

March 1, 1966

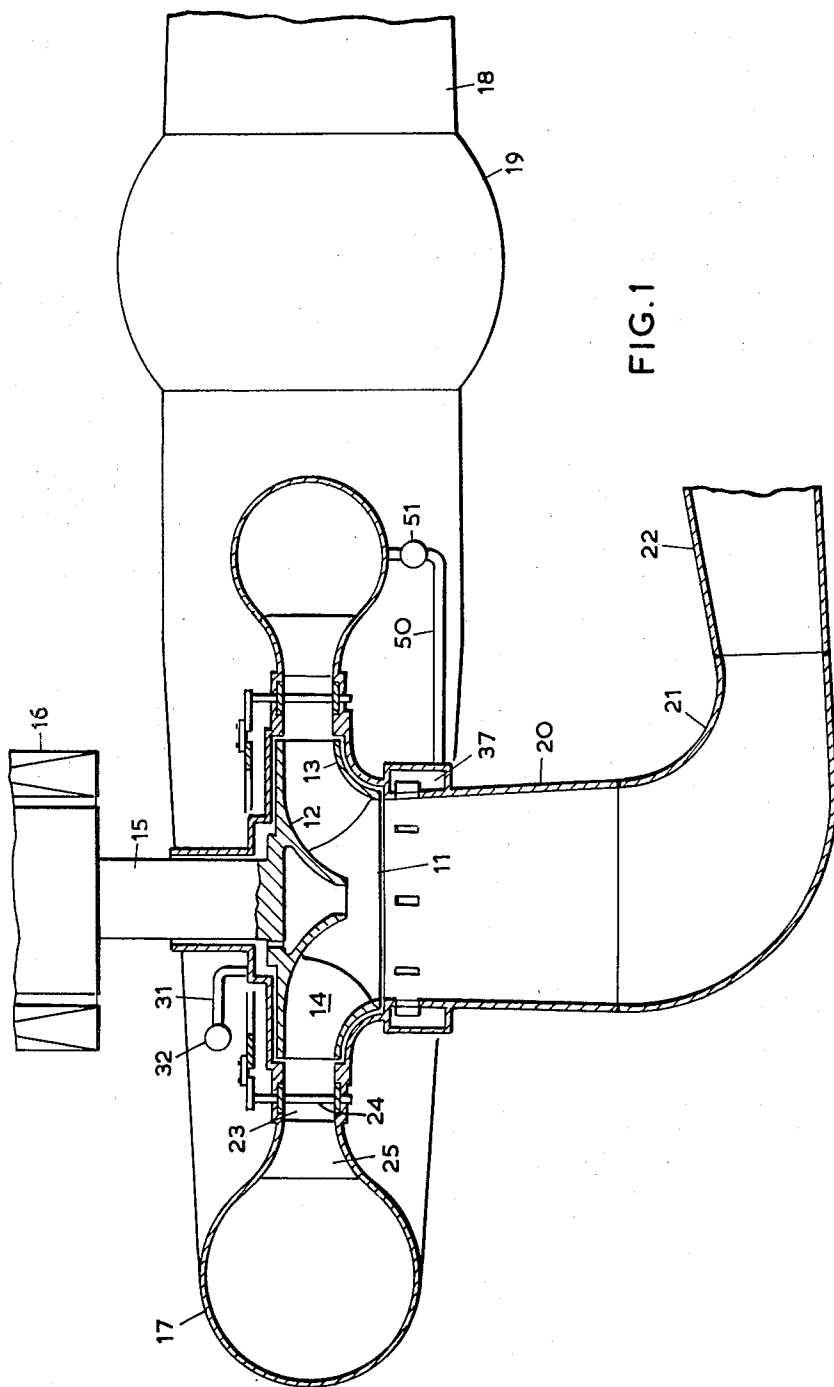
D. HARTLAND

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HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

