United States Patent [19]

Fritch et al.

[11] **3,791,780**

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

[54] **VACUUM PUMP**

[75] Inventors: **Junior L. Fritch,** Edgerton; **Don R. Brandeberry,** Montpelier, both of Ohio

[73] Assignee: **Robinair Manufacturing Corporation,** Montpelier, Ohio

[22] Filed: **May 11, 1972**

[21] Appl. No.: **252,213**

[52] **U.S. Cl.** **418/60,** 418/67, 418/99
[51] **Int. Cl.** ... **F01c 21/04,** F04c 27/02, F04c 29/02
[58] **Field of Search** 418/67, 83, 87, 60, 97–99

[56] **References Cited**

UNITED STATES PATENTS

2,988,009	6/1961	Kraissl	418/98
1,558,620	10/1925	Kagi	418/97
1,616,913	2/1927	McCallum	418/87
2,646,206	7/1953	Bram	418/97

FOREIGN PATENTS OR APPLICATIONS

596,978	5/1934	Germany	418/66

Primary Examiner—Carlton R. Croyle
Assistant Examiner—John J. Vrablik
Attorney, Agent, or Firm—Burton & Parker

[57] **ABSTRACT**

An improved vacuum pump of the rotary mechanical type having interchangeable component parts which may be assembled in "building block" fashion to provide single and multi-stage pumps built up from the same basic parts. The multi-stage pump may be provided with a switchable feature whereby the stages may be operated in series or in parallel, with automatic switching therebetween if desired. Both air ballast and oil injection are provided, the latter incorporating a check valve to control the supply of oil to the pumping chamber.

13 Claims, 13 Drawing Figures

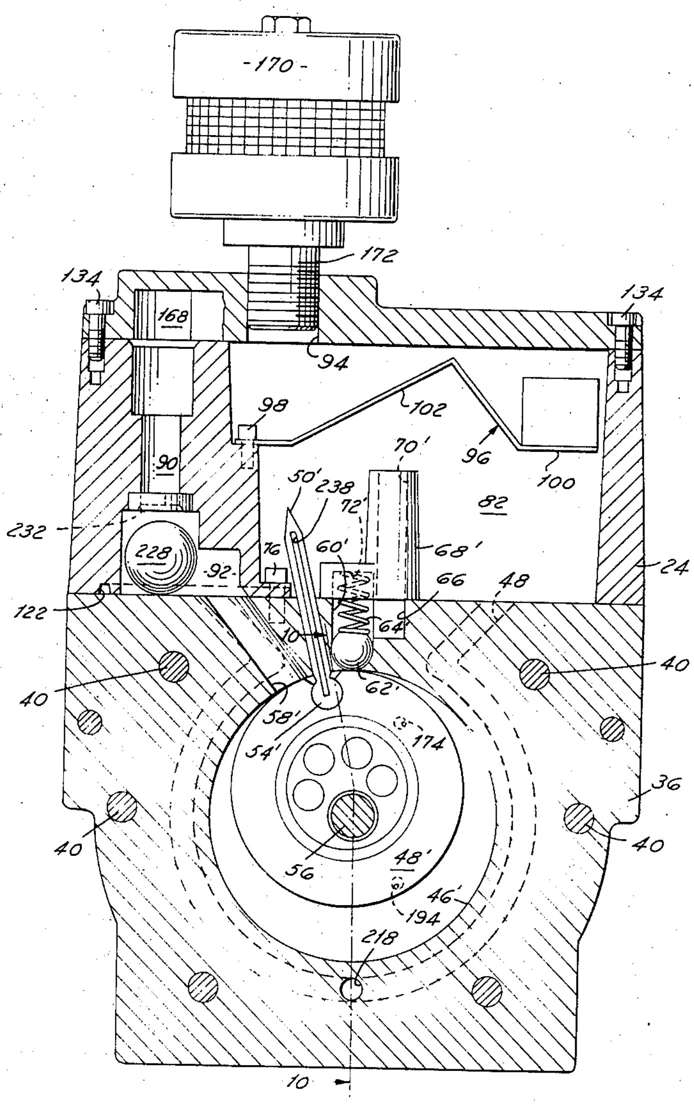


FIG.1

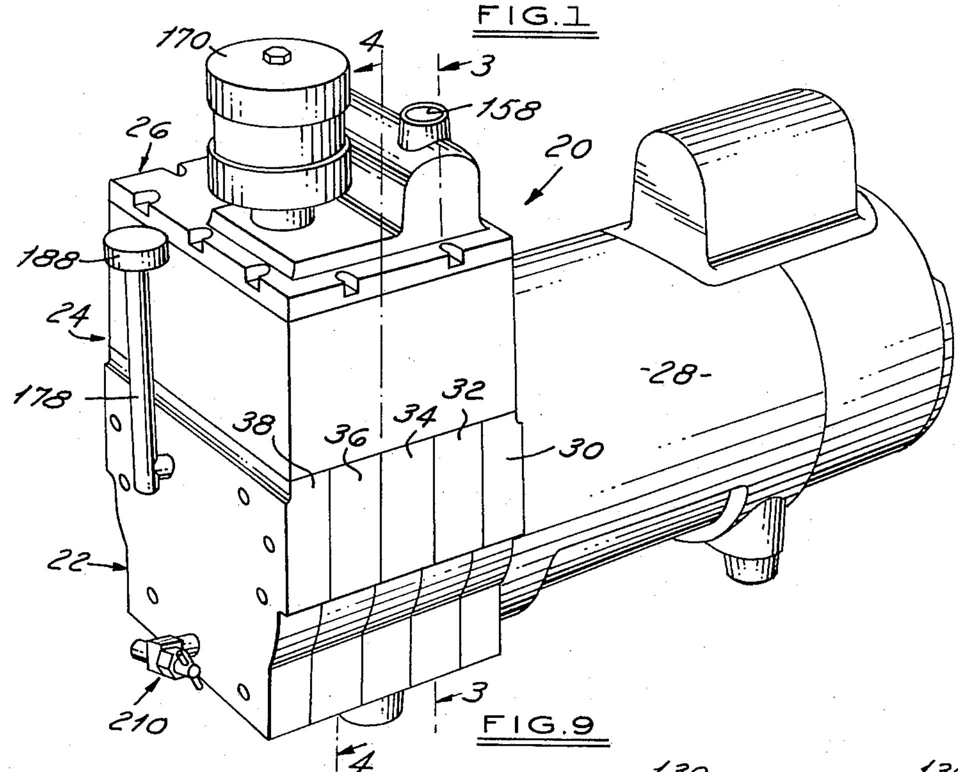

170
4
3
158
26
20
188
24
178
38
36
34
32
30
-28-
22
210
3
4

FIG.9

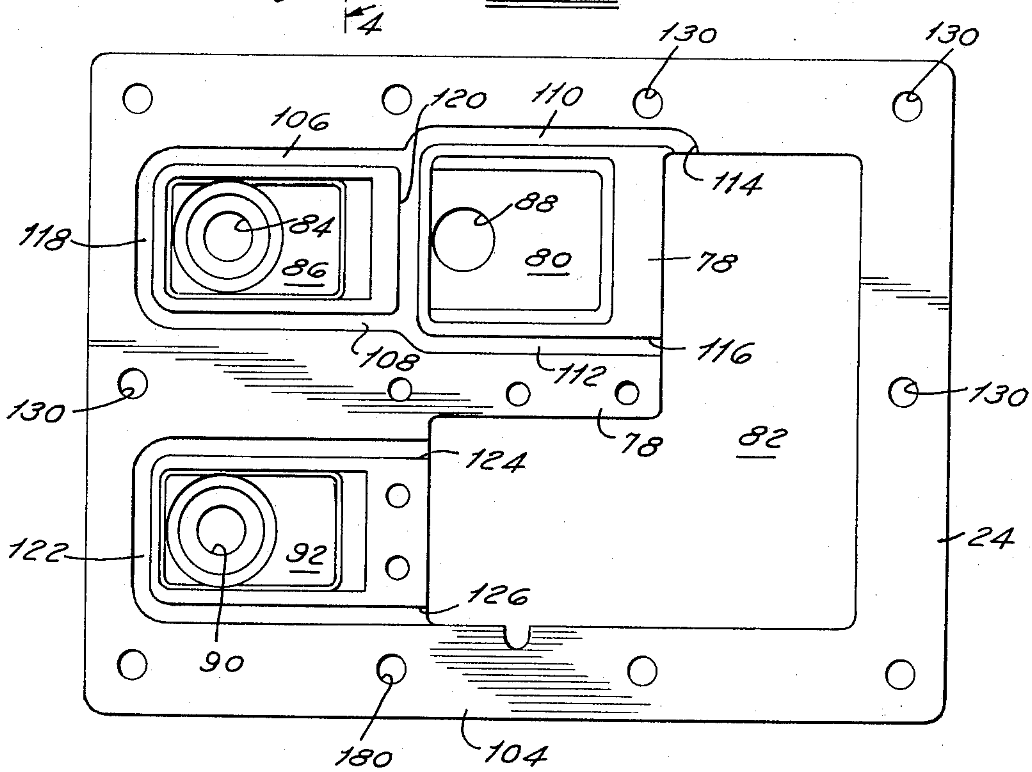

130
130
120
110
106
114
118
84
88
86
80
78
108
112
116
130
130
78
82
124
122
92
24
126
90
180
104

