

PATENT SPECIFICATION

(11) 1 522 468

1 522 468

- (21) Application No. 15987/77 (22) Filed 18 April 1977
(31) Convention Application No. 684 335
(32) Filed 7 May 1976 in
(33) United States of America (US)
(44) Complete Specification published 23 Aug. 1978
(51) INT CL² F04D 15/00//1/04
(52) Index at acceptance F1C 1K 2B3B 2J2J3



(54) VARIABLE OUTPUT CENTRIFUGAL PUMP

(71) We, SUNDSTRAND CORPORATION, a corporation organised and existing under the laws of the State of Delaware, United States of America, of 4751, Harrison Avenue, Rockford, Illinois 61101, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to variable output centrifugal pumps such as might be used as fuel pumps in aircraft.

In supplying fuel to the engine of an aircraft, it is desirable to keep the temperature rise in the fuel passing through a fuel pump to a minimum for both high flow and low flow fuel requirements. As is disclosed in United States Patent 3,784,318, issued to Donald Y. Davis, one way of accomplishing this in a centrifugal pump having diffuser vanes is to provide a shutter valve for closing off selected ones of the diffuser passages defined by the vanes. It will be appreciated, however, that with this type of pump operating at a low flow discharge, an undesirable pulsing flow of fluid may be introduced into the pumping system down-stream of the impeller because of the closing off of several of the diffuser passages. Moreover, the precise machining required for the vanes and the complicated assembly of the vanes in the pump housing makes this type of pump quite expensive to produce.

Another centrifugal pump including a shutter valve for producing a variable flow discharge is disclosed in United States Patent 3,826,586. This pump utilizes a volute type diffuser instead of vane diffusers. The variable flow is produced by restricting the flow from the impeller tip into the volute surrounding the impeller through the use of a shutter valve of similar construction to the valve disclosed in United States Patent No. 3,784,318. By restricting the output flow of the fluid from the impeller into the volute in this manner, however, turbulence may be

introduced in the fluid, causing losses in efficiency in the conversion of velocity head into pressure head. As a result, at lower flow-rates, the discharge pressure may not reach the magnitudes desired for proper operation of the aircraft engine, and the efficiency of the pump may be impaired substantially.

The present invention provides a centrifugal pump for receiving fluid at one flowrate and pressure head and discharging the fluid at an increased pressure head, comprising an impeller within a housing and mounted on a shaft for rotation therewith, inlet means for receiving fluid into the housing and directing the fluid to one end of the impeller, first and second diffusers axially spaced from each other and communicating with the other end portion of the impeller to receive fluid from the impeller, each diffuser being sized to handle fluid at a specific flowrate for producing a specific pressure head, and means for closing off the flow of fluid from the impeller into the first diffuser while still permitting fluid flow into the second diffuser.

The invention is hereinafter particularly described, by way of example only, with reference to the drawings, of which:

Figure 1 is an axial section through a centrifugal pump according to the present invention;

Figures 2 and 3 are sections taken substantially along lines 2—2 and 3—3, respectively, of Figure 1;

Figure 4 is a schematic axial section through the pump;

Figure 5 is an enlarged detail of part of Figure 1; and

Figure 6 is an enlarged detail similar to Figure 5 but showing a sleeve moved to a different operative position.

Referring first to Figure 1, there is shown a centrifugal pump 10 particularly adapted for use as a fuel pump to supply fuel to the engine of an aircraft. In use, fluid enters the pump at one flowrate and pressure head through an inlet 11 from a supply (not

shown) and is discharged from the pump at an increased pressure head to flow through conduits (not shown) to the engine for combustion. The fluid enters a pump housing 13 through the inlet and flows into an inlet chamber 14 which communicates with one end 15 of an impeller 16. The latter is mounted for rotation with a shaft 17 which is journaled within the housing and ultimately driven by the aircraft engine. From the inlet chamber the fluid flows in a generally axial direction through the impeller, being accelerated by the blade 19 of the impeller and eventually leaving the impeller at an accelerated velocity from the opposite end 20 of the impeller in a generally radial direction. In flowing from the impeller, the fluid passes through diffuser means which convert at least some of the velocity head of the fluid into pressure head and, from the diffuser means, fluid is discharged from the pump through the aforementioned conduits to the aircraft engine for combustion.

