Dec. 10, 1968 L. R. CONNELLY 3,415,194

PUMP

Filed Sept. 16, 1966 3 Sheets-Sheet 1

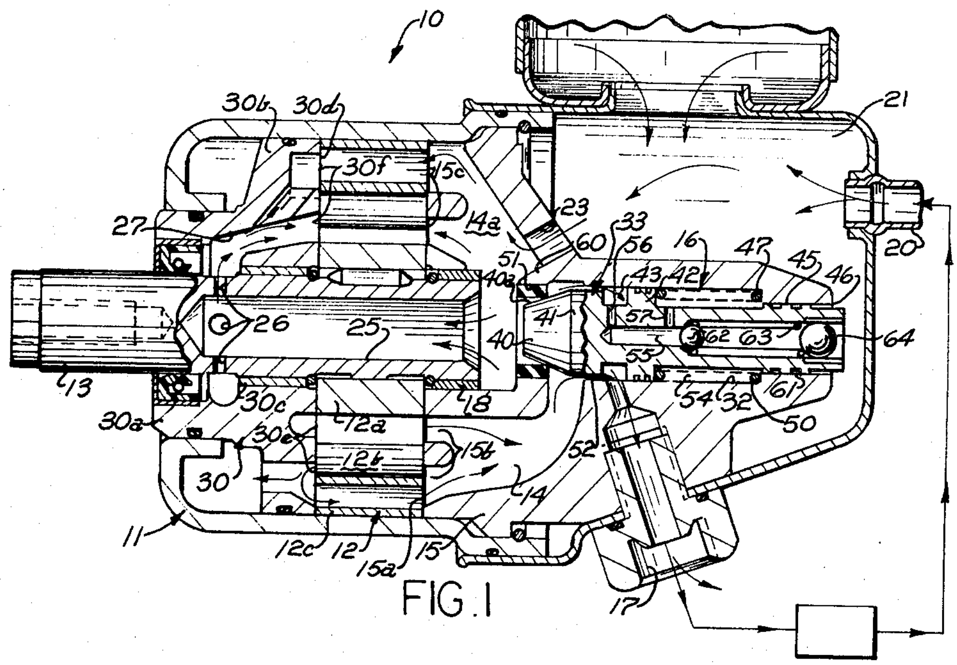

FIG. 1

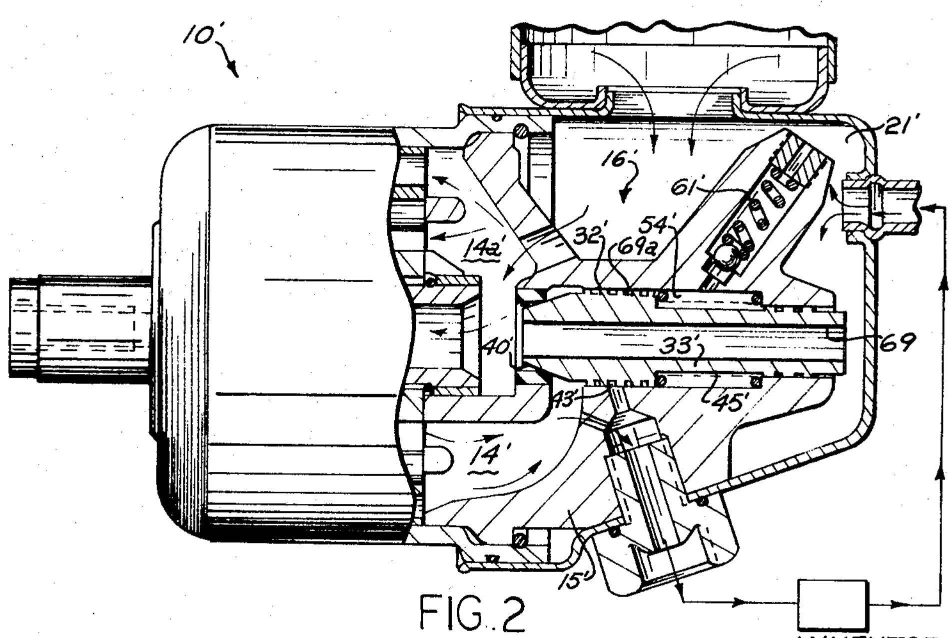

FIG. 2

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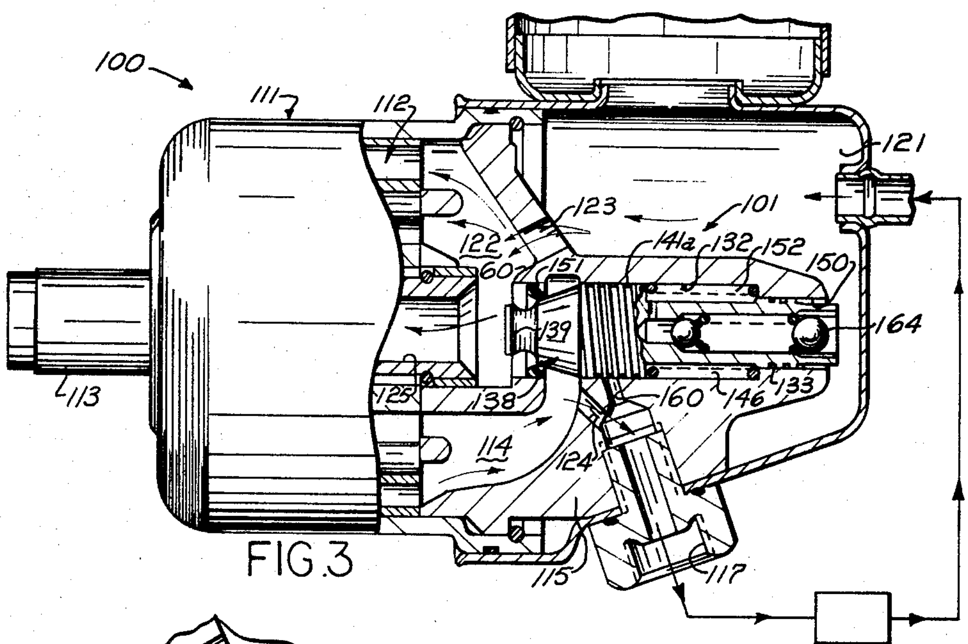

