United States Patent [19]

Manor

[11] **3,847,058**

[45] **Nov. 12, 1974**

[54] **VALVE MECHANISM FOR AN AIR OPERATED RECIPROCATING ENGINE**

[76] Inventor: **Robert T. Manor,** Box 95, Salmonia, Ind. 47381

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[21] Appl. No.: **341,318**

[52] **U.S. Cl.** **91/413,** 91/467, 137/596

[51] **Int. Cl.** **F15b 11/00**

[58] **Field of Search** 91/467, 413; 137/596

[56] **References Cited**

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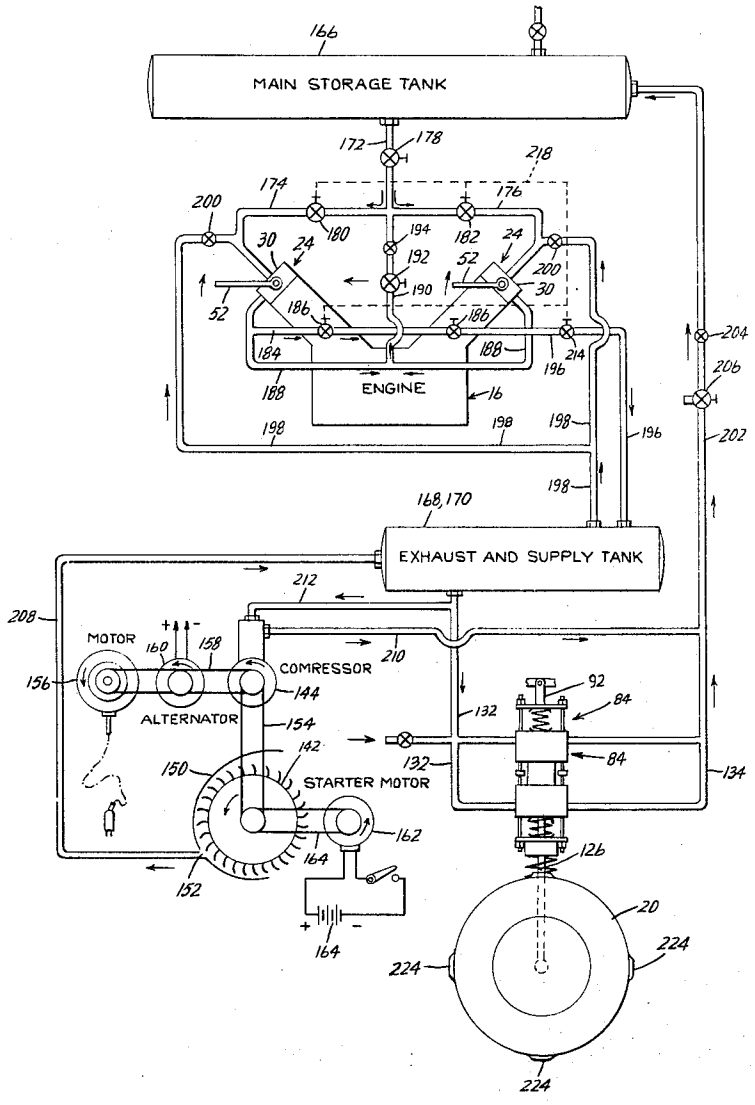
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Primary Examiner—Edgar W. Geoghegan
Assistant Examiner—William F. Woods
Attorney, Agent, or Firm—Gust & Irish

[57] **ABSTRACT**

For use in an air operated, reciprocating engine, a valve mechanism for controlling mode of engine operation as either a prime mover or compressor as well as direction of operation. The valve mechanism includes a spool valve rotatably mounted inside a sleeve valve, both having a plurality of passages alternatively registerable for determining mode of operation. The sleeve valve is rotatably mounted in a head block having registerable passages communicating with the pistons.