FIG. 2

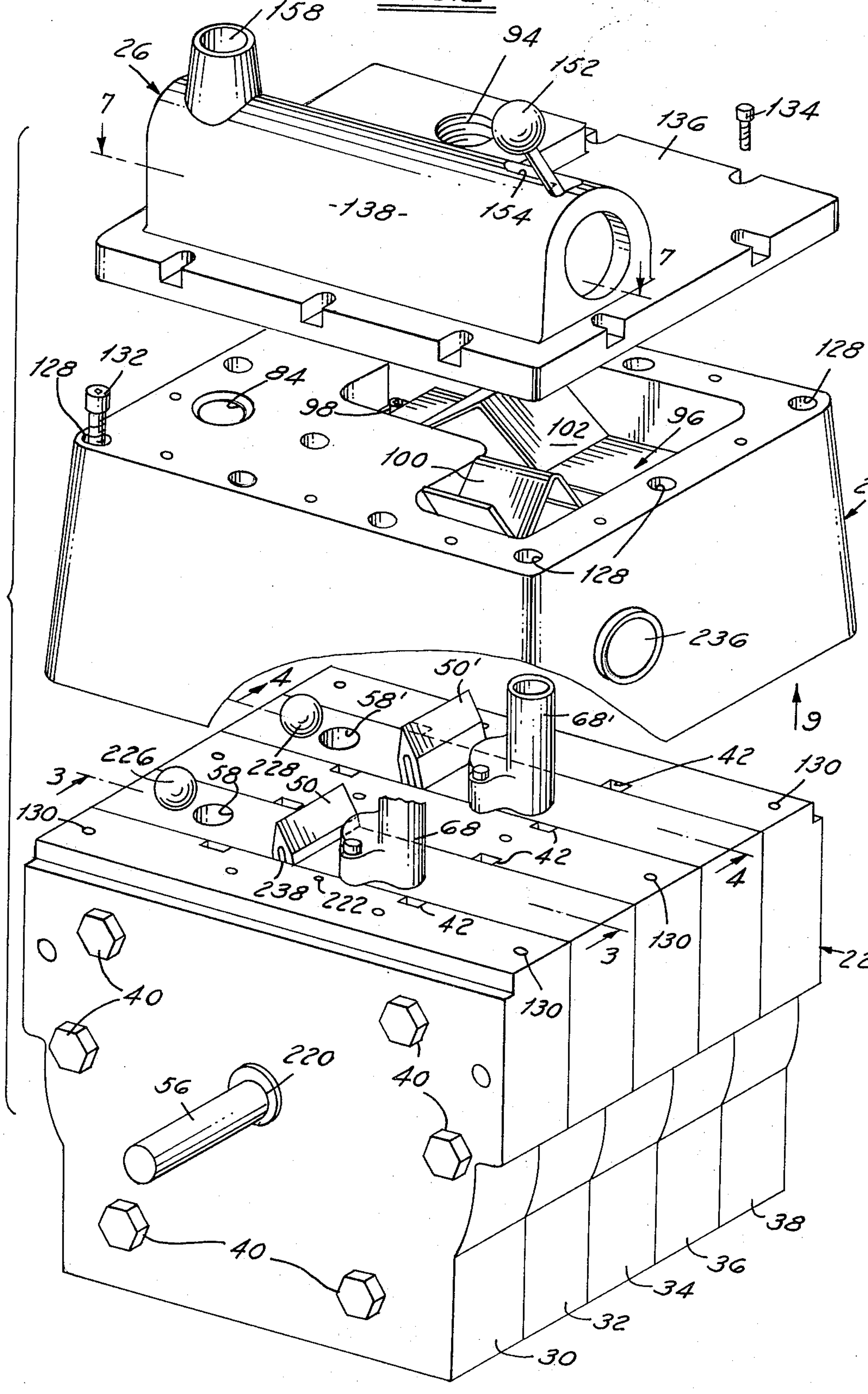

158
26
94
152
7
136
134
-138-
154
7
128
132
84
98
102
96
128
100
24
128
236
50'
4
58'
68'
9
42
130
3
226
228
50
58
130
68
42
238
222
42
4
130
3
22
130
40
40
220
56
40
38
40
36
34
32
30

