

[54] **CENTRIFUGAL PUMP WITH VARIABLE IMPELLER**

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[22] Filed: **Feb. 8, 1974**

[21] Appl. No.: **439,845**

[57] **ABSTRACT**

[52] U.S. Cl. **415/131; 415/140; 415/141; 415/143**

[51] Int. Cl.² **F03B 15/04; F01D 7/00**

[58] Field of Search 415/186 A, 149, 133, 177, 415/131, 140, 141, 157, 204, 203, 143

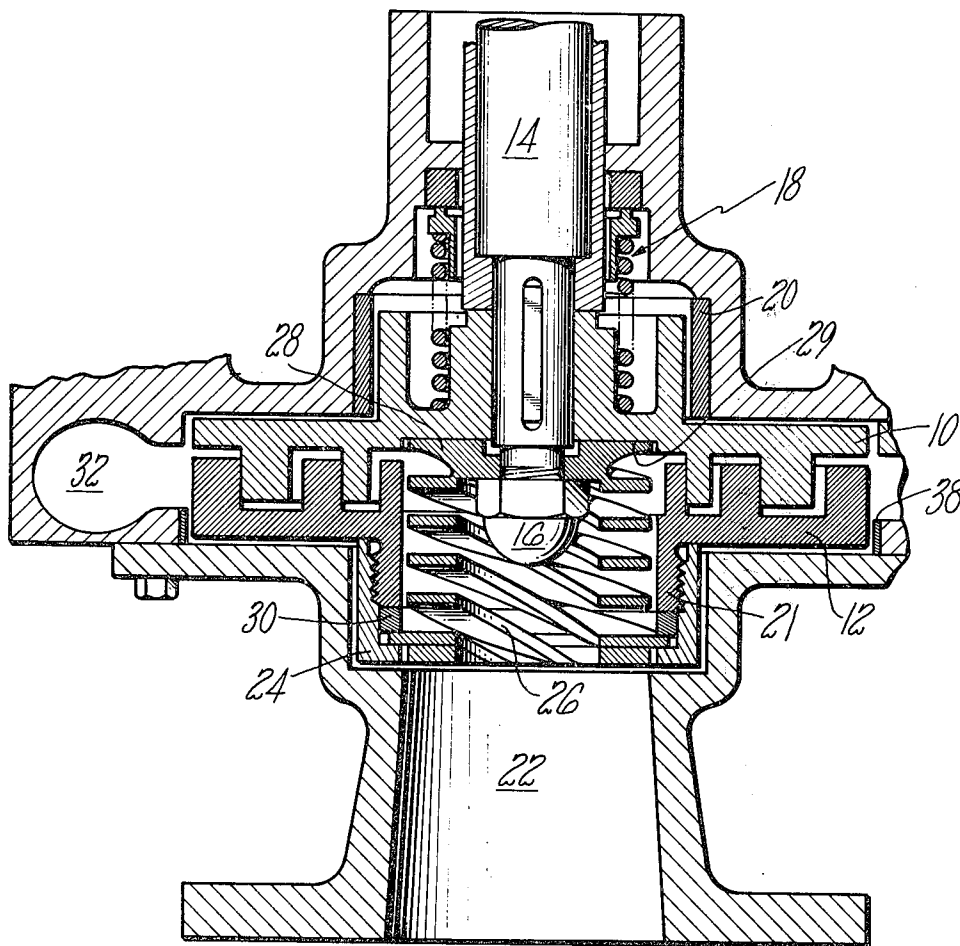
A centrifugal pump with a variable breadth impeller characterized by telescoping mirror image impeller sections. The blades on the mating impeller sections cooperate to define multiple cascades, consisting of pairs of hydraulically parallel flow channels circumferentially offset from each other, which discharge into a common collector.

