

March 3, 1959 **H. PH. G. A. R. VON ZBOROWSKI** **2,875,696**
CENTRIFUGAL PUMPS, IN PARTICULAR FOR FEEDING
FUEL TO FUEL INJECTION ENGINES
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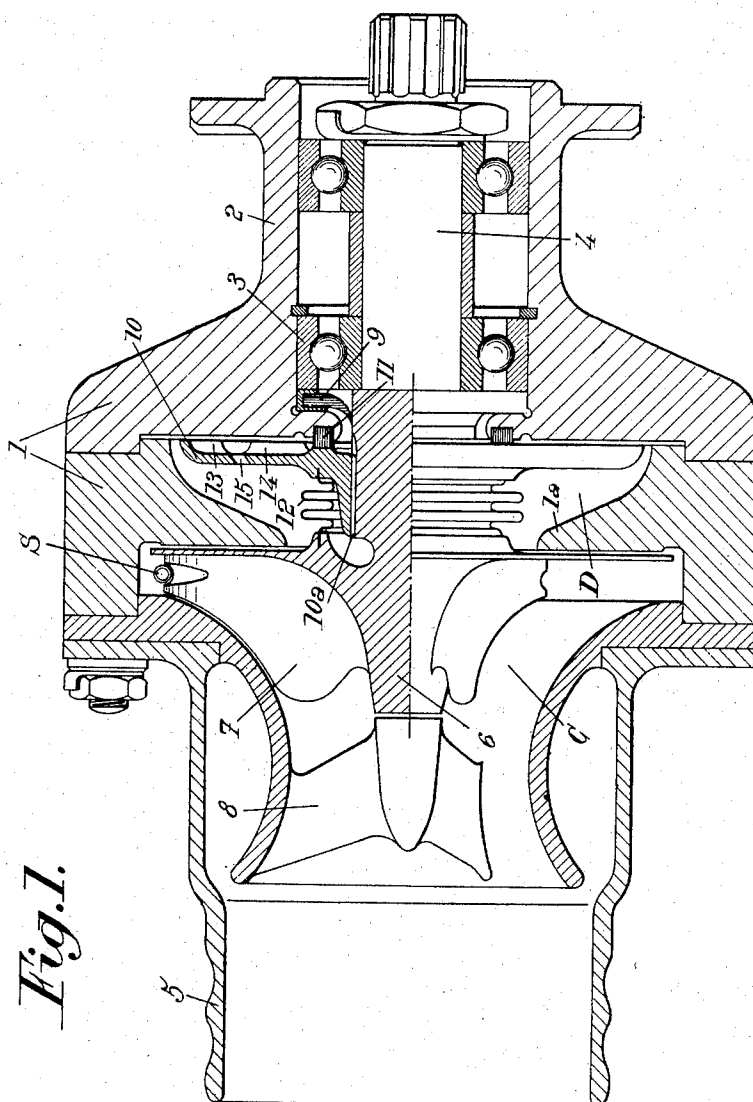


Fig. 1.

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Fig. 4.

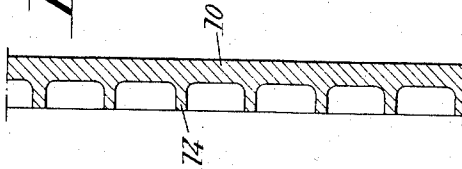


Fig. 3.

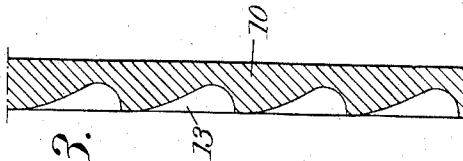


Fig. 2.

