LIQUID PUMP AND METER

Filed May 11, 1961 3 Sheets-Sheet 1

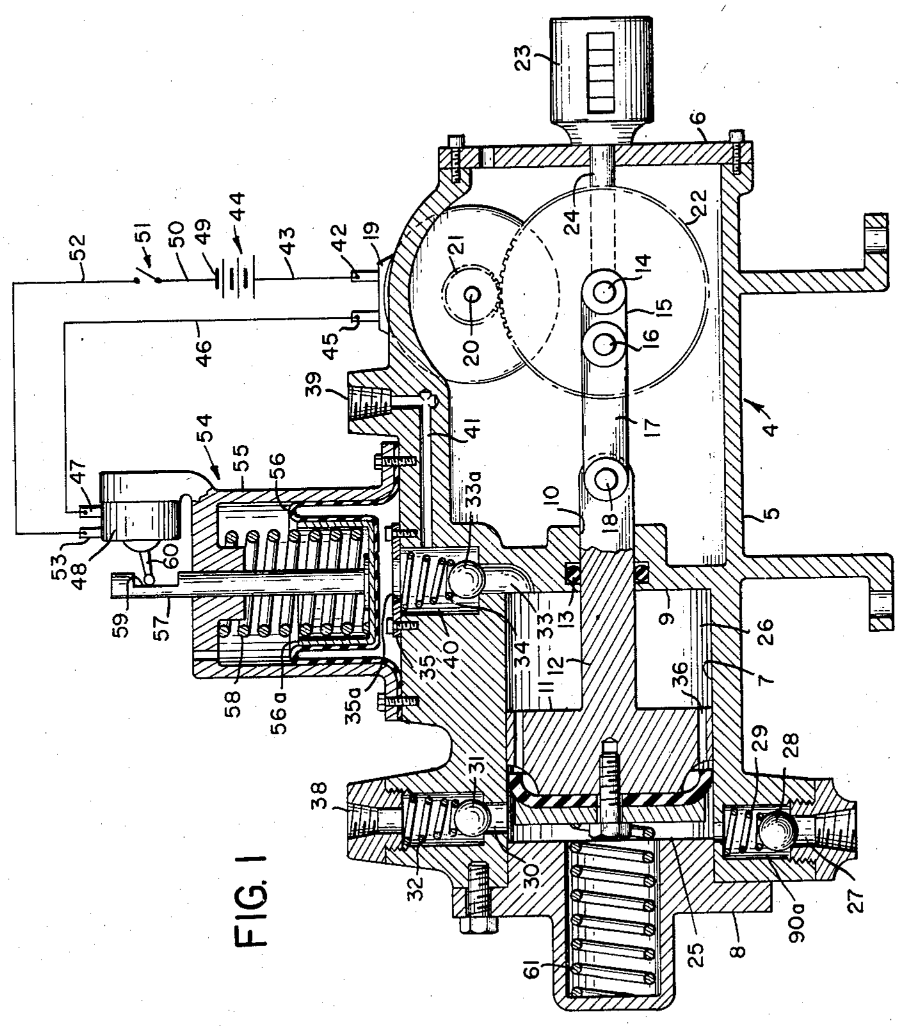

FIG. 1

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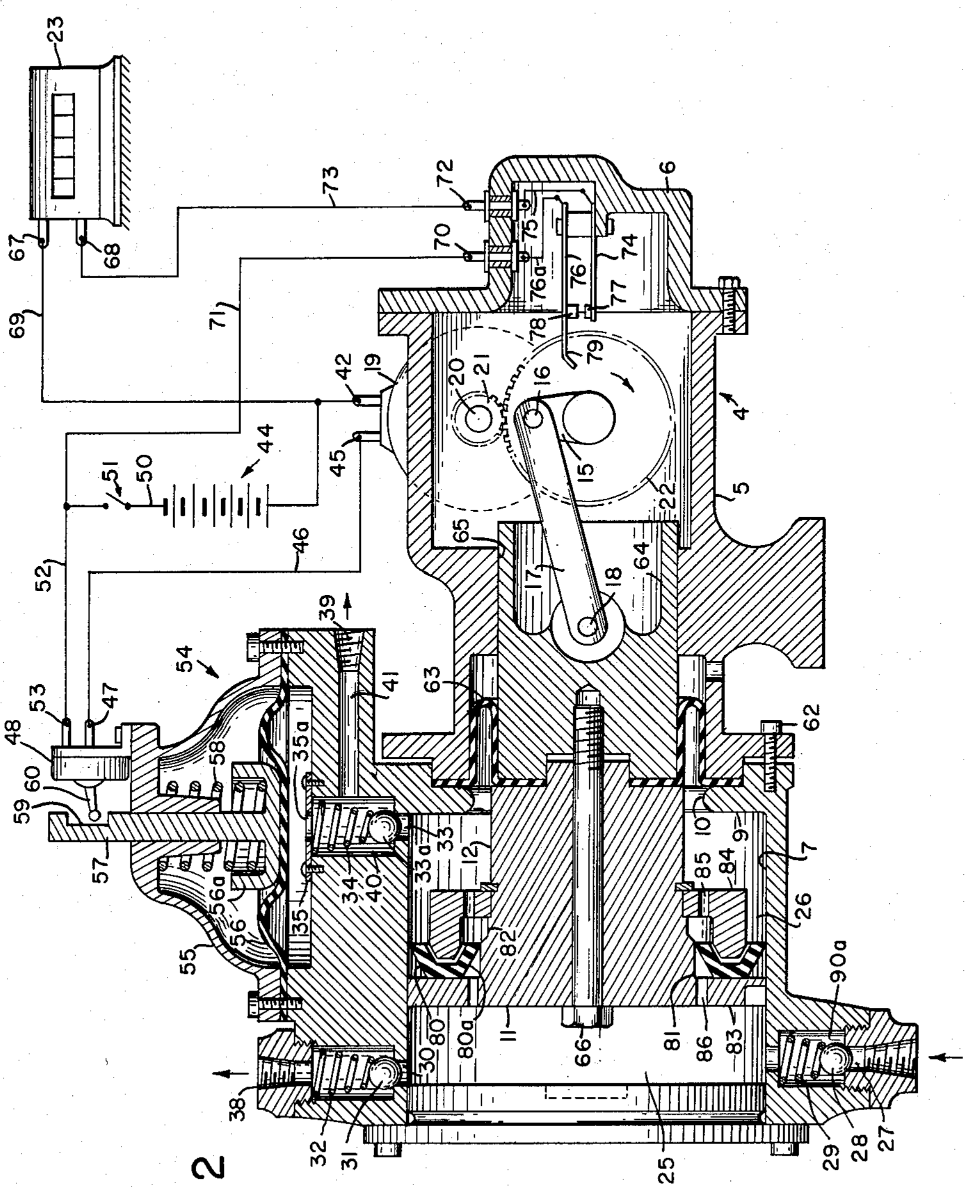

FIG. 2

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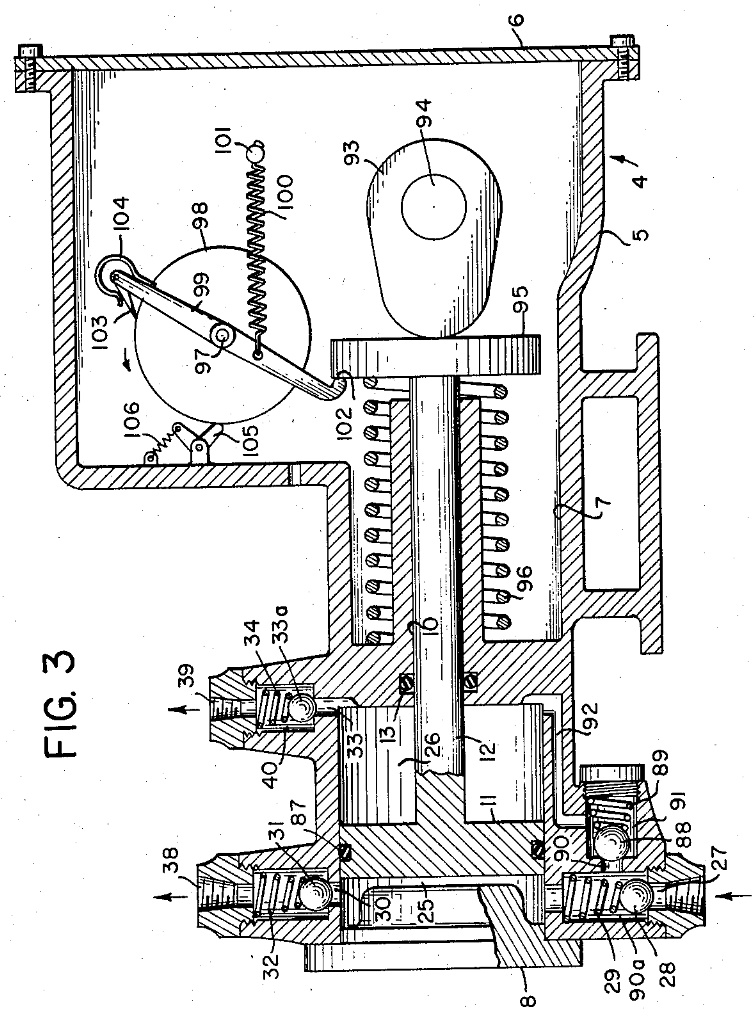

FIG. 3

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LIQUID PUMP AND METER

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11 Claims. (Cl. 103—42)

This invention relates to pumps, and more particularly to liquid pumps.

In connection with pumps for liquid, difficulty is often experienced due to the presence of entrained air and vapor in the liquid discharged from the pump, and it is accordingly one of the objects of the invention to provide means for automatically eliminating such air and vapor whenever the pump is operating.