FIG.3

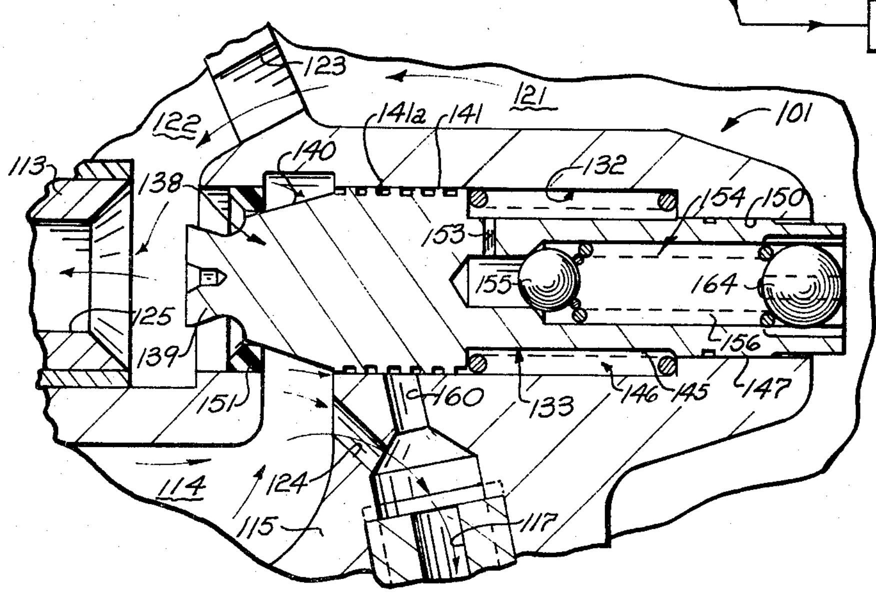

FIG.4

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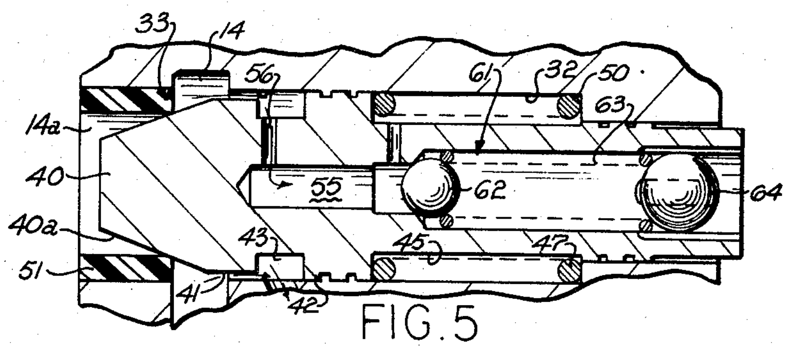

FIG. 5

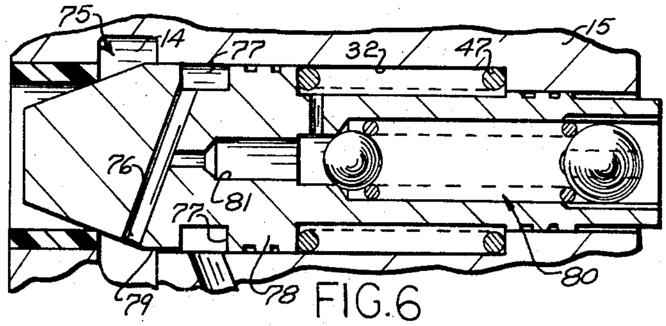

FIG. 6

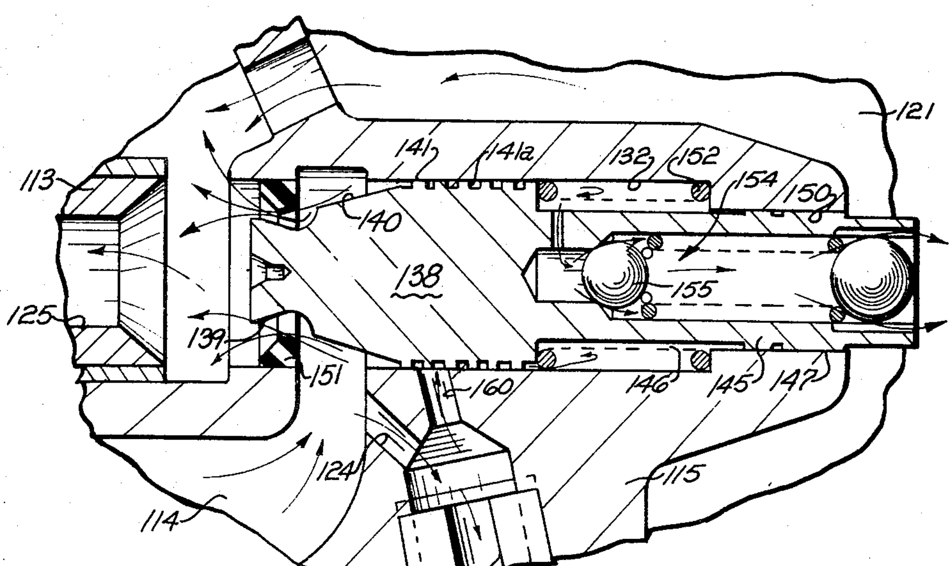

FIG. 7

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17 Claims. (Cl. 103—41)

ABSTRACT OF THE DISCLOSURE

A pump includes a flow control means which is effective to provide a generally constant flow of fluid to a fluid system at pump speeds below a predetermined speed and a controlled decreasing flow of fluid to the system at pump speeds above the predetermined speed. The flow control means is responsive to increases in the pressure in the system to provide increased flow to the system as a load is applied to the system.

The present invention relates to a pump, and more particularly relates to a pump having flow control means associated therewith for controlling the flow of discharge fluid from the pump to a fluid system.

A pump embodying the present invention may be utilized in a hydraulic power steering system in an automotive vehicle, or the like and is particularly adapted for such use. Such known pumps include a pump housing containing a pumping means having a fluid discharge for directing fluid to the system and an inlet for receiving flow from the system. The known pumps also include a flow control valve means which operates to bypass a portion of the fluid discharged from the pumping means to the inlet of the pumping means and thereby controls the amount of fluid which is directed from the pump.

An object of the present invention is the provision of a new and improved pump for supplying fluid to an external fluid system and having flow control means associated therewith for controlling the flow of fluid discharged from the pump to the system by bypassing discharged fluid to the pump inlet, and wherein the flow control means is operable to provide a decreasing amount of fluid flow to the system as pump speed increases above a predetermined speed and provides an increased amount of fluid flow to the system at pump speeds above the predetermined speed when system pressure increases.

Another object of the present invention is the provision of a new and improved pump for supplying fluid to a fluid system including pumping means having flow control means associated therewith to control the amount of fluid directed to the system by bypassing a portion of the fluid discharged from the pumping means to an inlet of the pumping means, and wherein the flow control means is constructed so as to bypass the fluid at a substantial velocity.

Another object of the present invention is the provision of a new and improved pump, as noted in the next preceding paragraph, wherein the flow control means includes a valve member having a surface portion which directs the bypassed fluid inwardly of the valve and has a flared end portion which then directs the fluid outwardly of the valve.