7 Claims, 19 Drawing Figures



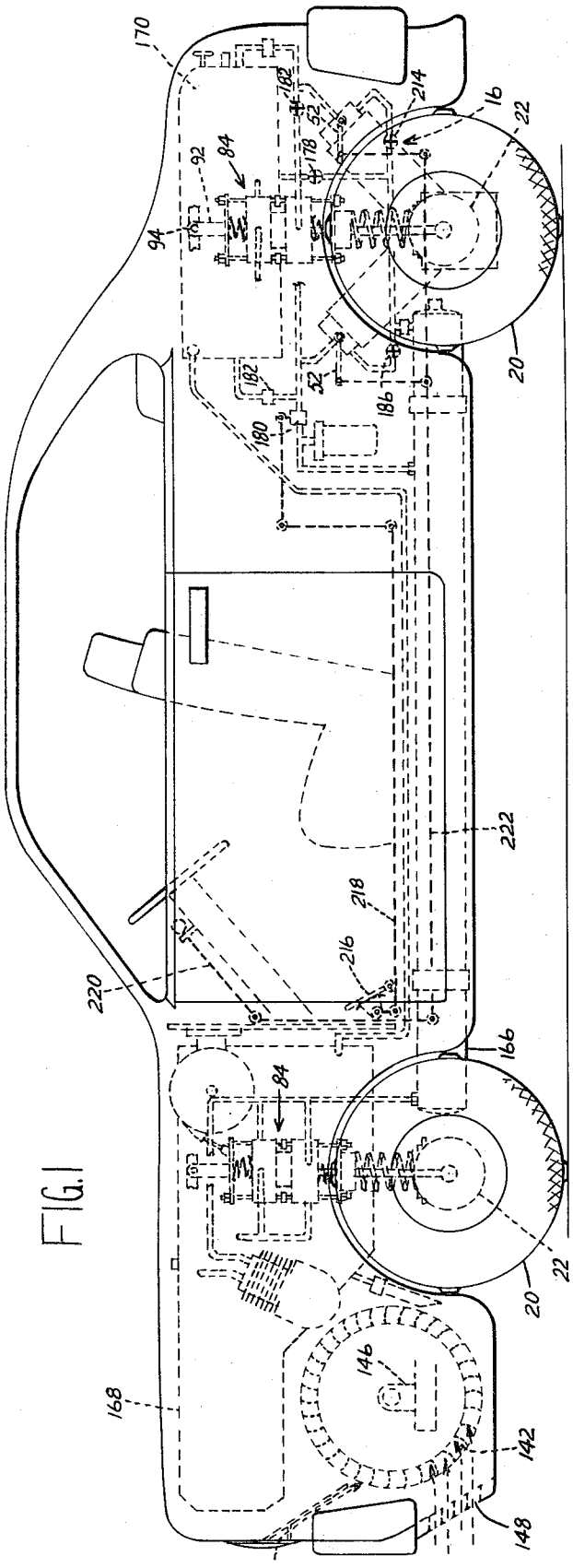


FIG. 1

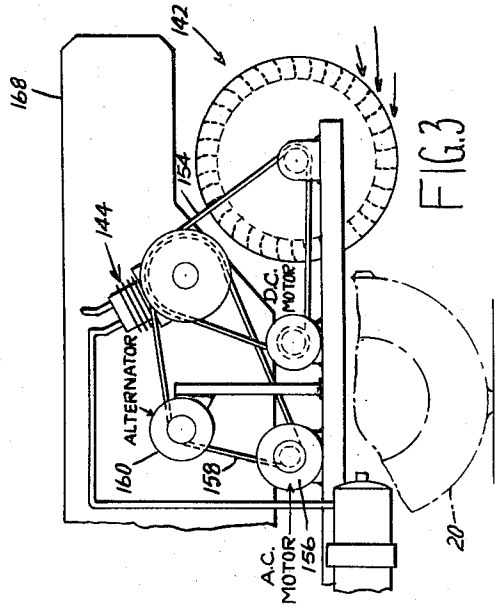


FIG. 3

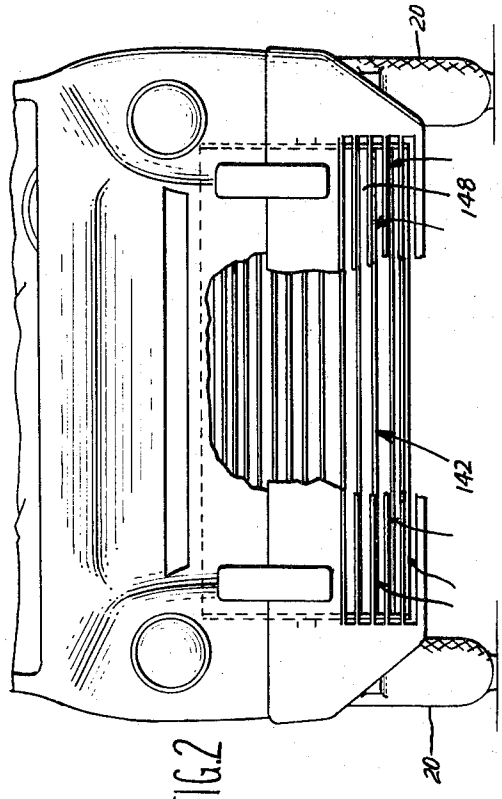


FIG. 2

FIG. 4

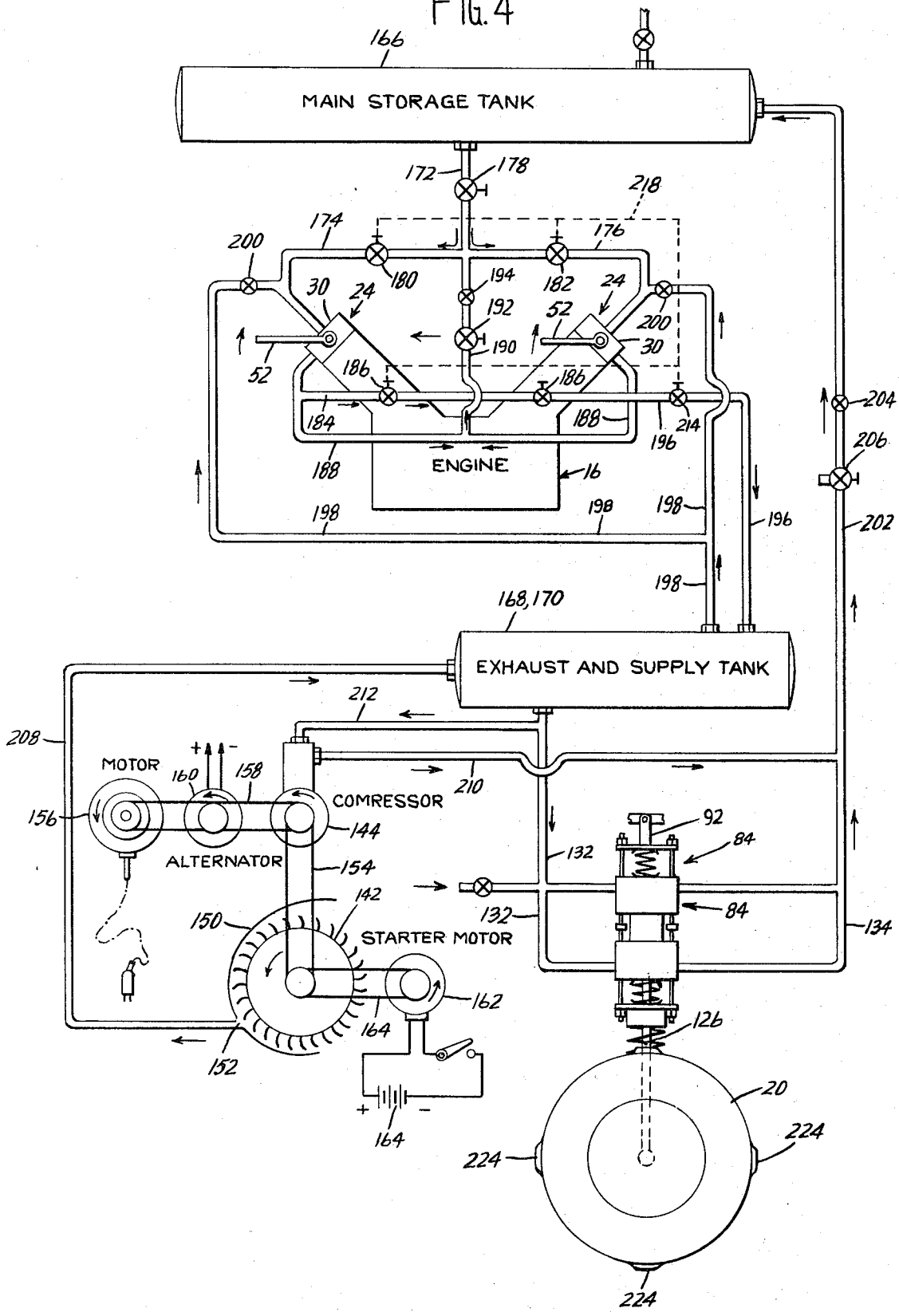

MAIN STORAGE TANK
166
172
178
218
174
176
200
180
194
182
24
30
192
52
190
186
184
188
214
196
ENGINE
16
198
204
206
202
168,170
EXHAUST AND SUPPLY TANK
212
208
MOTOR
160
158
210
COMRESSOR
156
144
ALTERNATOR
154
92
84
132
142
150
STARTER MOTOR
162
164
152
126
20
224

FIG.5

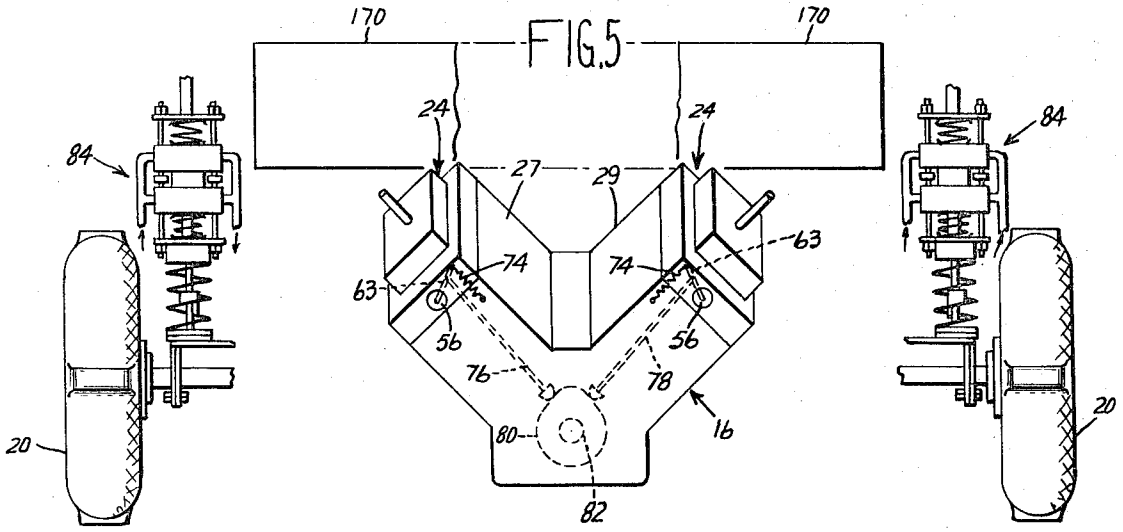
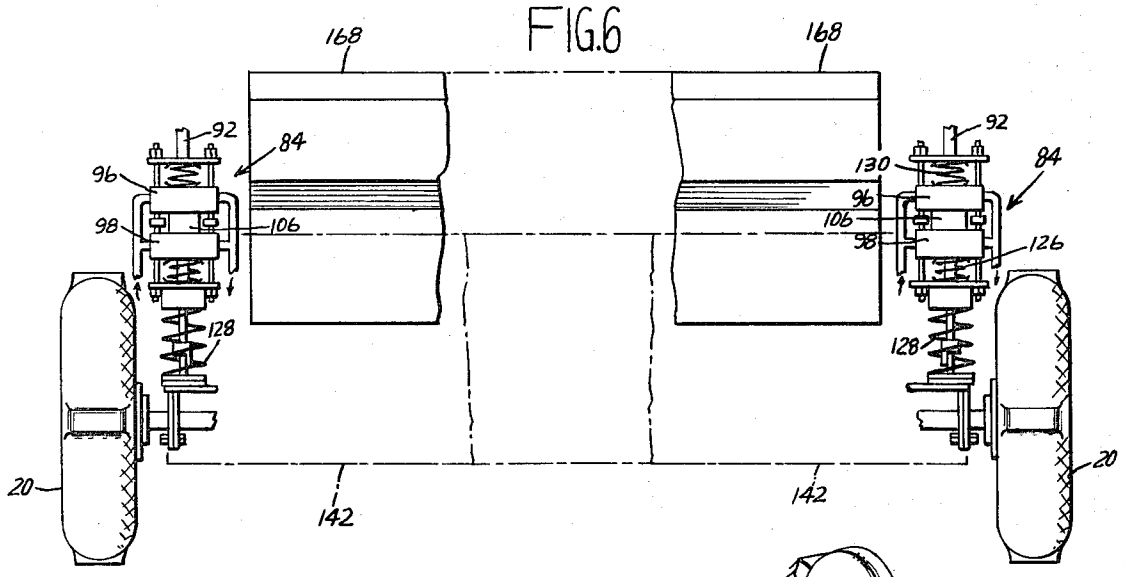


