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CENTRIFUGAL PUMPS FOR LIQUIDS

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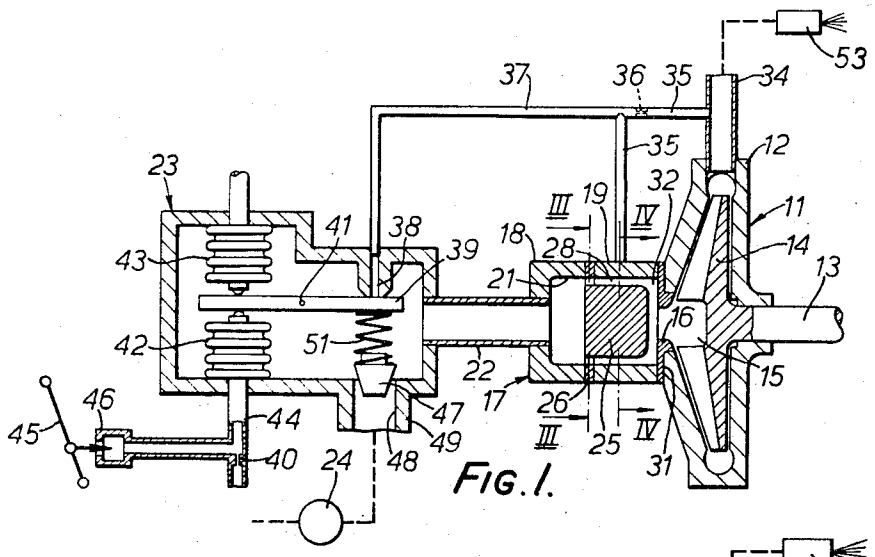


FIG. 1.

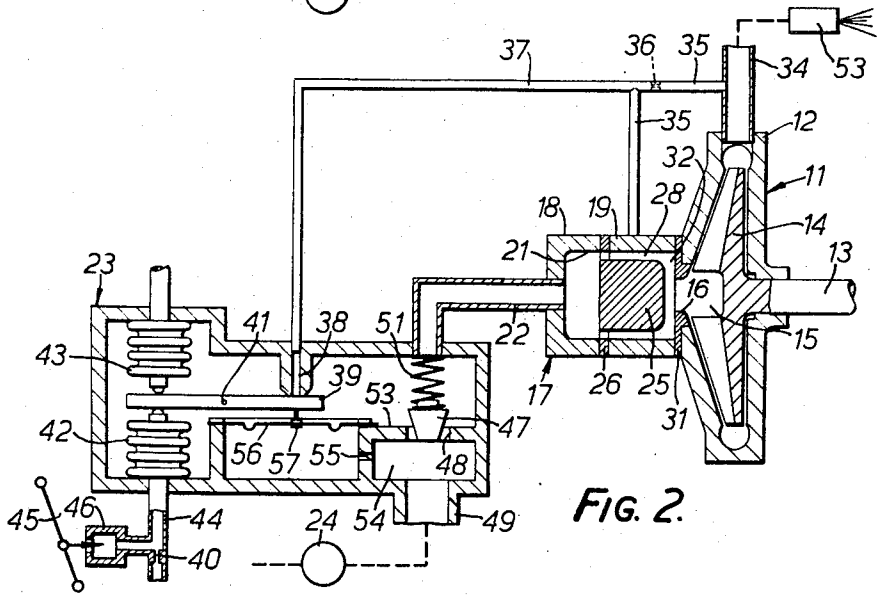


FIG. 2.

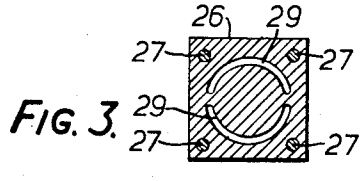


FIG. 3.

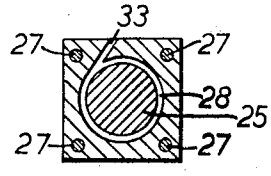


FIG. 4.

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CENTRIFUGAL PUMPS FOR LIQUIDS

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8 Claims. (Cl. 103—97)

ABSTRACT OF THE DISCLOSURE

A flow regulating mechanism is disclosed for a liquid supply system of the type wherein a hydraulic load is fed by a centrifugal pump having the inlet and outlet thereof adjacent the axis and the periphery of the pump chamber, respectively, and an operating speed at which its delivery rate exceeds the upper limit of the range of flow rates over which the demand may vary, so that the liquid flow-through in the chamber assumes the form of an annulus in the relatively peripheral portion thereof, the relatively axial portion of the chamber being closed to atmosphere so that a hollow core is formed centrally of the liquid annulus to enable it to compensate for variation in the load at a particular demand by adjusting its radial depth. The flow regulating mechanism comprises a source of low pressure liquid which communicates with the pump inlet through a connection having a passage therein for regulating the pump inflow. The passage has an orifice opening thereinto, at one peripheral boundary of the inflow, and control means are connected to the passage to discharge a variable amount of additional liquid into the inflow, through the orifice, to generate a pressure change in the inflow which is variable over a range corresponding to the range of inflow rates needed to satisfy the demand.