FIG. 3

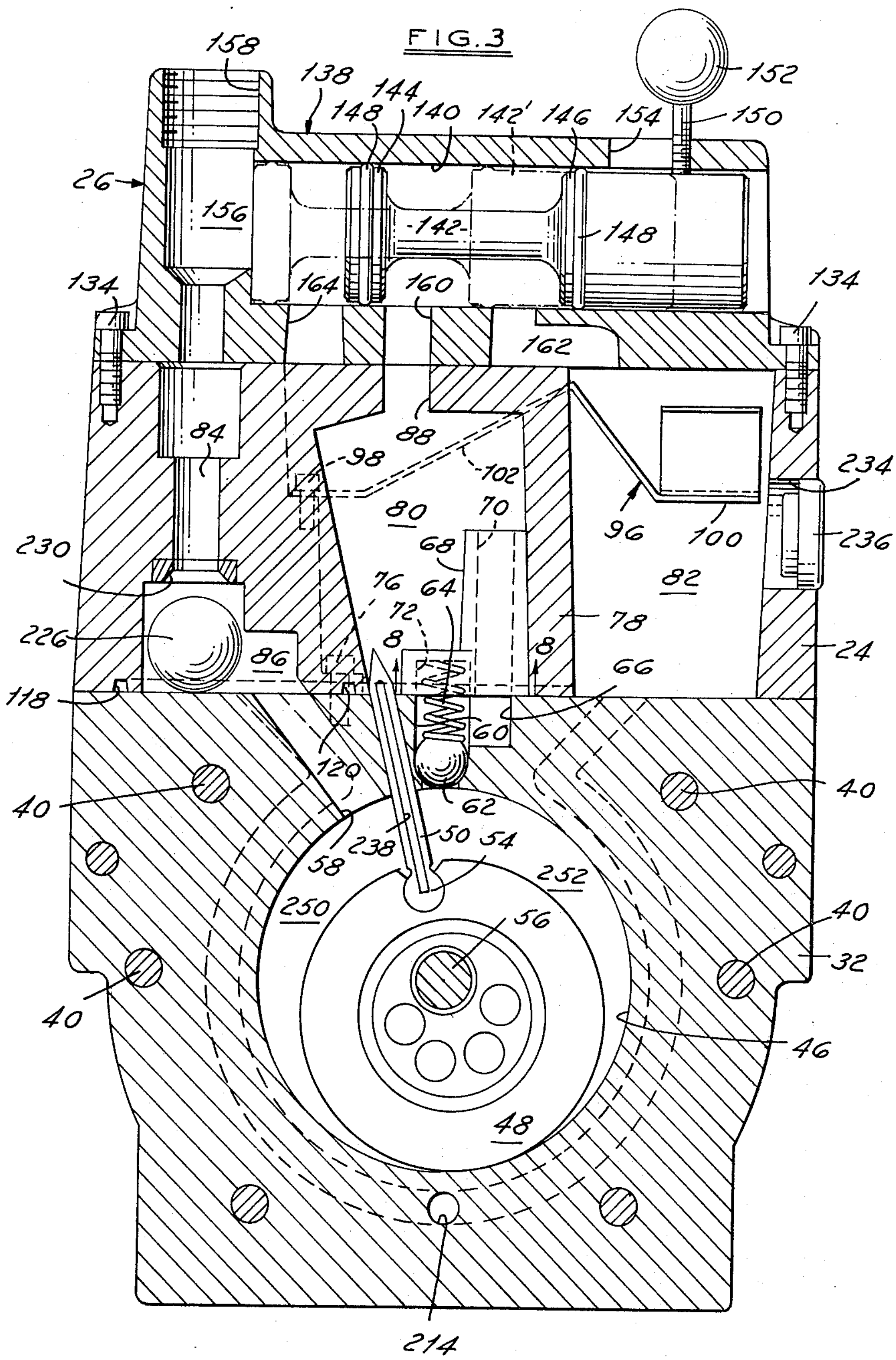
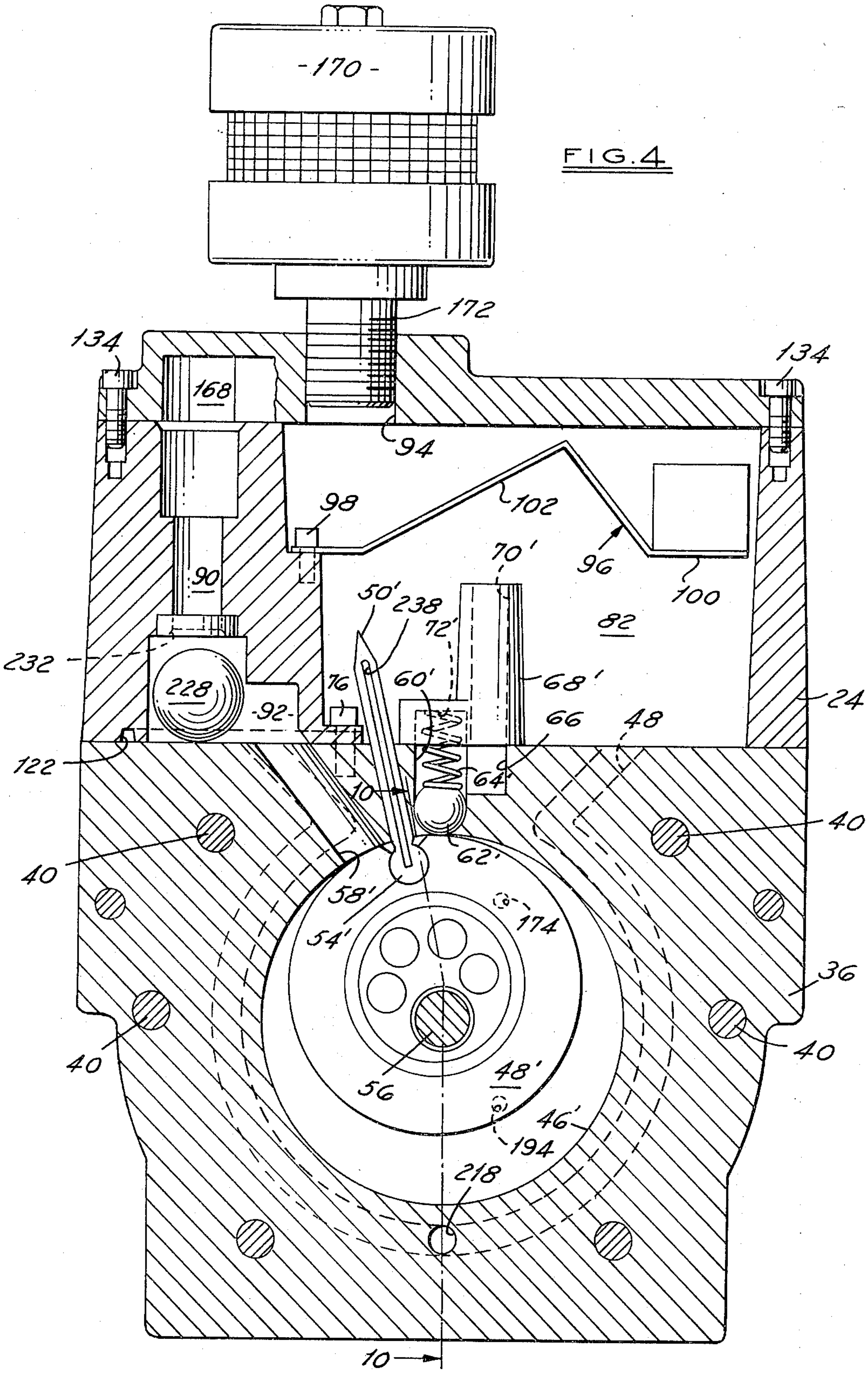

158
138
144
148
140
142'
146
154
152
150
26
156
-142-
148
134
164
160
134
162
84
88
98
102
234
80
70
96
100
236
230
68
82
76
64
78
226
72
8
8
24
86
66
118
60
120
62
40
40
238
50
54
58
252
250
56
40
32
40
46
48
214

FIG. 4



-170-
172
134
134
168
94
102
98
96
70'
100
90
50'
238
82
72'
232
228
60'
68'
24
-92-
76
66
48
122
10
64'
40
40
62'
58'
54'
174
36
56
40
40
48'
46'
194
218
10

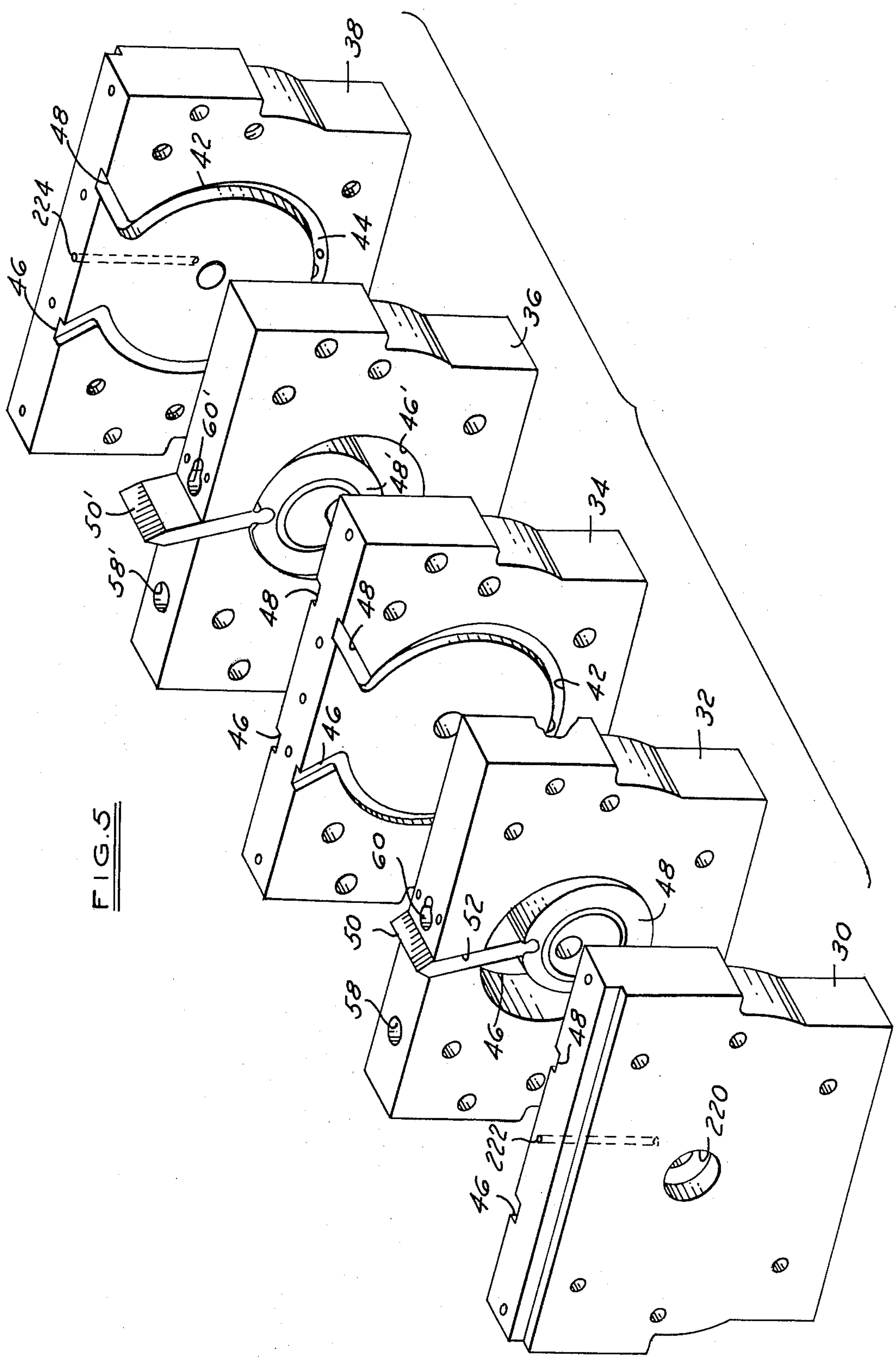

38
48
42
224
44
46
36
60'
46'
50'
48'
58'
34
48
48
42
46
46
32
60
52
50
48
58
30
46
48
220
222
46

