Feb. 5, 1957 L. T. STOYKE ET AL 2,780,170

SUPERCHARGING SYSTEM FOR FLUID PUMPS

Filed Nov. 17, 1953 3 Sheets-Sheet 1

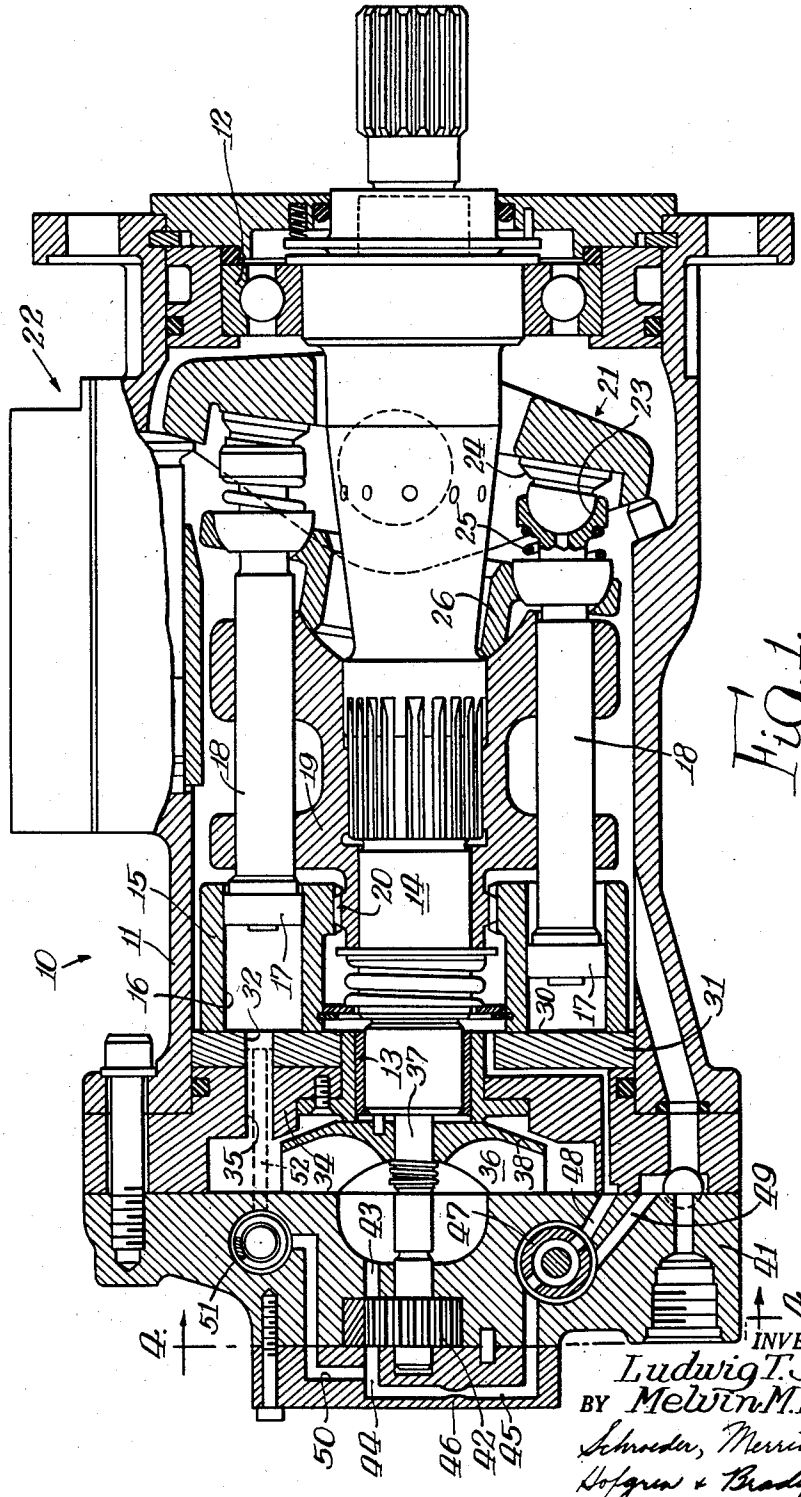


Fig. 1.

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Fig. 2.