This invention relates to pumping apparatus for liquids, of the kind in which the delivery of a centrifugal pump is controlled by regulating the supply of liquid to the eye of the pump impeller so that the liquid entering the pump and rotated by the pump impeller assumes a generally annular form within the radially outer part of the pump casing.

According to the invention, pumping apparatus for liquids comprises a centrifugal pump having a pump casing and an impeller rotatable therein, a flow regulating device connected between a low pressure liquid source and the pump inlet said regulating device having a main passage including a vortex chamber with a central discharge opening therefrom which forms the pump inlet, said regulating device having also at least one control orifice which is connected to a source of control liquid and which enters the main passage in a generally tangential direction, control means operable to vary the flow of liquid through the control orifice and thus to vary the angular velocity of the combined liquid streams at the periphery of the vortex chamber, the vortex chamber being so arranged that the rate at which liquid enters the pump through the discharge opening varies in inverse relation to the angular velocity, and a hydraulic load connected to the pump delivery, the load being such that, during operation of the pump, the liquid entering the pump and rotated by the impeller assumes a generally annular form within the radially outer part of the pump casing.

The main passage of the flow regulating device may include an annular passage leading into the vortex chamber, the annular passage and the vortex chamber having a common circumferential outer wall through which the control orifice opens substantially tangentially.

The source of control liquid may be provided by a connection to the delivery of the pump whereby the net delivery of liquid to the hydraulic load is substantially equal to the flow from the low pressure source. The control flow is therefore independent of the net delivery since it is circulated in a closed loop which has one connection downstream of the low pressure source and another connection upstream of the hydraulic load.

In the accompanying drawings

FIGURE 1 shows as one embodiment of the invention, pumping apparatus suitable for supplying liquid fuel to the burners of an internal combustion gas turbine engine,

FIGURE 2 shows another embodiment of the invention, forming a modification of FIGURE 1,

FIGURE 3 is a section on the line III—III of FIGURE 1, and

FIGURE 4 is a section on the line IV—IV of FIGURE 1.

A centrifugal pump **11**, shown diagrammatically in FIGURE 1, has a casing **12** in which a drive shaft **13** and impeller **14** are mounted. The impeller has an eye **15** at the radial inward limit of the impeller blades, and a circular inlet opening **16** on the rotational axis of the impeller adjacent the eye **15**. The opening **16** forms the discharge opening of a flow regulating device **17** which is secured to the pump casing **12**. The regulating device comprises a housing in two parts **18, 19** having a common cylindrical bore **21** providing a main passage for liquid to flow through the device. The housing part **18** has a central inlet conduit **22** on the axis of the bore **21**, which is connected through a servo device **23** to a boost pump **24** forming a low pressure liquid source. A cylindrical plug **25** has a flanged base **26** which is located and clamped between the housing parts **18, 19** by a number of bolt fastenings **27**. The cylindrical surface of the plug **25** is uniformly spaced from the bore **21** to provide an annular portion of the main passage **28** into which liquid from the conduit **22** can enter through arcuate openings **29** in the flanged base **26**.

A baffle **31** in which the opening **16** is formed, is spaced from the downstream end of the plug **25** to form a vortex chamber **32**. The opening **16** is flared on the discharge side to provide for a smooth flow of liquid into the eye **15** of the impeller **14**. A control orifice **33**, FIGURE 4, formed in the housing part **19**, opens tangentially into the annular passage **28**. The inlet to the control orifice **33** is connected to the pump delivery conduit **34** by a pipe **35** which has a fixed restrictor **36** therein. A branch pipe **37** leads to a control valve in the servo device **23**. The control valve comprises a nozzle **38** and a movable closure **39** which is formed by a lever pivoted at **41** in the servo device. Movement of the lever is controlled in part by a demand signal which is applied by two resilient bellows **42, 43** acting oppositely at the other end of the lever **39**. The pressure in the bellows **42** is supplied from the delivery side of the engine compressor by way of a fixed restrictor **40** and a pipe **44**. The pressure is variable by a control lever **45** which is movable to vary the opening of a vent valve **46** connected to the pipe **44**. The bellows **43** is supplied by the jet pipe pressure of the engine. A flow-measuring device is provided by a tapered plug **47** which is movable with respect to the end of the bore **48** in a liquid inlet **49** to the servo device. The tapered plug **47** is loaded towards the bore **48** by a spring **51** which is seated against the lever **39** on the opposite side thereof from the nozzle **38**. The position of the tapered plug **47** is a function of the flow through the inlet **49**, and the spring **51** therefore applies a force signal of flow on the lever **39** in the negative feedback sense.