Another object of the invention is to provide, in a pump of the above type, means for accurately measuring the amount of liquid pumped from the discharge.

A further object of the invention is to provide simple and efficient means for controlling the operation of such a pump in accordance with the demand for liquid from the pump.

Still another object of the invention is to provide novel valve means for a pump of the above type.

Yet another object of the invention is to provide an electrically driven pump adapted for use as a fuel pump for an internal combustion engine.

Another object of the invention is to provide a cam operated pump mechanism, together with means for accurately recording the amount of liquid pumped.

These and other objects of the invention will be more clearly understood when considered in the light of the following description and the appended claims.

In the drawings, wherein similar reference numerals refer to similar parts throughout the several views;

FIG. 1 is a sectional view of a pump incorporating the principles of the invention;

FIG. 2 shows a modification of the invention in section, and FIG. 3 is a sectional view of another modification.

Referring first to FIG. 1, showing a liquid pump constructed in accordance with the principles of the invention, the pump includes a pump housing **4** having a crankcase portion **5** at its right end closed by a cover plate **6**, and a cylinder bore **7** closed at its left by means of a cylinder head **8** and its right end by means of a wall **9** having a piston rod bore **10** extending therethrough from the cylinder into the crankcase. A differential piston **11** is slidably mounted in the cylinder bore and has a piston rod **12** at its right end extending through the piston rod bore **10** into the crankcase, the rod being sealed against leakage by a suitable seal **13**.

The driving means for the piston includes a crank shaft **14** having a crank **15** and a crank pin **16** thereon connected to the piston rod by means of a connecting rod **17** and a pivot pin **18** on the piston rod. An electric motor **19** is mounted on the outside of the housing with a motor shaft **20** extending into the crankcase portion of the housing and provided with a drive pinion **21** which meshes with a crankshaft gear **22** secured to the crankshaft. Since the piston is driven by a crankshaft, the travel of the piston in either direction is fixed at all times, and consequently in the event the liquid pumped is uncontaminated by entrained air or vapor, the number of revolutions of the crankshaft in a given period of time gives an accurate indication of the amount of liquid pumped, and in the present instance such indication may be given by means of a suitable counter **23** mounted on the outer surface of the end plate **6** and connected to the crankshaft by means of a shaft **24** and suitable bevel gears or other means, not shown.

The piston divides the cylinder into a suction chamber **25** at the left end of the piston and a pumping chamber **26** at the right end of the piston, and in view of the fact a differential piston is utilized, the change in volume in the suction chamber **25** is always greater than the change of volume in the pumping chamber **26** whenever the piston is moved in the cylinder. The cylinder is provided with an inlet port **27** normally closed by an inlet valve **28** loaded by an intake valve spring **29**, a liquid return port **30** normally closed by a return valve **31** held in closed position by a spring **32**, and a discharge valve port **33** having a discharge valve **33***a* normally held closed by a discharge valve spring **34** interposed between the valve and a ported plate **35**. The piston is provided with ports **36** extending therethrough, as well as with a flexible piston cup **37** of suitable material, the lip of the cup extending toward the pumping chamber **26**.

It will be understood from the foregoing, that on movement of the piston to the right by the operation of the crankshaft, liquid will be drawn from a supply into the suction chamber **25** through the inlet valve **28**, while at the same time, any liquid or fluid present in the pumping chamber **26** will tend to be compressed by the action of the piston cup acting as a seal and will be discharged through the discharge valve port **33**, and it will also be noted that the displacement in chamber **25** during a complete stroke of the piston to the right will be much greater than the displacement in pumping chamber **26** due to the use of the differential piston. When the piston moves to the left, liquid in suction chamber **25** will be forced past the flexible packing cup **37** and through the ports **36** into the pumping chamber **26** in order to maintain the latter chamber filled during the stroke of the piston to the left. However, the amount of liquid in the suction chamber **25** will be more than sufficient to fill the pumping chamber **26**, and consequently the excess, including any entrained air or vapor which may have been drawn in from the liquid supply during the suction stroke will be pumped out of the return port past the return valve **31** and returned to the supply, the lines to the supply being connected at **38**. In order to accomplish the above type of operation, tension of the return valve spring **32**, the exhaust valve spring **34**, and the tension or stiffness of the lip of the piston cup **37** are so correlated that during the movement of the piston to the left when liquid is bypassing the piston into the pumping chamber **26**, the pressure can never become sufficient to open the discharge valve to permit the escape of liquid therethrough. However, the spring **32** is so designed that the return valve **31** can open during movement of the piston to the left and permit the excess liquid which was drawn into the suction chamber to be returned to the supply through the return valve. On movement of the piston to the right, however, it will be clear that there is nothing to prevent opening of the discharge valve provided the electric motor is powerful enough to operate the piston to produce the necessary pressure.

