# United States Patent

**Yarger**

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## [54] MULTIPLE PISTON PUMP APPARATUS


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[58] **Field of Search**.....417/273, 286, 288, 270



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[57] **ABSTRACT**

A multiple piston pump apparatus having a plurality of pump cylinders and pump pistons in the cylinders operated in successive preselected phase relation to deliver fluid from the several cylinders to a common utilization device, and in which provision is made for relieving the output of one or more of the pump cylinders as the delivery pressure builds up, to thereby deliver the combined output from the pump cylinders to the utilization device at low pressures and to reduce the volume output of the pump and hence the power required to drive the pump at relatively higher delivery pressures.


**8 Claims, 2 Drawing Figures**

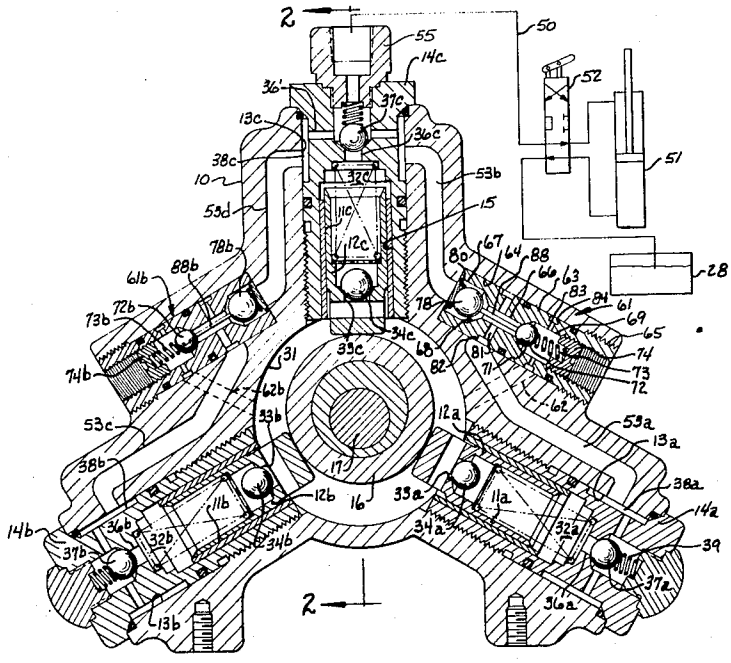
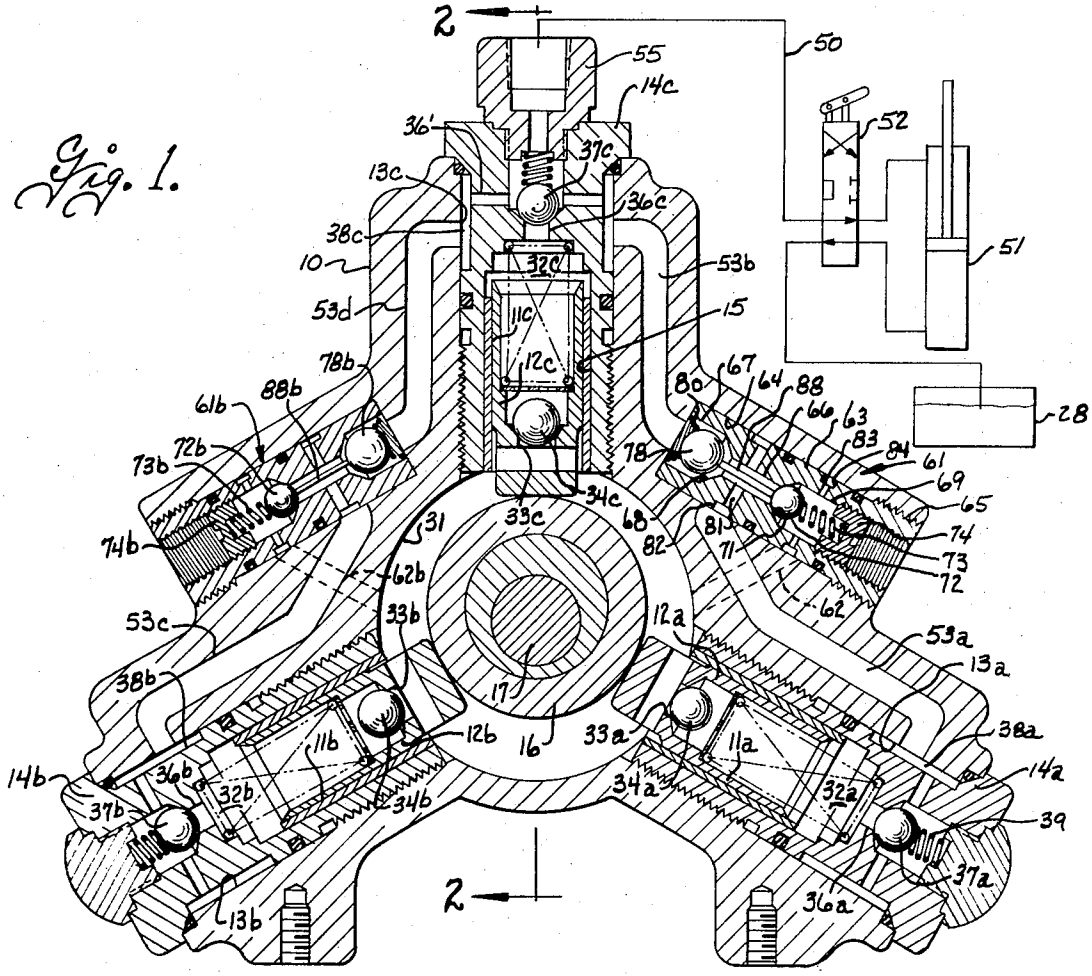