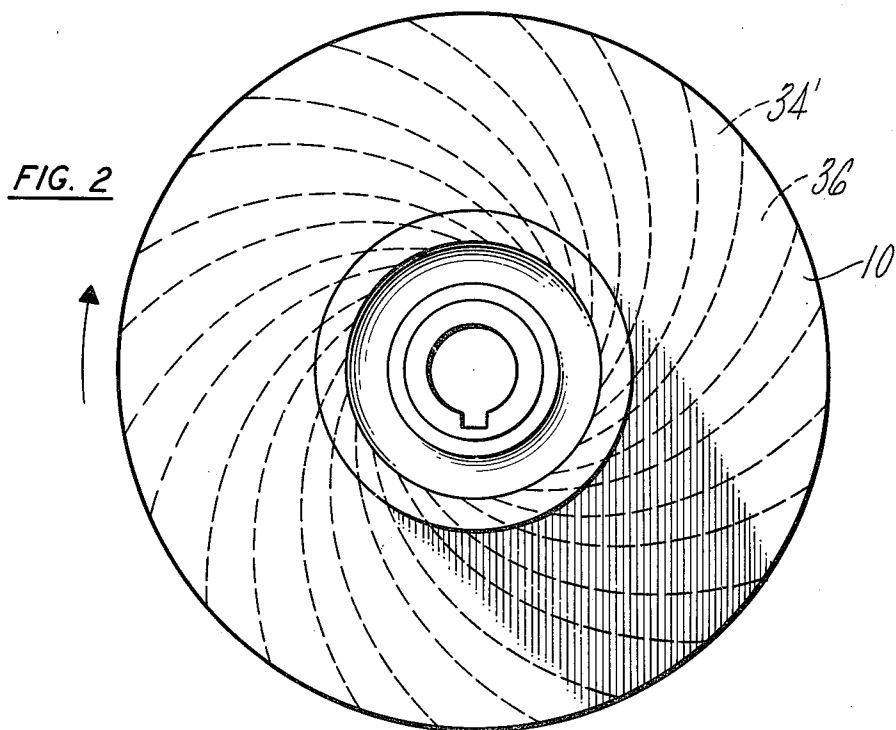
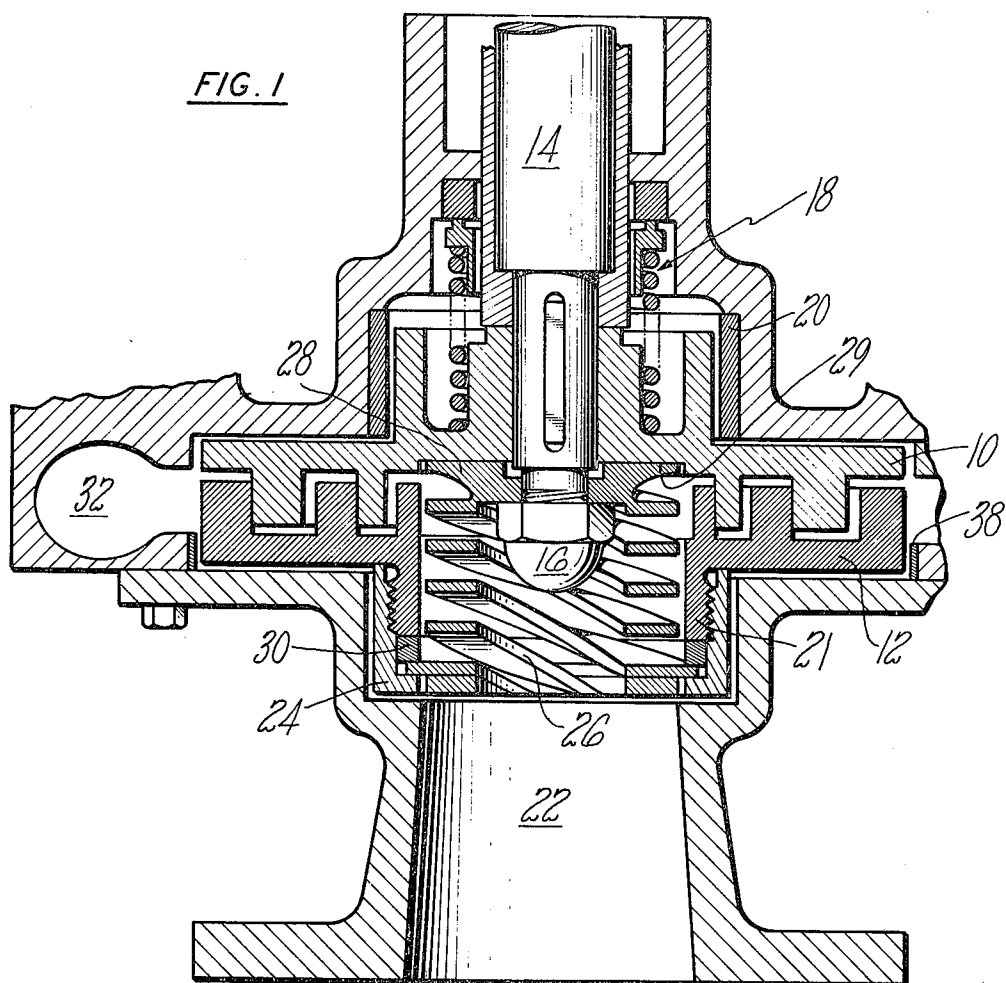
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7 Claims, 5 Drawing Figures