In the event it is desired to use this pump as an electric fuel pump for an automotive engine, for example, the discharge is connected to the carburetor at outlet **39**, a discharge chamber **40** being connected to the outlet by means of a passage **41**. In order to automatically control the operation of the pump in accordance with the demand of the vehicle engine carburetor, motor terminal **42** is connected by wire **43** to the vehicle battery **44**, while motor terminal **45** is connected by a wire **46** to terminal **47** of a snap action switch **48**. Battery terminal **49** is connected through wire **50** and switch **51** as well as wire **52** with terminal **53** of the snap action switch **48**, so that when the switch **51** is closed, the snap action switch **48** controls the operation of the motor.

The switch **48** is controlled by the pressure in the discharge line to the carburetor, the construction being such that when the pressure exceeds a certain amount, the motor is de-energized, and is again energized when the pressure drops to a lower predetermined value. To establish this control, an accumulator is mounted on the top part of the housing, this including a casing **55** and a flexible diaphragm **56** secured along its outer periphery between the lower end of the casing and the pump housing **4**. A diaphragm follower **56***a* engages the upper side of the diaphragm and has a switch operating rod **57** secured thereto. A spring **58** urges the diaphragm follower downward against the diaphragm, and the upper end of the rod is provided with a notch **59** adapted for engagement with lever **60** of the snap action switch **48**, the construction being such that on engagement of the rod at either end of the notch with the switch lever, a predetermined movement of the lever occurs before anything happens in the switch itself, at which time the switch contacts snap over to a different position, depending on whether the contacts were previously closed or opened. By properly adjusting the length of the notch and the construction of the snap action switch, the accumulator mechanism can be set to maintain the pressure in the line leading to the carburetor within a predetermined range at all times, and also insures against appreciable pulsations in the line leading to the carburetor.

In the operation of a pump of the above type, it has been found that the force required to move the piston to the right during the pumping stroke is greater than that required to move the piston in the other direction, a fact which increases the torque requirements of the electric motor, and if desired, in order to even out the torque required of the motor during a complete cycle, a helper spring **61** may be interposed between the cylinder head and the left end of the piston so that the spring will be compressed during movement of the piston to the left, and will assist the motor in moving the piston to the right during the pumping stroke in order to permit the use of a slightly smaller motor.

Although the pump is shown with the cylinder horizontal, it may be desirable to operate it with the axis of the cylinder vertical and with the return port **30** at the top in order to more fully eliminate any entrained air and vapor and to prevent the possibility of such air and vapor being forced past the lip of the piston cup during the movement of the piston to the left. The position of the return valve may be changed as desired in order to facilitate more fully the elimination of air and vapor when the pump is operated in a different position from that shown.

In the event the pump is used to handle flammable liquids such as gasoline, or toxic liquids, it may be desirable to insure against any possible leakage from the pumping chamber into the crankcase past the piston rod seal, and such a feature as well as other novel features are included in the pump illustrated in FIG. 2.

As was the case in FIG. 1, the mechanism includes a crankcase **5** closed by an end plate **6** and a cylinder **7** closed at its left end by a cylinder head **8** and at its right end by a wall **9** having a bore **10** extending therethrough. In this construction, however, the crankcase is separate from the cylinder and is secured thereto as by means of cap screws **62**. A piston **11** is slidably mounted in the cylinder and has a piston rod **12** of reduced diameter extending from the right side thereof, this rod extending through but spaced from the wall of the bore **10**. In order to seal against any leakage from the pumping chamber **26** at the right end of the piston, a "stocking type" diaphragm **63** is utilized, the outer periphery of the diaphragm being clamped between the crankcase and the cylinder, and the inner peripheral portion of the diaphragm being clamped between the right end of the piston rod **12** and a piston guide **64** slidably mounted in a piston guide bore **65** in the crankcase.

The piston is operated by means of a crank **15** having

a crank pin **16** connected to the piston guide **64** by means of a connecting rod **17** and a pivot pin **18** on the piston guide, the piston guide being secured to the piston by means of a cap screw **66** as shown. The crankshaft is provided with a gear **22** which meshes with a pinion **21** on shaft **20** of an electric motor **19** mounted on the crankcase housing.

The piston divides the cylinder into a suction chamber **25** and a pumping chamber **26**, the suction chamber having an inlet port **27** normally closed by a spring biased valve **28**, and a return port **30** normally closed by a spring biased valve **31**. A discharge port **33** is provided for the pumping chamber and this is normally closed by a spring biased valve **33***a*.

An accumulator **54** is provided similar to that shown in FIG. 1, the accumulator including an accumulator casing **55** mounted on the upper portion of the cylinder member with a flexible diaphragm **56** clamped therebetween along its outer periphery. A diaphragm follower **56***a* rests against the upper surface of the diaphragm, being pressed thereagainst by means of a spring **58**. As shown, the lower side of the diaphragm is subjected to the pressure in discharge chamber **40** through port **35***a* in the spring retaining plate **35**. The upper end of a follower rod **57** is provided with a switch operating notch **59** adapted to engage the end of the switch operating lever **60**. Motor terminal **42** is connected to switch terminal **53** through wire **43**, battery **44**, wire **50**, switch **51** and wire **52**, while terminal **45** of the motor is connected to the control switch terminal **47** through wire **46**. Thus, when the switch **51** is closed, the pressure acting on the diaphragm **56** controls the operation of the snap action switch in order to control the operation of the motor in accordance with the pressure in discharge outlet **41**, this portion of the operation being substantially the same as that occurring in the structure shown in FIG. 1.