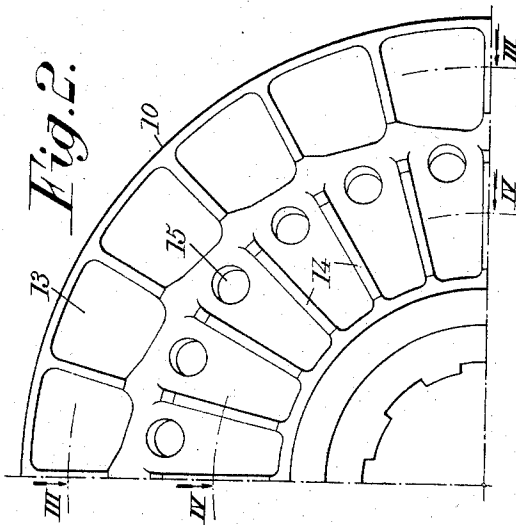


Fig. 5.

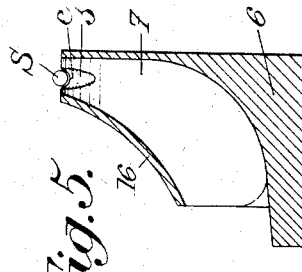
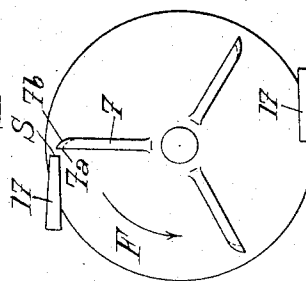


Fig. 6.



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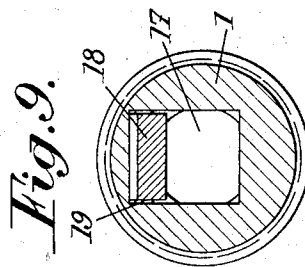
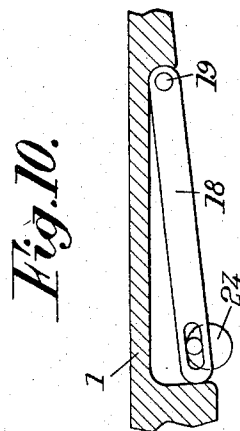
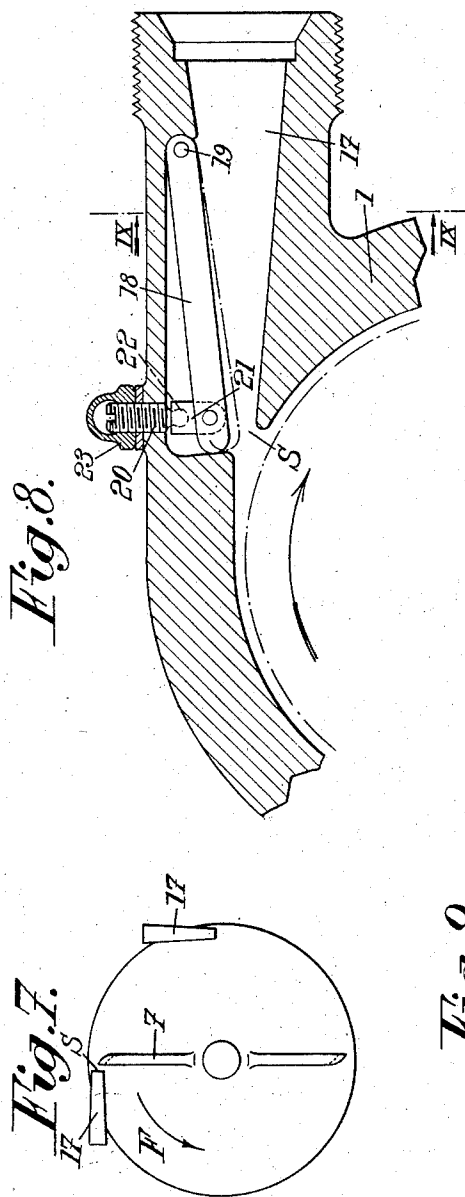
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Fig. 11.

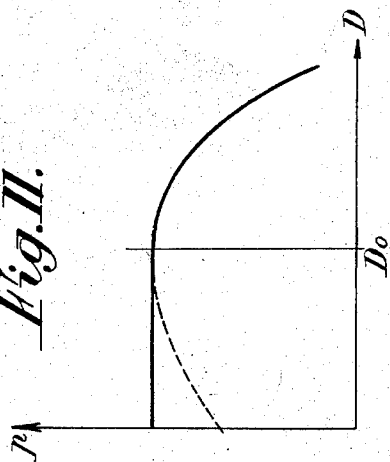


Fig. 13.