Filed Oct. 7, 1963

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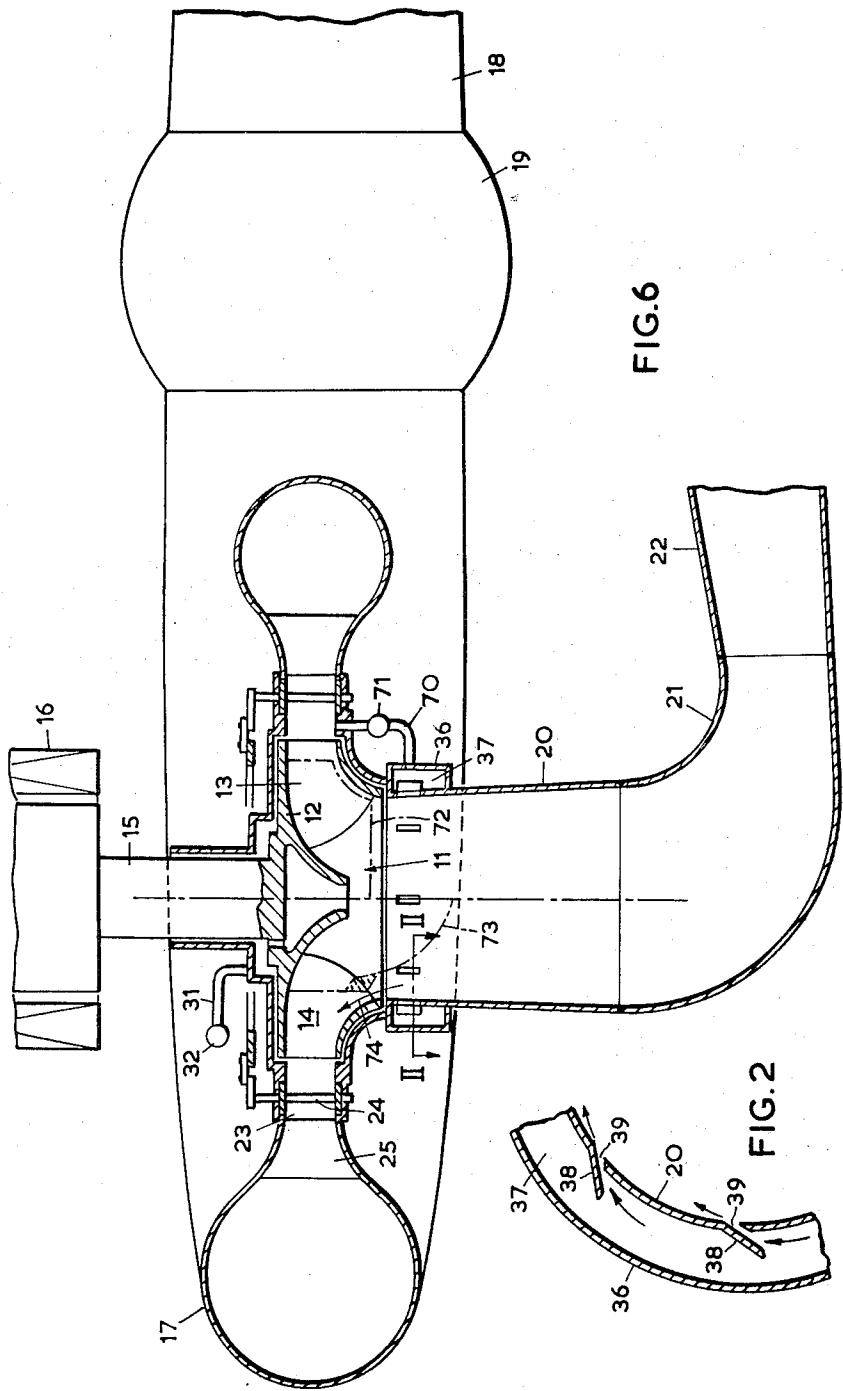
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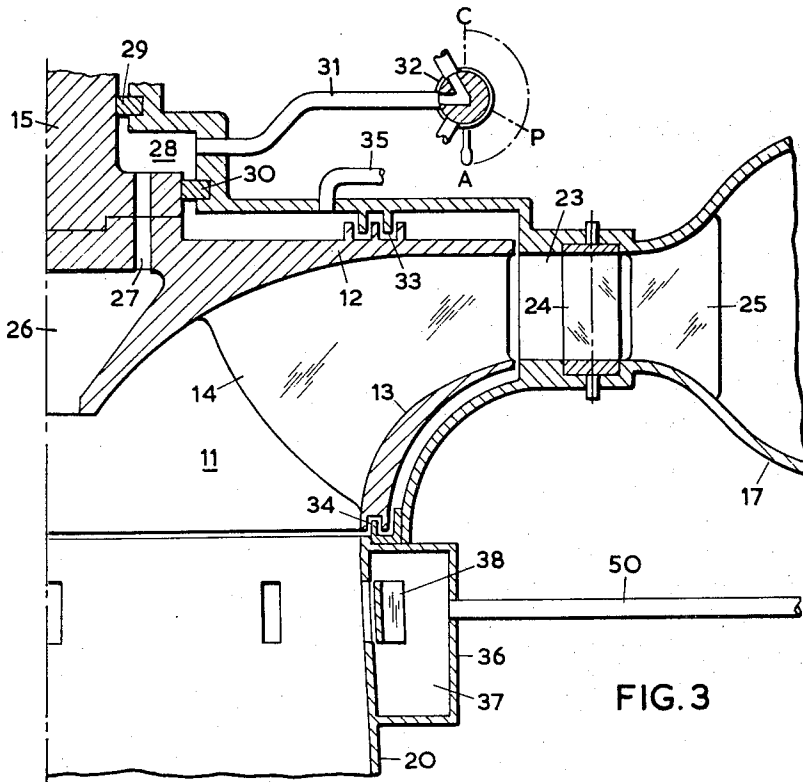


