Sept. 4, 1923. 1,467,168

V. KAPLAN

DRAFT TUBE

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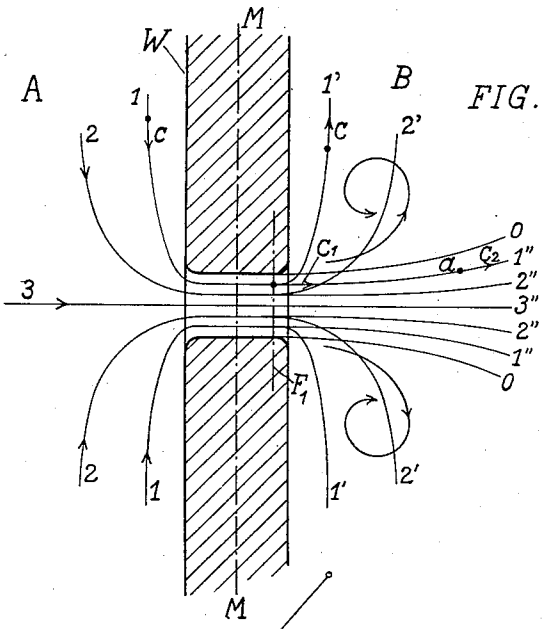


FIG. 1.

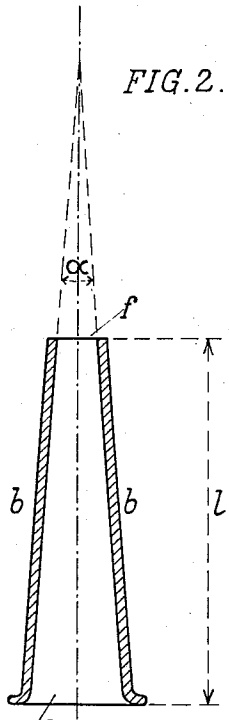


FIG. 2.

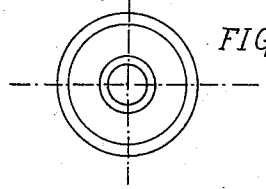


FIG. 3.

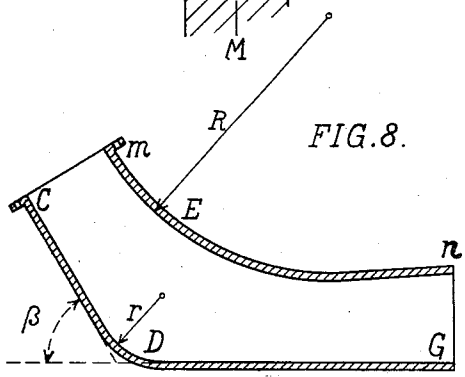


FIG. 8.

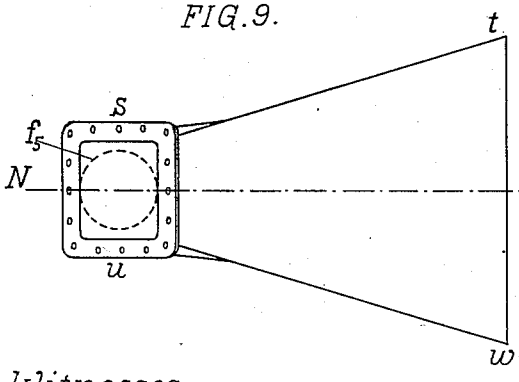


FIG. 9.

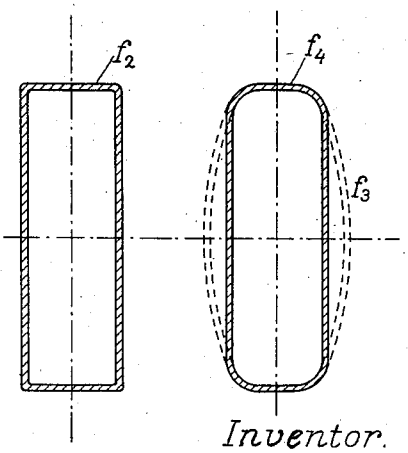


FIG. 10. FIG. 11.

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FIG. 4.

