Feb. 14, 1933. H. B. TAYLOR 1,897,501

DRAFT TUBE STRUCTURE

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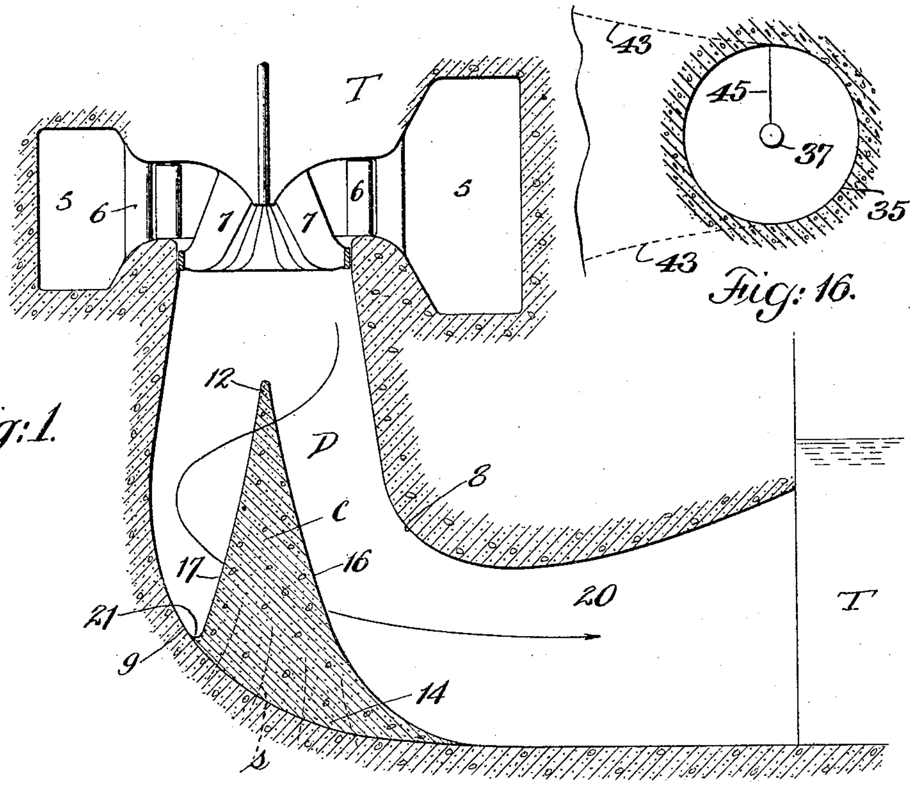

Fig: 16.

Fig:1.

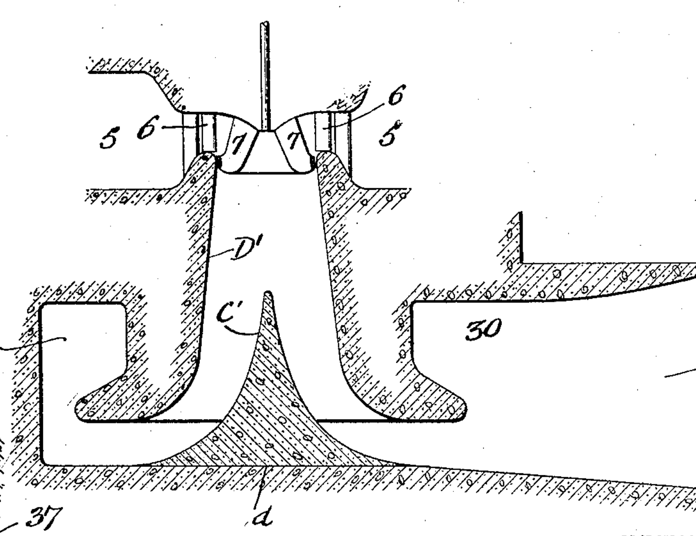

Fig:2.

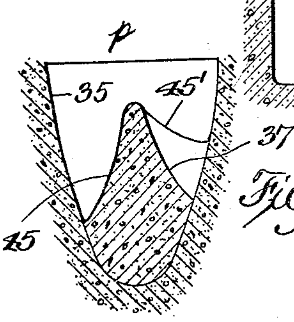

Fig. 17.

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Fig:3.

