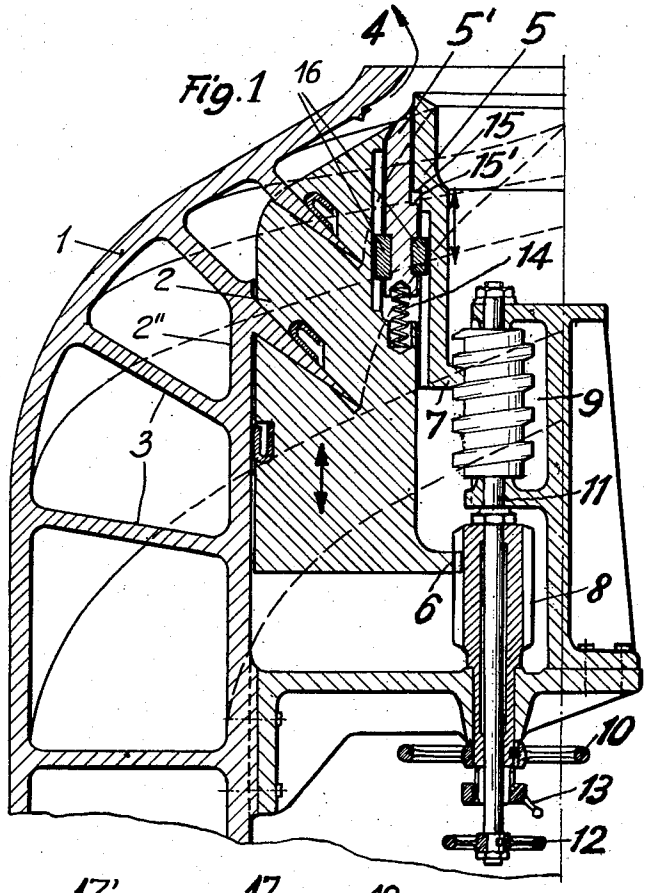
July 13, 1954 A. J. SCHNEIDER 2,683,419

GUIDING MEANS FOR LIQUIDS AND GASES

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Fig. 1



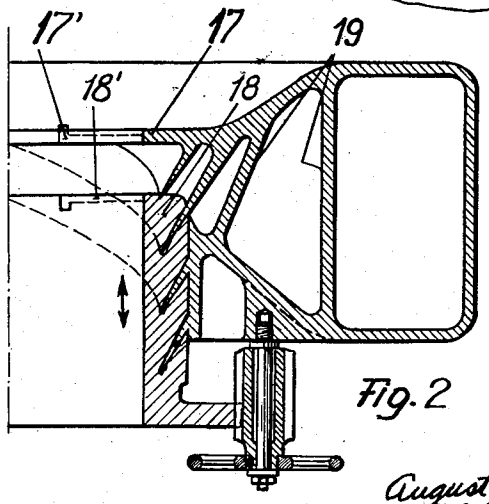


Fig. 2

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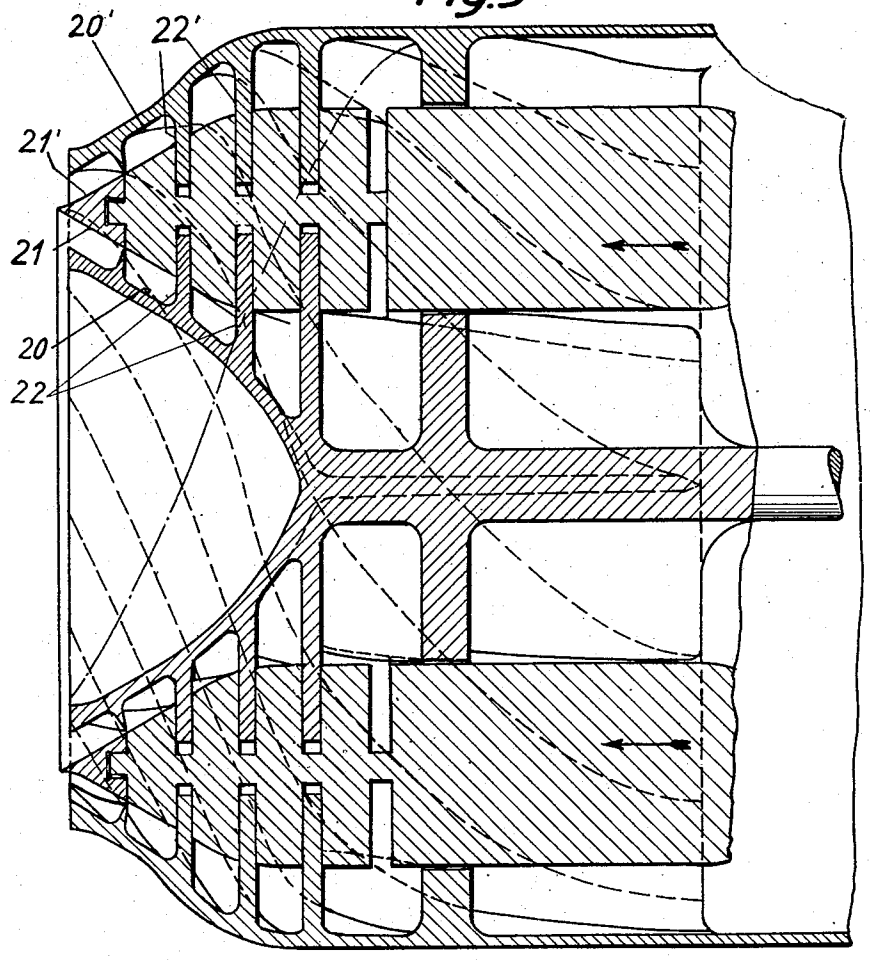
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GUIDING MEANS FOR LIQUIDS AND GASES

