Nov. 24, 1931. L. F. MOODY 1,833,529

HYDRAULIC APPARATUS

Filed Aug. 27, 1927 2 Sheets-Sheet 1

Fig-1

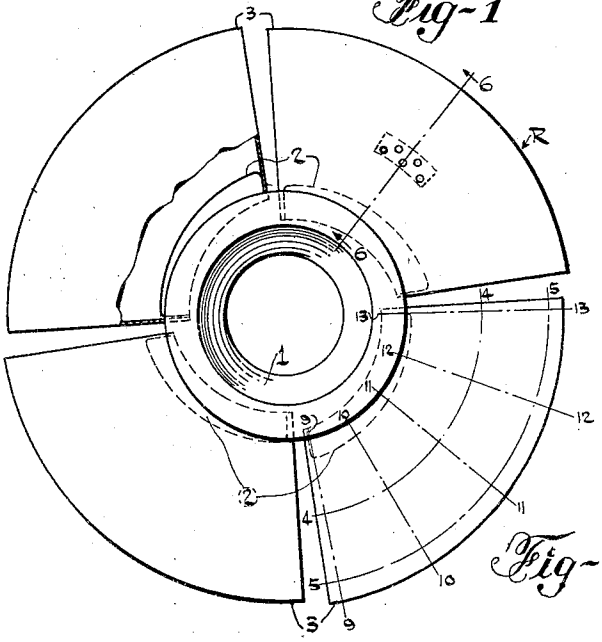


Fig-6

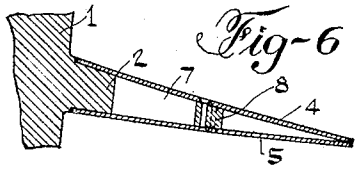


Fig-9

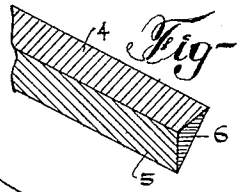


Fig-7

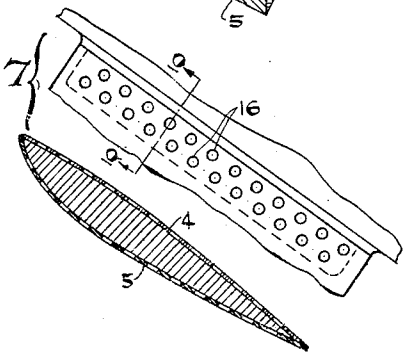


Fig-2

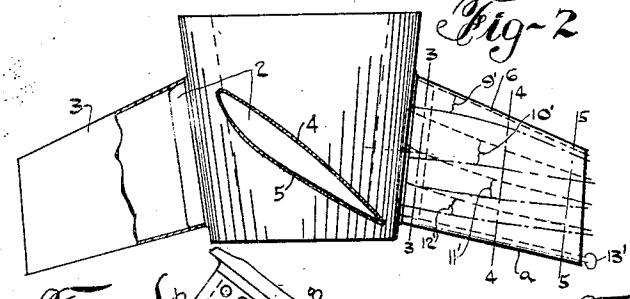


Fig-3

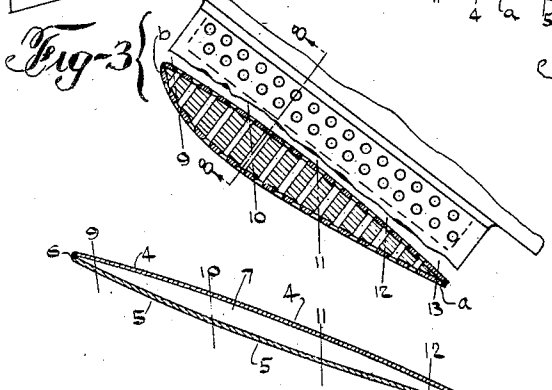


Fig-10

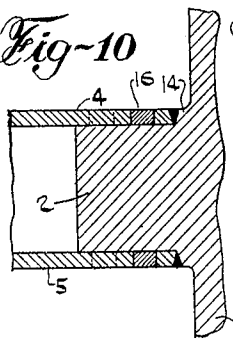


Fig-8

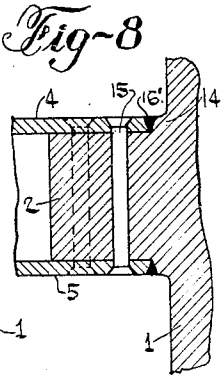
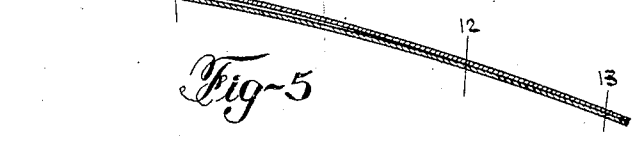


