

Nov. 16, 1965

M. A. SERCY ETAL

3,217,655

CENTRIFUGAL PUMP

Filed Aug. 9, 1963

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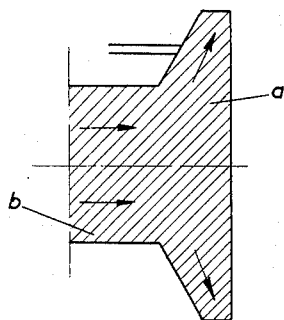


Fig. 1

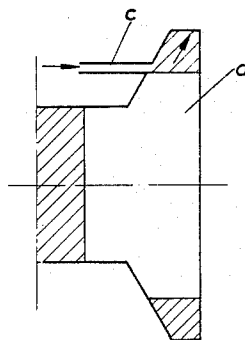


Fig. 2

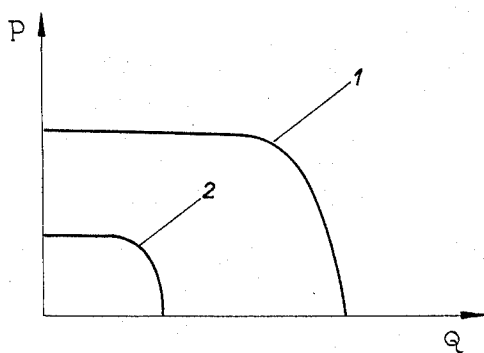


Fig. 3

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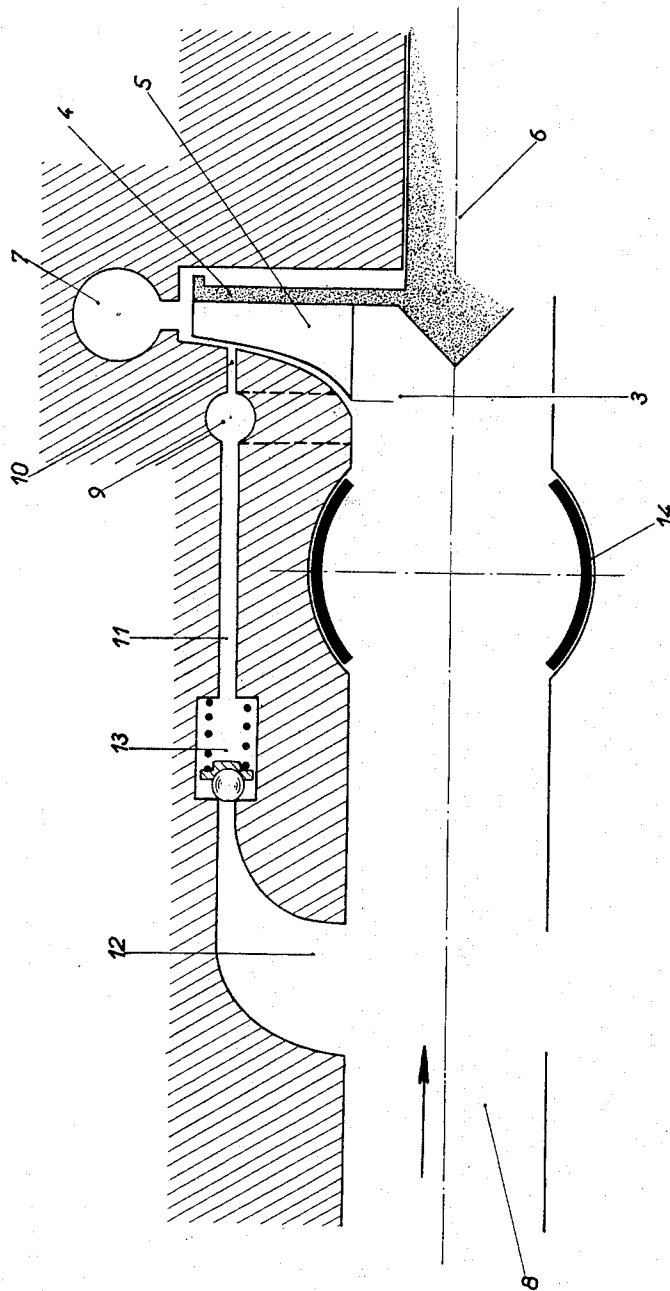


