Feb. 16, 1960 R. W. BRUNDAGE 2,925,044

HYDRAULIC PUMP OR MOTOR

Filed March 22, 1956

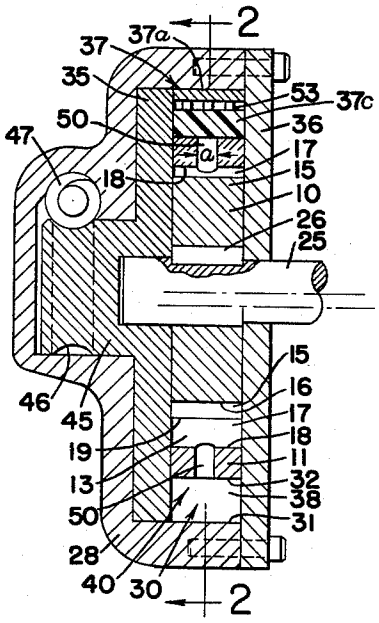


FIG. 1

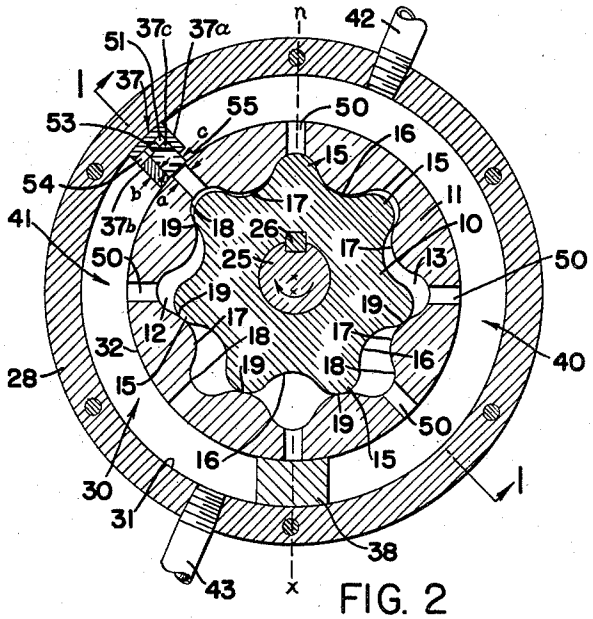


FIG. 2

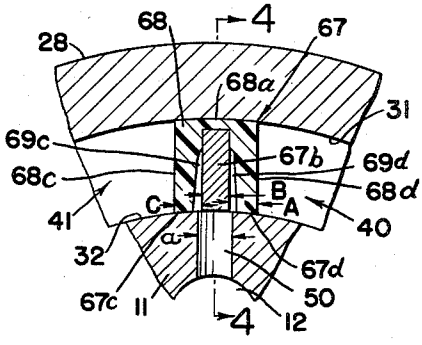


FIG. 3

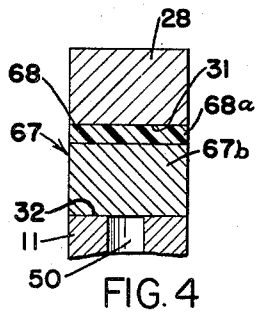


FIG. 4

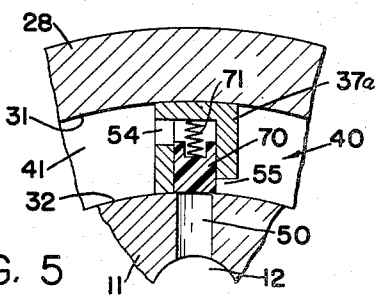


FIG. 5

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United States Patent Office 2,925,044
Patented Feb. 16, 1960

2,925,044

HYDRAULIC PUMP OR MOTOR

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Application March 22, 1956, Serial No. 573,292

6 Claims. (Cl. 103—120)

This invention pertains to the art of hydraulic pumps or motors and, more particularly, to a rotary positive displacement hydraulic pump or motor of the type having constantly increasing and decreasing volume chambers which are commutated by lands from inlet to outlet manifolds and vice versa.

The invention is particularly applicable to internal-gear type rotary pumps or motors and will be described as applied thereto although it will be appreciated that the invention is equally applicable to, without limitation, vane or barrel type pumps or motors.