The delivery conduit **34** leads to a burner gallery of the engine, shown symbolically by a burner nozzle **53**, which provides a hydraulic load maintaining pressure at the delivery of the pump **11**.

The operation of the regulating device will now be described. If there is no flow of control liquid through the tangential orifice **33**, liquid entering the device **17** from the low pressure source **24** will flow through the annular passage **28** without any rotation about the central axis, and continue as a radially inwardly converging flow in the vortex chamber **32** to be discharbed through the opening **16** into the eye **15** of the impeller **11**. The regulating device **17** then offers minimum resistance to the flow of liquid through it.

If, on the other hand, there is a flow of control liquid through the orifice **33**, rotation is imparted to the liquid flowing through the annular passage, whereby the combined liquid stream at the periphery of the vortex chamber **32** has an angular velocity which varies in accordance with the control flow. The rotation of the combined liquid stream in the vortex chamber **32** increases in angular velocity towards the centre, and this rotation creates a pressure difference between the bore **21** and the opening **16** which increases the effective resistance to flow from the low pressure source. The rate at which liquid enters the pump is therefore inversely proportional to the angular velocity.

The centrifugal pump is designed to operate as a vapour core pump, that is to say the liquid entering the pump and rotated by the impeller assumes a generally annular form within the radially outer part of the pump casing **12**. The regulating device **17** determines the rate at which liquid enters the pump, while the radial depth of the liquid annulus in the pump is self-adjusting at any given rotational speed of the pump impeller **14** to provide the delivery pressure at which the hydraulic load on the pump delivery will accept the liquid flow rate.

The operation of the pumping apparatus will now be described.

At any instant, the lever **39** of the servo device **23** is balanced under the opposed forces of the bellows **42, 43** at one end and under the opposed forces of the spring **51** and of pressure in the nozzle **38** at the other end. The pressure in the nozzle **38** determines the control flow through the tangential orifice **33** whereby the resulting rotation of the combined liquid stream in the vortex chamber **32** creates an effective resistance to liquid flow through the control device **17** as described.

The resulting flow from the source **24** is stabilised by the flow-measuring device **47, 48**, for if there is an increase, the tapered plug **47** applies an increased spring load on the lever **39** to close the nozzle **38**, thereby increasing the control flow through the orifice **33** and thus the effective resistance of the control device **17**. Conversely, a decrease of flow causes a reduction of effective resistance. Moreover, any increase in the delivery of the pump increases effective resistance of the regulating device **17**.

The lever **45** provides a control for varying the flow to the pump **11**. If it is turned clockwise to increase the restriction of the vent valve **46**, the resulting pressure rise in the bellows **42** acts through the lever **39** to decrease the pressure in the nozzle **38**. The flow through the tangential orifice **33** is decreased so that the pumping apparatus will stabilise at an increased flow rate. A decrease in resistance of the vent valve **46** conversely produces a reduced flow rate.

The pumping apparatus is preferably designed so that even at maximum flow, there is sufficient flow through the tangential orifice **33** to produce rotation of the combined stream in the vortex chamber **32** at a small angular velocity, though the rotation is not sufficient to produce any substantial effective resistance to flow. Thus over the operating range of the pumping apparatus, in which both the pump speed and flow may be varied, the liquid flows through the orifice **16** into the eye **15** with a swirling motion which tends to give an even distribution of liquid around the rotational axis of the impeller **14**. The swirling motion may either be in the same direction, or contrary to, the rotation of the impeller. Except possibly at higher flow rates, the vapour core extends centrally

from th eye **15** and within the swirling discharge up to the transverse end of the cylinder plug **25**.

The liquid which flows through the tangential orifice **33** and through the control nozzle **38** is drawn from the pump delivery conduit **34**, but it is returned to the flow from the low pressure source **24** downstream of the flow-measuring device **47, J8**, and combines with it before entering the pump. The net delivery of high pressure liquid to the burner gallery **52** is therefore substantially equal to measure the flow of liquid from the low pressure source. The fact that the control flow through the orifice **33** is large when the net delivery is small, is therefore no disadvantage in providing a wide range of flow control because the control flow is independent of the net delivery.