FIG. 3

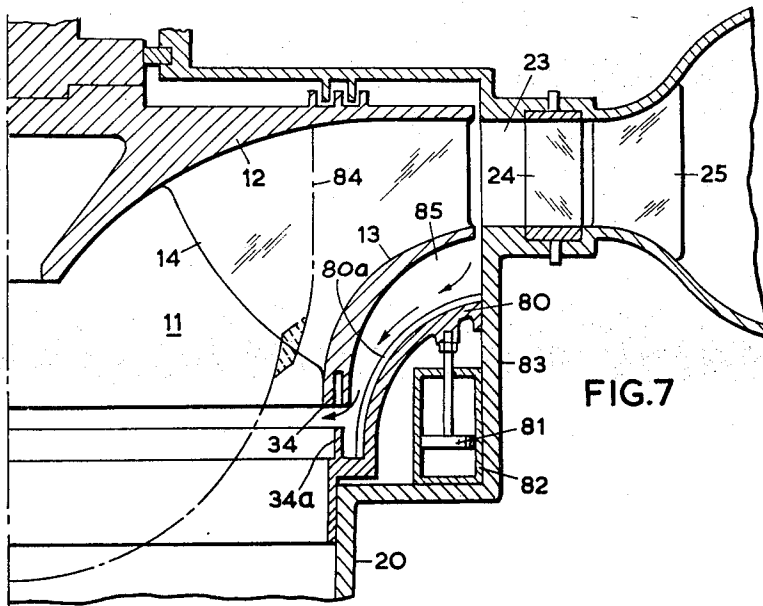


FIG. 7

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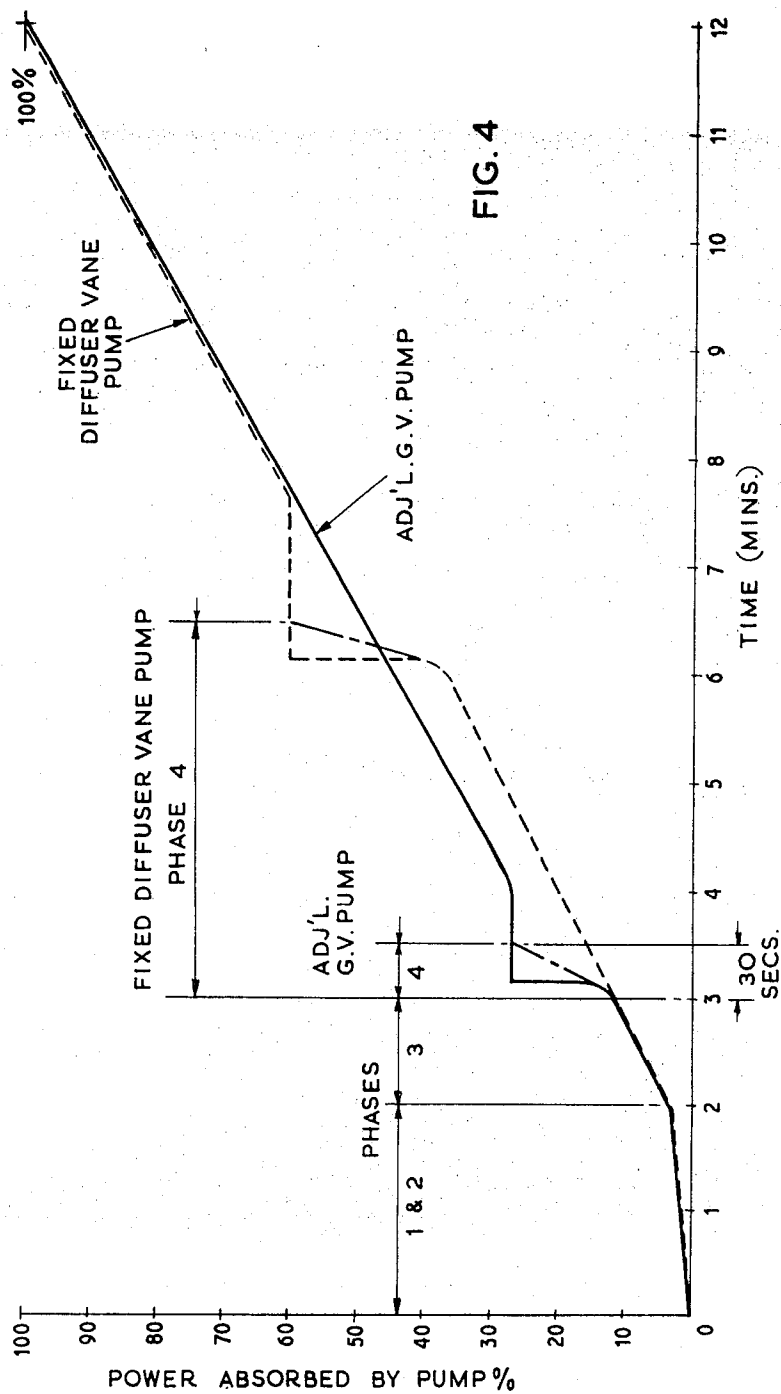