Fig-4



Fig-5



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HYDRAULIC APPARATUS

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Fig-11

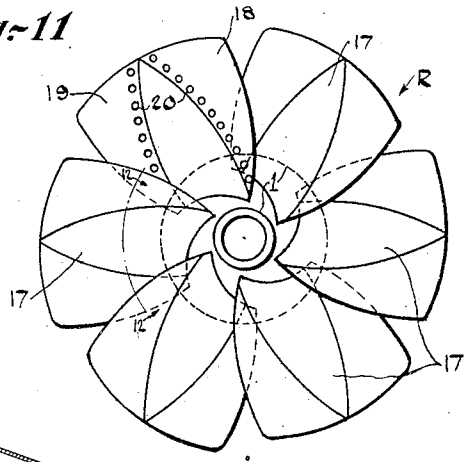


Fig-16

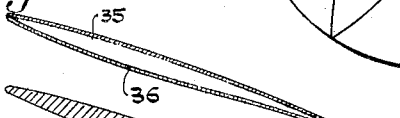


Fig-17

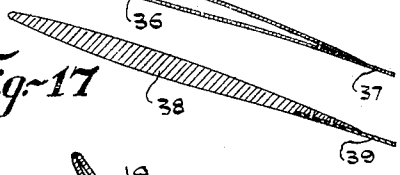


Fig-12

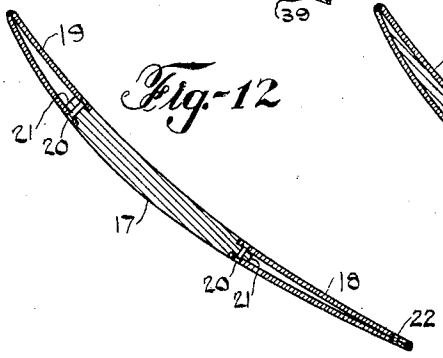


Fig-13

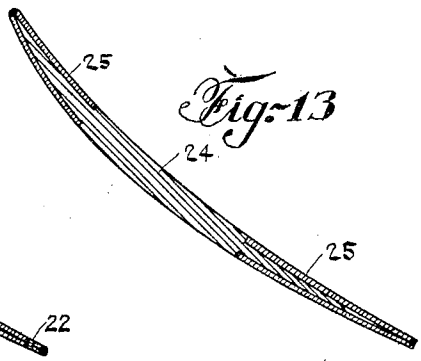


Fig-15

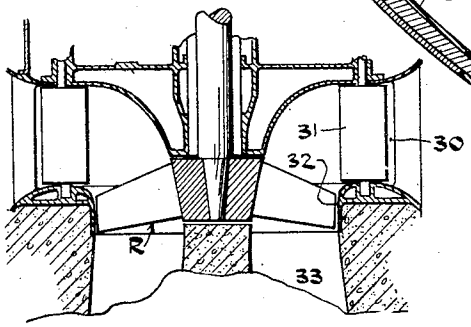
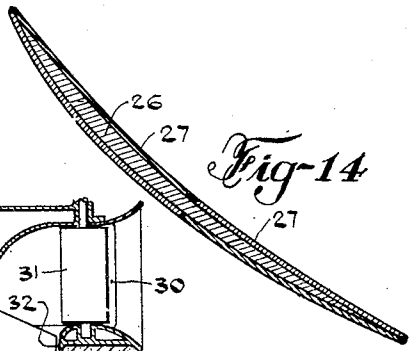


Fig-14



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Patented Nov. 24, 1931 1,833,529

UNITED STATES PATENT OFFICE

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HYDRAULIC APPARATUS

Application filed August 27, 1927. Serial No. 215,832.

