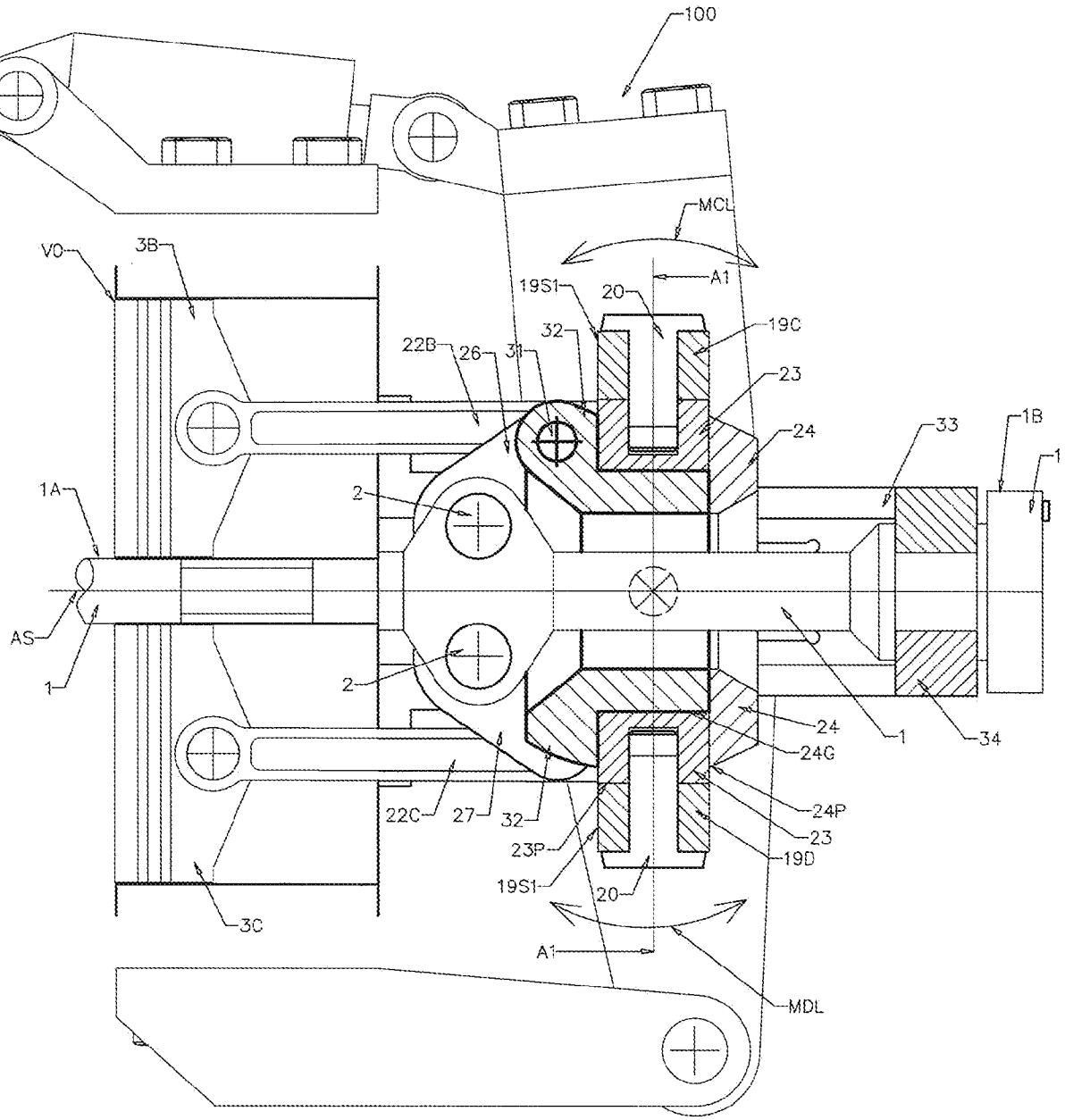
SEC. D–D

FIG 6


100
MCL
A1
V0
3B
19S1
20
19C
22B
27
32
23
33
1B
24
1A
2
AS
1
2
1
34
24
24G
22C
26
32
23P
23
24P
31
19D
20
19S2
A1
3C
MDL

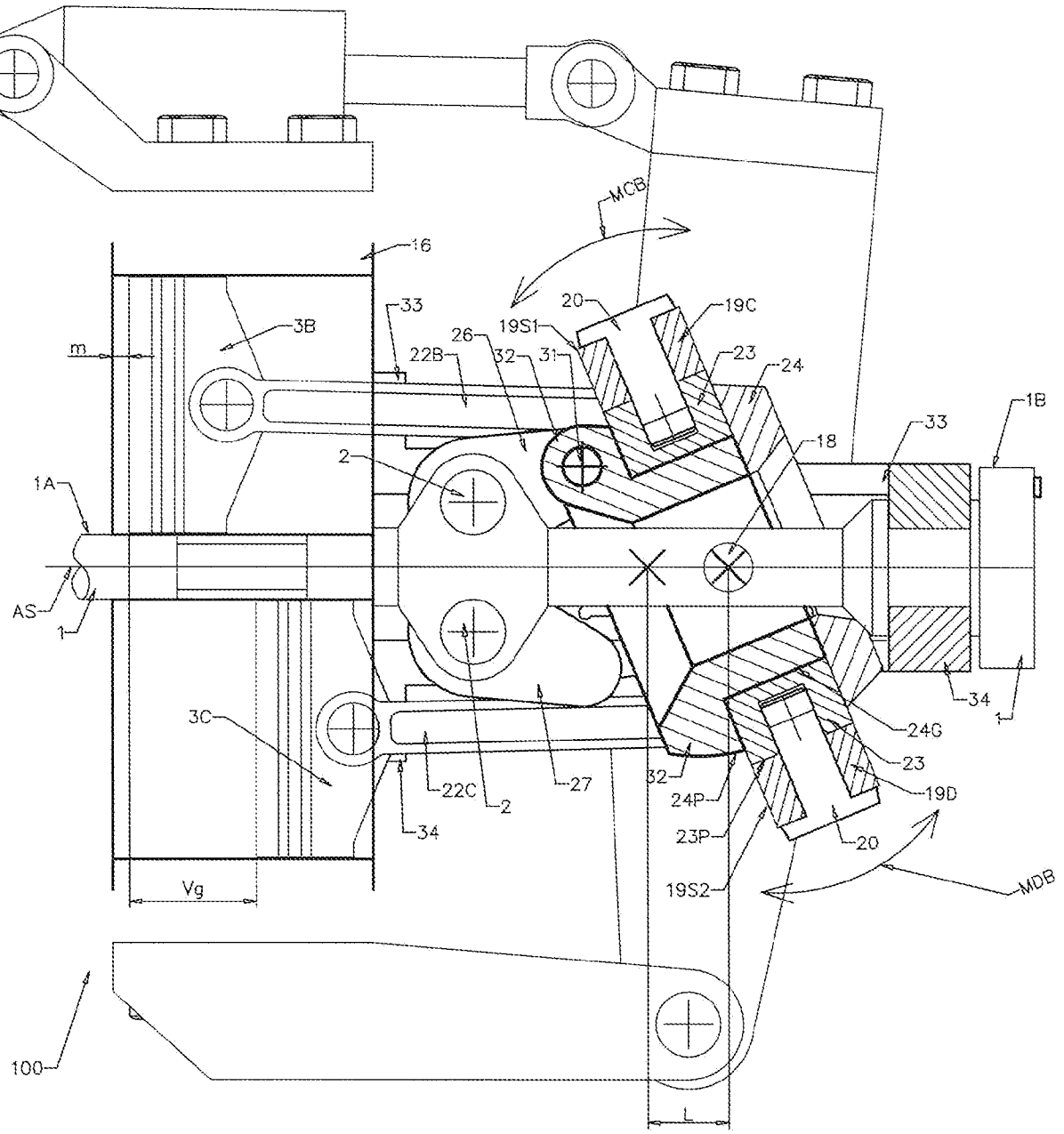
SEC.E–E

FIG 7


100
MCL
A1
V0
3B
19S1
20
19C
32
22B
26
31
23
24
33
1B
1
1A
2
AS
1
2
24
24G
1
34
22C
27
32
24P
23P
23
19D
19S1
20
3C
A1
MDL