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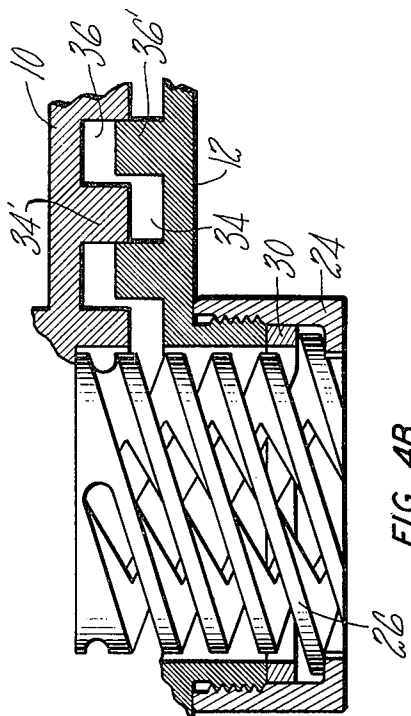


FIG. 4B

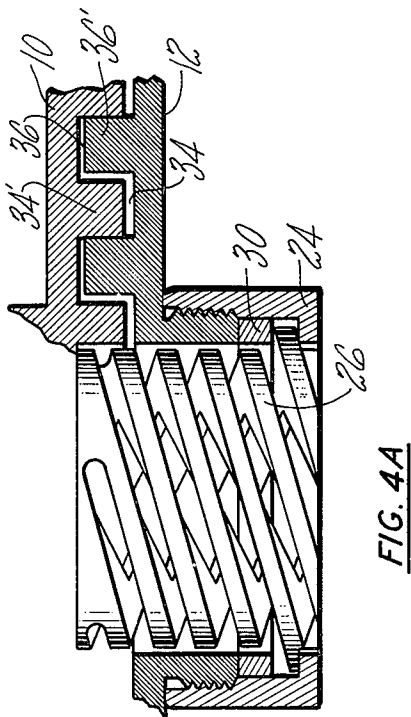


FIG. 4A

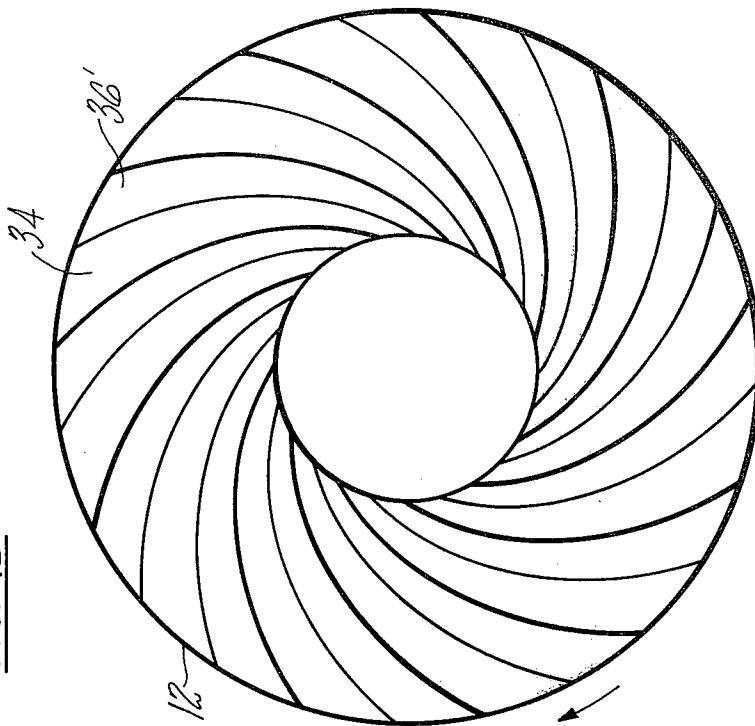


FIG. 3

CENTRIFUGAL PUMP WITH VARIABLE IMPELLER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improving the operating characteristics of pumps and particularly centrifugal pumps which are required to operate at low flow rates over a wide range of back pressures with a high maximum output pressure. More specifically, this invention is directed to low specific speed pumps with radial stage impellers. Accordingly, the general objects of the present invention are to provide novel and improved methods and apparatus of such character.

2. Description of the Prior Art

The present invention has been found to be particularly well suited for use with centrifugal pumps having a radial flow impeller; such pumps having an axial inlet and radial discharge for fluid delivered thereto. The achievement of constant flow, particularly with varying back pressure, has proven to be an elusive objective for designers of centrifugal pumps. Restated, a long felt need in the pump arts is to provide a centrifugal pump which would have the linear pressure-flow characteristics of a positive displacement pump, such as a gear or piston pump, but which would not subject the fluid being pumped to the coarse handling characteristics of a positive displacement pump. Thus, by way of example, there has not previously been available a high pressure, low flow centrifugal pump which would provide an output characterized by minimum hydraulic noise regardless of variations in back pressure. Such a pump would, for example, be desirable for use in any control system sensitive to flow pulsations or in cases where the process fluid could not stand harsh treatment conditions. The processing of food or blood plasma is an example where the process fluid must not be subjected to the coarse handling which is characteristic of positive displacement pumps. Numerous control systems, such as those on submarines, present environments where the hydraulic noise associated with output pressure pulsations is undesirable or unacceptable.

