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(54) **VARIABLE COMPRESSION PISTON ASSEMBLY**

KOLBENZUORDNUNG MIT VARIABLER KOMPRESSION

ENSEMBLE DE PISTONS A COMPRESSION VARIABLE

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Description

[0001] The invention relates to a variable compression piston assembly, and to an engine that has double ended pistons connected to a universal joint for converting linear motion of the pistons to rotary motion.

[0002] Most piston driven engines have pistons that are attached to offset portions of a crankshaft such that as the pistons are moved in a reciprocal direction transverse to the axis of the crankshaft, the crankshaft will rotate.

[0003] U.S. Patent 5,535,709, defines an engine with a double ended piston that is attached to a crankshaft with an off set portion. A lever attached between the piston and the crankshaft is restrained in a fulcrum regulator to provide the rotating motion to the crankshaft.

[0004] U.S. Patent 4,011,842, defines a four cylinder piston engine that utilizes two double ended pistons connected to a T-shaped T-shaped connecting member that causes a crankshaft to rotate. The T-shaped connecting member is attached at each of the T-cross arm to a double ended piston. A centrally located point on the T-cross arm is rotatably attached to a fixed point, and the bottom of the T is rotatably attached to a crank pin which is connected to the crankshaft by a crankthrow which includes a counter weight.

[0005] In each of the above examples, double ended pistons are used that drive a crankshaft that has an axis transverse to the axis of the pistons. US Patent 5,007,385 describes a crankless engine in which in place of a crankshaft there is used a rocking member having a rockable fulcrum and adapted to perform rocking motions without rotating on its own axis, like a spherical bearing or a cross-type universal bearing. Provision is made for changing the compression ratio of the engine.

[0006] The present invention is directed at a piston assembly comprising at least two pistons having axes lying on a common plane, and being configured for linear motion, a transition arm coupled to each of the pistons and including at least two drive arms, each drive arm defining a drive arm axis, the transition arm having an end mounted in a flywheel (322) on a shaft (400) to travel in a circle for transmitting linear motion of the pistons (306, 308) to rotary motion of the shaft. A universal joint connects the transition arm to a support by two pins to permit pivoting motion about two axes, wherein a centre of the universal joint lies other than on the common plane. According to the invention the assembly includes at least two joints, each joint coupling one of the drive arms to one of the pistons and providing four degrees of freedom between the drive arm and the piston, the four degrees of freedom being a first degree of freedom that includes rotation about the drive arm axis, a second degree of freedom that includes sliding along the drive arm axis, a third degree of freedom that includes pivoting about an axis perpendicular to the drive arm axis, and a fourth degree of freedom that includes sliding in the direction of the perpendicular axis, wherein each joint comprises an outer member coupled to the piston and an inner cylindrical member mounted within the outer member such that the inner cylindrical member slides along the perpendicular axis to provide the fourth degree of freedom. The pistons may be double ended pistons. In this variant the transition arm is coupled to each of the double ended pistons at approximately a centre of each piston.

[0007] An assembly of the invention may include two pistons, coupled in the transition arm to a member having an axis parallel to the common plane of the pistons. The member may be rotatable, and act as a flywheel. A control rod can be operationally connected to the flywheel. In such embodiments the transition arm may be configured to be positionable in a zero-stroke position in which rotation of the rotating member occurs without corresponding movement of the pistons. In other embodiments where the member is rotatable, it may comprise a member upon which a control member is pivotally mounted. Actuation of the control member results in movement of the pivot member to vary the compression ratio.

[0008] In a particular application of the invention, at least one of the plurality of pistons has an output pump piston for driving a pump.

[0009] Further features of the invention will be apparent from the following description of various piston assemblies embodying different aspects of the invention. Reference will be made to the accompanying drawings wherein:

FIGS. 1 and 2 are side views of a simplified illustration of a four cylinder engine;

FIGS. 3, 4, 5 and 6 are top views of the engine of FIG. 1 showing the pistons and flywheel in four different positions;

FIG. 7 is a top view, partially in cross-section of an eight cylinder engine;

FIG. 8 is a side view in cross-section of the engine of FIG. 7;

FIG. 9 is a right end view of FIG. 7;

FIG. 10 is a side view of FIG. 7;

FIG. 11 is a left end view of FIG. 7;

FIG. 12 is a partial top view of the engine of FIG. 7 showing the pistons, drive member and flywheel in a high compression position;

FIG. 13 is a partial top view of the engine in FIG. 7 showing the pistons, drive member and flywheel in a low compression position;

FIG. 14 is a top view of a piston;

FIG. 15 is a side view of a piston showing the drive member in two positions;

FIG. 16 shows the bearing interface of the drive member and the piston;

FIG. 17 is an air driven engine/pump embodiment;

FIG. 18 illustrates the air valve in a first position;

FIGS. 18a, 18b and 18c are cross-sectional view of three cross-sections of the air valve shown in FIG. 18;

FIG. 19 illustrates the air valve in a second position;

FIGS. 19a, 19b and 19c are cross-sectional view of three cross-sections for the air valve shown in FIG. 19;

FIG. 20 shows a piston assembly with slanted cylinders;

FIG. 21 shows a piston assembly with single ended pistons;

FIG. 22 is a top view of a two cylinder, double ended piston assembly;

FIG. 23 is a top view of one of the double ended pistons of the assembly of FIG. 22;

FIG. 23a is a side view of the double ended piston of FIG. 23, taken along lines 23A, 23A;

FIG. 24 is a top view of a transition arm and universal joint of the piston assembly of FIG. 22;

FIG. 24a is a side view of the transition arm and universal joint of FIG. 24, taken along lines 24a, 24a;

FIG. 25 is a perspective view of a drive arm connected to the transition arm of the piston assembly of FIG. 22;

FIG. 25a is an end view of a rotatable member of the piston assembly of FIG. 22, taken along lines 25a, 25a of FIG. 22, and showing the connection of the drive arm to the rotatable member;

FIG. 25b is a side view of the rotatable member, taken along lines 25b, 25b of FIG. 25a;

FIG. 26 is a cross-sectional, top view of the piston assembly of FIG. 22;

FIG. 27 is an end view of the transition arm, taken along lines 27, 27 of FIG. 24;

FIG. 27a is a cross-sectional view of a drive pin of the piston assembly of FIG. 22;

FIGS. 28-28b are top, rear, and side views, respectively, of the piston assembly of FIG. 22;

FIG. 28c is a top view of an auxiliary shaft of the piston assembly of FIG. 22;

FIG. 29 is a cross-sectional side view of a zero-stroke coupling;

FIG. 29a is an exploded view of the zero-stroke coupling of FIG. 29;

FIG. 30 is a graph showing the figure 8 motion of a non-flat piston assembly;

FIG. 31 shows a reinforced drive pin;

FIG. 32 is a top view of a four cylinder engine for directly applying combustion pressures to pump pistons; and

FIG. 32a is an end view of the four cylinder engine, taken along lines 32a, 32a of FIG. 32.

[0010] FIG. 1 is a pictorial representation of a four piston engine 10. Engine 10 has two cylinders 11 (FIG. 3) and 12. Each cylinder 11 and 12 house a double ended piston. Each double ended piston is connected to transition arm 13 which is connected to flywheel 15 by shaft 14. Transition arm 13 is connected to support 19 by a universal joint mechanism, including shaft 18, which allows transition arm 13 to move up an down and shaft 17 which allows transition arm 13 to move side to side. FIG. 1 shows flywheel 15 in a position shaft 14 at the top of wheel 15.

[0011] FIG. 2 shows engine 10 with flywheel 15 rotated so that shaft 14 is at the bottom of flywheel 15. Transition arm 13 has pivoted downward on shaft 18.

[0012] FIGS. 3-6 show a top view of the pictorial representation, showing the transition arm 13 in four positions and shaft moving flywheel 15 in 90° increments. FIG. 3 shows flywheel 15 with shaft 14 in the position as illustrated in FIG. 3a. When piston 1 fires and moves toward the middle of cylinder 11, transition arm 13 will pivot on universal joint 16 rotating flywheel 15 to the position shown in FIG. 2. Shaft 14 will be in the position shown in FIG 4a. When piston 4 is fired, transition arm 13 will move to the position shown in FIG. 5. Flywheel 15 and shaft 14 will be in the position shown in FIG 5a. Next piston 2 will fire and transition arm 13 will be moved to the position shown in FIG. 6. Flywheel 15 and shaft 14 will be in the position shown in FIG. 6a. When piston 3 is fired, transition arm 13 and flywheel 15 will return to the original position that shown in FIGS. 3 and 3a.

[0013] When the pistons fire, transition arm will be moved back and forth with the movement of the pistons. Since transition arm 13 is connected to universal joint 16 and to flywheel 15 through shaft 14, flywheel 15 rotates translating the linear motion of the pistons to a rotational motion.

[0014] FIG. 7 shows (in partial cross-section) a top view of an embodiment of a four double piston, eight cylinder engine 30. There are actually only four cylinders, but with a double piston in each cylinder, the engine is equivalent to a eight cylinder engine. Two cylinders 31 and 46 are shown. Cylinder 31 has double ended piston 32, 33 with piston rings 32a and 33a, respectively. Pistons 32, 33 are connected to a transition arm 60 (FIG. 8) by piston arm 54a extending into opening 55a in piston 32, 33 and sleeve bearing 55. Similarly piston 47, 49, in cylinder 46 is connected by piston arm 54b to transition arm 60.

[0015] Each end of cylinder 31 has inlet and outlet valves controlled by a rocker arms and a spark plug. Piston end 32 has rocker arms 35a and 35b and spark plug 44, and piston end 33 has rocker arms 34a and 34b, and spark plug 41. Each piston has associated with it a set of valves, rocker arms and a spark plug. Timing for firing the spark plugs and opening and closing the inlet and exhaust values is controlled by a timing belt 51 which is connected to pulley 50a. Pulley 50a is attached to a gear 64 by shaft 63 (FIG. 8) turned by output shaft 53 powered by flywheel 69. Belt 50a also turns pulley 50b and gear 39 connected to distributor 38. Gear 39 also turns gear 40. Gears 39 and 40 are attached to cam shaft 75 (FIG. 8) which in turn activate push rods that are attached to the rocker arms 34, 35 and other rocker arms not illustrated.

[0016] Exhaust manifolds 48 and 56 as shown attached to cylinders 46 and 31 respectively. Each exhaust manifold is attached to four exhaust ports.

[0017] FIG. 8 is a side view of engine 30, with one side removed, and taken through section 8-8 of FIG. 7. Transitions arm 60 is mounted on support 70 by pin 72 which allows transition arm to move up and down (as viewed in FIG. 8) and pin 71 which allows transition arm 60 to move from side to side. Since transition arm 60 can move up and down while moving side to side, then shaft 61 can drive flywheel 69 in a circular path. The four connecting piston arms (piston arms 54b and 54d shown in FIG. 8) are driven by the four double end pistons in an oscillator motion around pin 71. The end of shaft 61 in flywheel 69 causes transition arm to move up and down as the connection arms move back and forth. Flywheel 69 has gear teeth 69a around one side which may be used for turning the flywheel with a starter motor 100 (FIG. 11) to start the engine.

[0018] The rotation of flywheel 69 and drive shaft 68 connected thereto, turns gear 65 which in turn turns gears 64 and 66. Gear 64 is attached to shaft 63 which turns pulley 50a. Pulley 50a is attached to belt 51. Belt 51 turns pulley 50b and gears 39 and 40 (FIG. 7). Cam shaft 75 has cams 88-91 on one end and cams 84-87 on the other end. Cams 88 and 90 actuate push rods 76 and 77, respectively. Cams 89 and 91 actuate push rods 93 and 94, respectively. Cams 84 and 86 actuate push rods 95 and 96, respectively, and cams 85 and 87 actuate push rods 78 and 79, respectively. Push rods 77, 76, 93, 94, 95, 96 and 78, 79 are for opening and closing the intake and exhaust valves of the cylinders above the pistons. The left side of the engine, which has been cutaway, contains an identical, but opposite valve drive mechanism.

[0019] Gear 66 turned by gear 65 on drive shaft 68 turns pump 67, which may be, for example, a water pump used in the engine cooling system (not illustrated), or an oil pump.

[0020] FIG. 9 is a rear view of engine 30 showing the relative positions of the cylinders and double ended pistons. Piston 32, 33 is shown in dashed lines with valves 35c and 35d located under lifter arms 35a and 35b, respectively. Belt 51 and pulley 50b are shown under distributor 38. Transition arm 60 and two, 54c and 54d, of the four piston arms 54a, 54b, 54c and 54d are shown in the pistons 32-33, 32a-33a, 47-49 and 47a-49a.

[0021] FIG. 10 is a side view of engine 30 showing the exhaust manifold 56, intake manifold 56a and carburetor 56c. Pulleys 50a and 50b with timing belt 51 are also shown.

[0022] FIG. 11 is a front end view of engine 30 showing the relative positions of the cylinders and double ended pistons 32-33, 32a-33a, 47-49 and 47a-49a with the four piston arms 54a, 54b, 54c and 54d positioned in the pistons. Pump 67 is shown below shaft 53, and pulley 50a and timing belt 51 are shown at the top of engine 30. Starter 100 is shown with gear 101 engaging the gear teeth 69a on flywheel 69.

[0023] A feature of the invention is that the compression ratio for the engine can be changed while the engine is running. The end of arm 61 mounted in flywheel 69 travels in a circle at the point where arm 61 enters flywheel 69. Referring to FIG. 13, the end of arm 61 is in a sleeve bearing ball bushing assembly 81. The stroke of the pistons is controlled by arm 61. Arm 61 forms an angle, for example about 15°, with shaft 53. By moving flywheel 69 on shaft 53 to the right or left, as viewed in FIG. 13, the angle of arm 61 can be changed, changing the stroke of the pistons, changing the compression ratio. The position of flywheel 69 is changed by turning nut 104 on threads 105. Nut 104 is keyed to shaft 53 by thrust bearing 106a held in place by ring 106b. In the position shown in FIG. 12, flywheel 69 has been moved to the right, extending the stroke of the pistons.

[0024] FIG. 12 shows flywheel moved to the right increasing the stroke of the pistons, providing a higher compression ratio. Nut 105 has been screwed to the right, moving shaft 53 and flywheel 69 to the right. Arm 61 extends further into bushing assembly 80 and out the back of flywheel 69.

[0025] FIG. 13 shows flywheel moved to the left reducing the stroke of the pistons, providing a lower compression ratio. Nut 105 has been screwed to the left, moving shaft 53 and flywheel 69 to the left. Arm 61 extends less into bushing assembly 80.

[0026] The piston arms on the transition arm are inserted into sleeve bearings in a bushing in piston. FIG. 14 shows a double piston 110 having piston rings 111 on one end of the double piston and piston rings 112 on the other end of the double piston. A slot 113 is in the side of the piston. The location the sleeve bearing is shown at 114.

[0027] FIG. 15 shows a piston arm 116 extending into piston 110 through slot 116 into sleeve bearing 117 in bushing 115. Piston arm 116 is shown in a second position at 116a. The two pistons arms 116 and 116a show the movement limits of piston arm 116 during operation of the engine.

[0028] FIG. 16 shows piston arm 116 in sleeve bearing 117. Sleeve bearing 117 is in pivot pin 115. Piston arm 116 can freely rotate in sleeve bearing 117 and the assembly of piston arm 116, Sleeve bearing 117 and pivot pin 115 and sleeve bearings 118a and 118b rotate in piston 110, and piston arm 116 can moved axially with the axis of sleeve bearing 117 to allow for the linear motion of double ended piston 110, and the motion of a transition arm to which piston arm 116 is attached.