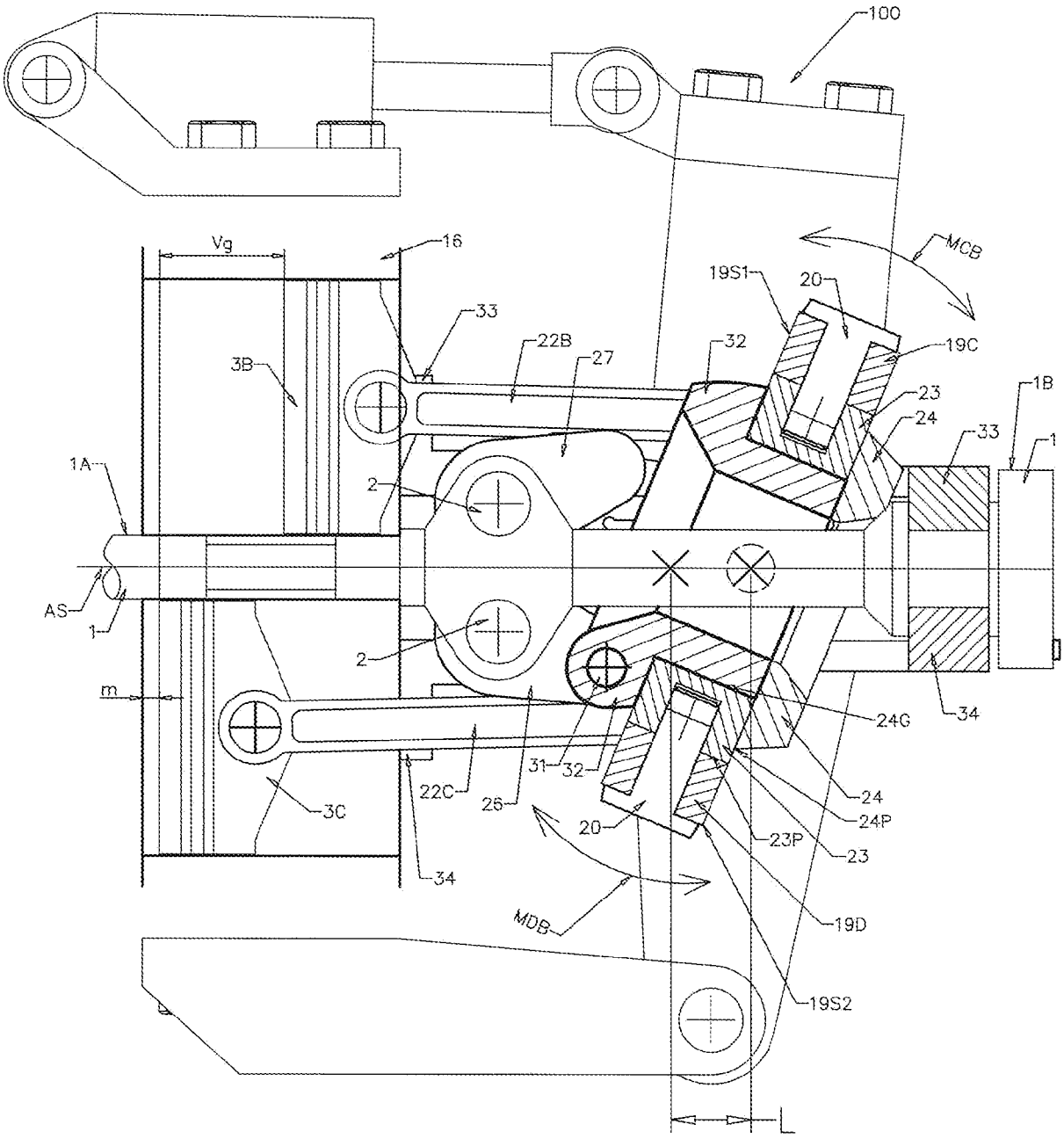
SEC.E—E

FIG 8


MCB
16
33
20
19C
19S1
26
22B
32
31
23
24
3B
m
18
33
1B
2
1A
AS
1
34
1
3C
24G
23
19D
22C
2
27
32
24P
23P
20
19S2
MDB
Vg
100
L

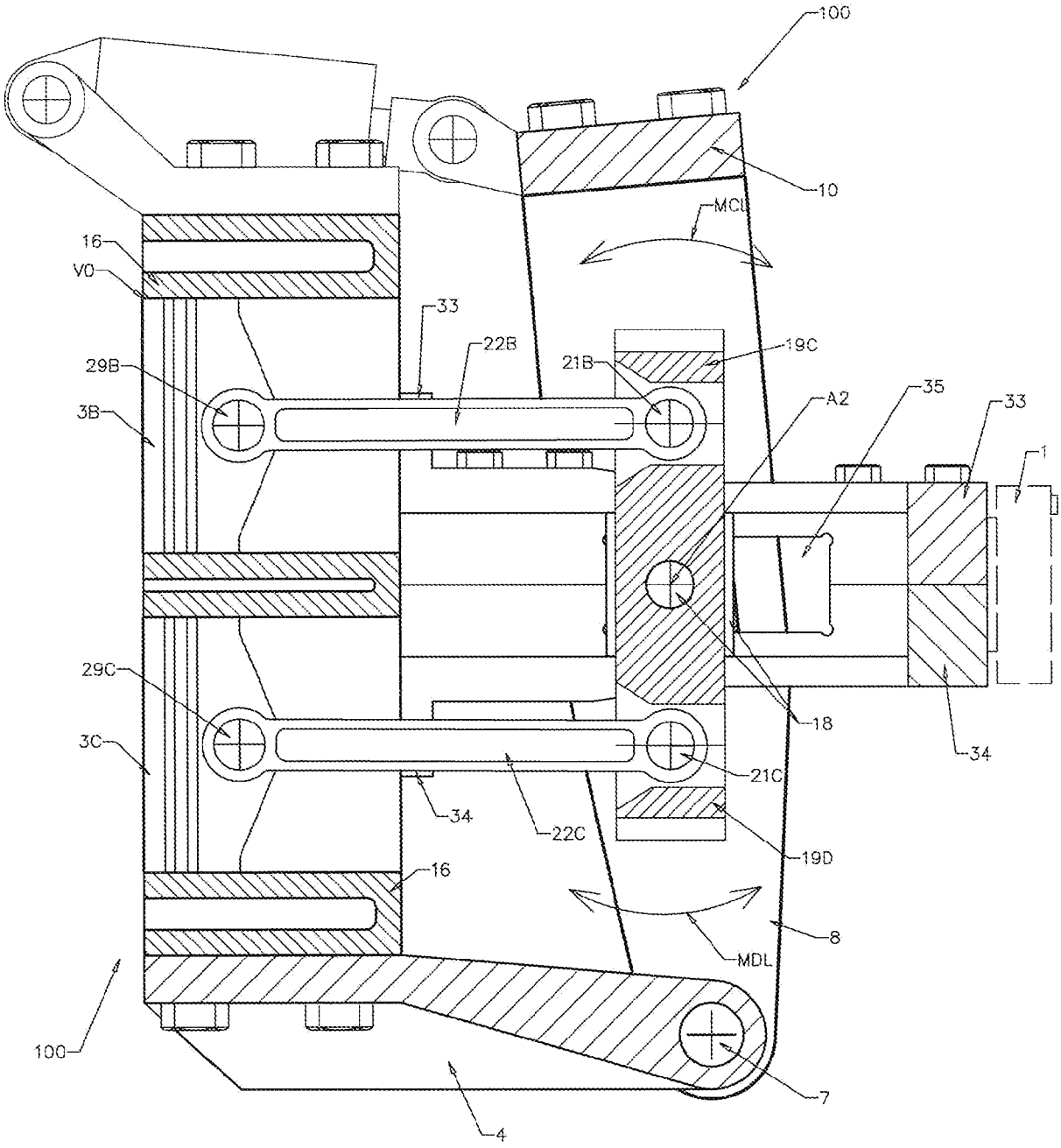
SEC.E–E

FIG 9


100
Vg
16
33
22B
27
3B
32
19S1
20
MCB
19C
23
24
33
1B
1
1A
2
AS
1
2
m
24G
34
22C
31
32
24
24P
23P
23
3C
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34
MDB
19D
19S2
L

