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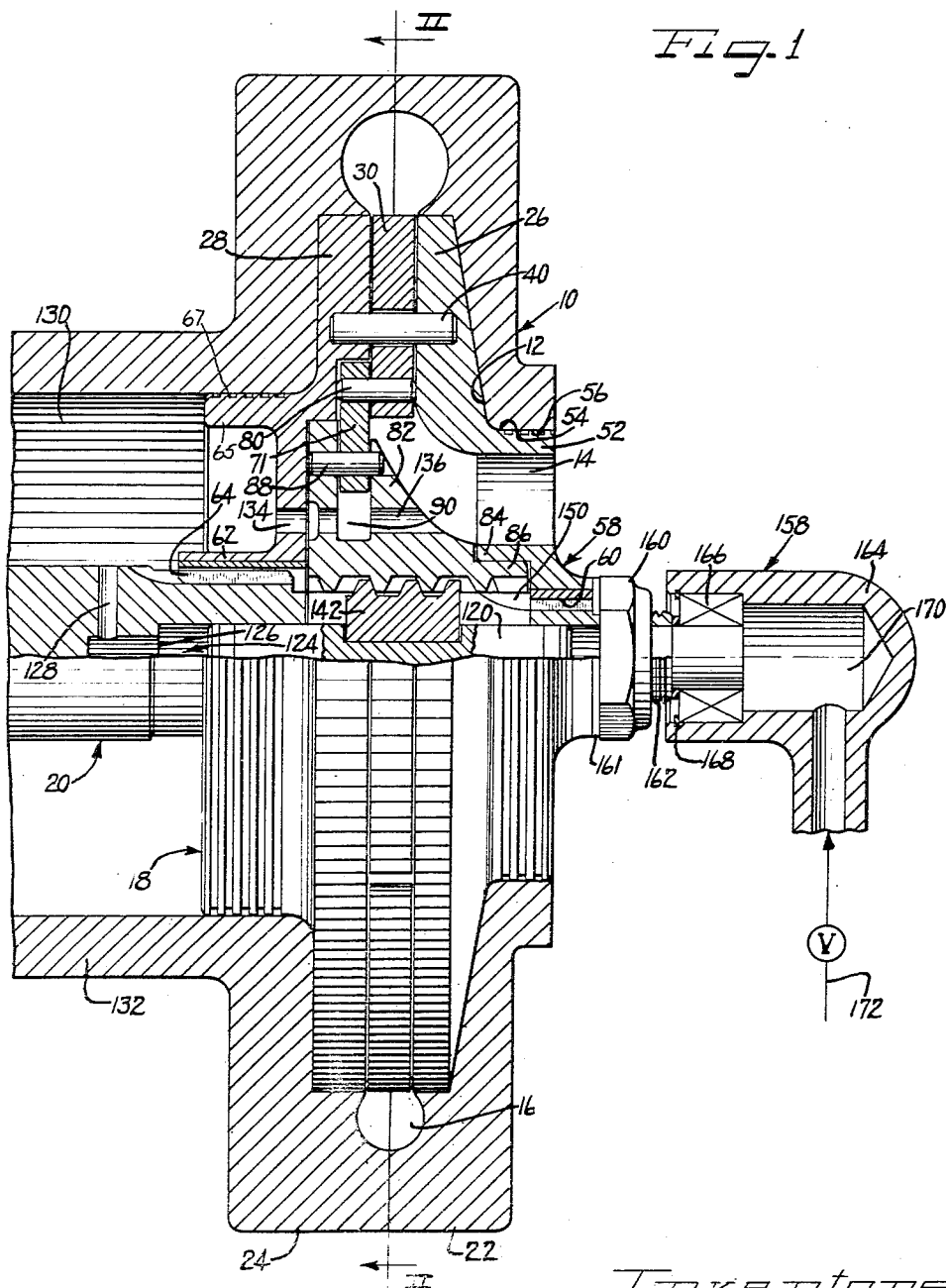
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2,950,686