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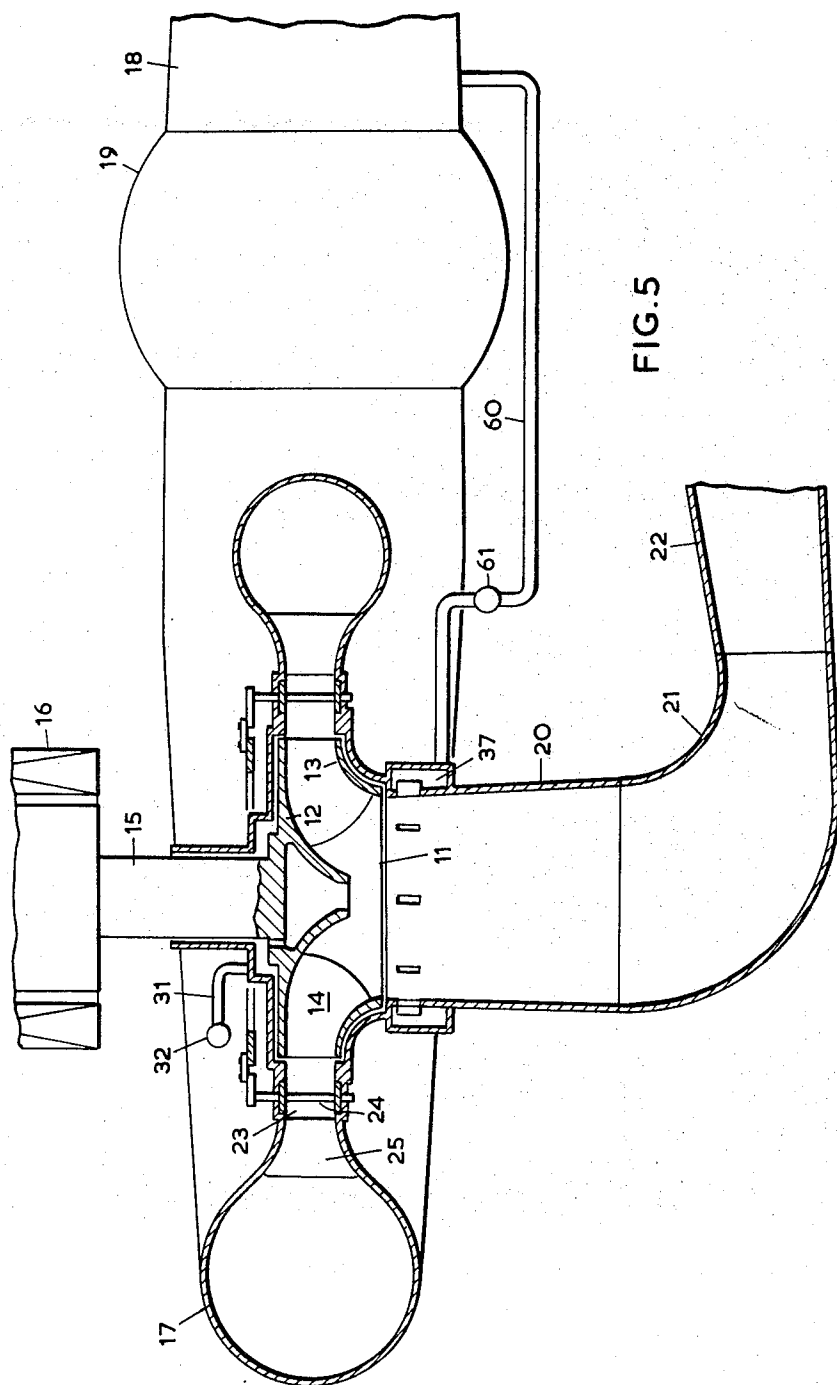
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HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