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Fig. 3



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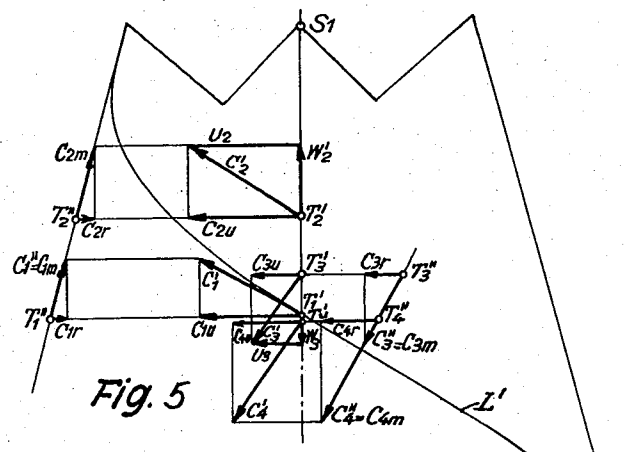


Fig. 5

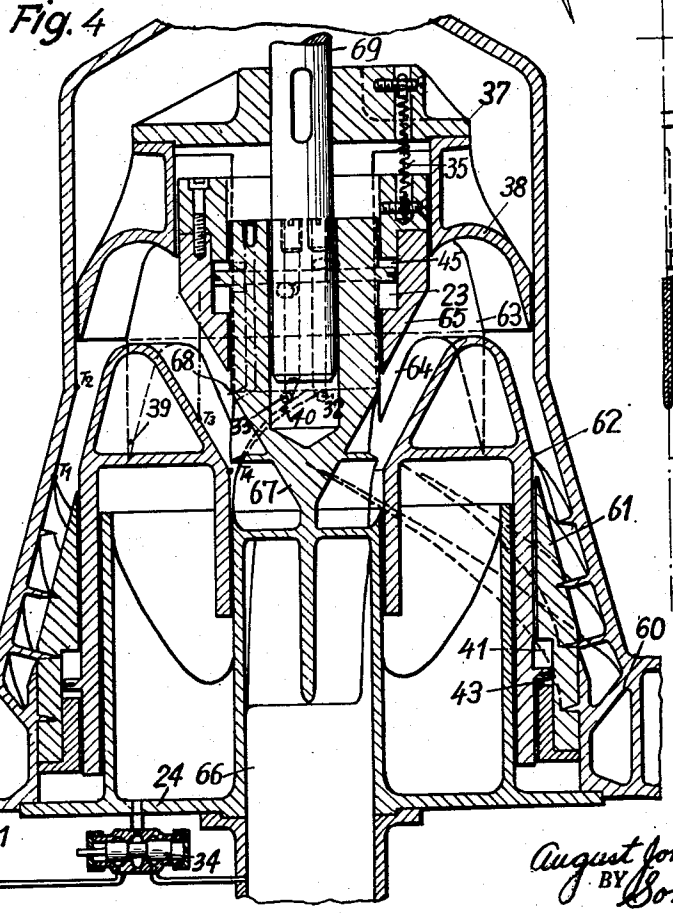


Fig. 4

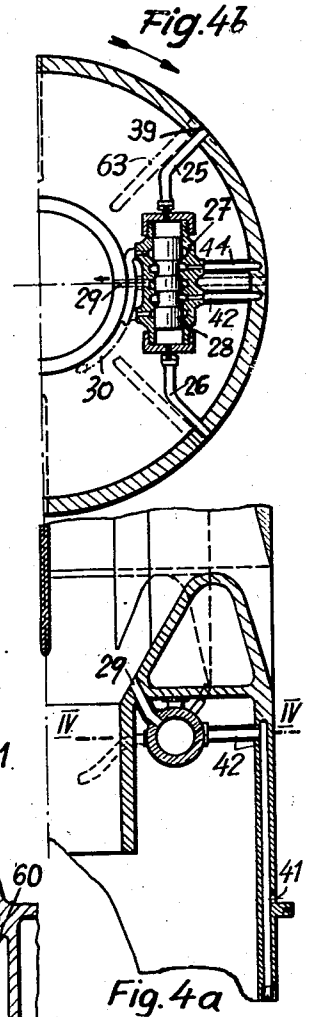


Fig. 4a

Fig. 4b

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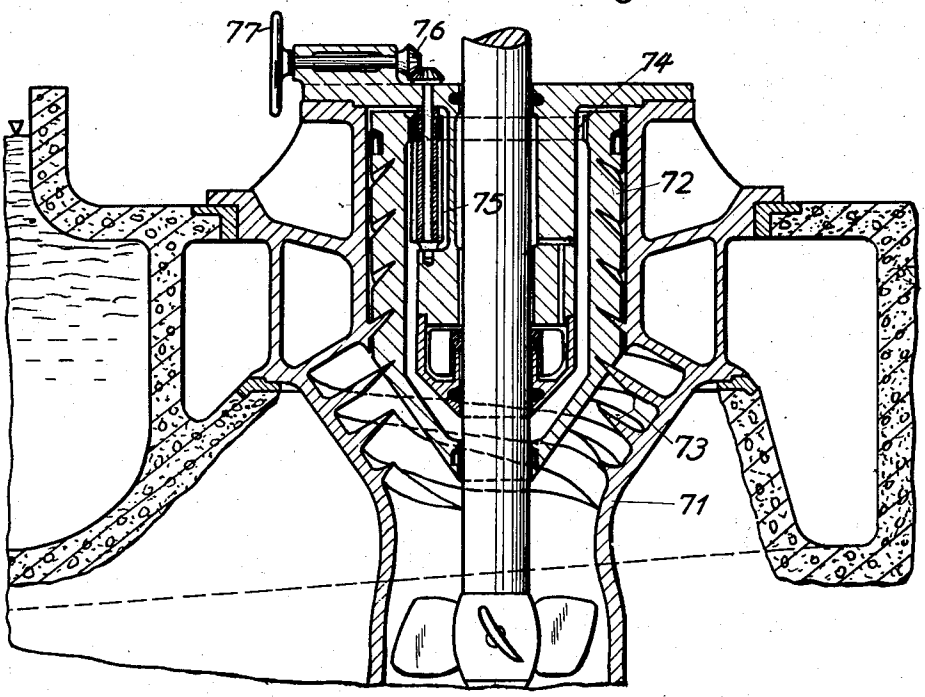
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GUIDING MEANS FOR LIQUIDS AND GASES

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Fig. 6



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2,683,419

GUIDING MEANS FOR LIQUIDS AND GASES

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Application February 26, 1948, Serial No. 11,157
In Switzerland April 16, 1946

Section 1, Public Law 690, August 8, 1946
Patent expires April 16, 1966

4 Claims. (Cl. 103—97)

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This invention relates to a novel guiding means for liquids and gases or for mixtures thereof with particles of matter carried along thereby.

The means in question serves to produce, or to guide, annular flow, in particular in centrifugal machines such as hydraulic turbines, pumps, gas turbines, fans, centrifuges, and the like.

The requirements which must be met by the guiding means employed in the construction of centrifugal machines are manifold, and they must be such as to guide a flow with a predetermined tangential component along a solid of revolution.

They must in addition form or produce a uniform flow with full admission about the entire circumference and if necessary convert potential energy into kinetic energy and vice versa. In addition, it must be possible to vary by means of regulating means the admission and the area of through-flow while maintaining the angle of flow constant, and in certain cases it must be possible to vary at will the tangential component of the flow, hereinafter referred to as the "twist," by means of further regulating means which are separately applied.