In passing from the pump 10 to the aircraft engine, some of the fluid may be used as a coolant for various accessories of the aircraft, thereby causing an increase in the temperature of the fluid arriving at the engine. In addition to the heat added to the fuel from the aircraft accessories, heat also is added to the fuel by operation of the pump. At high discharge flowrates for the pump, e.g. 250 gallons per minute (gpm), the amount of heat added does not significantly affect the character of the fuel because the pump, typically, is designed to operate efficiently without substantial heat losses to the fuel. But, at low discharge flowrates of about the same pressure head, e.g. 2-4 gpm, such as when the aircraft is at flight idle, inefficiency in pumping may generate enough heat in the fuel so that when combined with the heat added by the aircraft accessories the fuel becomes unstable, tending to coke and decompose. This, of course, is undesirable.

In the pump 10, first and second axially spaced volute diffusers 21 and 22 are formed around the outlet end portion of the impeller to receive the fluid flowing from the impeller. With the demand for a low flowrate discharge from the pump, a closure sleeve 23 blocks the flow of fluid into the first volute diffuser 21, thereby reducing the discharge flowrate by the amount which otherwise would be provided by the closed volute diffuser. Advantageously, the pressure head of the fluid discharged from either volute diffuser is about the same, so that, by closing off one of the volute diffusers, no effective change is seen in the pressure head of the discharge fluid of the pump even though the flowrate may be reduced considerably. Moreover, with the

volute-type diffuser means, a smooth and continuous flow of discharge fluid from the pump is assured while also providing a lighter weight and less expensive pump.

The volute diffusers 21 and 22 are integrally formed with the housing 13 and each volute diffuser is designed to handle fluid to produce a specific increase in the pressure head of the fluid output from the impeller 16, but not necessarily at the same flowrate. Herein, for instance, the first volute diffuser 21 is larger in size than the second volute diffuser 22 and is sized to handle most efficiently a flowrate of approximately 190 gpm, while the second volute diffuser 22 is sized to handle most efficiently a flowrate of approximately 60 gpm. As shown in Figure 3, for balance and compactness, each volute diffuser includes two volutes angularly spaced from each other approximately 180° with each volute being provided with a discharge outlet. In particular, the larger volutes 21a of the first volute diffuser 21 are provided with discharge outlets 24 communicating by means of parallel conduits 25 with a common outlet pipe 26 from the pump. Similarly, the smaller volutes 22a of the second volute diffuser 22 are provided with discharge outlets 27 (see Figure 2) communicating with a second outlet pipe 29 (see Figure 4) from the pump 10.

As shown in Figures 1, 5, and 6, the closure sleeve 23 is telescopically slidable in the pump housing 13 around the impeller 16. Opposite end surfaces 30 and 31 of the sleeve 23 communicate, respectively, with the inlet chamber 14 and an annular passageway 33 located between the outlet end portion of the impeller and the larger volute. Integrally formed with the sleeve 23 intermediate the opposite ends thereof is an annular flange 34 projecting radially outward from the sleeve and into an annular cavity 35 formed in the housing around the impeller. The flange divides the cavity into first and second pressure chambers 36 and 37 which are selectively pressurized by inlet and discharge fluid to shift the sleeve 23 between an extended position closing of the passageway 33 to the first volute 21 and a retracted position opening the passageway (compare Figures 5 and 6). To keep fluid from leaking between the two pressure chambers, a peripheral sealing member 39 in the form of an O-ring is located in the outer end of the flange to engage an axially extending sidewall 40 of the cavity 35.

For controlling the pressure differential between the pressure chambers 36 and 37, a first passage 41 (see Figure 4) extends between the first pressure chamber 36 (which is located closest to the pump inlet chamber 14) and the outlet pipe 29, containing discharge fluid from the smaller

diffuser 22. In this way, during normal operation of the pump 10, the first pressure chamber 36 is maintained at the discharge fluid pressure regardless of whether the passageway 33 to the larger volute diffuser is opened or closed by the sleeve 23. Means for selectively pressurizing the second pressure chamber 37 include a second passage 43 leading from the chamber 37 to a control valve 44 which serves to provide fluid to the chamber 37 at either inlet pressure or discharge pressure. As shown in Figure 4, third and fourth passages or lines 45 and 46 communicate with the valve from the inlet chamber 14 and the discharge conduit 29, respectively, and a valve spool 47 may be shifted axially to place either of these passages or lines in communication with the second passage 43 leading to the chamber 37. With a demand for a low flowrate discharge, a spring 49 within the control valve normally biases the spool into a position such that fluid at inlet pressure is supplied to the chamber 37. This results in a pressure differential across the flange 34 so that the sleeve is held in its operative position with the passageway 33 closed as shown in Figure 5. As the demand for fluid is increased, requiring a high flowrate discharge, a pressure signal from a fuel control 48 for the aircraft is supplied through a line 50 against the end of the spool opposite the spring to overcome the force of the spring and shift the spool (to the left in Figure 4), placing the chamber 37 in communication with the fluid at discharge pressure through the fourth passage or line 46 and the second passage 43 while at the same time cutting off the flow of fluid at inlet pressure through the valve. To shift the spool back again, the pressure signal is terminated by the fuel control so that the spring 49 then urges the spool back to the right.