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9 Claims. (Cl. 103—113)

This invention relates to hydraulic pumps and reversible pump turbines.

According to this invention, a hydraulic pump or reversible pump turbine includes means for injecting water into the draft tube with a substantial tangential component adjacent the wall of the suction tube below and adjacent to the impeller of the pump or reversible pump turbine, so as to generate a vortex having a substantial peripheral velocity, during priming of the pump, or of the reversible pump turbine in operation as a pump.

A number of embodiments of the invention will now be described by way of example, with reference to the accompanying drawings, of which:

FIG. 1 shows generally a first embodiment of hydraulic pump or reversible pump turbine in accordance with the invention;

FIGS. 2 and 3 show details of the arrangement of FIG. 1 on a larger scale;

FIG. 4 is a graph plotting power absorbed against time;

FIG. 5 shows another embodiment of hydraulic pump or reversible pump turbine in accordance with the invention;

FIG. 6 shows a further modification of hydraulic pump or reversible pump turbine in accordance with the invention; and

FIG. 7 shows yet another modification, on a larger scale than FIG. 1.

Referring to FIGS. 1, 2 and 3, a large hydraulic pump, i.e., a pump having an input power greater than one megawatt, includes an impeller 11 having a crown 12 and skirt 13 inter-connected by vanes 14. The pump also includes a shaft 15, through which the impeller is driven by a motor 16. The stationary structure of the pump includes a spiral casing 17, which surrounds the impeller and is connected to a delivery pipe 18 incorporating a valve 19. The delivery pipe is connected to a reservoir (not shown) to which water is to be delivered during pump operation.

Immediately below the eye of the impeller 11 is provided a suction tube 20 vertically below and symmetrical with the impeller. At the lower end of the suction tube there is provided an inlet bend tube 21 which communicates through a passage 22 with a lower reservoir (not shown) from which water is to be pumped.

The passage 23 surrounding the impeller 11 may be provided with adjustable guide vanes 24 and a ring of fixed vanes 25 as shown, through which water is delivered by the impeller 11 into the spiral casing 17, or alternatively in certain cases only a ring of fixed diffuser vanes may be provided.