Another object of the present invention is the provision of a new and improved pump, as set forth in the next preceding paragraph, and wherein the high velocity bypassed fluid is directed toward the inlet of the pumping means so that a low pressure region is created adjacent an inlet of the pump to draw fluid from the system into the pumping means.

A further object of the present invention is the provision of a new and improved pump operable to supply fluid to

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a fluid system and including inlet and discharge passageways communicating with the system, flow control means operable to control the amount of discharge fluid flowing to the system and including a valve member movable to bypass fluid from the discharge passageway to the inlet passageway in response to a pressure differential acting thereon, and wherein the pressure differential is created at least in part by the action of a flow restricting orifice in the form of a groove formed in the valve member and which variably restricts fluid flow therethrough in response to movement of the valve member.

Yet another object of the present invention is the provision of a new and improved pump for supplying fluid to a fluid system including pumping means having inlet and discharge passageways communicating with the system and flow control means operable to control the amount of fluid supplied by the pump to the system, the flow control means including a valve member movable to bypass fluid from the discharge passageway to the inlet passageway to reduce the flow of fluid to the system, and wherein the valve member has an opening therethrough between the inlet passageway and a fluid reservoir so that fluid flows from the reservoir into the inlet passageway therethrough.

Another object of the present invention is the provision of a new and improved pump, as set forth in the next preceding paragraph and in which the valve member is movably disposed in a bore defining a fluid chamber with pressure in the chamber acting on a portion of the valve member and tending to move the valve member, and wherein a relief valve means opens to direct fluid from the chamber to the reservoir when fluid pressure in the chamber is above a predetermined pressure.

Further objects and advantages of the present invention will be apparent to those skilled in the art to which it relates from the following detailed description thereof made with reference to the accompanying drawings forming a part of this specification and in which:

FIG. 1 is a sectional view of a pump embodying the present invention;

FIG. 2 is a section view of a modified pump embodying the present invention with portions thereof shown in elevation;

FIG. 3 is a sectional view of a further modified pump embodying the present invention and having parts thereof shown in elevation;

FIG. 4 is a fragmentary sectional view of a portion of the pump shown in FIG. 3;

FIG. 5 is a fragmentary sectional view of a portion of the pump shown in FIG. 1;

FIG. 6 is a sectional view of a further modified structure for use in a fluid pump; and

FIG. 7 is a sectional view of the portion of the pump shown in FIG. 4 in a different operative condition.

A pump **10** embodying the present invention is particularly suited for use in a hydraulically operated automotive power steering system and has been described in conjunction with such a system which has been illustrated schematically in the drawings. However, it will become apparent from the following description that a pump emmodying the present invention is suitable for use in many environments.

As shown in FIG. 1, the pump **10** includes a housing **11**, pumping means **12**, and a driving shaft **13** extending into the housing **11** and drivingly connected to the pumping means **12**. The shaft **13** is adapted to be driven from an engine of the vehicle, not shown, at speeds which vary with the engine speed. The pumping means **12** is preferably a rotary pump and, as illustrated, includes a rotor member **12a** which is secured to the shaft **13** for rotation therewith. The rotor member includes a plurality of radially extending grooves or slots therein which carry cylindrical pumping elements **12***b*. A cam member **12***c* surrounds the pumping rotor and includes a cam surface upon which the pumping elements **12***b* are moved by the rotor as the rotor is rotated by the shaft **13**. The cam surface is so configured that the pumping elements **12***b* are moved radially relative to the rotor member **12***a* during a revolution thereof. Radial movement of the pumping elements **12***b* relative to the rotor member **12***a* effects pumping of fluid in a manner which is well known. The cam surface of the cam member **12***c* may be configured to provide any number of pumping strokes of the pumping elements. In the preferred embodiment, two such pumping strokes are provided for.

A cover member **15** is positioned in the housing **11** adjacent the pumping means **12** at an axial side thereof. The cover member **15** includes a pair of discharge chambers **14**, only one of which is illustrated, and which are spaced approximately 180 degrees apart in the cover member **15**. The discharge chambers **14** open into a planar surface **15***a* adjacent the pumping means **12** to provide discharge ports **15***b* for the pumping means **12**. The discharge chambers **14** communicates with the discharge ports **15***a* and with the fluid system through a discharge passage **17**. The cover member **15** also includes a pair of inlet chambers **14***a* which are spaced approximately 180 degrees apart therein and which open into the surface **15***a* to provide inlet ports **15***c* for the pumping means **12**.

The inlet chambers **14***a* communicate with the inlet ports **15***c* and with a fluid reservoir **21** of the system. The cover member **15** additionally includes a central portion which forms a support for a suitable bearing **18**. The bearing **18** rotatably supports an end of the shaft **13** in the cover member **15**.

The pumping means **12** is positioned in the housing **11** between the cover member **15** and an end plate member **30**. The end plate member **30** is fixed in the housing by means of screws, not shown, which extend through the end plate member, the cam member and are threadedly engaged in the cover member **15**. The end plate member **30** includes a body portion **30***a* and a flange portion **30***b*. The body portion **30***a* surrounds the shaft **13** and provides a support for a bearing **30***c* which rotatably supports the shaft. The body portion **30***a* additionally is associated with siutable seals to prevent leakage of fluid between the body portion and the housing **11** and shaft **13**, respectively.

The flange portion **30***b* includes a planar surface **30***d* adjacent the pumping means **12** and which includes grooves or chambers therein which form discharge ports **30***e* for the pumping means **12** and which communicate with the discharge chambers **14**. The discharge ports **30***e* in the end plate are spaced apart approximately 180 degrees in the end plate member and are located in registry with the discharge chambers **14**. The flange portion **30***b* also includes grooves or chamber which form inlet ports **30***f* for the pumping means **12**. The inlet ports **30***f* communicate with the inlet chambers **14***a* in the cover member **15** by conduit means which extend therebetween. The conduit means includes a central flow passage **25** in the shaft **13** which opens into the inlet chamber **14***a* at the end of the shaft **13** supported in the cover member **15**. The passage **25** communicates with the inlet ports **30***f* in the end plate **30** through ports **26** extending between the passage **25** and the outer periphery of the shaft, and a flow passage **27** in the end plate which is operable to direct fluid from the ports **26** into the pumping means **12** through the inlet ports **30***f*.

The operation of the pump **10** should be apparent from the foregoing description. The rotor member **12***a* is rotated by the shaft **13** to effect pumping of the fluid. Fluid at discharge pressure of the pump flows into the discharge chamber **14** and is directed therefrom to the power steering system through the discharge passage **17**. Fluid which has traversed the system is returned therefrom to the fluid reservoir **21** and into the inlet chambers **14***a* in the cover member **15**. Fluid in the inlet chambers **14***a* is directed

to the pumping means **12** through the inlet ports in the cover member **15** and through the passage **25** in the shaft **13** and to the inlet ports in the end plate **30**. The pumping means **12** is of the positive displacement type and it should be apparent that the quantity of fluid pumped thereby in the manner described depends on the rotational speed of the pumping rotor member **12***a* as controlled by the vehicle engine speed.