As discussed above, it has long been desired to provide a centrifugal pump which would duplicate the constant flow with varying pressure characteristics of a positive displacement pump. In addition to the above briefly described examples of where such a pump could be employed, it is also to be noted that positive displacement pumps are characteristically sensitive to and thus can not be employed in the handling of contaminated fluids; i.e., fluids with entrained particulate matter. Conversely, centrifugal pumps are very insensitive to entrained particulate matter and their ability to handle contaminated fluids is well known. The applications for pumps providing a constant flow at varying back pressures while moving contaminated fluids are numerous.

While the above discussion has emphasized a constant flow rate, it is to be observed that a concomitant long standing desire has been the provision of a centrifugal pump which can affectively and quietly vary its flow and pressure to match system demands. Previous attempts to produce such a pump have resorted to varying pump speed, throttling techniques or variable pump geometry. As is well known, pressure rise and flow may be varied by changing pump speed. However, since the rate of pressure rise does not vary linearly

with the flow capacity of a fixed geometry centrifugal pump with increases in speed, variations in pump speed offer a limited solution, i.e., system demands can be matched only over a limited range of pressures and flows. Throttling, and its counterpart bypassing, inherently results in inefficient operation with attendant noise and process fluid temperature increases. Conventional throttling or bypassing techniques are, accordingly, not suitable for environments where either noise or the preservation of the characteristics of the process fluid are considerations. For an example of a centrifugal pump which employs throttling at the inlet, reference may be had to Mottram et al U.S. Pat. No. 3,442,220. Throttling at the pump input, as is well known in the art, results in cavitation and thus hydraulic noise. There are other centrifugal pumps known in the art which resort to throttling at the pump outlet. U.S. Pat. No. 3,168,870 to Hornschuch is representative of the prior art technique of internal bypassing in the interest of varying centrifugal pump capacity.

