Dec. 4, 1923. 1,476,210

L. F. MOODY

HYDRAULIC PUMP

Filed Sept. 8, 1920 4 Sheets-Sheet 1

Fig:1.

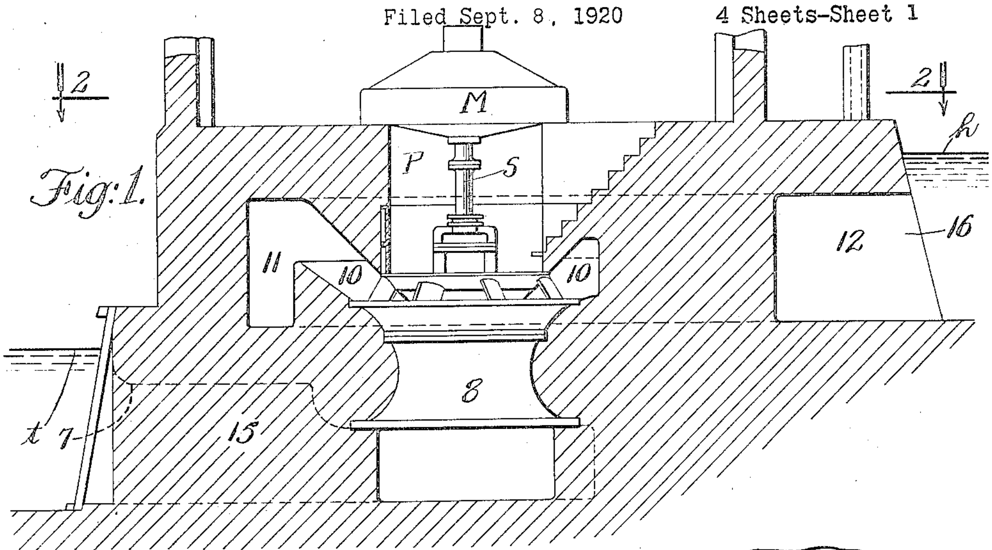
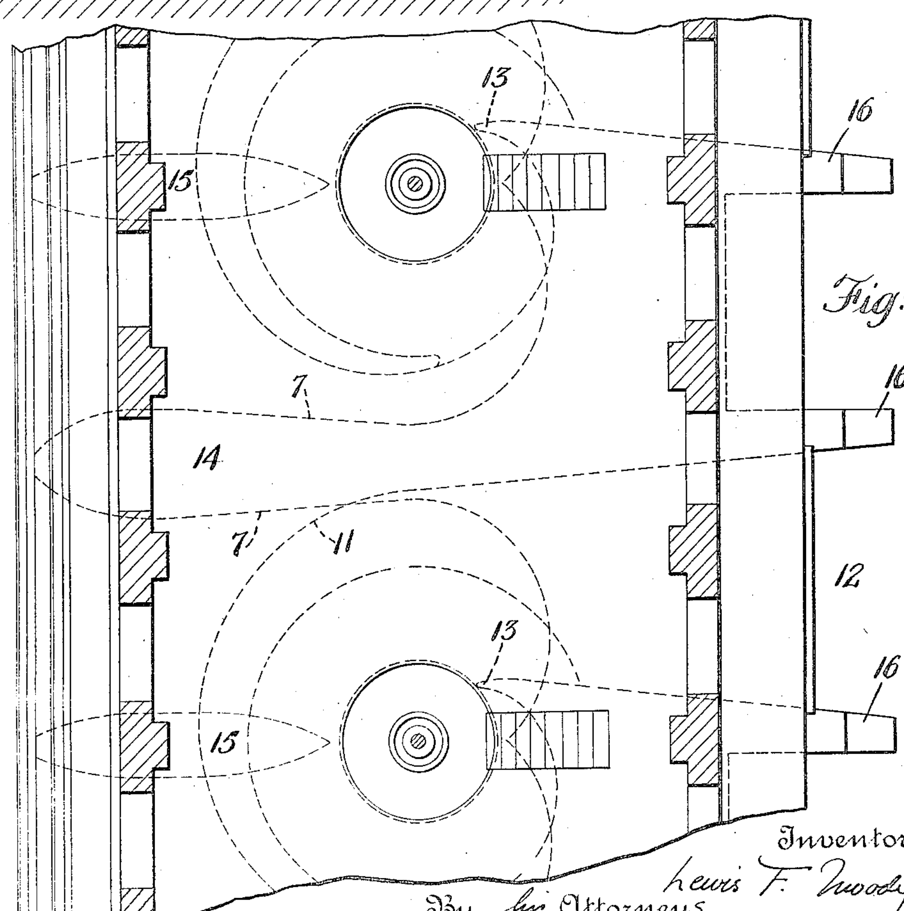



Fig:2.