FIG.5

FIG. 6

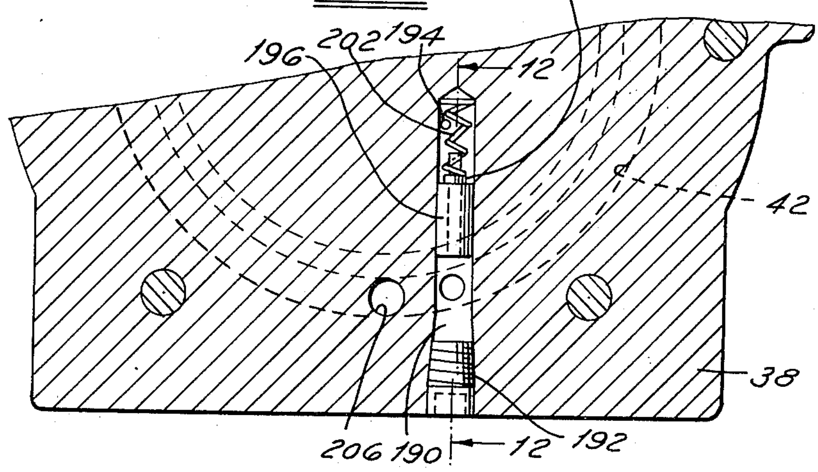


FIG. 7

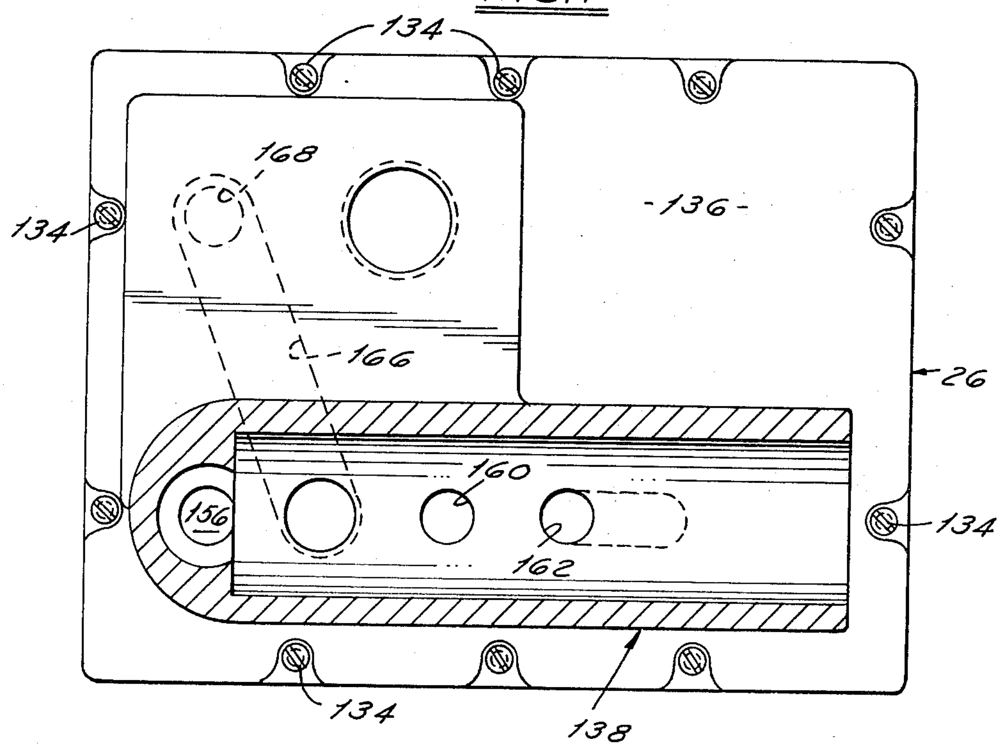


FIG. 8

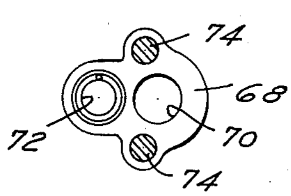


FIG. 13

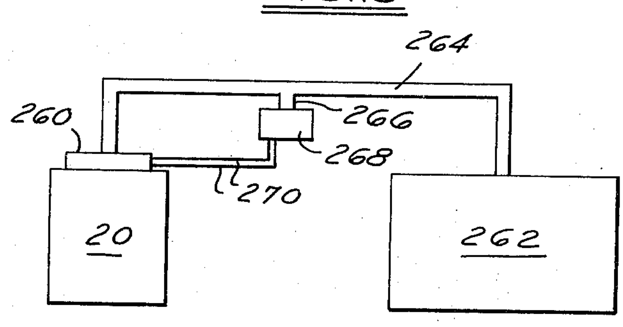


FIG. 11

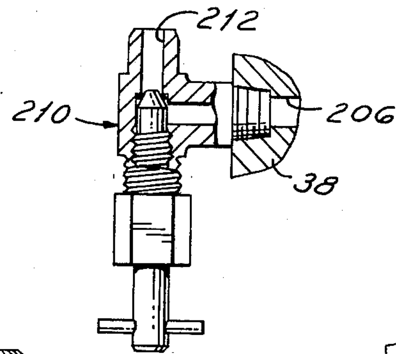


FIG. 12

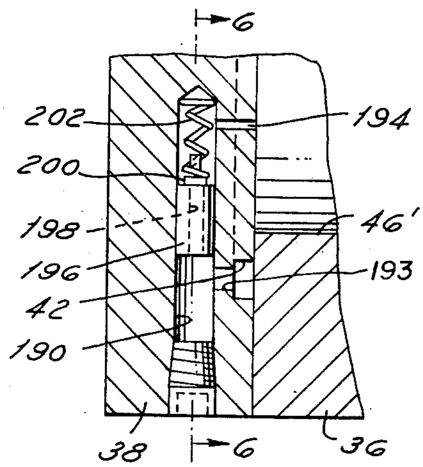
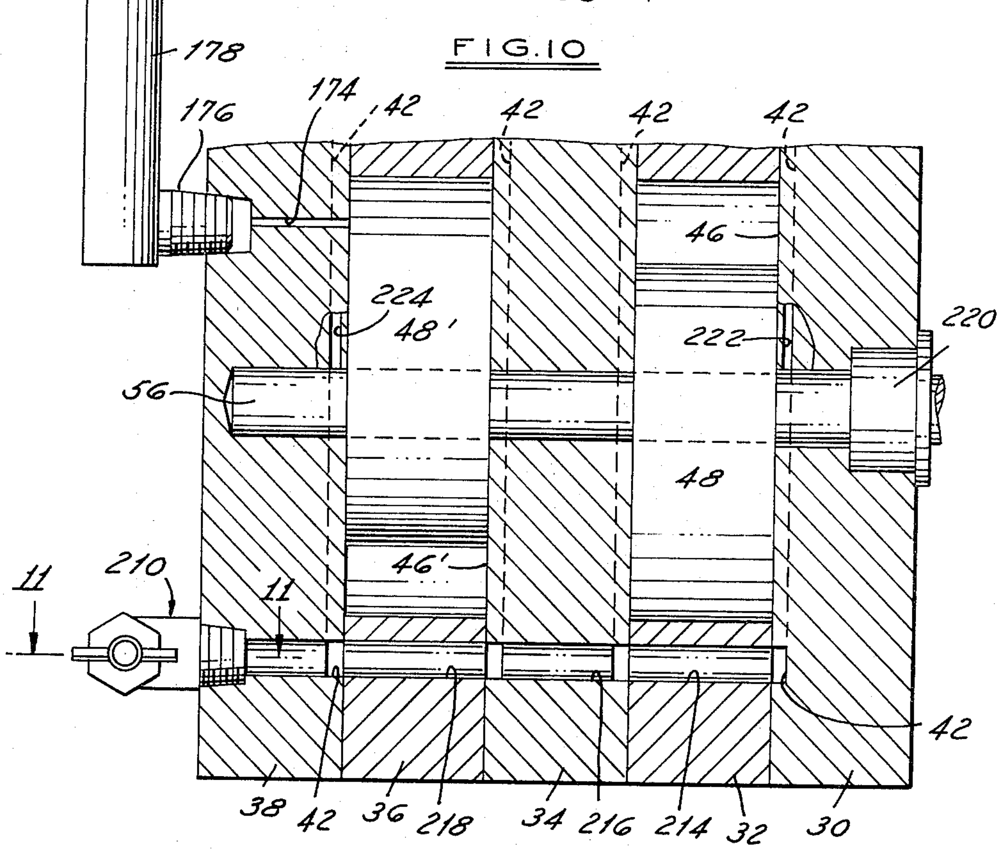


FIG. 10



VACUUM PUMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to vacuum pumps, and more particularly to an improved rotary mechanical vacuum pump.