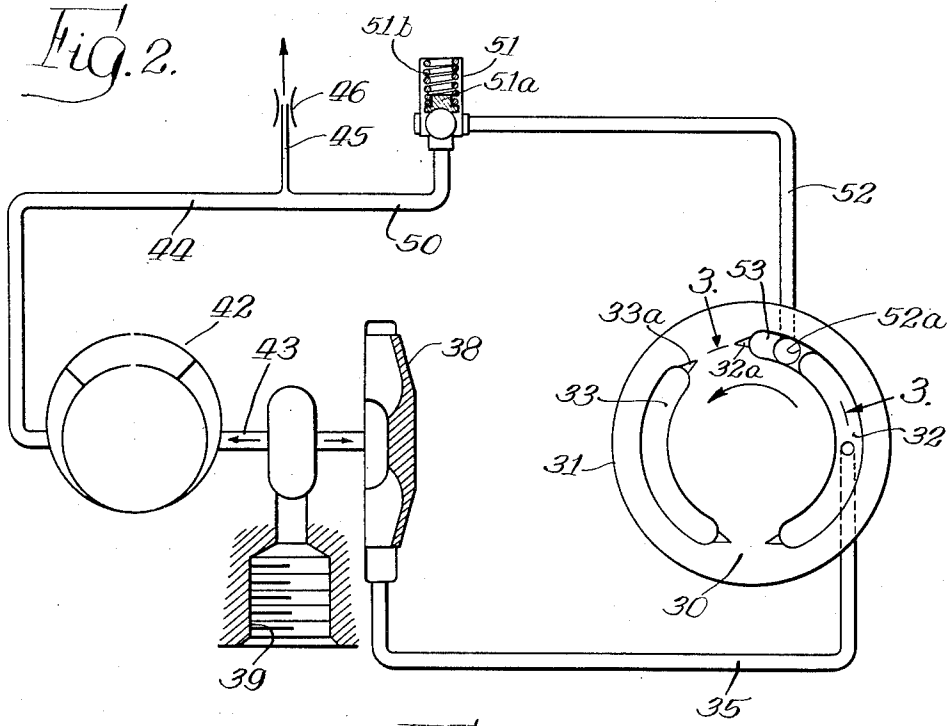


Fig. 3.

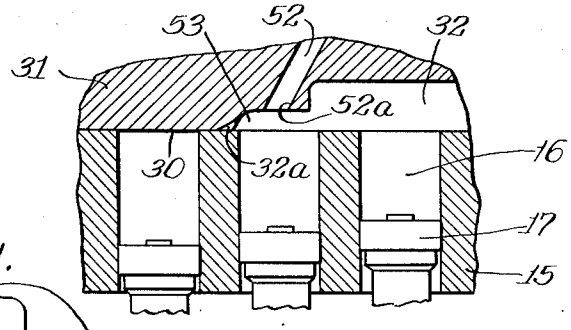
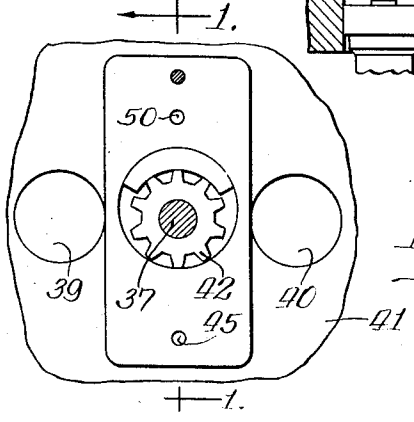


Fig. 4.



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Fig. 5.