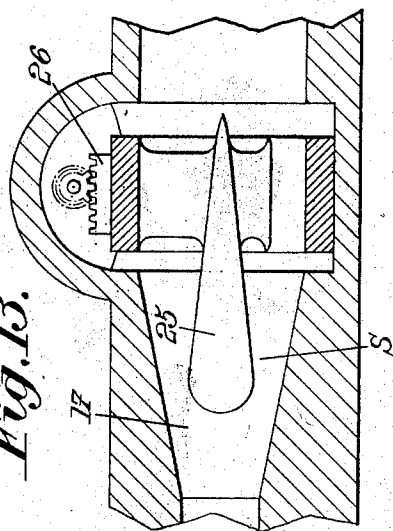
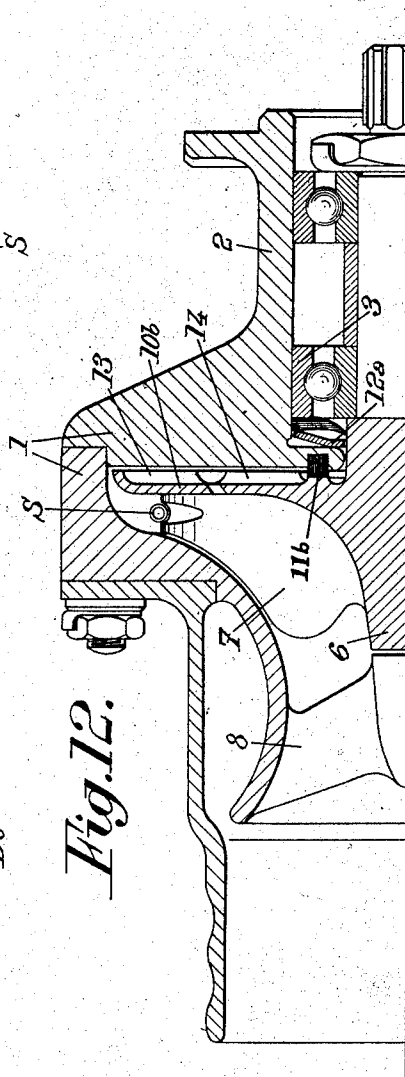


Fig. 12.



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CENTRIFUGAL PUMPS, IN PARTICULAR FOR FEEDING FUEL TO FUEL INJECTION ENGINES

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13 Claims. (Cl. 103—103)

The present invention relates to centrifugal pumps, and it is more especially concerned with centrifugal pumps. The chief object of the present invention is to provide a centrifugal pump which is free from any leakage of liquid past the ball bearings in which the pump rotor shaft is mounted, and this without involving too much friction which would result in a quick wear and tear of the parts of this pump.

Preferred embodiments of my invention will be hereinafter described with reference to the accompanying drawings, given merely by way of example, and in which:

Fig. 1 of these drawings shows in axial section a fuel pump for fuel injection engines made according to a first embodiment of my invention;

Fig. 2 is a partial front view of an element of the pump of Fig. 1;

Figs. 3 and 4 are circular sections respectively on the lines III—III and IV—IV of Fig. 2;

Fig. 5 shows, in axial half-section, a modification of the rotor of the pump illustrated by Fig. 1;

Figs. 6 and 7 illustrate two devices according to my invention for distributing the discharge diffusers at the periphery of the rotor;

Figs. 8 and 9 show, respectively in longitudinal section and in cross section on the line IX—IX of Fig. 8, a particular embodiment of such a diffuser;

Fig. 10 illustrates a modification of the flow rate adjusting means included in the diffuser of Fig. 8;

Fig. 11 shows the characteristic curves of the pump according to my invention and of a conventional pump;

Fig. 12 shows, in axial half-section, a fuel pump made according to a second embodiment of my invention;

Fig. 13 shows, in horizontal section, a modification of a delivery diffuser for such a pump.