This invention relates to hydraulic turbines and pumps and to the formation of the rotary element or runner therefor, and particularly to propeller runners having unshrouded blades. The runners of turbines and pumps of relatively high specific speed are subject to corrosion and pitting which usually occur more severely in the portions of highest relative velocity and lowest pressure of the flow. These portions are commonly near the entrance and discharge edges, and near the periphery of the runner, although corrosion may and often does occur in other portions of the blade. The corrosion is caused by the setting up of eddy currents and disturbances of the flow, and the separation of the water from its guiding surface. Generally the pitting takes place on the back side of the blade and works toward the front side or driving face, until as in some instances, holes have been made through the blade.

The object of this invention is to provide a turbine or pump structure in which the runner is formed with blades or vanes constructed in a novel manner to control or redu e corrosion and pitting and in any event to check or prevent the pitting action from working beyond a certain point.

A further object is to provide a blade construction which is adapted not only to accomplish the above results but which will be strong, of light weight, economical in manufacture and maintenance and efficient in operation. Another object is to provide a runner of built-up or composite construction, composed partly of cast metal and partly of plate, with blades of the best form for the hydraulic conditions of flow.

Fig. 1 is a plan view of one form of my improved runner partly broken away to show details of construction.

Fig. 2 is a side elevation of the runner shown partly in section.

Figs. 3, 4, and 5 are developed conical sections taken on their respective lines in Fig. 2, each of the sections being concentric to the runner axis as shown by lines 3—3, 4—4, and 5—5 in Figs. 1 and 2, the section line corresponding to line 3—3, Fig. 2, being omitted from Fig. 1 for clearness. In Fig. 3 is also shown a view, normal to the blade, of the portion near the hub to show the connection between the blade and hub.

Fig. 6 is an enlarged sectional view taken on a meridian plane 6—6 of Fig. 1.

Fig. 7 is a combined fragmentary plan and a sectional view thereof, of another construction for joining the blade and hub.

Fig. 8 is an enlarged fragmentary section, taken on lines 8—8 of Fig. 3.

Fig. 9 is an enlarged fragmentary section showing how the blade edges may be secured together.

Fig. 10 is an enlarged fragmentary section taken on line 10—10 of Fig. 7.

Fig. 11 is a bottom plan view of a modified form of runner embodying the principles of my invention.

Figs. 12, 13 and 14 are enlarged sectional views of various forms that the runner blade might take, all of said sections being taken on a line located similarly to the line 12—12 of Fig. 11.

Fig. 15 is a vertical section showing a runner, of any of the forms, in the cooperating structure of a hydraulic turbine.

Figs. 16 and 17 are further modifications of a blade construction which is generally shaped like those in Figs. 4 and 5.

My invention broadly contemplates the use of a runner having provision for supporting a fabricated blade and so arranging the elements constituting the blade that if operating conditions are conducive to cause pitting or corrosion, such may be effectively prevented, checked or controlled. In addition, the blade elements, a part or all of which are preferably made of plate metal, are arranged so that a vane shape is obtained highly conducive to efficient operation and conforming with the most advantageous flow conditions, and in addition the shape is such as to impart great strength to the blade.

In one specific aspect of the invention the blade is made not only extremely strong, considering its power capacity and the weight of material used, but the arrangement checks the extent of pitting action, if such should occur, by the provision of a relatively

large interior chamber within the blade so that if pitting action once penetrates some point of the chamber wall the destructive energy of any eddy currents or corroding conditions will be dissipated upon passing into the chamber or space. In this way the opposite chamber wall which may form the driving face of the blade is relatively free from the corroding conditions that it would be subjected to without the protection of the dissipating chamber or space.

To accomplish the above results in the form shown in Figs. 1 to 6 the four-bladed runner R has its hub 1 preferably of cast metal, usually of cast steel or in some cases cast iron, provided with four integrally cast lugs 2. The number of blades may be increased or decreased, but for runners of the high specific speed propeller type shown the number will usually be from three to six or at most eight. Secured to the lugs are blades 3, which, in order to form an interior chamber or space and also obtain great strength by utilizing principles of beam construction, are preferably made of plate metal, usually plate steel, although the same can be cast as a single blade unit either of cast iron or steel.