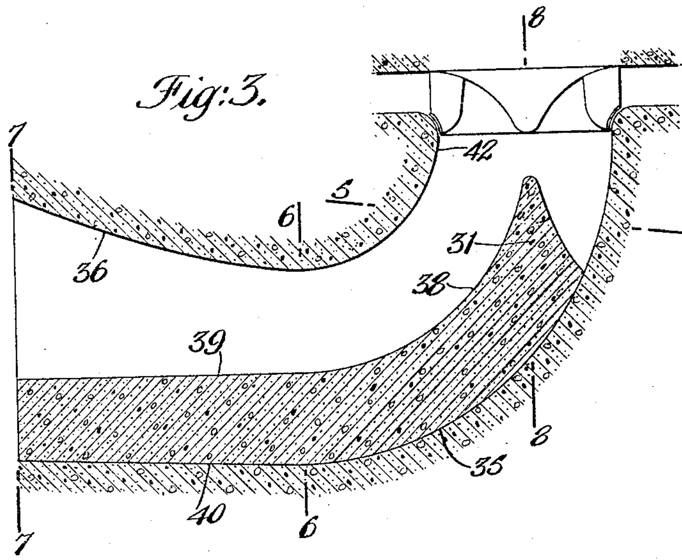


Fig:4.

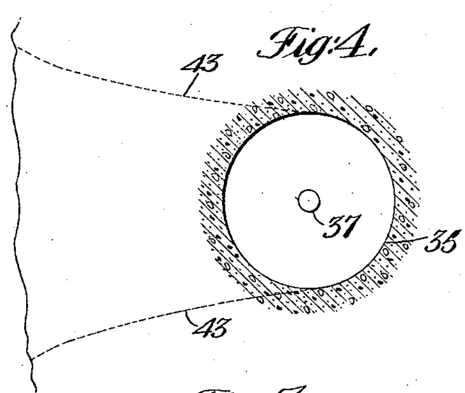


Fig:5.

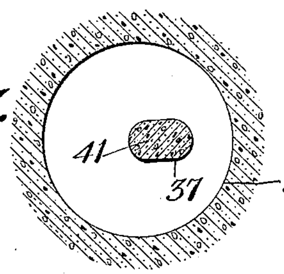


Fig:6.

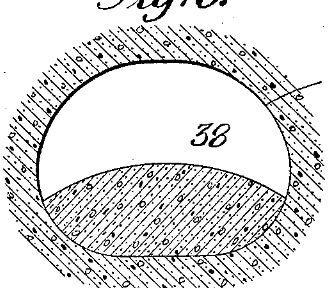
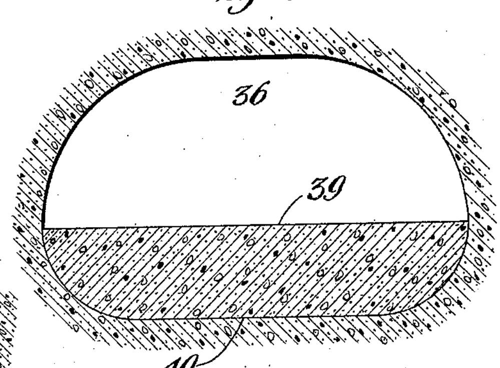


Fig:7.



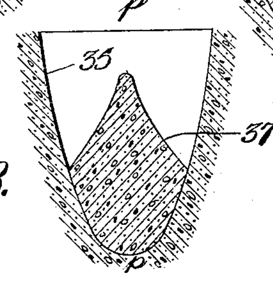


Fig:8.

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Fig: 9.

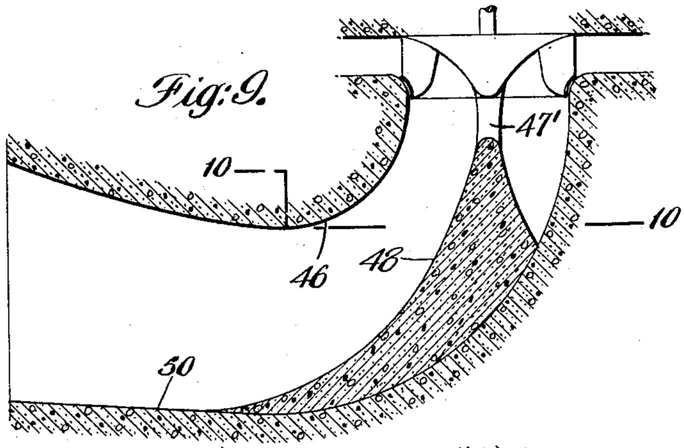

Fig: 15.