In acordance with the present invention, flow control means **16** is provided for controlling the amount of fluid flowing from the pumping means **12** to the system. The flow control means **16** is operable to bypass fluid from the discharge chamber **14** to the inlet chamber **14***a* and thereby reduce the quantity of fluid directed to the fluid system. As shown in FIG. 1, the flow control means **16** includes a bore **32** in the cover member **15** opening at its opposite ends into the inlet chamber **14***a* and the reservoir **21**. The bore **32** also includes openings therein communicating with the discharge chamber **14** and the discharge fitting **17** leading to the fluid system. A valve member **33** is slidably supported in the bore **32** and is movable axially therein in response to differential fluid pressure forces acting thereon to bypass fluid from the discharge chamber to the inlet chamber to provide a controlled amount of fluid flow to the system.

As shown in the drawings, the valve member **33** includes a generally cylindrical portion **41** at the end thereof adjacent the inlet chamber **14***a* and which has a diametrical extent slightly less than the diametrical extent of the bore **32**. The valve member **33** also includes a land portion **42** spaced from the aforementioned cylindrical portion **41** to provide an annular chamber **43** therebetween. The land portion **42** is provided with a plurality of grooves to effect a seal between the valve member **33** and the bore **32**, as well as to provide a floating relationship between valve member **33** and the bore **32**. The valve member **33** additionally includes an end portion **45** extending from the land portion **42** toward the reservoir **21** which is of smaller diametrical extent than the land portion **42**. The end portion **45** includes a plurality of sealing grooves adjacent its right-hand end, as viewed in the drawing, and which are effective to form a seal between the end **45** of the valve member **33** and a cylindrical opening **46** at the end of the bore adjacent the reservoir **21**, as well as to "float" the valve member in the opening **46**. The opening **46** is of a diametrical extent which is smaller than that of the bore **32**. Spring means **47** acts between the land **42** of the valve member **33** and a shoulder **50** formed by the juncture of the bore **32** at the opening **46**. The spring means **47** is effective to urge the valve member **33** to the left, as viewed in the drawings, and urges an end portion **40** of the valve member **33** into sealing engagement with a valve seat **51** fixed in the bore **32** between the discharge chamber **14** and the inlet chambers **14***a*.

When the valve member **33** is in its position shown in FIG. 1, fluid flowing from the discharge chamber **14** of the pump passes in a restricted manner through a controlled flow orifice **52** formed by the cylindrical portion **41** of the valve member 33 and the periphery of the bore **32**. Since discharge fluid flowing to the system traverses this orifice, it may be referred to as the primary flow controlling orifice or primary orifice. Fluid flowing through the primary orifice **52** is directed to the fluid system through the fluid discharge passage **17**. Fluid which passes through the orifice **52** and into the annular chamber **43**, formed between the portion **41** and the land **42** of the valve member, experiences a pressure drop so that the pressure in the chamber **43** is lower than that of the fluid in the pump discharge chambers **14**. The chamber **43** is in fluid communication with a chamber **54** formed between the end **45** of the valve and the bore **32** by means of a flow passage **55** in the valve member **33** and which communicates with the chambers **43**, **54** by way of ports **56**, **57**.

When the valve member **33** is in its position shown in FIG. 1, and the pump is operating at fairly low speed, fluid discharged from the pumping means **12** into the discharge chamber **14** is directed to the fluid system through the discharge passage **17**. At a given system pressure, and as pumping speeds increase, the amount of fluid flowing to the system increases, as noted above. At a predetermined pump speed, the pressure differential across the valve member is effective to shift the valve member toward the right, as viewed in the drawings, such that the end **40** thereof is moved out of sealing engagement with the valve seat **51**. When the valve member **33** moves to the right, as described, against the bias of the spring means **47**, fluid from the discharge chamber **14** flows between the end **40** of the valve member **33** and the valve seat **51** and is bypassed from the system to the inlet chamber **14*a***. As pump speeds continue to increase above the predetermined speed, greater quantities of discharge fluid are bypassed and a lesser amount of fluid flows to the system. The characteristic of decreasing flow as pump speed increases above a predetermined speed is referred to as "flow droop."

The flow control means **16** includes nozzle means for directing bypass fluid inwardly of the valve member and into the inlet chamber of the pump at a substantial velocity to conserve the energy of the fluid bypassed and reduce system temperatures accordingly. The nozzle means includes a frusto-conical peripheral portion **40*a*** at the end **40** of the valve member **33**. Fluid flowing from the discharge chamber **14** to the inlet chamber **14*a*** is directed through an opening formed by the frusto-conical periphery **40*a*** of the valve member **33** and the valve set **51** when the valve member is in a bypass position. The frusto-conical portion **40*a*** and the valve seat **51** cooperate to form a "Venturi" effect. When the valve member moves as described, fluid is bypassed between the portion **40*a*** and the valve seat **51** to provide the aformentioned flow droop. The amount of droop in flow for a particular pump is controlled by the angle of the frusto-conical portion **40*a*** with droop increasing as the included angle of the portion **40*a*** is increased.

The high velocity fluid flowing between the valve **33** and the valve seat **51** is directed into the inlet chamber **14*a*** in the cover **15** and into the passageway **25** formed in the shaft **13**, from which it is delivered to the inlet ports **30*f*** in the end plate **30** through the passages **26, 27**. It should be apparent that the bypassing of fluid effected by the valve **33**, as described, is extremely efficient and that recovery of the pressure of the discharged fluid is effected as the velocity of the fluid bypassed is reduced in the inlet of the pumping means. This recovery of the pressure is effective to minimize temperature rises of the fluid in the system which might otherwise occur if the fluid were bypassed in a restricted manner with a large pressure loss.

The pump **10** is constructed so that the high velocity bypass fluid is utilized to draw fluid into the inlet chambers **14*a*** from the reservoir **21**. As illustrated in FIG. 1, the cover member **15** is provided with a ledge **60** adjacent a port **23** between the reservoir **21** and the inlet chambers **14*a***. The ledge **60**, port **23**, and the valve member **33** are associated so that when high velocity bypass fluid flows past the ledge **60**, a low pressure area is developed in the inlet chamber **14*a*** adjacent the port **23**. This low pressure region in the inlet chamber **23** is created due to the high velocity of the bypassed fluid and causes fluid in the reservoir **21** to be drawn through the port **23** and into the inlet chamber **22**. This operation of the valve member **33** may be termed "supercharging", since the fluid in the reservoir **21** is urged into the pump inlet and is a result of utilization of the energy of the bypass fluid.