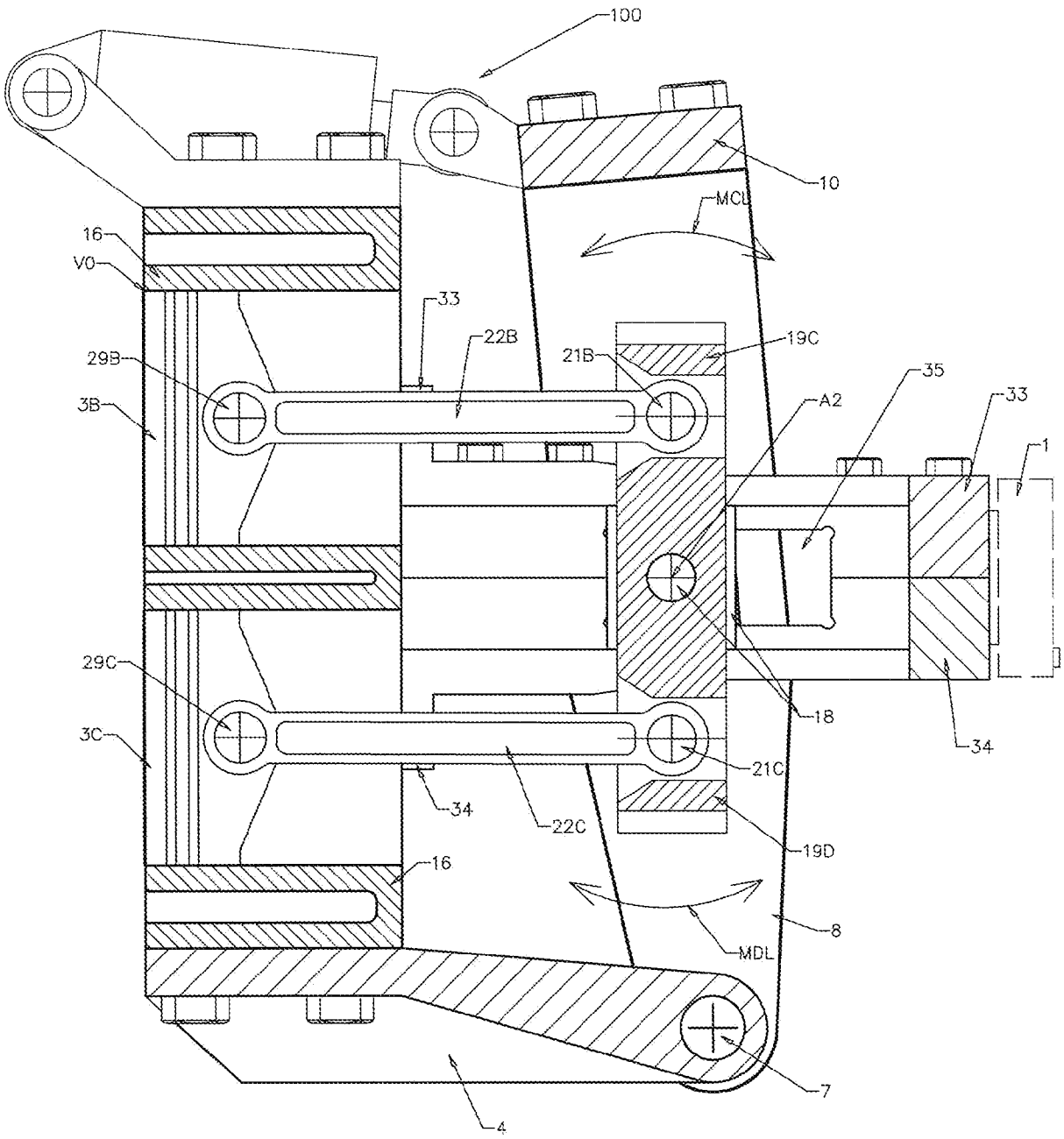
SEC.E–E

FIG 10


100
10
MCL
16
V0
33
22B
19C
21B
29B
3B
A2
35
33
1
29C
3C
18
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21C
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22C
19D
16
8
MDL
100
7
4