In the case of a plate metal blade the same is formed preferably of upper and lower plates 4 and 5, preferably welded at their edges as at 6 and suitably shaped so as to be conducive not only to efficient operation and flow conditions but also to impart great strength to the blade, and by such a formation there is thus formed the interior chamber 7. The blade as shown in Fig. 3 is, adjacent the hub, relatively deep in its middle portion and tapers more gradually toward the discharge edge *a* than it does toward the inlet edge *b*, the inlet edge being formed with a relatively blunt and rounded contour. As conical sections are taken on the blade at increasing distances from the runner axis, it is seen from Figs. 4 and 5 that the blade not only approaches a more horizontal position but also the depth of the blade diminishes while the width thereof increases until as partly shown in Fig. 5, the upper and lower plates come together adjacent the tip and are suitably secured preferably as by welding along the peripheral edge or tip.

In meridian sections, the blade thus presents a beam-like construction which more specifically would be of the cantilever type, one such section being shown in Fig. 6. In order to add further strength to the blade without materially increasing its weight, a block or support 8 is interposed between the front and back sides and secured thereto by rivets or suitable means such as welding, the number of supports being varied or entirely omitted as is deemed necessary in any given case. The section shown in Fig. 6 is substantially the same section shown between the pair of lines 11′ in Fig. 2 whereas other sections defined by the pairs of lines numbered 9′, 10′, 12′ and 13′ of Fig. 2 are taken on meridian sections indicated in Fig. 1 with the same numbers unprimed. These sections also are indicated in Figs. 3 to 5 by similar numbers. It will be noted in these latter figures that the section lines 9—13 converge toward a point on the lower sides of the blades, this being due to the fact that said sections are simply conical sections rolled out onto a plane and necessarily the meridian planes indicated by lines 9—13 must all pass through the apex of the cone. In each of the meridian sections indicated by the pairs of lines 9′—13′ in Fig. 2 the dot and dash line indicates the curvature along the lower surface or back side of the blade while the dotted lines indicate the curvature along the front or driving surface of the blades, it being noted that while certain of these lines curve when considering their entire length, yet a material or major portion of each of these lines is substantially straight, this being particularly true of the face lines which are dotted, thereby causing substantially the major portion of the blade surfaces to be formed of straight line elements in meridian sections.

The lugs 2 are preferably made to conform to the contour of the inner side of the blade plates, adjacent the hub while a small shoulder 14 is provided whereby the outer blade surface and hub will be flush. The plates after being shaped to the desired contour and assembled together will be placed upon the lugs 2 and secured thereto either by rivets 15 or by providing holes in the plates and then welding to the lugs 2 through the holes as shown at 16 in Figs. 7 and 10.

In either case however the inner blade ends are preferably welded to the shoulder 14 as at 16′ thereby increasing their strength and insuring against any open spaces, cracks or the like which might be conducive to causing pitting or corroding. It will also be understood that the lugs 2 instead of being shaped to conform to the entire inside contour of the plates may only do so partially but always of course to such an extent that sufficient strength may be had.

In view of the fact that pitting or corrosion most generally occurs on the lower blade surface, it will be understood that the lower plates may if desired be made of any special material which might be more resistant to pitting than the material forming the upper plate or if desired both plates may be made of special material. In any event, however, it will be noted that should pitting become so severe as to completely penetrate the lower plate 5 the relatively large chamber or space 7 will then act as a means of protection against pitting of the upper plate 4 by the conditions which exist on the lower side of the runner. One explanation of this protecting

feature is that eddy currents or other corroding conditions would be dissipated in entering or traveling through the space 7 and thereby would not be sufficient to attack the upper plate. Even though the plates may be relatively close together, yet due to the area of the blade the volume of such space will be relatively large. It is also seen that due to the use of the relatively thin plates the same could readily be restored as by local welding or replacement to their full normal condition both as to strength and contour. If pitting once occurs in the applicant's present type of runner blade, the pitting action will be arrested due to the built up construction permitting the use of resistant material fabricated in plate form, together with the hollow space or dissipating chamber, and in that way, the hollow runner blade negatives the destructive conditions which are set up by the elements forming the high specific speed installation.