2. Description of the Prior Art

Rotary mechanical vacuum pumps of the vane type, in which an eccentric cylinder or a rotor rotates within a hollow cylindrical chamber with a reciprocating vane extending through the chamber wall and journalled in the periphery of the rotor to provide separation between the inlet and outlet ports have long been known, as exemplified by U.S. Pat. Nos. 1,530,973; 2,929,550, and others. Both single and multi-stage pumps of this general type are known, and the prior art shows many specific features of construction, such as for example the oil injection feature of U.S. Pat. No. 2,929,550 and the multi-stage pump of U.S. Pat. No. 3,525,578 utilizing a single hollow rotor to effect stage-to-stage gas conductance.

A salient feature of the vacuum pump construction disclosed herein is that pumps of various capacities, including both single and multi-stage pumps, may be constructed utilizing the same basic components. The pumping section of the vacuum pump disclosed comprises a plurality of block-like members which are stacked in face-to-face relation, and various numbers of these members may be stacked in building block fashion to provide either single or multi-stage pumps. The oil reservoir section of the vacuum pumps disclosed is a completely separate member which is mounted atop the building blocks of the pumping section, facilitating manufacture and appreciably reducing manufacturing cost. Surmounting the oil reservoir section is a cover or top cap section which in the case of the multi-stage pumps may be provided with suitable manifold passages and valving to permit the pump stages to be operated either in series or in parallel. Thus, a multistage vacuum pump having identical pumping section and reservoir section parts may be converted from a series operated pump to a series-parallel operated pump merely by replacing the top cap section with a modified section of the same general structure and dimensions.

Another feature of the vacuum pump disclosed herein is the novel oil injection structure wherein the oil injection passage extends from the bottom of an oil sealing ring groove between the building blocks of the pumping section upwardly into the pumping chamber, the oil passage being controlled by a check valve means. By taking the injection oil from the lowermost portion of the oil groove, which communicates at its upper end with the oil reservoir, the oil within the pump is constantly being circulated throughout the pump. In addition, the contaminants in the pump oil, which are usually heavier than the oil, will gravitate to the bottom of the oil groove, and will be injected with the oil into the pumping chamber. As the condensed contaminants are injected into the chamber at low pressure, they will be vaporized and exhausted through the pump outlet as a gas, thereby purging the pump oil of entrained contaminants.

Another advantageous feature of the particular oil injection mode employed arises from the provision of

the check valve in the oil injection passageway, which valve may be adjusted to admit the ideal amount of oil into the chamber during each pump cycle. Furthermore, the provision of the oil injection valve substantially eliminates the hydraulic hammer which is prevalent in the prior art designs which relied on the rotating piston to close the oil orifice into the chamber. With these prior art designs, the oil would be forced back up through the oil injection passageway into the reservoir, and would bubble up through the oil in the reservoir, creating an audible hydraulic hammer.

SUMMARY OF THE INVENTION

A vacuum pump of the rotary piston type having a generally radial vane extending from the piston periphery through the side wall of the pumping chamber, a separate oil reservoir mounted atop the pumping chamber, and a cover surmounting the oil reservoir, with oil injection means comprising an oil conducting passage leading from the bottom of an oil groove upwardly into the pumping chamber through a side wall thereof, said passage having adjustable check valve means therein to control the supply of oil into the chamber and prevent oil flow through the passage in the reverse direction.

The pumping section of the vaccuum pump embodying the invention comprises a plurality of members stacked in face-abutting relation, at least some of which members are provided with oil grooves extending in spaced circumferential relation about the pumping chamber to provide an oil seal between the members. These oil sealing grooves communicate at their upper ends with the oil reservoir and at their lower ends with each other, and with the oil injection passage. There are in addition oil sealing grooves provided between the pumping section members and the oil reservoir member to effect a fluid-tight seal therebetween. This eliminates the need for any mechanical type seals between the various parts of the structure. In the multi-stage pump, a novel manifold cover member or top cap surmounts the oil reservoir section, which may be provided with suitable valves so that the pump may be either manually or automatically switched between parallel and series operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a double stage mechanical vacuum pump embodying the invention, the pump being directly driven by a suitable electric motor;

FIG. **2** is an exploded perspective view of the pump shown in FIG. **1** illustrating the relationship of the lower pumping section, the intermediate oil reservoir section, and the upper top cap section;

FIG. **3** is a vertical section taken along line **3—3** of FIGS. **1** and **2**;

FIG. **4** is a vertical section taken along line **4—4** of FIGS. **1** and **2**;

FIG. **5** is an exploded perspective of the pumping section of the vacuum pump showing the building block feature and the relationship of the various internal parts;

FIG. **6** is a partial cross-section taken through the lower portion of one of the building block end plates, generally along the line **6—6** of FIG. **12,** illustrating the oil injection passage with the check valve disposed therein;

FIG. **7** is a top view, partly in section, through the top cap of the pump, taken along line **7—7** of FIG. **2**;

FIG. 8 is a partial section taken along line 8—8 of FIG. 3 showing details of the chamber outlet stack;

FIG. 9 is a bottom elevation of the oil reservoir section taken in the direction of the arrow 9 in FIG. 2;

FIG. 10 is a cross section through the pumping section taken along line 10—10 of FIG. 4;

FIG. 11 is a partial section taken along line 11—11 of FIG. 10 showing details of the manually operated oil drain valve;

FIG. 12 is a partial section taken along line 12—12 of FIG. 6 showing further details of the oil injection feature; and

FIG. 13 is a schematic representation of means for automatically switching the two pump stages between series and parallel operation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and more particularly initially to FIG. 1, there is shown therein a vacuum pump of the rotary mechanical type 20 comprising in general a lower pumping section 22, and intermediate oil reservoir section 24 and a top cap or manifold section 26. The pump 20 is connected in direct drive relationship to a conventional electric motor 28, but it will be obvious to those skilled in the art that the pump could be driven in other manners, as for example by a belt drive, in which event the pump shaft and motor shaft could each be provided with suitable pulleys, with a drive belt entrained about the pulleys in well known fashion.

The pumping section 22 of the pump 20 comprises a plurality of members 30, 32, 34, 36 and 38 shown most clearly in FIGS. 2 and 5, which members are of identical exterior configuration and of generally rectangular cross section, the members being secured together in surface-abutting relation or stacked together as shown in FIG. 2 and secured by through bolts or the like 40. The end-most members or building blocks 30 and 38 constitute end plates which serve as closure members for the pumping chambers defined by the members 32 and 36, with an intermediate closure member 34 being interposed between the members 32 and 36 as shown.

Each of the closure members 30, 34 and 38 are provided with oil sealing grooves 42, the members 30 and 38 having such a groove in only one end face thereof, while the member 34 has a groove in both end faces thereof. The oil sealing grooves 42 in all of the members are substantially identical, and each comprises a generally circular portion 44 and a pair of upwardly extending portions 46 and 48 opening through the top face of the respective member. The mating faces of each of the building blocks 30, 32, 34, 36 and 38 are finished by a grinding or milling operation to be completely flat and smooth and are preferably coated with suitable grease or the like before assembly, and then the members are securely mounted in surface-abutting relation and secured by the through bolt 40 shown in FIG. 2.