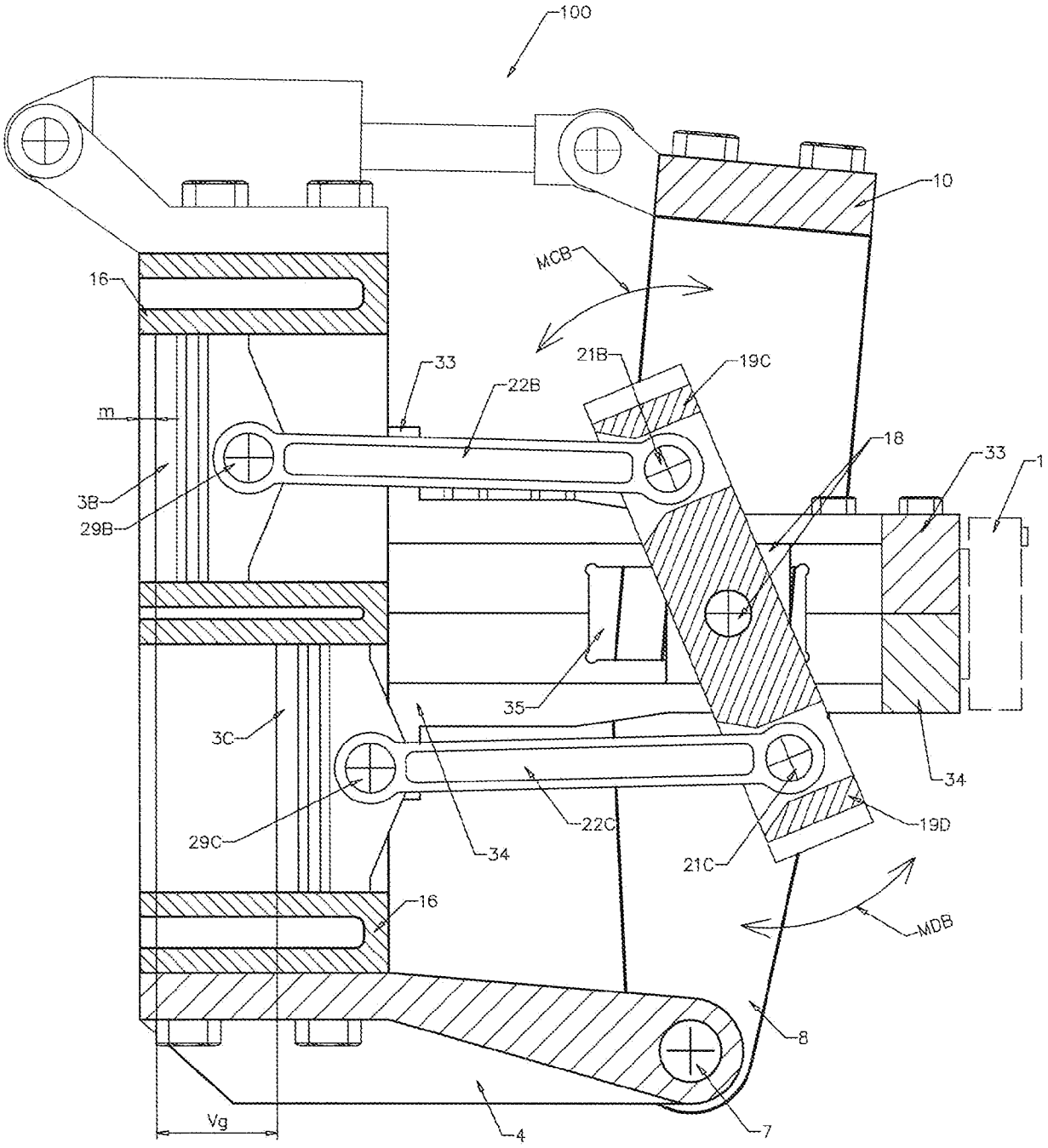
SEC.F–F

FIG 11

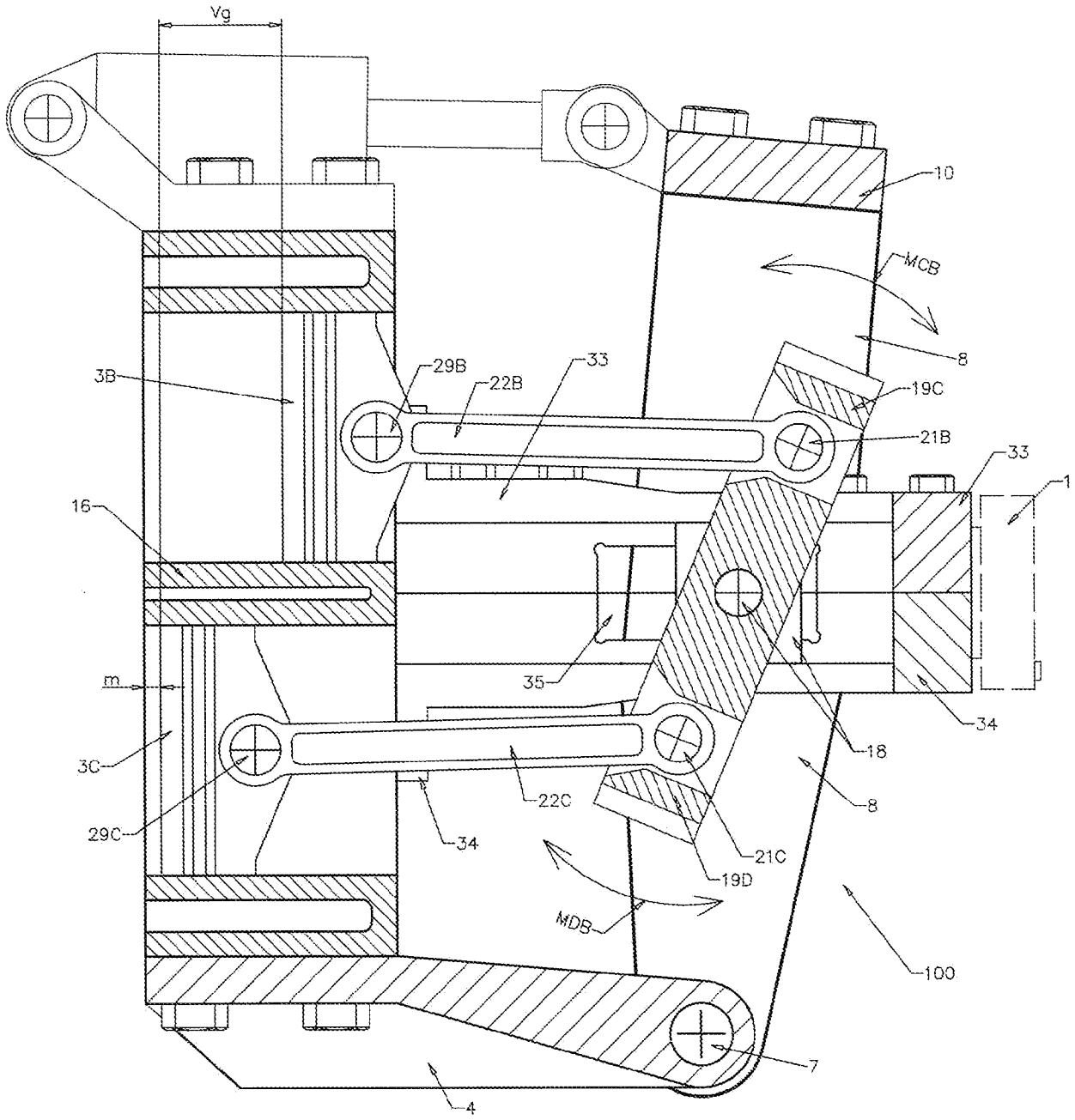

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MCL
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19C
29B
3B
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A2
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29C
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34
21C
34
22C
19D
16
8
MDL
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SEC.F–F