Fig. 4

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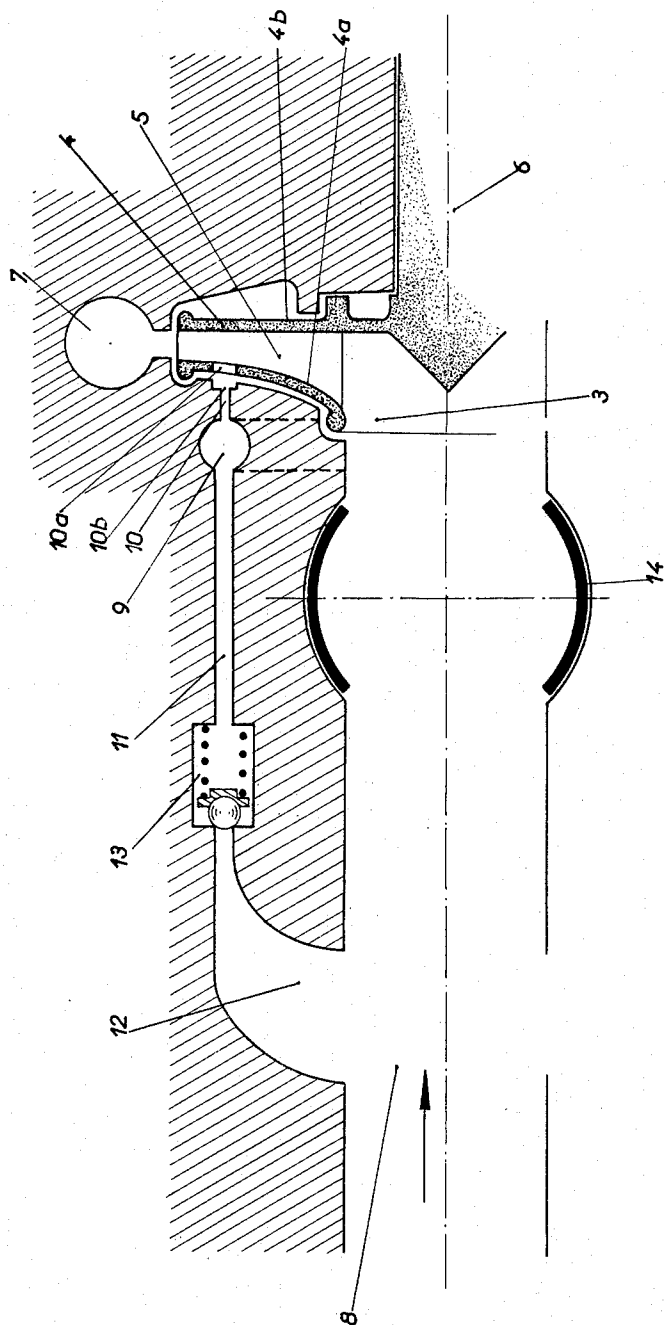
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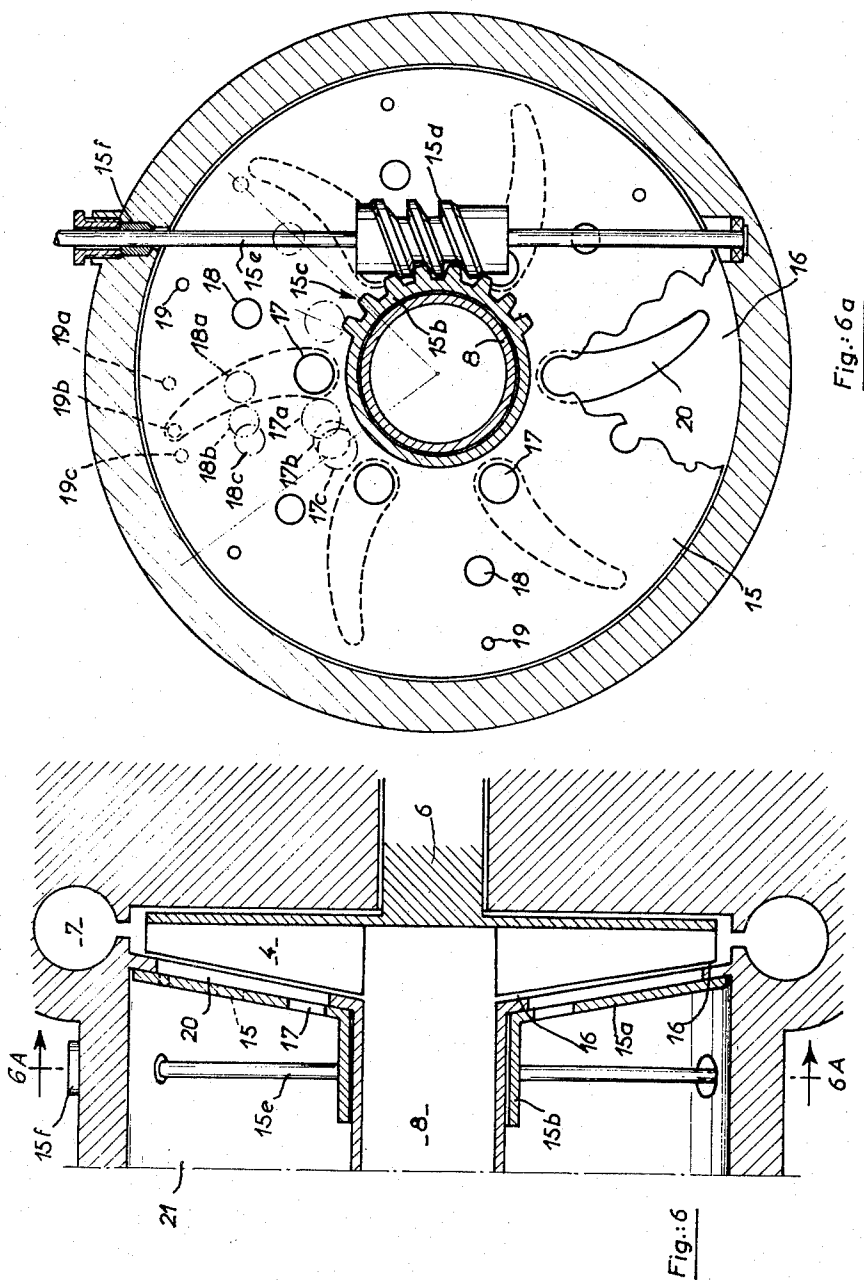
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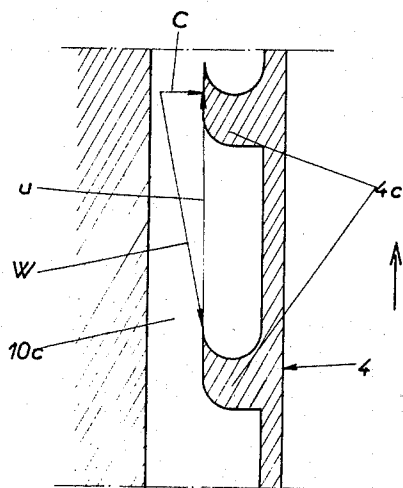