Positive displacement rotary pumps are normally comprised of inner and outer members relatively rotatable and so arranged as to define a plurality of chambers which progressively increase and decrease in volume to thus receive and discharge a hydraulic fluid. These chambers communicate with and are commutated between inlet and outlet manifolds by lands which also divide the manifold.

The width of these lands relative to the width of the passages communicating the chambers with the manifolds in the direction of movement heretofore has been a very important part of pump design and operation.

Thus, if the width of the land is narrower than the width of the passage, then for an instant in the arc of rotation of the passage past the land, fluid can leak from the outlet manifold to the inlet manifold around the land through the passage. With high pressure pumps, substantial amounts of fluid can leak past the land in such event. This is ordinarily called "leakage."

If the land is wider than the passage and, for example, the land is positioned adjacent a point in the movement of the chambers where they are decreasing volume, it will be appreciated that for an instant in the arc of rotation no fluid can leave the chamber and very high pressures within the chamber can result. This is ordinarily termed "trapping" and is considered very detrimental in pumps of the type to which this invention pertains. Trapping is the principal problem with which the present invention deals.

If the land is wider than the passage and is adjacent a point in the arc of movement of the chambers where their volume is increasing, there is an instant when fluid cannot enter the chamber and a "vacuum" results. A vacuum produces only relatively small pressure differentials from that which ordinarily exist and is not considered particularly detrimental.

Because of the problems of trapping and vacuum, it has heretofore been conventional to position the lands opposite the point of minimum and maximum volume where the problems of trapping and vacuum are minimized. Here the rate of volume change per arc of rotation is relatively low. Also, with the land positioned adjacent the point of maximum volume, there is a vacuum created in the chamber as it approaches the point which offsets the trapping which would occur after the chamber volume goes from increasing to decreasing.

However, in substantially all pumps of the type to

which this invention pertains there is a problem of leakage between the individual chambers, one exposed to a high pressure and the other to a low pressure, between the surfaces which separate the two chambers. It has been considered desirable to increase the width of a land, either positioned adjacent the points of minimum and maximum volume or otherwise in the pump, so that the land will cover a span of two or more chambers. In such a case, however, the problem of trapping becomes very serious.

This problem of trapping also exists in a serious way where the lands are of a width to prevent leakage and are moved from the points of minimum and maximum volume so as to adjust the volume of fluid passing through the pump or motor for a given arc or rotation or per unit movement.

One method and arrangement for preventing some of the difficulties referred to above has been described in my co-pending patent application Serial No. 497,779 filed March 29, 1955, now Patent No. 2,898,862, issued March 29, 1959. In this application, an arrangement is described wherein only the land normally located adjacent the point of minimum chamber volume is adjustable in the direction of rotation; that is, in the direction of increasing volume. The other land; namely, the one adjacent the point of maximum volume of the chambers, remains fixed. With such an arrangement, some of the fluid under pressure in the outlet manifold flows into some of the increasing volume chambers. These increasing volume chambers then act as a motor to recover the energy of the fluid or at least part of it.

Another method and arrangement for preventing these difficulties has been described in my co-pending application Serial No. 548,022 filed November 21, 1955. In this application, the arrangement is such that the decreasing volume chambers communicate during a portion of the time when opposite a land with an auxiliary passage which has either previously been in communication with an increasing volume chamber or is, at that time, in communication with such an increasing volume chamber and the increasing volume chamber is increasing its volume at a rate equal to, or greater than, the rate of decrease of the decreasing volume chamber.

The present invention contemplates a rotary pump or motor of the positive displacement type wherein the lands may be of any relative width relative to the passages communicating the chambers with the manifolds which is efficient, which avoids the problems of trapping and leakage and which is simple in construction.

The present invention pertains to a variable volume, positive displacement hydraulic pump which is comprised of a plurality of members movable relatively to each other and defining a plurality of pumping chambers which revolve in a fixed closed path of movement, the chambers gradually increasing in volume after they pass a fixed point of minimum volume along this path of movement until they reach a fixed point of maximum volume along this path and then gradually decreasing in volume until they again reach the minimum volume point, means defining an arcuate inlet manifold and an arcuate outlet manifold including a pair of lands, one at each arcuate end of the manifolds and sealingly separating the manifolds from each other, the manifolds and lands being disposed circumferentially along the path of movement of the chambers, and an opening for each chamber which revolves therewith, each of the chamber openings moving past the lands to alternately communicate its associated chamber with either the inlet manifold or the outlet manifold. One of the lands is normally located at the point of maximum volume, so that as each chamber reaches and passes through maximum volume its opening shifts from communication with the inlet mani-

fold to the outlet manifold. The other land is adjustable along the path of movement of the chambers so as to change the point in that path at which each opening moves past such land and shifts communication of its chamber from the outlet manifold to the inlet manifold, thereby enabling the output volume of the pump to be varied. This other land has a circumferential width greater than the circumferential width of each opening, so that when adjusted so as to be opposite a decreasing volume chamber, it will prevent leakage and will normally tend to cause trapping.