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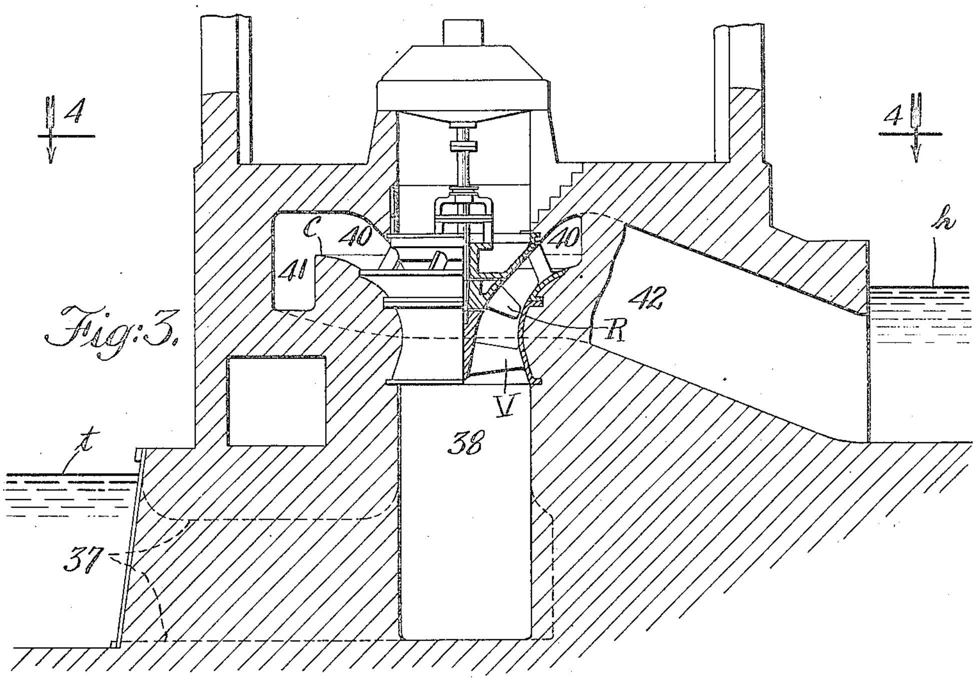


Fig:3.

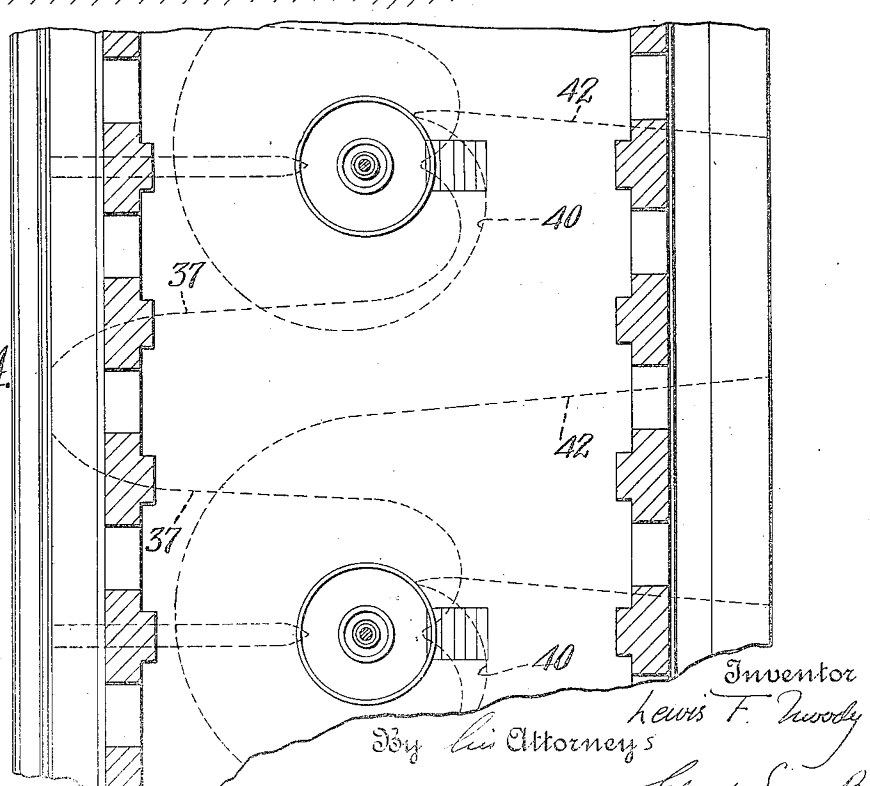


Fig:4.