FIG.6



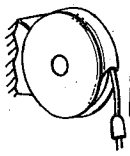


FIG.8

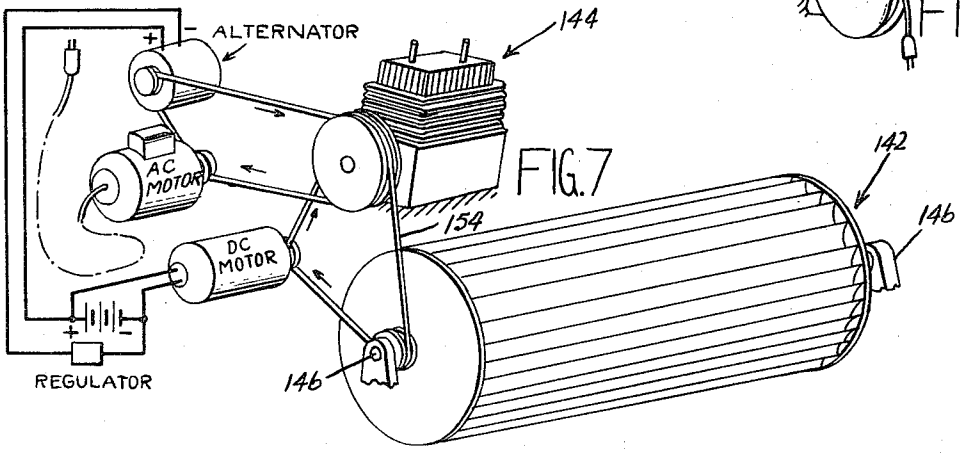


FIG.7

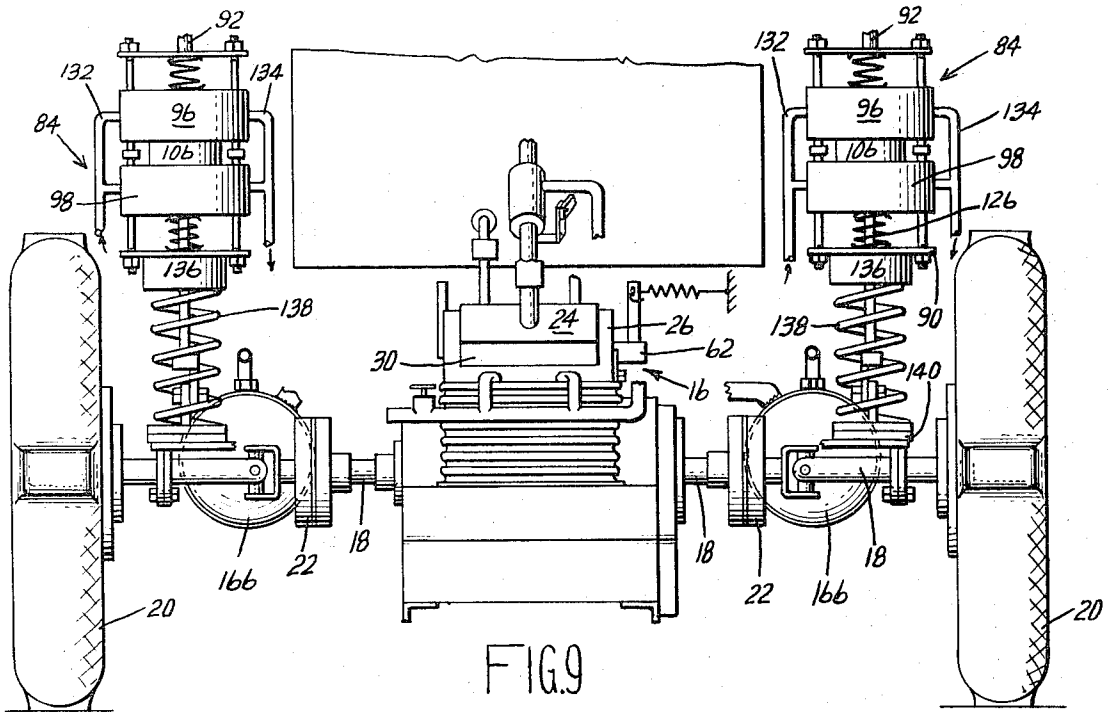

92
132
134
84
96
106
98
136
138
24
26
30
62
16
18
22
166
20
140
90
126

FIG.9

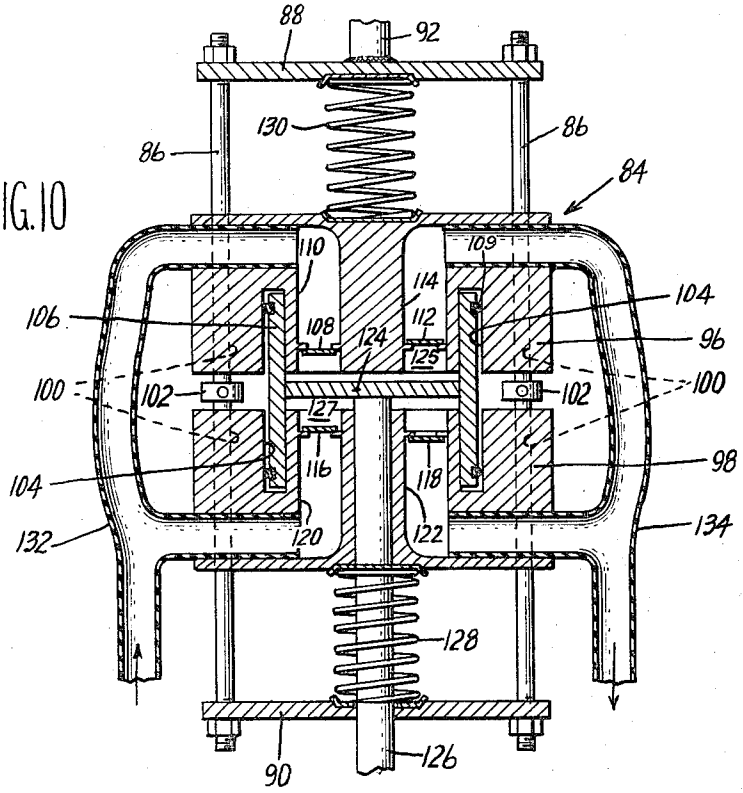

88
92
130
86
84
110
109
114
112
104
106
108
124
96
125
100
102
127
116
118
98
120
122
134
132
128
90
126