A further feature of the construction shown is that due to the spacing of the plates the upper and lower plates will be positioned a material distance from the neutral axis of the blade as a whole, it being noted that the strength of the blades are controlled in accordance with the principles of beam construction. Inasmuch as it is the outermost fibers of any beam which must take the maximum stresses it is seen that the plates are placed at the most effective position to take the entire load, and inasmuch as the plates are preferably made of steel, having high tensile and compressive strength, the same can be made relatively thin thereby providing not only a light weight runner but one which is economical in cost and very strong in resistance to both steady forces and shocks.

While the blades may be made of any desired shape it will be noted from Figs. 1 and 2 that in the specific embodiment herein described the total blade area is at least equal to the disc area bounded by circles containing the hub and the blade tips, while in meridian sections the blades on their upper surface tend toward or are slightly concave while in developed conical sections the upper surfaces of the plates are convex and certain of said sections on their lower surface are at least partially concave although as shown in Fig. 4, a considerable portion of the lower surface is convex.

In the modified form of the invention as shown in Fig. 11 the blades are not only increased in number and given a somewhat different shape than shown in Fig. 1 but the construction is such that a greater amount of cast metal is used either in forming the blade surface or supporting the blade.

The runner hub 1 is cast integral with the inner portions 17 of the blades, with sufficient metal in the casting to carry the bending stresses to which the runner is subjected in operation. These inner portions 17 of the blade are substantially triangular in formation when viewed in a plane perpendicular to the axis, as shown in Fig. 11. The entrance and discharge edges of the blades are composed of plate metal which will carry the bending stresses to which the runner is subjected and resist the corrosion of the blades at the edges. The plate metal sections 18 and 19 are riveted, welded, or otherwise secured to the inner cast sections 17. Countersunk rivets 20 are illustrated in Fig. 12 to produce a smooth surface free from any irregularity which would disturb the flow, these rivets for simplicity being shown on only one of the blades in Fig. 11. The inner cast sections 17 are cast with or subsequently formed with flanges 21, which if not so cast are formed by cutting away the casting to suit the thickness of the plate metal. The entrance section 19 of plate metal is constructed either of one piece bent in somewhat U-shape, forming the front and back surfaces of the blade, or of two pieces welded or riveted together and then secured to the flanges 21 of the inner cast section 17. The use of two plates will usually be preferable on account of greater ease in forming them. The discharge section 18 is formed of two pieces of plate metal tapered to a thin edge at discharge and either welded or secured together by countersunk rivets 22, forming the front and back surfaces of the blade. The discharge section is riveted to the lower flange 21 of the inner cast section. The plate sections also may be welded to the cast section by providing perforations or holes to be filled by welded metal.

As shown in Fig. 12 the arrangement of the upper and lower plate members forming the entrance and discharge portions of the blade is such that there is formed a chamber or space similar to that shown in the preferred form in Fig. 1. Due to securing the plates 18 and 19 at their inner edges to the central portion 17 said plates are in the form of a cantilever which is also generally true of similar plates shown in Fig. 13 to be described.

In the form shown in Fig. 13 the member 24 corresponding broadly to the lug 17 has reduced portions adjacent the entrance and discharge edges, the reduction being of sufficient depth that plate metal members 25 are continuous with the surfaces of the central portion 24. The plates 25 and portion 24 will be secured together either by rivets or welding and in any of the forms shown the edges of the blade members will be preferably welded together.

In the form shown in Fig. 14 the body of the vane 26 is either partially or wholly encased or covered by plate metal members 27. These plates may be made in a plurality of sections herein shown as two each for the

front and back sides of the blade. The adjacent edges of each set of plates are secured by welding while the front and back plates adjacent the entrance and discharge edges are likewise secured by welding. In case it should be deemed necessary, each of the blades wherein a hollow interior is used could be provided with a small opening to allow free circulation of fluid therein and in that way there is eliminated any tendency for the runner to become unbalanced in case water should enter only one, or less than all, of the interior spaces through leakage or the like. However, the means for securing the plates including welding or riveting would ordinarily be sufficient to provide an airtight and watertight space.

A runner R of this invention is shown in Fig. 15 in combination with a usual type of hydraulic turbine construction having a radial inlet 30 provided with any suitable flow control means such as wicket gates 31, an axial passage 32, and draft tube 33, the problem in connection with hydraulic turbines being peculiar thereto due to velocity conditions and other factors.