As shown in FIG. 3, the centre of the crown 12 is formed with a cavity 26 connected by a bore 27 with an annular space 28 between the stationary structure and the rotating parts of the pump, sealing rings 29, 30 between the stationary structure and the rotating parts being provided at the top and bottom of the space 28. The space may either be vented to atmosphere (or, where the suction tube is at sub-atmospheric pressure, to a vacuum chamber) through a bore 31 and valve 32, or may be connected to a source of compressed air or alternatively may be closed off.

A labyrinth seal 33 is provided between the crown 12

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and the stationary structure, and a further labyrinth seal 34 is provided between the skirt 13 and the stationary structure at the top of the suction tube 20. A drain pipe 35 is provided between the sealing ring 30 and the labyrinth seal 33 through which any leakage is drained off.

Immediately below the eye of the impeller 11 there is provided an annular structure 36 defining a chamber 37 surrounding the suction tube 20, and the suction tube wall is provided with baffles 38 defining slots 39 opening to the interior of the suction tube.

Instead of the elongated slots 39, there may be provided circular or other orifices, and instead of the annular chamber 37 there may be a series of short circumferential chambers, or the slots or orifices may be fed direct from pipes connected for example to a manifold. A single orifice of appropriate size and supplied with water of the appropriate head would be adequate.

In this embodiment a pipe 50 is connected to a source of water under pressure, such as may be afforded by the spiral casing 17, and is connected at its other end to the chamber 37. A valve 51 is provided in the pipe 50.

In starting operation of a pump or of a reversible pump turbine in the pumping sense, the impeller 11 is first accelerated by any known or convenient means such as an auxiliary motor from rest to synchronous speed in air, the water being depressed down the suction tube by the introduction of compressed air through pipe 31. A small amount of water may be admitted to the impeller seals during this phase, to reduce the risk of the fine clearances, with which the impeller runs, being taken up and seizing occurring. The valve 19 is closed, and the adjustable guide vanes 24 are in the closed position (as shown in FIG. 1) at this stage. The method of operation described with relation to the first embodiment is probably impractical in machines only fitted with fixed diffuser vanes.

Then at synchronous speed the motor 16 is connected to the power supply, e.g., to the grid, and synchronised and the auxiliary motor may be disconnected.

The power absorbed in these two phases rises from zero to about 3 percent of the normal full load, and they may be completed, for example, in two minutes (see FIG. 4).

In FIG. 4 the full line represents the starting of a pump fitted with adjustable guide vanes 24, which are closed during this period, and the dotted line represents the starting of a pump having only the fixed diffuser vanes 25.

The valve 19 is then opened to allow pressure water from the delivery pipe 18 into the spiral casing 17, the adjustable guide vanes 24 remaining shut. The valve 51 is then opened partially and slowing to allow pressure water into chamber 37 to produce a vortex in the suction tube 20. Some of the water, which owing to the centrifugal effect tends to remain against the wall of the suction tube 20, will travel downwards and some upwards into the passages between the vanes 14 of the impeller 11, and in this way the impeller will be slowly filled and the motor 16 will slowly take on load (phase 3, FIG. 4). Some of the water in the impeller leaks from the periphery through the space between the skirt 13 and the casing, and through seal 34, into the suction tube 20, but additional water is continuously flowing in from chamber 37.

Valve 51 is then fully opened, and the remaining air is allowed to escape in a controlled manner from the suction tube 20 through cavity 26, bore 27, bore 31 and valve 32. By this means additional load is taken on by the motor 16 relatively slowly (phase 4, FIG. 4).

This phase has hitherto produced a sudden rise in the power absorbed, caused by a rapid change in the flow regime in the suction tube. Once this phase was initiated, it was extremely difficult to arrest or reverse. Hitherto this sudden change, caused by circulation of

the water both circumferentially and axially of the suction tube, has caused the power absorbed to rise from about 17 percent to about 27 percent of normal full load for pumps with adjustable guide vanes, and from about 40 percent to about 60 percent for pumps with fixed guide vanes, in a fraction of a second (see FIG. 4).

By forming the rapidly rotating vortex, as described above, the air may be exhausted slowly through pipe 31 and the impeller filled without causing a sudden rise in the power which must be supplied by the motor 16. This is because the vortex generated by the jets of water issuing from chamber 37 artificially produces the final flow regime and there can be no sudden change which requires energy to be supplied by the motor 16. The air from the centre of the suction tube can be exhausted at a slow, controlled rate, and the motor will take on load at a steady rate. Moreover the energy required to maintain the vortex is derived from the supply of water from the delivery pipe 18, flowing through valve 19, spiral casing 17, and pipe 50, rather than being derived entirely from the impeller, as hitherto.