In this embodiment of the invention, the counter **23** is of the remotely controlled magnetic type having terminals **67** and **68**, the terminal **67** being connected by wire **69** to wire **43** leading to the battery, the battery in turn being connected to a terminal **70** on crankcase cover plate **6** through the wire **50**, the switch **51**, and a wire **71**. The other counter terminal **68** is connected to a terminal **72** on the crankcase cover plate by a wire **73**, terminal **72** being connected to a resilient switch leaf **74** by wire **75**, and terminal **70** being connected to a resilient switch leaf **76** by wire **76***a*. The switch leaves are provided respectively with contacts **77** and **78** which are normally open, and the left end of the switch leaf **75** is provided with a bent portion **79** adapted to be engaged by the outer end of the crank once during each revolution in order to make contact between the contacts **78** and **77** to energize the magnetic counter. It has been found in the operation of experimental pumps of this type that the piston never tends to stop at dead center at the right end of the stroke, and consequently the crank does not stop normally until it is past the switch leaf projection **79**, thus insuring against the contacts **77** and **78** remaining closed for a prolonged period of time with detrimental effects to the battery and to the counting mechanism. It will be understood that this mechanism can be incorporated in the structure of FIG. 1, or that conversely, the counter mechanism of FIG. 1 can be incorporated in FIG. 2 instead of the mechanism shown.

A unique feature of the structure shown in FIG. 2 resides in the arrangement for bypassing liquid from the suction chamber to the pumping chamber during movement of the piston to the left, and as shown in the drawing, such arrangement includes a U-shaped piston cup **80** which is flexible and of well known construction, the cup being slidably mounted in the cylinder with the outer lip in engagement with the cylinder wall and the inner lip **80***a* in engagement with a cylindrical portion **81** of the piston, which blends into a portion of reduced diameter at 82 just to the right of the right hand edge of the lip. As will be seen, the piston cup is mounted for limited axial movement relative to the piston, being located in one direction in the position shown in the drawing by a stop or flange 83 on the piston, and being adapted on limited relative movement in the opposite direction to be engaged and held against further movement in said direction by a stop ring 84 mounted on the piston rod for movement therewith. As shown, ports 85 are provided in the stop ring in order to insure the unrestricted passage of liquid by the ring from the left side to the right side during operation of the pump.

With the parts in the position shown, assuming that the switches 51 and 48 are closed, the crankshaft turns in a clockwise direction in order to move the piston to the right in the cylinder to draw liquid into the suction chamber 25 from a liquid supply through the inlet valve 28, and at the same to pump liquid to a carburetor or other liquid consuming device through the discharge valve 33*a* and the discharge outlet 39. Consequently due to the pressure in the pumping chamber 26, as well as the frictional engagement of the outer lip of the cup with the cylinder wall, the cup rests as shown against the flange 83 on the piston and moves bodily with the piston during the pumping stroke. As the crankshaft passes dead center however, the frictional engagement of the outer lip of the cup of the cylinder wall tends to hold the cup stationary while the piston moves to the left to take up the lost motion between the cup and the stop ring 84, and when this lost motion is taken up, the cylindrical portion 81 of the piston moves to the left relative to the inner lip of the cup sufficiently to clear the lip and allow free passage of liquid between the lip and the surface of the piston rod 12 which is of lesser diameter than the cylindrical portion 81, ports 86 being provided in the piston to insure the free passage of liquid to the left side of the cup when positioned against the stop ring. Thus, during movement of the piston to the left, liquid is free to pass the piston to maintain the pumping chamber 26 filled with liquid, while at the same time, the excess liquid which was drawn in during the suction stroke into the chamber 25, since it cannot go into the pumping chamber 26, and since it cannot be discharged through the discharge valve 33*a*, because of the loading imparted thereto by the discharge valve spring, is returned to the supply through the return valve 31 and the connection at 38 which goes to the supply.