With the known guiding means, there is no satisfactory method of fulfilling these requirements simultaneously, and in addition existing constructions (for example adjustable guide vanes and the like) have still further constructional disadvantages, such as the multiplicity of the parts to be moved by regulating means, difficulty of packing guide means, which are to be actuated by regulating devices, and the clearance losses thereof, compromise by limitation of the number of blades, and the like. Owing to the aforesaid disadvantages, it has hitherto been impossible to produce an impulse turbine with full admission about the entire circumference instead of the pelton turbine with its partial admission, in spite of the fact that a further field of application was open to the impulse turbine with complete admission, by reason of its higher speeds due to the reduced size of the rotor and by reason of its compact construction for maximum unit outputs, and also by reason of its simple design with high efficiency over all ranges of operation, at varying loads and pressure drops.

By reason of this fact, various attempts have also been made to provide guide means not having the aforesaid disadvantages. In particular, annular slide valves have been proposed with which a varying area of through-flow was produced by the axial displacement of a slide valve. It was desired to produce the tangential flow by

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the spiral inflow from the spiral casing, and by means of spirally curved guide blades with parallel axes, which were disposed directly in front of the slide valves, in the path of the inflow. These proposals, however, did not produce the desired constant "twist" over the entire circumference and for all opening positions, owing to the fact that at the moment when the annular slide valve commences to open a more meridional outflow occurs, instead of the outflow with a predetermined tangential component, at all places where no spiral guide surface is situated.

Only when the annular slide valve is fully open will the tangential component also reach its complete uniform degree.

The regulatability of the area of the annular flow with full admission over its entire circumference and constancy of the desired "twist" is produced with the guide means according to the present invention by the following three elements:

(1) A material surface of revolution limiting the annular flow on one side,

(2) A second surface of revolution limiting the annular flow on the other side, and

(3) A spiral surface, with at least one thread, which guides the annular flow and which must be imagined as having been formed by the spiral movement of a line with a pitch ranging from a value equal to or greater than zero up to infinity, inclusive, at least one of the said elements, being adapted to be screwed with respect to the other with a spiral movement equal to that referred to above for the purpose of carrying out an adjusting movement. The desired variation of the area of throughflow for the purpose of varying the admission or the quantity of the fluid flowing through is preferably obtained by screwing the two flow limiting surfaces with respect to one another.

Independently thereof, a variation of the angles of flow can be achieved, as will later be described:

(*a*) By a displacement, defined in (3) with a spiral movement of the spiral flow-guiding surface with respect to the two flow-limiting surfaces, whereby it is possible to vary the mean diameter of the inlet and outlet edges of these surfaces,

(*b*) By variation of the area of through-flow between the two flow-limiting surfaces at a certain distance outside the area of the spiral flow-guiding surface.

Fig. 1 is a vertical central section of a first embodiment;

Fig. 2 is a vertical central section of a part of a second embodiment;

Fig. 3 is a vertical central section of a further embodiment;

Fig. 4 is a vertical central section of a turbine having guiding means according to the invention;

Fig. 4*a* is a section at right angles to the axial section shown in Fig. 4, and

Fig. 4*b* is a section along line IV—IV in Fig. 4*a*.

Fig. 5 shows the velocity triangles of the embodiment of Fig. 4, and

Fig. 6 is a vertical central section of a Kaplan turbine provided with guiding means according to the invention.

In Figure 1, numerals 1, 2, and 2'' respectively refer to the outer and inner flow-limiting surfaces in section, the area of through-flow varying with the variation of the position of 2 in the direction of the double arrow. In Fig. 1, 3 designates in cross section a multi-threaded spiral surface determining the direction of flow and in particular the rotational component. In place of a multi-threaded spiral surface also a single threaded spiral surface could be provided. According to requirement, it is also possible to make only the part 2 movable, while its extension 2'' may be rigidly connected to the remaining part of the guiding means. The forward edges of 2 and 2'' would then coincide at full opening. The pitch of the spiral surface and its profile need only be constant insofar as this is necessary with a view to obtaining a constant outlet angle and with a view to the screwing of part 2 with respect to part 3, while it may gradually change to infinite outside of part 2, that is to say within the range of 2''.

The flow leaving freely in the direction of the arrow 4 has the form of a hyperboloid, the generatrices of which constitute the rectilinear discharge jets. When the guiding means shown in Figure 1 is traversed in the opposite direction to the arrow 4, it acts as a diffuser with the flow directed outwardly from the central axis, that is to say for converting velocity into pressure energy.

