

March 1, 1966

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3,237,564

HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

Filed Oct. 7, 1963

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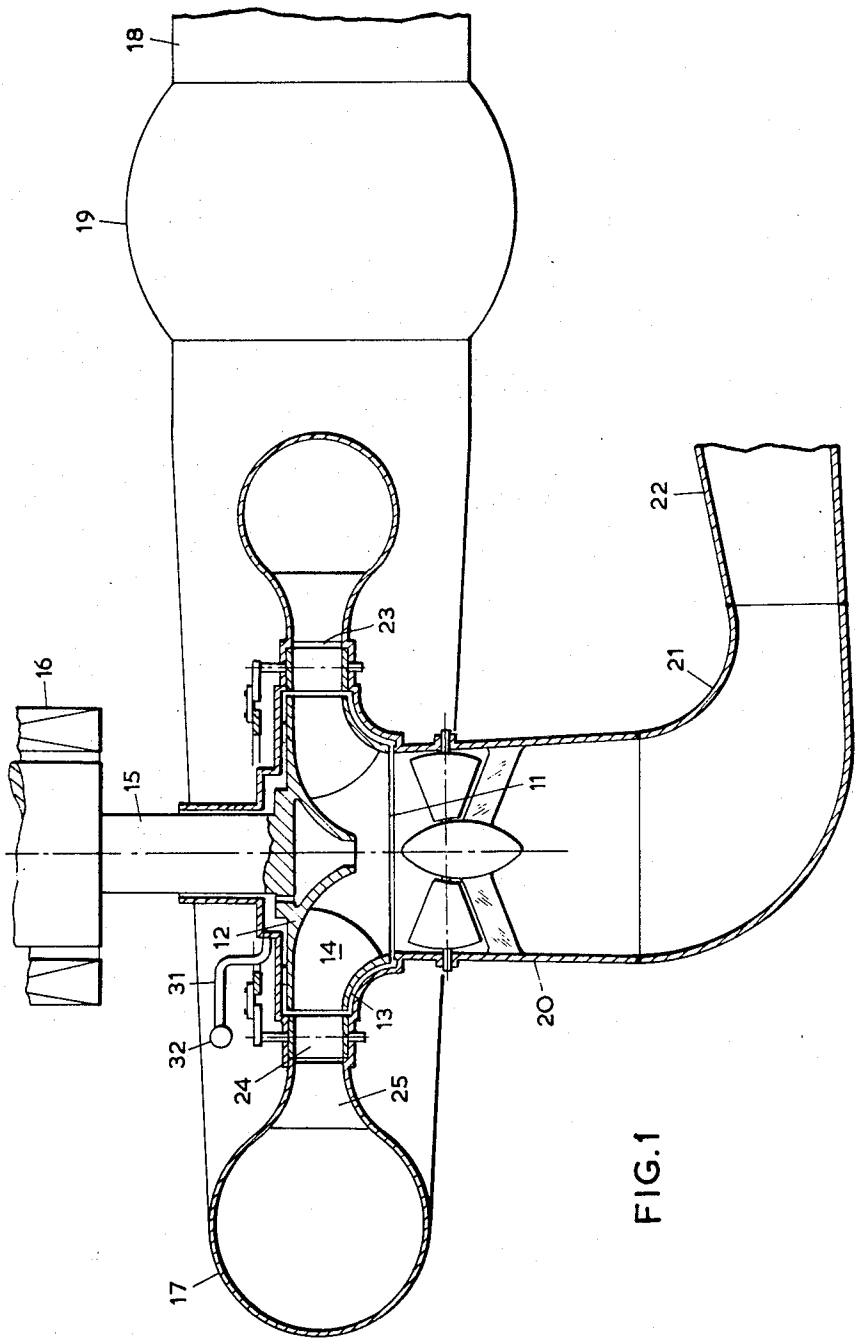