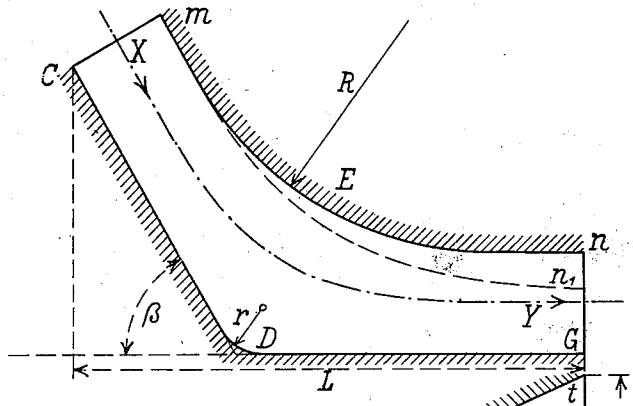


FIG. 5.

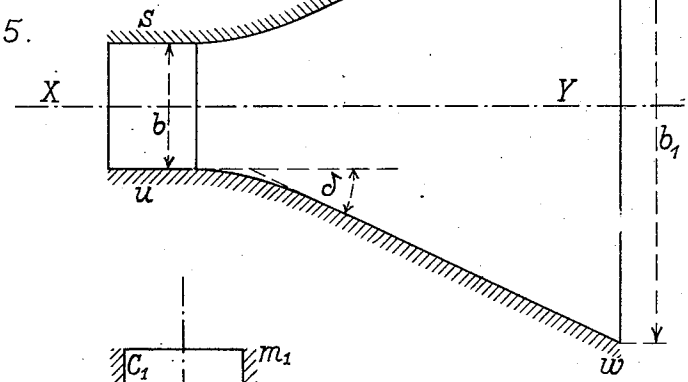


FIG. 6.

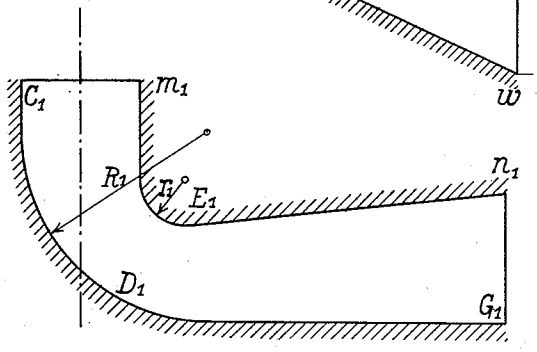
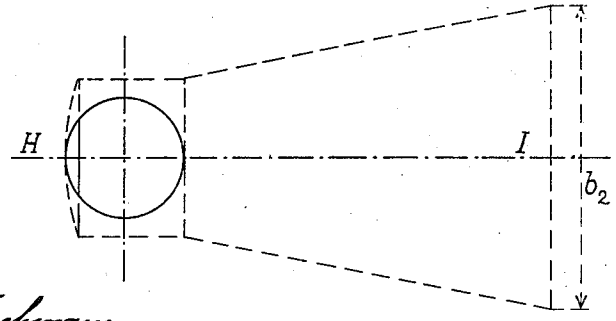


FIG. 7.



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FIG. 12.

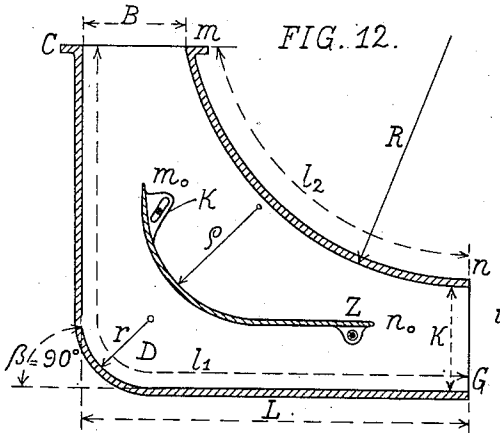


FIG. 14.

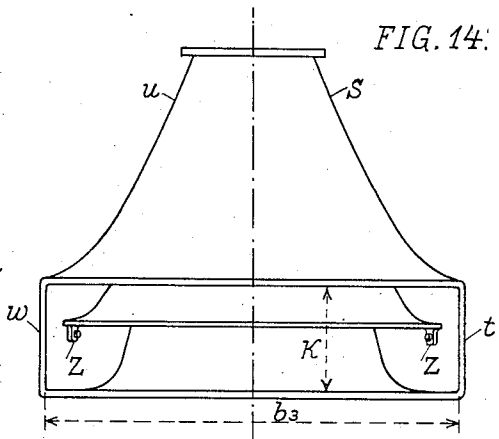


FIG. 13.