When all the air has been exhausted from the impeller 11, the valve 51 may be progressively closed, so that the load on the motor is gradually further increased.

Finally, in the fifth phase, the adjustable guide vanes 24 are gradually opened so that the power absorbed is increased in a controllable manner up to full load.

The valve 51 is closed for normal operation.

Referring now to FIG. 5, there is shown a modification of the arrangement of FIGS. 1-3 in which instead of pipe 50 and valve 51, there is provided a pipe 60 fitted with a valve 61, leading from the delivery pipe 18 to the chamber 37. This modification is suitable both for machines with adjustable guide vanes 24 and for machines having only fixed diffuser vanes 25.

The operation in this case is the same as described above except that it is not necessary to open valve 19 to allow pressure water into chamber 37, but valve 61 is operated as described for valve 51. The valve 19 need not be opened until the end of the fifth phase.

Referring now to FIG. 6, there is shown a further modification of the arrangement of FIGS. 1-3; in the modification intended for use with machines having adjustable guide vanes 24 there is provided a pipe 70 fitted with a valve 71, as shown; however in machines having only the fixed diffuser vanes 25 there may be provided a pipe 50 connected to the casing 17 and fitted with a valve 51, as shown in FIG. 1. (The latter arrangement is identical with that described with relation to FIGS. 1-3 except for the omission of the guide vanes, but the operation is different.)

In this illustrated modification, the impeller 11 is accelerated in air and the motor 16 synchronized, as described above, the valve 19 being shut.

Air is gradually released from the suction tube through pipe 31, allowing the water level in the suction tube 20 to rise slowly into the impeller inlet. The water picked up by the vanes 14 is centrifuged to the outer periphery and displaces the air in the impeller radially inward. The air/water boundary in the initial stage is shown by the chain-dashed line 72 (right-hand side of FIG. 6). The valve 71 (or 51 as appropriate) is then opened so that pressure water from the impeller periphery or from the spiral casing passes through the pipe into chamber 37, emerging through slots 39 into the suction tube 20 and imparting a rotational velocity to the water in the suction tube. This causes a vortex as shown approximately by the chain-dashed line 73 (left-hand side of FIG. 6). As the radial extent of the filling of the impeller increases, so that pressure increases at the inlet of pipe 70 (or 50) and the vortex is intensified. The water also circulates in the direction shown by arrow 74.

As further air is exhausted through pipe 31 the vortex is further intensified, and after completion of the escape of air, the adjustable guide vanes 24 (or in pumps with

only fixed diffuser vanes 25, the delivery valve 19) are gradually opened so that the power absorbed is increased in a controllable manner up to full load, as described above.

Instead of pipe 70 and valve 71, in yet another alternative, shown in FIG. 7, the means for injecting water into the suction tube 20 may be provided by arranging for the part of the stationary casing including part 34a of the lower runner seal 34 to be made retractable with a short downward stroke, providing a path for pressure water from the passage 23 to the suction tube 20. A number of small fixed vanes 80a set at an angle (as described in relation to baffles 38) on the retractable member 80 impart the required swirl to this water.

The retractable element 80 may be annular, as shown, and may be retracted by means of pistons 81 set in a series of cylinders 82 within the outer stationary casing 83 which forms a pressure-retaining wall.

Operation in this case is substantially as described with reference to FIG. 6, except that instead of opening valve 71 the element 80 is moved down. The air/water boundary 84 shown corresponds to that at 73 in FIG. 6. In this condition a large pressure difference exists between passage 23 and suction tube 20, and water flows as indicated by the arrows. The circumferential velocity of water entering the passage 85 between the skirt 13 and element 80 from passage 23 is almost equal to the circumferential velocity at exit from the impeller. This velocity will increase at exit from passage 85 proportionally to the decrease in radius of the vortex, and thus a very intense vortex may be set up in the suction tube 20.