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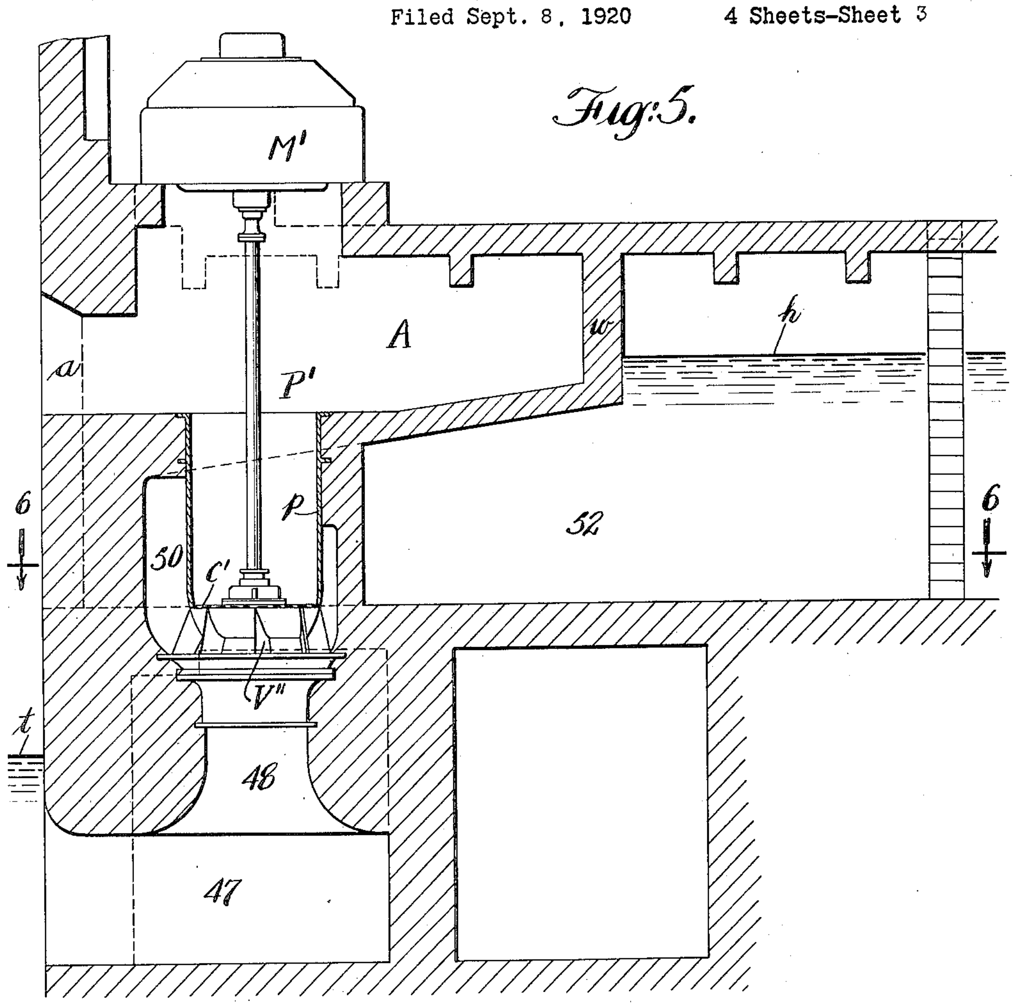


Fig:5.