When fluid is being bypassed and the system pressure increases, as when fluid is required by the system, the flow control means **16** effects an increase in the flow of fluid to the system. Increases in the system pressure result in increased pressure in the chamber **54** which urges the valve member **33** toward the left, as viewed in the drawings. Movement of the valve member **33** to the left reduces the amount of fluid being bypassed and thus increases the amount of fluid flowing to the system to satisfy system fluid requirements at pump speeds above the predetermined pump speed. It should be apparent that the flow control means is effective to provide a droop in the quantity of fluid flowing to the system and is also operable to increase the flow of fluid to the system when system fluid requirements increase.

In the event that fluid pressure in the system should exceed a predetermined pressure, relief valve means **61**, carried by the valve member **33**, opens to communicate fluid in the chamber **54** with the reservoir **21** through the port **57** and passage **55** thereby reducing pressure in the chamber **54** and effecting movement of the valve member **33** to the right, as viewed in the drawings, to bypass additional fluid from the system. As shown in the drawings, the relief valve means **61** includes a check ball **62** positioned in a passage in the valve member **33** and which is biased to a closed position by a spring means **63**. The spring means **63** acts between a reaction ball member **64** and the check ball **62** and yields at a predetermined pressure to provide for opening of the check valve means **61** to provide for a reduction of fluid pressure in the chamber **54** by communicating the chamber **54** with the reservoir **21** through the port **57** and valve **61**, permitting discharge fluid to flow from the chamber **43** to the reservoir **21** through the port **56** and the valve **61**. The system pressure therefore is controlled by the relief valve means **61** subsequent to opening thereof.

Operation of the pump **10** and flow control means **16** should be apparent from the foregoing description. When the pumping means **12** is stopped or pumping at low rates, the valve **33** is in its condition shown in FIG. 1 and fluid which is discharged from the pumping means **12** is delivered to the fluid system by way of the discharge chambers **14**, primary orifice **52** and discharge passage **17**. At a given system pressure, and as pump speed increases, flow rates from the pump increase, and the pressure forces in the discharge chamber **14** acting on the valve **33** toward the right increase at a rate which is greater than the increase in the pressure force acting toward the left on the valve member **33**. At a predetermined pump speed, the pressure forces produced by the fluid in the discharge chambers **14** overcome the opposing pressure forces acting on the valve member **33** and the force of the spring **47** to move the valve member **33** to the right, as viewed in the drawings. When the valve member **33** is moved to the right, the portion **40*a*** thereof is moved away from the valve seat **51** to produce the nozzle-like passageway between the discharge chambers **14** and the inlet chambers **14*a***.

Fluid flowing between the discharge chambers **14** and the inlet chambers **14*a*** is bypassed through the nozzle-like opening at relatively high velocities and with a minimum of pressure loss. The fluid traversing the aforementioned nozzle is directed into the inlet of the pumping means by way of the aforementioned inlet ports in the cover member and end plate. Additionally, the high velocity fluid creates a low pressure region to the left of the valve member **33**, as viewed in the drawings, and which low pressure region is effective to induce a flow of fluid from the reservoir **21** through the port **23** and into the inlet chamber **14*a***.

The valve member **33** moves toward the right, as viewed in the drawings, until the pressure acting thereon from the discharge chamber **14** is balanced by the opposing pressure and spring forces. Balancing of these forces occurs at a position of the valve member wherein a given amount of discharge fluid is being bypassed to the inlet chamber **14*a***. Further increases in pump speed will result in the valve member **33** being moved further to the right until the forces acting on the valve member are again balanced and with a still further increase in the amount of fluid bypassed from the discharge chamber **14** to the inlet chamber **14***a* to produce the aforementioned flow droop.

When the system pressure increases at a given pump speed above the predetermined speed, the valve member moves to increase the amount of fluid flowing to the system to satisfy system fluid requirements.

When the system pressure increases above a predetermined pressure, the relief valve means **61** in the valve member **33** cracks resulting in additional bypassing of fluid from the system and controlling of the system pressure.

Referring to FIG. 6, a modified valve member **75** is shown. The valve member **75** is similar in configuration to the valve member **33** previously described, but includes a flow restricting passageway **76** which extends between the discharge chamber of the pump and a chamber **77** formed between a land portion **78** and the cylindrical portion **79** of the valve member. The passageway **76** forms the primary orifice of the flow control means in this embodiment and, therefore, the land **78** and cylindrical portion **79** are of the same diameter. The chamber **77** is in fluid communication with a check valve means **80** positioned in the valve member by way of a fluid passageway **81** extending therebetween. At a predetermined pressure in the passageway **81**, which is a function of the system pressure, the check valve means **80** opens to bypass fluid from the discharge chamber of the pump to the reservoir thereof. Operation of the flow control means **16** including the valve member **75** is substantially the same as described previously in reference to FIG. 1.

Referring to FIG. 3, a modified pump **100** embodying the present invention is shown. The pump **100** is connected in the fluid system, as decribed above, to provide for circulation of fluid therethrough. The pump **100** includes a housing **111** containing a pumping means **112** drivingly connected to a shaft means **113** for rotation therewith. The pumping means **112** is supported between a cover member **115** and an end plate, not shown, which are fixed in the housing **111**. The construction of the aforementioned parts of the pump **100** is substantially the same as that described in reference to FIG. 1 and, therefore, the construction of these parts will not be further described in detail. The pump **100** also includes a flow control means **101** which is effective to control the flow of fluid from a discharge chamber **114** of the pump to the external system by bypassing fluid from the discharge chamber **114** to an inlet chamber **122** of the pump in a highly efficient manner.

The inlet chamber **122** of the pump is in fluid communication with an inlet of the pumping means **112** directly from the chamber **122**, and through a central opening **125** in the drive shaft **113**, which opening communicates fluid from the inlet chamber **122** in the pump to the opposite side of the pumping means **112**, as described above in reference to FIG. 1.

The chambers **114**, **122** are formed in the cover member **115** of the pump which also includes a port **123** communicating the inlet chamber **122** of the pump with a fluid reservoir **121**. The cover member **115** of the pump is formed with an axially extending bore **132** therein which opens at its ends into the inlet chamber **122** and the reservoir **121**, respectively. The bore **132** is configured as described above in reference to FIG. 1. A valve member **133** is slidably supported in the bore **132** and is operable to bypass fluid from the discharge chamber **114** to the inlet chamber **122** in response to a predetermined pressure differential thereacross, as will be described in detail below. An end **138** of the valve member **133** adjacent the inlet passageway **122** is adapted to sealingly engage a valve seat **151** which is fixed to the cover member **115** when the valve is in its position as shown in FIG. 3 so that discharge fluid in the chamber **114** is prevented from entering the inlet chamber **122**. The valve seat is an annular member having a generally triangular cross section to provide a frusto-conical surface which converges in the direction of the valve bore **132**. The valve member **133** moves toward the right, as viewed in the drawings, to bypass fluid from the discharge chamber to the inlet chamber between the end **138** of the valve member and the valve seat **151**.