I will now describe, by way of example, a centrifugal pump for feeding fuel to an engine such as a turbo-jet or a turbo-prop.

This pump includes a casing 1 one of the sides of which forms a tubular extension 2 supporting, through ball bearings 3, the driving shaft 4 of the centrifugal rotor, the other side of said casing being connected in a fluid-tight manner with a conduit 5 for the feed of fuel.

A rotor 6 provided with radial blades 7 is fitted in a housing C of centrifugal shape provided inside casing 1. This rotor will first be supported to be rigid with the driving shaft 4.

Upstream of this rotor, toward conduit 5, there is provided a set of fixed guiding blades 8.

I provide, in the periphery of casing 1, one or several delivery diffusers, the minimum section (inlet section) of such a diffuser being visible at S on Fig. 1.

It will be readily understood that it is necessary, in order to avoid leaks through ball bearings 3, to provide, in addition to the packing joint 9 which is usually provided in such bearings, a special device capable of acting in opposition to the delivery pressure of the pump.

For this purpose and according to my invention,

I provide, on the inside of casing 1 and moving with the same rotary speed as driving shaft 4, an axially slidable element constituted, according to a first embodiment of my invention, by a disc or wheel 10 distinct from centrifugal rotor 6 and slidable thereon owing to the provision of splines 10a;

I provide a return elastic system which tends constantly to apply the outer face of wheel 10 against a fixed annular packing joint 11 carried by a wall of casing 2 located opposite said wheel;

I provide another packing joint in order to prevent leaks along the hub of wheel 10, or, to be more accurate, along splines 10a, this second packing joint being advantageously constituted by an elastic diaphragm 12 inserted between rotor 6 and wheel 10, whereby said packing diaphragm plays at the same time the part of elastic return system for said wheel 10;

I provide, on the outer face of wheel 10, a set of inclined surfaces 13 (see Figs. 1, 2 and 3), preferably located at the periphery of said wheel, the direction of these inclined surfaces 13 being such that hydrodynamic efforts are created during the rotation of the rotor which tend to push wheel 10 axially against the action of the elastic return system 12, thus causing the outer face of wheel 10 to move away from the annular packing joint 11;

At least the outer face of wheel 10 carries a plurality of centrifugal blades 14 (visible on Figs. 1, 2 and 4) constituting a kind of auxiliary pump capable of driving back the liquid which would have a tendency to infiltrate between the outer face of wheel 10 and casing 1 in the direction of the annular packing joint 11, the latter being of course nearer to the axis of the rotor than blades 14 and inclined surfaces 13.

Preferably (in order to avoid beat phenomena during the axial sliding movement of wheel 10), when wheel 10 is in contact with annular joint 11, the periphery of said wheel is as close as possible to the corresponding face of casing 1, for which purpose, advantageously, the edge of wheel 10 is curved toward bearing 2.

It is necessary, in order to enable the hydraulic machine constituted by wheel 10 to start working, to provide orifices 15 for the passage of liquid from the inner face to the outer face of said wheel 10.

It should be noted that it will be advantageous to provide casing 1, opposite the face of rotor 6 which is not fitted with blades, with a shoulder 1a which limits an auxiliary chamber D forming a housing for wheel 10, the pressure in this chamber D being substantially lower than the delivery pressure due to the fact that the liquid located between the corresponding faces of rotor 6 and shoulder 1a is driven in rotation only by friction, whereas the liquid located along the face of the rotor provided with blades is driven at a much higher speed by said blades.

This system works as follows:

At rest, elastic diaphragm 12 applies wheel 10 against annular joint 11 and there remains only a very small passage between the periphery of said wheel 10 and the corresponding wall of casing 1, fluidtightness being ensured exclusively by said annular joint 11. As soon as rotor 6 is driven by shaft 4, blades 7 produce, at the outlets of the delivery diffusers, a pressure which is partly transmitted into housing D inside which wheel 10 participates in the rotary movement of rotor 6.