[0029] FIG. 17 shows how the four cylinder engine 10 in FIG. 1 may be configured as an air motor using a four way rotary valve 123 on the output shaft 122. Each of cylinders 1, 2, 3 and 4 are connected by hoses 131. 132, 133, and 144, respectively, to rotary valve 123. Air inlet port 124 is used to supply air to run engine 120. Air is sequentially supplied to each of the pistons 1a, 2a, 3a dn 4a, to move the pistons back and forth in the cylinders. Air is exhausted from the cylinders out exhaust port 136. Transition arm 126, attached to the pistons by connecting pins 127 and 128 are moved as described with references to FIGS. 1-6 to turn flywheel 129 and output shaft 22.

[0030] FIG. 18 is a cross-sectional view of rotary valve 123 in the position when pressurized air or gas is being applied to cylinder 1 through inlet port 124, annular channel 125, channel 126, channel 130, and air hose 131. Rotary valve 123 is made up of a plurality of channels in housing 123 and output shaft 122. The pressurized air entering cylinder 1 causes piston 1a, 3a to move to the right (as viewed in FIG. 18). Exhaust air is forced out of cylinder 3 through line 133 into chamber 134, through passageway 135 and out exhaust outlet 136.

[0031] FIGS. 18a, 18b and 18c are cross-sectional view of valve 23 showing the air passages of the valves at three positions along valve 23 when positioned as shown in FIG. 18.

[0032] FIG. 19 shows rotary valve 123 rotated 180° when pressurized air is applied to cylinder 3, reversing the direction of piston 1a,3a. Pressurized air is applied to inlet port 124, through annular chamber 125, passage way 126, chamber 134 and air line 133 to cylinder 3. This in turn causes air in cylinder 1 to be exhausted through line 131, chamber 130, line 135, annular chamber 137 and out exhaust port 136. Shaft 122 will have rotated 360° turning counter clockwise when piston 1a,3a complete it stroke to the left.

[0033] Only piston 1a,3a have been illustrated to show the operation of the air engine and valve 123 relative to the piston motion. The operation of piston 2a,4a is identical in function except that its 360° cycle starts at 90° shaft rotation and reverses at 270° and completes its cycle back at 90°. A power stroke occurs at every 90° of rotation.

[0034] FIGS. 19a, 19b and 19c are cross-sectional views of valve 123 showing the air passages of the valves at three positions along valve 123 when positioned as shown in FIG. 19.

[0035] The principle of operation which operates the air engine of FIG. 17 can be reversed, and engine 120 of FIG. 17 can be used as an air or gas compressor or pump. By rotating engine 10 clockwise by applying rotary power to shaft 122, exhaust port 136 will draw in air into the cylinders and port 124 will supply air which may be used to drive, for example air tool, or be stored in an air tank.

[0036] In the assemblies described above the cylinders have been illustrated as being parallel to each other. However, the cylinders need not be parallel. FIG. 20 shows an embodiment similar to the embodiment of FIG. 1-6, with cylinders 150 and 151 not parallel to each other. Universal joint 160 permits the piston arms 152 and 153 to be at an angle other than 90° to the drive arm 154. Even with the cylinders not parallel to each other the engines are functionally the same.

[0037] Still another modification may be made to the engine 10 of FIGS. 1-6. The assembly, pictorially shown in FIG. 21, may have single ended pistons. Piston 1a and 2a are connected to universal joint 170 by drive arms 171 and 172, and to flywheel 173 by drive arm 174. The basic difference is the number of strokes of pistons 1a and 2a to rotate flywheel 173 360°.

[0038] Referring to FIG. 22, a two cylinder piston assembly 300 includes cylinders 302, 304, each housing a variable stroke, double ended piston 306, 308, respectively. Piston assembly 300 provides the same number of power strokes per revolution as a conventional four cylinder engine. Each double ended piston 306, 308 is connected to a transition arm 310 by a drive pin 312, 314, respectively. Transition arm 310 is mounted to a support 316 by, e.g., a universal joint 318 (U-joint), constant velocity joint, or spherical bearing. A drive arm 320 extending from transition arm 310 is connected to a rotatable member, e.g., flywheel 322.

[0039] Transition arm 310 transmits linear motion of pistons 306, 308 to rotary motion of flywheel 322. The axis, A, of flywheel 322 is parallel to the axes, B and C, of pistons 306, 308 (though axis, A, could be off-axis as shown in FIG. 20) to form an axial or barrel type engine, pump, or compressor. U-joint 318 is centered on axis, A. As shown in FIG. 28a, pistons 306, 308 are 180° apart with axes A, B and C lying along a common plane, D, to form a flat piston assembly.

[0040] Referring to FIGS. 22 and 23, cylinders 302, 304 each include left and right cylinder halves 301a, 301b mounted to the assembly case structure 303. Double ended pistons 306, 308 each include two pistons 330 and 332, 330a and 332a, respectively, joined by a central joint 334, 334a, respectively. The pistons are shown having equal length, though other lengths are contemplated. For example, joint 334 can be off-center such that piston 330 is longer than piston 332. As the pistons are fired in sequence 330a, 332, 330, 332a, from the position shown in FIG. 22, flywheel 322 is rotated in a clockwise direction, as viewed in the direction of arrow 333. Piston assembly 300 is a four stroke cycle engine, i.e., each piston fires once in two revolutions of flywheel 322.

[0041] As the pistons move back and forth, drive pins 312, 314 must be free to rotate about their common axis, E, (arrow 305), slide along axis, E, (arrow 307) as the radial distance to the center line, B, of the piston changes with the angle of swing, α, of transition arm 310 (approximately $\pm$15° swing), and pivot about centers, F, (arrow 309). Joint 334 is constructed to provide this freedom of motion.

[0042] Joint 334 defines a slot 340 (FIG. 23a) for receiving drive pin 312, and a hole 336 perpendicular to slot 340 housing a sleeve bearing 338. A cylinder 341 is positioned within sleeve bearing 338 for rotation within the sleeve bearing. Sleeve bearing 338 defines a side slot 342 shaped like slot 340 and aligned with slot 340. Cylinder 341 defines a through hole 344. Drive pin 312 is received within slot 342 and hole 344. An additional sleeve bearing 346 is located in through hole 344 of cylinder 341. The combination of slots 340 and 342 and sleeve bearing 338 permit drive pin 312 to move along arrow 309. Sleeve bering 346 permits drive pin 312 to rotate about its axis, E, and slide along its axis, E.

[0043] If the two cylinders of the piston assembly are configured other than 180° apart, or more than two cylinders are employed, movement of cylinder 341 in sleeve bearing 338 along the direction of arrow 350 allows for the additional freedom of motion required to prevent binding of the pistons as they undergo a figure 8 motion, discussed below. Slot 340 must also be sized to provide enough clearance to allow the figure 8 motion of the pin.

[0044] Referring to FIGS. 24 and 24a, U-joint 318 defines a central pivot 352 (drive pin axis, E, passes through center 352), and includes a vertical pin 354 and a horizontal pin 356. Transition arm 310 is capable of pivoting about pin 354 along arrow 358, and about pin 356 along arrow 360.

[0045] Referring to FIGS. 25, 25a and 25b, as an alternative to a spherical bearing, to couple transition arm 310 to flywheel 322, drive arm 320 is received within a cylindrical pivot pin 370 mounted to the flywheel offset radially from the center 372 of the flywheel by an amount, e.g., 2.125 inches, required to produce the desired swing angle, α (FIG. 22), in the transition arm.

[0046] Pivot pin 370 has a through hole 374 for receiving drive arm 320. There is a sleeve bearing 376 in hole 374 to provide a bearing surface for drive arm 320. Pivot pin 370 has cylindrical extensions 378, 380 positioned within sleeve bearings 382, 384, respectively. As the flywheel is moved axially along drive arm 320 to vary the swing angle, α, and thus the compression ratio of the assembly, as described further below, pivot pin 370 rotates within sleeve bearings 382, 384 to remain aligned with drive arm 320. Torsional forces are transmitted through thrust bearings 388, 390, with one or the other of the thrust bearings carrying the load depending on the direction of the rotation of the flywheel along arrow 386.

[0047] Referring to FIG. 26, to vary the compression and displacement of piston assembly 300, the axial position of flywheel 322 along axis, A, is varied by rotating a shaft 400. A sprocket 410 is mounted to shaft 400 to rotate with shaft 400. A second sprocket 412 is connected to sprocket 410 by a roller chain 413. Sprocket 412 is mounted to a threaded rotating barrel 414. Threads 416 of barrel 414 contact threads 418 of a stationary outer barrel 420. Rotation of shaft 400, arrow 401, and thus sprockets 410 and 412, causes rotation of barrel 414. Because outer barrel 420 is fixed, the rotation of barrel 414 causes barrel 414 to move linearly along axis, A, arrow 403. Barrel 414 is positioned between a collar 422 and a gear 424, both fixed to a main drive shaft 408. Drive shaft 408 is in turn fixed to flywheel 322. Thus, movement of barrel 414 along axis, A, is translated to linear movement of flywheel 322 along axis, A. This results in flywheel 322 sliding along axis, H, of drive arm 320 of transition arm 310, changing angle, β, and thus the stroke of the pistons. Thrust bearings 430 are located at both ends of barrel 414, and a sleeve bearing 432 is located between barrel 414 and shaft 408.

[0048] To maintain the alignment of sprockets 410 and 412, shaft 400 is threaded at region 402 and is received within a threaded hole 404 of a cross bar 406 of assembly case structure 303. The ratio of the number of teeth of sprocket 412 to sprocket 410 is, e.g., 4:1. Therefore, shaft 400 must turn four revolutions for a single revolution of barrel 414. To maintain alignment, threaded region 402 must have four times the threads per inch of barrel threads 416, e.g., threaded region 402 has thirty-two threads per inch, and barrel threads 416 have eight threads per inch.

[0049] As the flywheel moves to the right, as viewed in FIG. 26, the stroke of the pistons, and thus the compression ratio, is increased. Moving the flywheel to the left decreases the stroke and the compression ratio. A further benefit of the change in stroke is a change in the displacement of each piston and therefore the displacement of the engine. The horsepower of an internal combustion engine closely relates to the displacement of the engine. For example, in the two cylinder, flat engine, the displacement increases by about 20% when the compression ratio is raised from 6:1 to 12:1. This produces approximately 20% more horsepower due alone to the increase in displacement. The increase in compression ratio also increases the horsepower at the rate of about 5% per point or approximately 25% in horsepower. If the horsepower were maintained constant and the compression ratio increased from 6:1 to 12:1, there would be a reduction in fuel consumption of approximately 25%.

[0050] The flywheel has sufficient strength to withstand the large centrifugal forces seen when assembly 300 is functioning as an engine. The flywheel position, and thus the compression ratio of the piston assembly, can be varied while the piston assembly is running.

[0051] Piston assembly 300 includes a pressure lubrication system. The pressure is provided by an engine driven positive displacement pump (not shown) having a pressure relief valve to prevent overpressures. Bearings 430 and 432 of drive shaft 408 and the interface of drive arm 320 with flywheel 322 are lubricated via ports 433 (Fig. 26).

[0052] Referring to FIG. 27, to lubricate U-joint 318, piston pin joints 306, 308, and the cylinder walls, oil under pressure from the oil pump is ported through the fixed U-joint bracket to the top and bottom ends of the vertical pivot pin 354. Oil ports 450, 452 lead from the vertical pin to openings 454, 456, respectively, in the transition arm. As shown in FIG. 27A, pins 312, 314 each define a through bore 458. Each through bore 458 is in fluid communication with a respective one of openings 454, 456. As shown in FIG. 23, holes 460, 462 in each pin connect through slots 461 and ports 463 through sleeve bearing 338 to a chamber 465 in each piston. Several oil lines 464 feed out from these chambers and are connected to the skirt 466 of each piston to provide lubrication to the cylinders walls and the piston rings 467. Also leading from chamber 465 is an orifice to squirt oil directly onto the inside of the top of each piston for cooling.

[0053] Referring to FIGS. 28-28c, in which assembly 300 is shown configured for use as an aircraft engine

300a, the engine ignition includes two magnetos 600 to fire the piston spark plugs (not shown). Magnetos 600 and a starter 602 are driven by drive gears 604 and 606 (FIG. 28c), respectively, located on a lower shaft 608 mounted parallel and below the main drive shaft 408. Shaft 608 extends the full length of the engine and is driven by gear 424 (Fig. 26) of drive shaft 408 and is geared with a one to one ratio to drive shaft 408. The gearing for the magnetos reduces their speed to half the speed of shaft 608. Starter 602 is geared to provide sufficient torque to start the engine.

[0054] Camshafts 610 operate piston push rods 612 through lifters 613. Camshafts 610 are geared down 2 to 1 through bevel gears 614, 616 also driven from shaft 608. Center 617 of gears 614, 616 is preferably aligned with U-joint center 352 such that the camshafts are centered in the piston cylinders, though other configurations are contemplated. A single carburetor 620 is located under the center of the engine with four induction pipes 622 routed to each of the four cylinder intake valves (not shown). The cylinder exhaust valves (not shown) exhaust into two manifolds 624.

[0055] Engine 300a has a length, L, e.g., of about forty inches, a width, W, e.g., of about twenty-one inches, and a height, H, e.g., of about twenty inches, (excluding support 303).

[0056] Referring to FIGS. 29 and 29a, a variable compression compressor or pump having zero stroke capability is illustrated. Here, flywheel 322 is replaced by a rotating assembly 500. Assembly 500 includes a hollow shaft 502 and a pivot arm 504 pivotally connected by a pin 506 to a hub 508 of shaft 502. Hub 508 defines a hole 510 and pivot arm 504 defines a hole 512 for receiving pin 506. A control rod 514 is located within shaft 502. Control rod 514 includes a link 516 pivotally connected to the remainder of rod 514 by a pin 518. Rod 514 defines a hole 511 and link 516 defines a hole 513 for receiving pin 518. Control rod 514 is supported for movement along its axis, Z, by two sleeve bearings 520. Link 516 and pivot arm 514 are connected by a pin 522. Link 516 defines a hole 523 and pivot arm 514 defines a hole 524 for receiving pin 522.

[0057] Cylindrical pivot pin 370 of FIG. 25 which receives drive arm 320 is positioned within pivot arm 504. Pivot arm 504 defines holes 526 for receiving cylindrical extensions 378, 380. Shaft 502 is supported for rotation by bearings 530, e.g., ball, sleeve, or roller bearings. A drive, e.g, pulley 532 or gears, mounted to shaft 502 drives the compressor or pump.

[0058] In operation, to set the desired stroke of the pistons, control rod 514 is moved along its axis, M, in the direction of arrow 515, causing pivot arm 504 to pivot about pin 506, along arrow 517, such that pivot pin 370 axis, N, is moved out of alignment with axis, M, (as shown in dashed lines) as pivot arm 504 slides along the axis, H, (FIG. 26) of the transition arm drive arm 320. When zero stroke of the pistons is desired, axes M and N are aligned such that rotation of shaft 514 does not cause movement of the pistons. This configuration works for both double ended and single sided pistons.

[0059] The ability to vary the piston stroke permits shaft 514 to be run at a single speed by drive 532 while the output of the pump or compressor can be continually varied as needed. When no output is needed, pivot arm 504 simply spins around drive arm 320 of transition arm 310 with zero swing of the drive arm. When output is needed, shaft 514 is already running at full speed so that when pivot arm 504 is pulled off-axis by control rod 514, an immediate stroke is produced with no lag coming up to speed. There are therefore much lower stress loads on the drive system as there are no start/stop actions. The ability to quickly reduce the stroke to zero provides protection from damage especially in liquid pumping when a downstream blockage occurs.

[0060] If two cylinders not spaced 180° apart (as viewed from the end) or more than two cylinders are employed in piston assembly 300, the ends of pins 312, 314 coupled to joints 306, 308 will undergo a figure 8 motion, as shown in FIG. 30. FIG. 30 shows the figure 8 motion of a piston assembly having four double ended pistons. Two of the pistons are arranged flat as shown in FIG. 22 (and do not undergo the figure 8 motion), and the other two pistons are arranged equally spaced between the flat pistons (and are thus positioned to undergo the largest figure 8 deviation possible). The amount that the pins connected to the second set of pistons deviate from a straight line (y axis of FIG. 30) is determined by the swing angle (mast angle) of the drive arm and the distance the pin is from the central pivot point 352 (x axis of FIG. 30).