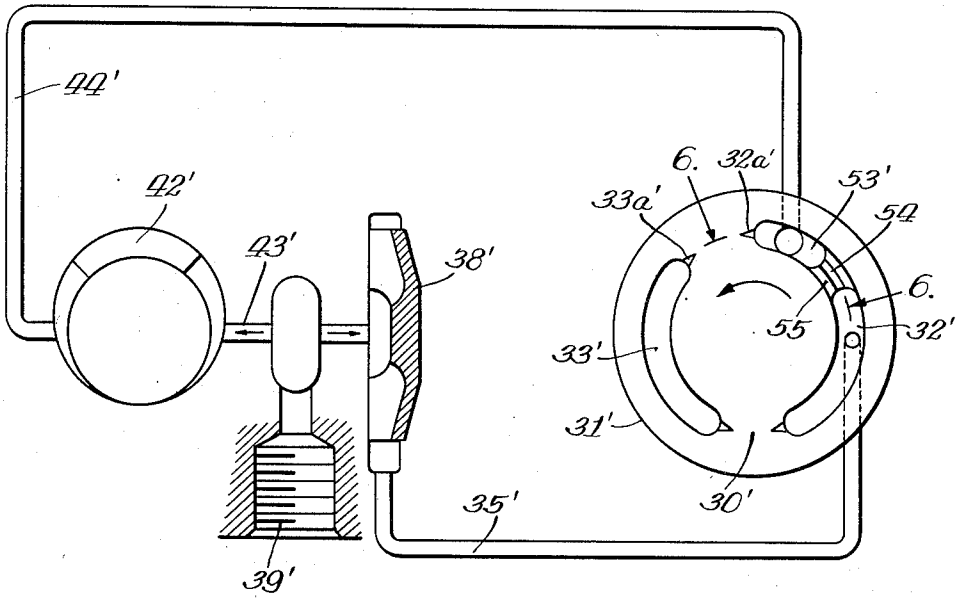
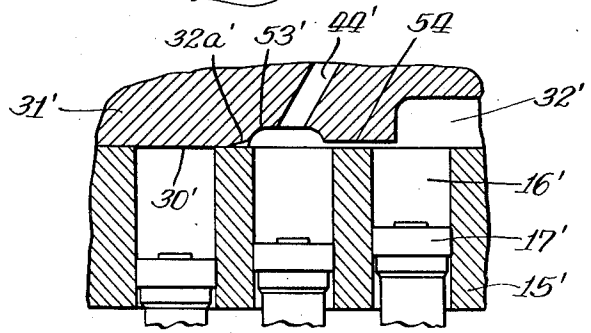


Fig. 6.



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SUPERCHARGING SYSTEM FOR FLUID PUMPS

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Application November 17, 1953, Serial No. 392,613
13 Claims. (Cl. 103—2)

This invention relates to a fluid pump and more particularly to supercharging systems for fluid pumps.

It is the general object of the invention to provide a new and improved supercharging system for fluid pumps.

It is a more specific object of the invention to produce a system for the prevention of cavitation in hydraulic equipment operating at high speeds and low inlet pressure conditions.

The hydraulic phenomenon of cavitation in hydraulic equipment occurs as the cavitation cavity begins to form when the pressure is reduced to the vapor pressure of the liquid. The growth of the cavity continues until the pressure is increased to a point above the vapor pressure whereupon the cavity immediately collapses. Because of higher pressure level experienced in hydraulic equipment the rate of collapse of the cavity is much higher than the rate of formation.

Cavitation effects are manifested in the form of erosion of the parts as well as reduction of the delivery capacity characteristics of hydraulic equipment which is accompanied by noise, pressure pulsation and vibration. Since hydro-dynamic machines depend for their operation on changing the velocity of fluid, prevention of cavitation resulting from the inherent pressure drop can be achieved only by changing the velocity of the fluid without reducing the local pressure to vapor pressure.

It is therefore a further object of the invention to produce a hydro-dynamic machine which is provided with a means for elevating the pressure of the liquid above the vapor pressure prior to transition from suction to discharge ports.

Yet another object of the invention is to produce a liquid pump provided with supercharging means for elevating the fluid handled by the pump above the vapor pressure.

Yet another object of the invention is to produce a supercharging means which will maintain constant delivery characteristics of the pump over the entire range of designed altitude or suction pressures.

Yet another object of the invention is to provide a device of the character described in the preceding paragraphs in which means in the form of a jet is provided for directing liquid under pressure into the pumping chambers of the pump at a point where the pressure thereof would otherwise tend to be below vapor pressure and thereby to elevate the pressure of the liquid above the vapor pressure to prevent cavitation.

Yet another object of the invention is to produce a device of the character described in the preceding paragraphs in which liquid under pressure is directed into the pumping chambers of the pump and restricted to the main inlet at a point where the pressure thereof would otherwise tend to be below the vapor pressure and, thereby, elevate the pressure of the liquid above the vapor pressure to prevent cavitation and assure complete filling of the pump during the inlet valving period.