When wheel 10 is driven in rotation, the liquid located between this wheel and the corresponding face of casing 1 reacts upon inclined surfaces 13 and pushes wheel 10 back against the action of elastic return system 12. The outer face of wheel 10 then ceases to be in contact with the annular packing joint 11 and I thus avoid the quick wearing of said joint which would certainly take place

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if a frictional contact were constantly maintained between fixed joint 11 and wheel 10 running at a high speed. Radial blades 14 then drive back, toward the periphery of wheel 10 and housing D, the infiltrations of liquid which would otherwise take place in the direction of annular joint 11.

As the counter-pressure created by centrifugal blades 14 and by the face of the rotor located opposite shoulder 1a varies proportionally to the pressure created by centrifugal blades 7, the effect achieved by the system will be independent of the speed of rotation of the pump and will remain satisfactory even during acceleration or slowing down periods.

I thus obtain a single stage pump which is perfectly fluidtight and therefore capable of operating at high speed so as to permit of obtaining high delivery pressures.

Furthermore, this pump is of a very simple construction and may be made mostly of pieces of a light metal machined with a relatively low precision, in view of the fact that no part of the device for preventing leaks is subjected to a frictional action once the pump has been set in rotation.

According to another feature of my invention, the blades 7 of rotor 6 (which blades may be made straight in view of the fact that the radial speed of the liquid is practically negligible as compared to its tangential speed in the vicinity of the trailing edge of the blades) are arranged in such manner that their trailing edge is thinned out, said edge being preferably limited, as shown by Fig. 6, by a flat wall 7a toward the front and by a convex wall 7b toward the rear (direction of rotation of the blades shown by arrow F).

Furthermore, I provide, in the trailing edge thus constituted, a notch e (see Figs. 5 and 6) the shape of which corresponds to that of the diffuser inlet.

In order to have the curved edge of this notch as sharp as the remainder of the trailing edge of the blade, I provide in convex wall 7b opposite notch e a recess s.

Thus I avoid pressure shocks when one of the blades passes opposite the inlet of the diffuser.

It should also be noted that the reduction of pressure resulting from the flow of a small amount of liquid between blade 7 and casing 1 may be reduced by surrounding blades 7 on their whole length by an annular casing 16, as shown by Fig. 5.

According to another feature of my invention, which relates to the position of the outlet diffusers, I provide at least two diffusers 17 which are so positioned that when the inlet section of one of them is located opposite one blade 7, the inlet section of the other diffuser is located between two blades.

Such an arrangement has been shown in Fig. 6 in the case of a rotor including three blades and in Fig. 7 in the case of a rotor including only two blades.

In both cases, it has been supposed by way of example that there are only two diffusers 17 and that, when the inlet section of one of them is located opposite one blade, the inlet section of the other is located at mid-distance between the two adjacent blades.

It should be noted that it is of interest to locate the inlet section S of every diffuser as close as possible to the part of the trailing edge of the blades, said section S being even advantageously located, when a blade passes therealong, in the notch e provided in said trailing edge (see Fig. 5).

Concerning the diffusers 17 proper, they are preferably provided with means for adjusting their minimum section S.

Such means make it possible to adjust the delivery flow rate of the pump while keeping the pressure substantially constant.

If, as it will first be supposed, diffuser 17 is of rectangular cross section, the adjusting means may be constituted, as shown by Figs. 8 to 10, by a shutter 18 pivoted about an axis 19 located in such manner that the pivoting

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movement of the shutter about said axis causes a variation of the inlet section S of the diffuser, said section being preferably fully cleared when shutter 18 is in position of rest.

When the engine driven by the pump is intended to work at constant speed (which speed must however be adjustable), it may be sufficient to provide, for controlling the shutters 18 of every diffuser, mere screws 20 advantageously connected to the shutters by links 21 swivelled at 22, said screws being protected and locked by nutlocks 23.

If the engine driven by the pump must, on the contrary, undergo variations of speed in the course of this operation, which is the case in particular of an aircraft engine, it will be advantageous to have all the shutters 18 of the respective diffusers actuated simultaneously, each for instance, as shown by Fig. 10, through a disc 24 carrying an eccentric pin engaged in a slot of shutter 18, this system then acting as a fuel distribution adjusting system, that is to say as the equivalent of a throttle pedal.