The valve member **133** includes a generally cylindrical portion **141** (see FIG. 4), having a diametrical extent substantially the same as the diametrical extent of the bore **132** and which guides the valve member as it moves in the bore **132**. The cylindrical portion **141** is formed adjacent an end portion **145** which extends from the portion **141** toward the reservoir **121**. The end portion **145** of the valve member **133** is smaller in diameter than the portion **141** and provides a chamber **146** between the end portion **145** of the valve member and the bore **132**. The end portion **145** includes a slightly enlarged cylindrical portion **147** having annular grooves therein and which is adjacent the reservoir **122**. The portion **147** is in sealing engagement with a cylindrical opening **150** at the end of the bore **132**. Spring means **152** is located in the chamber **146** and is effective to urge the valve member **133** to the left, as viewed in the drawings and into engagement with the valve seat **151**.

The chamber **146** communicates with a check valve means **154** through a passageway **153** which extends from the chamber **146** to the central portion of the valve member **133**. The central portion of the valve member **133** contains the check valve means **154** seated against a reaction ball **164** to urge the check ball against a valve seat formed in the valve member **133** to close the passage **153** against fluid flow therethrough. When pressure in the chamber **146** overcomes the force of the spring **156**, the check ball **155** is moved off the valve seat and fluid in the chamber **146** flows through the passage **153** past the check ball **155**, reaction ball **164** and to the reservoir **121**. The chamber **146** also communicates with the fluid system through a port **160** extending between the bore **132** and the discharge passage **117** by means which will be described in detail hereinafter, so that the fluid pressure in the chamber **146** changes in response to changes in the system pressure.

The pump **100** is provided with flow restricting means for controlling the differential pressure forces acting across the valve member **133**. As shown in FIG. 3, the flow restricting means includes a primary flow restricting orifice **124** in the cover member **115** between the discharge chamber **114** and the system and through which fluid flowing to the system passes. The flow restricting means additionally includes a secondary flow restriction between the primary flow restriction **124** and the chamber **146**. The secondary flow restriction is provided by a helical groove **141***a* formed in the cylindrical portion **141** of the valve member **133** and which extends between chambers **114**, **146** past the port **160**. When the check valve means **154** opens, fluid flows through the groove **141***a* to the chamber **146** in a restricted manner. Restriction of the fluid flowing to the chamber **146** causes a drop in the pressure thereof so that when fluid passes through the groove **141***a*, the force acting on the valve member to urge it to the left, as viewed in the drawings, is reduced to increase the differential pressure across the valve member and cause the valve member to move toward the right as viewed in the drawings. The pressure drop across the secondary orifice depends on the effective length of the groove **141***a*, so that the pressure in the chamber **146** varies as the valve member **133** moves in the bore **132**. Moreover, when the pressure in the system increases the pressure in the chamber **146** also increases, relative to the fluid pressure acting adjacent the end **138** of the valve member, thus tending to reduce the pressure differential across the valve member and shift the valve member toward the left to increase the flow of fluid to the system. It has been found that shifting of the valve member **133** in response to increases in system pressure can be controlled by varying the internal diameter of the valve seat **151**. To increase flow to the system under increasing pressure, for example, the internal diameter of the seat **151** is made larger.

The flow control means **101** additionally includes means for directing fluid bypassed from the discharge chamber **114** to the inlet chamber **122** at a high velocity to limit pressure losses which might otherwise be dissipated as heat in the fluid. The end **138** of the valve member **133** includes an arcuately curved or flared portion **139** which terminates in a frusto-conical peripheral portion **140** of the valve member. The portion **140** is adapted to sealingly engage the valve seat **151** when the valve member **133** is in its position illustrated in FIG. 3, and provides a nozzle-like opening between the discharge and inlet chambers as the valve member **133** moves to a bypass position. The portions **139**, **140** of the valve member provide an unimpeded flow path for the bypassed fluid and cooperate to direct the bypassed fluid inwardly of the valve member and then outwardly thereof into the inlet chamber **122** at a high velocity.

Moreover, the amount of fluid bypassed and, therefore, the flow droop provided by the flow control means, is determined by the angle of the frusto-conical peripheral portion of the valve member and the configuration and diameter of the flared end portion **139**.

The nozzle-like opening formed between the valve seat **151** and the end portion **139** of the valve member has an area which changes with movement of the valve. As the valve member **133** moves to the right, the nozzle formed between the valve seat **151** and the flared end portion **139** suddenly becomes large due to the curvature of the end portion, as described, so that the pressure tending to urge the valve member to the right, as viewed in the drawings, is controlled accordingly. It should be appreciated that the length of the secondary orifice formed by the helical groove **141a** and the area of the nozzle formed between the valve member and the valve seat **151** change simultaneously as the valve is moved in the bore **132** so that a controlled amount of flow droop of pumped fluid is maintained to the system when the valve member **133** is bypassing fluid.

Operation of the pump **100** should be apparent from the foregoing description. When the pump is operated at speeds below a predetermined speed fluid in pump discharge chamber **114** acts on the frusto-conical portion of the valve member **133**, tending to urge the valve member **133** to the right against the bias of the spring means **152**. The pump discharge fluid flows from the discharge chamber **114** through the flow restricting orifice **124** and to the system through the passage **117**. Fluid in the passage **117** is in communication with the chamber **146** through the port **160** and the helical groove **141a** formed on the valve member **133** so that a pressure differential is provided across the valve member which acts in conjunction with the bias of the spring means to maintain the valve member in a position wherein a controlled generally constant amount of fluid flows to the system at pump speeds above the predetermined speed, the valve member moves to bypass additional fluid from the system so that a controlled droop in flow to the system is provided. When the pressure of the fluid in the system reaches a value sufficient to overcome the force of the spring **156**, the check valve means **154** opens to permit fluid flow from the chamber **146** to the reservoir as described above. When the check valve means **154** opens, fluid flows through the secondary orifice formed by the helical groove, **141a** and into the chamber **146** in a restricted manner, increasing the pressure differential across the valve member **133** and resulting in movement of the valve member **133** to the right, as viewed in the drawings, to bypass additional fluid from the system. As noted above, the pressure of the fluid flowing into the chamber **146** is determined by the effective length of the secondary orifice formed on the valve member and thus the pressure in the chamber **146** increases in response to movement of the valve member toward the left and decreases as the valve member moves toward the right. The amount of movement of the valve member is controlled by the pressure differential acting thereon, as well as the force of the spring **152** and when the pressure forces and spring force are balanced, the valve ember **133** is stationary in the bore **132** at a position wherein fluid is being bypassed from the discharge chamber **114** to the inlet chamber **122**.