[0061] In a four cylinder version where the pins through the piston pivot assembly of each of the four double ended pistons are set at 45° from the axis of the central pivot, the figure eight motion is equal at each piston pin. Movement in the piston pivot bushing is provided where the figure eight motion occurs to prevent binding.

[0062] When piston assembly 300 is configured for use, e.g., as a diesel engines, extra support can be provided at the attachment of pins 312, 314 to transition arm 310 to account for the higher compression of diesel engines as compared to spark ignition engines. Referring to FIG. 31, support 550 is bolted to transition arm 310 with bolts 551 and includes an opening 552 for receiving end 554 of the pin.

[0063] Engines of the kind described herein can be used to directly apply combustion pressures to pump pistons. Referring to FIGS. 32 and 32a, a four cylinder, two stroke cycle engine 600 (each of the four pistons 602 fires once in one revolution) applies combustion pressure to each of four pump pistons 604. Each pump piston 604 is attached to the output side 606 of a corresponding piston cylinder 608. Pump pistons 604 extend into a pump head 610.

[0064] A transition arm 620 is connected to each cylinder 608 and to a flywheel 622, as described above. An auxiliary output shaft 624 is connected to flywheel 622 to rotate with the flywheel, also as described above.

[0065] The engine is a two stroke cycle engine because every stroke of a piston 602 (as piston 602 travels to the right as viewed in FIG. 32) must be a power stroke. The number of engine cylinders is selected as required by the pump. The pump can be a fluid or gas pump. In use as a multi-stage air compressor, each pump piston 606 can be a different diameter. No bearing loads are generated by the pumping function, and therefore, no friction is introduced other than that generated by the pump pistons themselves.

Claims

1. A piston assembly comprising:

   at least two pistons (306, 308) having axes lying on a common plane, and being configured for linear motion,
   a transition arm (310) coupled to each of the pistons and including at least two drive arms (312, 314), each drive arm defining a drive arm axis, the transition arm having an end mounted in a flywheel (322) on a shaft (400) to travel in a circle for transmitting linear motion of the pistons (306, 308) to rotary motion of the shaft; and
   a universal joint (318) connecting the transition arm to a support by two pins to permit pivoting motion about two axes, wherein a centre of the universal joint lies other than on the common plane,

   CHARACTERISED IN THAT
   the assembly includes at least two joints (334,334a), each joint coupling one of the drive arms to one of the pistons (306,308) and providing four degrees of freedom between the drive arm and the piston, the four degrees of freedom being a first degree of freedom that includes rotation about the drive arm axis (307), a second degree of freedom that includes sliding along the drive arm axis (307), a third degree of freedom that includes pivoting about an axis (350) perpendicular to the drive arm axis, and a fourth degree of freedom that includes sliding in the direction of the perpendicular axis, wherein each joint comprises an outer member (338) coupled to the piston and an inner cylindrical member (341) mounted within the outer member such that the inner cylindrical member slides along the perpendicular axis to provide the fourth degree of freedom.

2. The piston assembly of Claim 1 wherein at least one of the pistons comprises a double-ended piston (306,308).

3. The piston assembly of Claim 2 wherein a second of the at least two pistons comprises a double-ended piston (306,308).

4. The piston assembly of any preceding Claim wherein the axis of a first of the pistons (306) and an axis of rotation of a rotatable member (322) coupled to the transition arm (310) lie on a first plane, and the axis of the second of the pistons (308) and the axis of the rotatable member lie on a second plane substantially perpendicular to the first plane.

5. The piston assembly of any preceding Claim including four pistons (306,308).

6. The assembly of any preceding Claim wherein the two pins (354,356) form a cross member.

7. The assembly of any preceding Claim further comprising a second transition arm mounted back-to-back and 180° out of phase from the transition arm coupled to the pistons.

8. The assembly of Claim 7 wherein the transition arms are coupled by a rotating member.

9. The assembly of Claim 7 wherein the second transition arm is coupled to a member sharing a common cylinder with one of the pistons.

10. The piston assembly of any preceding Claim wherein a compression ratio of the pistons is adjustable such that with power maintained constant and the compression ratio increased from 6:1 to 12:1 there is an approximately 25% reduction in fuel consumption.

11. The piston assembly of any preceding Claim wherein the transition arm includes a plurality of drive arms, each drive arm being coupled to a respective one of the pistons by a joint having said four degrees of freedom.

Patentansprüche

1. Kolbenbaugruppe, umfassend:

   mindestens zwei Kolben (306, 308), die Achsen aufweisen, die auf einer gemeinsamen Ebene liegen und für eine Linearbewegung konfiguriert sind;
   einen Übergangsarm (310), der an jeden der Kolben gekoppelt ist und mindestens zwei Antriebsarme (312, 314) umfasst, wobei jeder Antriebsarm eine Antriebsarmachse definiert und der Übergangsarm ein Ende aufweist, das in ein Schwungrad (322) auf einer Welle (400) montiert ist, um sich in einem Kreis zu bewegen, damit die Linearbewegung der Kolben (306, 308) in die Drehbewegung der Welle übertragen wird; und
   ein Universalgelenk (318), das den Übergangs-

arm mithilfe von zwei Bolzen mit einem Stützlager verbindet, um die Schwenkbewegung um zwei Achsen zu gestatten, wobei ein Zentrum des Universalgelenks nicht auf der gemeinsamen Ebene, sondern woanders liegt;

dadurch gekennzeichnet, dass
die Baugruppe mindestens zwei Gelenke (334, 334a) umfasst, wobei jedes Gelenk einen der Antriebsarme an einen der Kolben (306, 308) koppelt und vier Freiheitsgrade zwischen dem Antriebsarm und dem Kolben bereitstellt, wobei sich die vier Freiheitsgrade zusammensetzen aus einem ersten Freiheitsgrad, der die Drehung um die Antriebsarmachse (307) umfasst, einem zweiten Freiheitsgrad, der das Verschieben längs der Antriebsarmachse (307) umfasst, einem dritten Freiheitsgrad, der das Schwenken um eine Achse (350) senkrecht zur Antriebsarmachse umfasst, und einem vierten Freiheitsgrad, der das Verschieben in Richtung der senkrechten Achse umfasst, wobei jedes Gelenk ein äußeres Element (338), das an den Kolben gekoppelt ist, und ein inneres zylindrisches Element (341) umfasst, das in das äußere Element so montiert ist, dass das innere zylindrische Element sich längs der senkrechten Achse verschiebt, um den vierten Freiheitsgrad bereitzustellen.

2. Kolbenbaugruppe nach Anspruch 1, bei der mindestens einer der Kolben einen doppelendigen Kolben (306, 308) umfasst.

3. Kolbenbaugruppe nach Anspruch 2, bei der ein zweiter der mindestens zwei Kolben einen doppelendigen Kolben (306, 308) umfasst.

4. Kolbenbaugruppe nach einem der vorhergehenden Ansprüche, bei der die Achse eines ersten der Kolben (306) und eine Drehachse eines drehbaren Elementes (322), das an den Übergangsarm (310) gekoppelt ist, auf einer ersten Ebene liegen und die Achse des zweiten der Kolben (308) und die Achse des drehbaren Elementes auf einer zweiten Ebene liegen, die zur ersten Ebene im Wesentlichen senkrecht ist.

5. Kolbenbaugruppe nach einem der vorhergehenden Ansprüche, die vier Kolben (306, 308) umfasst.

6. Baugruppe nach einem der vorhergehenden Ansprüche, bei der die zwei Bolzen (354, 356) ein Kreuzelement bilden.

7. Baugruppe nach einem der vorhergehenden Ansprüche, die außerdem einen zweiten Übergangsarm umfasst, der in Bezug auf den an die Kolben gekoppelten Übergangsarm mit den Rückseiten aneinander montiert und gegenüber demselben um 180° phasenverschoben ist.

8. Baugruppe nach Anspruch 7, bei der die Übergangsarme durch ein Rotationselement gekoppelt sind.

9. Baugruppe nach Anspruch 7, bei der der zweite Übergangsarm an ein Element gekoppelt ist, das sich einen gemeinsamen Zylinder mit einem der Kolben teilt.

10. Kolbenbaugruppe nach einem der vorhergehenden Ansprüche, bei der ein Verdichtungsverhältnis der Kolben so einstellbar ist, dass es bei konstant gehaltener Leistung und dem von 6:1 auf 12:1 erhöhten Verdichtungsverhältnis eine Verringerung des Kraftstoffverbrauchs von ungefähr 25 % gibt.

11. Kolbenbaugruppe nach einem der vorhergehenden Ansprüche, bei der der Übergangsarm eine Vielzahl von Antriebsarmen umfasst, wobei jeder Antriebsarm durch ein Gelenk, das vier Freiheitsgrade aufweist, an einen jeweiligen der Kolben gekoppelt ist.

Revendications

1. Assemblage de pistons, comprenant :

au moins deux pistons (306, 308), comportant des axes situés dans un plan commun, et configurés en vue d'effectuer un déplacement linéaire ;
un bras de transition (310), accouplé à chacun des pistons et englobant au moins deux bras d'entraînement (312, 314), chaque bras d'entraînement définissant un axe du bras d'entraînement, le bras de transition comportant une extrémité montée dans un volant (322) sur un arbre (400) afin de se déplacer dans un cercle pour transmettre le déplacement linéaire des pistons (306, 308) en un déplacement rotatif de l'arbre ; et
un joint universel (318) connectant le bras de transition à un support par l'intermédiaire de deux goupilles pour permettre un déplacement pivotant sur deux axes, un centre du joint universel étant situé dans un plan autre que le plan commun ;

caractérisé en ce que
l'assemblage englobe au moins deux joints (334, 334a), chaque joint accouplant un des bras d'entraînement à l'un des pistons (306, 308) et établissant quatre degrés de liberté entre le bras d'entraînement et le piston, les quatre degrés de liberté étant constitués par un premier degré de liberté englobant une rotation autour de l'axe du bras d'entraînement (307), un deuxième degré de liberté, englobant un

glissement le long de l'axe du bras d'entraînement (307), un troisième degré de liberté, englobant un pivotement sur un axe (350) perpendiculaire à l'axe du bras d'entraînement, et un quatrième degré de liberté, englobant un glissement dans la direction de l'axe perpendiculaire, chaque joint comprenant un élément externe (338) accouplé au piston, et un élément cylindrique interne (341) monté dans l'élément externe, de sorte que l'élément cylindrique interne glisse le long de l'axe perpendiculaire pour établir le quatrième degré de liberté.

2. Assemblage de pistons selon la revendication 1, dans lequel au moins un des pistons comprend un piston à deux extrémités (306, 308).

3. Assemblage de pistons selon la revendication 2, dans lequel un deuxième piston des au moins deux pistons comprend un piston à deux extrémités (306, 308).

4. Assemblage de pistons selon l'une quelconque des revendications précédentes, dans lequel l'axe d'un premier piston des pistons (306) et un axe de rotation d'un élément rotatif (322) accouplé au bras de transition (310) se situent dans un premier plan, l'axe du deuxième des pistons (308) et l'axe de l'élément rotatif se situant dans un deuxième plan pratiquement perpendiculaire au premier plan.

5. Assemblage de pistons selon l'une quelconque des revendications précédentes, englobant quatre pistons (306, 308).

6. Assemblage de pistons selon l'une quelconque des revendications précédentes, dans lequel les deux goupilles (354, 356) forment une traverse.

7. Assemblage de pistons selon l'une quelconque des revendications précédentes, comprenant en outre un deuxième bras de transition, monté dos-à-dos et déphasé de 180° par rapport au bras de transition accouplé aux pistons.

8. Assemblage de pistons selon la revendication 7, dans lequel les bras de transition sont accouplés par un élément rotatif.

9. Assemblage de pistons selon la revendication 7, dans lequel le deuxième bras de transition est accouplé à un élément partageant un cylindre commun avec l'un des pistons.

10. Assemblage de pistons selon l'une quelconque des revendications précédentes, dans lequel un rapport de compression des pistons peut être ajusté de sorte que, la puissance étant maintenue constante et le rapport de compression étant accru de 6:1 à 12:1, il y a une réduction d'environ 25% de la consommation de carburant.

11. Assemblage de pistons selon l'une quelconque des revendications précédentes, dans lequel le bras de transition englobe plusieurs bras d'entraînement, chaque bras d'entraînement étant accouplé à un piston respectif des pistons par un joint comportant quatre degrés de liberté.