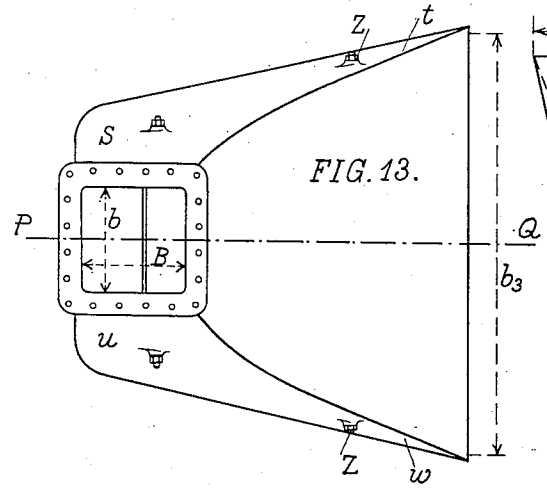


FIG. 15.

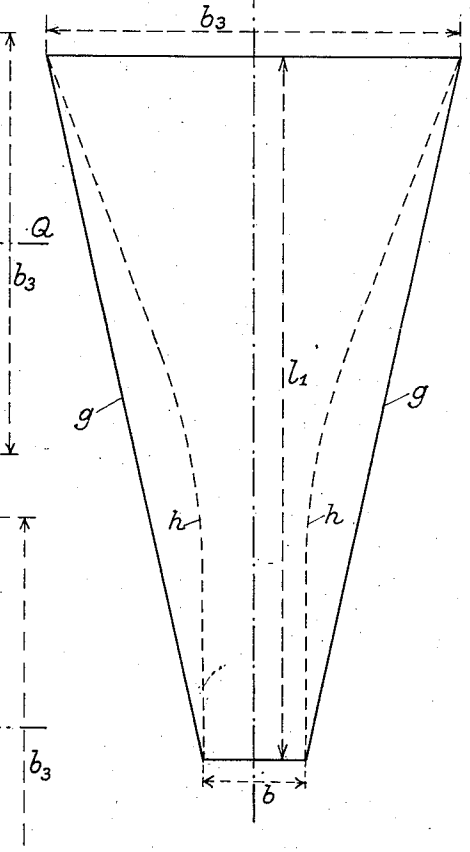
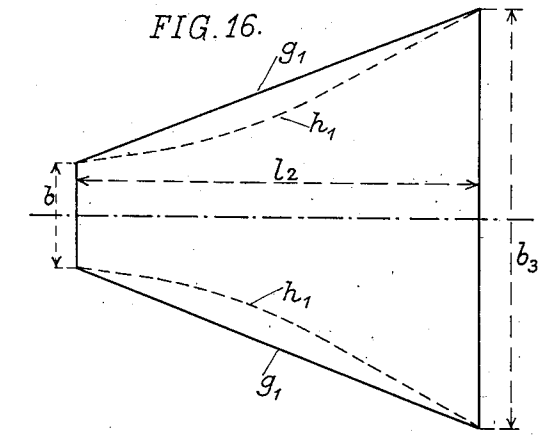


FIG. 16.



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UNITED STATES PATENT OFFICE.

VICTOR KAPLAN, OF BRUNN, AUSTRIA.

DRAFT TUBE.

Application filed September 1, 1921. Serial No. 497,681½.

To all whom it may concern:

Be it known that I, VICTOR KAPLAN, a subject to the Emperor of Austria, residing at the K. K. Deutsche techn. Hochschule at Brunn, Mahren, Austria, have invented certain new and useful Improvements in Draft Tubes (for which I have filed applications in Austria, filed Aug. 10, 1914; Germany, filed Apr. 8, 1915; Switzerland, filed Apr. 8, 1915; Sweden, filed July 31, 1915; Norway, filed Aug. 9, 1915; Czechoslovakia, filed Dec. 27, 1919; England, filed Jan. 10, 1921; and Brasilia, filed 1920), of which the following is a specification.

My invention refers to improvements in draft tubes of the kind generally employed as suction and as pressure tubes in water-turbines, centrifugal pumps, in water- and steam-jets and other machines of the kind.