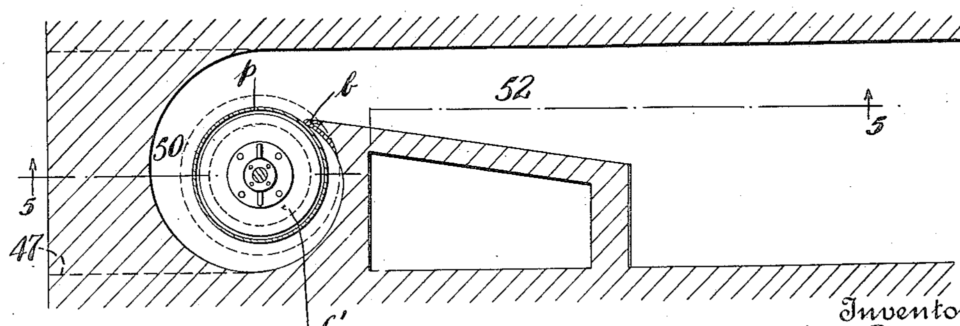


Fig:6.

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Fig: 7.

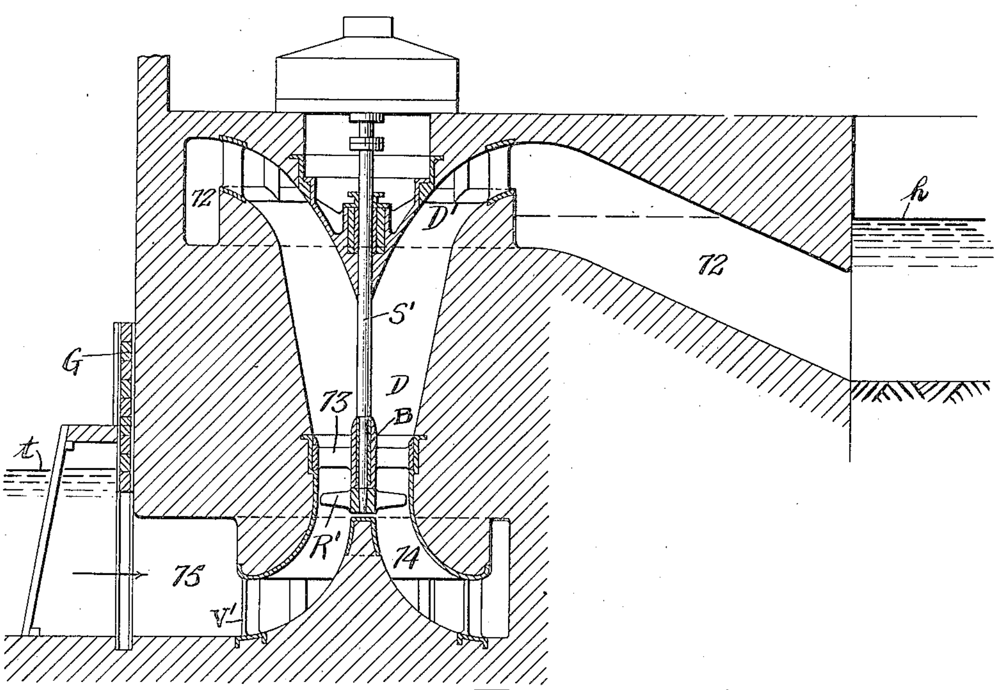
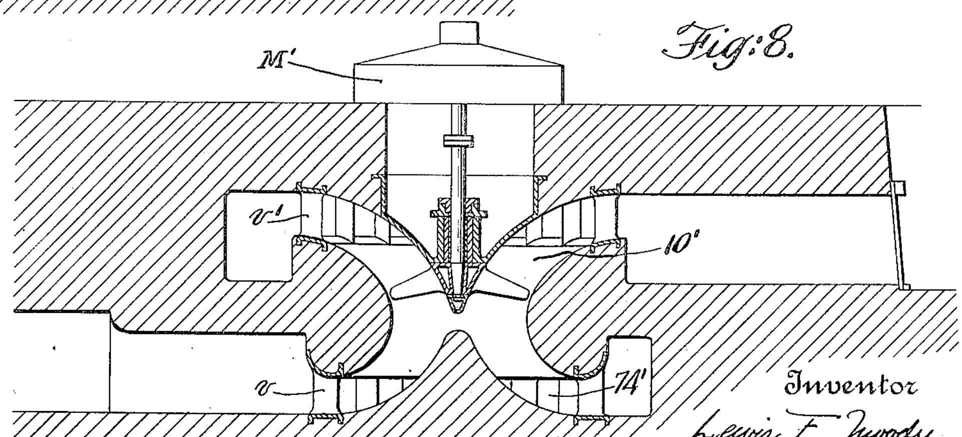



Fig: 8.

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Patented Dec. 4, 1923. 1,476,210

# UNITED STATES PATENT OFFICE.

LEWIS FERRY MOODY, OF PHILADELPHIA, PENNSYLVANIA.