In the event a pump constructed in this manner is to be used as an accurate fuel meter, it is important that the proper relationship be maintained between the effective area of the diaphragm 63 and the area of the cylindrical portion 81 of the piston, as during relative movement of the piston cup and piston, it is possible for a change in volume to take place in the pumping chamber 26 unless the diaphragm and the cylindrical portion have the same effective diameter. It will be noted that in effect the U-shaped piston cup acts as a valve, and that due to manufacturing tolerances and so forth, the point at which the inner lip of the cup engages or disengages cylindrical portion 81 may be indeterminate, and it is for this reason that a variation in volume can take place in the chamber 26 unless the two diameters in the two areas above referred to are substantially identical. The "stocking type" diaphragm shown is particularly adapted for use in this connection, since its effective area remains substantially constant regardless of stroke within reasonable limits and can be readily computed. As was the case in FIG. 1, it will be understood that the loading or biasing of the discharge valve relative to the loading of the return valve is such that during movement of the piston to the left, the pressure build up in pumping chamber 26 is insufficient to force open the discharge valve, but the pressure in the chamber 25 is sufficient to open the return valve 31. On the stroke to the right, the piston cup acts as a seal, and sufficient pressure is of course built up in the chamber 26 to open the discharge valve and to discharge a volume of liquid equal to the displacement of the piston during its stroke to the right, thus providing an accurate measure of the liquid pumped which can be recorded on a counter as shown if so desired. Any vapor or air which is entrained in the liquid entering the suction chamber through the intake valve during the suction stroke is thus discharged and returned to the liquid supply with the excess liquid in the chamber during the stroke of the piston to the left.

There has thus been provided a pumping unit which is sealed against leakage of flammable or toxic liquids, and which if desired can be used as an accurate device to meter the amount of liquid pumped for each complete cycle, and in addition in the event it is desired to use this for a fuel pump for an automotive engine or the like, means are provided for accurately controlling the pressure in the discharge line leading to the engine carburetor.

Referring now to FIG. 3, a pump of this general type is shown wherein the pump is operated mechanically as by means of a cam on the cam shaft of a vehicle engine in somewhat the same manner as the conventional diaphragm type fuel pumps now used on engines of this type. As was the case in the other modifications, the structure includes a crankcase or cam case 5 closed by an end plate 6, a cylinder 7 closed at its left end by a cylinder head 8 and at its right end by a wall 9 having a piston rod bore 10 therein. A piston 11 is slidably mounted in the cylinder and provided with a piston rod 12 extending to the right therefrom and slidably mounted in the bore 10, a seal 13 serving to prevent leakage at this point. The piston divides the cylinder into a suction chamber 25 and a pumping chamber 26, and leakage by the piston between these chambers is prevented by a suitable seal 87 carried by the piston. The cylinder is provided with inlet valve 28, return valve 31, and discharge valve 33*a*, all these valves being spring biased toward closed position in the same manner as previously described. The means for bypassing liquid from the suction chamber 25 to the pumping chamber 26 by the piston includes a bypass valve 88 biased toward closed position by a relatively light spring 89 and communicating through a port 90 with inlet chamber 90*a*. A chamber 91 at the right of this bypass valve is connected to the pumping chamber 26 through a bypass passage 92. Thus, on movement of the piston to the right, liquid is drawn from a supply into the suction chamber 25, and the liquid in the pumping chamber 26 is discharged through the discharge valve 33*a*, while on subsequent movement of the piston to the left, liquid is pumped from the suction chamber 25 through the bypass valve 88 and the bypass passage 92 to the pumping chamber 26 in an amount sufficient to maintain that chamber full during the entire stroke to the left, the excess previously drawn into chamber 25 above that necessary to maintain the chamber 26 filled being returned to the supply through the return valve 31 and a connection to the supply tank.

As stated heretofore, this particular embodiment of the pump is adapted to be operated mechanically by a cam, for example on the cam shaft of an internal combustion engine, and such a cam is shown as being a cam 93 mounted for rotation with a cam shaft 94 which may be mechanically driven in any suitable manner. This cam cooperates with a tappet head 95 at the right end of the piston rod 12, movement of the piston to the right being effected by a compression spring 96 interposed between the right side of the wall 9 and the left side of the tappet head 95. The piston is positively moved to the left by the action of the cam 93.

It will be noted, however, that in this case, the stroke of the piston is not necessarily fixed, as in the event the pressure in the discharge line builds up to a point such that the spring 96 has insufficient force to move the piston to the right, or in the event the discharge valve line is entirely closed momentarily, the tappet head **95** will not follow the cam, and the stroke temporarily at least will be less than that for which the device is designed. In like manner, in the event the cam is operated at extremely high speeds, it may be that the spring will be unable to make the tappet head follow the cam resulting in a variation of stroke. Consequently in the event it is desired to use this pump as a meter to measure the amount of liquid pumped through the discharge, a different counter arrangement is required, and this is shown in the drawing.