Draft tubes hitherto employed in such machinery used to consist of conical tubes widening slowly in the direction of the flow. The central line of the jet of the draft tube is a straight line in all contrivances of the class and, accordingly, the jet of fluid issuing from a draft tube must not be materially deflected from its original direction. Experiments have shown, that the angle of deflection of a conical draft tube must not exceed certain limits, otherwise the fluid will lose its contact with the walls of the tube, which would be equal to a loss of energy. If, therefore, a considerable amount of energy is to be transformed, the draft tube, according to the well known construction, must be of considerable length. The great length of the draft tube however, causes also considerable loss by friction of the fluid against the walls of the tube, and this is the reason, why, with the present draft tubes in use, great losses of energy are constantly experienced. The considerable length of the draft tube, besides, causes an increased cost of the building and frequently prevents the erection of the latter, as will be more fully described hereinafter. The object of my invention is to avoid the drawbacks above referred to, and thus to considerably reduce the losses of energy therefrom resulting. This object is obtained by arranging within the draft tube a deflecting wall, which wall simultaneously constitutes part of the wall of the draft tube proper. By means of said deflector, as I will term the said wall hereinafter, the jet of fluid will be forced to change its direction of entrance into the draft tube and it will equally be forced to extend in width, parallel to the said deflector. Owing to this circumstance, I am able to widen the discharge end of the draft tube considerably beyond the extent hitherto thought possible without the risk of losing the contact between the jet and the walls of the draft tube. The considerable enlargement of the discharge end, when compared to the entrance end of the draft tube will reduce the discharge velocity as compared to the entrance velocity to a great extent, and, thereby, a great amount of energy is saved, as will be explained hereinafter more particularly with reference to the accompanying drawings.

In the said drawings,

Fig. 1 shows a section through a vertical wall which serves to separate the two rooms A and B, both of which are supposed to be filled with water; the gap in said wall, through which the section is drawn, has rounded ends to facilitate certain incidences of the passage of the fluid, as hereinafter more fully described.

Fig. 2 is a vertical section of a draft tube of the usual kind, as employed, for instance, to constitute suction pipes for water-turbines.

Fig. 3 is a plan-view of Fig. 2.

Figs. 4 and 5 serve to show, diagrammatically, respectively, in vertical and horizontal sections, how a jet of water will be made to spread from its original breadth b to its desired breadth b_1 by means of a deflector D, G, forcing said jet to change its original direction X and to follow the line Y.

Figs. 6 and 7, represent, respectively, a vertical and a horizontal section of a curved tube, as employed hitherto in water-turbines made of concrete;

Figs. 8 and 9 show, respectively, a draft tube constructed according to the present invention, Fig. 8 being a section along line N—O of Fig. 9, and Fig. 9 a plan of Fig. 8.

Figs. 10 and 11 show examples of discharge-ends of such draft tubes.

Fig. 12 is a vertical section through a draft tube according to my invention, along line P—Q of Fig. 13;

Fig. 13 is a top-view of Fig. 12, and

Fig. 14 a front view;

Fig. 15 shows the wall deflection, spread out, and

Fig. 16 shows the wall opposite the deflector-wall also spread out.

In describing in detail my invention, I wish it to be understood, that, in general, I consider any driving fluid, whether in a liquid, a gaseous, or a vapor state, the same, as also mixtures of various fluids which might be employed.

By Fig. 1, I wish to explain the reason of an unfavorable result in transforming energy hitherto obtained by the use of a draft tube of but small length. I have supposed A and B to be two compartments separated by a wall having a gap F and being both filled with a fluid. As long as a greater pressure exists in A, the liquid will flow into B, the energy of pressure in A being converted into energy of velocity up to the line F_1 within the partition wall. This change of energy will proceed without any noticeable loss, as may be observed by mixing any foreign matter into the fluid, which will be seen in the lines 1, 2 and 3. It might be supposed, that in B the opposite would happen, i. e., that the velocity existing at F_1 would be re-changed into energy of pressure, or cause a symmetrical formation of the lines of current up to the medial line M of the wall. A practical trial, however will prove that a supposition of this kind is false. The section of the current will but very slightly increase, about as indicated by lines 0, 1'', 2'', 3'', and for this reason the velocity of the jet will be correspondingly small. On the contrary, Fig. 1 shows, that at sides of the line F_1, eddies will be formed lateral to the conical main current, the said eddies producing the losses objected to. For this reason the velocity c_2 existing at point a, is approximately as great as the velocity c_1 at F_1; if no such eddies occurred, the velocity at F_1 would be already greatly reduced (see c) at the point 1'.