VARIABLE CENTRIFUGAL PUMP

Filed March 20, 1958

2 Sheets-Sheet 1



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Fig. 2

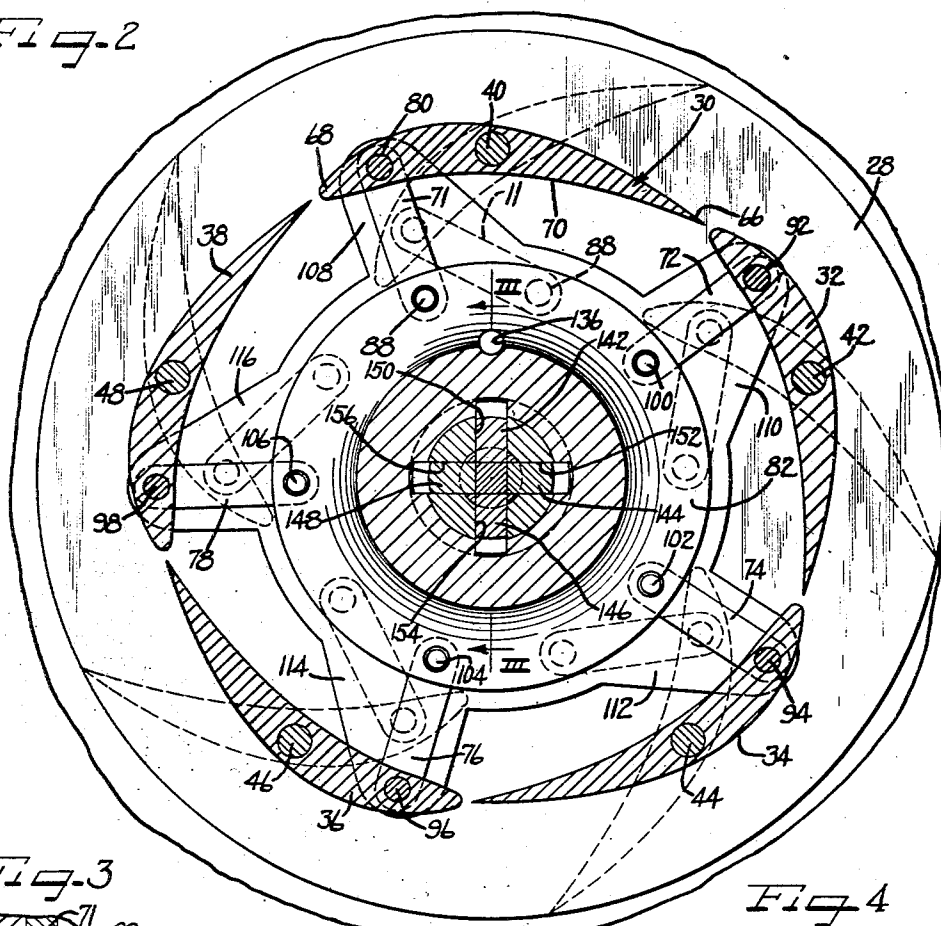


Fig. 3

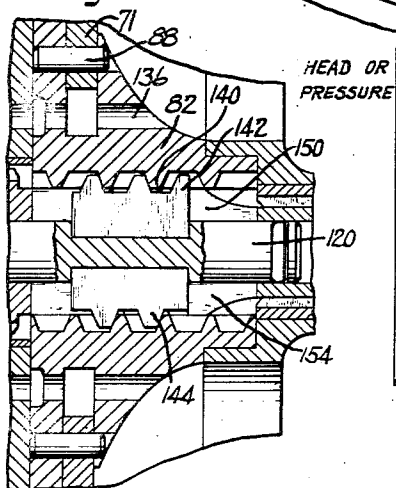
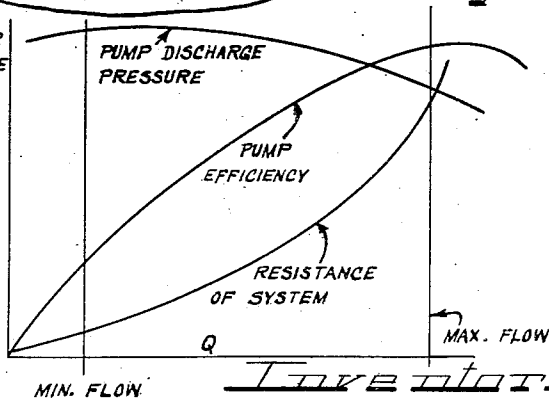