As the valve member **133** moves to the right, as viewed in the drawings, the arcuately flared end portion **139** of the valve is moved adjacent the valve seat **151** so that an increased amount of fluid is bypassed from the discharge chamber **114** to the inlet **122** to provide a controlled amount of flow droop in the fluid flowing to the system.

When the system pressure increases and the pump is operating at a speed above the predetermined speed, the increased system pressure is communicated to the chamber **146** and is effective to cause movement of the valve member toward the left to increase the flow of pumped fluid to the system.

From the above description, it should be apparent that at a given system pressure the flow control means is effective to provide a generally constant flow of fluid to the fluid system at pump speeds below a predetermined speed and a controlled decreasing flow of fluid to the system at pump speeds above the predetermined speed. That is to say, the flow control means is effective to provide a controlled droop in flow to the system at a given system pressure as pump speeds increase above the predetermined speed. However, if the pressure of the fluid in the system increases when the pump speed is above the predetermined speed, the flow control means is effective to provide increased flow to the system thereby providing steering power to the power steering mechanism at high engine speeds.

FIG. 2 shows a modified pump **10'** embodying the present invention and including a modified valve member **33'** forming a portion of the flow control means **16'**. The modified valve **33'** includes a central cylindrical opening **69** extending therethrough between the inlet chamber **14a'** of the pump and the reservoir **21**. Additionally, the cover member **15'** is modified such that a relief valve means **61'** opens into the chamber **54'** formed between the bore **32'** and the end portion **45'** of the valve member **33'**. Operation of the valve member **33'** is essentially the same as described in reference to FIG. 3 except that when fluid is bypassed from the discharge chamber **14'** to the inlet chamber **14a'** past the frustoconical portion **40'** of the valve member, the high velocity bypass fluid directed inwardly of the valve member effects a low pressure immediately to the left of the valve member **33'**. The low pressure created adjacent this end of the valve in the inlet chamber **14a'** is effective to provide a flow of fluid from the reservoir **21'** through the central passage **69** in the valve member **33'** and into the inlet chamber **14a'**. This operation of the valve member **33'** may also be termed "supercharging" since the pressure in the reservoir is effective to urge the fluid therein through the valve member **33'** into the inlet chamber **14a'**.

Fluid pressure in the system is communicated to a chamber **54'** between the end portion **45'** and the bore **32'** to open the relief valve means **61'**, as described above in reference to FIG. 3, so that fluid may be directed therethrough to the reservoir **21'**. Fluid from the system is communicated to the relief valve **61'** through a helical groove **69a** on the outer periphery of the valve **33'**, as described in connection with FIG. 3, which controls the fluid pressure in the chamber **54'**.

While several embodiments of the present invention have been illustrated and described herein in considerable detail, the present invention is not to be considered limited to the precise constructions shown. It is my intention to cover hereby all adaptations, modifications, and uses of the present invention which come within the scope of the following claims.

Having described my invention, I claim:

1. A pump for supplying fluid to a fluid system comprising pumping means for pumping fluid from a fluid inlet to an outlet in communication with the system, flow control means operable to bypass fluid from the system and to reduce flow to the system as pump speed increases above a predetermined speed, said flow control means including a valve member movable in a first direction to bypass fluid and in a second direction opposite to said first direction to bypass less fluid as the pressure in the system increases whereby said pump when fluid is being bypassed provides reduced flow to the system and provides an increased flow to the system as system pressure increases, a first flow restricting means located between the pump outlet and said system and a second flow restricting means located between said chamber and said system, said second flow restricting means including a helical groove formed on said valve member and wherein movement of said valve member in said first direction is effective to increase the length of said second flow restricting means.

2. A pump for supplying fluid to a fluid system comprising pumping means for pumping fluid from a fluid inlet to an outlet in communication with the system, flow control means operable to bypass fluid from the system and to reduce flow to the system as pump speed increases above a predetermined speed, said flow control means including a valve member movable in a first direction to bypass fluid and in a second direction opposite to said first direction to bypass less fluid as the pressure in the system increases whereby said pump when fluid is being bypassed provides reduced flow to the system and provides an increased flow to the system as system pressure increases, said valve member including a peripheral surface portion tapering inwardly in the direction of flow of the by-passed fluid so that the portion exposed to inlet pressure is of a lesser cross sectional area than the portion exposed to discharge pressure and effective to direct by-passed fluid radially inwardly of the valve member and toward the pump inlet at a substantial velocity.

3. A pump for supplying fluid to a fluid system comprising pumping means for pumping fluid from a fluid inlet to an outlet in communication with the system, flow control means operable to bypass fluid from the system and to reduce flow to the system as pump speed increases above a predetermined speed, said flow control means including a valve member movable in a first direction to bypass fluid and in a second direction opposite to said first direction to bypass less fluid as the pressure in the system increases whereby said pump when fluid is being bypassed provides reduced flow to the system and provides an increased flow to the system as system pressure increases, said valve member including a peripheral surface portion effective to direct bypassed fluid radially inwardly of the valve member and toward the pump inlet at a substantial velocity, and a second surface portion adjacent said peripheral surface portion, said second surface portion including an arcuately flared peripheral surface on said valve member and operable to direct bypassed fluid radially outwardly of said valve member and toward said pump inlet.

4. A pump for supplying fluid from a reservoir to a fluid system comprising means defining a pump inlet chamber in communication with said reservoir, pumping means operable to pump fluid from said reservoir through said inlet chamber to said system, flow control means operable to by pass fluid from the system including a valve member having a first position blocking bypassing of fluid and movable from said first position to bypass fluid to said inlet chamber, means for directing said bypass fluid at a relatively high velocity into said inlet chamber to effect flow of fluid from said reservoir into said inlet chamber due to the velocity and direction of flow of said bypassed fluid and nozzle means defining an opening and directing said bypassed fluid through the

opening to said pump inlet at a high velocity, said nozzle means including a peripheral portion of said valve member having a tapered surface engageable with a valve seat, said opening varying in area as said valve member moves from said first position to change the amount of bypass fluid.

5. A pump for supplying fluid from a reservoir to a fluid system comprising means defining a pump inlet chamber in communication with said reservoir, pumping means operable to pump fluid from said reservoir through said inlet chamber to said system, flow control means operable to bypass fluid from the system including a valve member having a first position blocking bypassing of fluid and movable from said first position to bypass fluid to said inlet chamber, means for directing said bypass fluid at a relatively high velocity into said inlet chamber to effect flow of fluid from said reservoir into said inlet chamber due to the velocity and direction of flow of said bypassed fluid, nozzle means defining an opening and directing said bypassed fluid through the opening to said pump inlet at a high velocity, said nozzle means including a peripheral portion of said valve member, and flow passage means communicating said inlet chamber with said reservoir and including a central opening extending through said valve member between said reservoir and said inlet chamber, whereby said nozzle means directs said bypassed fluid to provide a low pressure region adjacent said flow passage means and effects movement of fluid from said reservoir into said inlet chamber.