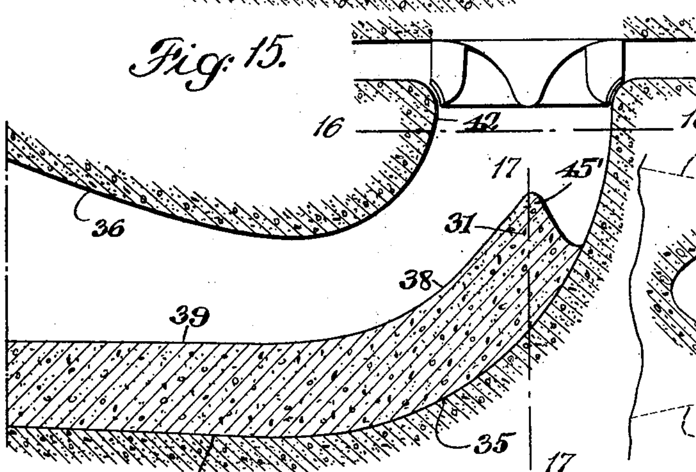

Fig. 10.

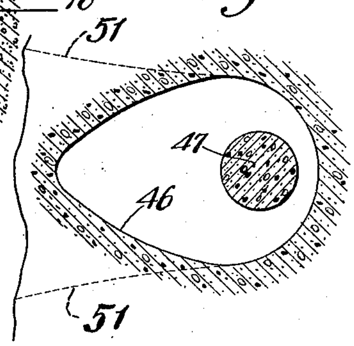

Fig: 11.

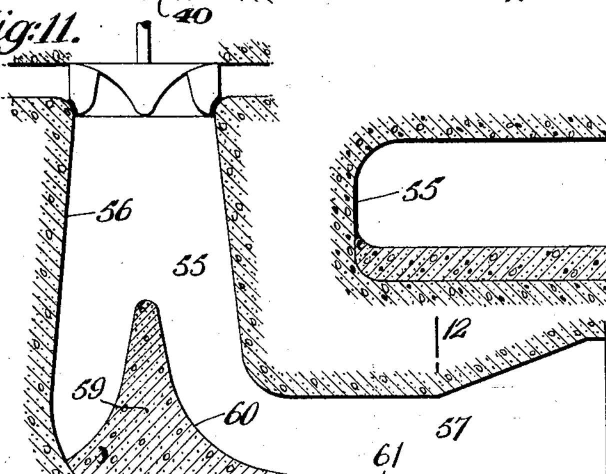

Fig: 12.

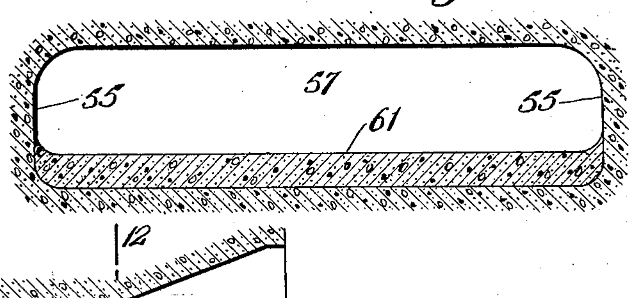

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Fig:13.