This counter mechanism measures the total stroke of the piston to the right only, regardless of the distance through which the piston moves at any one time. A counter shaft **97** is provided and connected to a suitable counter, not shown, a friction ratchet wheel **98** being secured to the shaft for rotation therewith. An actuating and pawl arm **99** is pivotally mounted on the shaft and is urged in a counterclockwise direction by means of a tension spring **100** interconnected between the lever and a pin **101** secured to the housing. The bottom end of the lever is provided with a portion **102** maintained against the left side of the tappet head **95** by the spring **100**, while at the upper end a spring pressed friction pawl **103** is pressed into frictional engagement with the outer periphery of the wheel **98** by means of a spring **104**. Thus, on movement of the piston and the tappet head to the right during the pumping stroke under the influence of the spring **96**, the lever **99** will rotate in a counterclockwise direction and by virtue of the engagement of the pawl **103** with the periphery of the ratchet wheel, will rotate the wheel in a counterclockwise direction through an angle proportional to the degree of movement of the piston to the right. In the event the piston and tappet head is now moved to the left by the action of the cam, the lever will move in a clockwise direction, and the pawl **103** will slide along the surface of the wheel without moving it, although in order to insure against retrograde movement, a pawl brake is provided comprising a bell crank shaped pawl **105** maintained in frictional engagement with the surface of the wheel **98** by means of a suitable spring **106**, and serving effectively to prevent rotation of the wheel in a clockwise direction during clockwise rotation of the lever **99**.

It will be seen from the foregoing that the operation of this pump is very similar to that obtaining in the well known diaphragm type engine driven fuel pump used on many automobile engines, and that in addition means are provided for eliminating entrained air and vapor and for utilizing such a pump as a meter to accurately measure the amount of fuel used if so desired. It is also to be understood that the cam shaft **94** may be driven by any suitable means such as an electric motor, and that such motor may be controlled by an accumulator controlled switch.

There has thus been provided by the present invention, simple and effective means for pumping volatile and other liquids uncontaminated by entrained vapor and air, and means which can be readily adapted if desired, and as shown in the drawings, as an accurate liquid meter for determining the amount of liquid pumped during any given period of time. Such pumps serve a very useful purpose in connection with the testing of the fuel consumption of automobiles and internal combustion engines as well as in many other applications where an accurate measure of the liquid pumped is desired, and the pump is particularly useful in connection with the pumping of very volatile fuels which tend to vaporize readily when subjected to reduced pressure during the intake stroke of the pump.

Although the invention has been illustrated and described in considerable detail, it is to be understood that other modifications may well suggest themselves to those skilled in the art, and that the invention is not to be considered as limited except as set forth in the appended claims. Reference will, therefore, be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. A pump for liquid including a suction chamber having an inlet valve and a return valve, said chamber being adapted to receive liquid from a liquid supply through the inlet valve and to return a portion of the liquid to the supply through the return valve, a pumping chamber having a discharge valve, means connecting said chambers including a one-way valve for conducting liquid from the suction chamber to the pumping chamber, movable differential liquid displacing means associated with said chambers movable in one direction to draw liquid into said suction chamber from a supply and to discharge liquid from the pumping chamber through said discharge valve and movable in the opposite direction to transfer a portion of the liquid drawn into the suction chamber to said pumping chamber through said connecting means and to return the rest of the liquid so drawn in to the liquid supply through said return valve, said displacing means being so constituted with respect to said chambers that on movement of the displacing means a given distance the change in volume effected thereby in the suction chamber exceeds the change in volume effected thereby in the pumping chamber by a predetermined amount, and means for biasing said intake, return and exhaust valves toward closed position, the biasing means being so constituted as to prevent opening of the discharge valve by the pressure in the pumping chamber and to permit opening of the return valve by the pressure in the suction chamber when the liquid displacing means is moving in said opposite direction.

2. A liquid pump as set forth in claim 1, including a discharge line connected to the pumping chamber through the discharge valve, power operated means having a connection with the liquid displacing means for moving the latter, and means responsive to the pressure in the discharge line for controlling the energization of the power operated means.

3. A liquid pump as set forth in claim 1, including indicating means for indicating the volume of liquid discharged from said pumping chamber during a given period of time, said indicating means including an indicator having an operative connection with the liquid displacing means, the indicator and operative connection being so constituted as to indicate the total travel of the displacing means in said one direction during said period.

4. A liquid pump as set forth in claim 1, including a crankshaft having an operative connection with said liquid displacing means, said crankshaft and operative connection being operable to reciprocate the displacing means with a fixed stroke, an electric motor connected to the crankshaft to rotate the shaft, means including a switch for controlling the energization of the motor, an expansible chamber connected to said pumping chamber through said discharge valve, and a switch operating member associated with said expansible chamber movable in one direction by the pressure in said expansible chamber and resiliently biased in the opposite direction, said switch operating member and switch being so arranged as to deenergize said motor when the pressure in said expansible chamber exceeds a predetermined value and to energize the motor when said pressure reaches a lower predetermined value.