Fig. 4



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VARIABLE CENTRIFUGAL PUMP

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The present invention relates to improvements in pumps and more particularly to an improved rotary pump assembly wherein a pump element is operated at a constant speed and its delivery pressure is controllable during operation to accommodate varying demand.

In rotary pumps, such as the centrifugal type, applications are encountered wherein the output requirements vary and are not related to pump speed. In many such utilizations, the pump is driven at substantially constant speed, whereas the output delivery requirements vary from a minimum output to a maximum. Such an application is encountered wherein a centrifugal pump is used to deliver fuel, such as to a turbine. The fuel output requirements of the pump will vary with load, and will not be related to speed.

A pump is usually designed for operating at optimum efficiency at the maximum flow. At partial and at minimum required flow rates, the centrifugal pump, which will be operating at a constant speed, produces a considerable excess of discharge pressure, and operates at reduced efficiency. The temperature rise across a centrifugal pump is a direct function of the head rise, and is hyperbolically proportional to the efficiency. If the pressure rise can be held to the lowest required value to overcome nozzle pressure drop at low flows and flows less than maximum flow, then the temperature rise across the pump will be held to a minimum and efficiency will be improved.

The present invention contemplates the provision of a rotary pump capable of operation at constant speed with varying output pressure to control the output pressure and reduce it at reduced flows to avoid the above and other undesirable features, and to provide an improved method and apparatus for controllably varying the output pressure of a pump which is improved over devices and methods heretofore used.

The present invention, in one form, contemplates the provision of a pump provided with a pump housing having an axial inlet and a volute-shaped discharge passage-way leading to a pump outlet with a pump chamber within the housing between the inlet and outlet. Mounted within the pump chamber is a rotary impeller assembly which carries pivotally mounted impeller vanes. These vanes are adjustable in their pivotal position to vary the output pressure head of the pump.

The impeller assembly includes a pair of spaced discs or plates with the forward plate having an annular projection through which the fluid is drawn and discharged between the plates by the centrifugal operation of the impeller vanes. Pivotal support pins project between the plates to pivotally support the impeller vanes. The base of the impeller vanes is connected in a pivotal manner to a radially extending control link which connects at its other end to a central adjustment hub mounted coaxially within the plates for rotation therewith. A shaft supports the rotor assembly and has a cylindrical chamber defined at its axial center carrying a control piston. The

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shaft has radially facing rectangular slots in which are located rack segments which are secured to the piston and which mesh with the helically extending teeth formed on the inner surface of the hollow adjustment hub. The shaft and the impeller assembly project forward in an axial direction to receive a fitting for conducting a control fluid to the chamber within the shaft. This controllably positions the piston to rotate the adjustment hub and vary the position of the control vanes over a wide adjustment range to vary the pressure discharge head of the pump.

Accordingly, an object of the invention is to provide an improved rotary pump which can be operated at constant speed, and wherein the output pressure head can be controlled over a substantial range during operation.

Another object of the invention is to provide an improved centrifugal pump wherein the discharge pressure can be reduced to the minimum pressure head necessary to thereby avoid the temperature rise which occurs at low flow conditions and improve low discharge efficiency.

Another object of the invention is to provide an improved apparatus for controlling the output of a pump employing elements which rotate with the pump, but which are rotated relative to each other by improved means, for adjusting the pump output, such as during operation.

A still further object of the invention is to provide an improved pump structure employing impeller elements operated within a housing for centrifugal pumping action.