The pumping chamber blocks or units 32 and 36 are basically identical, and a description of the member 32 will suffice for both. Member 32 is provided with a cylindrical aperture 46 extending therethrough which defines a pumping chamber within which is positioned a cylindrical rotor or displacer 48 having a generally radially extending vane attached thereto and projecting through a slot 52 beyond the upper face of the block. By reference to FIG. 3 it can be seen that the vane 50 is provided with an enlarged cylindrical lower end 54 interfitting in a correspondingly shaped recess or socket in the rotor 48, and the rotor or displacer is in turn mounted eccentrically on a drive shaft 56 which extends completely through both pumping chambers and beyond the end wall of member 38 for connection to the drive motor 28. The rotor 48 is driven in conventional fashion, and as the rotor rotates, the vane is reciprocated within its slot 52, serving as a separating wall between the pump chamber inlet and outlet, as will be described more fully hereinafter. Each of the oil sealing ring grooves 42 in the various members 30, 34 and 38 extends in circumferentially spaced relationship around the pumping chambers 46 of members 32 and 36 and as the grooves are completely filled with oil from the oil reservoir section 24 to be described, the grooves 42 provide an effective oil seal for the pumping chambers.

In FIG. 3 the pumping member 32 is shown in section, and includes an inlet 58 and outlet 60 opening into the chamber 46 on opposite sides of the vane 50 and spaced closely adjacent thereto. The outlet 60 is provided with a check valve comprising a ball 62 surmounted by a spring 64 to prevent reverse gas flow back into the chamber 46 and in addition exhibits a laterally offset passage portion 66. Referring to FIG. 4, pumping member 36 is provided with identical parts, which have been labelled with corresponding numbers primed to distinguish them from parts of the member 32.

Mounted atop the offset outlet passage portion 66 is a stack or chimney 68 comprising a vertically opening bore or passage 70 establishing communication between the passage 66 and the oil reservoir at a point spaced above the oil level therein and a laterally offset counterbore portion 72 which serves as a seat for the valve spring 64. The stack 68 may be secured to the top face of the member 32 as by screws or the like which are shown in cross section at 74 in FIG. 8. An identical stack 68′ is disposed atop the outlet of chamber 46′ as shown in FIG. 4. By providing the offset passage portions 66 and 66′, the gases out of the respective pumping chambers 46 and 46′ may pass unrestricted to the stack bores 70 and 70′ as soon as the associated ball is lifted from its seat, as the gases do not have to pass around the ball, but flow laterally thereof through these offset passages.

The intermediate oil reservoir section 24 is a one-piece member, preferably being of cast metal or the like which member surmounts the building block members of the pumping section 22 and is secured thereto as by cap screws or the like, two of which are shown at 76 in FIGS. 3 and 4. The reservoir section 24 is divided by interior wall means 78 to define two separate oil reservoirs 80 and 82 the former of which communicates with the pumping chamber 46 defined by the member 32 (FIG. 3) while the latter communicates with the pumping chamber 46′ defined by the member 36 as shown in FIG. 4. Referring to FIG. 3, the member 24 is provided with a generally vertical inlet passage 84 having a laterally offset lower end portion 86 communicating with the pumping chamber inlet 58 and an outlet passage portion 88 which communicates with the pumping chamber outlet 60 through passage 66, stack bore 70 and reservoir 80. Similarly, as shown in FIG. 4, the reservoir section 24 has an inlet passage 90 extending generally vertically therethrough and having a laterally offset portion 92 communicating with inlet 58′ of pumping chamber 46′, and an outlet 94 through section 26 to be described, which communicates with chamber outlet 60′ through the passage 66′, stack bore 70′ and the oil reservoir 82.

A gas baffle 96 is disposed within the reservoir 82, and is secured to a portion of the oil reservoir section 24 as by cap screws or the like 98 (FIGS. 3 and 4). Baffle 96 is preferably constructed of a non-corrosive sheet metal or the like and comprises a base portion 100 and a leg portion 102, the base portion being of substantially W-shape and the leg portion being of inverted V-shape, as shown most clearly in FIG. 2.

Referring now to FIG. 9, which is a view of the lower face of the oil reservoir section 24, the oil reservoirs 80 and 82 are shown in plan view. Also shown are the inlets 84, 86 and 90, 92 previously described. Surrounding the inlet 84, 86 is a shallow groove cut in the lower surface 104 of the oil reservoir section 24, such groove defining a continuous cutout having portions 106 and 108 extending on opposite sides of the inlet 84, 86, and portions 110 and 112 extending in spaced parallel relation on opposite sides of the reservoir 80 and outlet 88, which portions communicate at their ends 114 and 116 respectively with oil reservoir 82. The above mentioned groove portions are innerconnected by an end groove portion 118 and by an intermediate crossover groove portion 120, all of the groove portions being in communication with each other and thus with the oil reservoir 82.

As can be seen from FIG. 3, the groove portions 118 and 120 extend in spaced relation at opposite ends of the inlet 86, and as the grooves all communicate at the extremities 114 and 116 with the oil reservoir 82, when oil is introduced into such chamber, it flows into the grooves, filling them with oil, and effectively sealing the innerface between the oil reservoir section 24 and the members forming the pumping section 22. Likewise, a generally U-shaped groove 122 is formed in the surface 104 of member 24 extending in spaced relation around the inlet 90, 92 of the remaining pump stage, and has opposite end portions 124, 126 communicating with the oil reservoir 82 to provide an effective oil seal about the inlet 90, 92. The grooves 118 and 120 are shown in cross section in FIG. 3, while the bight portion of the oil groove 122 is shown in cross section in FIG. 4.

As can be seen from FIG. 2, the oil reservoir section 24 may be provided with a series of counterbored vertical apertures 128 extending generally vertically therethrough, and the members forming the pumping section 22 may be provided with aligned threaded apertures 130, and the sections 24 and 22 may then be secured together by cap screws or the like, one of which is shown at 132 in FIG. 2, in addition to the screws 76 previously described.

Mounted atop the reservoir section 24 is a top cap or cover section 26 which is shown in FIGS. 1, 2, 3, 4 and 7. The top cap section 26 may be conveniently secured to the oil reservoir section 24 as by a series of cap screws or the like 134, some of which are shown in FIGS. 2, 3 and 4, and if desired a suitable gasket (not shown) may be interposed between the mating surfaces of the sections 24 and 26. The top cap 26 includes a cover plate portion 136 and a manifold portion 138, the latter being disposed directly above the pumping chamber 46 as shown in FIG. 3. A longitudinally extending valve chamber 140 opens through one end of the manifold 138 and has disposed therein a spool valve 142 having spool portions 144 and 146 encircled by suitable seals 148. The valve 142 may be fitted for manual actuation by being provided with a handle 150 having a knob 152 on the outer end thereof, the handle projecting out of the manifold section 138 through an L-shaped slot 154 (FIG. 2).

Adjacent one end of the manifold portion 138 is an inlet passage 156 having an internally threaded open end 158 adapted to be coupled to the device to be evacuated, the lower end of the inlet 156 communicating with the inlet passage 84, 86 in section 24 and thence with the pumping chamber 46 through the passage 58 as shown in FIG. 3. An outlet passage 160 establishes communication between the outlet 88 from the pumping chamber 46 and the valve chamber 140. An additional passage 162 establishes communication between the valve chamber 140 and the reservoir 82, and the passages 160 and 162 are in communication with the spool valve 142 in the position shown in solid outline in FIG. 3. The valve chamber 140 in addition communicates with another passage 164 in top cap 26, the passage 164 having a laterally extending portion 166 (FIG. 7) formed by a cutout in the underside of the member 26, and communicating at its opposite end with the inlet 90, 92 through passage portion 168 (FIGS. 7 and 4). The outlet 94 from the reservoir 82 previously described is provided with internal threads, and a muffler 170 having an externally threaded fitting 172 is threadably engaged in the aperture 94.

Means for introducing ballast air into the pumping chamber 46′ is shown in FIG. 10, such means comprising an air passage 174 opening laterally into the chamber from the block member 38, with the outer end of the passage 174 having a fitting 176 threadably engaged therewith communicating with an upstanding tube 178 defining an internal air passage 180 and a lateral passage 182 opening to atmosphere. The upper end of the tube 178 is suitably designed to accept a needle valve 184 having a valve body portion 186 adapted to seat against a nylon insert in the port establishing communication between passages 180 and 182 as shown in FIG. 10. Valve 184 is provided with a knob 188 so that the valve body may be manipulated to open and close the port. Valve 184 is not intended as a metering valve, the passage 174 being of a predetermined diameter to admit only the necessary air to the pumping chamber 46′ for ballast purposes when the valve is open, the rotating pistons 48′ closing off the inner end of the aperture 174 as the piston rotates in the exhaust stroke, as more fully described hereinafter. The position of the passage 174 at its opening into the chamber 46′ is shown in dotted outline in FIG. 4.