FIG.10

CYL #2 FORWARD EXHAUST

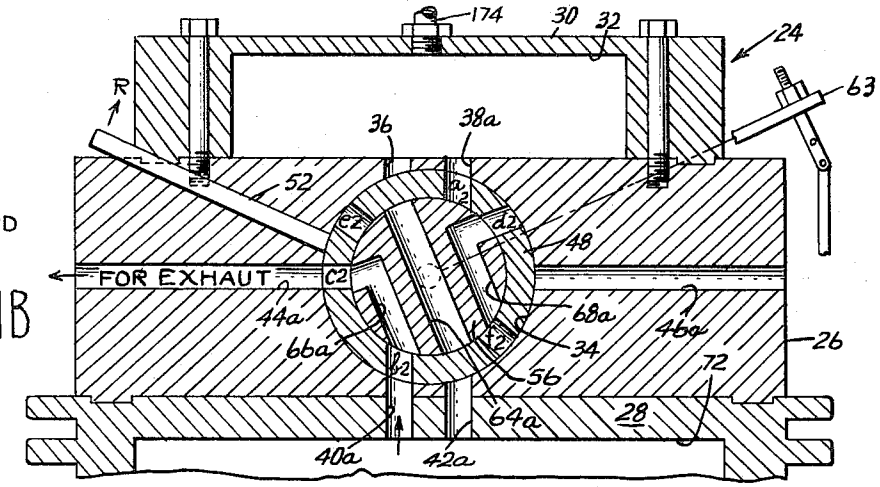


FIG. 11B

CYL #1 INTAKE FORWARD

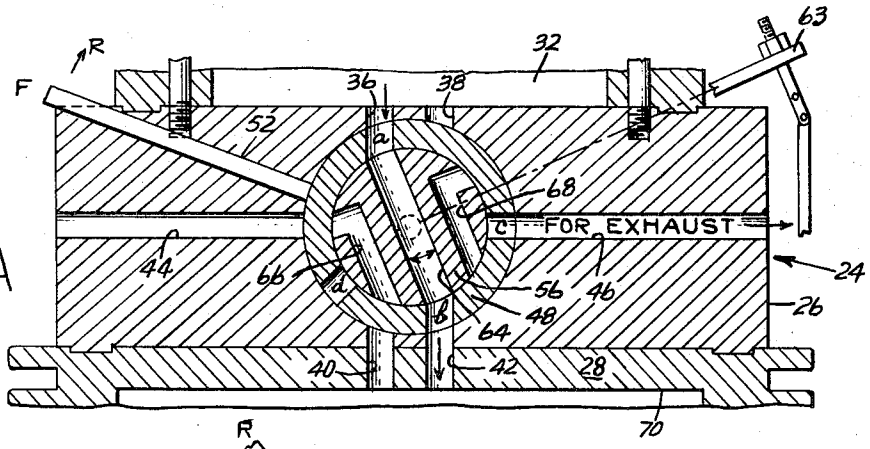


FIG. 11A

CYL #2 EXHAUST REVERSE

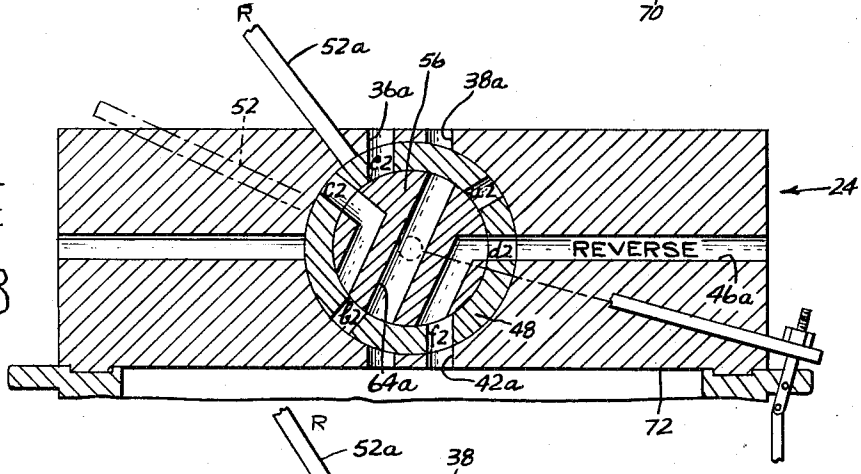


FIG. 12B

CYL #1 INTAKE REVERSE

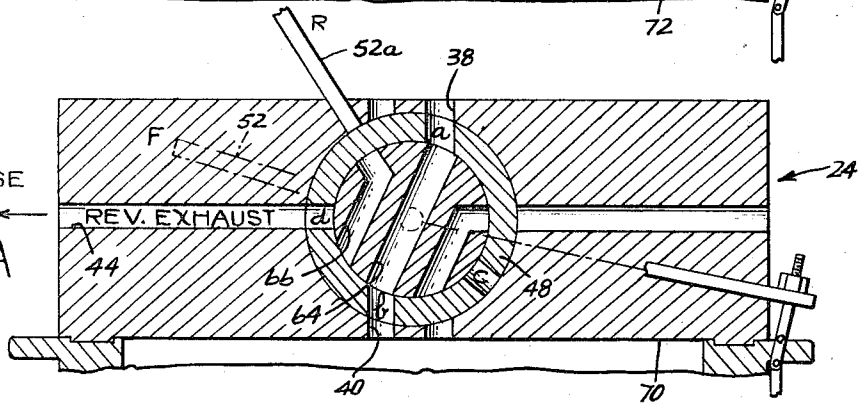


FIG. 12A

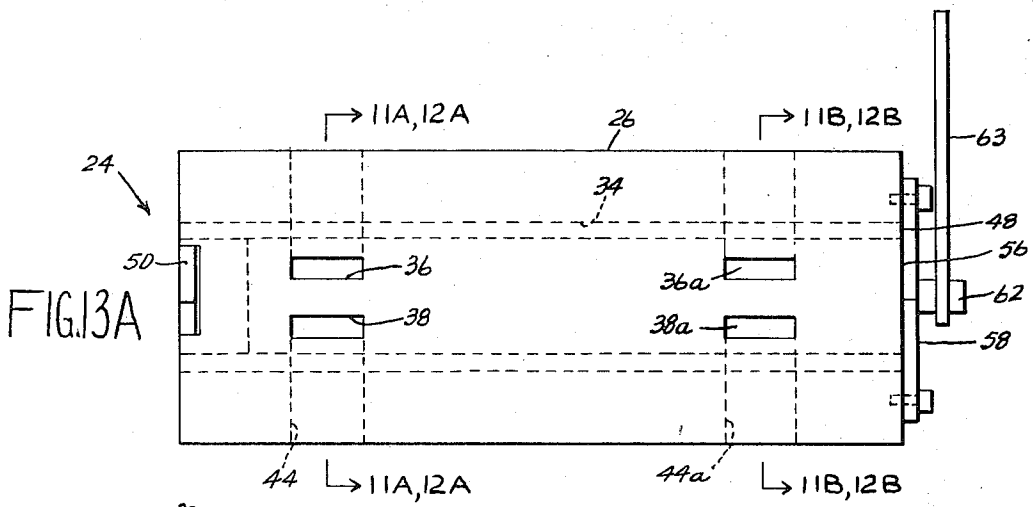


FIG.13A

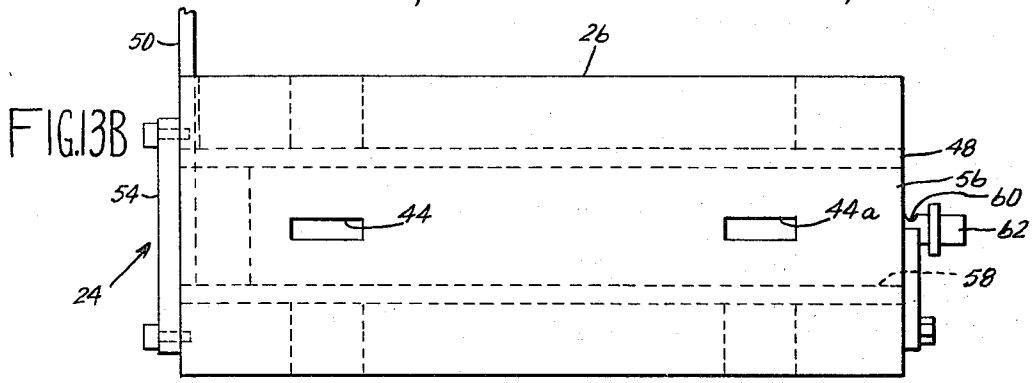


FIG.13B

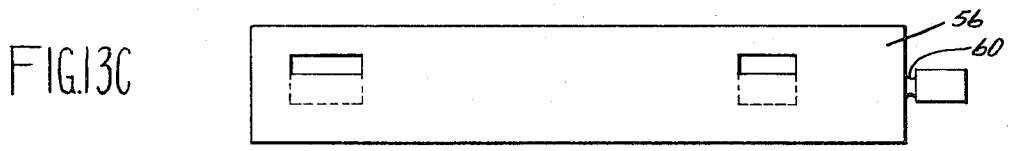


FIG.13C

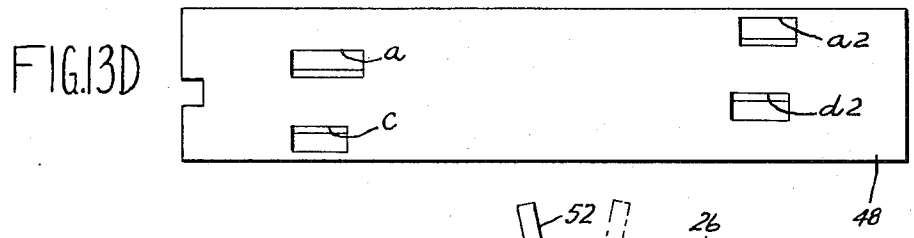


FIG.13D

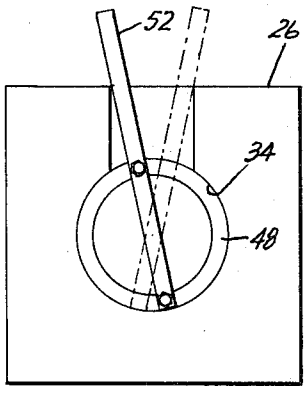


FIG.14

VALVE MECHANISM FOR AN AIR OPERATED RECIPROCATING ENGINE

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates generally to vehicles and more particularly to a vehicle that operates from gaseous fluid such as air under pressure. More specifically various means are provided for generating air pressure from the various motions of the vehicle, both forward and vertical.

SUMMARY OF THE INVENTION

In accordance with the broader aspects of this invention there is provided an air powered vehicle having a chassis and wheels. An air powered engine having intake and exhaust systems is mounted on the chassis and has a driving connection with the wheels. A first reservoir of gaseous fluid under pressure is connected to the intake system for operating the engine. Means are provided for regulating the flow of the fluid to the intake system for controlling the operation of the engine.

A second reservoir is connected to the exhaust system for receiving spent air, conduit means being connected between the second reservoir and the intake system. This conduit means is provided with a check valve which limits the flow of air in only the direction from aid second reservoir to said intake system.

A suspension-type compressor is operatively connected between a wheel and the chassis, whereby relative vertical motion between the wheel and the chassis will cause operation of the compressor. This compressor is provided with inlet and exhaust ports connected, respectively, to said second and first reservoirs, whereby operation of the compressor pumps air from the second reservoir to the first reservoir.

Means are provided for disconnecting the flow of fluid from the first reservoir to the intake system and connecting the exhaust system to the first reservoir whereby the engine may serve as a compressor for delivering air under pressure to the first reservoir.

Further means for supplying air under pressure to the first reservoir includes a fan type compressor mounted on the front portion of the chassis. This fan type compressor is exposed forwardly to be operated by the air flow induced by forward motion of the vehicle. A conduit connects this fan compressor to the second reservoir for delivering air under pressure thereto. A reciprocating piston type compressor mounted on the chassis and having a driving connection with the fan compressor has conduit means coupled to the first reservoir whereby operation of the fan compressor serves to operate the piston compressor for delivering air under pressure to the first reservoir.

As sub-combinations of the generic invention are (1) a valve mechanism for selectively admitting and exhausting pressure fluid from the chambers of the reciprocating piston engine and (2) a suspension type compressor which may be connected between the vehicle chassis and the axle which serves to provide air under pressure as a consequence of the relative vertical motion between the chassis and the axle or wheels.

It is an object of this invention to provide an air powered vehicle in which pressure air is generated from the forward and vertical movements of the vehicle.

Another object of this invention is to provide in an air powered vehicle a reciprocating piston engine which may be operated as a compressor, a suspension type compressor which provides compressed air as a consequence of the relative vertical motion between the vehicle chassis and the wheels, a fan type compressor that operates from the air flow induced by the forward motion of the vehicle and lastly a reciprocating piston compressor which is operated by the fan compressor for providing further compressed air.

Another object of this invention is to provide a valve mechanism for an air powered engine of the reciprocating piston type.

Still another object of this invention is to provide a suspension type compressor capable of generating air under pressure due to the relative vertical motion of the vehicle suspension system.

Still another object of this invention is to provide a fan type compressor which not only serves to generate air pressure itself but also to drive a reciprocating piston type compressor which generates air under pressure for use by the air powered engine.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation of a typical vehicle of this invention with certain of the mechanism being shown in phantom;