## HYDRAULIC PUMP.

Application filed September 8, 1920. Serial No. 408,928.

*To all whom it may concern:*

Be it known that I, LEWIS FERRY MOODY, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Hydraulic Pumps, of which the following is a specification.

This invention relates to hydraulic pumps and particularly to vertical shaft pumps having a rotary impeller of the unshrouded axial or diagonal flow type, and especially to such a pump when arranged to form one of a series of pump station units. The chief object of the invention is to provide such a pump of simple and efficient form and having a diffuser adapted to accommodate the whirling outflow from the pump impeller and to guide it out along a smooth expanding path.

Other objects of the invention, especially in the pump setting and the formation of a station sub-structure to contain the pump and water passages, will appear in the following specification taken in connection with the accompanying drawings, in which,

Fig. 1 is a vertical sectional view of one embodiment of the invention.

Fig. 2 is a section on line 2—2 of Fig. 1.

Figs. 3 and 5 are vertical sectional views of modifications, the latter being taken on the line 5—5 of Fig. 6.

Figs. 4 and 6 are sections taken on lines 4—4 and 6—6 of Figs. 3 and 5 respectively, and

Figs. 7 and 8 are vertical sectional views of further modifications.

In the specific embodiment of the invention shown in Figs. 1 and 2 a motor M on the pump station floor drives the pump impeller by shaft S extending down through the pit P. The pump receives its supply from the lower level *t* through intake passage 7 and vertical intake chamber 8 which is of general circular formation coaxial with the pump impeller. This intake chamber begins to diverge slightly in advance of the runner and its walls merge into a spreading diffuser 10 receiving the discharge from the pump and passing it on expanding lines to the spiral diffuser 11 and discharge outlet 12, the baffle 13 intervening between the outlet 12 and the spreading and spiral diffusers as shown. The passages 7, 8, 10, 11 and 12 are preferably formed in the pump station sub-structure with piers 14 intervening between successive intake passages 7 of a series and piers 15 interposed at the middle of each of said passages. Similarly a pair of piers 16 intervene between successive outlets 12 giving a very strong construction.

The impeller which is similar to that shown at R in Fig. 3 is of the diagonal outward flow type and the pit P between the impeller head cover and station floor gives access to the movable parts. The intake passage 7 is of the double spiral type leading the water from each portion to the inlet chamber 8. In this chamber the cross section of the flow contracts and the flow passes through the impeller diagonally outward being discharged into the spreading diffuser 10 with a large component of whirl around the impeller axis. In this diffuser the discharge is free to expand along spiral lines with continuous increase in cross section so that all components of the flow are evenly decelerated and their velocity head reconverted into pressure head. By the time the flow reaches the spiral diffuser 11 its velocity is considerably reduced and in this diffuser the flow lines are gathered into a stream progressing along expanding volute lines to the discharge outlet 12. The spreading diffuser 10 may discharge either into a spiral diffuser or merely a simplified form of chamber having a circular end wall. The end of the intake 7 may also be circular; both intake and discharge passages may be made to approximate spirals by making them eccentric.

In the embodiment of the invention illustrated in Figs. 3 and 4 the sub-structure is shown of greater vertical dimensions than in Figs. 1 and 2. The intake passage 37 leads to the vertical inlet chamber 38 first contracting and then diverging to turn into the spreading diffuser 40 at the discharge from impeller R. Guide vanes V in the inlet chamber are inclined to give a whirl to the entering flow. The spiral diffuser 41 passes the flow from impeller R to the outlet 42. In this modification the crest C between the spreading and spiral diffusers is at a higher elevation than the discharge water level *h* and the spiral diffuser 41 and outlet 42 are inclined downward in the direction of discharge to empty below the level *h*. With this construction the discharge passages are siphonic so that the impeller spaces may be emptied and the impeller removed without the use of gates in the discharge. It also becomes possible by this arrangement to start the pump at low torque by first running the impeller in air and then priming it after starting by the use of an ejector. This method of starting is sometimes desirable when certain types of motor are used for driving the pump.