In yet another alternative, the pressure water from between the impeller skirt 13 and the stationary casing may be admitted to chamber 37 to emerge into the suction tube as jets by means of a rotatable ported ring which can be rotated between a position in which its ports register with corresponding ports in the stationary structure and a position in which the ports are closed.

What I claim as my invention and desire to secure by Letters Patent is:

1. A hydraulic machine comprising a casing, an impeller mounted for rotation in said casing, a suction tube mounted on said casing upstream of said impeller for connection to a liquid reservoir, means for introducing gas into said impeller, means for controlling the pressure of said gas in said impeller whereby to control the advance of said liquid along the suction tube towards the impeller, and means for injecting liquid into said suction tube substantially tangentially to the direction of advance of said liquid whereby to cause the advancing liquid to describe a vortical flow during entry into the impeller.
2. A hydraulic machine according to claim 1, wherein said means for injecting liquid into said suction tube comprises, a plate mounted within said casing closely adjacent to said impeller, and control means selectively operable to move said plate away from said impeller whereby to define a channel between said plate and said impeller and create a flow path for liquid circulating through said impeller back into said suction tube.
3. A hydraulic machine according to claim 1, comprising a spirally-wound tube connected to said casing downstream of said impeller, and wherein said means for injecting liquid into said suction tube comprises, a wall portion integral with said suction tube and defining a plurality of apertures, a like plurality of deflecting vanes secured to said wall

portion externally of said suction tube and terminating adjacent respective ones of said apertures, an outer casing surrounding said suction tube and enclosing said deflecting vanes, a liquid flow tube connected between said spirally-wound tube and said outer casing, and valve means mounted in said liquid flow tube and selectively operable to permit the passage of said liquid from said spirally-wound tube into said suction tube through the said outer casing.

4. A hydraulic machine comprising, a casing, an impeller, means mounting said impeller for rotation within said casing, an inlet tube mounted on said casing upstream of said impeller, said tube having one end for receiving water from a reservoir and another end connected adjacent to said impeller for feeding the water thereto, a spirally-wound outlet tube mounted on said casing downstream of said impeller, said outlet tube having one end connected adjacent to said impeller and another end remote from said impeller, a water delivery tube connected to the other end of said outlet tube, first valve means mounted on said casing and selectively operable to introduce air into said impeller and control the rate at which air is subsequently exhausted from said impeller whereby the advance of water along said inlet tube is controlled during the period in which the said machine is started, an outer casing surrounding the other end of said inlet tube, a plurality of deflecting vanes secured to said other end of the inlet tube and extending outwardly therefrom into said outer casing in planes lying substantially tangential to the direction of water flow along said inlet tube, said other end of the inlet tube defining a like plurality of apertures adjacent which the said deflecting vanes terminate, a water flow pipe connected between said outer casing and a water source, and second valve means mounted in said water flow pipe and selectively operable to introduce water from said source into said inlet tube during the said period whereby to cause said water advancing along the inlet tube to describe a vortex during the said period.

5. A hydraulic machine according to claim 4, wherein said water flow pipe is connected between said outer casing and said spirally-wound outlet tube.

6. A hydraulic machine according to claim 4, wherein said water flow pipe is connected between said outer casing and said water delivery tube.

7. A hydraulic machine according to claim 4, wherein said machine is operative as a pump.

8. A hydraulic machine according to claim 4, where-

in said machine is operative as a reversible pump turbine.

9. A hydraulic machine comprising

a casing, an impeller mounted for rotation in said casing, a suction tube mounted on said casing upstream of said impeller for connection to a liquid reservoir, valve means for controlling the rate at which air is exhausted from said impeller during the period in which the machine is started whereby to control the advance of said liquid along the suction tube towards the impeller, a wall portion integral with said suction tube and defining a plurality of apertures adjacent said impeller, a like plurality of deflecting vanes secured to said wall portion externally of said suction tube, said vanes terminating adjacent respective ones of said apertures and lying in different planes tangential to the direction of advance of said liquid, an outer casing surrounding said suction tube and defining with said wall portion a cavity including said deflecting vanes, and means for injecting liquid into said cavity during a period in which the machine is started whereby said liquid is deflected by said vanes into said suction tube substantially tangentially to the direction of advance of said liquid along the suction tube thereby to cause the advancing liquid to describe a vortical flow upon entry into the impeller during said period.

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