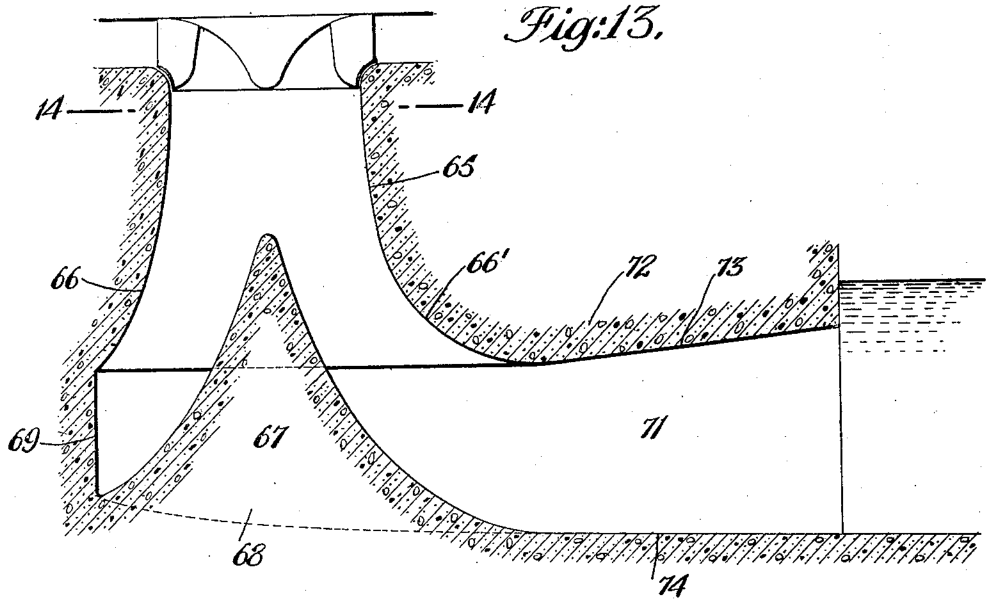
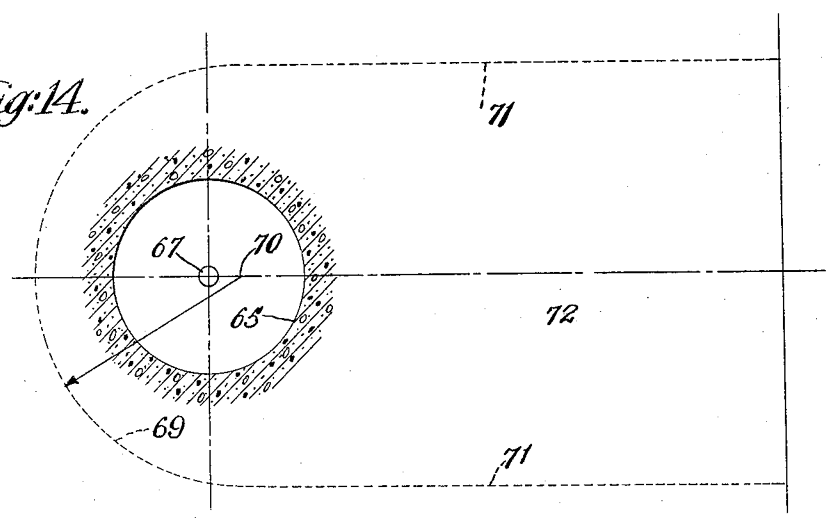


Fig:14.



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UNITED STATES PATENT OFFICE

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DRAFT TUBE STRUCTURE

Application filed January 14, 1922, Serial No. 529,172. Renewed May 6, 1929.

This invention relates to a draft tube for a hydraulic turbine and particularly to a draft tube or discharge passage in which the flow is turned from the generally axial direction to a direction at an angle thereto. In making such a bend, the design of many existing tubes fails to take proper account of all components of the velocity of discharge from a turbine runner. The result is that wasteful eddies and disturbances are set up, which often cause serious vibration of the water column and frequently of the entire powerhouse foundation; and such eddy formation, besides representing a waste of energy and loss of efficiency, may in some cases cause serious damage to the structure through vibration and erosion. In many installations it has been necessary to redesign the entire draft tube passages or to admit air to the discharge from the runner in order to reduce the shocks due to the hydraulic disturbance, but this introduction of air does not avoid wasteful disturbances of the flow and by reducing the vacuum at the runner discharge further decreases the efficiency of the turbine. In many installations the available space which can be occupied by the draft tube is limited, particularly in a horizontal direction measured lengthwise of the powerhouse; it being frequently necessary to make this dimension small to permit a close spacing of successive units and a short total length of powerhouse.

The object of the present invention is to overcome the objections to prior structures and provide a draft tube adapted to turn the flow at right angles to the axial without excessive disturbance and obstruction and within limited lateral dimensions permitting a close spacing of adjacent turbine units. In particular, this invention comprises the formation within the bend of the draft tube of central surfaces adapted to give the passage in its portion near the beginning of the bend a generally annular formation spreading the flow outward from the axis and when applied to whirling flow conforming to the lines of flow which the stream lines tend to take and preventing as far as possible the formation of wasteful disturbances.

In the accompanying drawings illustrating the invention

Fig. 1 is a vertical sectional view of a draft tube of the elbow type with central surfaces formed in accordance with this invention.

Figs. 2 to 14 are sectional views of modifications showing the application of the invention to different forms of tube and various conditions of flow.

Figs. 15 and 16 are modified forms of the draft tube, and

Fig. 17 is a sectional view on line 17—17 of Fig. 15.