Centrifugal pumps with variable impeller geometry are also known. For an example of a centrifugal pump with a variable geometry impeller which is adapted to high specific speed applications, reference may be had to copending application Ser. No. 277,593 entitled "Centrifugal Pump With Variable Flow Area", now U.S. Pat. No. 3,806,278 which is assigned to the assignee of the present invention. A further approach to variable geometry impellers are those proposed pumps which have blade configurations of conventional cross-section and a single flow channel without pulse generation compensation. For examples of such further proposed variable geometry pumps reference may be had to U.S. Pat. No. 2,927,536 to Rhoades and U.S. Pat. No. 3,482,523 to Morando.

SUMMARY OF THE INVENTION

The present invention overcomes the above discussed and other problems of the prior art by providing a novel and improved radial flow centrifugal pump which is characterized by a variable flow area. In accordance with the invention the breadth of the impeller is adjusted to meet the required pressure conditions. Impeller breadth adjustment is accomplished through the use of an impeller which is divided into mirror image male and female sections. The sections of the impeller are designed to mate with each other whereby the impeller blades cooperate to define multiple cascades which discharge into a common collector or volute. These cascades, which consist of pairs of hydraulically parallel flow channels circumferentially offset from each other, establish counteracting pressure pulses which have a subtractive effect leading to constant pump output pressure. The flow channels, for example the channels of each parallel pair, may be of identical cross-section or may be purposefully varied.

The cross-section of the flow channels of the multiple cascades of a pump in accordance with the present invention is varied by telescoping the male and female halves of each impeller by causing movement of one or both of the impeller sections in a direction parallel to the axis of rotation. This telescoping of the impeller halves may be achieved through the use of an actuator or actuators located within the rotating impeller assembly or by an externally positioned actuator which operates on the impeller assembly. In accordance with a preferred embodiment of the invention, a self-compensating pump having an actuator within the rotating im-

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PELLER assembly is provided; the actuator balancing the pressure differential across the impeller against the bias of a hubless inducer whereby the flow rate in the impeller will be automatically sensitive to pump back pressure. Thus, in accordance with the invention, actuators for varying the impeller geometry may be designed to provide for automatic compensation. Alternatively adjustment may be achieved under the control of a human operator.

In a preferred embodiment the invention employs curved impeller blades designed with an artificial blockage which gives the pump an improved hydraulic radius when compared to the prior art. Restated, in accordance with the present invention the impeller blades are themselves of unusual width and, for most applications, the width of the blades is equal to the width of the channel between the vanes of the mating part.

Although a conventional volute or diffuser can be employed, in accordance with a preferred embodiment of the invention a pump may be characterized by an axial inlet and a toroidal collector. The toroidal collector will possess the desirable features of no-cut water or tongue for generating pressure pulses.

BRIEF DESCRIPTION OF THE DRAWING:

The present invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawing wherein like reference numerals refer to like elements in the several figures and in which:

FIG. 1 is a cross-sectional, top view of a centrifugal pump with a variable geometry impeller in accordance with a preferred embodiment of the invention;

FIG. 2 is a front view depicting the driver impeller of the pump of FIG. 1;

FIG. 3 is a front view depicting the driven impeller of the pump of FIG. 1;

FIG. 4A is an enlarged partial schematic view showing the pump of FIG. 1 in a low flow, low pressure condition; and

FIG. 4B is an enlarged partial schematic view showing the pump of FIG. 1 in the high flow, high pressure condition.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