By accordingly interchanging 1 and 2 (Figure 1) with respect to the central axis, the inwardly directed annular nozzle is converted into an outwardly directed annular nozzle, and by reversal of the direction of the arrow 4 it is converted into an inwardly directed diffuser.

While part 2 (Figure 1) determines the area of through-flow at the outlet from the space containing the flow-guiding surfaces, that is to say where the exact outlet angle, or the tangential component thereof, is still determined by the presence of the flow-guiding surfaces, the area of through-flow can be narrowed at a certain distance outside the space containing the flow-guiding surface by an additional control member.

By such a reduction in the area of through-flow, the direction of flow is deflected towards the meridian plane and consequently the tangential component, that is to say the "twist" can be reduced.

Such a control member for adjusting the tangential component in the outlet from the annular flow, is constituted by the annular slide valve 5, or 5' in Figure 1. Upon the complete withdrawal of valves 5 and 5', or upon complete freeing of the area of through-flow, the angle of out flow determined by the spiral surface is obtained, and the flow retains the maximum tangential component determined by the spiral surface.

If, on the other hand, valve 5' is first moved forward towards the flow issuing from the outlet

and the said flow is then further narrowed by means of valve 5, the filaments of the stream will be diverted in the meridional direction in the degree in which the area is reduced by valve 5.

In the extreme case, directly before the closing of the annular outlet aperture by the control valve member 5, the tangential component of the filaments will become zero and will be a meridional out flow.

The carrying out of this regulation in two stages by means of control valves 5 and 5' is not necessary, but with this method a certain impact loss when the marginal jets impinge upon valve 5 can be avoided owing to this slight rounding of the control edge of valve 5' at the point of transition into valve 5.

The regulating movements of the annular slide valves 5, 5' and 2 may, for instance, be effected in a mechanical manner as is shown in Fig. 1. To that end the annular slide 2 and the valve 5 are each provided with a rim 6 and 7. The toothed rim 6 is in mesh with a toothed wheel 8 and the rim 7 is in mesh with a screw wheel 9. Wheel 8 can be turned by means of the hand wheel 10 and screw wheel 9 by means of the hand wheel 12 and the spindle 11. If it is desired to vary the through-flow area through the nozzle the annular slide 2 may be simultaneously displaced together with the annular valves 5 and 5' by rotating the toothed wheels 8 and the screw wheel 9. Rotation of the wheels 8 and 9 by the same angular extent causes the same axial displacement of the annular slide 2 and valve 5. The toothed wheel 8 is rigidly connected with the spindle 11 and thereby with the screw wheel 9 by means of the clamping device 13. The annular slide 2 is prevented against turning relative to slide valve 5' and the latter relative to slide 5 by the splines 16, which, however, permit axial displacements of said slides. If the tangential component has to be altered, the slide 2 has to be displaced relatively to slides 5 and 5' respectively, to which end the clamping device 13 is loosened and the screw wheel 8 only is turned by the hand wheel 10, the hand wheel 12 being kept stationary. The above described dependency between the movements of slide 5' and slide 5 is automatically obtained by a pressure spring 14 and the two abutments 15 and 15' provided in the slides 5 and 5' respectively. As long as the slide 5 is positioned against the liquid stream a clearance is present between the abutments 15 and 15' and the spring 14 will maintain the slide 5' in its foremost position. Only when the slide 5 is completely withdrawn from the liquid stream the abutment 15' and the slide 5' is also withdrawn from the liquid stream thereby overcoming the force of the spring 14.

Figure 2 shows, by way of example, an arrangement of such an annular nozzle having an inwardly directed flow without any substantial axial component at the outlet. The principle of the arrangement is the same as in Fig. 1 Numeral 17 designates the first surface of revolution, and numeral 18 the second surface of revolution having helical slots, and being adjustable with a hand wheel by screwing it on the helical surfaces 19. The variation of the throughflow is achieved by the variation of the outlet area caused by the rotation of the flow limiting surface 18 (which has the shape of a screw) on the helical surface 19.

The radial extensions 17' and 18', shown in chain lines, of the guide surfaces 17 and 18 limiting the flow render possible by means not shown a small scale-reduction of the outlet area outside the range of the flow-guiding surfaces.

These radial extensions may be made of elastic material and can consequently have, within certain limits, a similar function to the control members 5, 5' of Figure 1.