An important functional advantage inherent in pumps made as above described lies in the shape of the characteristic curve of the pump.

In Fig. 11, there are plotted in ordinates the delivery pressures and in abscissas the delivery flow rates this diagram showing in solid lines the curve of a pump made according to my invention (corresponding to a given speed of operation), whereas the characteristic curve of a conventional pump working at the same speed is shown in dotted lines.

It appears clearly that with a pump according to my invention, there is a very wide margin of adjustment of the flow rate, inside which the delivery pressure remains substantially constant, which is not the case with a conventional pump where the margin in question is restricted to the vicinity of flow rate value D_0 corresponding to the top point of the conventional characteristic curve of parabolic shape.

In what precedes, it has been supposed that the disc 10 of the packing system is distinct from the centrifugal rotor 6 of the pump.

But I may also, according to another embodiment illustrated by Fig. 12, make in a single piece the centrifugal rotor 6 and the disc. In Fig. 12, said disc is designated by reference numeral 10b.

Inclined surfaces 13 and radial blades 14 similar to those of Fig. 1 are carried by said disc 10b, which is integral with blades 7.

The liquidtight diaphragm 12 of the construction of Fig. 1 is no longer necessary. But the resilient action of this diaphragm is exerted, in the construction of Fig. 12, by a mere elastic ring 12a inserted between casing 1 and the outer race of one of the ball bearings 3 (both bearings being slidable axially along with rotor 6).

The whole of said rotor 6 and said bearing 3 is slidable axially in casing 1 in such manner that the hydrodynamic forces that are brought into play may produce, when the pump is driven, a movement of disc 10b away from the corresponding wall of casing 1. Packing ring 11b is equivalent to the packing ring 11 of Fig. 1.

Finally, Fig. 13 shows a modification of the diffusers, which are given a circular cross section. There is provided, to adjust the diffuser minimum section S, an axially movable central core 25 actuated, for instance, by means of a rack device 26.

It should be noted that the parts of the pump made as above described which are in contact with the fuel may advantageously be subjected to a surface treatment, for instance a chromizing treatment, to reinforce their resistance to corrosion.

The pump above described may be used for injection engines of low speed, or for turbine engines of a higher speed (turbine for a stationary plant or turbine for a

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vehicle), the injection of fuel corresponding in this case either to the main combustion or to after-burning.

On the other hand, a pump of this kind might be applied to the conveying of many liquids other than fuels for injection engines, for instance to convey liquid in a liquid rocket or for conveying liquid (in particular acids) in chemical industry plants.

In a general manner, while I have, in the above description, disclosed what I deem to be practical and efficient embodiments of my invention, it should be well understood that I do not wish to be limited thereto as there might be changes made in the arrangement, disposition and form of the parts without departing from the principle of the present invention as comprehended within the scope of the accompanying claims.

What I claim is:

1. A centrifugal pump which comprises, in combination, a casing having an axial intake at one end thereof and a peripheral discharge, at least substantially radial blades in said casing carried by said rotor on the side thereof turned toward said intake, whereby liquid in said casing is impelled centrifugally by said blades toward said discharge, a bearing carried by said casing in line with said rotor at the end of said casing opposed to said intake, a shaft journaled in said bearing operatively connected with said rotor for driving it, an annular packing ring carried by said casing coaxial with said shaft, a disc coaxial with said shaft slidable axially in said casing, operatively connected with said rotor for rotation together therewith, said disc being adapted to cooperate at rest with said packing ring to prevent leakage of liquid from the inside of said casing through said bearing, a part fixed in the axial direction with respect to said casing, a part fixed in the axial direction with respect to said disc, spring means interposed between said two last mentioned parts for urging said disc toward said packing ring, packing means mounted on said disc to prevent liquid from leaking along its hub portion, inclined surfaces carried by the face of said disc turned toward said bearing, the inclination of said surfaces being such as to produce, when said disc is driven in rotation, a reaction of the liquid present between said disc and said casing which urges said disc axially away from said packing ring, and centrifugal blades carried by the last mentioned face of said disc and at least as close to the shaft axis as said inclined surfaces to produce a counterpressure opposing a centripetal flow of liquid between said disc and the face of said casing which supports said annular packing ring.