FIG 12


100
10
MCB
16
33
21B
19C
22B
m
18
33
1
3B
29B
35
3C
34
22C
19D
29C
34
21C
16
MDB
8
Vg
4
7

SEC.F–F
FIG 13


Vg
10
MCB
8
3B
29B
22B
33
19C
21B
33
1
16
m
35
34
18
3C
22C
8
29C
34
21C
19D
MDB
100
7
4

SEC.F—F
FIG 14

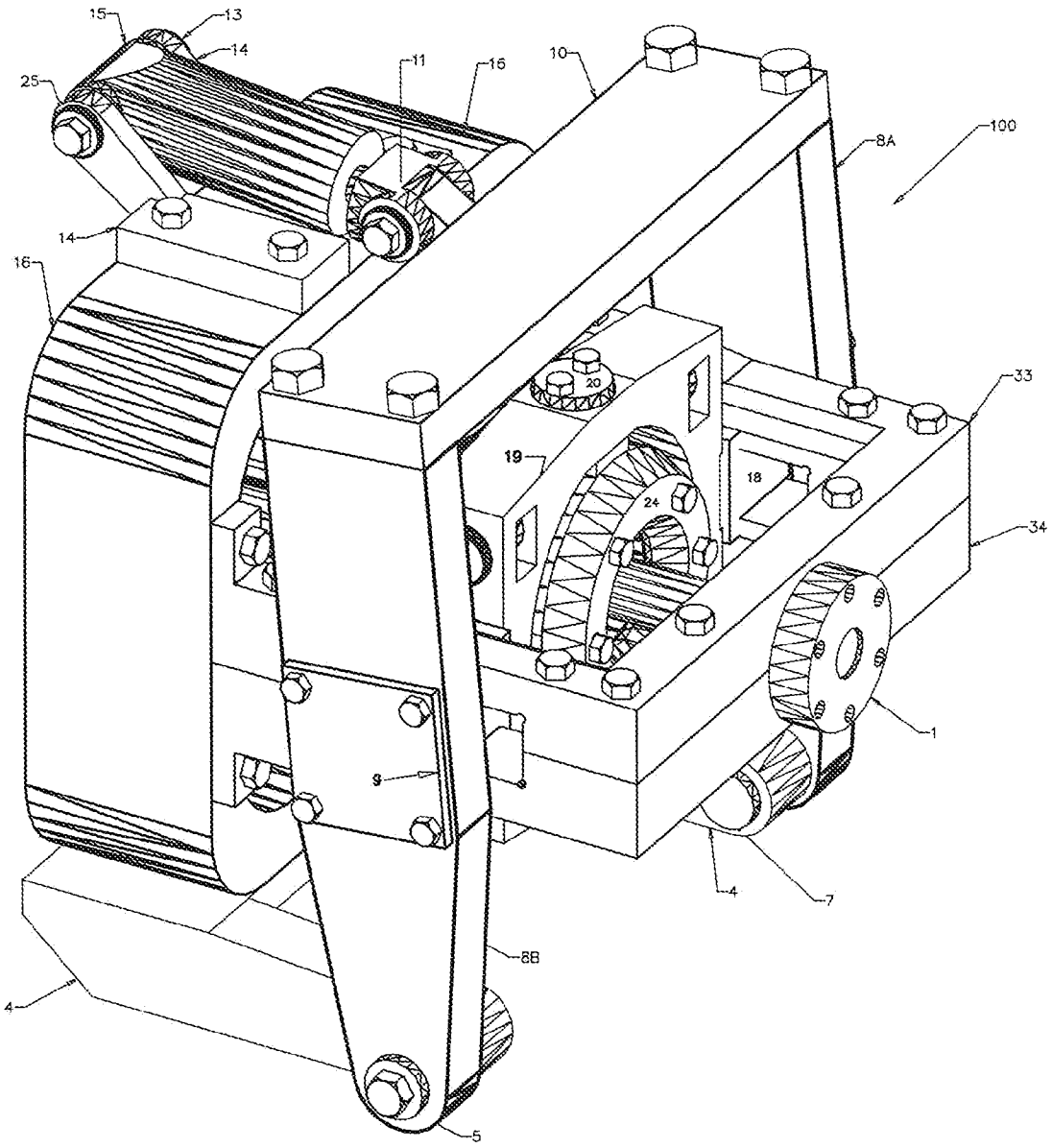



FIG 15

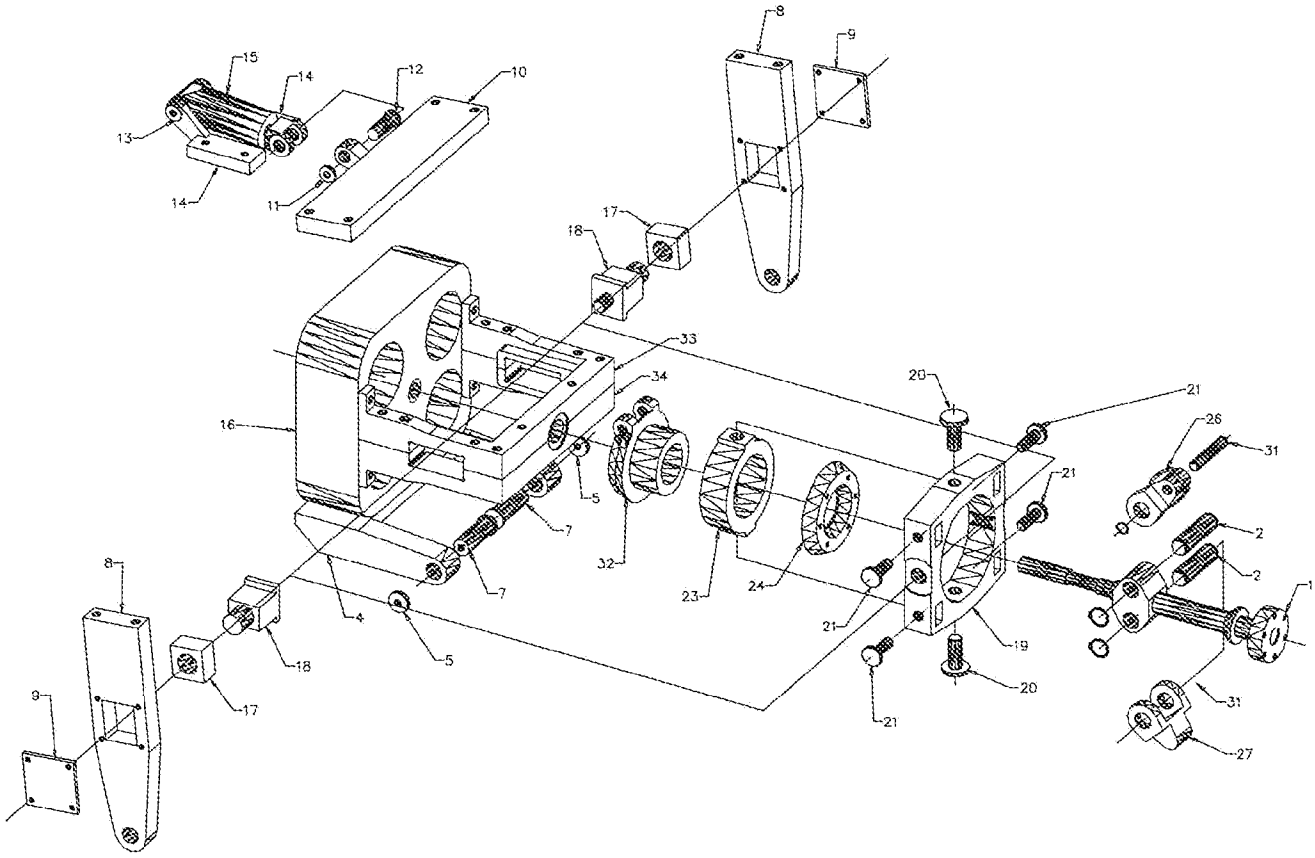

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FIG 15A

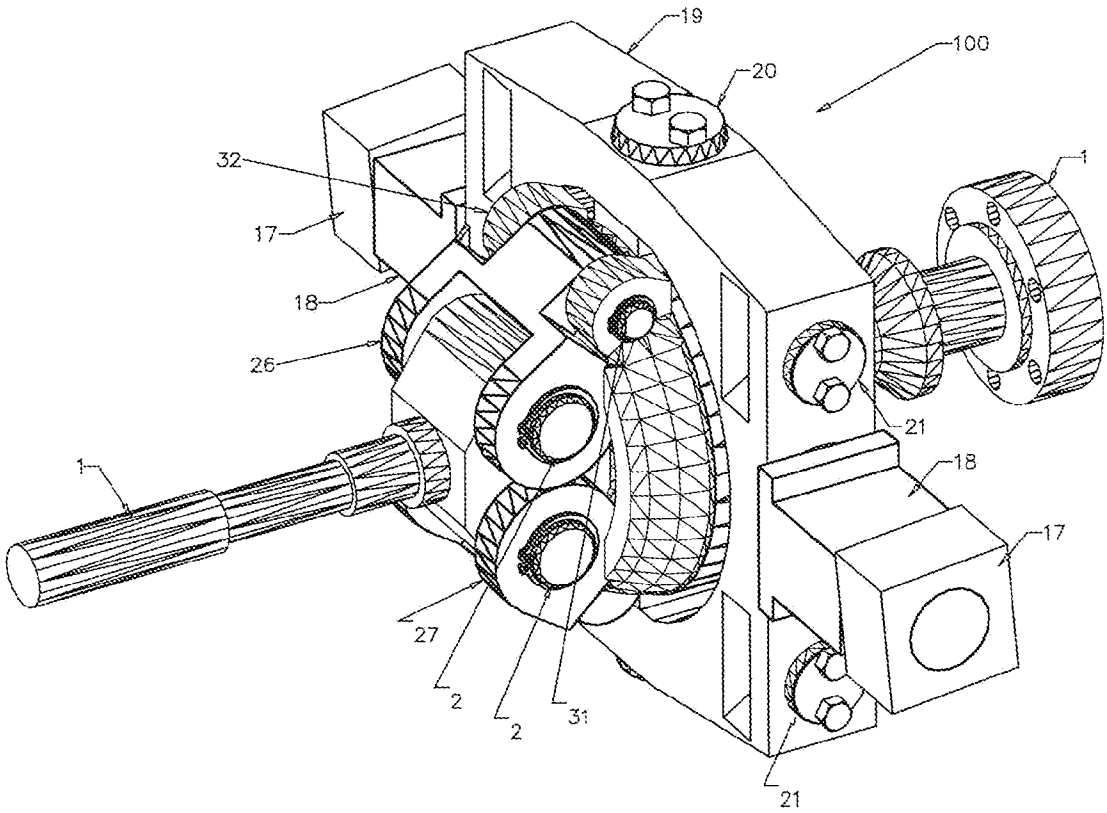