However, and in accordance with the present invention, this other land includes valve means arranged to be opened by pressure in such decreasing volume chamber, when such chamber is closed by this land, in excess of that in the outlet manifold so as to communicate such chamber with the inlet manifold at this time and thereby avoid trapping.

Still further in accordance with the invention, at least the land to be positioned opposite the decreasing volume chambers includes a movable member biased to closed position by pressures in the outlet manifold and moved by excess pressure in the decreasing volume chamber opposite the land to communicate the chamber discharge passage with the inlet manifold.

Further in accordance with the invention, at least the land to be positioned opposite the decreasing volume chambers includes an expansible chamber biased to a minimum volume by pressures in the outlet manifold and arranged to communicate with the chamber discharge passage and expand when pressure in the decreasing volume chamber exceeds that of the pressure in the outlet manifold.

Still further in accordance with the invention, the movable member may be formed of a rigid material yieldingly biased by spring pressure or may be formed of a material having a low modulus of elasticity capable of deflecting under the pressures in the pump or motor.

Either one, or both, lands may be adjustable relative to the point of minimum and maximum volume of the chambers.

The principal object of the invention is the provision of a new and improved hydraulic pump or motor of the type where the increasing and decreasing volume chambers are commutated from one manifold to another by lands wherein trapping pressures are immediately relieved by communicating the decreasing volume chamber to the inlet manifold.

Another object of the invention is the provision of a new and improved hydraulic pump or motor of the type described, having lands which are of a width to prevent leakage but which pump or motor is not subject to the problems of trapping.

Another object of the invention is the provision of a new and improved hydraulic pump or motor which is simple in construction, positive in operation and has a high efficiency without troubles from trapping.

Another object of the invention is the provision of a new and improved means of leading off trapping pressures in a hydraulic pump or motor.

The invention may take physical form in certain parts of arrangements of parts, all differing radically in appearance one from the other, preferred embodiments of which will be described in detail in this specification and illustrated in the accompanying drawing which is a part hereof and wherein:

Figure 1 is a side cross-sectional view taken approximately in line 1—1 of Figure 2 of an internal gear-type pump or motor embodying the present invention;

Figure 2 is a cross-sectional view of Figure 1 taken approximately in the line 2—2 thereof;

Figure 3 is a fragmentary detail view showing an alternative embodiment of the invention;

Figure 4 is a cross-sectional view of Figure 3 taken approximately in the line 4—4 thereof; and,

Figure 5 is a view similar to Figure 3 but showing a still further alternative embodiment of the invention.

Referring now to the drawings wherein the showings are for the purposes of illustrating preferred embodiments of the invention only, and not for the purposes of limiting same, Figures 1 and 2 show a plurality of, in this case 2, members **10, 11** relatively movable to each other and so formed as to define a plurality of chambers **12, 13** which respectively increase and decrease in volume as the chambers move. The reference character **12** indicates those chambers which are increasing in volume and the reference character **13** indicates those which are decreasing in volume.

The members 10, 11 can be either the relatively movable members of a vane type pump, the movable members of a reciprocating rotatable cylinder or wobbleplate-type pump, or any other form of pump wherein there are a plurality of chambers which progressively increase and decrease in volume as the members move, and positive chambers are continuously in communication with the input manifold and another part are continuously in communication with an output manifold.

In the embodiment of the invention shown, an internal gear type pump is employed wherein the inner gear is the member **10** and the outer gear is the member **11** and these two gears rotate relative to each other with the direction of rotation being assumed, for the purpose of describing the invention, as clockwise.

The inner gear **10** has a plurality of teeth **15**, and intermediate roots **16** which mesh with teeth **17** and roots **18** of the outer gear **11**. There is one less tooth **15** on the inner gear **10** than there is on the outer gear **11**, and the shape of the teeth and roots is so arranged that at all times each tooth **15** will have a point **19** of sealing engagement with the tooth **17** of the outer gear **10**. Obviously, there could be greater than one tooth differential.