Fig.: 7

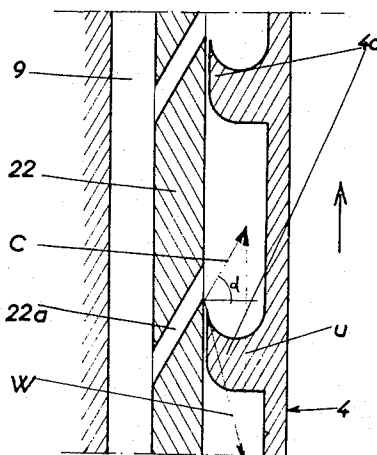


Fig.: 7a

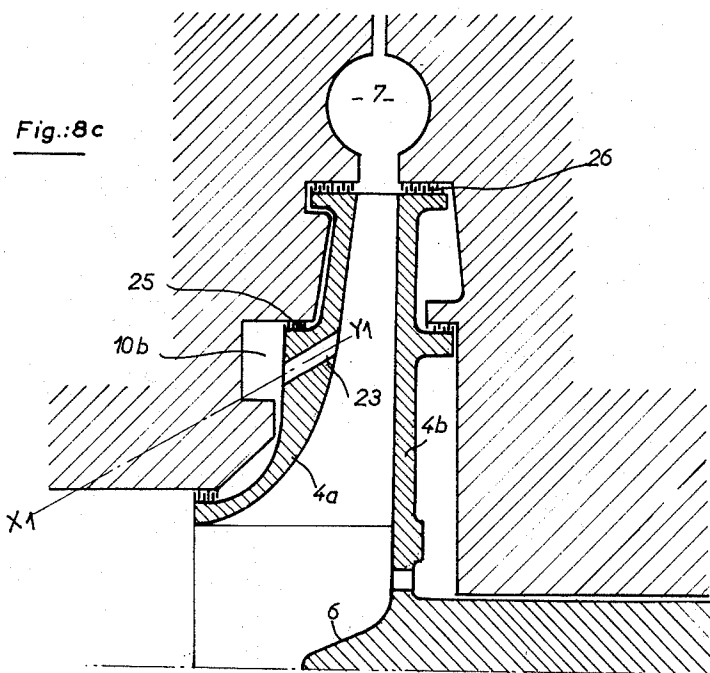


Fig.: 8c

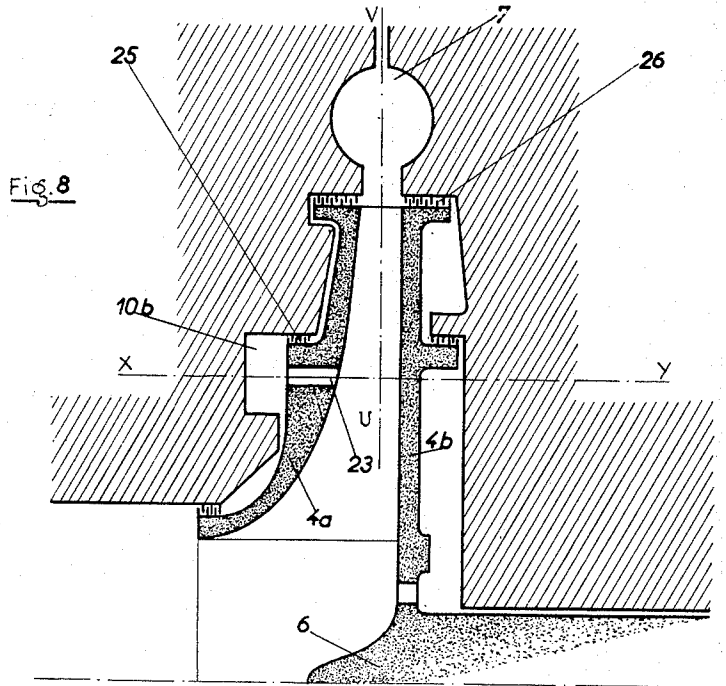
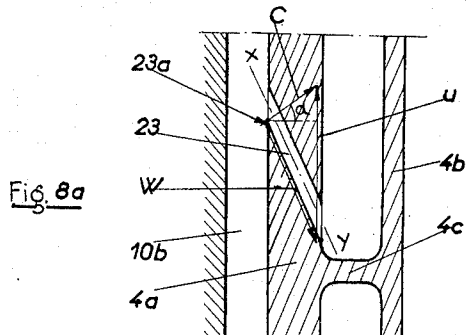
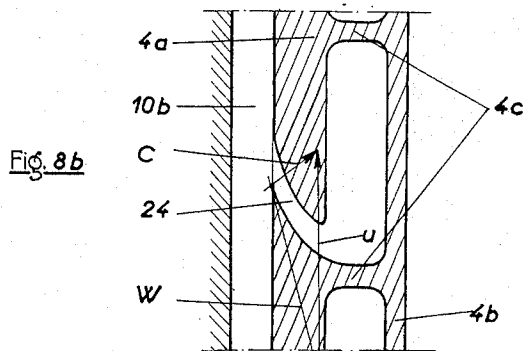
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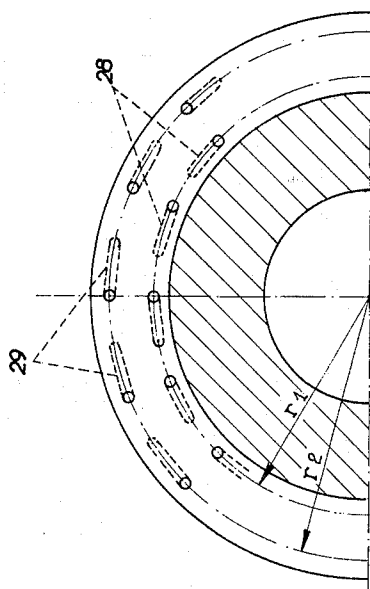


Fig. 10a

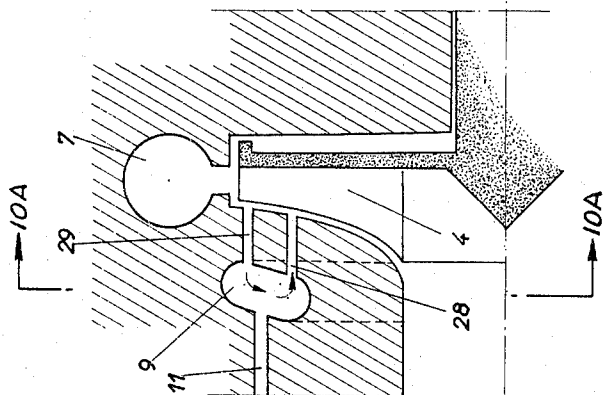


Fig. 10

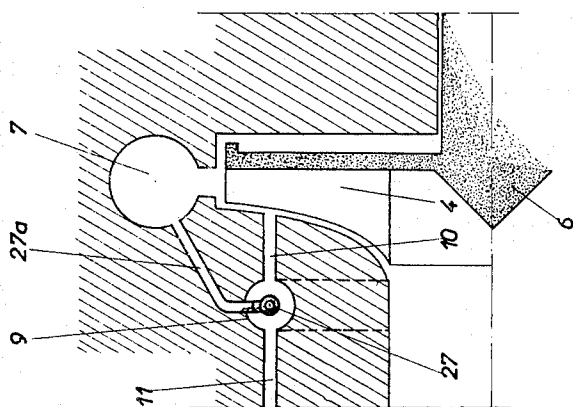


Fig. 9

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3,217,655

CENTRIFUGAL PUMP

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9 Claims. (Cl. 103—103)

The invention relates to centrifugal pumps, especially those which are used for the supply of fuel for post-combustion in aircraft jet-engines, and it has for its object the provision of means to permit the regulation of the flow of such pumps.