FIG.1

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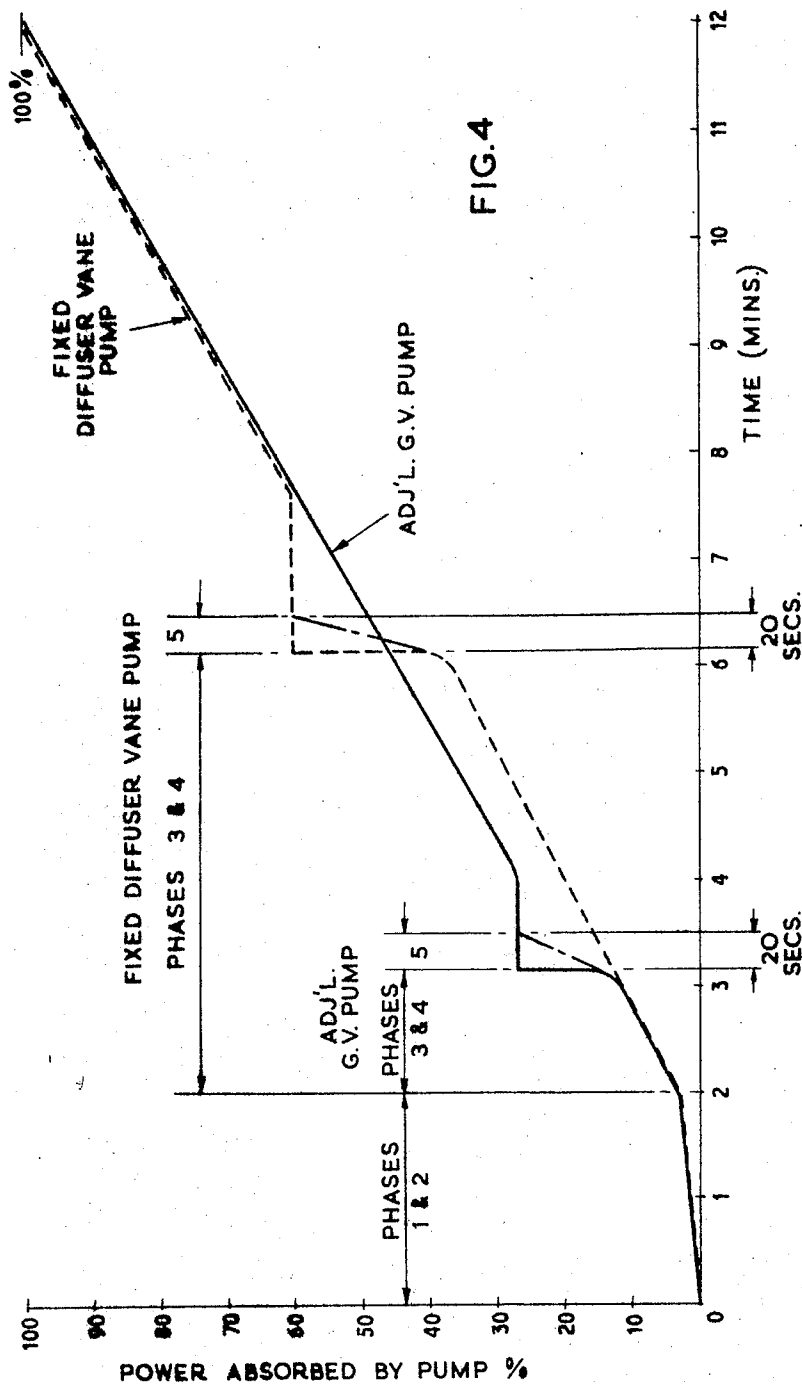
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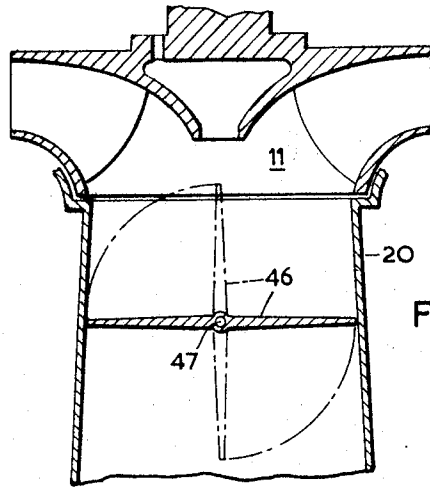


FIG. 5

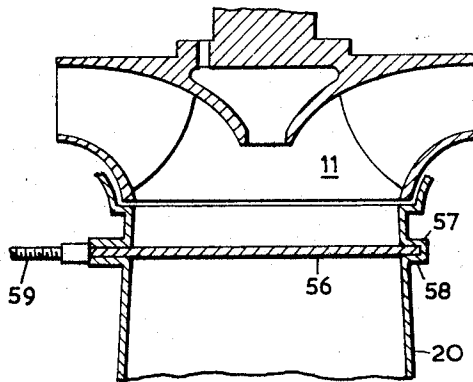


FIG. 6

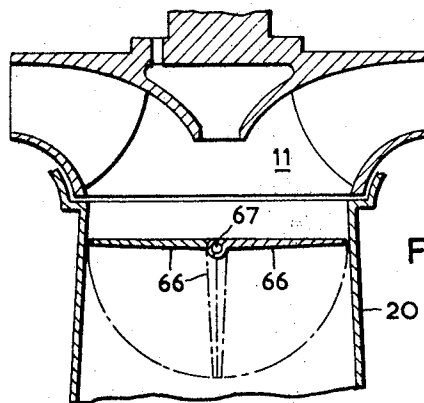


FIG. 7

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HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