FIG. **2** is a front elevation thereof partially broken away for clarity of illustration;

FIG. **3** is a partial side view of the fan compressor mechanism mounted in the front end of the vehicle of FIG. **1**;

FIG. **4** is a diagrammatic illustration of the fluid pressure system used in the vehicle of FIG. **1**;

FIG. **5** is a diagrammatic view taken from the rear of the vehicle of FIG. **1** showing the reciprocating piston engine in perspective and rotated 90° from its normal position;

FIG. **6** is a fragmentary front view of the vehicle of FIG. **1** showing the position of one of the air tanks;

FIG. **7** is a diagrammatic perspective view of the compressor system mounted in the front end of the vehicle;

FIG. **8** is a perspective of the electrical power cord housing and retriever;

FIG. **9** is a fragmentary rear view of the vehicle with the body removed;

FIG. **10** is a longitudinal sectional view of the suspension type compressor;

FIGS. **11A** and **11B** are cross-sections of different parts of the engine valve mechanism in position for forward operation;

FIGS. **12A** and **12B** are similar cross-sections but with the parts shown in position for reverse operation of the engine;

FIGS. **13A** and **13B** are top and side views, respectively, of the valve mechanism;

FIG. **13C** is a side view of the spool valve used in the mechanism of the preceding figure;

FIG. **13D** is a side view of the sleeve valve used in the valve mechanism; and

FIG. 14 is an end view of the mechanism of FIGS. 13A and 13B showing the directional control lever.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings and more particularly to FIG. 1, a vehicle which includes a conventional body, chassis, wheels, suspension system, steering and the like has mounted in the rear end thereof an air powered, reciprocating-piston engine generally indicated by the numeral 16. The engine 16 has its crank shaft (not shown) directly connected to the drive axle 18 (FIG. 9) which in turn is connected to the wheels 20 via two slip clutches 22 which permits one wheel 20 to rotate relative to the other wheel during turning motion of the vehicle.

The engine 16 is conventional in the respect that it corresponds to the usual reciprocating-piston gasoline engine having four cylinders in two banks of two cylinders each in a "V" configuration as shown more clearly in FIG. 5. Conventional are the piston and cylinder assemblies, the piston rods, the crank shaft, the block and the like. However, the valve mechanism for controlling the intake and exhaust cycles is different as is the cam mechanism for operating the same. Such valve mechanism is shown in more detail in FIGS. 11 through 14.

In general, one valve mechanism 24 is provided for each of the two cylinder banks 26 and 28 (FIG. 5). Since both valve mechanisms 24 are constructed the same, a description of one will suffice for both.

Referring to FIGS. 11 through 14, the valve mechanisms 24 each include a body 26 in the form of a rectangular steel block adapted to be securely bolted in fluid-tight relation to the heads 28 of the engine cylinders and have securely bolted thereto also in fluid-tight relation a housing 30 formed of a block of steel having a cavity or plenum 32 therein.

The block 26 for number one cylinder, otherwise indicated by numeral 70, is provided with a cylindrical cavity 34 and communicating intake passages 36, 38 cylinder passages 40, 42 diametrically opposed exhaust passages 44, 46.

That portion of the valve mechanism 24 for number two cylinder, 72, is identically arranged with components thereof indicated by the same numerals with the suffix "*a*" added.

Close fitting in fluid-tight relation in the cylindrical cavity 34 but rotatable therein is a cylindrical sleeve valve or sleeve 48 having a series of rectangular ports indicated by the letters *a*, *b*, *c*, and *d* for cylinder 70 as shown in FIGS. 11A and *a*2, *b*2, *c*2, *d*2, *e*2 and *f*2 for cylinder 72 as shown in FIG. 11B. The particular angular relationships between these ports are shown in FIGS. 11A and 11B and will be explained further later. These ports are rectangular to coincide in size and shape with the ports 36 through 46. As viewed in FIGS. 13A through 13D and 14, the block 26 has a rectangular notch 50 formed in one end thereof which communicates with the cavity 34, this notch receiving a lever 52 secured to the end of the sleeve valve 48 in notches provided therefor. A suitable plate 54 (FIG. 13B) is bolted to the left-hand end of the block 26 so as to retain the sleeve valve 48 against leftward movement. The right-hand end of the sleeve 48 is flush with the right end of the block 26.