An important object of the invention is to provide an improved apparatus for transmitting a control signal to a variable discharge centrifugal pump by means of a pressurized fluid.

Another important object is to provide a centrifugal pump which may be controlled as to discharge head as a function of a change in flow requirements to decrease the temperature rise at less than maximum discharge rates and to increase the efficiency.

Another object of the invention is to provide an improved centrifugal pump apparatus employing adjustable impeller vanes permitting maximum adjustment of the vanes between a maximum adjustment position and a minimum adjustment position wherein the outer and inner diameters of the vanes will be equal.

Other objects and advantages will become more apparent with the teaching of the principles of the invention in connection with the disclosure of the preferred embodiments in the specification, claims and drawings, in which:

Figure 1 is a vertical sectional view taken through a pump embodying the principles of the present invention and showing the rotor assembly partially in section;

Figure 2 is a vertical sectional view taken along line II—II of Figure 1 illustrating an end view of the rotor assembly;

Figure 3 is a detailed sectional view taken along line III—III of Figure 2; and,

Figure 4 is a graph plotting pump and system characteristics along the axes of head and flow.

As illustrated in the drawings, the rotary centrifugal pump includes a housing 10, Figure 1, which is provided with an internal pump chamber 12. The chamber communicates with an intake port 14 and a discharge port, not shown. The peripheral edge of the pump chamber 12 is defined by a volute-shaped pump chamber 16 which leads to the discharge port.

Rotatably mounted within the pump chamber is a rotor assembly 18. The rotor assembly includes a supporting shaft 20 which carries the rotor assembly and is driven in rotation for operation of the pump. The housing then may be formed of a casting having a forward section 22 and the rear section 24 for assembly of the elements.

The rotor assembly includes a first plate or disc 26 and a second plate or disc 28, which is mounted to rotate with the first and is coaxial with, and spaced therefrom.

Between the plates 26 and 28 are carried a plurality of impeller vanes 30, 32, 34, 36, and 38 as are well shown in Fig. 2. The impeller vanes are pivotally mounted for adjustable movement on a plurality of angularly disposed pivotal support pins 40, 42, 44, 46, and 48. These support pins extend across the space between the plates 26 and 28, which are spaced to form a gap sufficient for adjustably carrying the impeller vanes.

Each of the plates 26 and 28 is secured on the shaft 20 for rotation therewith to carry the impeller vanes. The first forward plate 26 has an annular projecting rim or flange 52 with the area inside of the flange defining the inlet port 14 leading into the housing. The outer surface 54 of the flange 52 is provided with ribs to form a labyrinth seal with the opening 56 in the housing 10.

Coaxially located within the projecting flange 52 of the first forward plate 26 is a center ring 58 which may be part of the plate and joined to it by spoke portions, not shown, or which may be independent. If the ring 58 is independent, the plate 26 will be carried by the impeller vane supporting pins 40, 42, 44, 46, and 48. With either construction, the ring 58 is joined to the shaft such as by a spline connection 60 so that the ring will be driven in rotation with the shaft.

The second rear plate 28 has an opening through its center and has a central rearwardly projecting flange 62 which is secured to the shaft such as by a spline connection 64. In this manner the rear plate 28 is driven in rotation with the shaft 20. An outer flange 65 carries a labyrinth seal 67.

As illustrated in Fig. 2, the vanes 30, 32, 34, 36, and 38 are elongated in shape, and as illustrated by the vane 30, have a flat pointed free end 66 and an opposed control end 68 with the inner surface 70 being slightly arcuate in shape. Thus the pivotal support pin 40 extends substantially through the center of the impeller vane. Each of the impeller vanes is identically constructed and therefore only one need be described in detail.

The teaching of the present invention obtains the provision of a mechanism whereby the impeller vanes may be pivotally adjusted for a maximum positional variation. Thus the output pressure head of the pump may be varied over a maximum range. For minimum pump output pressure, the vanes are positioned in the solid line position as shown in Fig. 2 and for the maximum output pressure of the pump, the vanes are pivoted to the dotted line position. In the minimum output pressure position, the outer diameter of the pump, as defined by the tip 66 of the vane 30, and the inner diameter, as defined by the inner surface of the opposing end 68, become equal.