In the modification illustrated in Figs. 5 and 6 the motor M′ is placed on a station floor above the surface of the discharge. The pump pit P′ terminates below this floor and leaves above a space A open at *a* and closed to the discharge by end wall *w* and the walls surrounding the outlet passage 52. The pit liner *p* extends downward from the space A to the cover plate *c′* and stay vane ring V″. The intake passage 47 leads the flow to the inlet chamber 48 contracting and then diverging at its upper end as the flow approaches the impeller. The diffuser 50 is in the form of a spiral or volute expanding along and wrapping around the pit liner *p*. This diffuser increases progressively in radial width from its baffle *b* around toward the outlet 52 and also increases in vertical length so that the flow both expands and progresses axially and all the outflow lines are gathered together and discharged into the outlet 52. The whirling discharge lines will therefore be free to follow along naturally expanding spiral paths and will only be turned slightly and gradually into the axial direction. This form of diffuser permits of very close spacing of the pump units with all their outlets 52 parallel to each other, and the concrete structure is simple and easily molded. At the same time plenty of space is provided for access to the moving parts through the pit P′ and all the turbine elements are compactly arranged.

Fig. 7 shows another modification, involving some of the special features of the pump of Figs. 3 and 4 and introducing other innovations not shown in any of the previous figures. In this arrangement the station substructure is of considerable height, as with the pump of Figs. 3 and 4, and the discharge 72 is siphonic, as in the previous case. The pump of Fig. 7, however, has a modification to adapt it for very high specific speed and for operation under a moderate or fairly high head. This consists in the location of the impeller R′ at a low point in the substructure, instead of as in Fig. 3; in the arrangement of Fig. 7 the impeller is shown at an elevation even lower than the tailwater surface *t*. To provide a compact construction with reduced axial dimensions the intake passage 75 surrounds the inlet chamber 74 and has its upper wall in a substantially radial plane nearer to the impeller than is the plane of the intake of said inlet chamber. By this disposition of the impeller, it operates upon water having a greater absolute head, and the velocity head of the water entering the impeller can be greatly increased without reducing the absolute pressure head to a value unduly close to an absolute vacuum. This increase in velocity of the water permits a corresponding increase in the rotational speed of the impeller. In order to regain the high velocity head of the water discharged from the impeller a long vertical diffuser D is provided, terminating above the level of the headwater *h* in a spreading diffuser D′ as in Fig. 3. The impeller shaft S′ is laterally supported just above the impeller by a bearing B which may be of the lignum vitæ type, carried by transverse stay vanes 73 which are so shaped in cross-section as to conform to the flow of the water and to avoid introducing disturbances in the flow. These vanes are therefore provided for mechanical rather than hydraulic reasons. Tail gates G may be provided at the entrance to the intake passage, to permit the impeller to be unwatered for inspection or repair.

The impeller R′ shown in Fig. 7 is of the axial flow type; it should be understood however that this type of impeller could also be used instead of a diagonal-flow impeller in the other embodiments of the invention shown in the other figures.

Another modification shown in Fig. 7 which could be equally well applied to any of the pumps of the other figures, and which is not limited to the particular pump here shown, is the form of water passage 74 between the intake chamber 75 and the impeller R′. In general, it is proposed to use in the pumps of this invention stationary guide vanes in the entrance passage leading to the impeller as at V in Fig. 3; although these vanes may sometimes be omitted where special pump characteristics are desired, and where a sacrifice of efficiency is permissible. Fig. 7 shows a way of obtaining a modification of the pump characteristics without omitting the guide vanes or reducing the efficiency.

The method of modifying the pump characteristics consists in changing the arrangements of the entrance vanes relatively to the impeller. By this means the pump may be adapted to various requirements. With a moderate size of transition space between the entrance vanes and impeller, the pump has steeply rising curves of head and power when plotted against discharge; that is, the head and power increase rapidly when the discharge decreases—this characteristic partaking (to a less degree) of the properties of a positive-displacement pump—that is, the pump endeavors to maintain its discharge against an increased head. This characteristic is desirable under some conditions; but under others it is objectionable, for example, when it is necessary to operate the pump against a closed valve, requiring increased motor capacity. By modifying the design, the power required to operate the pump against a closed valve can be reduced. With a given impeller design, this can be accomplished to some extent by increasing the distance between the discharge edges of the entrance vanes, and the entrance edges of the impeller vanes, thus enlarging the transition space. A modification for obtaining a greater reduction of the shut-down power is shown in Fig. 7. The pump of Fig. 7 is arranged for a setting similar to that of Fig. 1; but instead of having entrance vanes only a moderate distance from the impeller (see Fig. 3) these vanes V′ are placed at the entrance to a long transition space 74 in which during normal operation of the pump the flow after leaving the entrance vanes V′ turns from radial to axial, at the same time continuing to whirl due to the diagonal direction given by the entrance vanes. As the radius of the space 74 decreases in approaching the runner the velocity of whirl will increase due to the principle of constancy of moment of momentum, and by properly inclining the entrance vanes V′ this velocity of whirl at the runner entrance can be made suitable for the runner, to give the highest obtainable efficiency. At the same time, this design will reduce the power under shut-down conditions.