In the specific embodiment of the invention shown in Fig. 1 a turbine T has an intake passage 5 leading through vanes 6 to the runner 7 which discharges vertically downward into the draft tube D of elbow shape, receiving the flow vertically and discharging it horizontally into the tailwater T. The draft tube D is of generally circular section in its entrance portion and its bend has an inner curve at 8 and an outer curve at 9 turning the flow through approximately 90°. In such a draft tube, it has been found that cross currents and disturbances are set up under practically all conditions of operation; and frequently it is found that in such tubes a portion of the passage is occupied by water flowing upward toward the runner. The conditions in such a tube are particularly unfavorable in turbines of high specific speed in which the discharge from the runner at all gate openings contains large whirl components of velocity about the turbine axis. In some turbines of low specific speed, there may be operating conditions at approximately normal gate in which the discharge from the runner contains little whirl about the axis, but even in such installations there is severe whirl at part gate and wide open gate operation; and the whirl set up in the draft tube under such conditions may have serious consequences. This is particularly true when the turbine is supplied through a long penstock in which water hammer or surging may be set up by the draft tube vibration.

When the flow entering the draft tube contains large rotational motion about the axis, there is a tendency for a space to be left within the downward flowing stream in which the flow is frequently upward toward the runner and in which the conditions are unsteady. In the horizontal portion of the draft tube, the flow is frequently outward on one side of the tube and reversed in direction on the other side.

To avoid this wasteful disturbance of the flow and the accompanying loss of power and efficiency, as well as danger to the power house structure through vibration, there is added in accordance with this invention a core C in the form of a cone with its apex 12 at or near the axis of the tube and its surfaces formed generally as surfaces of revolution co-axial or nearly so with the entrance portion of the draft tube. The surfaces of the cone expand and curve downward to a base 14 resting on the outer curve 9 of the draft tube elbow. This core C may be of metal or of concrete built up from the bottom of the elbow in the general direction of the turbine axis and extended upward any desired distance. The core, if of concrete, would contain proper reinforcement and would be bonded to the surrounding structure by anchor rods or reinforcing rods such as is shown at *s*, Fig. 1. This reinforcement is necessary to withstand the tendency of the core to be drawn upward by the reduction of pressure in the draft tube.

The outflow through the draft tube is thus guided into annular form around the central core C within the elbow and the core fills any void that may tend to form and provides central surfaces around which the flow may pass on naturally whirling lines to the lower horizontal portion 20 of the draft tube. The side 16 of the core has a longer surface than the opposite side 17 and may extend somewhat into the horizontal discharge portion 20, while the corners 21 formed by the meeting of the core and tube surfaces are rounded off in smooth and even manner. In many existing tubes of the elbow type, the flow is not only turned sharply at the elbow, but the cross sectional areas of the passage enlarge with undue rapidity in passing around the bend so that the flow does not fill the entire passage. The central core is of value in reducing the excessive areas in such tubes and is of advantage when used with non-whirling flow, in addition to providing for the tangential components of flow when the flow is whirling.

In some cases it may be desirable to make the core C somewhat non-circular in section in order to accommodate it to the areas of the particular form of bend involved or it may be desirable to cut away or build up portions of the surrounding tube surfaces to give desired form to the water passage around the cone.

In the modification shown in Fig. 2 the draft tube D′ instead of having a curved elbow turns the flow at right angles against a deflecting surface *d* and collects the spreading flow in the surrounding passage 30 leading to tailwater at 31. Such a form of draft tube causes abrupt changes in velocity of the flow and has been found in practice to set up serious vibrations of the water column. To overcome this objection in accordance with this invention a central core C′ is shown built up on the deflector surface *d* and extending into the draft tube D′ any desired distance and forming the lower end of the draft tube into a spreading annular passage. Preferably the surfaces of the central core C′ are so spaced with relation to the draft tube surfaces as to form a passage gradually increasing in area across the lines of flow so that throughout the draft tube there will be a substantially continuous deceleration of the flow and resultant conversion of velocity head into pressure head at the outlet.

In the formation of the central core it is desirable to avoid obstruction of the flow as by sudden changes in velocity or direction. In some existing installations the shape of the outer wall may be such that the restriction caused by the central core may interrupt the desired gradual enlargement of the cross section but the smoother flow lines and absence of vibration with the resulting increased efficiency and reliability will more than offset any loss due to the short contracted portion.