The axes of rotation of the two gears **10, 11** are offset one from the other and in the embodiments shown, there is a point "*n*" of minimum volume and a point "*x*" of maximum volume of the chambers **12** and **13**. It will be noted that a line through the points "*n*," "*x*" divides the chambers **12** and the chambers **13** from each other. Obviously, when the chambers are exactly opposite either the point "*n*" or "*x*," there is no relative increase or decrease of volume although just prior to and after passing by these two points there is a slight change of volume.

The inner gear **10** is mounted for rotation on a drive shaft **25** and is keyed thereto by means of a key **26**.

The two gears **10, 11** are of the same axial thickness and are mounted for rotation in a housing **28** having a circular cavity **30** of a diameter somewhat greater than the outer diameter of the gear **11** and an outer peripheral surface **31** concentric with the outer surface **32** of the gear **11**.

A control member **35** in the form of a circular plate and having a diameter generally equal to the diameter of the cavity **30** is disposed at the base thereof and with the gears **10, 11** substantially fills the cavity **30**. A cover plate **36** fits over the cavity **30** and is in sealing arrangement with the right-hand side of the gears **10, 11** as viewed in Figure 1, as is the control member **35** which is in sealing arrangement with the left-hand side of the gears **10, 11** as viewed in Figure 1.

The control member **35** has a land indicated generally at **37**, which extends axially into the space between the surfaces **31, 32** and is in sliding but sealing engagement with the surfaces. Additionally, there is a land **38** fixedly positioned at the point "*x*" and in sliding, sealing engagement with the surface **32**. These lands **37, 38** divide the space between the surfaces **31, 32** into an inlet manifold **40** and an outlet manifold **41**. Pipes **42, 43** communicate through the wall of the housing **28** with the inlet and outlet manifold **40, 41** respectively to provide an inlet and outlet passage for the pump. It will be noted that the pipes **42, 43** are located about 15° in

the direction of rotation from the points of minimum and maximum volume "*n*," "*x*." Obviously, the pipes **42**, **43** could be otherwise located but because of the adjustability of the land **37**, this location of the inlet and outlet point is particularly advantageous to give maximum range of adjustability with a maximum degree of efficiency. While the land **38** is preferably fixably positioned, it can be made adjustable along with the land **37** by fastening it to the control plate **35**.

The control member **35** is rotatably supported in the housing **28** and has a boss **45** extending into a counter bore in the housing **28**. The boss **45** has helical teeth **46** formed in its surface engaged by a worm wheel **47** having a shaft not shown which extends through the side of the housing **28** and is accessible from the outside so that the control member **35** may be fixedly adjusted to any desired point.

It will be noted that the shaft **25** extends into a recess in the right-hand face of the control member **35** for the purpose of providing a physically strong rotatable assembly.

Each chamber **12**, **13** has a passage **50** extending radially outwardly from each root **18** through the outer surface **32** of the gear **11** communicating either with the inlet manifold **40** or the outlet manifold **41** as the gears rotate.

In operation, as the gears **10**, **11** rotate, the chambers **13** constantly increase in volume thus creating a suction effect. Hydraulic fluid, not shown, flows inwardly through the pipe **42** to the inlet manifold **40**, then through the passages **50** to the chambers **13**.

Hydraulic fluid also flows out of the decreasing volume chambers **12** through the passages **50** into the outlet manifold **41** and then through the pipe **43**. The lands **37**, **38** prevent communication between the inlet and outlet manifolds **40**, **41**. In effect, the passages are commutated as they pass the lands.

If the stops **37**, **38** are positioned adjacent the points of minimum and maximum volume "*n*," "*x*" respectively, the pump would pump its maximum capacity. Thus, all of the enlarging chambers **13** would be in communication through the passages **50** with the inlet chamber **40** and all of the decreasing volume chambers **12** would be in communication with the outlet manifold **41**.

In accordance with the present invention, however, the land **37** is adjustable away from the point "*n*" to provide an adjustable output volume for the pump for a given constant rotational speed. Thus, if the land **37** is adjusted to the position shown in Figure 2, it will be seen that the outlet manifold **41** is in communication with only a portion of the decreasing volume chambers **12** while the inlet manifold **40** is in communication not only with all of the increasing volume chambers **13**, but with the decreasing volume chambers **12** between the land **37** and the point "*n*." Thus the volume output of the pump is decreased.