With reference now to FIG. 1, a pump in accordance with a preferred embodiment of the present invention comprises a variable breadth impeller comprising two mating impeller sections or halves. A first of these impeller sections, hereinafter referred to as the driver impeller, is indicated at 10 in FIGS. 1, 2 and 4. The second impeller section, hereinafter referred to as the driven impeller, is indicated at 12 in FIGS. 1, 3 and 4. The driver impeller 10 is keyed to the pump drive shaft 14 and is held in position on the drive shaft by means of a lock nut 16. Rearwardly of the driver impeller 10, and coaxial with the shaft 14, is a conventional face seal assembly which is indicated generally at 18. A conventionally loaded wear ring 20 is disposed about a rearwardly extending portion of the driver impeller 10, as shown between the impeller and the pump housing, for the purpose of sealing the pump discharge to the impeller back face. Wear ring 20 is thus located to balance axial thrust loads. A labyrinth seal may be employed rather than wear ring 20 if deemed desirable or necessary.

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As may be seen from FIGS. 4A and 4B, the driver and driven amplifiers are telescopically related and, even in the high flow-high pressure condition depicted in FIG. 4B, there is sufficient bearing area for the driven impeller 12 to be caused to rotate with the drive shaft 14; torque being transmitted to the driven impeller via the driver impeller 10.

Referring again to FIG. 1, and with reference also to FIGS. 4A and 4B, the driven impeller 12 is provided with an aperture coaxial with the pump axis and a flange 21 which extends forwardly toward the pump inlet 22. Impeller flange 21 is engaged by a nut 24 which has a radially inward extending portion which defines a shoulder at the upstream end of nut 24. A hubless inducer 26 passes through the axial aperture in driven impeller 12 and is positioned in a recess 29 provided in the facing surface of the driver impeller 10. Inducer 26 is, in the disclosed embodiment, a flat coil spring having a solid washer-like downstream end which is received in recess 29 of driver impeller 10. The opposite or upstream end of spring 26 has an external flange which, via an annular spacer member 30, presses the axially movable driven impeller 12 against the shaft mounted driver impeller 10. As discussed above, the two impellers are interlocked through their mirror image vanes. In the compressed condition, as depicted in FIG. 4A, the hydraulically parallel flow paths or channels defined by the interlocking vanes offer minimum flow area for the fluid being pumped. A pair of flow channels 34 and 36, and the vanes 34' and 36' respectively on the driver and driven impellers which define these flow channels, are indicated on FIGS. 2-4.

Fluid discharged radially outward from the flow channels defined by the driver and driven impellers 10 and 12 is received, in the disclosed embodiment, in a toroidal collector indicated schematically at 32. Collector 32 possesses the desirable features of no cut-water or tongue for generating pulses and does not result in the generation of a circumferential pressure gradient which is transmitted to the pump bearings.

A wear ring 38 is radially located with respect to the driver impeller 10 so as to balance the pressure gradient against the spring loading of the hubless inducer 26. The wear ring 38 seals the pump discharge from the inlet and the flow area in the impeller assembly is thus sensitive to the pump back pressure.

A particularly unique feature of the present invention, as may best be seen from FIGS. 2 and 3, is the use of a backward curved impeller having vanes of unusual width. This unusual vane width is achieved by fabrication of the vanes with an artificial blockage which gives the impeller an improved hydraulic radius. In the disclosed embodiment of the invention the flow channels are of constant arc from the inlet to discharge ends thereof and the width of the vanes on each of the driver and driven impellers approximates the width of the channels defined by the vanes of the mating impeller. In terms of fluid mechanics this design approaches the optimum hydraulic radius; i.e., minimum friction loss; for a given area.

During operation of the variable breadth impeller of the present invention, the hubless inducer 26 performs the function of an axial inducer charging the fluid into the radial impellers. The pressure within the impellers will act to separate the impeller assembly against the tension of the inducer coil 26. This action results from the location of the wear ring 38 and the pressure forces

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generated within the impeller assembly. The breadth of the impeller is, therefore, directly responsive to system back pressure.

In the above described preferred embodiment of the invention, the single impeller assembly defines two cascades which charge into a common collector or volute to thus establish counteracting pressure pulses. These counteracting pressure pulses have a subtractive affect and accordingly a substantially constant pump output is achieved. The desirable characteristics of the present invention are thus achieved through the use of mirror image impellers defining multiple cascades which discharge into a common collector. The desirable affects are enhanced in the disclosed embodiment through the use of a self-compensating actuator wherein feedback pressure works against an inducer spring.