A cylindrical spool valve 56 is rotatably received within the sleeve valve 48 with a close tolerance, fluid-tight fit. As shown more clearly in FIGS. 13A and 13B, a plate 58 is bolted to the right-hand end of the block 26 and is provided with a semi-circular cutout having a semi-circular tongue (not shown) which slidably fits into an annular, coaxial groove 60 in the protruding shaft 62 of the spool valve 56. The plate 58 thereby retains the spool valve 56 against end-wise movement and furthermore retains the sleeve valve 48 from rightward movement.

The spool 56 and the sleeve valves 48 are operated between two different angular or rotated positions, the sleeve 48 (see FIG. 14) being swingable from a first position represented by the dashed-line position of the lever 52 (FIGS. 12A, 12B) to a second position represented by the solid line lever 52*a*. The spool 56 has a first angular position as shown in FIG. 11A and a second angular position as shown in FIG. 12A. For moving the spool valve 56 to these two positions is provided a rocker arm 63 secured to the shaft extension 62 (see FIGS. 13A and 13B).

The spool valve 56 has two sets of transverse passages therein, the sets having axially spaced apart to register with the cylinders 70 and 72 of one of the V-engine banks, such as with ports 36, 38 of one set and 36*a*, 38*a* of the other set. Thus, a description of one set will suffice for both. Referring first to FIG. 11A, the spool valve 56 has a rectangular diametral passage 64 which communicates with the rectangular ports "*a*" and "*b*" in the sleeve valve 48 and the passages 36 and 42 in the block 26. Two other passages 66 and 68 on opposite sides of the passages 64 have right angle bends therein as shown and are positioned to communicate with the various ports in the sleeve 48 as shown. In FIG. 11A, neither of the passages 66 and 68 communicate with any sleeve 48 ports. However, in FIG. 11B, passage 66 is shown communicating with the ports *b*2 and *c*2 as well as passages 40*a* and 44*a*, respectively. It may now be stated that FIG. 11A shows the position of the valve mechanism for forward engine operation with cylinder number one (70) on the intake stroke and FIG. 11B with cylinder number two (72) on the exhaust stroke.

By moving the spool 56 clockwise to its second position as shown in FIGS. 12A and 12B, with lever 52 remaining in the solidline position of FIGS. 11A, 11B, in FIG. 11A for cylinder number one passage 68 registers with ports *b* and *c* so as to provide an exhaust for cylinder 70, for continuing forward operation of the engine. In FIG. 11B cylinder number two (72) is shown as having ports *a*2 and *b*2 connected by passages 64 with none of the other spool passages connecting with any ports.

It may now be stated that air under pressure is admitted to the plenum 32 from which it may flow through the passages 36, 38, 36*a* and 38*a* through the respective spool 56 passages to the cylinders 70 and 72 as determined by the position of both the sleeve 48 and the spool 56.

Further explanation of operation and port arrangement will now be given for forward operation of the engine as determined by the position of the lever 52 as shown in FIGS. 11A, 11B. Referring again to FIGS. 11A and 11B, cylinder 70 of FIG. 11A is on the intake stroke, air pressure from the plenum 32 passing through passage 36, port *a*, passage 64, port *b* and pas-

sage 42 into the cylinder 70. Simultaneously therewith, cylinder 72 of FIG. 11B is exhausting with the piston being on the up stroke, exhaust air passing out of the passage 40*a*, port *b*2, passage 66, port *c*2, and exhaust passage 44*a*.

With the spool 56 next swung to its rightward position as shown in FIGS. 12A and 12B, but with the lever 52 in the position of FIGS. 11A, 11B, cylinder 72 (FIG. 11B) intakes through passage 38*a*, port *a*2, passage 64, port *b*2 and passage 40*a* with the piston in cylinder 72 thereby being on its down stroke, while cylinder 70 is exhausting with the piston on the upstroke through passage 42, port *b*, passage 68, port *c* and exhaust passage 46. Thus, by the spool valve 56 oscillating between the two angular positions, cylinders one (70) and two (72) are operated alternately on the intake and exhaust strokes.

For reverse operation of the engine, reference is made to FIGS. 12A and 12B. The lever 52 is moved from the dashed line position to the full line position 52*a* thereby swinging the sleeve valve 48 to the position shown. In this position, the cycle of operation as between cylinders 70 and 72 reverses such that cylinder number one (70) now intakes through passage 38, port *a*, passage 64, port *b*, and passage 40 into cylinder 72. Simultaneously therewith, cylinder number two (72) is exhausting from cylinder 70 through passage 42*a*, port *f*2, passage 68*a*, port *d*2 and out of exhaust port 46*a*. With the spool valve moved to its opposite position as shown in FIGS. 11A and 11B, cylinder 70 (FIG. 12A) will exhaust through passage 40, port *b*, passage 66, and port *d* and out of exhaust passage 44. Simultaneously therewith, cylinder 72 (FIG. 12B) which is also cylinder number two, is intaking through passage 36*a*, port *e*2, passage 64*a*, port *f*2, passage 32*a*, into cylinder 70.

Thus, the position of the sleeve valve 48 as determined by operation of the lever 52 determines whether the engine will operate either forwardly or reversely. The rapid rocking motion of the spool valve 56 between the two illustrated positions determines the intake and exhaust strokes of the cylinders.

Referring more particularly to FIGS. 4 and 5, the engine there shown is of "V-4" configuration having two banks 27 and 29, with two cylinders 70 and 72 being in each bank. Thus, cylinders one (70) and two (72) may be considered to be in the left bank as viewed in FIG. 5 while cylinders three (70) and four (72) will be in the right bank.

The rocker arms 63 on the two valve spools 56 are spring biased by means of suitable tension springs 74 (FIG. 5) such that clockwise force is exerted on the left-hand spool 56 and counterclockwise force on the right-hand spool 56. Operatively connected to each of the rocker arms 63 are two push rods 76 and 78 which ride on a rotatable cam 80 secured to the engine crank shaft 82. As the cam 80 rotates, both of the rocker arms 63 will be swung between two extreme positions as shown in FIGS. 11 and 12, thereby placing the spool valve 56 in position for the intake and exhaust strokes, respectively.

The cam 82 is so shaped and the ports and passages in the valve mechanism 24 so positioned that the piston movement in one bank 27 is 90° out of phase with the piston movement in the other 29. The pistons in one bank 27, 29 are 180° out of phase with each other thereby providing for concurrent exhaust and intake stroking. The cam 80 is so shaped, and the valve mechanisms 24 with the ports and passages therein so positioned that the engine cylinders will "fire" according to a sequence of one, three, two, four. Thus, with piston movement, crank shaft rotation as a result thereof, and cam 80 rotation, the spool valves 56 are oscillated between their intake and exhaust positions for admitting pressure air and providing for exhaust in proper, timed sequence.

Referring now to FIGS. 1, 9 and 10, description of the suspension type compressors 84 will be given. Four such compressors 84 are used, one for each of the four vehicle wheels, such that a description of one compressor 84 will suffice for all. A rectangular, rigid frame includes two upright, horizontally spaced rods 86 having two cross bars 88 and 90 secured to the opposite ends thereof as shown. Secured to the upper cross bar 88 is a tie rod 92 secured rigidly at the end 94 (FIG. 1) to a part of the vehicle frame. Slidably mounted on the rods 86 are two heads 96 and 98 in vertically spaced relation which conform generally to rectangular blocks which are preferably formed of steel. Each of the heads 96 and 98 are provided with bores 100 which closely slidably receive the respective rods 86 whereby the heads 96 and 98 may move vertically on the rods. Spacer blocks 102 on the rods 86 between the heads 96, 98 provide minimum spacing therebetween.

Both heads 96, 98 have formed therein an elongated cylindrical groove 104 adapted slidingly to receive a tubular member 106 having O-ring seals 109 for providing a sliding, sealing engagement with the outer cylindrical walls of the grooves 104. Within each head 96, 98 are provided two valve assemblies, one of these being for intake and the other exhaust. In the head 96 the intake valve is indicated by the numeral 108 in the form of a one-way check valve mounted in a passage 110 in the head. Another valve 112 for exhaust, also being a one-way check valve, is mounted in the passage 114. In the head 98 are two similar valves 116 and 118 in the two passages 120 and 122, respectively.