Fig. 1.



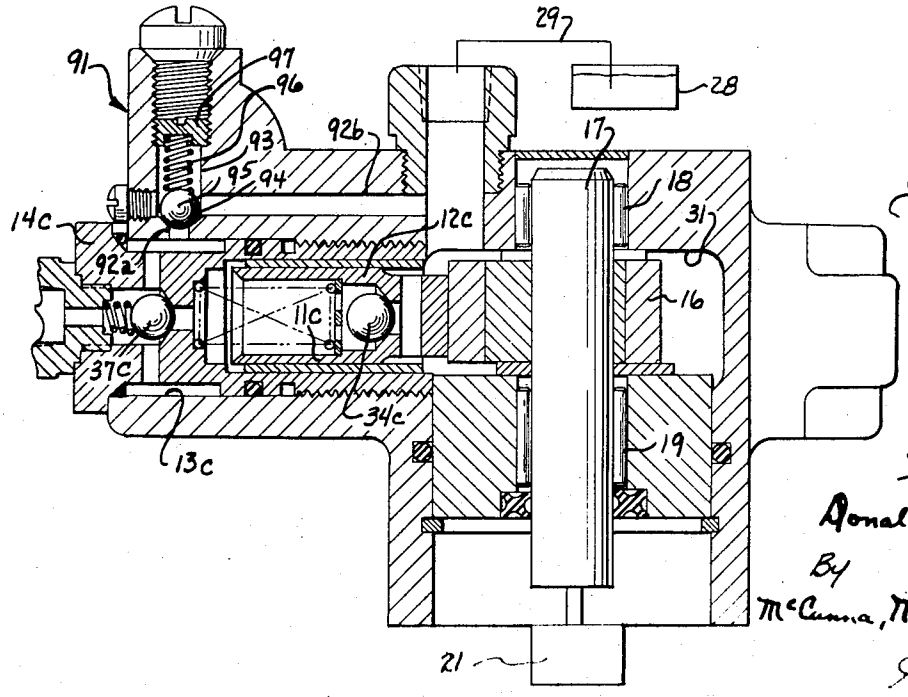




Fig. 2.