5. A liquid pump including a cylinder, a differential piston slidaby mounted in the cylinder and dividing the latter into suction and pumping chambers, the change in volume in the suction chamber being greater than the change in volume of the pumping chamber during movement of the piston a given distance, an inlet valve for the suction chamber, means for conducting liquid from the suction chamber to the pumping chamber including a one-way valve, a discharge port in the pumping chamber, means for reciprocating the piston in the cylinder, the piston being operable on movement in one direction to draw liquid from a supply into the suction chamber through said inlet valve and to discharge liquid from the pumping chamber through said discharge port

and operable on movement in the other direction to force liquid from the suction chamber into the pumping chamber through said conducting means to maintain the pumping chamber full of liquid, the volume of liquid drawn into the suction chamber during piston movement in said one direction being greater than that required to maintain the pumping chamber full of liquid during movement of the piston an equal distance in said other direction, and means operable during operation of the pump for eliminating entrained air and vapor from the liquid drawn into said suction chamber including a discharge valve for the discharge port, valve biasing means for urging the discharge valve to closed position against the pressure in the pumping chamber, a return port in the suction chamber adapted to be connected to the liquid supply, a return valve for the return port, and biasing means for urging said return valve to closed position against the pressure in the suction chamber, the biasing force of the discharge valve biasing means being so chosen as to prevent opening of the discharge valve by the pressure in said pumping chamber during movement of the piston in said other direction.

6. A liquid pump as set forth in claim 5, wherein the liquid conducting means includes a flexible packing cup secured to the piston adjacent the suction chamber with the lip of the cup extending toward the pumping chamber and being in engagement with the cylinder wall, the cup acting on movement of the piston in said one direction to prevent the passage of liquid between said chambers and the lip being forced away from the cylinder wall by the liquid on movement of the piston in said other direction to provide a passage for liquid from the suction chamber to the pumping chamber.

7. A liquid pump as set forth in claim 5, wherein the means for reciprocating the piston includes a rotatable crankshaft having a crank and a connection between the crank and the piston, the crank insuring a predetermined length of piston travel during each pumping cycle, and means for indicating the volume of liquid discharged from the pumping chamber including a counter having an operative connection with the crankshaft.

8. A liquid pump including a cylinder, a differential piston slidable therein and forming in conjunction therewith a closed suction chamber at one end thereof and a closed pumping chamber at the other end thereof, means for reciprocating the piston in the cylinder, means including a one-way valve for conducting liquid from the suction chamber to the pumping chamber, an inlet valve for the suction chamber, a return valve for the suction chamber, a discharge valve for the pumping chamber, and means for biasing said return and discharge valves to closed position against the pressures in the corresponding chambers, the discharge valve being biased to open at a pressure at least equal to that required to open the return valve, the inlet and return valves both being adapted to be connected to a liquid supply to respectively receive liquid from the supply and to return liquid from the suction chamber to the supply, and the discharge valve being adapted to be connected to a pump discharge line.

9. A liquid pump including a cylinder, a differential piston slidably mounted therein and forming in conjunction therewith a closed suction chamber at one end thereof and a closed pumping chamber at the other end thereof, an inlet valve for the suction chamber, a return valve for the suction chamber, a discharge valve for the pumping chamber, means for biasing the return valve and discharge valve to closed position against the pressures in the corresponding chambers, the discharge valve being biased to open at a pressure equal to or greater than that at which the return valve opens, means for reciprocating the piston in the cylinder to draw liquid from a supply into the suction chamber through said intake valve on movement of the piston in one direction and force a portion of said liquid into the pumping chamber on movement of the piston in the other direction, and means for preventing the flow of liquid between said chambers during movement of the piston in said one direction and for conducting liquid from the suction chamber to the pumping chamber during movement of the piston in the other direction including a flexible packing cup mounted on the piston for limited axial movement with respect thereto with a lip of the cup in frictional engagement with the cylinder wall and directed toward the pumping chamber, a passage in the piston between the two chambers, and a seat for the cup on the piston, the cup being engageable with said seat during movement of the piston in said one direction to close said piston passage and the piston seat moving away from the cup to open the passage on movement of the piston in said other direction.

10. In combination with a cylinder body having a bore and a differential piston slidably mounted therein and forming, in conjunction with the cylinder, a closed chamber at either end of the cylinder, combined piston sealing and valve means for preventing the flow of fluid between the chambers during movement of the piston in one direction and for conducting fluid between the chambers during movement of the piston in the opposite direction, said means including a passage through the pistion, a cylindrical portion of lesser diameter than the cylinder formed on the piston in one of the chambers, a U-shaped flexible packing cup mounted on the piston and movable axially a limited distance with respect to the piston, the outer lip of the cup being in frictional and sealing engagement with the cylinder wall, and fixed stops on the piston of limiting the relative axial movement of the cup and piston, the inner lip of the cup being in sealing engagement with said cylindrical portion of the piston when the cup is in engagement with one of said stops and being out of engagement with said cylindrical portion when the cup is in engagement with the other of said stops.

11. The combination set forth in claim 10, wherein an extension of said reduced portion of the piston extends outward through a bore in the end of the cylinder body, and the bore is sealed against leakage by a stocking-type diaphragm, the diaphragm being secured along its outer periphery to the cylinder body and along its inner periphery to the piston extension, and the effective area of the diaphragm being substantially the same as the cross sectional area of said cylindrical portion of reduced diameter on the piston.

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