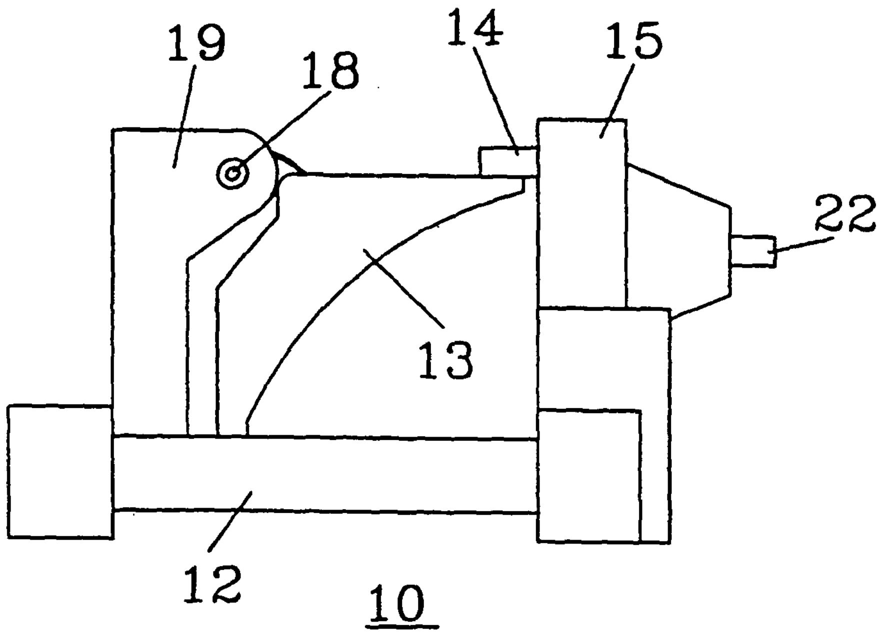


FIG. 1

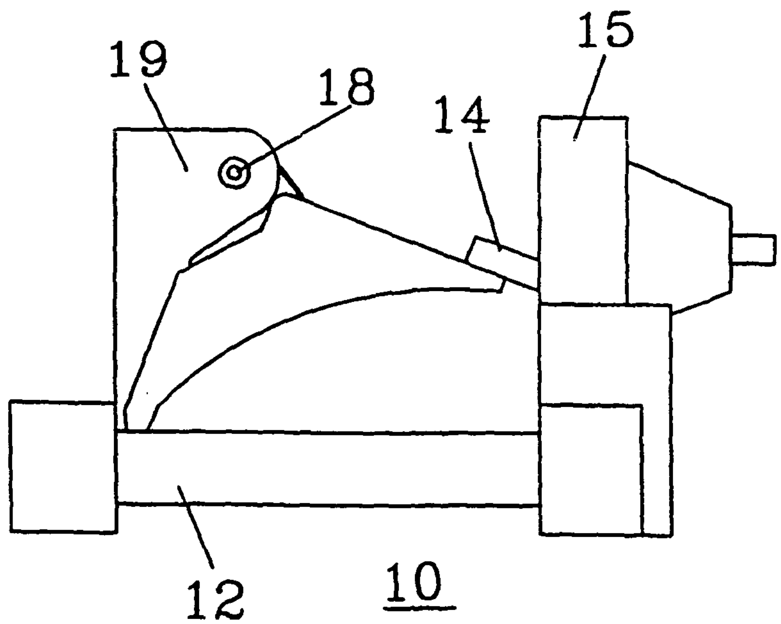


FIG. 2

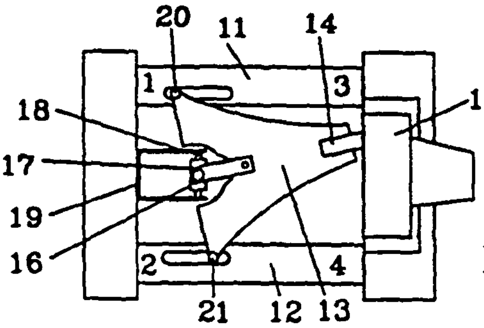


FIG. 3

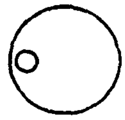


FIG. 3a

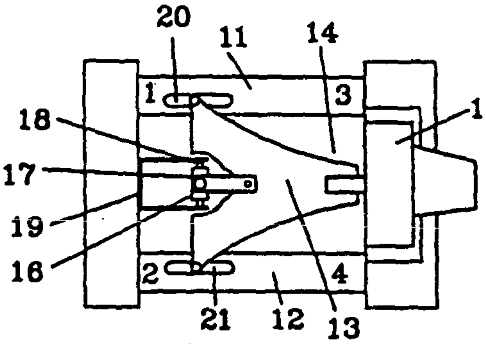


FIG. 4

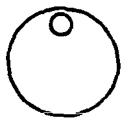


FIG. 4a

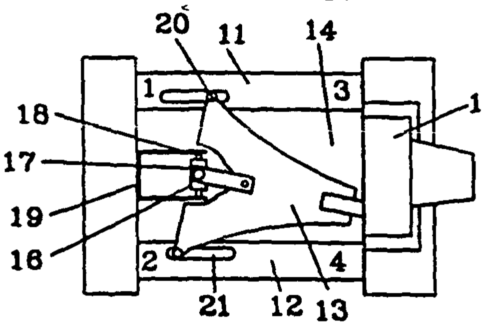


FIG. 5

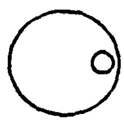


FIG. 5a

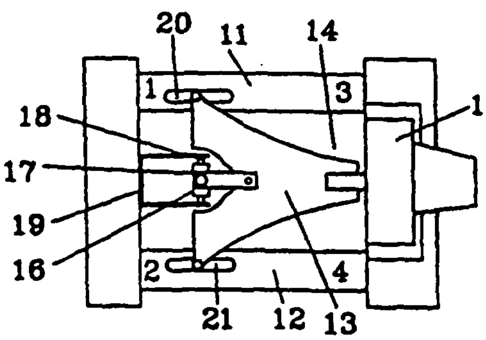


FIG. 6

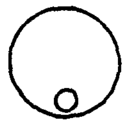


FIG. 6a

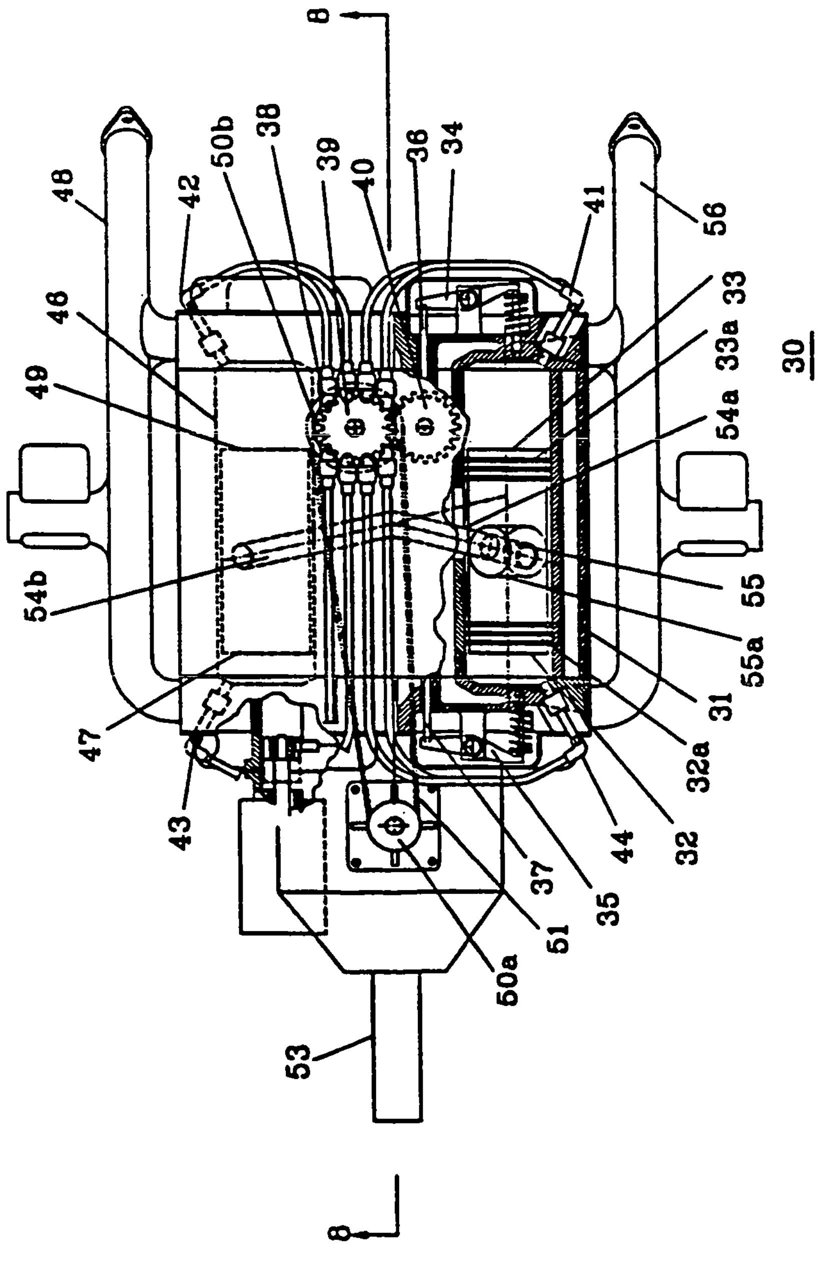
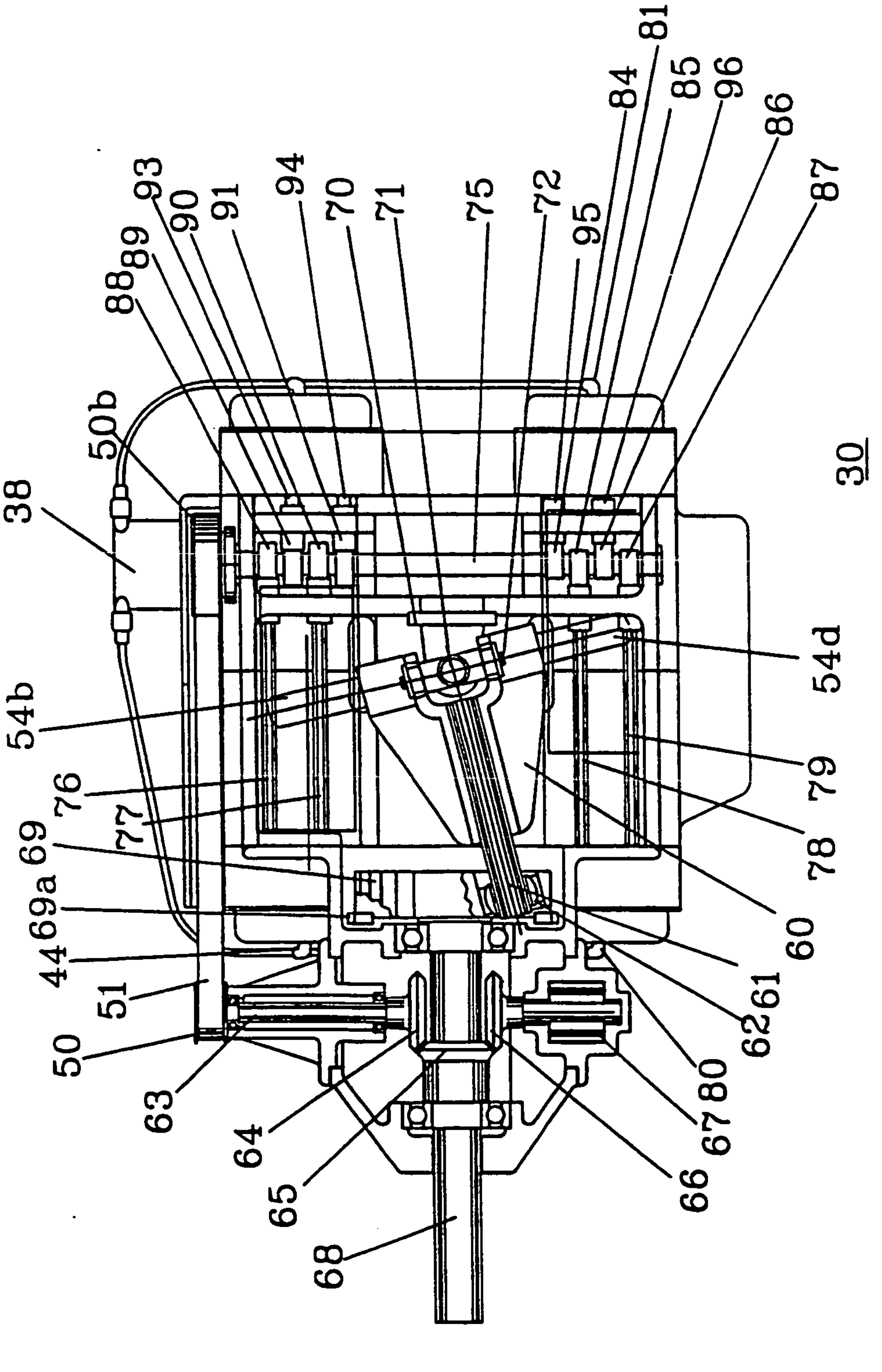

8
8
48
42
50b
38
39
40
36
34
41
56
46
49
54b
47
43
53
50a
51
37
35
44
32
32a
31
55a
55
54a
33a
33
30

FIG. 7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77
69
69a
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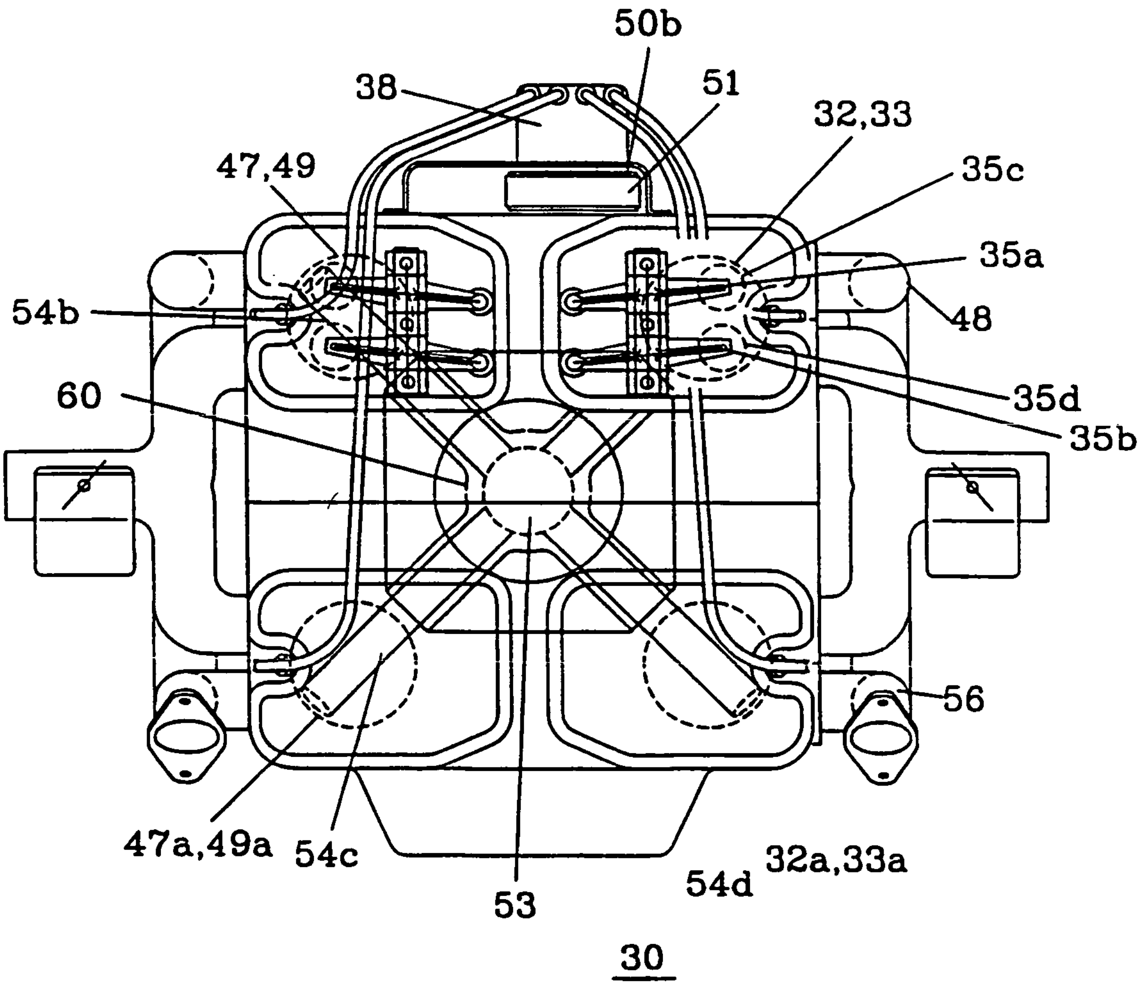
78
79
54d
30

FIG. 8


50b
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51
32,33
47,49
35c
35a
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48
60
35d
35b
56
47a,49a
54c
53
54d
32a,33a
30