With the valve spool 47 shifted to the left, both chamber 36 and 37 are pressurized to discharge pressure. In order for the sleeve 23 to be shifted to the position of Figure 6 to open the passageway 33 so the fluid from the impeller 16 may flow into the first volute 21, advantage is taken of the difference in fluid pressures acting on the opposite end surfaces 30 and 31 of the sleeve 23. As previously mentioned, the inlet end surface 30 of the sleeve 23 is in communication with the inlet chamber 14 and the outlet end 31 of the sleeve communicates with fluid substantially at discharge pressure. With this arrangement, the fluid at inlet pressure acts against the end 30 of the sleeve 23, urging it toward its operative position, while the fluid at discharge pressure acts against an equivalent surface area at the end 31 urging the sleeve toward its inoperative position.

The forces acting on the ends of the sleeve 23 from the inlet and outlet pressures are, of course, unbalanced, with the force at the outlet end of the sleeve being substantially higher than the force acting at the inlet end of the sleeve. With the pressures in the chambers 36 and 37 balanced, the result is that the sleeve will be shifted into its retracted position of Figure 6. In order to assure that the sleeve will shift back into its extended position when the demand for fluid is again low, the radial surface area of each side of the flange 34 is large enough so that the difference in forces acting on opposite sides of the flange is greater than the difference in forces acting at the opposite ends of the sleeve.

The variable output centrifugal pump 10 efficiently provides a low flowrate discharge without substantial increases in the temperature of the discharge fluid, while maintaining a discharge pressure head which is about the same as the pressure head at high flowrates. This is achieved by virtue of the construction of the pump with the two axially spaced volutes 21 and 22 in conjunction with the single impeller 16.

WHAT WE CLAIM IS:—

1. A centrifugal pump for receiving fluid at one flowrate and pressure head and discharging the fluid at an increased pressure head, comprising an impeller within a housing and mounted on a shaft for rotation therewith, inlet means for receiving fluid into the housing and directing the fluid to one end of the impeller, first and second diffusers axially spaced from each other and communicating with the other end portion of the impeller to receive fluid from the impeller, each diffuser being sized to handle fluid at a specific flowrate for producing a specific pressure head, and means for closing off the flow of fluid from the impeller into the first diffuser while still permitting fluid flow into the second diffuser.

2. A centrifugal pump according to claim 1, wherein the first and second diffusers are volute diffusers of different sizes designed to handle different flowrates.

3. A centrifugal pump according to claim 1 or claim 2, wherein the first diffuser is designed to handle the greater flowrate.

4. A centrifugal pump according to any preceding claim, wherein the means for closing off the fluid flow into the first diffuser comprises an axially slidable member in the housing, movable between an extended position closing a passageway to the first diffuser and a retracted position permitting fluid to flow from the impeller into the first diffuser, and means for axially sliding the member in the housing comprising

diffuser 22. In this way, during normal operation of the pump 10, the first pressure chamber 36 is maintained at the discharge fluid pressure regardless of whether the passageway 33 to the larger volute diffuser is opened or closed by the sleeve 23. Means for selectively pressurizing the second pressure chamber 37 include a second passage 43 leading from the chamber 37 to a control valve 44 which serves to provide fluid to the chamber 37 at either inlet pressure or discharge pressure. As shown in Figure 4, third and fourth passages or lines 45 and 46 communicate with the valve from the inlet chamber 14 and the discharge conduit 29, respectively, and a valve spool 47 may be shifted axially to place either of these passages or lines in communication with the second passage 43 leading to the chamber 37. With a demand for a low flowrate discharge, a spring 49 within the control valve normally biases the spool against the opposite end of the valve bore into a position such that fluid at inlet pressure is supplied to the chamber 37. This results in a pressure differential across the flange 34 so that the sleeve is held in its operative position with the passageway 33 closed as shown in Figure 5. As the demand for fluid is increased, requiring a high flowrate discharge, a pressure signal from a fuel control 48 for the aircraft is supplied through a line 50 against the end of the spool opposite the spring to overcome the force of the spring and shift the spool (to the left in Figure 4), placing the chamber 37 in communication with the fluid at discharge pressure through the fourth passage or line 46 and the second passage 43 while at the same time cutting off the flow of fluid at inlet pressure through the valve. To shift the spool back again, the pressure signal is terminated by the fuel control so that the spring 49 then urges the spool back to the right.