In the modification shown in Figs. 3 to 8 the draft tube elbow 35 begins to curve toward the horizontal immediately at the runner discharge and its design is such as to provide an excessively large final outlet passage 36. The cone 37 built into this tube has its surface 38 carried out into a flat floor 39 above the elevation of the original floor 40. As is clearly shown in Figs. 6 and 7, which are sectional views on lines 6—6, 7—7 of Fig. 3, this reduces the cross sectional area of the outlet passage so as to avoid the formation of obstructive countercurrents and eddies. Fig. 5 is a sectional view on line 5—5 of Fig. 3 and shows the eccentric position occupied by the core 37 with relation to the center 41 of the portion of the passage in which it is set. This core is however shown as vertically concentric with the center of the entrance 42 to the draft tube as shown in Fig. 4 which is a plan view with dotted lines 43 representing the extreme horizontal width of the tube at various sections. The initial portion of core 37 is shown as formed as a surface of revolution around a vertical axis.

This shape is however modified for instance to give the core surfaces a generally spiral formation as indicated by lines 45 in Fig. 16 which is a sectional view on line 16—16 of Fig. 15. The rounded entrance edge of this spiral is shown by the line 45′

of Figs. 15 and 17. This form of passage allows a greater area of the passage on one side of the central plane $p—p$ of the draft tube than on the other, thus providing for the increased flow on one side produced by the whirl, so that this form will in some cases be preferable in providing for the whirling components of flow.

In draft tube 46 of Figs. 9 and 10 the curvature commences close to the runner discharge and the core 47 is installed close to the runner. As indicated at lines 47′ in Fig. 9, the core is carried all the way up to the runner and merges with the runner hub. The surface 48 of the core is carried down far enough to merge with the original floor 50 of the tube. In Fig. 10 a section is shown taken on the line 10—10 of Fig. 9 and indicating by dotted lines 51 the extreme horizontal width of the passage at various points. In Figs. 11 and 12 the draft tube 55 has a straight entrance portion 56 and a horizontal outlet passage 57 which is flat in section. The core 59 for this draft tube is located at the elbow portion and has its surface 60 extending to the final outlet edge of the passage thus providing an inclined floor 61 above the original floor 62 and extending across the passage as indicated in Fig. 12 which is a section on the line 12—12 of Fig. 11.

In Figs. 13 and 14 a draft tube is shown formed in accordance with this invention and involving a turning of the flow within an unsymmetrical annular space which is only slightly flared on the upstream side and laterally. This embodiment of the invention is particularly advantageous in giving smooth and efficient flow lines while keeping the overall width within a narrow lateral space so as to permit a close spacing of a series of draft tubes in a powerhouse foundation. In the tube of these figures the entrance portion 65 is straight with a limited flare 66 at the lower end. This flare may be symmetrical all around or may be increased on the downstream side at 66′. A core 67 is provided projecting into the flared portion of the tube and having its base portion 68 on the upstream side connected to the flared portion of the tube by surface 69 which may for instance be semi-circular or approximately so around a center 70 eccentrically displaced downstream with relation to the axis of the entrance portion of the draft tube as shown in plan view in Fig. 14. This surface extends around the core 67 and merges with the sides 71 of the outlet 72 of the draft tube, which outlet has a top surface 73 and floor 74. The spacing between the flare 66, 66′ and the surface of the core 67 may be made the same all around or it may be increased on the downstream side as compared with the upstream side. In the draft tube of this invention the surface 69 connects with the flaring portion 66 of the draft tube before this flare has completed its curve to 90° from the axial direction and thus the passage around the core 67 has a limited flare on the upstream side and laterally while the flare 66′ on the downstream side is completed to substantially right angles to the axial to merge with the top 73 of outlet 72. The flow will therefore be unsymmetrical around the axis, a greater portion passing on the downstream side of the central core than passes on the upstream side. This construction gives a limited flare to the vertical portion of the draft tube reducing the lateral width of the passage around the core 67 and permitting closer spacing of the turbines in the powerhouse and a reduction in the width of the cavity in the powerhouse substructure below the turbine.