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# MULTIPLE PISTON PUMP APPARATUS

## BACKGROUND OF THE INVENTION

In some hydraulic apparatus, the load on the hydraulic apparatus changes during its cycle of operation from a light load to a relatively heavy load. In other hydraulic apparatus, the load on the hydraulic apparatus may vary due to unusual or above normal peak loading on the hydraulically operated equipment. It is heretofore been proposed, for example as disclosed in U.S. Pat. No. 2,366,388 and 2,377,556 to utilize several different pumps, usually of the rotary gear or vane type, arranged in a system to deliver large volumes of fluid at low pressures and relatively smaller volumes of fluid at high pressures. It was a common practice in such multiple pump systems to arrange the multiple pumps so as to operate in parallel when the delivery pressure is low and to thereafter connect the pumps in series so that the output of one pump is delivered to the input of a second pump to reduce the pressure differential across each pump stage.

## SUMMARY OF THE INVENTION

The present invention relates to a multiple piston type pump having a plurality of pump cylinders and pump pistons in the cylinders operated in successive preselected phase relation. The discharge passages from the several cylinders are normally connected to a common delivery line leading to the fluid utilization device for a relatively high volume flow. Provision is made for relieving the output of some of the pump pistons as the delivery pressure builds up so as to reduce the number of pumping pistons which are effective to deliver fluid to the utilization device, and thereby minimize the peak power requirements for driving the pump. When the output of any one of the pump cylinders is relieved, flow from the delivery passage to that pump cylinder is automatically shut off. The valve arrangement for relieving the pump cylinders is advantageously so arranged as to unload that cylinder when the delivery pressure reaches the preset relief pressure for that cylinder.

An important object of this invention is to provide a multiple piston pump apparatus which is adapted to deliver high volume at low pressures and relatively lower volume at high pressures to reduce the overall power requirements necessary for driving the pump.

A more particular object of this invention is to provide a multiple piston pump in which the output of the several pump cylinders is successively relieved as the delivery pressure increases to thereby successively reduce the number of pistons in the pump which are effective in delivering fluid pressure, as the delivery pressure increases.

Yet another object of this invention is to provide a multiple piston pump in accordance with the foregoing object having an improved valve arrangement for unloading the pump cylinder, when the delivery pressure reaches the relief pressure preset for that pump cylinder.

These, together with other objects and advantages of this invention will be more readily understood by reference to the following detailed description when taken in connection with the accompanying drawings wherein:

FIG. 1 is a sectional view through a multiple piston pump apparatus embodying the present invention; and



FIG. 2 is a transverse sectional view taken on the plane 2—2 of FIG. 1.

Referring now more specifically to the accompanying drawings, the pump apparatus in general includes a casing **10** having a plurality of pump cylinders **11** therein, pump pistons **12** slidably mounted at each of the cylinders, and a cam means **16** for reciprocating the pistons in successive preselected phase relation. In the embodiment shown, a three piston type pump is illustrated, it being understood that a greater number of cylinders and pistons can be utilized if desired in practicing the present invention. The pump may be of the radial or axial piston type wherein the pump cylinders and pistons are circumferentially spaced apart for operation by the cam in preselected phase relation. In the embodiment illustrated, the pump is of the radial piston type and the pump cylinders **11** are formed in cartridges mounted in bores in the pump casing, as more fully disclosed in my copending application for U.S. letters Pat. Ser. No. 58,529 filed July 27, 1970, entitled "Piston Type Pump." In general, the pump includes a plurality of circumferentially spaced bores, herein shown three in number and designated **13***a*, **13***b* and **13***c*, cartridges **14***a*–**14***c* removably mounted in the bores as by threaded engagement therewith, and sleeve liners **15** in the cartridges defining the pump cylinders **11***a*–**11***c*. Pump pistons **12***a*–**12***c* are slidably mounted in the pump cylinders **11***a*–**11***c* respectively and are cyclically reciprocated in preselected phase relation by a cam **16**. As best shown in FIG. **2**, the cam **16** is mounted on a shaft **17** ratatably supported by bearings **18** and **19** on the pump casing, and the shaft is adapted to be driven by a motor diagrammatically indicated at **21**.