The supercharging system of the present invention is particularly adapted for use in a rotating barrel, axial piston type, hydraulic pump of either variable or constant delivery. In such a pump the liquid is subjected to cavitation at the point of the change in direction of reciprocation of the pistons which occurs at the transition period during which the pump completes its suction stroke and begins its discharge stroke. As previously stated, to prevent cavitation the pressure of the liquid must be kept above the vapor pressure at the point where the velocity of the liquid is changed. In order to elevate the pressure of the liquid above the vapor pressure each cylinder bore, previous to the end of the suction stroke of the piston therein, communicates with a jet of liquid supplied from a source of liquid under pressure, preferably a positive displacement type gear pump, and the dynamic energy of the jet stream directed into the cylinder bores serves to maintain the static pressure level within the bores above the vapor pressure of the liquid therein. Preferably a chamber is associated with the jet and is positioned to open into the cylinder bores during the time when the pistons in the bores make the transition from suction to pumping stroke. The chamber serves to trap excess fluid from the jet and simultaneously to extend the period of time in which the cylinder bores are in communication with fluid from the jet. With the above arrangement the pressure level within the cylinder bores may be elevated above the vapor pressure of the fluid during the change of velocity of the fluid and thus cavitation may be prevented.

An alternate supercharging system for a pump described in previous paragraphs is to supply liquid under pressure, preferably, by means of a positive displacement type gear pump, or by liquid under pressure from the high pressure side of the piston pump to the cylinders at the end of the suction stroke. The oil is directed into a secondary valving port which is supercharged and pressurized with the excess return flow throttled through an orifice and conducted to the main valving inlet port kidney. In this manner the excess is also made available during the inlet stroke. The gear pump is sized to fill the piston pump cylinders during the supercharging stroke in addition to filling the voids created during the balanced period of the suction stroke. With this arrangement the pressure level in the piston pump cylinder is raised above the vapor pressure of the liquid prior to the valving to high pressure and complete filling is assured and cavitational effects are avoided.

The features and advantages of the apparatus of the present invention discussed above, and other features, will be readily apparent from the following description and drawings, in which:

Fig. 1 is a longitudinal sectional view of a rotating barrel, axial piston type pump embodying the supercharging system of the invention;

Fig. 2 is a diagrammatic view of the hydraulic circuit employed;

Fig. 3 is a sectional view taken along line 3—3 of Fig. 2;

Fig. 4 is a vertical sectional view along line 4—4 of Fig. 1;

Fig. 5 is a view like Fig. 2 of a modified hydraulic circuit; and

Fig. 6 is a view like Fig. 3 of the modified form of construction.

While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail one specific embodiment, with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiment illustrated. The scope of the invention will be pointed out in the appended claims.

While it will be readily apparent to those skilled in the art that the supercharging system hereafter to be described in detail may be applied in many hydro-dynamic machines, for the purposes of exemplary disclosure it will be described as employed with a rotating barrel, axial piston pump of the type more fully described and claimed in the

copending application of Joseph S. Cardillo et al., Serial No. 217,258, filed March 23, 1951.

Referirng now to the drawings, there is provided a pump **10** having a casing **11** rotatably supporting in bearings **12** and **13** a drive shaft **14**. Splined to the drive shaft is the rotatable barrel of the pump including a portion **15** having a plurality of axial cylinders **16** formed therein in which pistons **17** are reciprocable. Each of the pistons **17** is provided with a piston push rod **18** slidably carried in a push rod supporting section **19** splined to the drive shaft and being provided with splines **20** securing it to the cylinder forming portion **15**.

Pivotally mounted within the casing **11** is a swash plate or wobbler **21** together with control means therefor generally designated **22** and more fully described in said copending application. At the outer end of each of the piston push rods there is formed a ball socket **23** carrying a ball member **24** having a face adapted to slide against the corresponding face of the swash plate **21**. Means in the form of springs **25** are provided for each piston to hold the members **24**, and hence the piston push rods, against the face of the swash plate, with each of the springs bearing at one end against the end of the push rod and at the other end riding in a rockably mounted member **26**. The spring arrangement for the push rods and the construction of the member **26** are also more fully described and claimed in said copending application and further discussion thereof in the present case is believed unnecessary. It will of course be understood that the piston push rods are moved to move the pistons secured thereto on their discharge strokes by the cooperation between the wobbler and the rotation of the barrel while the springs **25** serve to aid in returning the pistons on their suction strokes and to maintain the members **24** in contact with the adjacent face of the swash plate.