Shown in FIGS. 6 and 12 most particularly is the structure for the oil injection into the pumping chamber 46′, and referring first to FIG. 6, a vertical aperture 190 is formed in the block member 38, and the lower end of the aperture is then plugged by a threaded plug 192. The vertically extending passage 190 communicates with the oil groove 42 at the lower portion thereof through short aperture 193, and continues upwardly into communication with a small laterally disposed aperture 194 which establishes communication between the passage 190 and the pumping chamber 46′. The relative position of the oil injection aperture 194 with respect to the end wall of the pumping chamber **46'** is indicated in dotted outline in FIG. **4**. Disposed within the vertical passage **190** above its point of communication with the oil groove **42** is a sleeve member **196** having a passage **198** opening therethrough, the sleeve being surmounted by a valve body **200** which is biased by a spring **202** against the sleeve **196**. The valve body **200** may be T-shaped in cross section, having a cylindrical head seated against the sleeve **196** and a cylindrical body portion of lesser diameter projecting upwardly from the head and over which the spring **202** is received bearing against the head and biasing the valve body against the upper end of the sleeve **196**, thereby closing the passage **198**.

Spaced a short distance from the passage **190** is a laterally extending aperture **206** as shown in FIGS. **6, 10** and **11**, communicating at its inner end with the bottom of the oil groove **42**. At its outer end, the aperture **206** has a shut-off valve assembly **210** threaded thereinto, the valve **210** having an outlet **212** open to the atmosphere. The block members **32, 34** and **36** are provided with lateral openings **214, 216** and **218** respectively which are in axial alignment with and communicate with the aperture **206** and with all of the oil grooves **42**. Therefore, the provision of the manually operable valve **210** permits the entire oil supply in the vacuum pump to be drained easily and conveniently.

Referring to FIGS. **3, 4** and **10**, it can be seen that the shaft **56** is journalled in the member **38**, and extends completely through the members **36, 34, 32** and **30** and outwardly therebeyond for connection to the drive motor **28** (FIG. **1**). A suitable seal **220** is provided in the member **30** surrounding the shaft **56**, and the shaft **56** extends axially through the pumping chambers **46** and **46'**. The rotors **48** and **48'** are eccentrically mounted on the shaft **56** in opposed positions of eccentricity, as shown in FIGS. **3** and **4**. Each of the end blocks **30** and **38** is provided with a generally vertically extending aperture **222** and **224**, which apertures communicate with the oil reservoir at their upper ends and and with the shaft **56** at their lower ends to lubricate the shaft.

As shown in FIGS. **2, 3** and **4**, each inlet to the pumping chambers is provided with a ball **226** and **228** respectively made of a non-corrosive, comparatively lightweight material such as hollow aluminum. The balls are positioned to rise into contact with the seat portions **230** and **232** respectively of the inlets to prevent oil flow from the respective pumping chambers back through the inlets. If the pump is stopped while connected to a device being evacuated, and the device is under vacuum, the oil in the pump will tend to be sucked into the device. The balls **226** and **228** prevent this occurring.

An aperture **234** is provided in the end wall of the oil reservoir section **24**, and a transparent window member **236** is disposed therein, for visual inspection of the oil level within the oil reservoir. The oil level in the oil reservoirs **80** and **82** is preferably maintained slightly below the top of the stacks **68** and **68'**, so that the gas issuing from the pumping chamber outlets is exhausted through the stacks above the level of oil in the reservoir and impinges against the baffle **96**. A sight line may be provided on the member **236** to provide a quick visual indication of the proper oil level in reservoir **82**.

Each of the reciprocating vanes **50** and **50'** is provided with a shallow oil groove **238** extending longitudinally of the end face of the vane and terminating spaced from opposite ends thereof, one of which grooves is shown in FIG. **3**. As the vane **50** reciprocates upon rotation of the piston or displacer **48**, its free end projects into the oil reservoir **80**, and oil can thereby flow into the grooves **238** in opposite end faces of the vane to provide an oil seal between the vane and the adjacent surfaces of the blocks **30** and **34**, thereby preventing any leakage across the vane.

By reference to FIGS. **2** and **5**, it will be apparent that a pumping section **22** for a double stage vacuum pump may be provided by assembling the members **30, 32, 34, 36** and **38** in face-to-face relation, and securing them together by the through bolts **40** shown in FIG. **2**. Some of these same basic parts may be utilized to construct a single stage vacuum pump, i.e. members **30, 32** and **38** may be assembled together in similar fashion to provide a pumping section for a single stage vacuum pump. Thus it can be seen that the same basic components can be utilized for constructing both single and multi-stage vacuum pumps, and that such parts may be stockpiled and assembled with a minimum of delay to satisfy orders as they are received.

As can be seen from FIG. **2** the oil reservoir section **24** may be easily and quickly assembled atop the pumping section **22**, and the oil reservoir section **24** may be identical for double stage pumps, irrespective of whether they are to operate in series only, or whether they are provided with means for enabling both series and parallel operation. For the so-called switchable pump, i.e. one that can be operated in either series or parallel, a top cap such as shown at **26** in FIG. **2** is provided, whereas if it is desired that the pump be capable of operating in only one mode, a top cap assembly can be provided without the valve structure shown in FIG. **3** to satisfy such requirement. However, the remaining parts of the pump, namely all of the components comprising the pumping section **22** and the oil reservoir section **24** will be identical, thereby considerably simplifying the pump assembly procedures, and in addition diminishing to a greater extent the number of parts necessary to be kept on hand to satisfy incoming orders.

Assuming that a double stage switchable pump is to be provided, the pumping section members **30, 32, 34, 36** and **38** of FIG. **5** are assembled together to provide the pumping section assembly **22** shown in FIG. **2**, with the rotor and vane assemblies, drive shaft and exhaust stacks properly positioned as shown. The oil reservoir section **24** is then fastened atop the pumping section **22**, and finally the top cap section **26** is fastened atop the reservoir section **24**. The reservoir section is charged with oil until the oil reaches a level spaced slightly below the upper end of the stack **66** and **68'**, say about one-eighth of an inch therebelow. This oil fills all of the oil sealing grooves **42**, thereby serving to provide an effective oil seal surrounding each pumping chamber **46** and **46'**. These oil seals eliminate the need for mechanical sealing means between the members which make the pumping section **22** shown in FIG. **5**, and thus simplify the assembly procedure and in addition are not subject to deterioration and failure as are mechanical seals. The oil in the oil reservoir **82** also fills the sealing grooves **106, 108, 110, 112, 118, 120** and **122** shown for example in FIG. **9** by virtue of the fact that the ends **114, 116, 124** and **126** of such grooves communicate with the oil reservoir **82**. These grooves thereby provide an oil seal between the abutting faces of the reservoir section **24** and the pumping section **22,** again eliminating the need for mechanical seals about the fluid passages therein.

The top cap section **26** is then superimposed upon the oil reservoir section **24**, and the exhaust muffler **170** is threaded into the top cap exhaust port **94.** The vacuum pump assembly may be either directly coupled to a suitable electric drive motor **28** as shown in FIG. **1** by connecting the shaft **56** to the output shaft of the motor **28,** or the pump may be belt-driven by providing suitable pulleys and a drive belt interconnecting the pump shaft **56** and the drive shaft of the motor **28.**

The two vacuum pump stages shown in FIGS. **3** and **4** are fixed to a common shaft, and thus operate in identical fashion, albeit 180° out of phase, so a description of one will suffice for both. Referring to FIG. **3,** with the parts positioned as shown and the rotor or diplacer **48** rotating in a counterclockise direction, the portions of the chamber **46** identified by numerals **250** and **252** are of approximately the same size. As the displacer **48** continues rotation, chamber **252** decreases in volume, compressing the gases therein and eventually opening valve **62** to exhaust the compressed gases. Meanwhile chamber **250** is increasing in volume, drawing gases from the device to be evacuated through inlet **58** into the chamber. Rotor **48** eventually reaches a position blocking outlet **60,** at which point the entire pumping chamber is open to inlet **58,** and the displacer begins compressing the gases therein as it continues its rotation to close inlet **58** and then to begin compression of the gases within the chamber.