Control adjustment of the position of the vanes is obtained by a plurality of links attached pivotally to the base ends of the vanes. Vanes 30, 32, 34, 36 and 38 are each controlled by links 71, 72, 74, 76, and 78.

As illustrated in Fig. 1, by the link 71, the links are attached to the control ends of the impeller vanes and the link 71 is pivotally attached to the impeller vane 30 by a pivotal connecting pin 80. Each of the links projects inwardly in a generally radial direction and connects at its inner end to an adjusting hub 82.

The adjusting hub 82 is mounted for rotation with the impeller assembly but can be rotated relative thereto for adjustment of the position of the impeller vanes. For supporting the adjustment hub 82 on the impeller, the central ring 58 has a rearwardly extending flange 84 which extends annularly around the projecting forward end 86 of the adjustment hub. The surfaces between the

flanges 84 and 86 provide a bearing support for the adjustment hub.

As illustrated in Fig. 1 by the link 71, each of the links is pivotally pinned to the adjustment hub. Link 71 is connected to the adjustment hub 82 by a pin 88 which extends across an annular slot 90 in the outer surface of the adjustment hub 82. With reference to Fig. 2, links 71, 72, 74, 76, and 78 are connected at their outer ends to the vanes by pivotal pins 80, 92, 94, 96 and 98. These links are connected at their inner ends to the adjustment hub 82 by pins 88, 100, 102, 104 and 106.

As illustrated in Fig. 2, the adjustment hub 82 is rotated relative to the forward plate 26 and the rear plate 28 whereby the links will move between the dotted and solid line positions to move the vanes between the dotted and solid line positions. It will be observed that a positive control of the vanes is obtained and a very firm and powerful connection is achieved. In order to afford a clearance space for the links, the rear plate 28 is provided with recesses such as illustrated at 108, 110, 112, 114, and 116 for the respective links 71, 72, 74, 76, and 78.

Rotation of the adjustment hub 82 is obtained by translating reciprocating motion of a control piston 120 to rotating motion of the hub 82.

The shaft 20 is provided with a hollow coaxial cylindrical chamber 124 in which is slidably located the control piston 120. The rear end 126 of the chamber is vented, by means of a passageway 128 into a space 130 behind the rear plate 28 within a rearwardly projecting tubular extension 132 of the housing 10. Fluid can flow into an outer passageway 128 which is maintained at the intake pressure of the pump. For this purpose, the rear plate 28 has a communicating port 134 which is exposed to a passageway 136 through the adjustment hub 82.

As illustrated in Figs. 1, 2, and 3, and in detail in Fig. 3, rotation of the adjustment hub 82 is obtained by reciprocation of the piston 120. The hub 82 has a hollow axial center which carries internal inwardly facing helical screw teeth 140. In mesh with the helical teeth are four rack members which are evenly spaced around the piston 120 as illustrated in Fig. 2 with the rack members being shown at 142, 144, 146, and 148. It will be observed that forced reciprocation of the rack members will drive the helical teeth 140 to cause rotation of the adjustment hub 82.

To prevent rotation of the rack members and permit them to be secured to the piston 120, four radially extending slots are cut in the wall of the cylindrical chamber to extend radially through the shaft 120. These radial openings are in the form of rectangular elongated slots having a width to accommodate the rack members and are shown at 150, 152, 154, and 156.