The cylinder forming member **15** bears against the face portion **30** of a port plate **31** having an arcuate intake port **32** (Fig. 2) and an arcuate discharge port **33**. The port plate is secured to a member **34** having a passage **35** establishing communication between the intake port **32** and a chamber **36** formed in the casing.

Secured to an extension **37** of the drive shaft is a centrifugal pump **38** which, being rotated with rotation of the drive shaft, serves to create a head of pressure within the chamber **36** and thus, through the passage **35** and port **32**, within the cylinder bores to aid in filling the bores with liquid during each suction stroke of the pistons therein. The chamber **36** is in direct communication with the pump inlet **39** and, of course, the discharge port **33** communicates with the pump outlet **40** through passages provided in the casing.

Mounted in a suitably formed recess in the cover plate **41** for the pump is a positive displacement gear pump **42** of th crescent type. The inlet of the pump is connected by means of a passage **43** to the chamber **36** while the discharge of the pump **42** is into a passage **44**. Passage **44** connects to a second passage **45** provided with a restricted orifice **46** therein, with the passage **45** leading to a priming valve **47** connected to lubricating passages **48** and by-pass channel **49** as more fully described in the previously mentioned copending application. Thus, the pump **42** serves to provide lubricating fluid under pressure to the interior of the casing **11** for lubricating the various moving parts of the pump **10**.

As previously indicated, means are provided in the present pump for elevating the liquid within the cylinder bore **16** above the vapor pressure of the liquid so as to prevent cavitation from occurring therein during the transition from suction to pumping strokes. For this purpose there is provided a passage **50** opening at one end into the passage **44** and at the other end into a back pressure valve **51**. The back pressure valve, which may be of the usual construction, is provided with a plunger **51***a* normally held in a position closing the passage **50** by a compression spring **51***b*. Thus on start up, when the positive displacement of pump **42** is operated at a relatively slow rate, the valve **51** serves to block communication between the passage **50** and a second passage **52** hereafter to be more fully described. By this means a reasonable constant back pressure is etablished to provide lubricating flow through the orifice **46** to the case chamber **11** over the entire speed range. At low speed when the supercharging flow requirement is at a minimum, the flow is directed for lubrication of the pump ports in case **11**. As the pump speed increases the flow from the pump **42** creates an increasing pressure drop through the orifice **46** and the increased pressure will then serve to overcome the compression of the spring **51***b* opening the relief valve **51** to permit flow of fluid under pressure in the passage **50** into the passage **52**.

As best seen in Figs. 2 and 3, the passage **52** opens into a chamber **53** formed as a stepped extension of the arcuate intake port **32**. The chamber **53** is in communication with the cylinder bores **16** and acts as a huddling chamber wherein the dynamic jet effects are converted into pressure for efficient pressurization of the cylinder bore chambers **16**. The size of this chamber is determined experimentally and is affected by the supercharging flow requirement at designed altitude conditions. The chamber **53** is extended along the face **30** of the port plate so as to be in communication with the cylinder bores during the transition of the piston therein from suction stroke to pumping stroke. Thus, during the period when cavitation would otherwise be most apt to occur within the cylinder bores, the pressure of the fluid therein is elevated above the vapor pressure of such fluid by the conversion of the dynamic velocity head to static pressure head as well as completing the filling of the cylinder bores **16**. The passage **52** is slanted in the direction of movement of the cylinder bores as they pass thereby so as to form a natural, streamlined pasage through which fluid may enter the cylinder bores, thus eliminating entrance shock which would cause a pressure drop in the fluid and retard filling and pressurization of the cylinder bore chamber **16**.