FIG. 9

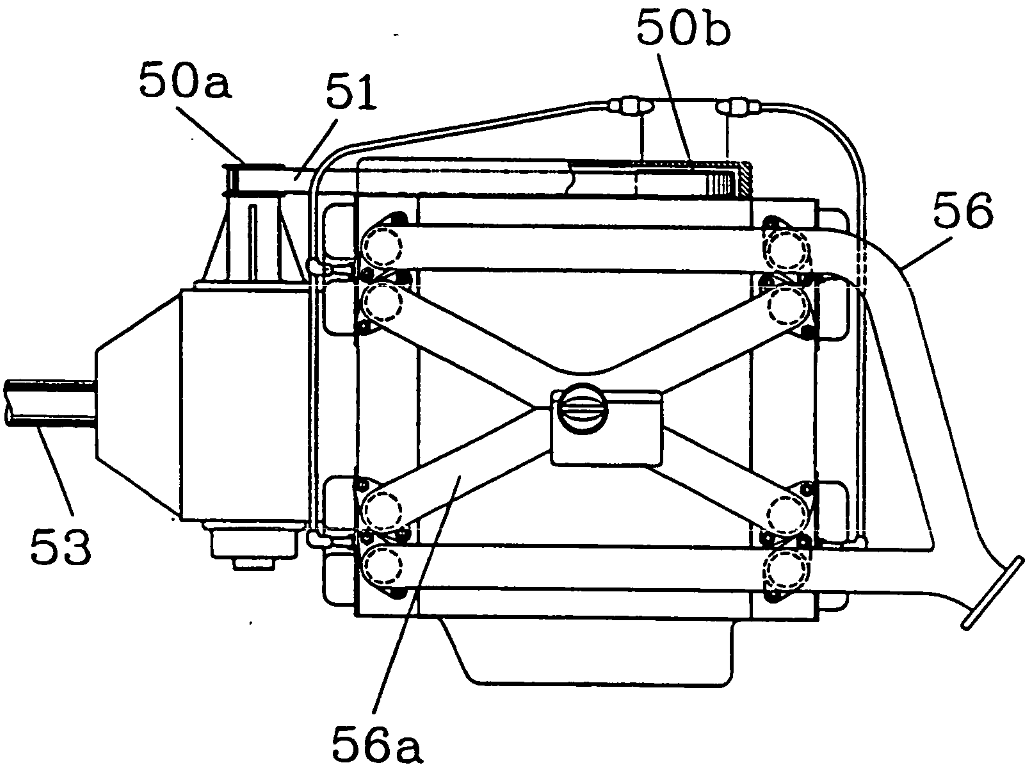


FIG. 10

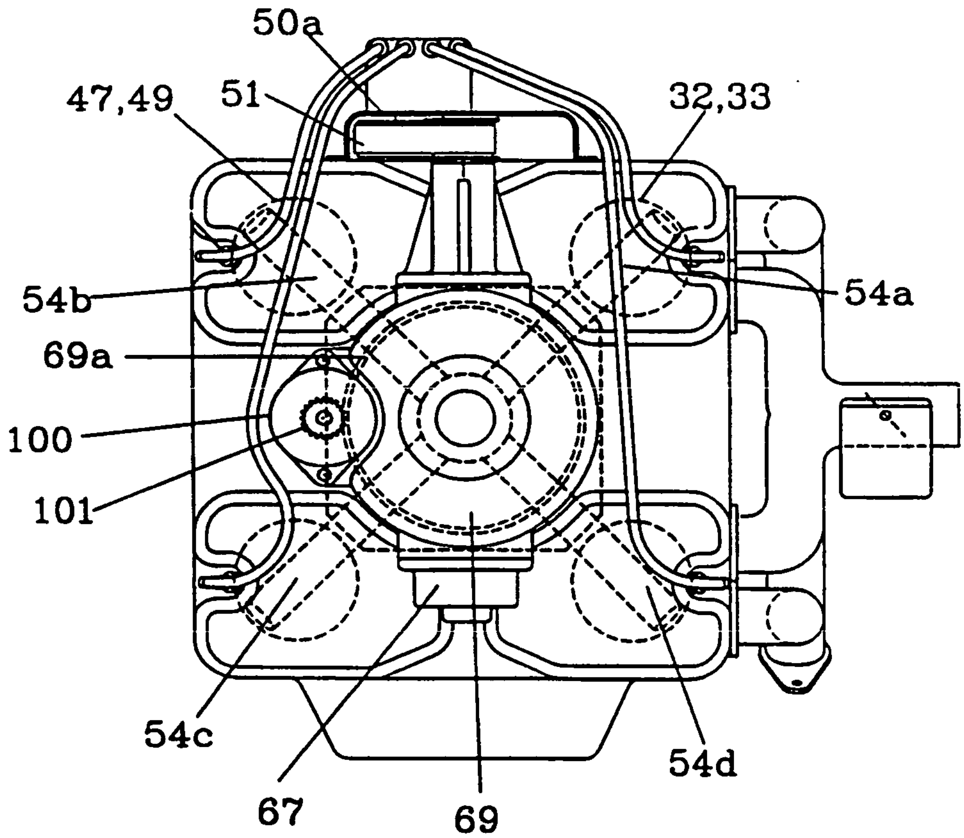


FIG. 11

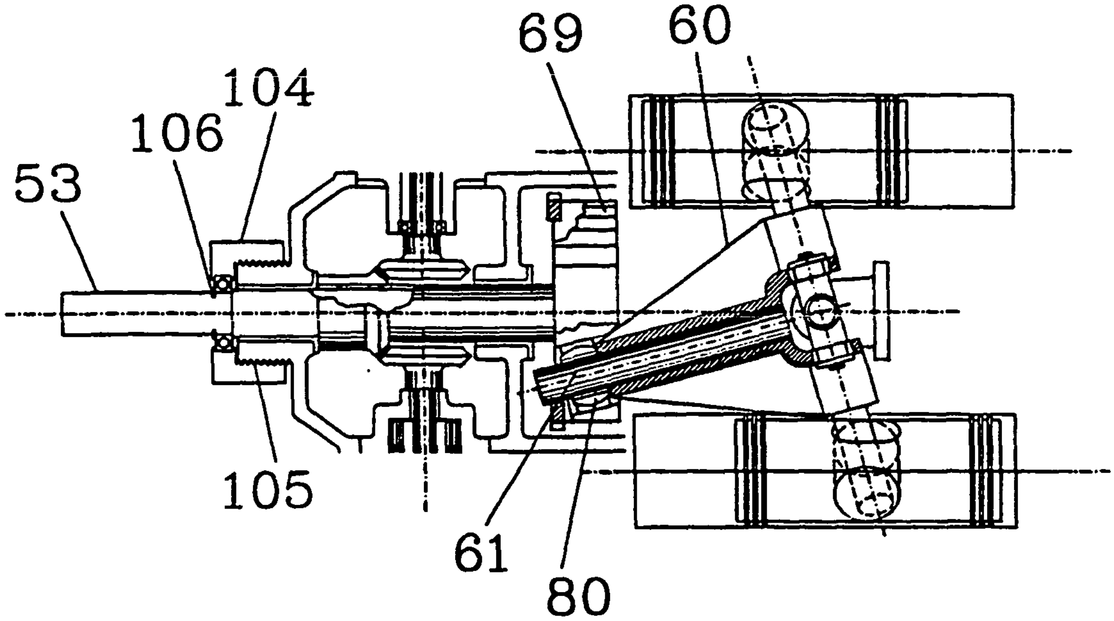


FIG. 12

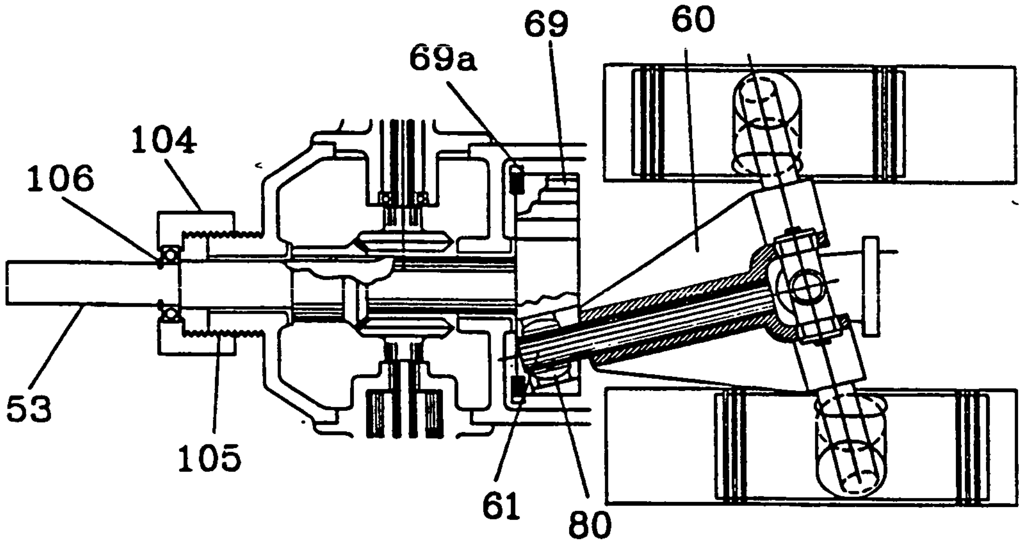


FIG. 13

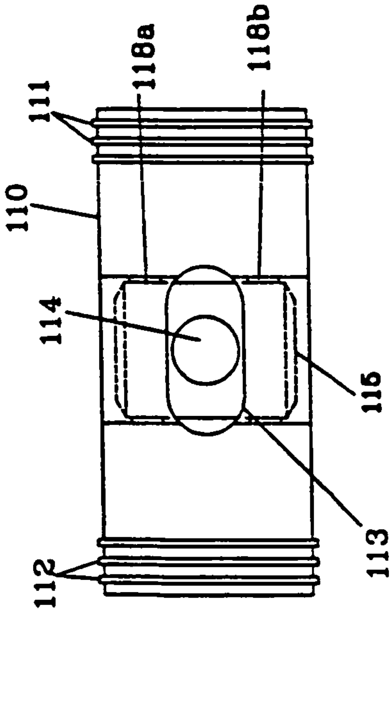


FIG. 14

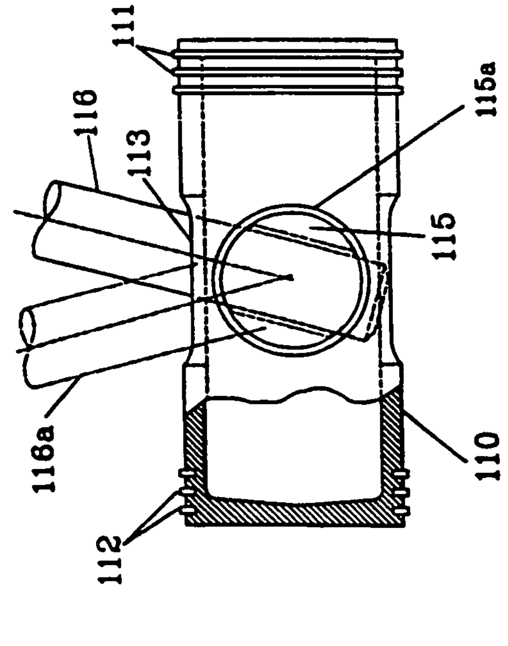


FIG. 15

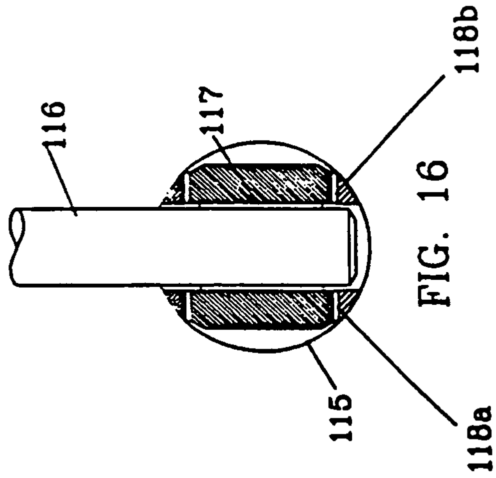


FIG. 16

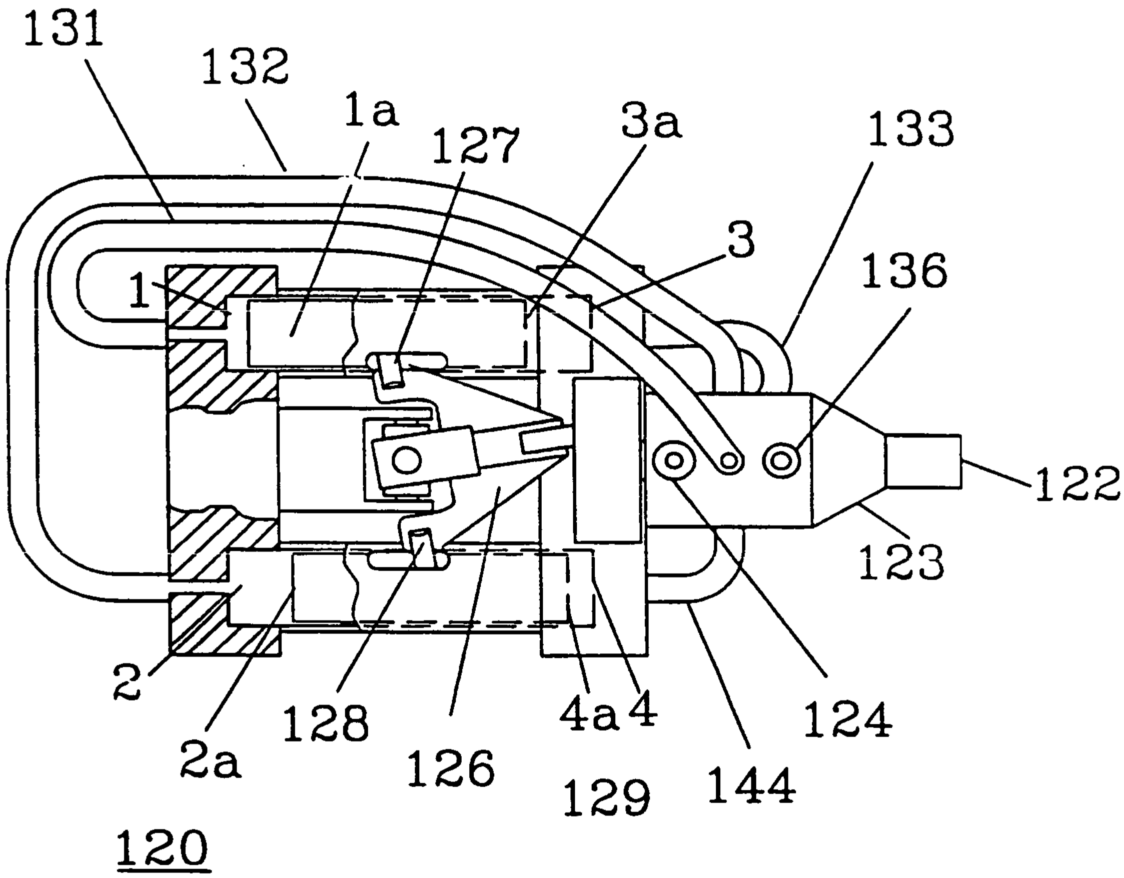

131
132
1a
127
3a
133
3
136
1
122
123
124
2
2a
128
126
4a
4
129
144
120

FIG. 17

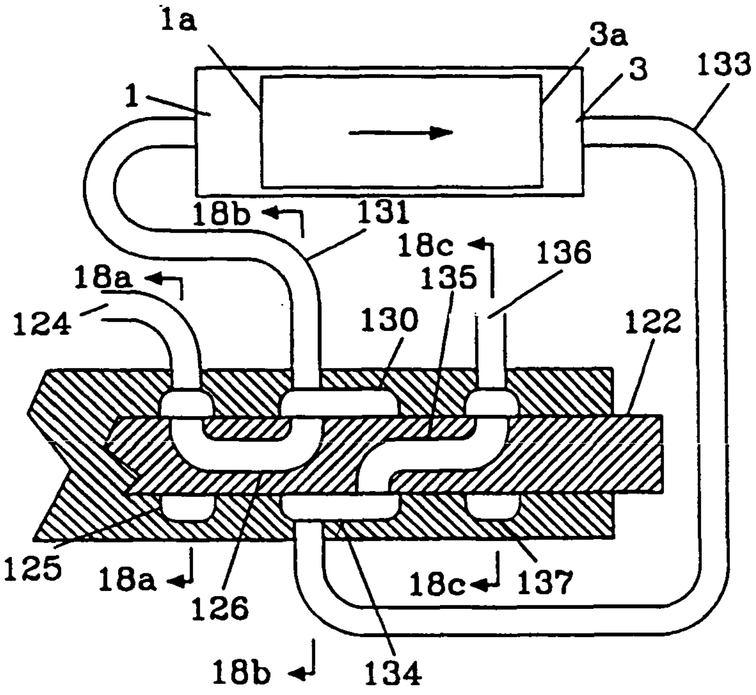


FIG. 18

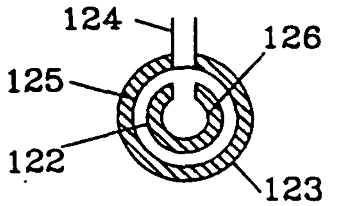