Under these conditions there will be no continuous flow through the entrance vanes into the transition space, and the water within this space will not receive its direction of motion from the entrance vanes. Instead, the water in this space will receive a high degree of whirl from the impact of the impeller vanes; but by the time this whirl reaches the entrance vanes it will be reduced in the inverse ratio of the radii, and the impact on the entrance vanes will be greatly reduced by their being located at a greater distance from the axis. Another advantage of this design, when the loads carried by the substructure require it, is that the entrance vanes can be utilized to act as columns or stays to support the superposed portions of the structure.

The hydraulic action within this inflow chamber when the pump is operating at zero discharge is similar in some respects to the action in a turbine draft tube. By giving the chamber a form somewhat similar to that of a spreading draft tube the whirl in the contained water, originating at the impeller, is greatly diminished by the time it reaches the guide vanes and creates little disturbance by impinging on them. At the same time, the guide vanes can be given the proper angle of discharge to enable high efficiency to be secured during operation of the pump at normal discharge.

As mentioned above, the intake passage shown in Figure 7 can be used with any of the other pumps previously described herein. If this type of intake passage is combined with a pump having a spreading diffuser such as the pump shown in Figure 1 the combination will provide a pump having entrance and discharge passages of the same general form as illustrated in Fig. 8. If the entrance passage 74′ is so designed that the velocity is accelerated at a sufficiently gradual rate it will become possible to allow the pump to operate with reversed flow, the entrance passage then becoming a diffuser or draft tube and the machine operating as a turbine rather than a pump. Such a design would therefore produce a pump capable of storing water in a reservoir and, when desired, utilizing the stored water to generate mechanical power by flowing through the machine in a reverse direction and driving the impeller or runner in the opposite direction of rotation to drive the motor M′ as a generator. The pump being so designed that the original entrance passage may become an efficient diffuser or draft tube, and the original diffuser 10′ may become a well formed entrance passage, it is particularly well suited for such a purpose and it may be designed to produce the regenerative action described without material sacrifice of efficiency either when operating as a pump or turbine. In connection with Fig. 8 it should be noted that the passage containing the runner is molded directly in the concrete without a metal casing, a construction which can be used with any of the pumps described herein. The pump of Fig. 8 preferably will have radial flow guide vanes $v$ at the entrance to the converging intake passage and stay vanes $v'$ at the discharge from the diverging diffuser, these two sets of vanes being similar in form and similarly located. When the direction of flow is reversed the stay vanes $v'$ at the discharge of the diffuser will become guide vanes in what will then be the entrance. Since both the directions of whirl and radial flow are reversed the direction and form of the vanes will still be correct for the reversed flow.

The pump units of this invention have a simple, symmetrical design utilizing a maximum part of their allotted space for the water passages and at the same time providing continuous supporting piers at short intervals. This gives a close spacing and economical structure. The spreading diffuser receiving and guiding the discharge on naturally expanding lines decelerates the whirling stream effectively in advance of the volute collection chamber in which the flow lines are gathered in a single expanding spiral stream. The regaining of the velocity head as pressure head is thus made gradual and efficient without abrupt changes of direction or losses by eddies and disturbances. At the same time the water passage walls are not complicated in shape but follow simple geometric shapes quite easy to construct.

I claim:

1. In a hydraulic pump the combination with a vertical shaft pump impeller, of a pit surrounding said shaft above said impeller and a spreading diffuser passage adapted to gradually decelerate the outflow surrounding said pit and receiving the discharge from said impeller.

2. In a hydraulic pump station a series of pump units each comprising the combination with a vertical shaft pump impeller, of a pit surrounding said shaft above said impeller and a spreading diffuser passage adapted to gradually decelerate the outflow surrounding said pit and receiving the discharge from said impeller.

3. In a hydraulic pump the combination with a pump impeller, of a pit surrounding the impeller shaft, an inlet chamber coaxial with said pit, and an intake passage extending at right angles to said inlet chamber.