The piston 120 is reciprocated for controlling the position of the adjustment hub 82 by the operation of a control fluid. This control fluid is supplied into the piston in a unique and convenient manner by a nose hub assembly 158, as illustrated in Fig. 1. The nose hub assembly is located and secured to the threaded reduced end 162 of the shaft 20. This threaded reduced end receives a nut 160 and a washer 161 to hold ring 58 in place on the end of the shaft and to rotate therewith. The nose assembly includes an elbow shaped conduit member 164 which is suitably connected to the end of the shaft 20 by a rotatable fluid seal 166 secured on the end of the shaft and held in the open end of the nose piece 164 by a locking snap ring 168. Through the interior of the nose piece 164 extends a conduit 170 which receives pressurized control fluid, the flow being controlled by a valve 172. This pressurized fluid may be supplied from the output of the pump or from other sources and flows through the conduit 170 to act against the end of the piston 120 positioning it within its chamber 124 to control the rotational position of the adjustment hub 82. The

relative position of the adjustment hub, of course, determines the operative position of the impeller vanes.

In operation of the pump, the rotor assembly 18 is driven in rotation by the shaft 20. Pumped fluid enters the annular inlet opening 14 to flow between the spaced plates 26 and 28 and be centrifugally forced outwardly by the action of the impeller vanes 30 into the volute-shaped chamber 16 to a discharge outlet, not shown. The hydraulic system to which the pump is connected will normally be one of varying demand and at full demand the pump will be operated at full capacity and will deliver pressure at a full pressure head. At full pressure the impeller vanes 30, 32, 34, 36 and 38 will be in their outermost angular position as shown by the dotted line position in Fig. 2. At this position of the impeller vanes, the pump will operate at optimum efficiency. When the demand of the hydraulic system decreases, and the pump delivers less than maximum flow, to increase the efficiency and decrease the temperature increase, the impeller vanes are drawn inwardly toward the solid line position, as shown in Fig. 2, to reduce the discharge pressure head.

The impeller vanes are drawn inwardly as a function of the flow requirements of the system and the head is reduced as much as possible but kept sufficient for the system requirements. At a minimum flow, the impeller vanes are drawn into the position of minimum head, as illustrated in Fig. 2.

Figure 4 illustrates graphically the operational characteristics and the features of the pump. The flow is plotted against output pressure and the points of minimum flow and maximum flow are indicated. The upper line of the graph indicates the pump discharge pressure for the operation of the pump with the impeller vanes at the full pressure outermost position and without adjusting the position in accordance with the present invention. The lowermost line of the graph indicates the resistance of the system. It will be noted that the resistance which is indicated in mounting pressure head is proportional to the output squared which may be indicated by the relationship $H \sim Q^2$. This increase in resistance of the system with increase and discharges illustrated wherein the pump is used as a fuel pump to supply an after burner nozzle of the gas turbine or gas jet engine.

The intermediate line of the graph indicates pump efficiency or a pump of ordinary design and it will be seen that efficiency increases at near maximum output.

The pump is usually designed for close to maximum efficiency at the maximum flow. At partial and minimum flow rates, the pump is operated at a constant speed, a considerable excess of discharge pressure may occur and reduced efficiency will occur. The temperature rise across the centrifugal pump is a direct function of the head rise and is hyperbolically proportional to the efficiency. The exact relationship is as follows:

$$\Delta T = \left(\frac{1-\eta}{\eta} \right) \left(\frac{144}{CJP} \right) \Delta P$$

wherein:

T = the temperature rise across the pump.

η = the efficiency.

P = fluid pressure.

C = a constant dependent on the nature of the fluid.

It is seen that ΔT will approach ∞ when η approaches 0. At very low flows the efficiency increase is not great, but the efficiency is improved by reducing pressure increase in flows below maximum. If ΔP (pressure rise) can be held to the lowest required level to overcome nozzle pressure drop, which is the resistance of the system, the temperature rise across the pump will be held to a minimum.

Thus it will be seen that we have provided an improved pump which meets the objectives and advantages hereinbefore set forth. The invention enables maximum control of the pressure head of a pump and thereby enhances the control of factors which improve the efficiency and

decrease temperature rise. With the arrangement illustrated, the maximum adjustment of the vane can be achieved, permitting the outer diameter and inner diameter of the vanes to become equal at minimum discharge head.

We have, in the drawings and specification, presented a detailed disclosure of the preferred embodiments of our invention, but it is to be understood that we do not intend to limit the invention of the specific forms disclosed but intend to cover all modifications, changes and alternative constructions and methods falling within the scope of the principles taught by our invention.