FIG 16

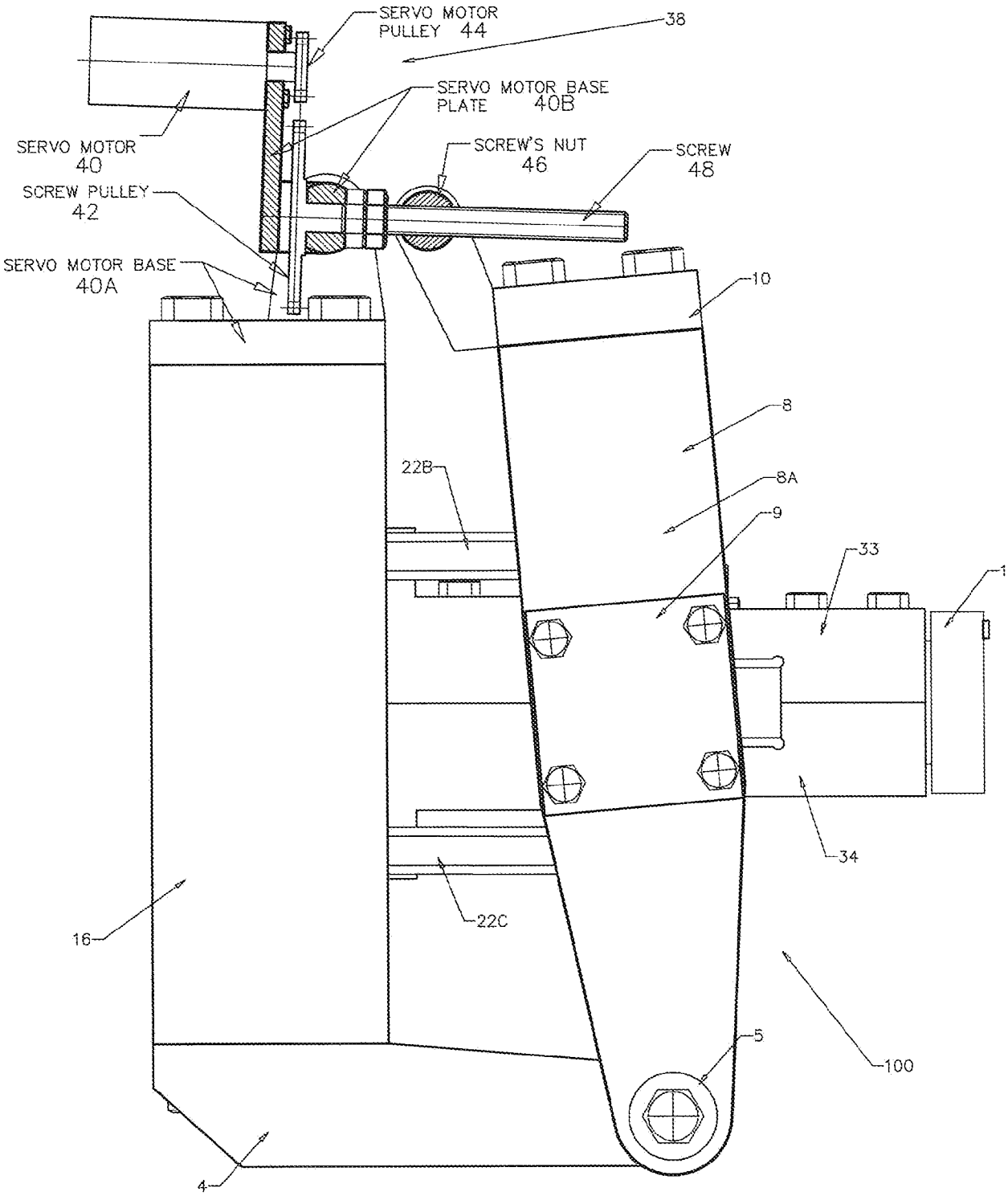

SERVO MOTOR PULLEY 44
38
SERVO MOTOR BASE PLATE 40B
SERVO MOTOR 40
SCREW'S NUT 46
SCREW 48
SCREW PULLEY 42
SERVO MOTOR BASE 40A
10
8
22B
8A
9
33
1
34
16
22C
5
100
4

FIG 17

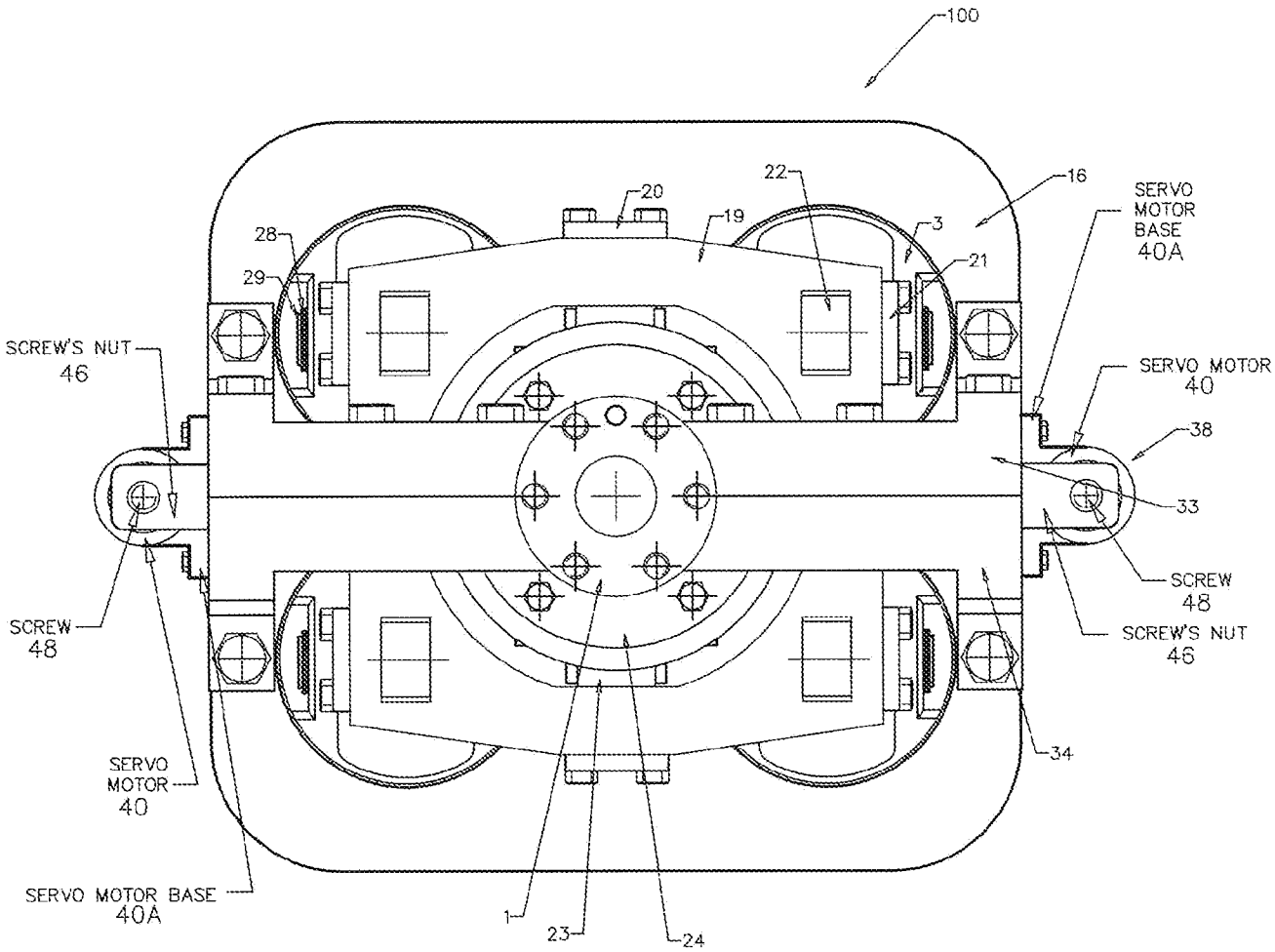

100
16
SERVO MOTOR BASE 40A
22
20
19
3
21
28
29
SCREW'S NUT 46
SERVO MOTOR 40
38
33
SCREW 48
SCREW'S NUT 46
SCREW 48
SERVO MOTOR 40
SERVO MOTOR BASE 40A
1
23
24
34