It will be noted that the passages **50** each have a width "*a*" in the direction of movement. The relationship of the width of the lands **37** in relation to the dimension "*a*" form an important part of the present invention. It should be noted that if the width of the land **37** is equal to or greater than the dimension "*a*," then for a fraction of the arc of rotation, fluid cannot be discharged nor taken into the passage **50**. In the case where discharge of fluid is prevented, a situation, as previously referred to, called "trapping" arises wherein extremely high pressures internally of the decreasing volume chamber **13** can result.

On the other hand, if the width of the land **37** is made less than the dimension "*a*" then for a small fraction of the arc of rotation fluid can flow from the outlet manifold around the land through the outer portions of the passage **50** to the inlet manifold **40**. Leakage results. The present invention deals directly with this problem.

Thus, the land **37** is actually comprised of a plurality of minor, or auxiliary, lands, one of which is operable or

movable to communicate the passage **50** with the inlet manifold **40** when the pressures in the decreasing volume chambers opposite the land reach values above that in the outlet manifold **41**.

As shown in Figure 2, the land **37** is actually comprised of a fixed land **37***b* of a width "*b*" less than the passage width "*a*" and a movable land **37***c* of a width "*c*" greater than the width "*a*" of the passage **50**. The lands **37***b* and **37***c* face or are exposed to the outlet and inlet manifolds respectively. The land **37***c* is preferably movably supported relative to the land **37***b* and is held in position by an L-shaped member **37***a* spaced from the land **37***b* and terminating short of the outer surface **32** of the gear **11** to form a passage **55**. It will be noted that if the auxiliary land **37***c* is moved away from the surface **32**, the passages **50** can communicate with the inlet manifold **40**.

The auxiliary land **37***c* preferably has projections **53** on the outer surface thereof, spacing the outer surface of the land **37***c* from the inner surface of the circumferentially extending portion of the member **37***a*. Additionally, the outer surface of the land **37***b* is spaced from this inner surface to provide a passage **54** from the outlet manifold **41** to the outer surface of the auxiliary land **37***c*. Thus, the land **37***c* is continuously urged into engagement with the surface **32** by the pressures in the outlet manifold **41**.

In accordance with the invention, the land **37***b* is preferably formed of a material having a high modulus of elasticity such as steel, metal or rigid plastic. However, the land **37***c* is preferably formed of a material having a low modulus of elasticity, such as nylon, rubber or the like such as to be movable under pressure to communicate the passage **50** with the inlet manifold **40** through passage **55**.

In operation, the pressure in the outlet manifold **41** continuously presses the land **37***c* toward the surface **32** to maintain the passages **50** closed while opposite the land **37**. However, if for any reason the pressures in the chambers **12** should reach a value above that of the pressure in the outlet manifold **41**, it will be appreciated that the land **37***c* will be deflected and raised from the surface **32** to allow pressure to flow through the passages **50** and **55** to the inlet manifold **40**.

In effect, there is provided a differential pressure valve acting to relieve pressure in the decreasing volume chambers when pressures therein tend to exceed pressures in the outlet manifold.

Figures 3 and 4 show an alternative embodiment of the invention. Here the adjustable land indicated generally at **67** is comprised of a fixed land **67***b* of rigid material and a pair of movable lands **67***c* and **67***d* of a flexible material and arranged so as to move relative to the fixed land **67***b* as will appear.

The land **67***b* is preferably of metal either integral or fastened to the control member **35** and has a surface in sealing engagement with the outer surface **32** of the gear **11** and a width B less than the dimension *a*. The movable lands **67***c*, **67***d* are actually the legs **68***c*, **68***d* of a U-shaped member **68** formed of a material having a low modulus of elasticity such as nylon, rubber or the like and having a base **68***a* in sliding sealing engagement with the surface **31**. The legs **68***c*, **68***d* extend in spaced relationship on both sides of the land **67***b* to form spaces **69***c*, **69***d* respectively on both sides of the land **67***b*. The ends of these legs **68***c*, **68***d* sealingly and slidingly engage the surface **32**. The lands **67***c*, **67***d* have a width when combined with that of the width of the lands **67***b* greater than that of the width *a* of the passage **50**.