As shown in Fig. 16 the blade comprises a body 35 having upper and lower plates, the lower one 36 extending beyond the upper one as indicated at 37 thereby forming a thin discharge edge portion consisting of only a single plate.

In Fig. 17 the blade body 38 has its discharge edge portion formed by a single plate 39 secured preferably to the underside of the body which is suitably recessed to receive the plate and thereby provide smooth continuous upper and lower surfaces. In either of the above forms the plates may be secured by welding as in any of the manners previously considered.

It is thus seen that from the constructions herein described the blades are so formed and constructed that not only is a very inexpensive and effective runner blade provided but the blade is so formed that it is particularly resistant to corroding action and that in case any corrosion might occur the same will not only be checked but may be readily repaired. In the event of local injury or corrosion, one of the plates of Figs. 3 to 5 and 16 may be replaced without replacing the other; and in the arrangements of Figs. 12, 13, 14 and 17 only a portion of either the front or back blade surface need be replaced without replacing the remainder. Also, in the accomplishment of these results a very strong runner blade is obtained with the use of a relatively small amount of metal, this being due to the utilization of structural beam principles which also apply to those forms shown in Figs. 12 to 14, as well as to Fig. 6.

While the invention is illustrated and described particularly with reference to runners for hydraulic turbines and pumps it is not confined thereto but is intended to cover any other uses or modifications where a fluid rotor of the type herein disclosed would be useful under similar circumstances.

I claim:—

1. A runner for a turbine or pump comprising a hub carrying a hollow blade, certain meridian sections of said blade having their upper and lower surfaces curved.

2. A runner for a turbine or pump comprising a hub carrying a hollow blade, certain meridian sections of said blade having their upper and lower surfaces oppositely curved.

3. A runner for a turbine or pump comprising a hub carrying a hollow blade, certain meridian sections of said blade having their upper and lower surfaces both concave.

4. A runner for a turbine or pump comprising a hub carrying a hollow blade, certain meridian sections of said blade having upper and lower surfaces one of which is substantially straight and the other concave.

5. A propeller type runner for a high specific speed turbine or pump comprising a hub carrying hollow blades the opposite sides of which comprise sheet metal plates, said plates being relatively flat in the direction in which fluid normally flows thereover, while one of said plates has at least the major portion of its surface formed along substantially straight line elements in meridian sections.

6. A propeller runner for a high specific speed turbine or pump comprising a hub carrying hollow blades, the opposite faces of which comprise sheet metal plates, the upper one of said plates having straight line elements in meridian sections.

7. A propeller type runner for a high specific speed turbine or pump comprising a hub carrying hollow blades each formed of spaced sheet metal plates secured together at their edges and being relatively flat in meridian section, while the upper plate is also flat in the direction in which fluid normally flows thereover.

8. The combination in a high specific speed turbine, comprising a propeller type runner having blades with a hollow interior, the outer portion of each blade being inclined at a small angle to the plane of runner rotation, means forming an entrance passage for conducting fluid to said runner and having provision for whirling the inflowing fluid, and a draft tube for decelerating the flow discharged from said runner whereby the back surfaces of the runner blades are subjected to pressure below atmosphere.

9. The combination in a high specific speed turbine, comprising a propeller type runner having blades with a hollow interior, the outer portion of said blades in the direction of flow thereover being disposed more nearly to the horizontal than vertical, means forming

an entrance passage for conducting fluid to said runner and having provision for whirling the inflowing fluid, and a draft tube for decelerating the flow discharged from said runner whereby the back surfaces of the runner blades are subjected to pressure below atmosphere, said runner being formed of plate metal on the front and back sides.

10. The combination in a high specific speed turbine, comprising a propeller type runner having blades with a hollow interior, the outer portion of said blades in the direction of flow thereover being disposed more nearly to the horizontal than vertical, means forming an entrance passage for conducting fluid to said runner and having provision for whirling the inflowing fluid, and a draft tube for decelerating the flow discharged from said runner whereby the back surfaces of the runner blades are subjected to pressure below atmosphere, said runner having blades at least one side of which is formed of plate metal.