The small increase of breadth of the jet issuing from the point F_1 shows, that, with a draft tube of the construction hitherto employed increasing in breadth towards the outlet, the side walls, or generatrices, b must only have a small deviation, shown by the angle α as in Fig. 2. Through practical trials it has been found, that the said angle α should not be greater than 10 degrees. In enlarging said angle, eddies will be formed, as shown in Fig. 1. Therefore a fixed area of entrance f, and a fixed length l, of the draft tube, the breadth F_1 of the area of discharge can be calculated. A further increase of the area of discharge, exceeding the maximum amount f_1, would cause the formation of eddies, accompanied by losses.

In the improved draft tube according to my present invention, I have avoided the losses thus caused by a considerable enlargement of the area of discharge and a reduced length of the tube and by forcing the jet entering the tube to spread by means of a deflecting wall, and parallel to said deflecting wall, as will be seen from Figs. 4 and 5. In Fig. 4, two walls C—D, and D—G, are shown, the said walls being inclined towards each other by an angle β. To avoid the angle, it has been rounded off by an elbow r. Now, if a jet of fluid of the breadth b Fig. 5 enters the tube and flows down along the wall C—D, in the direction of the line X, it will be deflected by the wall D—G and forced to follow its way in the direction Y. Any movement of a fluid in a curvilinear race will call forth centrifugal forces, which, being centrally directed against the curvature, will engender a great increase of pressure within the said fluid, and the said increase of pressure will cause an essential enlargement of the jet in the direction of the breadth of the deflecting wall D—G, thereby causing the jet b, which has entered of a small breadth b, to leave the said wall of a large breadth b_1, as clearly shown in the plan view of Fig. 5. By experiments I have found, that the angle δ (Fig. 5), by which the enlargement may be measured, will be the greater, the smaller I make the radius of the arc at D and the more the angle β (Fig. 4) approaches a right angle. It will further be shown by experiments, that the surface m, n_1, (Fig. 4) of a jet of fluid deflected by such a wall D—G, will form a gentle curvature, the radius of which will be less than that of the rounding off at D. Therefrom it will be evident that also the walls of a tube so curved should be well applied to such a passing current, a fact which is lacking however with reference to the usual suction tubes of turbines as will be more precisely pointed out. In case of the jet being enclosed by the wall D—G from one side, by the opposite wall m, n (Fig. 4) and by the two side-walls s, s, and w, w (Fig. 5), in such a manner, that the increase in breadth of the jet is principally obtained parallel to the surface of the deflector C D G, and not, or not essentially, parallel to the said two side-walls, the current of the fluid will form a free surface, if the length L of the draft tube be small and if the discharge from the draft tube is made into the free air, as shown by m, n_1, in Fig. 4. But when the tube terminates under water, the fluid will also fill up the space indicated by n, m, n_1, the free air filling said space being displaced by the fluid. A new state of the current is thereby formed within the tube, characterized by an entire

filling of all sectional areas of the tube with fluid. The fluid contained within the space n, m, n_1, will be carried along by the fluid flowing in close proximity to the deflector wall, owing to the tangential forces (viscosity) of the same. Yet, according to the increase of the contact surface (m, n_1) between the two parts mentioned of the fluid, such an exchange of velocity, relative to the deflector wall, will be reached, there will result a constant velocity of the fluid within the discharge. The line X Y (Fig. 4) then, will approximately indicate the average line of the flow through the draft tube.

I have stated above, that, in the usual forms of draft tubes hitherto employed, only an increase of 10 degrees had been deemed admissible. According to my present invention the said angle of increasing the breadth of the flow may be multiplied without the risk of losing the contact between the current of fluid and the enclosing walls of the draft tube. Such loss of contact cannot occur in a tube according to my present invention, for the reason, that the desired increase of breadth of the flow will be brought about only by the arrangement of the deflector wall and without the use of side-walls, while, with the use of draft tubes of the usual kind (Figs. 2 and 3), an increase of the cross-section of the flow could not be obtained at all, without the use of lateral walls for enclosing the flow.

The method of increasing the breadth of the fluid discharged with relation to the fluid supplied by means of the deflector, on the other hand, causes a material reduction of the velocity of discharge from the draft tube and, accordingly, is an effective means for converting velocity into pressure.