A piston is reciprocally positioned in the cylinder 106 and has a coaxially extending piston rod 126 secured thereto which is slidably sealingly received by a close fitting coaxial bore in the head 98. The piston rod 126 is adapted to be operatively secured at its distal end (see FIG. 9) to the vehicle axle 18.

A compression spring 128 is interposed between the cross 90 and head 98 as is another compression spring 130 between the cross bar 88 and the head 96. These two springs 128, 130 yieldably urge the heads 96, 98 toward each other into abutting engagement with the respective ends of the tubular cylinder 106. Movement of the heads 96, 98 on the rods 86 is, as explained previously, limited by the stops 102.

Connected to the passages 110, 120 is a flexible conduit 132, another flexible conduit 134 being connected to the other two passages 114 and 122.

For the suspension compressor 84, the conduit 132 constitutes the air intake and the conduit 134 the exhaust. Since the rod 92 is secured to the vehicle chassis, for purposes of explaining the operation of the compressor, the rod 92 may be regarded as stationary with respect to the movable piston rod 126 which is secured to the vehicle axle which obviously moves vertically as the wheels 20 move over uneven terrain. Thus, as the piston rod 126 moves vertically from its illustrated position (FIG. 10), any air trapped in chamber 125 will

be exhausted past check valve **112** out of conduit **134**, the check valve **108** remaining closed since it will open only for air flow in the opposite direction. Simultaneously therewith, check valve **116** will be unseated thereby to admit air through conduit **132** into the chamber **127**. On the down stroke of piston **124**, air trapped in chamber **127** is forced through check valve **118**, valve **116** remaining closed, and out of the exhaust conduit **134**. Simultaneously, air is drawn through valve **108** into chamber **125**, check valve **112** remaining closed. Thus, as the piston rod **126** reciprocates, air will be pumped from the intake conduit **132** outwardly through the exhaust conduit **134**.

If the vehicle wheel **20** should encounter a sizable bump which causes corresponding upward movement of the piston rod **126**, the piston **124** will engage the underside of the head **96** causing it to move upwardly slightly against the force of spring **130**. Conversely, should the piston **124** move downwardly sufficiently to engage the head **98**, the later will move downwardly against the force of its spring **128**. Any such movement of the heads **96** and **98** will correspondingly provide an increase in the size of the respective chamber **125**, **127** whereby on that stroke a larger volume of air will be taken in and exhausted via the conduits **132**, **134**, respectively.

As seen in FIG. **9**, the cross bar **90** is secured to a suitably, rigid pad **136** through which the piston rod **126** projects, a helical compression spring, which serves as the spring suspension for the vehicle, bearing thereagainst and against another pad **140** which is secured to the axle **18** as shown. Thus, the load of the vehicle rests primarily on the springs **138** which permit relative movement between the axle **18** and the vehicle chassis such that the piston **124** in the compressor **84** may reciprocate vertically.

Now referring to FIGS. **1** through **3**, **7** and **8**, compressor system mounted in the front end of the vehicle will be described. This system includes a compressor type fan, generally indicated by the numeral **142**, the fan in this instance being of the squirrel cage type, and a conventional reciprocating piston compressor indicated by the numeral **144**. The fan **142** is generally cylindrical, having the usual circumferentially arranged blades, and is journalled in bearings **146** to rotate about its axis arranged parallel to the axles of the vehicle. As shown in FIG. **1**, the fan **142** is exposed forwardly to air flow through the front of the vehicle via an open grill **148** such that during forward motion, air flow causes rotation of the fan **142**. As shown diagrammatically in FIG. **4**, the fan **142** is provided with the usual hood **150** having an outlet **152** through which air pumped by the fan **142** may escape from the chamber between the hood **150** and fan **142**.

The compressor **144** is fixedly mounted on a stationary part of the vehicle, and is driven by a belt **154** connected to the fan **142**. Thus, as the fan **142** rotates, the compressor **144** will be operated to produce compressed air. Also mounted on the vehicle chassis is an alternating current motor **156** drivingly connected to the compressor **144** by means of a belt **158**. A conventional alternator **160** mounted on the chassis is also drivingly connected to both the motor **156** and compressor **144** by means of the belt **158**.

A starter motor **162** mounted on the vehicle chassis and operative from a conventional vehicle storage battery is drivingly connected to the fan **142** and compressor **144** by means of a belt **164**. Thus, the compressor **144** may be driven by any one or more of three different power sources, the fan **142** and the two motors **156** and **162**. For operating the motor **162**, the conventional electrical circuit to a storage battery **164** is utilized.

Referring now more particularly to FIGS. **1**, **3**, **5** and **6**, additional components used in the fluid power operating system will be described. Mounted rigidly to the underneath side of the vehicle chassis are two main reservoirs or storage tanks (FIG. **9**) connected in parallel by suitable piping. In the front end of the vehicle is mounted a storage tank **168** and in the rear another storage tank **170**. All of the storage tanks, of course, are fixedly secured in place in the vehicle.

The various parts and mechanisms thus far described are connected together in a fluid system shown diagrammatically in FIG. **4**. The reservoir or main storage tank **166** is of such strength as to contain air at relatively high pressure, such as **100** to **150** pounds per square inch. Outlet piping connected to this tank includes a section **172**, and two branches **174** and **176**, these latter branches being connected to the plenum housing **30** of the two valve mechanisms **24** (FIGS. **11** and **12**). A main control valve **178** in the section **172** may close or open in degrees the latter as may be desired. Two other control valves **180** and **182** connected in series with the two branches **174** and **176**, respectively, are manually controllable to determine the flow of pressure fluid through the branches. Thus, with valves **178**, **180** and **182** fully opened, air at the pressure in the tank **166** is communicated to the plenums **32** for the engine cylinders.

The exhaust passages of the valve mechanisms **24** as shown in FIGS. **11** and **12** are connected together by a pipe **184** having a manually controlled regulating valve **186** in series therewith. Another section of pipe **188** connects between the exhaust passages of the valve mechanisms **24** and also back to the pipe section **172** via a branch **190**. In this branch **190** is a shut-off valve **192** and a one-way check valve **194** which permits flow only in the direction upward, or in other words, toward the tank **166**. The valve **192** is vented to atmosphere such that air in the system may be vented.

Another pipe **196** is connected to the exhaust system of the two valve mechanisms **24** and to the storage tanks **168**, **170** as shown. Another pipe **198** is connected to tanks **168**, **170** back to the intake side of the two valve mechanisms in parallel with the branches **174**, **176**. One-way check valves **200** are provided in the lines **198** as shown to permit flow in only the direction from the tanks **168**, **170** to the plenums **32** of the valve mechanisms.

Also connected to the supply tanks **168**, **170** is the conduit **132** which leads to the suspension compressor **84**. Suffice it to say at this point all four of the suspension compressors **84** are connected in parallel such that there would be four lines **132** connected to the supply tanks **168**, **170**. The exhaust conduit **134** of the compressor **84** is connected by means of a line **202** back to the main storage tank **166**, a one-way check valve **204** therein permitting flow only in this direction, and a manually controlled shut-off valve **206** being operable to close off the line **206** and furthermore vent the pressure in the system to atmosphere if desired.

The outlet **152** from the fan compressor **142** is connected by means of a pipe **208** to the supply tanks **168**,

170 while the exhaust side of the compressor **144** is connected by means of the line **210** to line **202,** with the input thereto being connected by a line **212** to the tanks **168, 170.**

A manually controlled valve **214** is connected in the line **196** leading from the exhaust side of the engine **16,** and this valve is connected by suitable mechanical linkages to the other valves **180, 182** and **186** for operating the engine **16.** Such engine control is shown in one form in FIG. **1** as including an accelerator pedal **216** connected by means of a control line, such as a Bowden cable, to the valves **174, 176, 186** and **214** such that all these valves may be operated in the same manner simultaneously. A Bowden cable is well known, consisting of a stiff wire reciprocably contained in a tubular supporting sheath, such cable being conventional in operating carburetor chokes and the like of internal combustion engines. To start the engine **16,** the valve **178** is first opened following which the pedal **216** (FIG. **1**) is operated to open the valves **180, 182, 186** and **214.** Air under pressure is admitted to the plenums **32** in the valve mechanisms **24,** to cause operation of the engine as already explained. Spent exhaust fluid passes to the tanks **168, 170** via the line **196** where it is stored until it is pumped therefrom back to the main storage tank.