6. A pump for supplying fluid from a reservoir to a fluid system comprising means defining a pump inlet chamber in communication with said reservoir, pumping means operable to pump fluid from said reservoir through said inlet chamber to said system, flow control means operable to bypass fluid from the system including a valve member having a first position blocking bypassing of fluid and movable from said first position to bypass fluid to said inlet chamber. means for directing said bypass fluid at a relatively high velocity into said inlet chamber to effect flow of fluid from said reservoir into said inlet chamber due to the velocity and direction of flow of said bypassed fluid, nozzle means defining an opening and directing said bypassed fluid through the opening to said pump inlet at a high velocity, said nozzle means including a peripheral portion of said valve member, and flow passage means communicating said inlet chamber thereof with said reservoir and including a port extending between said reservoir and said inlet chamber adjacent said nozzle means, whereby said nozzle means directs said bypassed fluid to provide a low pressure region adjacent said flow passage means and effects movement of fluid from said reservoir into said inlet chamber.

7. A pump for supplying fluid from a reservoir to a fluid system comprising means defining a pump inlet chamber in communication with said reservoir, pumping means operable to pump fluid from said reservoir through said inlet chamber to said system, flow control means operable to bypass fluid from the system including a valve member having a first position blocking bypassing of fluid and movable from said first position to bypass fluid to said inlet chamber, means for directing said bypass fluid at a relatively high velocity into said inlet chamber to effect flow of fluid from said reservoir into said inlet chamber due to the velocity and direction of flow of said bypassed fluid, flow restricting means effective to produce a drop in pressure of said fluid flowing from the discharge of said pumping means, said flow restricting means including a primary flow restriction between said discharge chamber and said system and effective to provide a pressure drop therebetween, and a secondary flow restriction between said primary flow restriction and a portion of said valve member, said secondary flow restriction effective to produce a pressure differential across said valve member and wherein said secondary flow re-

striction variably restricts the flow of fluid therethrough in response to movement of said valve member.

8. A fluid pump for supplying fluid to an external fluid system and comprising, pumping means having inlet and discharge chambers, flow control means for controlling the flow of fluid from said discharge chamber to said system, said flow control means including a valve member movable in response to a predetermined fluid pressure differential acting thereacross to bypass fluid from said discharge chamber to said inlet chamber and flow restriction means operable to control the pressure differential acting on said valve member, said flow restriction means including a flow restriction between said system and a part of said valve member remote from said discharge chamber, said flow restriction including a helical groove formed on a periphery of said valve member and being operable to variably restrict the flow of fluid therethrough in response to movement of said valve member to vary the pressure differential acting on said valve member, and relief valve means communicating with said flow restriction and effective at a predetermined system pressure to permit fluid flow through said flow restriction and to a reservoir of said system.

9. A fluid pump for supplying fluid to an external fluid system comprising pumping means having inlet and discharge chambers, said inlet chamber communicating with said pumping means and operable to direct inlet fluid thereto from a reservoir of said system and said discharge chamber communicating discharge fluid from said pumping means with said system, flow control means communicating with said discharge chamber and operable to bypass fluid from said discharge chamber to said inlet chamber, said flow control means including a valve member movable from a first position wherein the fluid in said discharge chamber flows to said system to a bypass position wherein a portion of said fluid in said discharge chamber is directed into said inlet chamber at a relatively high velocity to provide a low pressure region in said inlet chamber, port means communicating said inlet chamber with said reservoir including an opening in said inlet chamber adjacent said low pressure region, with said high velocity bypass fluid effecting movement of said fluid from said reservoir into said inlet chamber through said port means, a first flow restriction between said discharge chamber and said system, and a second flow restriction between said system and a portion of said valve member remote from said discharge chamber, said second flow restriction including a helical groove formed on a periphery of said valve member and effective to communicate pressure of said system to said portion of said valve member for urging said valve member toward its said first position.

10. A pump as defined in claim **2** wherein said frusto-conical periphery of said valve member is engageable with a valve seat member in its position wherein fluid is not bypassed, said valve member and said valve seat cooperating to provide a variable area opening through which said bypass fluid flows and wherein the area of said opening increases as said valve member moves in said first direction.

11. A pump as defined in claim **4** further including flow passage means communicating said inlet chamber thereof with said reservoir and wherein said nozzle means directs said bypassed fluid to provide a low pressure region adjacent said flow passage means and effects an increased movement of fluid from said reservoir into said inlet chamber.

12. A pump as defined in claim **6** and further including a ledge formed in said inlet chamber intermediate said nozzle means and said port.

13. A pump as defined in claim **4** wherein said nozzle means further includes an arcuately flared end portion of said valve member adjacent said frusto-conical surface.

14. A pump as defined in claim **7** wherein said secondary flow restriction is formed by a helical groove on a periphery of said valve member.

15. A fluid pump for supplying fluid to an external fluid system comprising pumping means having inlet and discharge chambers, said inlet chamber communicating with said pumping means and operable to direct inlet fluid thereto from a reservoir of said system and said discharge chamber communicating discharge fluid from said pumping means with said system, flow control means communicating with said discharge chamber and operable to bypass fluid from said discharge chamber to said inlet chamber, said flow control means including a valve member movable from a first position wherein the fluid in said discharge chamber flows to said system to a bypass position wherein a portion of said fluid in said discharge chamber is directed into said inlet chamber at a relatively high velocity to provide a low pressure region in said inlet chamber, and port means communicating said inlet chamber with said reservoir including an opening in said inlet chamber adjacent said low pressure region, with said high velocity bypass fluid effecting an increased movement of said fluid from said reservoir into said inlet chamber through said port means, said port means including a first opening extending axially through said valve member and opening at one end thereof into said inlet passageway and at the other end thereof into said reservoir, and a second opening directly communicating said inlet passageway with said reservoir, said second opening being remote from said first opening.

16. A pump as defined in claim **15** and wherein said valve member includes a peripheral portion operable to direct fluid inwardly of said valve member from said discharge chamber to said inlet chamber at said relatively high velocity and effective to create said low pressure region adjacent said one end of said opening in said valve member.

17. A pump as defined in claim **16** and further including chamber means surrounding a portion of said valve member and communicating with said system, and relief valve means between said chamber means and said reservoir for communicating said chamber means with said reservoir at system pressures above a predetermined pressure.

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