Fluid is supplied to the pump from a supply source such as a reservoir diagrammatically shown at **28** in FIGS. **1** and **2**, trough a fluid supply line **29** connected to an inlet chamber **31** in the pump. The pistons **12***a*–**12** in the respective cylinders **11***a*–**11***c* define motive chambers **32***a*–**32***c* between the pistons and the cylinder heads. Inlet passage means **33***a*–**33***c* and inlet valve means **34***a*–**34***c* are provided to supply fluid to the motive chamber during the intake stroke of the respective piston, that is during movement of the piston relative to the cylinder in a direction to expand the respective motive chamber. In the form shown, the inlet valve means are in the form of check valves conveniently located in the pistons, and the inlet passage means are also located in the pistons and extend from the respective motive chamber to the fluid supply chamber **31**. Fluid discharge passage means **36***a*–**36***c* and fluid discharge valve means **37***a*–**37***c* are provided for each motive chamber to allow delivery of fluid from each motive chamber during the discharge stroke of the respective piston, that is during movement of the piston in a direction to contract the respective motive chamber. In the embodiment shown, the discharge valve means **37***a*–**37***c* are in the form of check valves and the discharge passages **36***a*–**36***c* are formed in the cartridges to communicate at one end with the respective motive chamber and have lateral passage portions **36'** that communicate at their outer ends with a respective annular distribution channel **38***a*–**38***c* formed between the cartridge and the bores in the pump casing. As is well known, the inlet check valves **34***a*–*34c* are arranged to close in a direction opposite the

direction of fluid flow from the supply chamber **31** through the inlet passage into the motive chamber, and the discharge check valves **37***a*–**37***c* are arranged to close in a direction opposite the direction of flow of fluid from the respective motive chamber. Springs **39** are provided for yieldably urging the outlet check valves to a closed position with a relatively light force. The inlet check valves can be urged to a closed position by the fluid pressure in the respective motive chamber or by a suitable check valve spring (not shown).

The discharge passages **36***a*–**36***c* from the several motive chambers **32***a*–**32***c* respectively are connected to a common delivery passage **50** so as to supply fluid from the several motive chambers to a fluid utilization device **51**. While the utilization device can be of different forms, it is herein diagrammatically shown as a cylinder having a movable piston therein which is reversibly operated under the control of a flow reversing valve **52**. As shown, the discharge chamber **38***a* of motive chamber **32***a* is connected through cored passages **53***a* and **53***b* in the valve casing to the discharge chamber **38***c* and, similarly, the discharge chamber **38***b* of motive chamber **32***b* is connected through cored passages **53***c* and **53***d* in the valve casing to the discharge chamber **38***c*. The delivery passage **50** is in open communication with the discharge camber **38***c* and in the form shown, is connected through a fitting **55** on the cartridge **14***c* and through the lateral discharge passage portions **36'** in the cartridge **14***c* with the discharge camber **38***c*.