The increase of the breadth of the flow being obtained by centrifugal forces, according to my invention, it follows, that the change of direction given to the fluid which passes along said deflector wall, must be the more sudden, the larger the said angle of deflection (δ Fig. 5) is made. It will be expedient, therefore, to select a small radius r for the elbow in Fig. 4, if a considerable angle of deflection is desired, to obtain an increased pressure through the centrifugal forces about the point D, Fig. 4. The rounded off angle, therefore, may be omitted or replaced by an ordinary angle. While, in many cases, the opinion has been maintained, that corners of this kind would cause losses by occasioning shocks, yet, such opinion cannot be asserted to be true. It has been found, that in the neighbourhood of such corners exist the smallest velocities and the largest amounts of pressure. From such quite insignificant velocities, which can happen to be negligible there cannot arise any serious resistance. A gentle curvature of the opposite wall m, n, Fig. 4, however can be of the utmost value for the reduction of resistances to the flow. As has been stated before, the minimum amount of velocity and the maximum amount of pressure are to be found adjacent the point D, and it follows, that the minimum pressure and the maximum velocity must be encountered at E. The said point E, accordingly, offers the greatest danger for a separation of air, a formation of steam and a loosening of the flow from the wall. Such objectionable disturbances, indeed, frequently occur within ordinary draft tubes, but they may be counteracted, by my invention, or at least be considerably reduced, by forming the curvature of said wall m, n, with under no circumstances a sharper bending, than the deflector-wall, thereby producing a shape, which perfectly corresponds to the natural flow. A measure of that kind will reduce the velocity of that part of the flow in the neighbourhood of the point E, and will increase the desired pressure around that point. On the other hand, the extension of these parts of the flow may be obtained before the curvature of the path is reached, that is the point E, whereby a further decrease of velocity is obtained. This leads to the further condition, that the smallest radius of r (Fig. 4) be made equal, or not larger than the smallest radius of R, opposite the deflector-wall. This supposes the radius to be measured in a plane placed substantially perpendicular to the deflector wall, the said plane passing through the line X—Y, Fig. 4.

Besides the usual draft tubes having a straight centre line, as shown in Figs. 2 and 3, vertical water-turbines of small height are also employed which have a curved centre line, as represented in Figs. 6 and 7. Such draft tubes used to be made of concrete and the passage from their circular entrance-area changes gradually into the rectangular discharge-area, as shown in Fig. 7. The well known shape of the draft tubes of this kind, however, does not fulfil the purpose of my said invention, because the effective increase of breadth of the flow of water on the surface C_1, D_1, G_1, Fig. 6, will not be possible for the reason, that, owing to the slight curvature intentionally given to the wall of the pipe having the radius R_1, it will be impossible to obtain the same. For this reason a considerable increase of breadth (b_2, Fig. 7) would not only be useless, but perhaps objectionable, as, thereby, the formation of eddies could easily be produced within the widened portion of the draft tube. On the other hand, and contrary to my invention, the radius r_1, (Fig. 6) of the wall m_1, E_1, n_1, in all usual draft tubes is essentially smaller than the radius R_1 of the wall C_1, D_1, G_1, a circumstance, which, even with slow velocities,

will lead to separations of air, to the formation of vapours and to the separation of the flow near the sharp curvature E_1 (Fig. 6). In my invention I have purposely avoided the slight deflection from the vertical direction into the bottom of the channel, by which the alleged losses are thought to be caused. According to the prevailing opinion hitherto great losses are thought to be produced by a sharp curvature already described with reference to E_1.

Concerning the shape of the deflector C, D, G, Fig. 4, the piece D, G, may, in some cases of greater simplicity, be shaped as a plane, which, in case there exists a rounded off portion at D, may pass over into a cylindrical surface, the generatrices of which are placed perpendicular to the corresponding medium line of flow. The surface C, D, independently of the entrance area of the ejector, may equally pass over into a plane or into a cylindrical surface, in the direction of the deflecting wall. The increase in breath towards the deflector wall may begin in said surface. The same may be said concerning the upper or covering wall m E n, while the two side faces s t and u w may be simply constructed for guiding the flow. The construction of a draft tube of this kind is represented by Figs. 8 and 9. To obtain the proper extension of the flow, the two radii r and R must be of equal size, or the smaller one (r) must be that of the deflector wall. Fig. 10 shows the discharge-gap shaped rectangular, at f_3. The same, however, may be rounded off at its corners f_4 (Fig. 11), or it may have an oval area f_3, as indicated by the broken lines in Fig. 11.

The good functioning of a draft tube of the kind described will not suffer if the discharge gap does not lie in a plane but on a curved surface. In the plan of Fig. 9, a rectangular entrance section has been shown by black lines, while in many cases a round entrance is preferred, as indicated by the broken lines at f_5; the shape of the entrance may be varied.