A combination of inward and outward flow with respect to the central axis is shown in Figure 3, in which 20 and 20' are fixed flow limiting surfaces, while the surfaces 21 and 21' to be adjusted are assembled in a wedgeshaped annular body with spiral slots for the passage of the helical surfaces 22 and 22', which are assembled on the fixed flow limiting surfaces 20 and 20'. The regulation of the through-flow is achieved by a screwing displacement of the body 21—21'.

This construction renders unnecessary any packing between the flow limiting surfaces 21 and the spiral surface 22, and also between the parts 21 and 21' of Figure 3, even at high pressures. A disadvantage of this construction, on the other hand, is the higher outlet loss and the somewhat greater danger of obstruction, owing to the divided through-flow aperture.

The angles of the two guide surfaces 20 and 21 must so correspond to those of surfaces 20' and 21' that the confluence of the two annular streams takes place at equal angles that is to say without losses.

Figure 4 shows an embodiment of the combined application of the above described annular flow guide means. It shows, by way of example, a turbine which is theoretically adjustable without losses for any admission from zero to maximum, and for any variations in pressure drop, suitably modified, the design is also applicable to a pump. In this figure, 31 is the inlet distributor of the turbine of a similar design to the annular nozzle, Figure 1.

In contrast to Figure 1, the control edge 62, which is already associated with the rotating rotor, here has the same function as the control member 5 in Figure 1. The opening which is freed both by the control edge 62 and by the control member 61, determines the area of through-flow and consequently the admission to the rotor and to the turbine. The rotating rotor consists of the shaft 69, the hub 37, the actual rotor 38 and the control member 65. The rotor comprises at 63 an annular diffuser and at 64 an annular nozzle the opening of which is regulated by the control member 65, as also by the control edge 68, from the non-rotating suction pipe inlet. The spiral surfaces 63 of the annular diffuser and 64 of the annular nozzle of the runner wheel are here illustrated for the sake of simplicity with an infinite pitch, as simple radial surfaces. The relative velocity at the inlet into the runner wheel, as also the relative outlet velocity from the runner wheel will accordingly be purely meridional. By the geometrical addition of the meridional directed relative outlet velocity from the runner wheel with its circumferential component, there is set up in this case a certain "twist" at the inlet into the suction pipe. This "twist" flow will theoretically be converted without losses into an axial flow in the manner of an annular diffuser by a slender spiral surface in the suction pipe which gradually merges into an infinite spiral pitch.

If it is now desired to adjust the opening of the turbine, the entire rotor is to be displaced in the axial direction. Thereby the area of through flow of the distributor and also the area of through flow of the runner wheel will simultaneously be adjusted with strict geometrical

accuracy without altering any of the angles of flow, that is to say without thereby having to allow for any impact losses at the inlet into the runner wheel and in the suction pipe of the turbine. The axial displacement of the rotor may be effected hydraulically for example as shown in Fig. 4 by regulating the static pressure present in the space above the cover 24 and below the runner, respectively, by a regulating movement of the valve piston 34 in accordance with the desired admission of the turbine or by means of impulse blades operated by the annular flow itself. Furthermore the impulse for moving the valve piston may be derived from a speed governor or from a float.

The aforementioned displacement of the annular slide 61 relative to the control edge 62 may be automatically effected by hydraulic means as is shown in Figs. 4*a* and 4*b*. Fig. 4*a* is a section at right angles to the axial section shown in Fig. 4 and Fig. 4*b* is a section along line IV—IV in Fig. 4*a*. If, as mentioned above, an impact loss occurs in front or the forward side of the blades 63, the pressure immediately in front of a blade is higher than that at the rear of a blade. This pressure difference is used as an impulse for the hydraulic regulation. The pipe 25 (Fig. 4*b*) derives the pressure from in front of a blade at 39 whereas the pipe 26 derives the pressure immediately at the rear of a blade. The surplus pressure in front of the blades is conducted into one end of the cylinder 27 having a valve piston 28, whereas the lower pressure at the rear of the respective blade is conducted to the other end of the cylinder 27. The piston 28 will therefore move in the downward direction looking at Fig. 4*b*; the pipe 44 is connected by way of the pipe 29 with the suction pipe and the pipe 42 is connected by way of the pipe 30 with the pressure chamber above the runner. The high-pressure in pipe 42 is conducted, as is shown in Fig. 4*a* into the annular chamber 41 (Fig. 4), while the suction pipe pressure in the pipe 44 gets in a similar manner into the annular chamber 43 (Fig. 4). The surplus excessive pressure in the chamber 41 over that in chamber 43 causes a displacement of the annular body 61 in the upward direction towards the control edge 62 until after the pressure difference in front and at the rear of the entrance of the runner blade is compensated.