With the valve spool 47 shifted to the left, both chamber 36 and 37 are pressurized to discharge pressure. In order for the sleeve 23 to be shifted to the position of Figure 6 to open the passageway 33 so the fluid from the impeller 16 may flow into the first volute 21, advantage is taken of the difference in fluid pressures acting on the opposite end surfaces 30 and 31 of the sleeve 23. As previously mentioned, the inlet end surface 30 of the sleeve 23 is in communication with the inlet chamber 14 and the outlet end 31 of the sleeve communicates with fluid substantially at discharge pressure. With this arrangement, the fluid at inlet pressure acts against the end 30 of the sleeve 23, urging it toward its operative position, while the fluid at discharge pressure acts against an equivalent surface area at the end 31 urging the sleeve toward its inoperative position.

The forces acting on the ends of the sleeve 23 from the inlet and outlet pressures are, of course, unbalanced, with the force at the outlet end of the sleeve being substantially higher than the force acting at the inlet end of the sleeve. With the pressures in the chambers 36 and 37 balanced, the result is that the sleeve will be shifted into its retracted position of Figure 6. In order to assure that the sleeve will shift back into its extended position when the demand for fluid is again low, the radial surface area of each side of the flange 34 is large enough so that the difference in forces acting on opposite sides of the flange is greater than the difference in forces acting at the opposite ends of the sleeve.

The variable output centrifugal pump 10 efficiently provides a low flowrate discharge without substantial increases in the temperature of the discharge fluid, while maintaining a discharge pressure head which is about the same as the pressure head at high flowrates. This is achieved by virtue of the construction of the pump with the two axially spaced volutes 21 and 22 in conjunction with the single impeller 16.

WHAT WE CLAIM IS:—

1. A centrifugal pump for receiving fluid at one flowrate and pressure head and discharging the fluid at an increased pressure head, comprising an impeller within a housing and mounted on a shaft for rotation therewith, inlet means for receiving fluid into the housing and directing the fluid to one end of the impeller, first and second diffusers axially spaced from each other and communicating with the other end portion of the impeller to receive fluid from the impeller, each diffuser being sized to handle fluid at a specific flowrate for producing a specific pressure head, and means for closing off the flow of fluid from the impeller into the first diffuser while still permitting fluid flow into the second diffuser.

2. A centrifugal pump according to claim 1, wherein the first and second diffusers are volute diffusers of different sizes designed to handle different flowrates.

3. A centrifugal pump according to claim 1 or claim 2, wherein the first diffuser is designed to handle the greater flowrate.

4. A centrifugal pump according to any preceding claim, wherein the means for closing off the fluid flow into the first diffuser comprises an axially slidable member in the housing, movable between an extended position closing a passageway to the first diffuser and a retracted position permitting fluid to flow from the impeller into the first diffuser, and means for axially sliding the member in the housing comprising

(18)



4

1,522,468

4

means for biasing the member towards its extended position and means for overcoming the bias when required and urging the member into its retracted position.

5 5. A centrifugal pump according to claim 4, wherein the inlet means includes an inlet chamber within the housing, communicating with the one end of the impeller, and the means for axially sliding the member in the housing comprises first and second end surfaces of the member of substantially the same cross-sectional area, the first end surface communicating with the inlet chamber whereby the inlet pressure of the fluid acts against the first end surface to urge the member towards its extended position, and the second end surface communicating with fluid flowing from the impeller whereby the pressure of such fluid acts against the second end surface to urge the member towards its retracted position.

10 6. A centrifugal pump according to claim 5, wherein the member comprises a sleeve around the impeller, an annular flange on the sleeve cooperating with the housing to define first and second pressure chambers, and the means for overcoming the bias when required and urging the sleeve into its retracted position comprises means for

selectively pressurizing one of the first and second pressure chambers. 30

7. A centrifugal pump according to claim 6, including a first passage between the first pressure chamber and the fluid discharged from the second diffuser so that the pressure of the discharge fluid acts against the flange to urge the sleeve towards its extended position, and the means for selectively pressurizing the second pressure chamber comprises a control valve, a second passage between the control valve and the second pressure chamber, a third passage between the control valve and the inlet chamber, a fourth passage between the control valve and the fluid discharged from the second diffuser, and means for actuating the control valve selectively to supply inlet pressure fluid or discharge pressure fluid through the second passage to the second chamber. 35 40 45 50

8. A variable output centrifugal pump substantially as particularly described herein with reference to the drawings.

SERJEANTS,
Chartered Patent Agents,
25 The Crescent,
Leicester.