2. A centrifugal pump which comprises, in combination, a casing having an axial intake at one end thereof and a peripheral discharge, a rotor in said casing, at least substantially radial blades in said casing carried by said rotor on the side thereof turned toward said intake, whereby liquid in said casing is impelled centrifugally by said blades toward said discharge, a bearing carried by said casing in line with said rotor at the end of said casing opposed to said intake, a shaft journaled in said bearing rigid with said rotor for driving it, an annular packing ring carried by said casing coaxial with said shaft, a disc coaxial with said shaft slidable axially on said rotor and operatively connected therewith for rotation together therewith, said disc being adapted to cooperate at rest with said packing ring to prevent leakage of liquid from the inside of said casing through said bearing, spring means interposed between said rotor and said disc for urging said disc toward said packing ring, packing means mounted on said disc to prevent liquid from leaking along its hub portion, inclined surfaces carried by the face of said disc turned toward said bearing, the inclination of said surfaces being such as to produce, when said disc is driven in rotation, a reaction of the liquid present between said disc and said casing which urges said disc axially away from said packing ring, and centrifugal blades carried by the last mentioned

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face of said disc and at least as close to the shaft axis as said inclined surfaces to produce a counterpressure opposing a centripetal flow of liquid between said disc and the face of said casing which supports said annular packing ring.

3. A pump according to claim 2 in which the spring means for urging said disc toward said packing ring consists of a diaphragm which also constitutes the packing means mounted on said disc to prevent liquid from leaking along its hub portion.

4. A centrifugal pump which comprises, in combination, a casing having an axial intake at one end thereof and a peripheral discharge, a rotor in said casing, at least substantially radial blades in said casing carried by said rotor on the side thereof turned toward said intake, whereby liquid in said casing is impelled centrifugally by said blades toward said discharge, a bearing carried by said casing in line with said rotor at the end of said casing opposed to said intake, a shaft journaled in said bearing operatively connected with said rotor for driving it, an annular packing ring carried by said casing coaxial with said shaft, a disc coaxial with said shaft slidable axially in said casing operatively connected with said rotor for rotation together therewith, said disc being adapted to cooperate at rest with said packing ring to prevent leakage of liquid from the inside of said casing through said bearing, a part fixed in the axial direction with respect to said casing, a part fixed in the axial direction with respect to said disc, spring means interposed between said two last mentioned parts for urging said disc toward said packing ring, packing means mounted on said disc to prevent liquid from leaking along its hub portion, inclined surfaces carried by the face of said disc turned toward said bearing in the peripheral portion of said face, the inclination of said surfaces being such as to produce, when said disc is driven in rotation, a reaction of the liquid present between said disc and said casing which urges said disc axially away from said packing ring, and centrifugal blades carried by the last mentioned face of said disc, nearer to the axis of said disc than said inclined surfaces, to produce a counterpressure opposing a centripetal flow of liquid between said disc and the face of said casing which supports said annular packing ring.

5. A centrifugal pump according to claim 4 in which the periphery of said disc is curved toward the wall of said casing which it faces, whereby the edge of said disc periphery is very close to said casing wall.

6. A pump according to claim 1 in which said disc is provided with orifices for the flow of liquid there-through.

7. A pump according to claim 2 in which the inside of said casing forms two circular chambers, to wit a main chamber containing the bladed portion of said rotor and an auxiliary chamber containing said disc, with a throttled passage between said two chambers.