Also in the above described preferred embodiment of the invention, the automatic control of the pump is predicted upon the presumption that the back pressure of the system within which the pump is connected will be unaffected by flow rate. Any impeller will produce a flow rate (Q) directly proportional to the blade or passage area (S) and peripheral speed (V) and inversely proportional to the back pressure (P). This relationship may be stated as follows:

$$(1) Q = fV^2S/P$$

Employing the actuator system discussed above, the impeller will have a passage area (S) and/or peripheral speed (V) proportional to back pressure (P). This relationship may be expressed as follows:

$$(2) S = fP/V^2$$

If back pressure is invariant with flow, the system is balanced and the flow will remain constant within the consistency of the V^2S/P ratio built into the actuator. If, however, the system back pressure varies with flow, as with a conventional discharge throttled plumbing loop, then the actuator will drive the impeller to the maximum flow position as depicted in FIG. 4B. If this mode of operation is not desired a different mode of actuation will be implemented.

While a preferred embodiment has been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. In a radial flow centrifugal pump, said pump having a drive shaft and a housing which defines an axial inlet and a collector for receiving a fluid being pumped, means for varying the pump capacity comprising:

a driver impeller coupled to the pump drive shaft, said driver impeller including a base member having a plurality of vane defining projections on a first face thereof;

a driven impeller, said driven impeller including a base member having a plurality of vane defining projections on a first face thereof, said driven impeller being positioned with the vanes thereof facing and engaging the vanes on said driver impeller whereby said impellers define multiple cascades of flow channels which discharge into the common pump collector; and

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means including an inducer spring positioned within the assembly defined by said driver and driven impellers for varying the axial relationship between said impellers, said spring inducing flow into said flow channels and cooperating with said driver and driven impellers to establish a preselected impeller flow area at a given back pressure.

2. The apparatus of claim 1 further comprising:

seal means for hydraulically isolating the pump inlet and collector regardless of impeller assembly width whereby the pressure differential across the impeller assembly is balanced against the inducer spring and the flow areas within the impeller assembly are sensitive to the pump back pressure.

3. In a radial flow centrifugal pump, said pump having a drive shaft and a housing which defines an axial inlet and a collector for receiving fluid being pumped, means for varying the pump capacity comprising:

a driver impeller coupled to the pump drive shaft, said driver impeller including a disc-shaped base member having a plurality of arcuate projections on one face thereof, said projections defining impeller vanes which increase in width from the inlet toward the collector;

a driven impeller, said driven impeller including a disc-shaped base member having a plurality of arcuate projections on one face thereof, said projections defining impeller vanes which increase in width from the inlet toward the collector, said driven impeller being the mirror image of said driver impeller and being positioned with the vanes thereof facing and engaging the vanes on said driver impeller, said engaged impeller vanes cooperating to define pairs of diverging circumferentially offset flow channels whereby said impellers define multiple cascades of flow channels which discharge into the common pump collector; and self-compensating hubless flow inducer means at least partly positioned within the assembly defined by said driver and driven impellers, said flow inducer means varying the axial relationship between said driver and driven impellers to vary the depth of the impeller flow channels.

4. The apparatus of claim 3 wherein said hubless flow inducer means comprises:

an inducer spring, said spring urging said driver and driven impellers toward one another.

5. The apparatus of claim 4 further comprising:

seal means for fluidically isolating the pump inlet and collector regardless of the relative position of said impellers whereby the pressure differential across the impeller assembly will oppose said inducer spring.

6. The apparatus of claim 3 wherein said inducer means comprises:

an inducer spring, said spring including flow into the impeller and cooperating with said driver and driven impellers to establish a preselected impeller flow area at a given pump back pressure.

7. The apparatus of claim 3 wherein said impeller flow channels are of constant arc from the inlet to the discharge ends thereof, the width of said vanes on each impeller approximating the width of the channels defined by the vanes of the mating impeller.

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