FIG. 18a

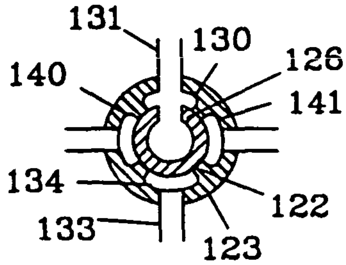


FIG. 18b

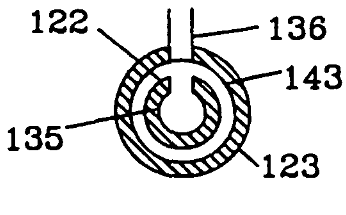


FIG. 18c

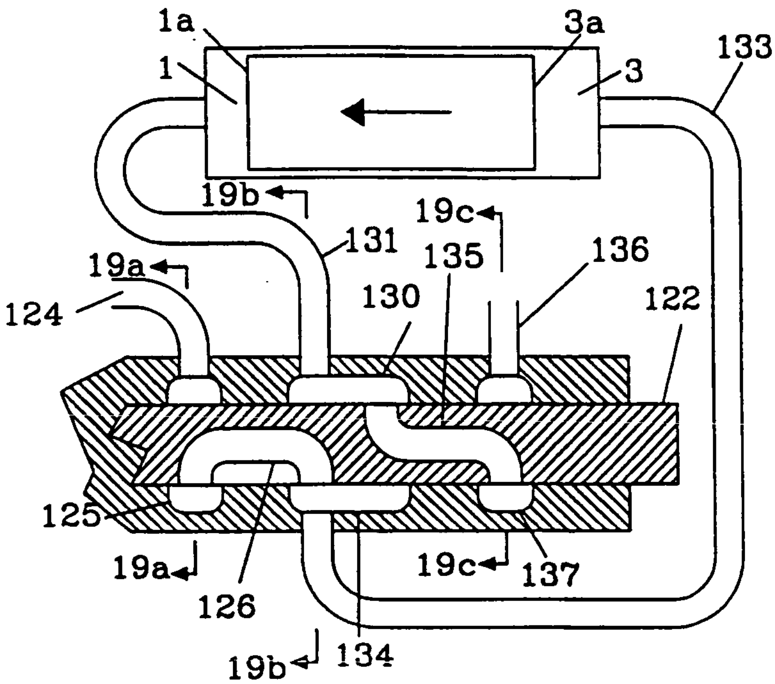


FIG. 19

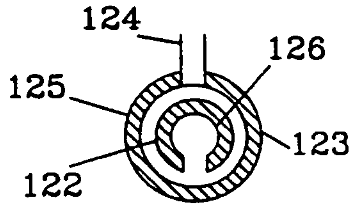


FIG. 19a

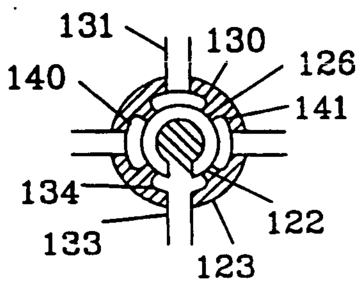


FIG. 19b

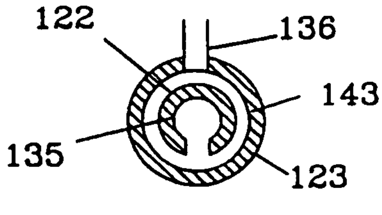


FIG. 19c

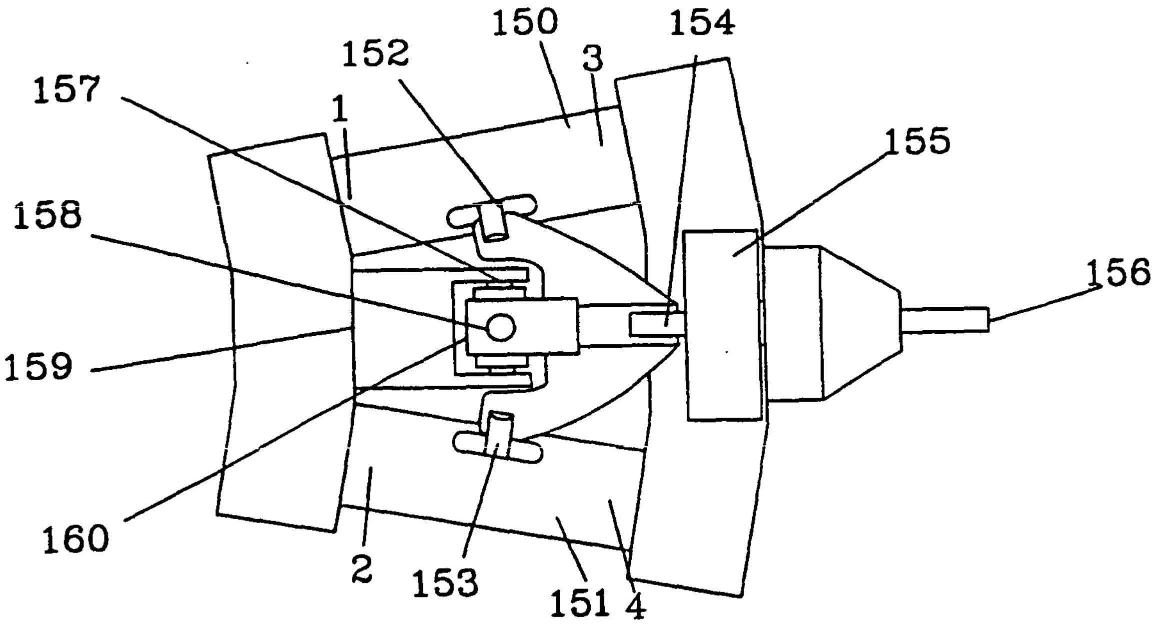


FIG. 20

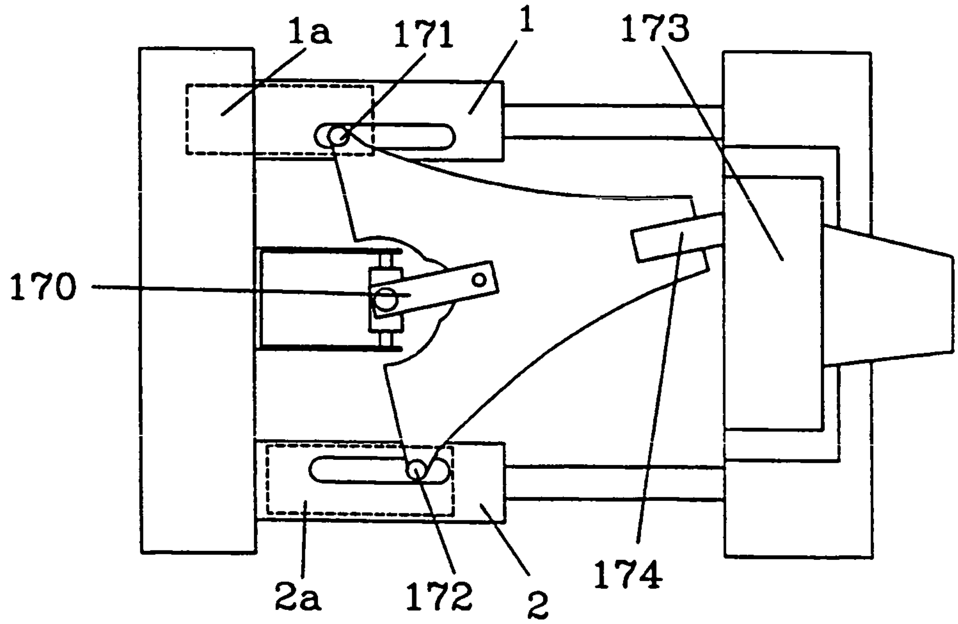


FIG. 21

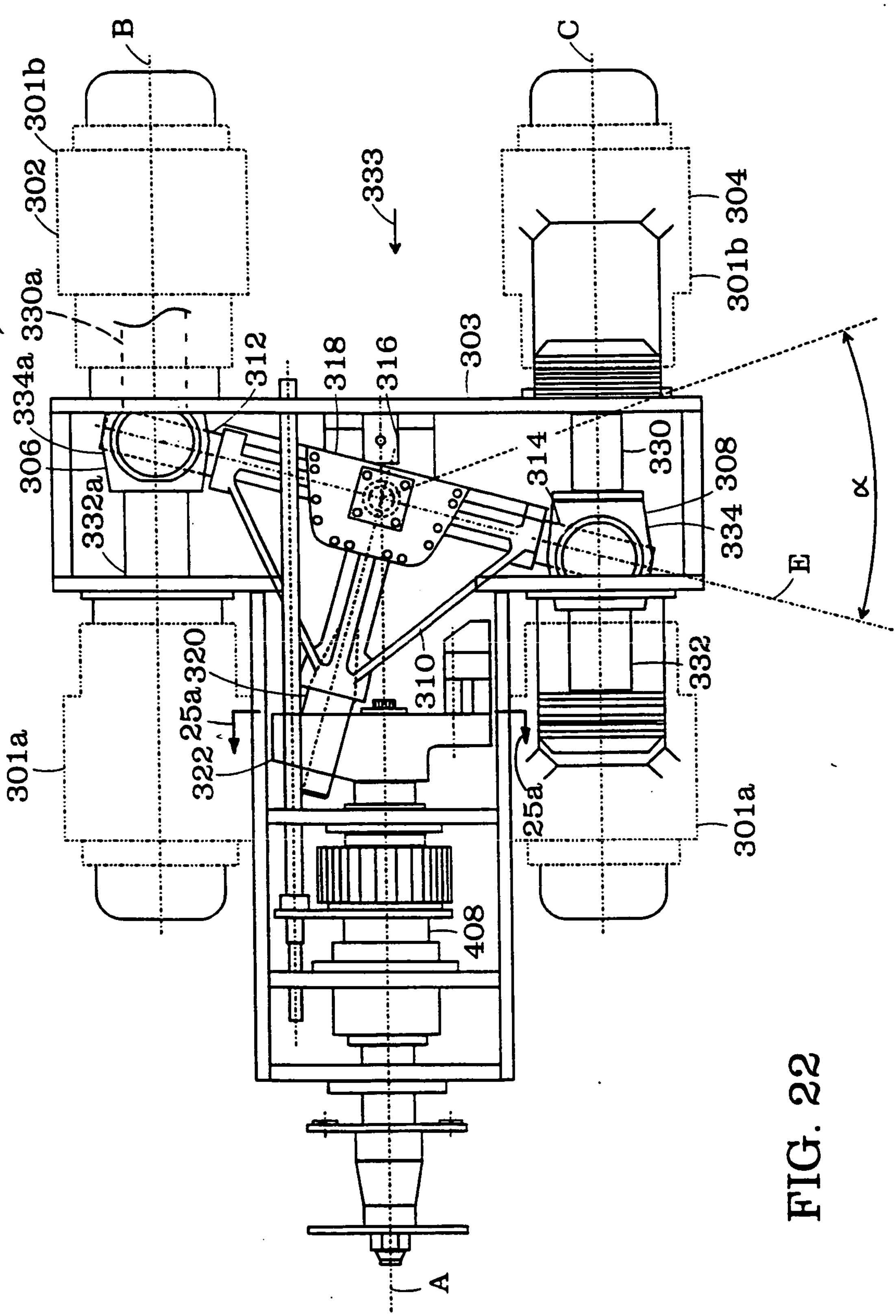

B
C
300
301b
302
330a
334a
306
332a
312
318
316
303
333
304
330
308
314
334
α
E
332
320
25a
322
310
301a
408
A