8. A centrifugal pump which comprises, in combination, a casing having an axial intake at one end and a peripheral discharge, a bearing carried by said casing at the other end thereof, at least substantially in line with said intake, a shaft journaled in said bearing, an annular packing ring carried by said casing coaxial with said shaft, a disc mounted on said shaft coaxially therewith, means for connecting said disc with said shaft to cause said disc to rotate together with said shaft, said disc being slidable in said casing in the direction of the shaft axis, said disc being adapted to cooperate at rest with said packing ring to prevent leakage of liquid from the inside of said casing toward said bearing, a part fixed in the axial direction with respect to said casing, a part fixed in the axial direction with respect to said disc, spring means interposed between said two last mentioned parts for urging said disc toward said packing ring, at least substantially radial blades within the casing connected to said disc for rotation therewith, whereby liquid

in said casing is impelled centrifugally by said blades toward said discharge, said disc having inclined surfaces on the face thereof directed toward said bearing, the inclination of said surfaces being such as to produce, when said disc is driven in rotation, a reaction of the liquid present between said disc and said casing which urges said disc axially away from said packing ring, and centrifugal blades carried by the same face of said disc and at least as close to the shaft axis as said inclined surfaces to produce a counterpressure opposing a centripetal flow of liquid between said disc and the face of said casing which supports said annular packing ring.

9. A centrifugal pump which comprises, in combination, a casing having an axial intake at one end and a peripheral discharge, a bearing carried by said casing at the other end thereof, in line with said intake, a shaft journaled in said bearing, an annular packing ring carried by said casing coaxial with said shaft, a disc mounted on said shaft coaxially therewith, means for connecting said disc with said shaft to cause said disc to rotate together with said shaft, said disc being slidable in said casing in the direction of the shaft axis, said disc being adapted to cooperate at rest with said packing ring to prevent leakage of liquid from the inside of said casing through said bearing, a part fixed in the axial direction with respect to said casing, a part fixed in the axial direction with respect to said disc, spring means interposed between said two last mentioned parts for urging said disc toward said packing ring, a rotor having at least substantially radial blades thereon within the casing, said rotor being rigidly connected to said disc for rotation therewith, whereby liquid in said casing is impelled centrifugally by said blades toward said discharge, said disc having inclined surfaces on the face thereof directed toward said bearing, the inclination of said surfaces being such as to produce, when said disc is driven in rotation, a reaction of the liquid present between said disc and said casing which urges said disc axially away from said packing ring, and centrifugal blades carried by the same face of said disc and at least as close to the shaft axis as said inclined surfaces to produce a counterpressure opposing a centripetal flow of liquid between said disc and the face of said casing which supports said annular packing ring.

10. A centrifugal pump according to claim 9, in which said discharge includes at least one pump diffuser carried by said casing and extending substantially tangent to the surface described by said first mentioned blades, said blades being provided with notches of a shape adapted to accommodate the inlet of said diffuser.

11. A centrifugal pump according to claim 9, in which said discharge includes at least two delivery diffusers carried by said casing and having their inlets arranged so that when one diffuser inlet is opposite one blade

edge, the other diffuser inlet is located between two blades.

12. A centrifugal pump according to claim 9, in which said discharge includes delivery diffusers carried by said casing and extending to the inside thereof, with means for adjusting the minimum section of said diffusers.

13. A centrifugal pump which comprises, in combination, a casing having an axial intake at one end and a peripheral discharge, a part rigid with said casing forming a cylindrical housing at the other end thereof, at least substantially in line with said intake, a ball bearing mounted in said housing coaxially therewith, the outer race of said ball bearing being slidable axially in said housing, a shaft journaled in said bearing, a rotor having at least substantially radial blades thereon within the casing, said rotor being rigid with said shaft and coaxial therewith, whereby liquid in said casing is impelled centrifugally by said blades toward said discharge, an annular packing ring carried by said casing coaxial with said shaft, a disc rigid with said rotor and coaxial therewith, said disc being adapted to cooperate at rest with said packing ring to prevent leakage of liquid from the inside of said casing toward said housing, a spring washer interposed between said casing and said ball bearing outer race for urging said disc toward said packing ring, said disc having inclined surfaces on the face thereof directed toward said bearing, the inclination of said surfaces being such as to produce, when said disc is driven in rotation, a reaction of the liquid present between said disc and said casing which urges said disc axially away from said packing ring, and centrifugal blades carried by the same face of said disc and at least as close to the shaft axis as said inclined surfaces to produce a counterpressure opposing a centripetal flow of liquid between said disc and the face of said casing which supports said annular packing ring.

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