The capacity of the pump **42** is such as to be sufficient to supply the required lubricating flow through the passage **48** to completely fill any of the cylinder bores **16** which had not become completely filled through their communication with the intake port **32** and to elevate the pressure above the vapor pressure of the liquid in the area of the jet at all operating speeds of the pump. The size of the opening **52***a* of the passage **52** and its distance to the valving face **30** of the port plate is such as to insure that the jet energy will not be dissipated in the region outside of the cylinder bores. Within the chamber **53** the velocity head of the fluid entering through the passage **52** is converted into static pressure and trapped within the chamber to pressurize the cylinder bores during the transition of the pistons therein from suction to pumping strokes. The chamber also provides a longer period of time in which the cylinder bores are subjected to the dynamic effects of the jet.

As the cylinder bore leaves the area of impingement by the fluid from the passage **52** and moves out of communication with the chamber **53**, the piston has started its discharge stroke and has begun to impart energy to the liquid in the cylinder bore. To provide a smooth transition of pressure from that in the cylinder bores at that time, which is above the vapor pressure of the liquid, to a very high pressure, as the piston continues its discharge stroke the cylinder bore in moving toward the discharge port communicates first with a fishtail passageway **32***a* which permits a gradual increase in pressure by permitting a controlled rate of leakage into the intake port **32**. Instantaneously following communication with the passageway **32***a* on the inlet side of the pump the cylinder bore communicates with a fishtail passageway **33***a* which is in communication with the discharge port

33. Upon communicating with the passageway 33*a* the pressure within the cylinder bores will of course increase. A gradual increase in pressure to the full value of the discharge pressure is applied to the cylinder bore as it moves along the passageway 33*a* which increases in size until the cylinder bore communicates directly with the discharge port 33. Thus, the pressure level within the bore is gradually increased during the transition from suction to discharge in steps from fluid at vapor pressure to fluid slightly above vapor pressure to finally discharge pressure. By providing a gradual transition cavitation is substantially eliminated with the accompanying elimination of the deleterious effects on the performance characteristics of the pump thereof previously discussed.

It will be understood from the foregoing that the jet of fluid emitted from the passage 52 need not be of great volume but because of the fact that it is directed at the point prior to the valving transition it provides a simple means not only of preventing cavitation effects, but also of insuring complete filling of the cylinder bores and thus full delivery at high speeds of operation. The velocity of the jet of fluid of course increases with increasing speeds of rotation of the drive shaft 14 of the pump which is a highly desirable effect inasmuch as the effects of cavitation and lack of complete filling are most evident as speed increases. A relief valve is not necessary to control the upper limit of the pressure within the passage 52 as excess of pressure is relieved into the intake port 32.

The advantages of employing a relatively low capacity gear pump together with a jet and chamber system described over a fully supercharged pump are primarly because of the small amount of power and fluid required to make up any loss of flow due to vapor cavities. This loss is actually only about 2% to 3% of the total flow. The fully supercharged pump must be provided with means to pressurize the complete volume of inlet oil and thus relatively large pressure pumps must be provided, particularly when used with pumps with large displacements. In addition, where the pump to be supercharged is variable delivery, completely supercharged pumps of that nature must be provided with means to relieve the excess flow when the pump is operating at partial or zero flow operation. In the present system, however, excess flow through the passage 52 is merely returned to the intake port and thus to the intake system of the main pump. Leakage of excess flow through the passage 52 and into the intake port 32 is somewhat restricted by the jet of fluid emitting from the opening 52*a*. As shown in Fig. 2, the diameter of this opening is preferably equal to the diameter of the chamber 53 and thus fluid is at least partially entrapped by the jet in the opposite end of the chamber, elevating fluid in that end of the chamber to a pressure well above that existing in the intake port.

An alternate method for supercharging the piston pump to elevate the fluid in the piston bore cavities above the vapor pressure when operating at altitude or high suction pressure is illustrated by the schematic diagrams Fig. 5 and Fig. 6. As many of the parts are similar to those already described; similar, but primed, reference numerals will be used to designate similar parts. The supercharging fluid is supplied as previously described preferably by a positive displacement type of gear pump through channel 44' which directs the fluid in a chamber 53'. A small orifice 54 is provided between the supercharging port 53' and the inlet port 32'. This orifice directs the excess flow to the inlet port 32' and creates a pressure drop to maintain fluid in the supercharging port 53' above the vapor pressure. The supercharging pump naturally must be sized to fill the piston bore cavity 16' during the supercharging stroke, fill up the voids created during the suction stroke due to incomplete filling as well as to provide some flow through the orifice 54 to create a pressure drop to elevate the fluid in the cavity 53' above the vapor pressure.