The heating or reheating fuel pumps of jet-engines must ensure, under satisfactory conditions of efficiency, a very variable flow of fuel to the injectors, according to the load required.

In certain types of jet-engines for example, the same pump must be able to supply fuel at a flow rate which can vary from small flow rates for cruising flight at high altitude, up to flow rates which may be about one hundred times larger for flight at low altitude with high Mach number and low external temperature.

The supply of fuel for post-combustion is frequently effected by means of a pump driven by a separate turbine. By varying the speed of rotation of this turbine as a function of the altitude, the turbo-pump permits of effecting the necessary fuel flow, but the energy efficiency of the assembly comprising the jet-engine and turbo-pump is necessarily rather poor. In the case of, for example, a turbo-jet, the energy transferred to the turbine, generally by withdrawing compressed air from the delivery of the compressor of the turbo-jet, does not take place with a good efficiency, the efficiency being further reduced by the variation of the rotational speed of the turbo-pump assembly.

Therefore attempts have been made to vary the flow of the pump by other means and it has already been proposed to obtain this variation by throttling the flow either downstream or upstream of the pump, while retaining a substantially constant rotational speed of the latter. The downstream throttling causes heating of the fuel. An upstream throttling arrangement possesses the drawback of constituting, with the centrifugal pump, a device equivalent to a volumetric pump, which does not lend itself to certain kinds of regulator arrangement for the post-combustion, such as include a throttle regulating valve.

According to the invention the centrifugal pump comprises a central suction conduit serving for high rates of flow and peripheral suction conduits which are used at small rates of flow, the central suction conduit then being closed. Thus, at low flow rates, only the peripheral part of the vanes of the pump and of the fluid current circulating therein is used. The delivery pressure is thus reduced, whence there arises a substantial gain as regards heating. The various features of the invention and the manner in which it may be carried into effect will be more clearly understood from the following description with reference to the accompanying drawings, which is given by way of non-limitative example only. Any arrangement appearing either from the text or from the drawings comes within the scope of the invention.

In the drawings:

FIGURES 1 and 2 represent diagrammatically the principle of the device according to the invention;

FIGURE 3 shows the characteristic curves of the device;

FIGURE 4 shows a pump according to the invention, partly in axial section through an inlet channel;

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FIGURE 5 is a view similar to FIGURE 4, showing the application of the invention to a pump comprising a rotor with double shrouding;

FIGURE 6 is a view similar to FIGURE 4, showing another form of pump;

FIGURE 6a is a view in section along the line 6A—6A in FIGURE 6, partly broken away;

FIGURES 7 and 7a represent the diagram of the speeds at the entry of the peripheral injection into a rotor having a single shrouding, without and with a distributor, respectively;

FIGURE 8 is a view similar to FIGURE 5 and on a larger scale, showing particularly the detail of the peripheral admission through the holes in the front shrouding;

FIGURE 8a represents the diagram of the speeds at the entry into the vanes of the rotor;

FIG. 8b is a view similar to FIGURE 8a, but showing another arrangement;

FIGURE 8c is a view similar to FIGURE 8, but showing a modification of the holes in the front shrouding.

FIGURE 9 is a view similar to FIGURE 4, but on a larger scale, showing another arrangement of the peripheral admission;

FIGURE 10 is a view similar to FIGURE 9, showing yet another arrangement;

FIGURE 10a is a view in section along the line 10A—10A in FIGURE 10;

FIGURE 11 is a fragmentary view of a pump according to the invention, comprising a partly open rotor, seen in half axial section;

FIGURE 11a is a partial representation of this rotor, in end view in the direction of the arrow *f* in FIGURE 11;

FIGURE 11b is a sectional view along the line 11B—11B in FIGURES 11 and 11a;

FIGURE 12 is a view similar to FIGURE 11b, showing another arrangement.

Referring to FIGURES 1 and 2, the wheel of the centrifugal pump is represented diagrammatically at *a*, the central suction conduit at *b* and the peripheral admission conduits at *c*. The hatched parts represent the parts where the fluid is situated. At high rates of flow, fluid is sucked in at *b* and fills all the vanes and the wheel *a* of the pump. At low rates of flow, the central suction conduit *b* is closed and the fluid sucked through the conduits *c* fills only the peripheral part of the pump.