FIG 18

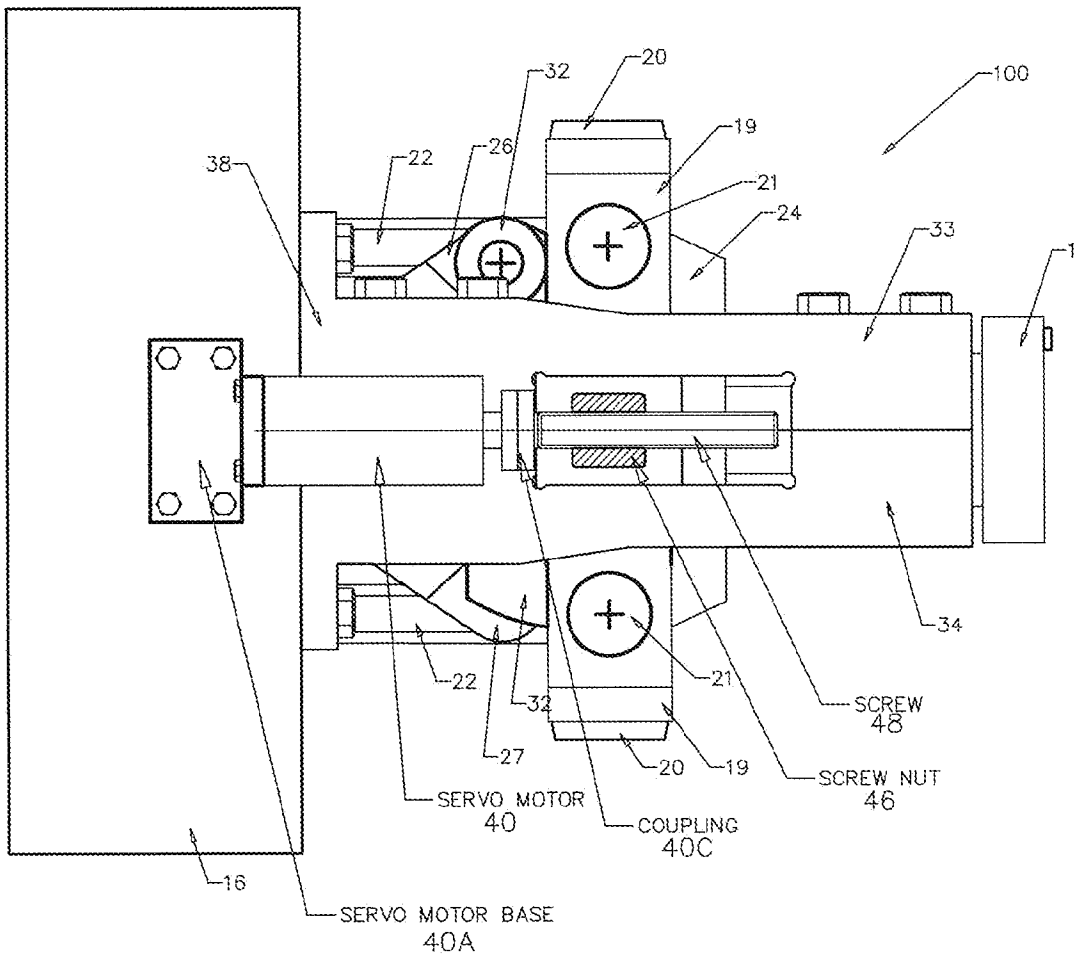

100
1
20
32
19
21
24
33
38
22
26
34
22
21
32
27
20
19
SCREW
48
SCREW NUT
46
SERVO MOTOR
40
COUPLING
40C
16
SERVO MOTOR BASE
40A

FIG 19

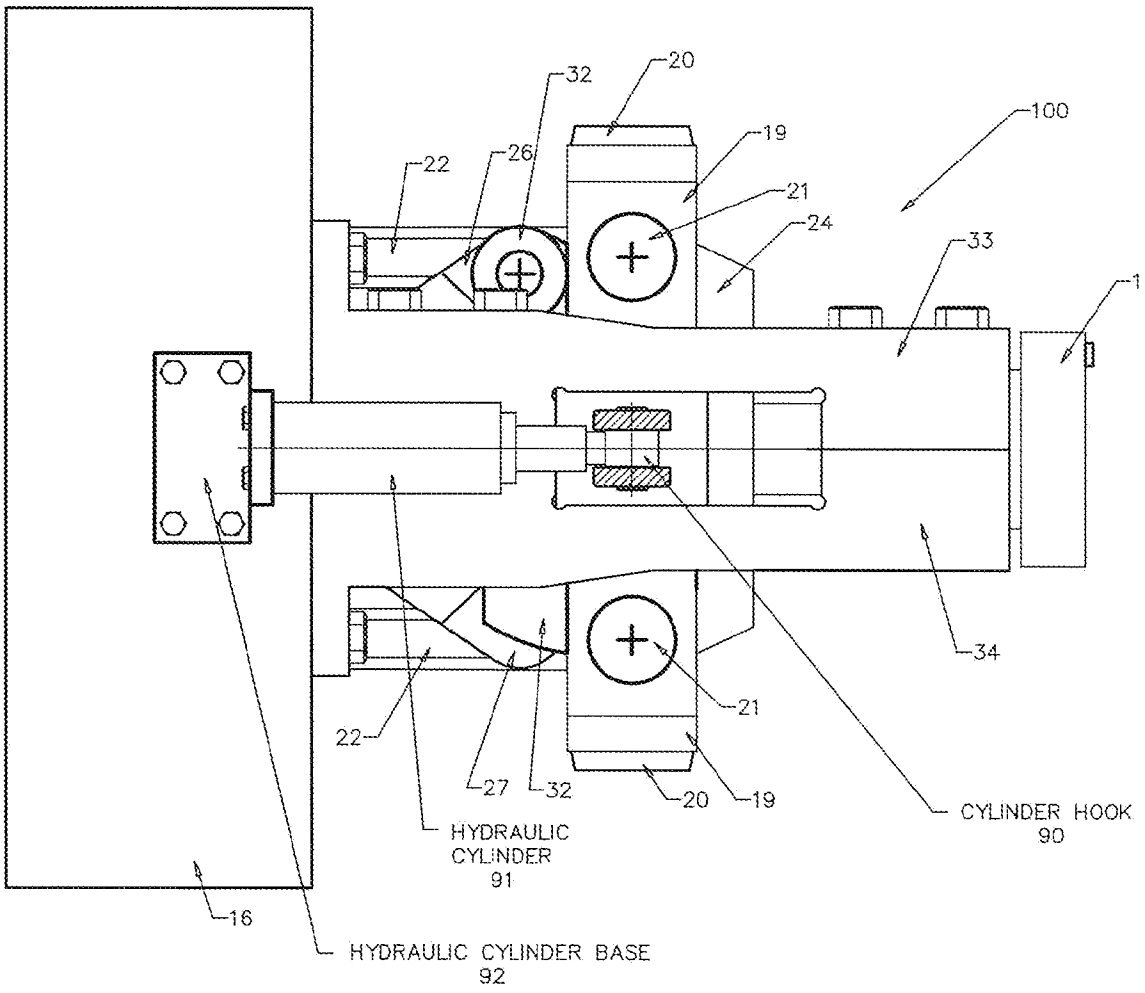

32
20
100
19
22
26
21
24
33
1
34
21
22
27
32
20
19
CYLINDER HOOK
90
HYDRAULIC
CYLINDER
91
16
HYDRAULIC CYLINDER BASE
92

FIG 19A

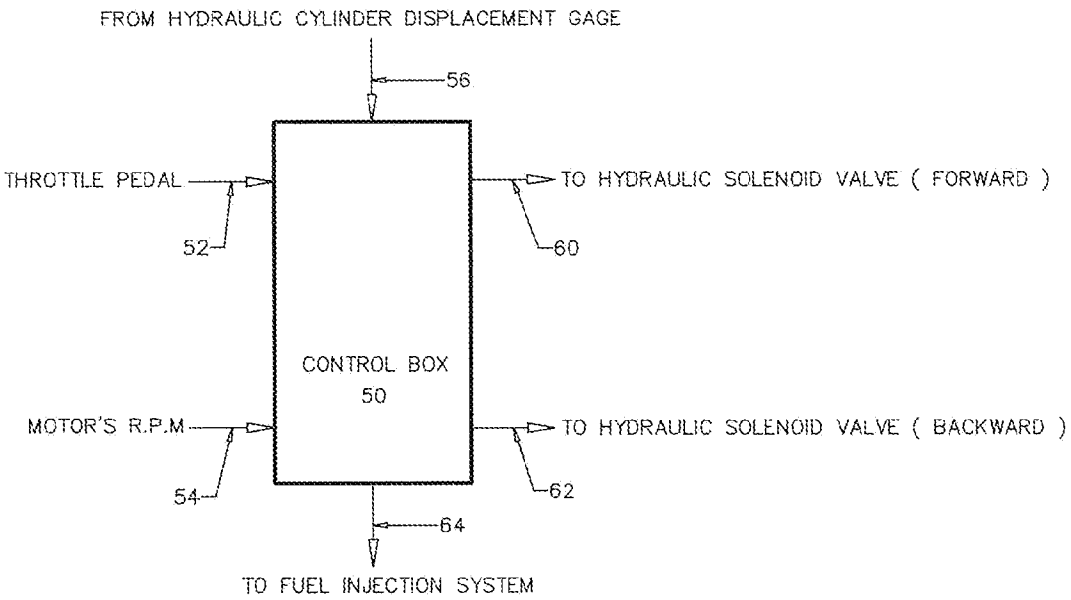

FROM HYDRAULIC CYLINDER DISPLACEMENT GAGE
56
THROTTLE PEDAL
52
TO HYDRAULIC SOLENOID VALVE ( FORWARD )
60
CONTROL BOX
50
MOTOR'S R.P.M
54
TO HYDRAULIC SOLENOID VALVE ( BACKWARD )
62
64
TO FUEL INJECTION SYSTEM