FIG. 22

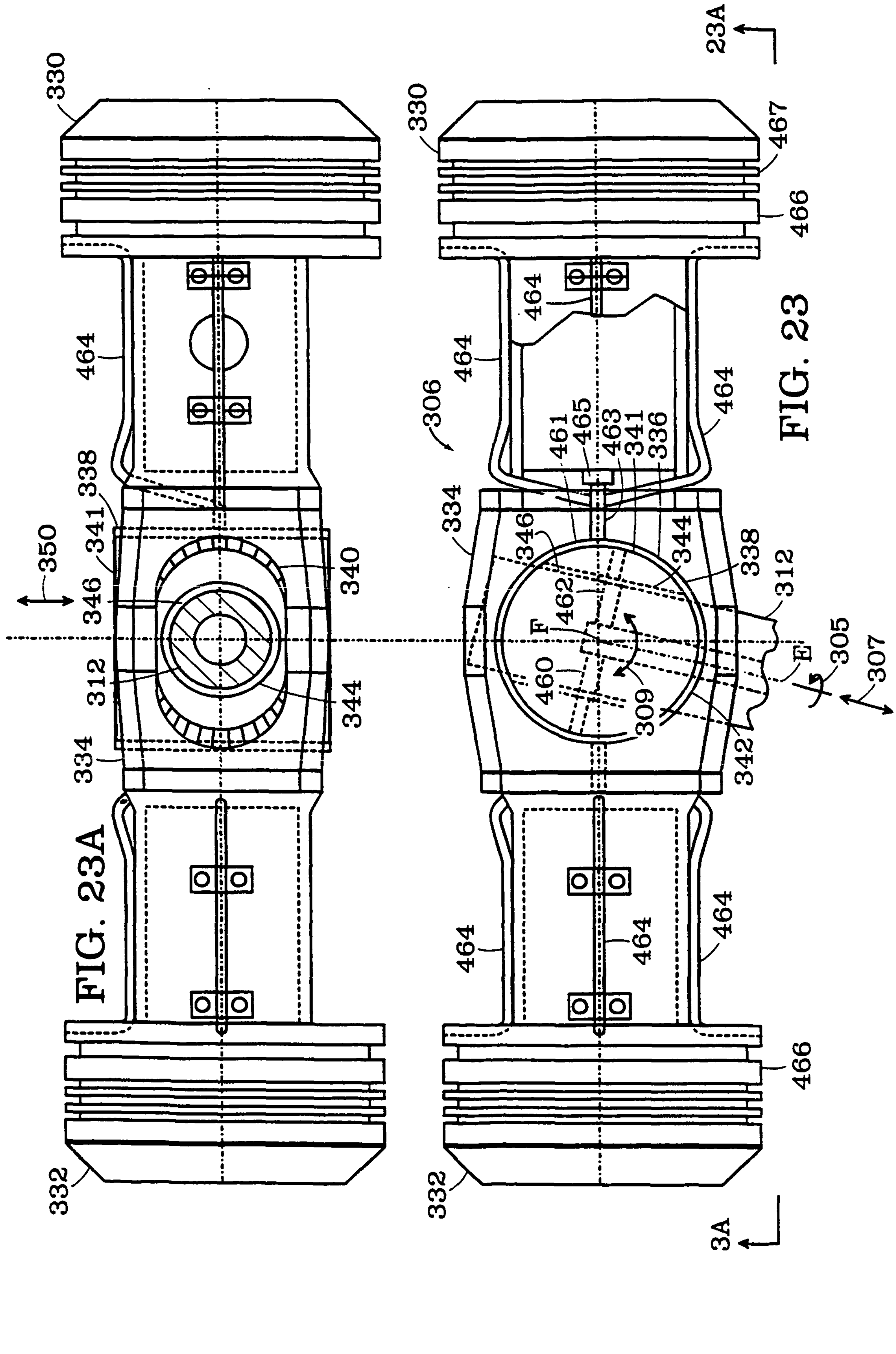


FIG. 23A

FIG. 23

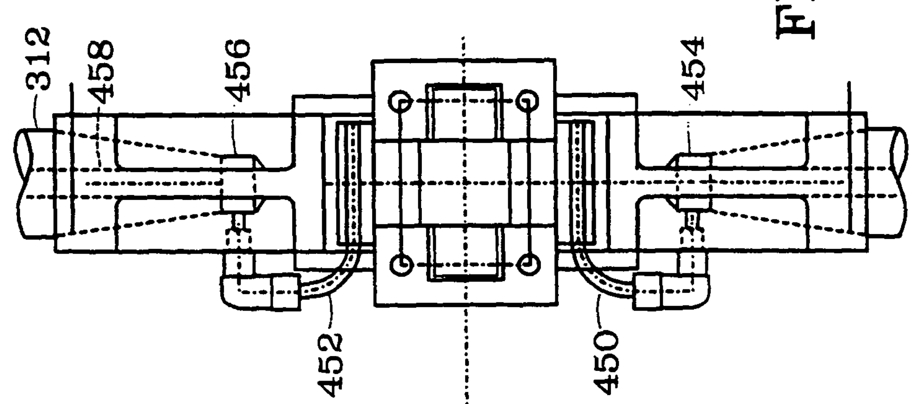


FIG. 27

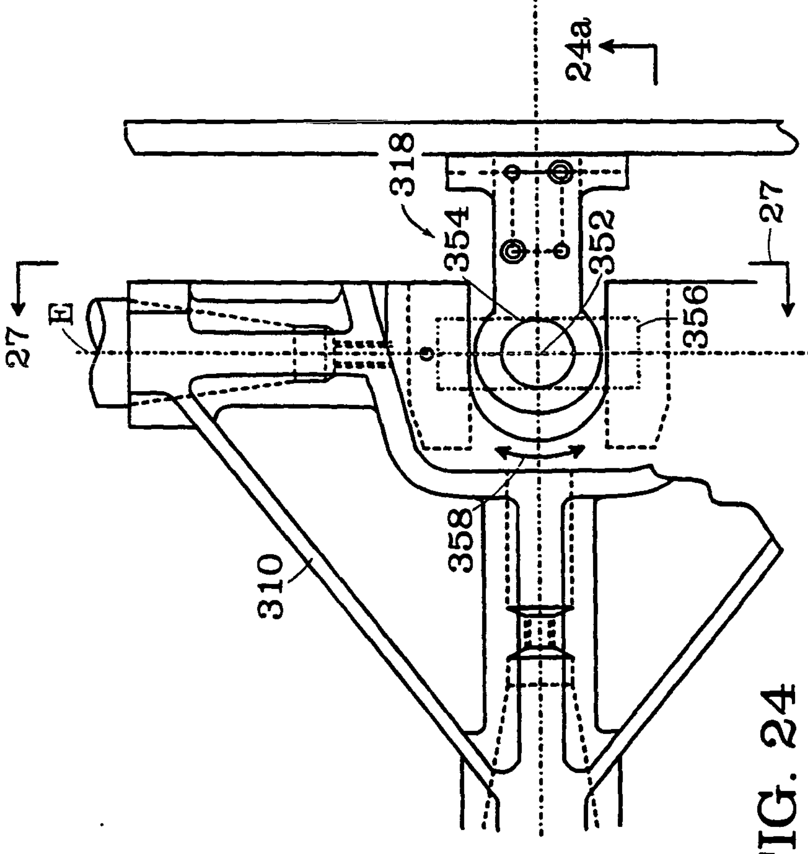


FIG. 24

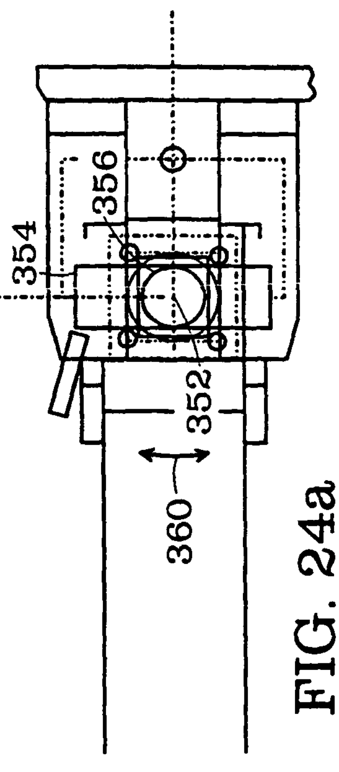


FIG. 24a

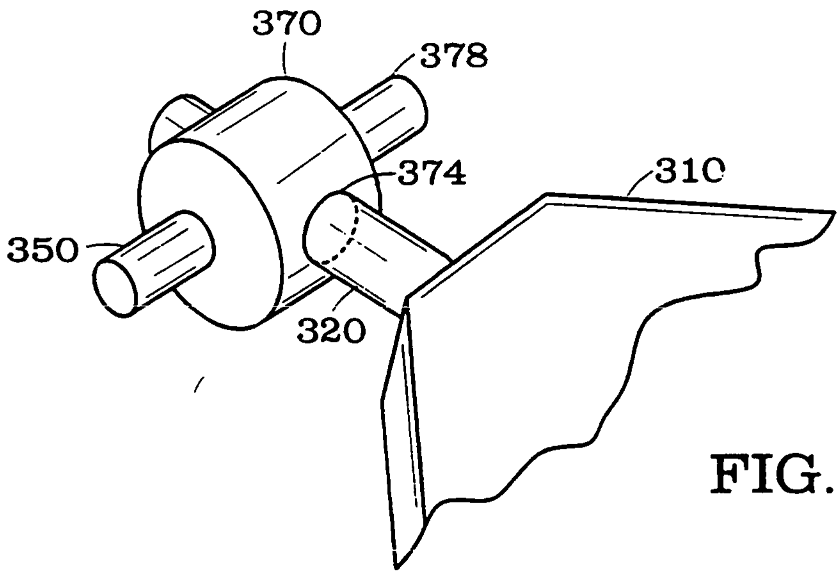


FIG. 25

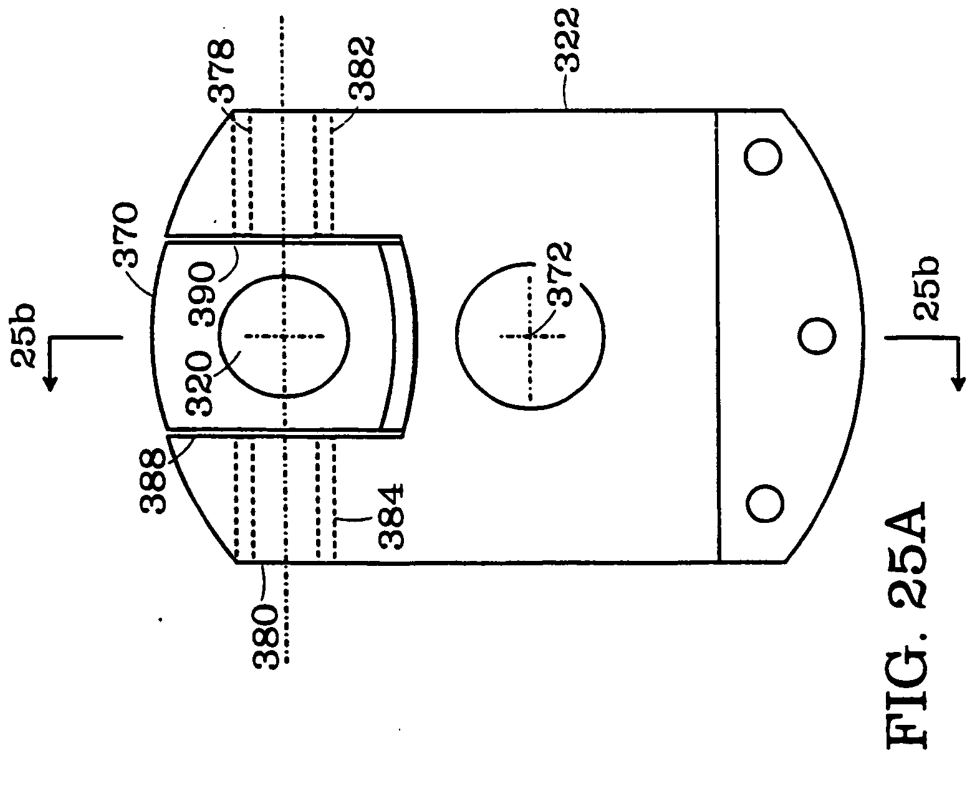


FIG. 25A

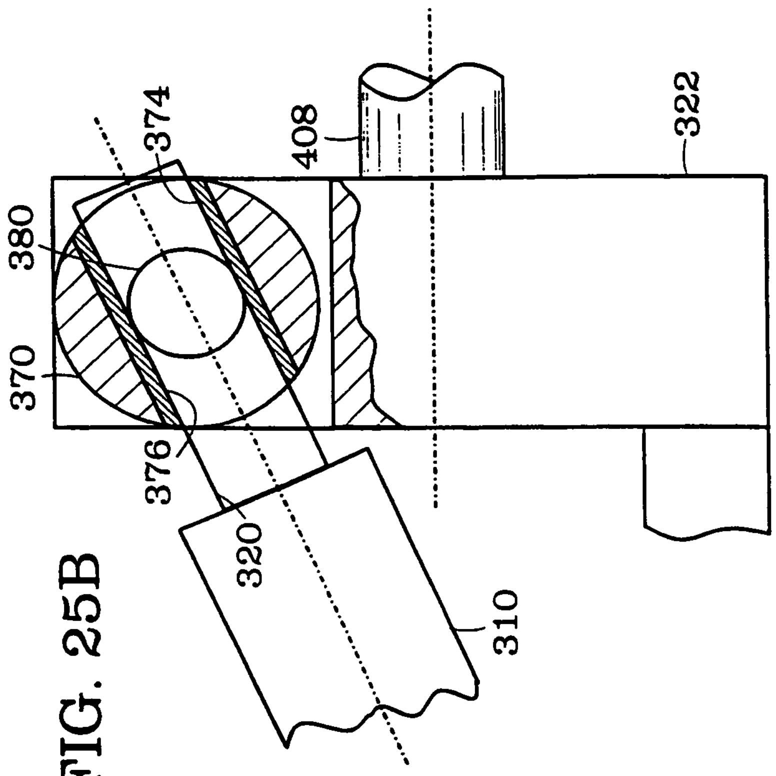


FIG. 25B

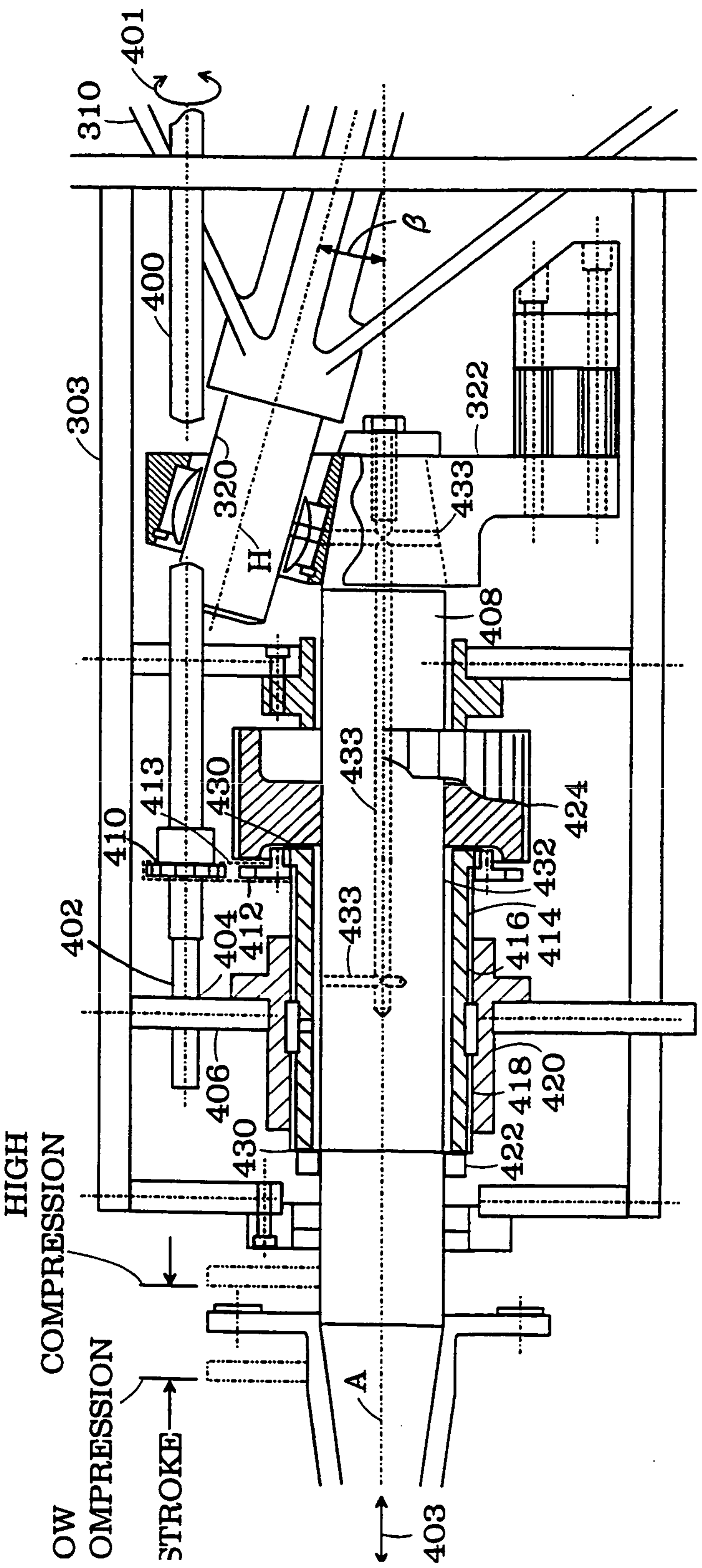

401
310
400
303
β
320
H
322
433
408
433
424
413
430
410
433
432
402
404
412
416
414
406
418
420
430
422
HIGH
COMPRESSION
OW
OMPRESSION
STROKE
A
403

FIG. 26

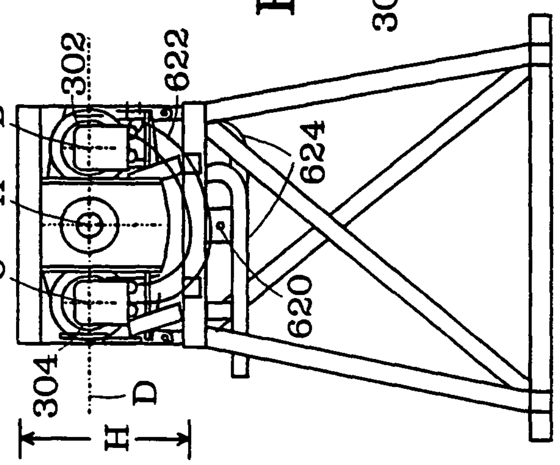


FIG. 28a

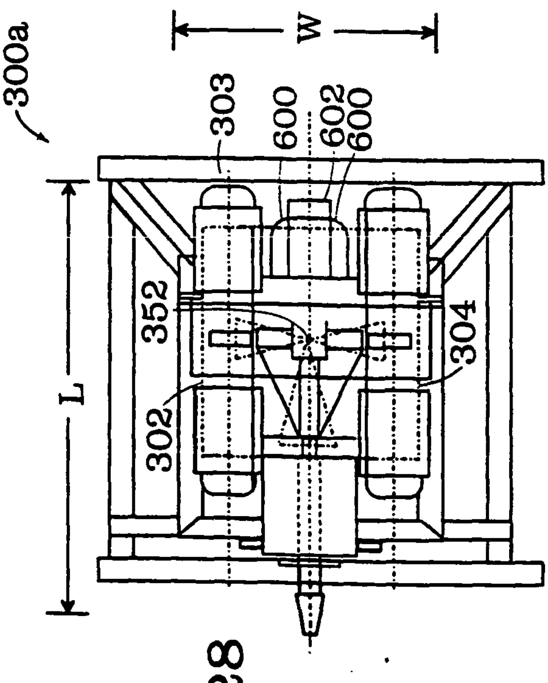


FIG. 28

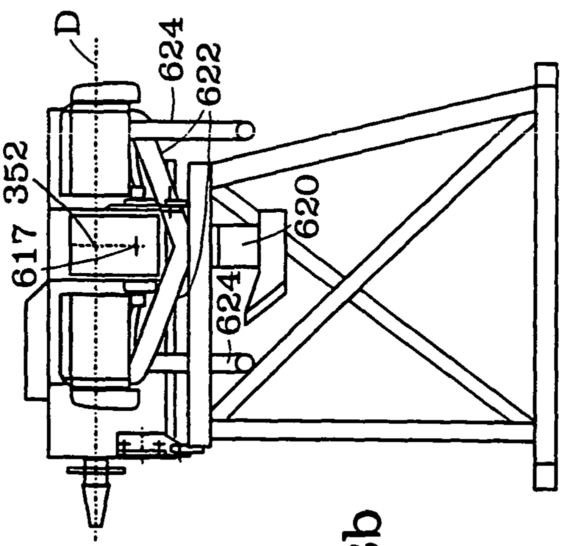
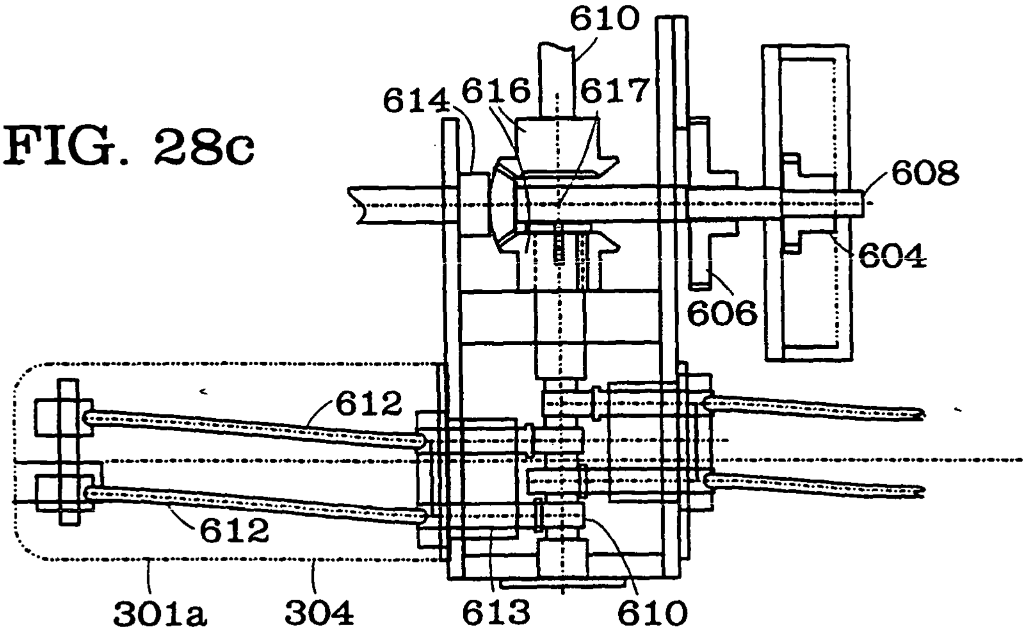