In operation, the pressure in the outlet manifold **41** tends to bias the leg **68***c* against the side of the land **67***b*. Thus, as the passage **50** moves past the land **67**, trapping would normally tend to occur. However, when pressure in the passage **50** exceeds the pressure in the outlet manifold **41**, the legs **68***c* will move toward the outlet manifold **41** and the trapped fluid can flow into the space

69c. If the space 69c is not sufficient to relieve the trapping pressure, the leg 68c can continue to move until the fluid can flow directly into the outlet manifold 41.

As the passage 50 continues to move past the land 67, the trapped fluid can then flow into the space 69d and if this space is not sufficiently large, then the leg 68d can be further deflected in the direction of the inlet manifold 41 until a passage is provided between the passage 50 and the inlet manifold 40.

It will be appreciated that the land 67c, 67d could be comprised of rigid members yieldingly biased toward the surface 32 as will generally be described in connection with Figure 5.

Thus, Figure 5 shows a still further alternative embodiment of the invention constructed in a manner quite similar to that of Figure 2 but with the exception that the land 70 is formed of a material having a high modulus of elasticity and is arranged so as to be biased to the sealing engagement with the surface 32 by means of a spring 71 between the portion 37a and the upper or outer surface of the member 70. In a like manner, the upper surface of the member 70 is exposed to the pressures in the inlet chamber 41. Thus, whenever the pressure in the passage 50 exceeds the pressure in the outlet manifold 41 plus the force of the spring 71, the member 70 will move radially outwardly to communicate the passage 50 with the inlet manifold and thus bypass away the fluids which would be trapped.

It will thus be appreciated that embodiments of the invention have been described wherein the land to be positioned opposite the discharge or decreasing volume chambers has means for receiving and/or bleeding-off trapped fluid to the inlet chamber by means of a member movable under the effects of the trapped pressure to create the necessary space or fluid passage. Obviously, by so adjusting the modulus of elasticity of the low-modulus material or the bias of the spring 71, the pressure at which such valving occurs can be adjusted from either a pressure just slightly greater than the pressure in the outlet manifold to pressures substantially greater.

Having thus described my invention, I claim:

1. In a variable volume hydraulic pump comprised of a plurality of members movable relatively to each other and defining a plurality of pumping chambers revolving in a fixed closed path of movement, said chambers gradually increasing in volume after they pass a fixed point of minimum volume on said path of movement until they reach a fixed point of maximum volume on said path of movement and then gradually decreasing in volume until they reach said fixed point of minimum volume, means defining an arcuate inlet and an arcuate outlet manifold including a pair of lands one at each arcuate end of said manifolds and sealingly separating said manifolds one from the other, said manifolds and lands being disposed circumferentially along said path of movement of the chambers, an opening for each chamber revolving therewith, each of said openings moving past said lands to alternately communicate its associated chamber with either said inlet or said outlet manifold, one of said lands being normally located at the point of maximum volume so that as each chamber reaches and passes through maximum volume its opening shifts from communication with the inlet manifold to the outlet manifold, said other land being adjustable along the path of movement of said chambers so as to change the point in the path of movement at which each opening moves past said other land and shifts communication of its chamber from the outlet to the inlet manifold whereby the output volume of said pump may be varied, the improvement which comprises said other land having a circumferential width greater than the circumferential width of each opening, such that when adjusted so as to be opposite a decreasing volume chamber it will prevent leakage and normally tend to cause trapping, said other land including valve means opened by pressure in said decreasing volume chamber when closed by said other land in excess of that in the outlet manifold for communicating said decreasing volume chamber with said inlet manifold.

2. The pump of claim 1 wherein said other land has a first portion of a circumferential width less than the circumferential width of each opening, and a second portion of a circumferential width such that the total circumferential width of said first and second portions is greater than the circumferential width of each opening, said second portion being movable under the influence of pressure in an opening when opposite said other land to communicate said opening with the inlet manifold.

3. The pump of claim 2 wherein said second portion has a modulus of elasticity substantially lower than said first portion.

4. The pump of claim 2 wherein said second portion has a modulus of elasticity substantially lower than said first portion and is urged by pressure in the outlet manifold to a position blocking communication of said opening with the inlet manifold.

5. The pump of claim 2 wherein there is provided spring means biasing said second portion to a position blocking communication of said opening with the inlet manifold.

6. The pump of claim 5 wherein said second portion is also urged to said blocking position by pressure in the outlet manifold.

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