We claim as our invention:

1. A rotary pump adapted to be driven at a substantially constant speed with varying flow rate and controllable discharge pressure head comprising in combination a rotary impeller rotor assembly, a shaft secured to drive the rotor assembly in rotation, a plurality of impeller vanes pivotally mounted on the rotor assembly to be rotated at varying adjustable angular positions, an impeller vane control disc mounted for rotation with the rotor assembly and mounted for relative rotational adjustment thereon, impeller vane control links pivotally connected between the impeller vanes and said disc whereby relative rotation of the disc will pivot the impeller vanes and change their adjusted position, a cylindrical inner surface on said disc carrying helically arranged teeth, rack members within the inner surface of said disc having teeth in engagement with said helical teeth, a cylinder defining means positioned concentrically within said disc and having radial openings for receiving said rack members, a piston reciprocally mounted in said cylinder and provided with recesses for receiving said rack members, and pressure supply passageways leading to the ends of said cylinder for controllably adjusting the position of the piston within said cylinder and thereby adjusting the position of said impeller vanes.

2. A rotary pump adapted for operation at a substantially constant speed with varying output flow rate and adapted for controlled discharge head comprising in combination a housing having an axial fluid inlet with a volute-shaped chamber leading to a discharge outlet and a pump chamber therebetween, a rotor assembly within said pump chamber including a rotating shaft member, a pair of spaced plates mounted for rotation on said shaft, a plurality of impeller vanes adjustably positioned between said plates, individual pivot pins extending between said plates and pivotally supporting said vanes at a point intermediate the end thereof, impeller vane control links pivotally connected to an end of said impeller vanes opposite a free end, an impeller vane adjustment hub located between said plates and concentric therewith, said hub mounted for rotation on said shaft and mounted for adjustment rotation relative to said plates, means connecting said links to said adjustment hub whereby relative rotation thereof will pivot the impeller vanes, means defining a hollow chamber within said shaft, a reciprocal piston mounted within said chamber, a rack member secured to said piston and projecting through a slot in the wall of said hollow chamber, means defining helical teeth on the inner surface of said adjustment hub, said rack member engaging said teeth and adapted to relatively rotate the hub with reciprocation of said piston, and a coaxial conduit leading into the axial inlet of said hollow chamber and adapted to deliver a pressurized fluid thereto for positively locating the position of said piston.

3. A centrifugal pump assembly comprising a rotor member carrying adjustable impeller means thereon, a housing for said rotor member, means defining a cylindrical chamber in the axial center of said rotor, a reciprocating piston located within the cylindrical chamber, means defining rectangularly shaped radially facing openings through said cylindrical chamber defining means, rack members projecting through said rectangular open-

ings and secured to said piston; rotation of said rack members being prevented by the walls of said rectangular openings, a rotary hub member engaging teeth in said rack for relative rotation with respect to the rotor with reciprocation of the rack, means connecting the hub member to the impeller means for varying the discharge pressure head of the pump, and means connected to the cylindrical chamber defining means for controllably positioning the piston within said cylindrical chamber for controlling the pump discharge head.

4. A centrifugal pump assembly comprising in combination a housing having a circular chamber therein with a centrally located axial inlet, a rotor mounted within said chamber and having a projection extending axially through said inlet opening, means within said axial projection of the rotor having a hollow axially extending passageway, non-rotatable conduit means connected to the axial projection of the rotor and communicating with the passageway for supplying a control fluid to said passageway, adjustable impeller means carried on the rotor to vary the discharge pressure head of the pump, a rotatable hub member on said rotor connected to said adjustable impeller means for adjusting said impeller means, a reciprocating plunger member in said passageway, a reciprocating rack connected to said plunger member, a helix in mesh with said rack and connected to said hub

member, said rack rotating said helix and hub member for adjusting the impeller means, and means defining an elongated slot through said rotor for preventing relative rotation of the rack and for driving the helix with reciprocation of the plunger.

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