4. In a hydraulic pump the combination with a vertical shaft pump impeller, of a discharge diffuser therefor having a crest above the level of the water into which the pump is discharging so as to form a siphon permitting the impeller passages to be emptied without shutting off the discharge passages.

5. In a hydraulic pump the combination with a vertical shaft impeller, of a diffuser receiving the discharge therefrom and a downwardly inclined outflow passage receiving the flow from said diffuser and leading it to a level below the top of the lower wall of said diffuser.

6. In a hydraulic pump the combination with a vertical shaft pump impeller, of a diffuser receiving the discharge therefrom, an expanding volute passage receiving the outflow from said diffuser and a downwardly expanding outlet leading the flow to a level below the highest level of the lower wall of said diffuser.

7. In a hydraulic pump the combination with a vertical shaft pump impeller adapted to be placed above the level of the discharge reservoir, of a diffuser receiving the discharge from said impeller and an outlet passage receiving the flow from said diffuser and inclined downward and open below the level of said discharge.

8. In a hydraulic pump the combination with a pump impeller, of a pit surrounding the shaft of said impeller and having a pit liner casing, and a diffuser receiving the discharge from said impeller and having its inner wall formed by said casing.

9. In a hydraulic pump the combination with a vertical shaft pump impeller of substantially axial flow type, of an expanding diffuser receiving the discharge therefrom and extending substantially from tail water to head water level.

10. In a hydraulic pump the combination with a vertical shaft pump impeller, of an intake means therefor comprising means for imparting an initial whirl to the flow and intermediate means for increasing said whirl comprising a converging vane-free passage.

11. In a hydraulic pump the combination with a vertical shaft pump impeller, of an intake means therefor comprising means for imparting an initial whirl to the flow and intermediate means for increasing said whirl comprising a converging vane-free passage, and an expanding diffuser receiving the discharge from said impeller.

12. In a hydraulic pump the combination with a vertical shaft pump impeller, of an intake means therefor comprising means for imparting an initial whirl to the flow and intermediate means for increasing said whirl, and an expanding diffuser receiving the discharge from said impeller and extending substantially from tail water to head water level.

13. In a hydraulic pump the combination with a vertical shaft pump impeller, of an intake means therefor comprising means for imparting an initial whirl to the flow and intermediate means for increasing said whirl comprising a converging vane-free passage contained between two concentric surfaces of revolution.

14. A turbine of the type which employs an impeller and guide vanes in the inlet passage thereto for the purpose of imparting a whirl to the flow, characterized by the fact that the increase in power with decreased discharge is lessened due to the presence of a vane free passage of substantial length between the impeller and guide vanes.

15. A hydraulic machine having a discharge passage comprising an upwardly directed straight conical portion, a curved flaring portion in communication therewith at one end and opening in all directions in a plane at the other end and a downwardly inclined portion in communication with said flaring portion.

16. A hydraulic machine having a discharge passage comprising an upwardly directed straight conical portion, a curved flaring portion in communication therewith at one end and opening in all directions in a plane at the other end and a downwardly inclined portion in communication with said flaring portion and guide vanes at the outlet of said flaring portion.

17. A hydraulic pump having a long diffuser passage rising vertically from the runner and an outlet passage therefrom descending toward the head water.

18. In a hydraulic machine a runner hav-

ing a shaft, means forming a radially expanding diffusing chamber extending from said runner, a bearing for said shaft having a conical external surface located centrally of said diffusing chamber and serving to guide the flow from an axial to a radial direction.

19. In a hydraulic pump the combination with a substantially axial flow impeller, of an annular entrance passage contained between inner and outer surfaces of revolution guiding the flow to the impeller, and a diffuser receiving the flow axially from the impeller and comprising an axially directed conical passage.

20. In a hydraulic pump the combination with an impeller, of an annular entrance passage contained between inner and outer surfaces of revolution guiding the flow to the impeller, a diffuser receiving the flow from the impeller and comprising a conical expanding passage, an impeller shaft bearing on the discharge side of the impeller and stay vanes supporting said bearing.

21. In a hydraulic pump the combination with an impeller of an entrance conduit for the flow to said impeller comprising an inlet chamber coaxial with the impeller and comprising inner and outer flared walls formed as surfaces of revolution, and an intake passage surrounding the annular entrance to said inlet chamber and leading the flow thereto, said intake passage having its upper wall in a substantially radial plane which is nearer to the impeller than is the plane of the entrance of said inlet chamber.

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