The pump is arranged so as to deliver fluid from the several motive chambers **32***a*–**32***c* to the delivery passage **50** leading to the utilization device **51** when the pressure in the delivery passage is relatively low to provide high volume flow at low pressures and provision is made for relieving the fluid pressure discharge from one or more of the motive chambers as the pressure in the delivery passage builds up to reduce the volume output of the pump and hence the power required to drive the pump at relatively higher pressures. At best shown in FIG. **1**, a first valve assembly **61** is provided for controlling the flow of fluid between the discharge passage **36***a* associated with one motive chamber **32***a*, the delivery passage **50**, and a first relief passage **62** that leads back to the fluid supply such as the inlet chamber **31**. The valve assembly **61** is conveniently of the cartridge type including a body **63** which is mounted in a bore **64** in the valve casing, as by threaded engagement therewith as indicated at **65**. The valve body **63** has an axial passage **66** and is counterbored at one end to form a valve chamber **67** and a seat **68** between the chamber **67** and the bore **66**. The body **63** is also counterbored at its other end to provide a valve camber **69** and a second seat **71** between the chamber **69** and the passage **62**. A relief valve member **72** is disposed in the chamber **69** and is yieldably urged as by a relief valve spring **73** to a closed position against the seat **71**. As shown, the spring **73** is interposed between the valve member **72** and an adjustable plug **74** to allow adjustment of the spring pressure applied to the valve member **72** to thereby adjust the relief pressure. A delivery valve member **78**, conveniently in the form of a ball valve, is disposed in valve chamber **67** and is movable to a position in engagement with seat **68** to block flow therethrough.

The passage **66** in the valve body **63** communicates through passages **81** and groove **82** with the passage **53***a* leading to the discharge chamber **38***a* and discharge passage **36***a*. Valve chamber **67** in the body **63** communicates through passage **53***b*, discharge camber **13***c* and lateral passage portions **36'** in the cartridge **14***c* with the delivery line **50**. Valve chamber **69** in the valve body **63** communicates through lateral passages **83** and groove **84** with the relief passage **62**. Thus, fluid discharged from motive chamber **32***a* normally flows through discharge passage **36***a*, discharge chamber **38***a*, passage **53***a* and through passages **81**, past seat **68** and through passage **53***b* to the delivery passage **50**. As will be seen, valve **78** is arranged to open for flow from the passage **66** to the delivery passage. Relief valve **72** is normally urged to its closed position blocking flow to the relief passage until the pressure in the delivery passage reaches a preselected value sufficient to overcome the pressure of spring **73**. At that time, the relief valve opens to allow flow from the passage **53***a* through the relief passage **62**. At that time, the pressure in the passage **66** drops below the pressure in the delivery passage and the delivery valve **78** is thereby pressure urged to a position against seat **68** to block flow from the delivery line back to the discharge passage of chamber **32***a*. If desired, a lightweight spring **80** can be provided to aid in moving the valve **78** to its closed position. The valve assembly is advantageously arranged so as to unload the motive chamber associated with the valve as soon as the delivery pressure reaches the preset relief pressure of the spring **73**. For this purpose, a member **88** is interposed between the valve member **78** and the relief valve member **72** so that the fluid pressure acting on the delivery valve member **78**, when the latter is closed, holds the associated relief valve member **72** in its open position to thereby provide relatively free discharge of fluid from passage **53***a* back through the relief passage.

A second valve assembly **61***b* is advantageously provided for controlling flow from the motive chamber **32***b* to the delivery passage **50** and a relief passage. The valve assembly **61***b* is conveniently constructed in the same manner as the valve **61** and like numerals followed by the subscript prime (b) are used to designate corresponding parts. Thus, valve assembly **61***b* also includes a relief valve **72***b* for controlling flow of fluid from discharge passage **53***c* back trough a relief passage **62***b*, and a delivery valve **78***b* for controlling flow of fluid between the passage **53***d* leading to the delivery passage **50** and the passage **53***c* leading to motive chamber **32***b*. Relief valve **72***b* is also yieldably urged as by a spring **73***b* to a closed position, the spring pressure being adjustable as by an adjustable plug **74***b*. The relief pressure on relief valve **73***b* can be adjusted as to relieve the discharge from the motive chamber **32***b* at a pressure relatively different from that of relief valve **72** and may, for example, be a relatively higher pressure so that the motive chambers **32***a* and **32***b* are successively relieved as the pressure builds up. Valve **78***b* is arranged to close when the relief valve **72***b* opens to block flow from the delivery passage back to the motive chamber and a member **88***b* is provided to hold the relief valve in its open position while the delivery valve **78***b* is closed so as to unload motive chamber **32***b*.