With the parts completely assembled as above described, the inlet **158** in the top cap section **26** may be suitably connected to a device to be evacuated, and the motor **28** connected to a suitable electric supply to run the pump. In the case of a so-called switchable pump, the two stages of the pump shown most clearly in FIGS. **3** and **4** will be first operated in parallel until a predetermined vacuum is reached, and then the valve **142** will be shifted to switch to series operation, so that a desired high vacuum may be attained. For example, with a system at atmospheric pressure, the pump stages are operated in parallel, i.e. each stage is directly coupled to the system to be evacuated, and a partial vacuum is quickly attained. Then the pump is switched to series operation, i.e. the first stage is coupled to the system, and the second stage is coupled to the first stage exhaust, whereby a much higher vacuum may be attained. When operated in series, the pump stage shown in FIG. **3,** which is the first stage, may be referred to as the "roughing" stage, while the second stage depicted in FIG. **4** may be referred to as the "finish" stage.

To operate the two stages of the pump in parallel, the spool valve **142** is positioned as shown in solid outline in FIG. **3,** and the inlet **158** is connected to the device to be evacuated. With the valve in this position, the inlet passage **156** communicates with the pumping chamber **46** through the passages **84, 86** and **58,** and also with the pumping chamber **46'** through passages **164, 166, 168, 90, 92** and **58'** (FIGS. **3, 7** and **4**). Both stages of the pump are thus directly coupled to the device to achieve a predetermined vacuum therein as quickly as possible with the pump stages operating in parallel. As can be seen from FIG. **3,** during this mode of operation, the pumping chamber **46** draws gases in through inlet **58** and exhausts the compressed gases through passages **60, 66** and **70** into the oil reservoir **80,** and thence through passages **88, 160,** valve chamber **140** and passage **162** into the oil reservoir **82,** and thence to the outlet **94.** At the same time, pumping chamber **46'** draws gases in through passages **156, 164** (FIG. 3), crossover **166** (FIG. 7) and passages **168, 90, 92** and **58** ', and exhausts through passages **60', 66', 70'** into the reservoir **82** and thence to the outlet **94.**

When the system or device reaches a predetermined vacuum, the spool valve is shifted to its position indicated in phantom outline at **142'** in FIG. **3,** which switches the pump from parallel to series operation. In this position, communication between inlet **158** and passage **164** is blocked, as is communication between passages **160** and **162,** while communication is established between passages **160** and **164.** Thus incoming gases are introduced first through a "roughing" stage defined by chamber **46** in FIG. **3,** and from there they pass through the exhaust and thence into "finish" stage **46'** (FIG. **4**) through passages **160, 140, 164** (FIG. **3**), **166, 168** (FIG. **7**), **90, 92** and **58'** (FIG. **4**). Exhaust from the "finish" stage is as before through oil reservoir **82,** exhaust port **94** and muffler **170.**

In FIG. **13** there is shown schematically control means for automatically switching the pump between parallel and series operation. THe vacuum pump is therein identified by numeral **20** and is shown as having solenoid-operated valve **260,** the valve portion of which may be similar to valve **142** (FIG. 3) and which operates in an identical fashion as previously described, except that it is solenoid-actuated rather than manually actuated. The system to be exhausted, indicated at **262,** is coupled to the pump inlet **158** by a suitable conduit **264** having a Tee fitting **266.** Connected to the free end of the Tee **266** is a pressure responsive switch **268,** which is in turn electrically coupled to the solenoid valve **260** by suitable connectors **270.** Solenoid **260** is normally in a position whereby its valve is in the position of the spool valve **142** in FIG. **3,** i.e. for parallel pump operation. When the system **262** is drawn down to a predetermined point as determined by the setting of switch **268,** the switch is actuated, thereby energizing the solenoid to shift its valve to the position wherein the pump is operated in series. If pressure in the system again rises past the setting of switch **268,** the solenoid will be deenergized, shifting the valve back to its "parallel" operating position.

In a double stage pump as depicted in the drawings, both gas ballast and oil injection are provided in the second or finish pump stage. Gas ballast is accomplished through the passage **174** (FIGS. **4** and **10**) and opening of the valve **184** serves to connect such passage to atmosphere so that as the piston **48'** rotates counterclockwise as shown in FIG. **4,** it passes passage **174** shortly after start of its compression cycle. Air is therefore introduced into the chamber **46'** during that portion of the piston stroke when the chamber pressure is below atmospheric. As the piston **48'** continues its rotation, passage **174** is obturated by the piston face, closing off the air ballast during the remainder of the piston stroke.

Oil injection into the chamber **46'** is governed by the valve **200** (FIGS. **6** and **12**) and obturation of the port **194** by the piston is not relied upon to shut off the oil injection. Referring to FIG. **4,** just after the piston passes inlet **58'** the pressure in the chamber **46'** is at minimum and the pressure of the oil in passage **190, 198,** which is at atmosphere plus the head of oil in the oil reservoir **82** and groove **42,** overcomes the pressure of spring **202** against valve **200,** opening the valve to admit oil to the chamber **46'**. As the piston continues its rotation, pressure in the chamber increases due to compression of the gas therein, until the gas pressure plus the spring pressure overcomes the pressure of the oil in passage **190, 198,** closing the valve, the pressure of spring **202** determines the length of time the valve **200** is open, and hence by variation of the spring pressure, the amount of oil injected may be varied.

What is claimed is:

1. In a rotary vacuum pump having at least one member defining a pumping chamber with a rotary displacer therein and an end plate overlying and closing one end of the chamber and mating with the chamber member, an oil reservoir atop said chamber, an oil sealing groove at the interface between the end plate and the chamber member and extending in circumferentially spaced relation around the chamber and communicating at the upper end with the oil reservoir, and passageway means establishing communication between the lower end of the oil sealing groove and the pumping chamber whereby oil flows from said reservoir downwardly through the oil groove and is admitted to said pumping chamber from the lower end of the oil groove.

2. A rotary vacuum pump as defined in claim **1** characterized by a pressure responsive check valve means for permitting flow from said oil sealing groove into said chamber and preventing flow in the reverse direction.

3. A rotary vacuum pump as defined in claim **1** characterized in that said oil reservoir comprises a housing abutting said at least one member and having a fluid inlet passage communicating with said chamber and adapted for connection with a device to be exhausted, and an oil sealing groove at the interface between said housing and said member and surrounding said fluid inlet to the chamber and communicating with the oil reservoir to provide an oil seal about the chamber inlet between said member and said housing.

4. A rotary vacuum pump as defined in claim **1** characterized in that said passageway means comprises a generally vertical passageway communicating at its lower end with said oil sealing groove and a generally horizontal passageway establishing communication between said vertical passageway and said chamber at a point spaced above said lowermost extremity of the groove.

5. A rotary vacuum pump as defined in claim **4** characterized in that pressure responsive check valve means is positioned in said vertical passageway to permit oil flow from said oil sealing groove to said chamber and prevent flow in the reverse direction, said valve means comprising a valve seat, a valve body above said seat for sealing engagement thereagainst and constant rate spring means engaging said valve body urging the body toward said seat.

6. The invention defined by claim **1** characterized in that there are a pair of said end plates closing opposite ends of the chamber and mating with the chamber member, and there is an oil groove as aforesaid at the interface between each end plate and the chamber member, and passageway means for establishing communication between the pair of oil grooves at the lower ends thereof, whereby oil flows downwardly through each oil groove for entry into the chamber.

7. The invention defined by claim **6** characterized in that valve means is provided for controlling flow between said oil sealing grooves and the chamber.

8. The invention defined by claim **1** characterized in that said pump includes a plurality of block-like members secured together in face-to-face relation defining a plurality of axially aligned pumping chambers and there is one of said oil sealing grooves at the interfaces between said members.

9. The invention defined by claim **8** characterized in that each of said grooves communicates at its upper end with said oil reservoir.

10. The invention defined by claim **9** characterized by passage-way means for establishing communication between all of the oil sealing grooves at their lower ends and one of said pumping chambers.

11. The invention defined by claim **10** characterized by pressure responsive check valve means in said passageway means for permitting oil flow into said chamber from said oil grooves but preventing reverse oil flow.

12. The invention defined by claim **1** characterized by the provision of valve means for controlling the amount of oil admitted to said pumping chamber from the oil sealing groove.

13. The invention defined by claim **12** characterized in that said valve means is responsive to a predetermined lower pressure in the pumping chamber than in the oil sealing groove to admit oil to the pumping chamber from the groove and responsive to a lesser or reverse pressure differential to prevent oil flow either into the chamber from the groove or reverse pressurization from the chamber to the oil sealing groove.

* * * * *