Referring to FIGURE 3, rates of flow are shown as abscissae *Q* and the delivery pressures as ordinates *P* for a constant rotational speed of the pump. The curve 1 is the characteristic of the pump at high rates of flow (i.e. the arrangement according to FIGURE 1) and the curve 2 shows the characteristic at low rates of flow (i.e. the arrangement according to FIGURE 2). It will be seen that, in the latter arrangement, the delivery pressure is considerably reduced.

In the embodiment according to FIGURE 4, the centrifugal pump comprises a central admission orifice 3, a wheel 4, vanes 5, a shaft 6 on which the wheel 4 is keyed, and a diffusor 7. The fuel arrives by way of an inlet conduit 8 and is delivered under pressure from the diffusor 7 toward the point of utilisation.

A circular collector 9 in the casing communicates, on the one hand, with the body of the pump at a position intermediate between the entry and the diffusor of the pump, by means of a plurality of admission passages 10, and, on the other hand, with the main fluid supply conduit 8 through an inlet channel 11. A non-return valve 13 is arranged in the channel 11. A branch-pipe 12 connects the valve 13 to the supply conduit 8. A gate 14 is mounted in the supply conduit 8, between the branch-pipe 12 and the admission orifice 3.

In the case of operation at high rates of flow, the gate 14 is opened and the fuel passes wholly through the central admission orifice 3. The non-return valve 13 prevents the fuel from flowing back into the supply conduit 8.

In the case of operation at low rates of flow, the gate 14 is closed and the fuel passes wholly through the branchpipe 12, the channel 11, the collector 9 and the ring passage 10; the valve 13 permits the fuel to pass from the conduit 8 to the passages 10 and to the pump 4. The fluid is not in contact with the central part of the vanes; only the peripheral part is effective. The delivery pressure and the rate of flow thus become smaller.

The non-return valve 13 can be replaced by a valve, the operation of which is governed by the operation of the gate 14.

In a modified form thereof, the device is utilisable, as shown in FIGURE 5, with a rotor having double shroudings 4a and 4b and having holes 10a in the front face or shrouding 4a of the wheel, opposite the circular admission passage 10b.

It will be understood that, if the pump is a fuel supplying pump for post-combustion, the fuel is delivered into the conduit 8 by a pump which is known as the "force-feeding" pump and is delivered under pressure from the diffuser 7 to the injectors of the post-combustion burners.

In order to ensure more progressive operation, in accordance with the embodiment shown in FIGURES 6 and 6a, it is possible to provide almost continuous admission over the entire height of the rotor, by means of a facing 15 rotating in front of a distributor 16. The facing is provided with a plurality of rings of holes 17, 18, 19 which can come opposite ports 20 passing through the distributor. In the position shown in the drawing, only the holes 17 of the inner ring are opposite the ports 20 and provide an open passage for fluid arriving through the space 21, the main conduit 8 being closed.

Rotation of facing 15 can be controlled by conventional means. In the embodiment shown, facing 15 comprises a frusto-conical plate 15a, which is perforated as above described, and an axially extending sleeve 15b, which is mounted for rotation about inlet conduit 8. Sleeve 15b has a worm gear segment 15c integral therewith, which extends over a portion of the periphery thereof corresponding to the overall angular displacement of the facing which is desired. Meshing with worm gear segment 15c is a worm 15d whose shaft 15e extends across the pump body, is journaled in the wall thereof on both sides of worm 15d, and projects at one side beyond a sealing device 15f. Shaft 15e can be rotated by a motor (not shown) connected to its projecting end, to shift facing 15 angularly to a desired position.

As represented in dotted lines in FIGURE 6a, by rotating the facing 15 it is possible to bring the holes of the middle ring successively into position opposite the port 20, at the position 18a, followed by the holes of the outer ring at the position 19b. By rotating the facing further, the holes are brought into the positions 17c, 18c and 19c, in which they are all masked by the distributor 16; the conduit 8 is then opened by a gate similar to the gate 14 in FIGURE 4.

The arrangement according to the invention, several embodiments of which have just been described by way of example, presents, in particular, the following advantages over known arrangements such as consist in throttling the flow of the pump or branching off a part thereof:

Lower heating at low rates of flow;
Lower power for compression;
More stable operation.

The embodiments described are susceptible of various modifications and of various improvements, which are of course included within the scope of the invention.

More especially, it is possible to produce a pump having a plurality of flow and pressure stages, by providing collectors such as 9 and passages such as 10 of different diameters and with different cross-sections.

In place of admission passages of circular cross-section distributed uniformly around the periphery, it is possible to utilise, for the auxiliary admission, conduits of groove form distributed in sectors or, preferably, one single continuous collector of crown or ring form.