A relief valve is also provided for the delivery passage to limit the maximum pressure in the delivery line **50**. As shown in FIG. **2**, this relief valve **91** is conveniently located in the pump casing and includes a relief passage portion **92***a* communicating with the chamber **13***c*; a relief valve chamber **93**, and a relief passage portion **92***b* extending from the valve chamber **93** back to the fluid supply such as the chamber **31**. A relief valve seat **94** is provided between the chamber **93** and the relief passage portions **92***a* and **92***b* and a relief valve member **95** is mounted in the chamber and yieldably urged as by a relief spring **96** to its closed position. An adjustable plug **97** is provided for adjusting the relief pressure applied to valve **95**. Plug **97** is adjusted so as to relieve at a somewhat higher pressure than either relief valve **72** or **72***b*.

From the foregoing it is thought that the construction and operation of the pump apparatus will be readily understood. The pump drive cam **16** driven by the motor **21** operates to cyclically reciprocate the pistons **12***a*–**12** in preselected phase relation and the motive chambers **32***a*–**32***c* associated with the several pump pistons are arranged so as to deliver their combined discharges to the common delivery passage **50** leading to the fluid utilization device **51**, when the pressure in the delivery passage is below a preselected value determined by the setting of relief valves such as **72** and **72***b*. When the pressure in the delivery passage reaches the preset relief pressure for relief valve **72**, relief valve **72** opens and delivery valve **78** closes to thereby bypass the fluid discharged from chamber **32***a* back through the relief passage **62**. Closing of delivery valve **78** prevents flow of fluid from the delivery passage back through the relief passage or to the discharge passage associated with chamber **32***a* and also holds the relief valve **72** in its open position to unload the motive chamber **32***a*. In the three piston pump shown, it is contemplated that a second one of the motive chambers be relieved at a relatively high pressure and that relief valve **72***b* be set to operate in a relief pressure somewhat higher than valve **72** and below the delivery line relief pressure determined by relief valve **95**. Accordingly, after relief valve **72** opens, fluid will continue to be delivered from motive chambers **32***b* and **32***c* to the delivery line **50** until the pressure in the delivery line reaches the relatively higher relief pressure set for valve **72***b*. At that time, relief valve **72***b* opens to bypass the fluid discharged from motive chamber **32***b* back to the relief passage and delivery passage **50** and to also hold the relief valve **72***b* open. Motive chamber **32***c* continues to delivery fluid under pressure to the delivery line **50** to thereby enable delivery of fluid at a relatively high pressure but reduced volume so as to minimize the power requirements necessary for achieving a certain maximum pressure. For example, in the three piston pump shown, the relief valves **72** and **72***b* can be preset so as to relieve at respectively ⅓ and ⅔ of the maximum discharge pressure required and under these circumstances, the horsepower requirements of the motor **21** will be only approximately ⅓ of that which would be required if all three pistons were effected to deliver fluid under the maximum pressure requirements of the system. As will be appreciated, the numbers of cylinders and pistons utilized can be increased from the three piston arrangements shown and may, for example, be increased to five or seven. As will be appreciated, relief of several motive chambers could be achieved at the same pressure, if a high number of pressure steps are not required.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