11. The combination in a high specific speed turbine, comprising a propeller type runner having blades with a hollow interior, the outer portion of said blades in the direction of flow thereover being disposed more nearly to the horizontal than vertical, means forming an entrance passage for conducting fluid to said runner and having provision for whirling the inflowing fluid, and a draft tube for decelerating the flow discharged from said runner whereby the back surfaces of the runner blades are subjected to pressure below atmosphere, said runner blades being formed of plate metal on the front and back sides which are welded together along the entrance and discharge edges of the blade.

12. The combination in a high specific speed turbine, comprising a propeller type runner having blades with a hollow interior, means forming an entrance passage for conducting fluid to said runner and having provision for whirling the inflowing fluid, and a draft tube for decelerating the flow discharged from said runner whereby the back surfaces of the runner blades are subjected to pressure below atmosphere, said runner blades having plate metal on the front and back sides, the front side being relatively flat in the direction of the fluid flow thereover.

13. The combination in a high specific speed turbine, comprising a propeller type runner, having blades with a substantially hollow interior, means forming an entrance passage for conducting fluid to said runner and having provision for whirling the inflowing fluid, and a draft tube for decelerating the flow discharged from said runner whereby the back surfaces of the runner blades are subjected to pressure below atmosphere, said runner blades having plate metal on the front and back sides, the front side being relatively flat while the back side has curvature in the direction of the fluid flow thereover.

14. The combination in a high specific speed hydraulic turbine comprising a propeller type runner having a hub provided with lugs inclined with respect to the runner axis and extending circumferentially, upper and lower sheet metal plates spaced apart and secured together adjacent their edges to form runner blades which are secured to said lugs, means forming an entrance passage having provision for whirling the inflowing fluid to said runner, and a draft tube for conducting the fluid discharged from said runner whereby the back sides of said blades are subjected to pressure below atmosphere.

15. The combination in a high specific speed turbine comprising a propeller type runner having blades which, in plan view, have substantially straight radial entrance and discharge edges extending from substantially the blade tip to the hub, means forming an entrance passage for conducting fluid to said runner and having provision for whirling the inflowing fluid, and a draft tube for conducting the fluid discharged from said runner, the front and back sides of said blades being formed of sheet metal plates spaced apart to form a hollow interior and secured together adjacent their edges.

16. A runner for a hydraulic turbine or pump comprising, a hub carrying a plurality of hollow blades the opposite sides of which comprise sheet metal plates and, the combined peripheral edge portions thereof extending over a major extent of the runner periphery, said hub having vane-shaped bosses integral therewith and to which the blade plates are secured substantially throughout their complete contour at their hub ends.

17. A propeller type runner for a high specific speed turbine or pump comprising a hub carrying a plurality of hollow blades, the opposite sides of which include sheet metal plates, said blades being relatively flat in the direction in which fluid normally flows thereover and the combined peripheral edge portions of said blades extending over a major portion of the runner periphery, said plates when cut in a section taken in the direction of flow having an entrance edge which is rounded from face to back in a substantially continuous curve and a discharge end which is gradually tapered to a thin edge, the entrance portion of the blade being relatively thick and the discharge portion thereof relatively thin.

18. A runner for a hydraulic turbine or pump comprising a hub carrying hollow blades, the opposite sides of which include sheet plates, said hub having its outer contour formed as a surface of revolution having substantially straight elements in meridian section.

19. A runner for a hydraulic turbine or pump comprising a hub carrying hollow blades the opposite sides of which include sheet plates, said hub having its outer contour formed as a surface of revolution having substantially straight elements in meridian section, the elements being inclined to the runner axis thereby forming a conical hub.

20. A propeller type runner for a high specific speed turbine or pump comprising a hub carrying hollow blades the opposite sides of which comprise sheet metal plates, said plates being relatively flat in the direction in which fluid normally flows thereover, and said blades also having an axially projected area substantially equal to the disc area between the hub and runner periphery.

21. A runner for a hydraulic turbine or pump comprising a hub carrying hollow blades, the opposite sides of which include sheet metal plates spaced apart adjacent the hub and brought substantially gradually together at the discharge and peripheral edges of the blades thereby to provide relatively thin sections of the blade adjacent the peripheral and discharge edges.

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