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Filed Oct. 7, 1963, Ser. No. 314,358

Claims priority, application Great Britain, Oct. 15, 1962, 38,855/62

11 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 valve means for isolating the impeller of the pump or reversible pump turbine from the suction tube 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 a general arrangement of hydraulic pump or reversible pump turbine in accordance with the invention;

FIG. 2 is a detailed view of part of FIG. 1;

FIG. 3 is a cross-section on the line III—III of FIG. 2;

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

FIG. 5 shows diagrammatically one modification of the arrangement of FIGS. 1-3;

FIG. 6 shows diagrammatically a second modification of the arrangement of FIGS. 1-3; and

FIG. 7 shows diagrammatically a third modification of the arrangement of FIGS. 1-3.

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 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 only a ring of fixed diffuser vanes may be provided.

As shown in FIG. 2, 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 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.

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A valve which includes a number of rotatable shutters 36 is provided in the suction tube 20 near to the impeller 11. The shutters 36 are mounted on trunnions in journal bearings in the suction tube wall and in a central streamlined fairing 37 to pivot about axes which are radial of the suction tube. The fairing is supported from the suction tube wall by a number of struts 38. The shutters 36 are of truncated sector shape, so that in the closed position (as shown) they substantially block communication between the suction tube and the impeller, though they do not seal, and thus the pressures on both sides of the valve remain approximately equal during the priming operation.

In the open position (shown in chain-dashed lines in FIG. 2) the shutters 36 present little obstruction to the flow of water. To move the shutters between the open and closed positions, a shaft 39 is fixed to the outer extremity of each shutter, passing through the journal bearing formed in the suction tube wall, and a crank arm 40 is fixed to each shaft, all the crank arms co-operating with a control ring 41 which is rotated by any known or convenient means, e.g. by a hydraulic jack. The pin on the end of the crank arm 40 which cooperates with control ring 41 preferably lies on a true radius of the suction tube, as shown in FIG. 3.

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.

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 comprising shutters 36 should be moved to the closed position at or before this stage.

Next the impeller is progressively filled with water; owing to the centrifugal effect the water builds up progressively from the outer periphery of the impeller inwards. The filling may be achieved either (a) by gradually exhausting the air from the suction tube through pipe 31 allowing the water level 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 is thus compressed and opposes the rise of the water level, and thus the process is stable. Or it may be achieved by (b) feeding water from the delivery pipe 18 into the space between the impeller 11 and the adjustable guide vanes 24 (or fixed diffuser vanes 25) and thence inward into the impeller against the action of centrifugal force. The water may be fed in through a pipe connected to the wall of passage 23, or connected to the stationary casing adjacent the crown 12 (outside seal 33) or adjacent the skirt 13 of the impeller. Or again it may be achieved by (c) directing a jet or jets of water aimed at the impeller inlet from the suction tube, the jets being supplied from the delivery pipe or from an extraneous source.

The inner boundary of the water may be brought in-

ward in this way to substantially the radius of the smallest-diameter part of the skirt 13, and it is found that the power absorbed in this phase rises from 3 percent to about 10 percent of the normal full load in a machine fitted with adjustable guide vanes, which are in the closed position. This third phase may take a further minute.

More of the air from the suction tube 20 is then exhausted through pipe 31, allowing water to rise through the gaps between shutters 36 and enter the eye of the impeller 11. In this fourth phase, the power absorbed rises from about 10 percent to about 17 percent of normal full load for pumps with adjustable guide vanes, depending on their design, and to about 40 percent for pumps having only fixed diffuser vanes. The rate of increase of power absorption by the pump during this phase is controllable by careful control of the rate at which the air is exhausted.

The four phases described above are reversible, i.e. the sequence can easily be reversed at any time, and controllable, i.e. the rate of increase of power absorption can be controlled.

Exhausting the remaining air, so that the water rises further into the vanes of the impeller, 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). It has been found that by use of the valve comprising shutters 36, which maintains the flow in the impeller, above the valve, substantially separate from the flow in the suction tube below the valve, this rise in power absorbed can be caused to take place over a longer period, at a rate at which the electrical grid can more easily accept the load. For example this rise in power may take place over 20 seconds, as shown in chain-dashed lines in FIG. 4.