The intermediate regulation of the flow within each stage can be effected by the usual means, such as variable throttling at the delivery.

In order, more especially, to improve the behavior of the vanes of the rotor, it is possible to adopt various arrangements having the effect of increasing the angle of impingement upon these vanes of the liquid entering through the peripheral admission orifices. Examples of such arrangements are described below with reference to FIGURES 7 to 12.

FIGURE 7 represents the diagram of the speeds at the entry of the vanes, which latter are represented diagrammatically at 4c, of a rotor with single shrouding 4, supplied directly by a groove or circular admission channel 10c. For a given peripheral speed u , the relative speed W (which causes impact upon the vane if the profile is poorly adapted) will be diminished by inclining the absolute speed vector C through an angle α , as may be seen from FIGURE 7a, where the inclination of the vector C is obtained by means of a distributor 22 formed with admission channels 22a inclined forward in the direction of rotation of the rotor. At the same time the relative speed will form a greater angle with the peripheral speed u , which permits of having a larger angle of impingement upon the vane and consequently a less acute profile, so that easier production and better behaviour of the vane are obtained.

FIGURES 8 and 8a show an example of the application of this principle to a rotor with two shroudings 4a, 4b. Unlike the vanes in FIGURE 7 which are fully open on the circular admission channel 10c, the vanes 4c of FIGURES 8 and 8a are fed with fluid by admission holes 23 formed in the shrouding 4a and analogous to the holes 10a in FIGURE 5. Holes 23 have their axis XY inclined tangentially to guide the fluid to the vanes 4c, and accordingly have acute leading edges 23a projecting in the direction of rotation like the leading edges of the vanes 4c in FIGURE 7. Leading edges 23a must be sufficiently acute to avoid the impact on the surface of holes 23 of the fluid entering the said holes at a relative speed W . It will be observed that, due to its viscosity, the fluid in the circular admission passage 10b is dragged forward by the shrouding 4a, resulting in minimizing the impact of the fluid on the leading edges 23a and inclining the absolute speed vector C forwardly.

Instead of being inclined in the tangential direction only, the admission holes can be inclined in the radial direction also. Such a tangentially and radially inclined hole is represented in FIGURE 8c; its axis is shown at XY in FIGURE 8a and at X_1Y_1 in FIGURE 8c.

Like their inclination, the peripheral distribution of the holes also is advantageously selected in such manner as to obtain an admission as close as possible to the intrados of the vane 4c, in order to act upon the intercellular circulation in the desired direction. The admission holes represented in FIGURES 8 and 8a are rectilinear and one will frequently be obliged to adopt this solution in order to facilitate machining. However if foundry conditions permit it, it will be advantageous to impart a rational incurved form to these holes, such as that which is represented at 24 in FIGURE 8b.

It will be observed, especially from FIGURE 8, that the admission holes are advantageously formed in a part of the forward shrouding 4a which is of extra thickness, with a view to imparting to them a sufficient guid-

ance length (ratio of length to diameter) to define the direction of admission in a more precise manner. This extra thickness can be used to support a labyrinth seal 25, thus permitting the use of an external labyrinth seal 26 which extends over a smaller radius and also permitting an easier longitudinal hydraulic balancing of the rotor.

It is possible to provide a second peripheral injection arrangement (not shown), symmetrical with the first in relation to the axis U-V of the fluid flow, with a view to acting upon the obtainable variations of flow and upon the intercellular circulation. The vanes will then have to have a suitable shape.

In order to impart a peripheral component to the fuel entering the pump, and if necessary to increase the force-feeding pressure, it is also possible to impart a certain amount of movement to the fuel in the admission chamber. In the embodiment shown in FIGURE 9 a part of the fuel delivered into the diffuser 7 is re-injected into the admission chamber 9 through a channel 27a terminating at an ejector 27 mounted in the said chamber. The suction fuel arriving through the channels 11 is entrained by the delivery fuel in the direction imparted by the outlet nozzle of the ejector 27. The latter will be given a suitable oblique position relatively to the tangential direction, and possibly also relatively to the radial direction. The admission channels 10 will of course also have the necessary obliquity so as not to counter the flow. They can further be united into one single circumferential annular channel allowing complete freedom of flow to the fuel in the tangential direction.

In the embodiment according to FIGURES 10 and 10a, the peripheral injection takes place from the chamber 9 through a number of channels 28 inclined forwardly in the direction of rotation of the rotor and disposed around a ring of radius r_1 . A part of the fluid from the pump is recovered by channels 29 inclined in the converse direction and disposed in a ring of radius r_2 which is greater than r_1 in the case of a centrifugal pump. A part of the fluid injected through the channels 28 returns through the channels 29 into the chamber 9, where it serves to set the fluid in rotation before injection.