**1**. A pump apparatus comprising:

a. a multiple piston pump including casing means defining at least two pump cylinders, a pump piston slidable in each pump cylinder and defining a motive chamber therein, eccentric means for cylically reciprocating the pistons in successive preselected phase relation, fluid supply means including inlet passage means and inlet valve means operative to open to supply fluid to the motive chambers during the intake stroke of each piston, fluid discharge valve means operative to open to allow delivery of fluid from each motive chamber to the respective fluid discharge passage means during the discharge stroke of each piston, fluid delivery passage means adapted to supply fluid to a utilization device and communicating with the fluid discharge passage means associated with at least two of said motive chambers to receive fluid therefrom, a first pressure relief passage means communicating with said fluid supply means and with a first of said fluid discharge passage means associated with a first of said motive chambers,

b. a first valve means controlling flow between said first discharge passage means and said first relief passage means and said delivery passage means, said first valve means including a relief valve seat intermediate said first discharge passage means and said first relief passage means and facing in the direction of fluid flow to the first relief passage means, a relief valve member having means yieldably biasing the same toward a seated position against said relief valve seat and responsive to a first preselected fluid pressure in said first discharge passage means to unseat for flow through the relief passage means, said first valve means also including a delivery valve seat intermediate said first discharge passage means and said delivery passage means and facing in the direction of fluid flow to the delivery passage means, a delivery valve member cooperable with said delivery valve seat and operable when seated to block return flow from the delivery passage means to said first discharge passage means, and means operatively interconnecting said delivery valve member and said relief valve member for holding said relief valve member in an unseated position when said delivery valve member is seated to thereby unload said first motive chamber, and

c. at least one other valve means operative when the fluid pressure in a second of said passage means reaches a pressure substantially higher than said first preselected fluid pressure for passing fluid from the second discharge passage means back to said supply means.

**2**. A pump apparatus according to claim **1** wherein said relief valve seat and said delivery valve seat are disposed in axial alignment, said means for holding said

relief valve member unseated comprising a rigid member extending between said relief valve member and said delivery valve member.

3. A pump apparatus according to claim 1 wherein said delivery valve member is larger than said relief valve member.

4. A pump apparatus according to claim 1 wherein said first valve means including said first relief valve seat and first relief valve member and said first delivery valve seat and first delivery member are formed in a cartridge body removable as a unit from said casing means.

5. A pump apparatus comprising:

a. a multiple piston pump including casing means having at least two pump cylinders, a pump piston slidable in each cylinder and defining a motive chamber therein, eccentric means for cylically reciprocating the pistons in successive preselected phase relation, fluid supply means including inlet passage means and inlet valve means operative to open to supply fluid to the motive chambers during the intake stroke of each piston, fluid discharge passage means and fluid discharge valve means individual to each motive chamber operative to open to allow delivery of fluid from each motive chamber to the respective fluid discharge passage means during the discharge stroke of each piston,

b. a first valve means including a valve passage means communicating intermediate its ends with a first of said discharge passage means associated with a first of said motive chamber; a relief valve chamber at one end of the valve passage means defining a relief valve seat around one end of the valve passage means; and a delivery valve chamber at the other end of said valve passage defining a delivery valve seat around the other end of the valve passage means, a relief passage means communicating with said relief valve chamber, a fluid delivery passage adapted to supply fluid to a utilization device communicating with said delivery valve chamber and with the discharge passage means associated with at least one other motive chamber, a relief valve member in said relief valve chamber having relief spring means yieldably biasing the relief valve member to a seated position against said relief valve seat and responsive to a first preselected fluid pressure in said first discharge passage means to unseat for flow through the relief passage means, a delivery valve member in said delivery valve chamber operable when seated to block flow from the delivery passage means to said valve passage means, and means operatively interconnecting said delivery valve member and said relief valve member for holding said relief valve member in an unseated position when said delivery valve member is seated to unload said first motive chamber, and

c. at least one other valve means operative when the fluid pressure in a second of said discharge passage means reaches a pressure substantially higher than said first preselected fluid pressure for passing fluid from the second discharge passage means back to said supply means.

6. A pump apparatus according to claim 5 wherein said means interconnecting said relief valve member and said delivery valve member includes a rod extending through said valve passage means.

7. A pump apparatus according to claim 6 wherein said delivery valve member is larger than said relief valve member.

8. A pump apparatus according to claim 7 wherein said relief valve member and said delivery valve member comprise ball members.

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