FIG. 28b

FIG. 28c



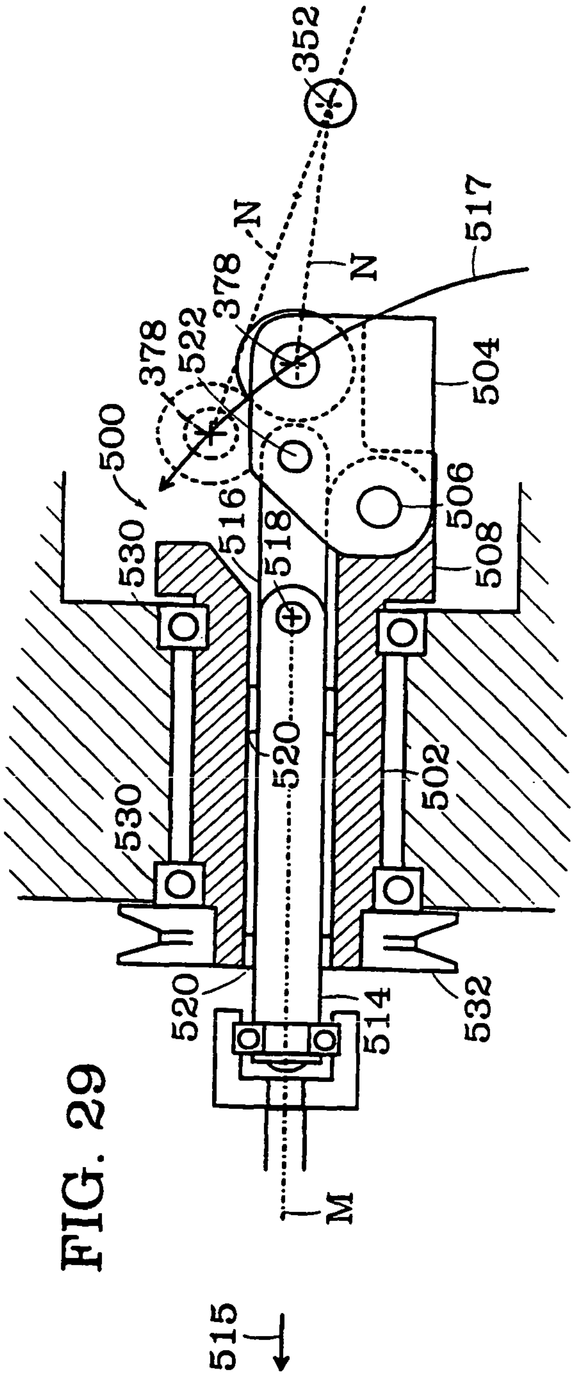


FIG. 29

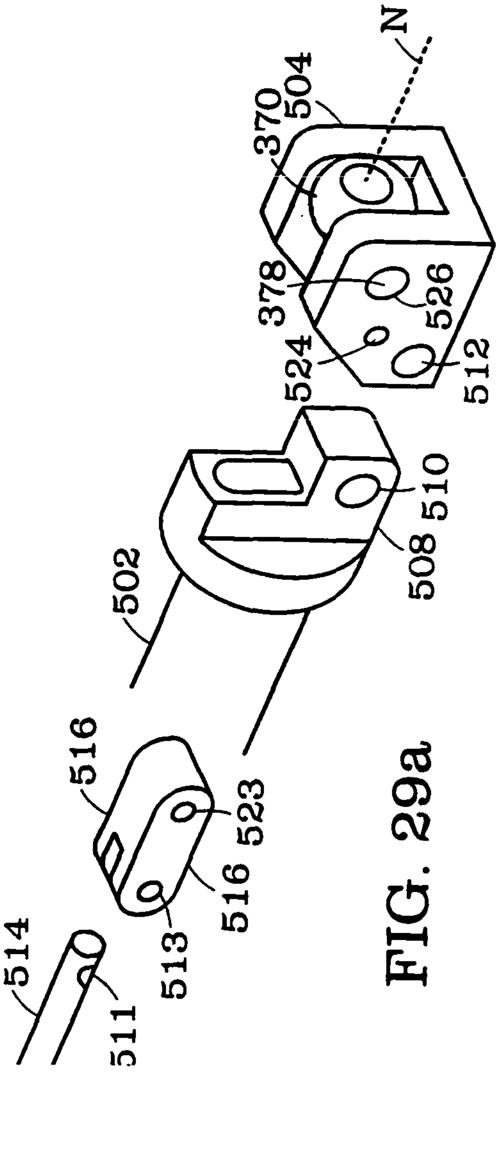


FIG. 29a

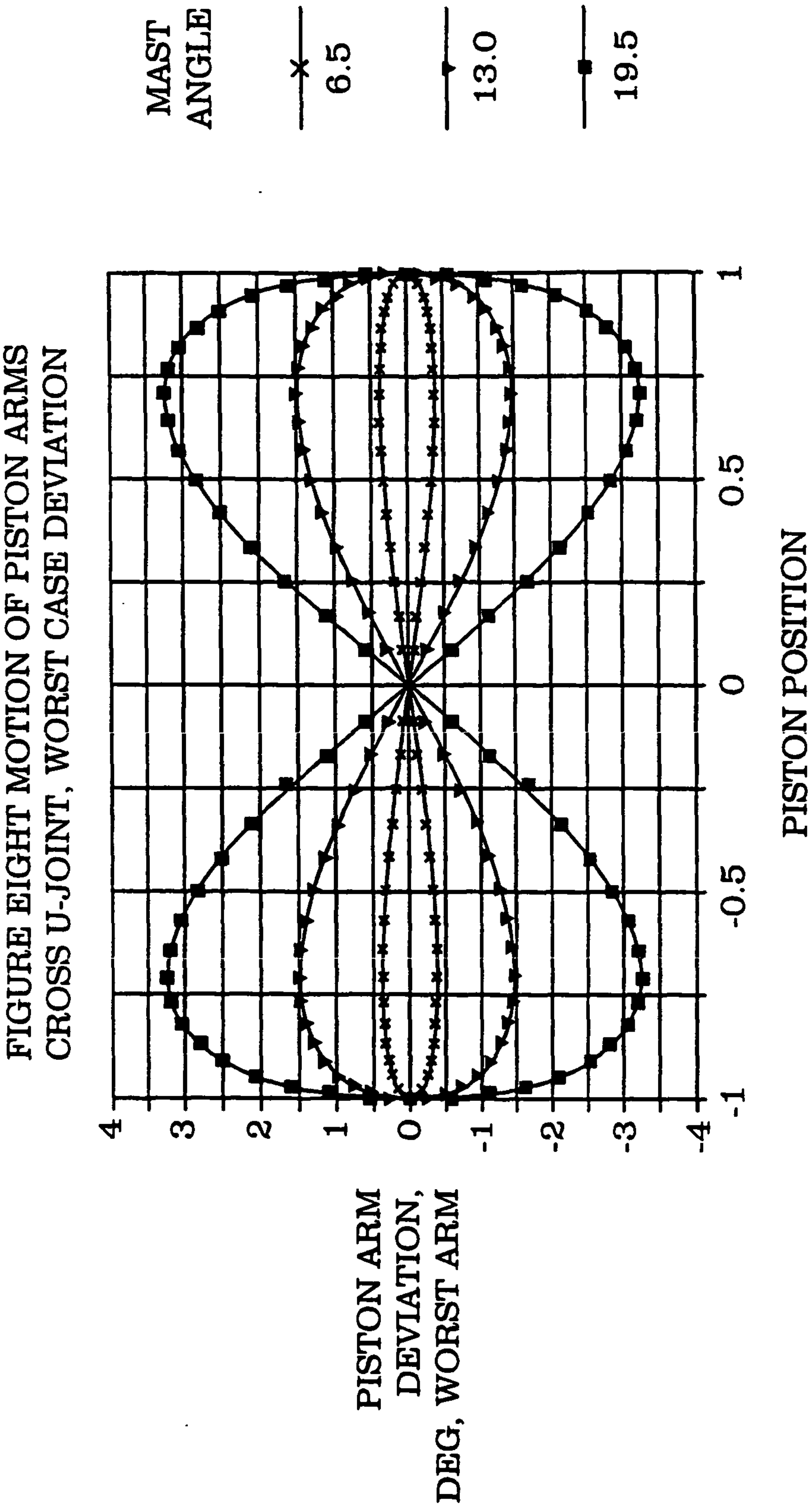


FIGURE EIGHT MOTION OF PISTON ARMS
CROSS U-JOINT, WORST CASE DEVIATION
MAST ANGLE
6.5
13.0
19.5
PISTON ARM DEVIATION, DEG, WORST ARM
4
3
2
1
0
-1
-2
-3
-4
-1
-0.5
0
0.5
1
PISTON POSITION

FIG. 30

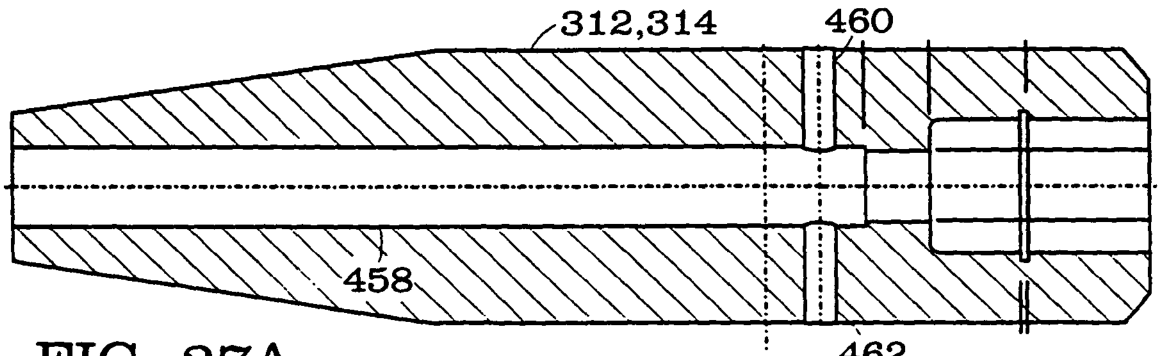


FIG. 27A

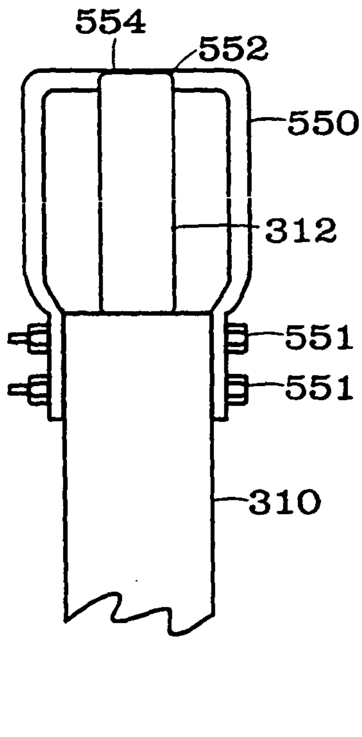


FIG. 31

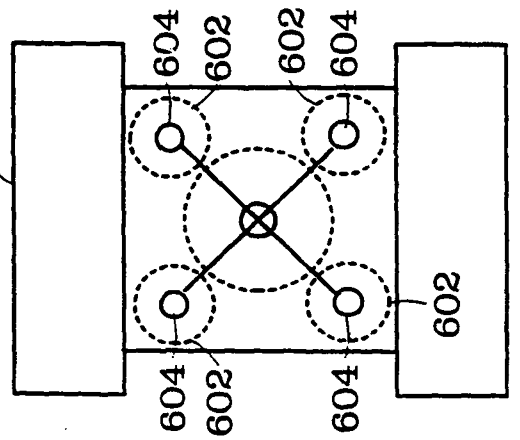


FIG. 32a

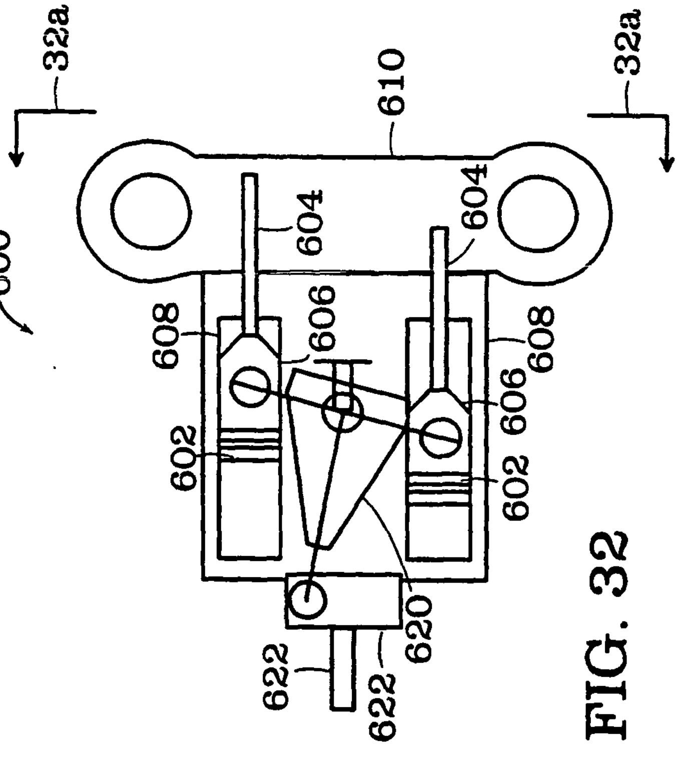


FIG. 32

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 5535709 A **[0003]**
- US 4011842 A **[0004]**
- US 5007385 A **[0005]**