In the construction of water- turbines and pumps the necessity occurs to transform velocity into pressure by the shortest possible way, i. e., by a draft tube of small length.

The economy of use, in many cases, prohibits a plant of that class, but by using a draft tube according to my invention, provided with a deflector, and whose side walls diverge towards the discharge end in a manner to form the breadth of the discharge end equal to, or not longer than the length L of the tube, as shown by b_3 in Fig. 13, the measure of transforming the energy, in spite of the small length of the tube, will be sufficient to effect an economical use of the power of water in spite of the loss of the discharge.

The mode of increasing the width of the flow, in general, may be obtained without the employment of intermediate walls; only in the case, as shown in Fig. 12, where the breadth of the flow B is considerable in comparison to the length L of the draft tube, the insertion of intermediate walls may be considered as the best means for increasing the breadth of the flow even in those portions of the draft tube, which are adjacent to the wall m, n.

In Figs. 12, 13 and 14 I have shown an intermediate wall for increasing the breadth of the flow, which wall, for the sake of simplicity, is considered to be cylindrical and whose generatices stand perpendicular to guide line, as shown by m_0, n_0. Considering the fact already mentioned, that the angle of increase of the flow will be the greater, the more acute the curvature of the deflector is shaped, it will be advisable to make the radius of the curvature (ϱ, Fig. 12) of the intermediate wall smaller, than the radius R of the wall m n. It will be equally preferable, in case of employing a plurality of intermediate walls, to reduce the radii of the curvatures towards the deflector. The further course of the intermediate wall, towards the discharge, may be laid in a plane parallel to the deflector, as indicated in Figs. 12 and 14. In a case of this kind the whole draft tube may be composed of a number of partial draft tubes, in which the radii of the curvatures of the deflectors become smaller towards the deflector wall of the whole tube.

In the construction of water-turbines the provision of intermediate walls within a curved turbine-suction pipe is known, but such intermediate walls serve another purpose. This is evident from the fact, that such curved suction-pipes generally are formed with the same or approximately the same section. Also, contrary to my invention, the sharpest curvature coincides with the greatest velocity of the water, whereby the separation of the flow from the wall can take place near the point of sharpest curvature, even if the velocity of the water is slight. In any such case, therefore, the application of an intermediate wall can only be meant to prevent the separation of the water-jet from the curved wall, but not to increase of breadth of the jet.

The position of the intermediate wall within the tube having an influence on the distribution of velocity therein, it may be desired in many cases to effect a subsequent change in the position of such wall, which change it is desirable to administer in a simple manner and without disturbing the working of the turbine. A change of such kind may, for instance, be achieved by movably arranging the said wall to be turned on pivots Z, Figs. 12 and 13, and to be kept in any desired position by keys, as shown in

Fig. 12. The range of such change being very small it is sufficient to provide a small space between the intermediate wall and the two side walls of the draft tube in order to prevent the jamming between the two walls. Fig. 15 shows in this simplest form the deflector wall unrolled in the plane. It will be seen from (Fig. 15) that the cylindrical surface (with the radius r (Fig. 12) of the deflector wall at point D extends in a flat wall both towards the entrance and the discharge section of the draft tube. The broken line l_1, of Fig. 12, appears therefore, in its developed form as a straight line. The breadth of entrance b of the tube is gradually transformed along the two lines g, g into the discharge breadth b_3. However the starting point of the increase of breadth, may begin at a point nearer to D, as shown by the two broken lines h, h, in Fig. 15. According to Fig. 16, finally, the wall m n, opposite to the deflector has been shown unrolled in a plane, whereby the line l_2 of Fig. 12 appears flattened. In this form of execution, too, the course from the entrance to the discharge b_3 may lead either along the straight lines g_1, g_1, or along suitable curved lines h_1, h_1. The two side walls s, t and u, w, Figs. 13 and 14, in general are curved surfaces diverging from the entrance to the discharge end according to the increase of breadth. Since said side-walls cannot be provided with deflector walls for enlarging the breadth of the flow parallel to said side walls and towards the discharge end, it is no material advantage to increase the height of the side walls. With a small length of the tube L, as shown in Fig. 12, it will, therefore, be advisable not to materially increase the height K of the discharge section with relation to the breadth B of entrance section.