The rotor 4 according to FIGURES 9 and 10 has one single shrouding, but it is self-evident that the arrangements shown could equally well apply to a pump having a double-shrouded rotor.

In the case of pumps with open or partly open rotors (and especially when the rotor comprises an attached forward member), the peripheral admission is advantageously combined with an arrangement such as that represented in FIGURES 11 and 12, consisting in imparting to the vane end a milled form which provides, at the leading edge, a profile cut to an acute angle, in order to avoid cavitation by impact of the vane upon the fluid. In FIGURE 11 the rotor 4 includes a rear member 30 and a formed member 31, attached to the rear member by screwing or riveting at 31a so as to leave open the peripheral part 32 of the vanes, where the peripheral admission takes place through the channels 10. The milled form of the peripheral part of the vane, constituting a leading edge profile 32a cut to an acute angle, can be seen in FIGURE 11a (which is an end of the rotor, showing one single vane only) and in FIGURE 11b (which is a sectional view along the line 11B—11B in FIGURES 11 and 11a).

The end profile of the vane can be shaped to provide for a second peripheral admission symmetrical with the first (as shown in broken lines at 33 in FIGURE 11). As can be seen from FIGURE 12, the profile of the vane is itself approximately symmetrical in relation to the flow axis U—V and comprises two leading edges 32a, 32b cut at an acute angle.

These arrangements are difficult to use in the case of a closed rotor (two shrouds) or semi-closed rotor (one

rear shroud) for reasons of manufacture. On the other hand they can be applied very easily in the case of the open rotor. The end form of the vane can then be provided as being a shape adapted to the profile to be obtained for peripheral admission without impact.

Naturally the embodiments described are given only as examples and they could be modified, particularly by combining them with one another in various ways, or by substitution of equivalent technical means, without departing from the scope of the invention as defined by the claims.

What we claim is:

1. A centrifugal pump capable of effecting a variable flow of fluid, especially for use for supplying fuel for post-combustion in aircraft jet engines, comprising a pump body and a rotor rotating in said body, said body having a diffuser disposed around the periphery thereof, a central suction orifice disposed axially and communicating with the central suction conduit, a plurality of peripheral suction conduits disposed in an intermediate zone between the central suction orifice and the diffuser and peripheral suction conduits which communicate with the peripheral suction orifices, said peripheral suction conduits being disposed in the pump body around at least two circles of different radii, annular collector means connected to the peripheral suction conduits and communicating with the central suction conduit upstream of the closure device, non-return valve means between the central suction conduit and the peripheral suction orifices, means provided to connect the orifices of the various circles selectively with the annular collector means and means for closing the central suction orifice.

2. A centrifugal pump according to claim 1, including a facing plate mounted for rotary movement relatively to a distributor and provided with ports which progressively uncover holes or slots in the said distributor during rotation of the facing plate relatively to the distributor, thereby to control peripheral admission over at least a part of the height of the rotor.

3. A centrifugal pump according to claim 1, wherein means are provided to incline the fluid current also radially.

4. A centrifugal pump according to claim 1 wherein said peripheral suction conduits are inclined forwardly in the tangential direction and are adapted to supply the incoming fluid to a peripheral portion of the rotor.

5. A centrifugal pump according to claim 1 wherein a plurality of peripheral channels are arranged in a first ring inclined forwardly in the tangential direction and are adapted to supply the fluid from the annular collector means to a peripheral portion of the rotor, and a plurality of channels are arranged in a second ring of larger radius and are inclined rearwardly in the tangential direction and are adapted to feed fluid from the rotor back to the annular collector means to rotate the fluid therein forwardly.

6. A centrifugal pump capable of effecting a variable flow of fluid according to claim 1 wherein said centrifugal rotor has a shrouding on at least one side thereof, said peripheral suction conduit means adapted to supply the incoming fluid to a peripheral portion of the rotor through a plurality of passages in the shroud which are inclined forwardly in the tangential direction.

7. A centrifugal pump according to claim 1 wherein said peripheral suction conduit means are adapted to supply a flow of the incoming fluid to a peripheral portion of the rotor in a direction which is inclined forwardly on the tangential direction of the rotor.

8. A centrifugal pump according to claim 7, including an injection chamber through the intermediary of which the pump is supplied by the peripheral suction conduits, the injection chamber comprising means to cause fluid circulation in a direction such that the fluid enters the pump in a forwardly inclined direction.

9. A centrifugal pump according to claim 8, wherein the injection chamber includes an ejector device for creat-

ing the said fluid circulation, means being provided for supplying the ejector device with fluid from the fluid delivered by the pump.

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