The automatic displacement of the annular slide 65 (Fig. 4) may, for instance be effected by the influence of the pressure difference immediately in front and at the rear of the spiral surfaces 40. By a two-fold system of bores on the body 67 the upper annular chamber 45 is directly connected with the point 32 immediately in front of the spiral surface for obtaining an impulse and the lower annular chamber 23 is connected with the point 33 immediately behind the spiral surface. As this system of bores could only be shown in dotted lines it has also been turned into the plane of section and shown in chain-dotted lines in the left half of Fig. 4. In order to obtain a correct regulation with small differences in pressure as impulses the weight of the annular slide 65 must be balanced by springs 35.

Should the pressure conditions alter in front of the turbine, the turbine must automatically vary the position of 61 with respect to 62, and also of 65 with respect to 68. If, for example, the pressure in front of the distributor were reduced, an impact loss on the forward side of the inlet edges of the blades of the runner would occur,

while the speed of rotation of the rotor would remain constant. These impact losses, however, can be avoided owing to the fact that the tangential component at the outlet from the distributor is increased if 61 is moved towards the control edge 62. This can be explained by the fact that the velocity and consequently also the circumferential component c_u is increased by reduction of the area of through-flow between the spiral surfaces and that owing to the fact that $c_u.r=k$, this increase is maintained during the passage past the control edge 62 in spite of the fact that the total velocity is not at the same time increased.

At the same time, the relative velocity of flow from the runner wheel into the suction pipe will be reduced owing to the reduction of the pressure. In order nevertheless to avoid impact losses at the inlet into the spiral surfaces of the suction pipe, the tangential component in the runner wheel outlet must be increased, that is to say, the control member 65 is here also moved nearer to the control edge 68 automatically by the turbine and the desired freedom from impact losses in the suction pipe is again established for the new pressure drop. Consequently, with this type of turbine both an alteration in the degree of admission without impact losses and also theoretically loss-free allowance for fluctuation in pressure drop are for the first time rendered possible by a completely satisfactory guiding of water from the strictly geometrically and hydraulic points of view.

Figure 5 shows the velocity triangles associated with Figure 4. This figure may be considered as a covering sheet to Figure 4. It will be assumed that c_1 (or c_1' in this projection) is the outlet velocity for the point T_1 or T_1' (Figure 4 and Figure 5) at the outlet from the range of the spiral surfaces of the distributor. It coincides in direction with the tangent to the filament passing through T_1. This filament is identical to the line of intersection of the conical flow-limiting surface with the spiral flow-guiding surface. Thus, c_1' in Figure 5 represents the elevational projection of the outlet velocity as a tangent to this line of intersection L'. (All references provided with a dash represent elevation projection, while all velocity vector references having a dash refer to the fact that they are shown in their true value in this projection.) If now the point T_1' is rotated through 90 about the axis of the cone with the apex S_1, the point T_1'' is obtained with the corresponding velocity vectors c_1'' and c_{1r} constituting the radial component and c_1'' the meridional component c_{1m} in its true value.

The velocity diagram for the point T_2 can simply be calculated from these values:

Since the same quantity of water can flow through all the annular areas, the radial component for the point T_2 (Figure 4) is calculated from that of the point T_1 by the equation:

$$r_1.c_{1r}=r_2.c_{2r}.\frac{h_2}{h_1}$$

$$\frac{h_2}{h_1}$$

representing the contraction factor due to the control edge 8.

A further equation is given by the following statement regarding eddy flows:

$$c_u.r=k$$

so that

$$c_{2u}=\frac{C_{1u}.r_1}{r_2}$$

Where

h_1 is the axial distance between T_1 and control member 61.

h_2 is the axial distance between T_2 and control member 62.

$\frac{h_2}{h_1}$ is the contraction of the trough-flow area from T_1 to T_2

r_1 and r_2 are the radii at the points T_1 and T_2

c_u is the circumferential component of the absolute velocity c;

k is a constant

u_2, u_3 are circumferential speeds at the points T_2 and T_3.

The velocity vectors for point T_2 are obtained therefrom in the drawing.