The various forms of draft tubes described with reference to Figs. 8 to 15, in general, may serve as examples for the form of construction, where the energy of velocity in flowing fluids is desired to be converted into energy of pressure with as little loss as possible. The said forms above all, will be most convenient, where the limited length of construction hitherto required formed an obstacle, or at least a great hindrance in employing the forms of draft tubes hitherto used. Draft tubes of the kind, accordingly, will be particularly applicable in the plants of water-turbines, to replace the conical suction pipes, which, having a horizontal arrangement of the turbine axis, require a curved suction conduit for exhausting the waste water. It is a matter of fact, that with the use of curved tubes hitherto employed, having circular cross-sections, very heavy losses of effect of the turbine are caused. Owing to the possibility of replacing such curved tubes by a draft tube according to my present invention, not only the waste-water may be guided away without any obstacle, but also the inevitable losses are spared which have been caused by curved tubes hitherto used with circular cross-sections. And, further, a draft tube of the class before described will be found to offer great advantages, if employed in turbines having a vertical or an inclined shaft, said advantages consisting particularly, in effectively converting energy of velocity into energy of pressure without increasing the length hitherto required, an advantage, which is most valuable particularly if the circumstances should demand the plant to be built in concrete.

Claims:

1. A draft tube for converting the energy of velocity of a fluid into energy of pressure, comprising two side walls diverging from each other towards the discharge opening of the draft tube, a deflector wall forcing the fluid to change its direction from the entrance towards the outlet under the influence of the increase of the breadth of flow and a wall opposite to the said deflector, the latter having a curve at the point of deflection, the radius of said curve being not greater than the radius of the wall opposite the said deflector.

2. A draft tube for converting the energy of velocity of a fluid into energy of pressure, comprising two side walls diverging from each other towards the discharge opening of the draft tube, a deflector wall forcing the fluid to change its direction from the entrance towards the outlet under the influence of the increase of the breadth of the flow, and a wall opposite to the deflector, the latter having a curve at the point of deflection, the radius of said curve being not greater than the radius of the wall opposite said deflector and the length of the draft tube not exceeding the length of the discharge opening of the draft tube.

3. A draft tube for converting the energy of velocity of a fluid into energy of pressure, comprising two side-walls diverging from each other towards the discharge opening of the draft tube, a deflector wall forcing the fluid to change its direction from the entrance towards the outlet under the influence of the increase of the breadth of the flow, and a wall opposite to the deflector, the latter having a curve at the point of deflection, the radius of said curve being not greater than the radius of the wall opposite the said deflector, in combination with at least one intermediate wall dividing the area of the draft tube into at least two portions of a draft tube.

4. A draft tube for converting the energy of velocity of a fluid into energy of pressure, comprising two side-walls diverging from each other towards the discharge opening of the draft tube, a deflector wall

forcing the fluid to change its direction from the entrance towards the outlet under the influence of the increase of the breadth of the flow, and a wall opposite to the deflector, said deflector having a curve at the point of deflection, the radius of said curve being not greater than the radius of the wall opposite the deflector and the length of the draft tube not exceeding the width of the discharge opening of the draft tube, in combination with at least one intermediate wall dividing the area of the ejector into at least two portions of a draft tube.

5. A draft tube for converting the energy of velocity of a fluid into energy of pressure, comprising two side walls diverging from each other towards the discharge opening of the draft tube, a deflector wall forcing the fluid to change its direction from the entrance towards the outlet under the influence of the increase of the breadth of the flow, and a wall opposite to the deflector, said deflector having a curve at the point of deflection, the radius of said curve being not greater than the radius of the wall opposite the deflector, in combination with at least one intermediate wall dividing the area of the draft tube into at least two portions of a draft tube, and means to change the position of said intermediate wall.

6. A draft tube for converting the energy of velocity of a fluid into energy of pressure, comprising two side-walls diverging from each other towards the discharge opening of the draft tube, a deflector wall forcing the fluid to change its direction from the entrance towards the outlet under the influence of the increase of the breadth of the flow, and a wall opposite to the deflector, said deflector having a curve at the point of deflection, the radius of said curve being not greater than the radius of the wall opposite the deflector, and the length of the draft tube not exceeding the width of the discharge opening of the same, in combination with at least one intermediate wall dividing the area of the draft tube into at least two separate portions of a draft tube, and means for changing the position of said intermediate wall.

In testimony whereof I affix my signature in presence of two witnesses.

VICTOR KAPLAN.

Witnesses:
JOHANN FLEISCHMANN,
EUGURD FUGGER.