The seal space 55 is proportioned to avoid overlap of supercharging port 53' and inlet port 32' by the piston bores 16'. Any overlap tends to increase the by-pass flow to chamber 32' and, thereby, reduce the pressure level in chamber 53'.

By this method of gradually elevating the pressure of the fluid during the transition from the inlet to the discharge ports and filling all voids, cavitational effects are minimized as also demonstrated in the jet supercharging methods. The circuit shown in Fig. 5 and Fig. 6 does not utilize the dynamic energy effect of a jet directed into the piston chamber bores 16' but rather provides an independent supercharging port in which the fluid pressure is elevated above the vapor pressure.

The fishtails 32*a*', 33*a*' shown on the valving arrangement are used as previously described to make the transition between supercharging pressure and discharge pressure more gradual. Such provision minimizes entrance shock when a body of fluid at low pressure is suddently transported into a region of high pressure.

We claim:

1. In a multiple piston rotatable barrel wobbler type pump having a port plate provided with a face portion having an intake port and a discharge port formed in said face portion positioned to register with the cylinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port, and superchanging means comprising a passage opening through said face portion adjacent the cut-off end of the intake port, and means connecting the passage to a source of fluid under pressure whereby to direct a jet of said fluid at the cylinders as said cylinders pass said passage.

2. In a multiple piston rotatable barrel wobbler type pump having a port plate provided with a face portion having an intake port and a discharge port formed in said face portion positioned to register with the cylinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port, and supercharging means comprising a chamber formed in the port plate and opening through said face portion adjacent the cut-off end of the intake port, a passage opening into said chamber and directed toward the plane of said face portion, and means connecting the passage to a source of fluid under pressure whereby to direct a jet of said fluid at the cylinders as said cylinders pass said passage.

3. In a multiple piston rotatable barrel wobbler type pump having a port plate provided with a face portion having an intake port and a discharge port formed in said face portion positioned to register with the cylinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port, and supercharging means comprising a chamber formed in the port plate and opening through said face portion adjacent the cut-off end of the intake port, said chamber having a restricted opening communicating with the intake port, a passage opening into said chamber and directed toward the plane of said face portion, and means connecting the passage to a source of fluid under pressure whereby to direct a jet of said fluid at the cylinders as said cylinders pass said passage and to retain fluid in the chamber at a pressure in excess of the fluid pressure in the intake port.

4. In a multiple piston rotatable barrel wobbler type pump having an inlet and an outlet, a port plate having an annular flat face portion provided with arcuate intake and discharge ports spaced around said face portion and positioned to register with the cylinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port under pressure, and said intake port terminating at its cut-off end in a restricted chamber, a passage opening into said chamber, and means connecting the passage to a source of fluid under

pressure to maintain in said chamber fluid at a pressure in excess of the fluid pressure in the intake port.

5. In a multiple piston rotatable barrel wobbler type pump having an inlet and an outlet, a port plate having an annular flat face portion provided with arcuate intake and discharge ports spaced around said face portion and positioned to register with the cylinders upon rotation of the barrel, said intake port terminating at its cut-off end in a restricted chamber, a passage opening into said chamber, means for supplying fluid to be pumped to said intake port under pressure, other means for supplying said fluid to said passage under pressure in excess of the pressure of fluid supplied to said intake port to maintain in said chamber fluid at a pressure in excess of the fluid pressure in the intake port.

6. In a multiple piston rotatable barrel wobbler type pump having an inlet and an outlet, a port plate having an annular flat face portion provided with arcuate intake and discharge ports spaced around said face portion and positioned to register with the cylinders upon rotation of the barrel, said intake port terminating at its cut-off end in a restricted chamber, a passage opening into said chamber and directed toward the plane of said face portion, means for supplying fluid to be pumped to said intake port under pressure, other means for supplying said fluid to said passage under pressure in excess of the pressure of fluid supplied to said intake port to direct a jet of said fluid at the cylinders as said cylinders pass the chamber and to maintain in said chamber fluid at a pressure in excess of the fluid pressure in the intake port.