The invention is not confined to the specific draft tubes shown but may be applied to draft tubes of horizontal shaft turbines or various other forms within the principles above set forth. In some cases it may be desirable to cut away an existing draft tube for the base of the cone or to provide anchorage rods *s* (Fig. 1) between the tube and the cone, it being understood that the principles of my invention are not only applicable to the reconstruction of existing draft tubes but may be equally applied and embodied in newly built draft tubes. The result is that a newly formed draft tube may be provided with a floor 39 which in longitudinal section such as shown in Fig. 3 would be composed of substantially straight line elements along the major portion of its length while in transverse section, which is usually considered as being normal to the direction of flow, the surface 39 would be higher at one point than at another such as shown in Fig. 6, thus presenting a ridge disposed longitudinally along, preferably, the central axis of the outlet 38 and extending to the terminus of outlet 38 to which point the ridge is substantially fully maintained. It is also to be noted that in Fig. 6 the ridge immediately below numeral 38 is specifically shown of convex formation in opposed relation to the roof which is herein specifically shown of concave formation, although it is of course readily apparent that other specific formations and arrangements might be employed while maintaining the principles of the invention and without departing from the spirit of the invention as set forth in the appended claims.

I claim:—

1. A hydraulic draft tube having a central core concave away from the turbine axis in sections containing said axis, and an outer surface unequally spaced from said core around the circumference thereof at points equally distant from the turbine axis, said outer surface flaring substantially from vertical to horizontal upon the side of the draft tube downstream from said turbine, and flar-

ing outward to a less extent on the side upstream from the turbine axis.

2. A draft tube having a central core projecting upward toward the runner from the bottom of said tube and an outer surface curving substantially from vertical to horizontal on the downstream side of the draft tube and curving to a less extent and not attaining a horizontal direction on the upstream side of the draft tube.

3. A draft tube comprising for at least a portion of its length an annular passage of greater cross section on one side than on the other.

4. The combination with an elbow type draft tube, of an auxiliary core in the curved portion of said draft tube forming an annular passage of greater cross section on one side than on the other.

5. The combination with a draft tube of the elbow type, of a core in the curved portion of said draft tube projecting upward from the outer surface of the elbow to lower the rate of increase in area so as to avoid obstruction and more efficiently convert velocity head into pressure head.

6. A draft tube comprising for at least a portion of its length an annular passage of greater cross-section on one side than on the other and having means providing a spiral surface in said tube.

7. The combination with an elbow-type draft tube, of a core in the curved portion thereof forming an annular passage of greater cross-section on one side than on the other, and at least a portion of said core having a spiral surface.

8. A draft tube comprising an axially extending straight portion adapted to decelerate the flow, a deflecting portion of generally elbow formation turning the flow from axial to radial while simultaneously decelerating it and comprising a bottom deflecting surface and spreading side walls, a radial discharge passage receiving and decelerating the radially directed flow and having its width at least twice its height, and means forming a spiral surface in said draft tube.

9. A draft tube of generally elbow formation having a bend for turning the flow from an axial portion to a radial portion, the upstream surface of the elbow bend lying substantially entirely on the downstream side of the upstream surface of said axial portion, and means forming a spiral surface in said tube.

10. A draft tube comprising an axially extending straight portion adapted to decelerate the flow, a deflecting portion of generally elbow formation turning the flow from axial to radial while simultaneously decelerating it, and a horizontal portion also adapted to decelerate the flow, and said elbow formation being so proportioned that the rate of increase of the cross sectional area of the draft tube is lowered when passing around said elbow formation and is subsequently increased in the horizontal portion.

11. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion when cut by a transverse plane substantially normal to the flow presenting a surface curved to provide a ridge of greater length than its greatest width.

12. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion when cut by a transverse plane substantially normal to the flow presenting a convex surface disposed so as to provide a ridge of greater length than its greatest width and extending in a downstream direction to the terminus of said outlet.

13. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion having floor and roof surfaces, one of which when cut by planes normal to the flow being convex to provide a ridge and the other surface being concave.

14. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion when cut by a transverse plane substantially normal to the flow presenting a ridge disposed centrally and extending longitudinally of said outlet portion, said ridge in the direction of flow having substantially straight lines for the major portion of its length.

15. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion having a ridge between its sides extending longitudinally to the terminus of said outlet to which point the ridge is substantially fully maintained.

16. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion having a floor provided with a longitudinally extending ridge.

17. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion having a floor provided with a longitudinally extending ridge disposed along the center axis of the floor.

18. A draft tube of generally elbow formation comprising inlet and outlet portions, said outlet portion having a floor provided with a longitudinally extending ridge disposed along the center axis of the floor, said ridge in longitudinal section having substantially a straight line for the major portion of its length and extending to the terminus of the outlet.

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