FIG 20

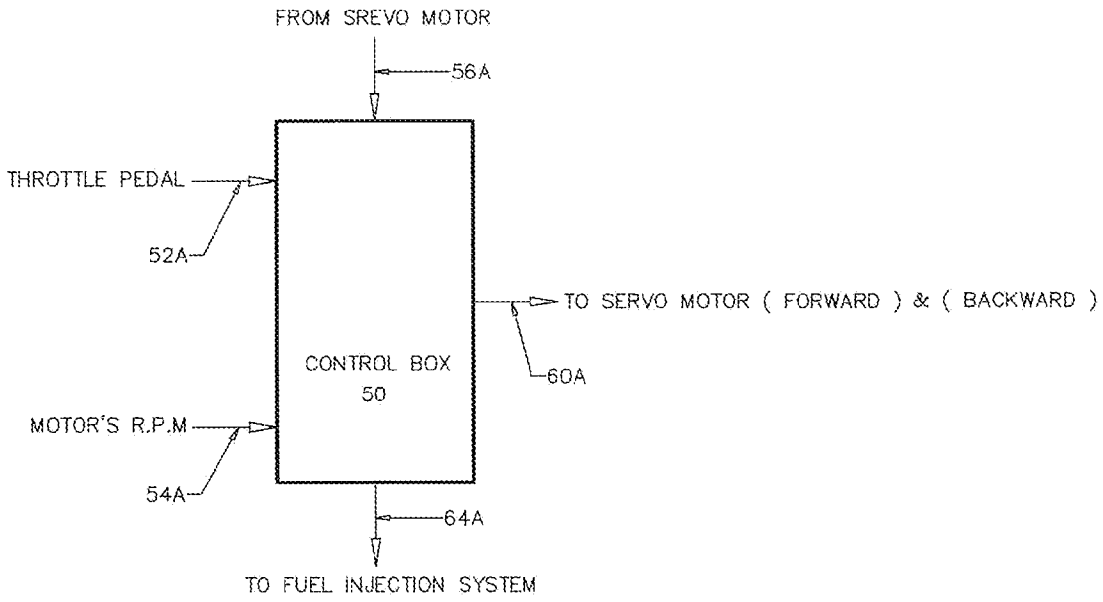

FROM SREVO MOTOR
56A
THROTTLE PEDAL
52A
TO SERVO MOTOR ( FORWARD ) & ( BACKWARD )
60A
CONTROL BOX
50
MOTOR'S R.P.M
54A
64A
TO FUEL INJECTION SYSTEM

FIG 21

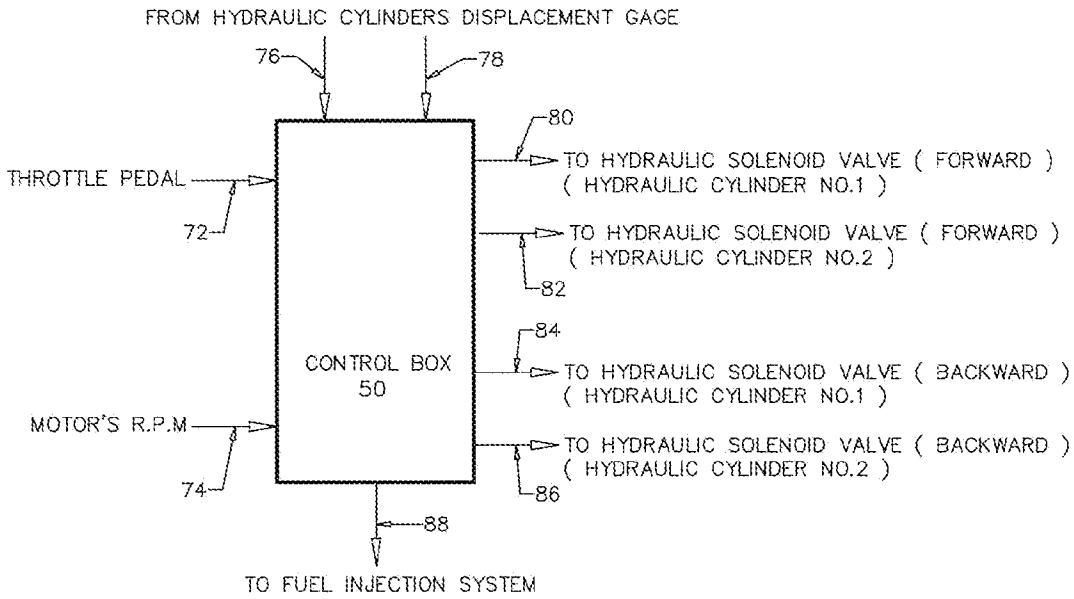

FROM HYDRAULIC CYLINDERS DISPLACEMENT GAGE
76
78
80
THROTTLE PEDAL
72
TO HYDRAULIC SOLENOID VALVE ( FORWARD )
( HYDRAULIC CYLINDER NO.1 )
TO HYDRAULIC SOLENOID VALVE ( FORWARD )
( HYDRAULIC CYLINDER NO.2 )
82
84
CONTROL BOX
50
TO HYDRAULIC SOLENOID VALVE ( BACKWARD )
( HYDRAULIC CYLINDER NO.1 )
MOTOR'S R.P.M
74
TO HYDRAULIC SOLENOID VALVE ( BACKWARD )
( HYDRAULIC CYLINDER NO.2 )
86
88
TO FUEL INJECTION SYSTEM

FIG 22

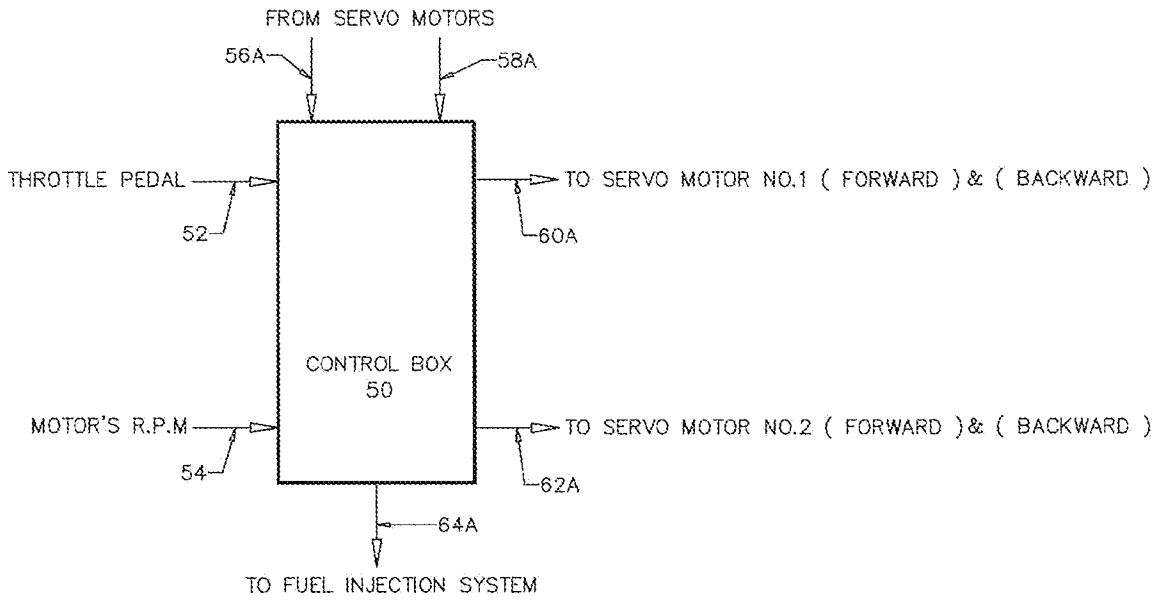

FROM SERVO MOTORS
56A
58A
THROTTLE PEDAL
52
TO SERVO MOTOR NO.1 ( FORWARD ) & ( BACKWARD )
60A
CONTROL BOX
50
MOTOR'S R.P.M
54
TO SERVO MOTOR NO.2 ( FORWARD ) & ( BACKWARD )
62A
64A
TO FUEL INJECTION SYSTEM

FIG 23