7. In a multiple piston rotatable barrel wobbler type pump having an inlet and an outlet, a casing housing the pump, a drive shaft rotatably supported in the casing and carrying the barrel, a port plate in the casing having an annular flat face portion provided with arcuate intake and discharge ports spaced around said face portion and positioned to register with the cylinders upon rotation of the barrel, said intake port terminating at its cut-off end in a restricted chamber, a passage opening into said chamber, an inlet chamber in the casing communicating with the inlet and the intake port, pumping means in the inlet chamber connected to be driven by the drive shaft for supplying fluid to be pumped to said intake port under pressure, another pumping means in the casing connected to be driven by the drive shaft for supplying said fluid to said passage under pressure in excess of the fluid pressure in the intake port.

8. In a multiple piston rotatable barrel wobbler type pump having a port plate provided with a face portion having an intake port and a discharge port formed in said face portion positioned to register with the cylinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port, and supercharging means comprising a chamber formed in the port plate and opening through said face portion adjacent the cut-off end of the intake port, said chamber opening extending along said face portion a sufficient distance as to register with each cylinder at least until the piston therein initiates its discharge stroke, a passing opening into said chamber and directed toward the plane of said face portion, and means connecting the passage to a source of fluid under pressure whereby to direct a jet of said fluid at the cylinders as said cylinders pass said passage.

9. In a multiple piston rotatable barrel wobbler type pump having an inlet and an outlet, a port plate having an inlet and an outlet, a port plate having an annular flat face portion provided with arcuate intake and discharge ports spaced around said face portion and positioned to register with the cylinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port under pressure, and a chamber in the face portion communicating at one end with the cut-off end of the intake port and extending from said one end along the face portion toward the discharge port, a passage having a diameter substantially equal to the diameter of the chamber and opening thereinto adjacent said one end thereof, and means connecting the passage to a source of fluid under pressure to maintain in said chamber fluid at a pressure in excess of the fluid pressure in the intake port.

10. In a multiple piston pump having a port plate provided with arcuate intake and discharge ports and having a cylinder block provided with a plurality of cylinders in which said pistons are reciprocable and means for producing relative rotary movement between said plate and said block to bring the cylinders alternately into register with the intake and discharge ports, means for supplying fluid to be pumped to said intake port under pressure, and means for supercharging the cylinder comprising a chamber in the port plate communicating at one end with the cut-off end of the intake port and extending along the port plate toward said discharge port, a passage having a diameter substantially equal to the diameter of the chamber and opening thereinto adjacent said one end thereof, and means connecting the passage to a source of fluid under pressure to maintain in said chamber fluid at a pressure in excess of the fluid pressure in the intake port.

11. In a multiple piston rotatable barrel wobbler type pump having a port plate provided with a face portion having an intake port and a discharge port formed in said face portion and positioned to register with the cylinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port, and supercharging means comprising a chamber formed in the port plate and opening through said face portion, said chamber being spaced from the cut-off end of the intake port and positioned to register with the cylinders subsequent to registry thereof with the intake port, a passage opening into said chamber, means connecting said passage to a source of fluid under pressure, and a restricted passageway connecting said chamber to the intake port.

12. In a multiple piston rotatable barrel wobbler type pump having a port plate provided with a face portion having an intake port and a discharge port formed in said face portion and positioned to register with the cyinders upon rotation of the barrel, means for supplying fluid to be pumped to said intake port, and supercharging means comprising a chamber formed in the port plate and opening through said face portion, said chamber being spaced from the cut-off end of the intake port a distance at least equal to the diameter of the cylinders and said chamber extending along said face portion a sufficient distance as to register with each cylinder at least until the piston therein initiates its discharge stroke, a passage opening into said chamber, means connecting said passage to a source of fluid under pressure, and a restricted passageway formed in said face portion of the port plate and interconnecting the chamber and the intake port.

13. In a multiple piston rotatable barrel wobbler type pump having an inlet and an outlet, a port plate having a flat face portion provided with an intake port and a discharge port connected respectively to the inlet and to the outlet with said ports being positioned to register with the cylinders upon rotation of the barrel, supercharging means comprising a chamber formed in the port plate adjacent the cut-off end of the intake port, an auxiliary pump having its inlet communicating with the pump inlet, a passage interconnecting the outlet of the auxiliary pump with said chamber, and means providing a restricted passageway interconnecting the chamber with the intake port.

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