Again the velocity factors for the point T_3 (Figure 4) are shown by the condition that the radial components are inversely proportional to the throughflow areas, that is to say,

$$c_{1r}.r_1=c_{3r}.r_3.\text{contraction factor}\ \frac{h_3}{h_1}$$

(The contraction factor, given by the position of 61 with respect to 65 in Figure 4, is shown as equal to one in the drawing.)

Further, the direction of the filaments of the stream, or the direction of the velocity vector w_3, is given so that the velocity triangle for the point T_3 in Figure 4 could be drawn. The vectors for the point T_4 were drawn from T_3 (Figure 4) in exactly the same way as for the determination of the vectors for the point T_2 from T_1.

Figure 6 shows the application of the principle of the invention to the guide wheel of a Kaplan turbine. This affords the advantage of simpler design as compared with the use of adjustable guide vanes, and a very good steady delivery to the Kaplan propeller. As in the above described figures, the flow limiting surfaces 71, 72 and the flow guiding surface 73, represent again the main parts of an annular flow nozzle. The regulation of the admission is again effected by the one flow limiting surface 72 relatively to the flow guiding surface 73. This screwing may be obtained by toothed rim 74, toothed wheel 75, bevel drive 76 and hand wheel 77 as shown.

By the use of this guiding means the constancy of the "twist" with different degrees of admission is, however, lost for geometrical reasons, but it can be compensated for by the adjustability of the Kaplan blades. It is known that by this adjustability of the Kaplan blades a compromise is obtained between avoiding as much as possible impact losses at the entrance side of the runner blades and "twist" losses in the suction pipe.

By the possibility of converting the kinetic energy of the "twist" in the suction pipe, the Kaplan runner can be set to be entirely free of losses at the entrance side and the "twist" remaining at varying admission and head can be converted free of losses.

I claim:

1. Guiding means for annular flow in rotary machines, comprising, in combination nested bodies providing a pair of coaxial surfaces of revolution for limiting said annular flow, means providing a helical surface having at least one thread disposed between said surfaces of revolution in helically adjustable engagement with one of said bodies and secured to the other of said bodies and adapted to guide the annular flow, said limiting surfaces being provided with portions extending parallel to each other and approximately over the distance between two adjacent helical surfaces, said helical adjustment

comprising helical slots on one of said flow limiting surfaces engagingly cooperating with said helical surface, means for axially displacing said one flow limiting surface by screwing it relatively to said helical surface for effecting a controlling action to regulate the quantity of the through flow, and packing cups provided adjacent to said helical slots.

2. Guiding means for annular flow in rotary machines comprising in combination nested bodies providing a pair of coaxial surfaces of revolution for limiting said annular flow, means providing a helical surface having at least one thread disposed between said surfaces of revolution in helically adjustable engagement with one of said bodies and secured to the other of said bodies and adapted to guide the annular flow, said helical surface being arranged in a zone of a relatively large diameter in which the guided flow has low velocities, to which zone a further zone of guided flow at high velocities joins which is free of helical surfaces, and means for axially adjusting one of said flow limiting surfaces relatively to the other by screwing it on said helical surface to regulate the quantity of the through flow.

3. A turbine having a runner, a guide apparatus, annular flow guiding means for each said guide apparatus and said runner, said means in each instance comprising a nested pair of surfaces of revolution for limiting said annular flow and helical flow guiding surfaces having at least one thread arranged between said pair of said surfaces of revolution, means for causing an axial relative displacement between said guide apparatus and said runner and causing thereby a regulation of the proportion of the discharge sections between said runner flow guiding surfaces and thereby determining the entrance angle of flow into the runner, and an additional control device provided in said guide apparatus and having a control face situated within the flow-guiding surfaces thereof and adapted to aviod impact losses at the entrance of the runner.

4. A rotary pump having a runner, a discharge guide-apparatus annular flow guiding means for each of said runner and said guide apparatus, said means in each instance comprising a nested pair of surfaces of revolution for limiting said annular flow, and helical surfaces having at least one thread arranged between said pair of said surfaces of revolution, means for causing a relative axial displacement between said runner and said discharge guide apparatus, a control edge provided on one of said surfaces of revolution of the discharge-guide apparatus and causing a regulation of the discharge cross-section from said runner upon said axial displacement, a further control edge provided on one of said surfaces of revolution of the runner and causing a regulation of the cross-section of the zone of the discharge guide apparatus which is free of helical guide surfaces, and a further device for controlling the cross-section of the through-flow within the guide-apparatus provided with the helical surfaces, said control causing the avoidance of impact losses on the entrance of the discharge guide apparatus by a readjustment of the angle of flow.

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