In the embodiment described, the tapered plug **47** applies a direct load on the lever **39** through the spring **51**. FIGURE 2 shows a modification in which the spring **51** is seated against the interior of the servo device **23**, while the tapered plug **47** co-operates with an orifice **48** in the wall **53** of an inlet chamber **54**. The pressure in the inlet chamber **54** acts through another orifice **55** in the wall **53** against the underside of a diaphragm **56**, while the pressure on the downstream side of the orifice **48** acts against the upper side of the diaphragm, the latter having a central stem **57** acting against the lever **39**. The diaphragm **56** provides an amplified load signal compared with the load in the spring **51** and it is therefore more sensitive at low flow rates. The diaphragm enables the flow-measuring device **47, 48** to be designed for smaller pressure differences across it than in the embodiment of FIGURE 1.

It is possible, if desired, to impart a certain amount of prerotation to the liquid stream through the annular passage **28** in advance of the control orifice **33** by means of swirl vanes set at a suitable angle. Such swirl vanes may take the place of the supporting portions of the flange **26** which extend radialy-inwardly at the ends of the arcuate gaps **29**.

To provide an additional control for shuting down net pump delivery, a shut-off cock may be provided in the branch pipe **37**. Alternatively, additional tangential orifices opening into the annular portion of the main passage **28** may be connectable with a source of shut-down control liquid.

An alternative embodiment of the pumping apparatus may have a servo device provided with a flow-measuring device in the delivery conduit **34** beyond the connections of the pipe **35**.

The hydraulic load supplied by the delivery conduit **34** may, if desired, include alternative or additional means to determine the relationship of delivery pressure and net flow.

I claim as my invention:

1. Pumping apparatus for liquids comprising a centrifugal pump having a pump casing and an impeller rotatable therein, a flow regulator device connected between a low pressure liquid source and the pump inlet, said regulator device having a main passage including a vortex chamber with a central discharge opening therefrom which forms the pump inlet, said regulator device having also at least one control orifice which is connected to a source of control liquid and which enters the main passage in a generally tangential direction, control means operable to vary the flow of liquid through the control orifice and thus to vary the angular velocity of the combined liquid streams at the periphery of the vortex chambers, the vortex chamber being so arranged that the rate at which liquid enters the pump through the discharge varies in inverse relation to the angular velocity, a hydraulic load connected to the pump delivery, the load being such that, during operation of the pump, the liquid entering the pump and rotated by the impeller assumes a generally annular form within the radially outer part of the pump casing, and the main passage including an annular passage leading into the vortex chamber, the annular

passage and the vortex chamber having a common circumferentially outer wall through which the control orifice opens substantially tangentially.

2. Pumping apparatus according to claim 1, wherein the circumferentially inner wall of the annular passage is formed by a cylindrical plug while the vortex chamber is defined in the axial direction by one end of the plug and by a baffle in which the central discharge opening is formed.

3. In a liquid supply system of the type wherein a hydraulic load is fed by a centrifugal pump having the inlet and outlet thereof adjacent the axis and the periphery of the pump chamber, respectively, and an operating speed at which its delivery rate exceeds the upper limit of the range of flow rates over which the demand may vary, so that the liquid flowthrough in the chamber assumes the form of an annulus in the relatively peripheral portion thereof, the relatively axial portion of the chamber being closed to atmosphere so that a hollow core is formed centrally of the liquid annulus to enable it to compensate for variation in the load at a particular demand by adjusting its radial depth: a flow regulating mechanism comprising a source of low pressure liquid which communicates with the pump inlet through a connection having a passage therein for regulating pump inflow, said passage having an orifice opening thereinto, at one peripheral boundary of the inflow, and control means connected to the orifice to discharge a variable amount of additional liquid into the inflow along a tangent thereto, whereby a vortical movement is generated in the inflow and the pressure change therein is variable over a range corresponding to the range of inflow rates needed to satisfy the demand, the pump inflow regulating passage being connected to the pump inlet by a discharge opening which is disposed adjacent the vortical axis of the inflow and characterized with a smaller outside diameter than that of the passage.

4. A liquid supply system according to claim 3 wherein the passage has an annular cross section, and a vortex chamber is interposed between the passage and the discharge opening to collect and feed the inflow through the opening.

5. The liquid supply system according to claim 3, wherein the discharge opening coincides with the pump inlet and is disposed on the rotational axis of the pump adjacent the eye of the pump impeller.

6. The liquid supply system according to claim 3, wherein the control means includes a connection to the delivery of the pump whereby the net delivery of liquid to the hydraulic load is substantially equal to the pump inflow from the low pressure source.

7. The liquid supply system according to claim 6, wherein the control means also includes a flow selector operable to produce a demand signal, a flow-measuring device arranged to produce a signal of pump inflow from the low pressure source, and a valve which is operable to vary the flow of liquid through the orifice, the valve having a movable member which is operated in response to the demand signal, and in response to the pump inflow signal applied in the negative feedback sense.

8. The liquid supply system according to claim 7, wherein the flow-measuring device is disposed in the connection between the low pressure source and the pump inlet.

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