For braking the vehicle, assuming that the vehicle is in forward motion, the pedal **216** is operated reversely to close the valves **180, 182, 186** and **214** in which event the engine **16** becomes a compressor, withdrawing air from the supply tanks **168, 170** via the lines **198** and pumping it back to the storage tank **166** via the line **188,** branch **190,** and through the check valve **194.** Thus, during coasting or down-hill movement of the vehicle, the engine **16** may be used as a compressor for producing compressed air which is returned to the storage tank **166.**

For reversing the movement of the vehicle, a control **220** in the cab is operated, this control being connected by means of a Bowden line **222** to the levers **52** (FIGS. **1, 11** and **12**), moving these levers **52** to their reverse positions. As explained previously in connection with the valve mechanisms of FIGS. **11** and **12,** pressure air in the plenums **32** will cause reverse operation of the engine **16.**

During motion of the vehicle over uneven terrain, the wheels **20** will move vertically in the usual manner causing corresponding movement of the pistons **124** (FIG. **10**) in the suspension compressors **84.** This results in withdrawing air from supply tanks **168, 170,** compressing and exhausting it through conduit **134** and line **202** back to the main storage tank **166.** For facilitating this pumping action, circumferentially spaced bumps **224** are applied to the peripheries of the wheels **20** whereby reciprocatory movement of the pistons **124** is assured.

The compressors **142** and **144** are operated primarily from the air flow induced by forward motion of the vehicle. This motion rotates the fan **142** which in turn operates the compressor **144.** The fan **142** with its shroud or hood **150** produces some air flow back to the tanks **168, 170** via the line **207.** The compressor **144** operates to provide compressed air to the line **202** and back to the storage tank **166.**

When the compressed air in the system becomes depleted, operation of the motor **156** drives the compressor **144** for refilling the storage tank **166.** If alternating current power is not available, the D.C. motor **162** which operates from the vehicle battery **164** is energized for driving the compressor **144.** Simultaneously therewith, the fan **142** is operated, this assisting to a small extent the supplying of air to the system while the vehicle is stationary.

During operation of the vehicle, the alternator **160** is driven, and this is operatively connected to the storage battery **164** for maintaining the charge thereon.

When not in operation, for example at night in the garage, the motor **156** may be connected to an electrical outlet for the purpose of recharging the storage tank **166.** Necessary conventional automatic devices may be employed for cutting off the electric motor **156** when the tank **166** has become suitably filled.

The vehicle is operated solely, in the preferred embodiment, by the use of compressed air initially stored in the tank **166.** The vehicle may be operated to move forwardly, rearwardly, and furthermore the engine may be used as a compressor during coasting, braking or down hill motion of the vehicle, thereby restoring spent pressure to the storage tank **166.** Vertical motion of the wheels is utilized for the purpose of operating the suspension pumps **84,** further replenishing the used energy taken from the storage tank **166.** Also during vehicle movement in coasting, braking or down hill, the fan **142** is operated when a sufficient velocity has been reached, for pumping air back into the system.

Inasmuch as the vehicle operates on compressed air, it is obvious that in contrast with the internal combustion engine, there will be less pollution of the atmosphere, it will not be necessary to use inflamable liquid, and the air which is used as fuel is ever present in the atmosphere. The engine itself uses a minimum of moving parts, is simpler in construction than its internal combustion counterpart and is more economical to produce and operate. Also, the engine will operate with less noise than is true of the gasoline engine.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. For use in a reciprocating engine, a valve mechanism comprising body means having two inlets, two outlets and two exhaust passages therein, a cylindrical cavity in said body means intersected by said passages, said inlets and outlets being on different sides of said cavity, a cylindrical sleeve valve rotatably slidably fitted into said cavity and having a first series of ports in the wall thereof, a cylindrical spool valve rotatably mounted coaxially inside said sleeve valve and having a plurality of passages therethrough extending generally transversely with respect to the axis thereof, said sleeve and spool valves each having two angularly related operative positions, in one of said positions first and second ones of said ports registers with opposite ends, respectively, of a first one of said spool passages and first ones, respectively of said inlet and outlet passages, none of the other ports register with any other passages for said first position; with said sleeve valve in said first position and said spool valve in said second position a second passage in said spool valve registers at opposite ends with said second port and a third port in said sleeve valve and said second and third ports in turn register with said first outlet passage and a first ex-

haust passage, none of the other ports and passages being in registry; with said sleeve and spool valves in said second position said first spool passage registers at opposite ends with said first and second sleeve ports which registers in turn with second ones of said inlets and outlets and none of the other ports and passages being in registry; with said sleeve in said second position and said spool in said first position a third passage in said spool registers at opposite ends with said second sleeve port and a fourth sleeve port, said second and fourth sleeve ports also registering, respectively, with said second outlet and the second exhaust passage; with said sleeve in said second position and said spool in said second position said first spool passage registers at opposite ends with said first and second sleeve ports and these in turn register, respectively, with said second inlet and outlet while none of the other spool passages register with any other sleeve port; the first position of said sleeve valve being for forward operation of said engine and the second position for reverse; means for moving each of said sleeve and spool valves individually to the first and second positions thereof; a first engine cylinder having a piston defining a chamber therein, said outlets communicating with the chamber above said piston.

2. The mechanism of claim **1** including an additional set of two inlets, two outlets and two exhaust passages in said body means which intersect said cavity arranged as aforesaid, said sleeve valve having a second series of ports in the wall thereof and said spool valve having a plurality of additional passages therethrough arranged as aforesaid, in said one of said positions first and second of said second series sleeve ports registering with the opposite ends of one of said additional spool passages and first ones of said outlets and exhaust passages, respectively, none of the other additional passages and second series ports being in registry; with said sleeve valve in said first position and said spool valve in said second position a second one of said additional passages registers at opposite ends with said first one and a third of said second series of ports and these latter ports in turn register with said first outlet and a first one of said additional inlets; with said sleeve valve in said second position and said spool valve in said first position, said second one said additional passages registers at opposite ends with fourth and fifth second series ports and these in turn, respectively, with second ones of said inlets and outlets of said additional set, while none of the other second series ports are in registry with any other additional passage; with said sleeve and spool valves in said second position, a third one of said additional passages registers at opposite ends with said fifth port and a sixth port of said second series ports, said fifth and sixth ports registering, respectively, with said second outlet and said second exhaust passage of said additional set while none of the other second series ports register with any other additional passages; a second engine cylinder having a second piston defining a second chamber therein, said second set outlets communicating with said second chamber.

3. The mechanism of claim **1** in which said body means is a solid block of metal and said inlets and outlets, respectively, being on diametrically opposite sides of said cavity as are said exhaust passages but angularly spaced 90° therefrom, said sleeve and spool valves operatively sealingly engaging each other and the wall of said cavity whereby fluid flow occurs only when an inlet, an outlet, two sleeve ports and a spool passage are in operative registry.

4. The mechanism of claim **2** including means providing a plenum in constant communication with all of said inlets.

5. The mechanism of claim **2** including two additional engine cylinders with a piston in each, said four cylinders being arranged in a "V" configuration having two cylinder banks, each bank including two cylinders, each bank of cylinders including a valve mechanism as aforesaid, a crank-shaft for said pistons, a valve-actuating cam secured to said crank shaft for rotation therewith, two push-rods operatively engaged with said cam and operatively connected to said two spool valves, respectively for operating the latter alternately between said first and second positions in response to rotation of said crank-shaft, said cam having raised and depressed portions on diametrically opposite sides thereof and of a shape that actuates said spool valves of the two banks ninety degrees out of phase with each other.

6. The mechanism of claim **5** in which each spool has a lever secured thereto for operating the same between said first and second positions, said push-rods being operatively connected to said levers, respectively, for swinging the latter in response to reciprocation of said push-rods by said cam.

7. The mechanism of claim **6** in which each of said sleeves has a lever secured thereto for operating the same between said first and second positions, and means for operating the lastmentioned levers in unison between said first and second positions.

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