Finally, in the sixth phase, 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 from 27 percent or 60 percent respectively to full load.

The valve comprising shutters 36 is opened for normal operation.

Referring now to FIG. 5, there is shown a modification of the arrangement of FIGS. 1-3 in which the valve, instead of comprising shutters 36, has the form of a butterfly valve 46, that is to say a flat disc of a shape corresponding to the cross-section of the suction tube 20 (usually circular), pivoted at or near its centre by means of a shaft 47 attached to the valve 46 and passing through journal bearings in the wall of the suction tube. The butterfly valve is moved from its closed position (shown in solid lines) to its open position (shown in chain-dashed lines) by means of a crank arm attached to the shaft 47 outside the suction tube and operated by any known or convenient means, for example, a hydraulic jack.

A second modification is shown in FIG. 6, in which the valve has the form of a sluice gate member 56 operating between upper and lower flanges 57, 58 secured to the suction tube wall. The flanges 57, 58 are connected together, except on the side (the left-hand side as seen in FIG. 6) through which the sluice gate member 56 is withdrawn to open the valve, a suitable seal being provided on this side. The sluice gate member 56 is moved from the closed position to the left (as shown) to an open position, in which the suction tube is substantially unobstructed, by means of a rod 59 operated by any known or convenient means.

A third modification is shown in FIG. 7, in which the valve has the form of two substantially semi-circular flaps 66 pivotally mounted about a diameter on a rod 67 extending from wall to wall of the suction tube. The flaps are moved from the closed position shown to the open position (shown in dotted lines) by means for example of torque tubes, one secured to each flap and passing through journal bearings in the suction tube wall at opposite ends of the diameter, each torque tube having a crank arm secured to it outside the suction tube wall. The crank arms may be operated by any known or convenient means, for example by hydraulic jacks.

In the modification shown in FIGS. 5, 6, 7, the valves should not seal tightly in the suction tube, and the pressure above the valve will thus always be approximately the same as the pressure below it. The operation of the pump or reversible pump turbine fitted with these modified forms of valve is exactly as described above with reference to the valve of FIGS. 1-3.

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
 - valve means in said suction tube for adjusting the cross-sectional area of the liquid flow path within said suction tube.
2. A machine according to claim 1, wherein said valve means comprises
 - at least one shutter rotatable about an axis lying in a plane substantially perpendicular to the direction of said flow path.
3. A machine according to claim 2, wherein said suction tube is circular in cross-section, and wherein said valve means comprises only one said shutter, said shutter being a circular disc.
4. A machine according to claim 2, wherein said suction tube is circular in cross-section, and wherein said valve means comprises two said shutters rotatable about a common axis, each shutter being a semi-circular disc.
5. A machine according to claim 2, wherein said suction tube is circular in cross-section and said valve means comprises a plurality of said shutters rotatable about a like plurality of axes, respectively, each said shutter being sector-shaped.
6. A machine according to claim 1, wherein said valve means comprises,
 - a sluice-gate member movable rectilinearly in a plane substantially perpendicular to the direction of said flow path.
7. A hydraulic machine comprising
 - a casing,
 - an impeller,
 - means mounting said impeller for rotation in said casing,
 - a water inlet tube connected to said casing upstream of said impeller,
 - a water delivery tube connected to said casing downstream of said impeller,
 - first valve means for controlling the rate at which air is exhausted from said impeller during the period in which the machine is started whereby the advance of said water along the inlet tube towards the impeller is governed, and
 - second valve means mounted in said inlet tube adjacent said impeller for controlling the cross-sectional area of the water flow path within said inlet tube.

8. A hydraulic machine according to claim 7, comprising means for feeding a limited amount of water into said impeller during the said period in which the machine is started.

9. A hydraulic machine according to claim 8, wherein said machine is operative as a pump. 5

10. A hydraulic machine according to claim 8, wherein said machine is operative as a reversible pump turbine.

11. A hydraulic machine comprising
a casing, 10
an impeller mounted in said casing for rotation about an axis,
a water inlet tube mounted on said casing upstream of said impeller and having at least a portion thereof coaxial with the said impeller axis,
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a spirally-wound water delivery tube mounted on said casing downstream of said impeller and lying in a plane substantially perpendicular to said axis, and
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first and second valve means for controlling the advance of water along the inlet tube towards the impeller when the machine is started, said first valve means being mounted on said casing and operable to control the rate at which air is exhausted from said impeller and said second valve means being

mounted in said inlet tube and operable to adjust the cross-sectional area of the water flow path within said inlet tube.

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