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HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

Filed Oct. 7, 1963

3 Sheets-Sheet 1

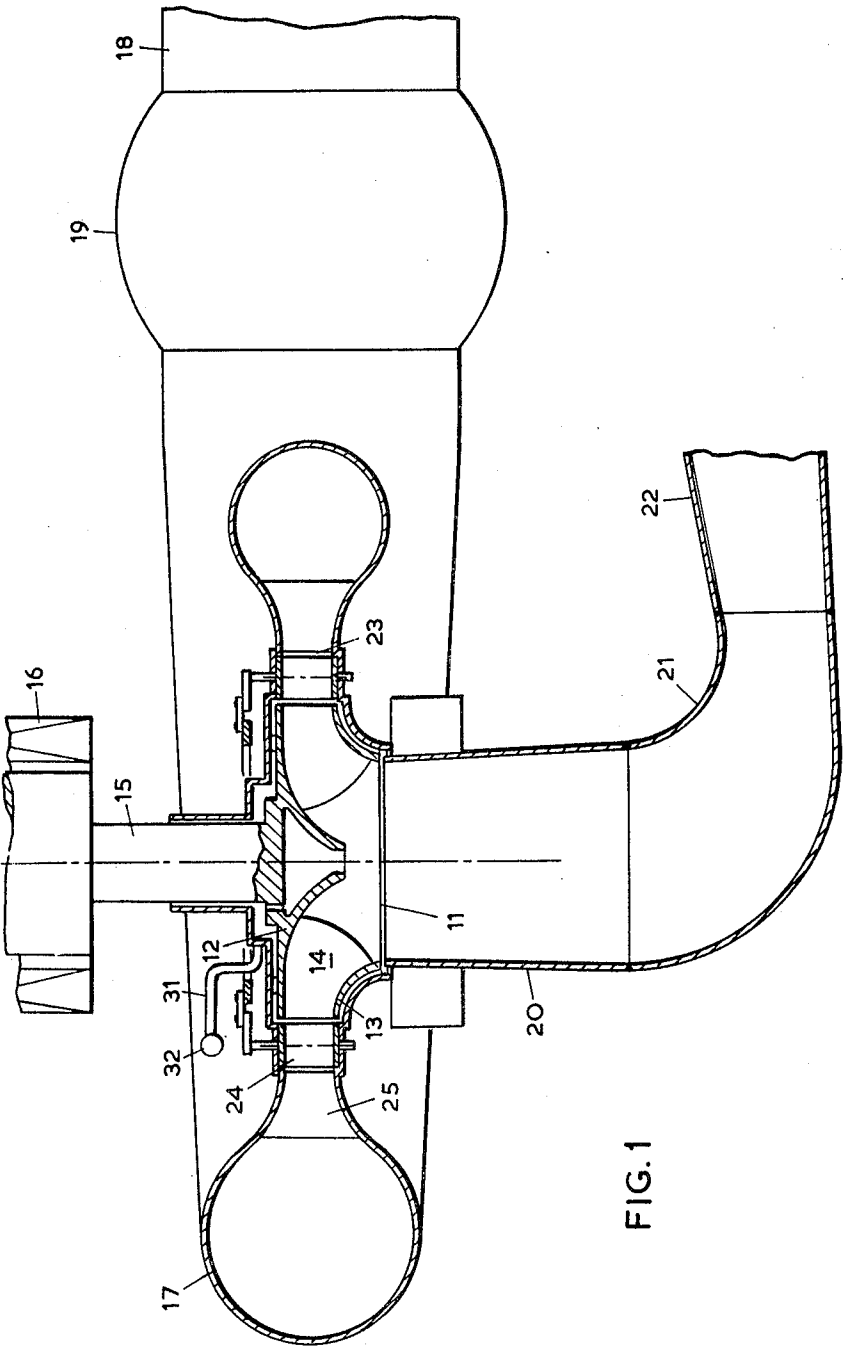


FIG.1

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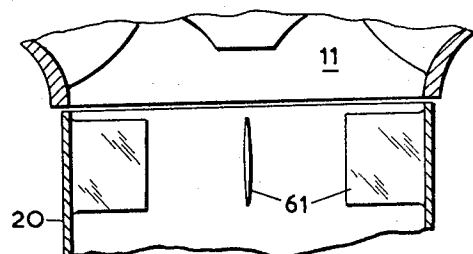
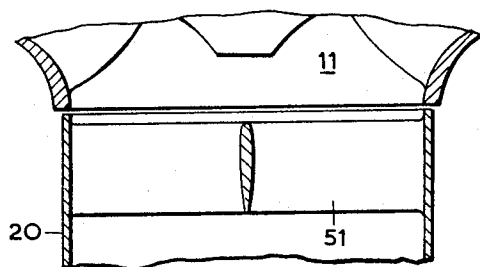
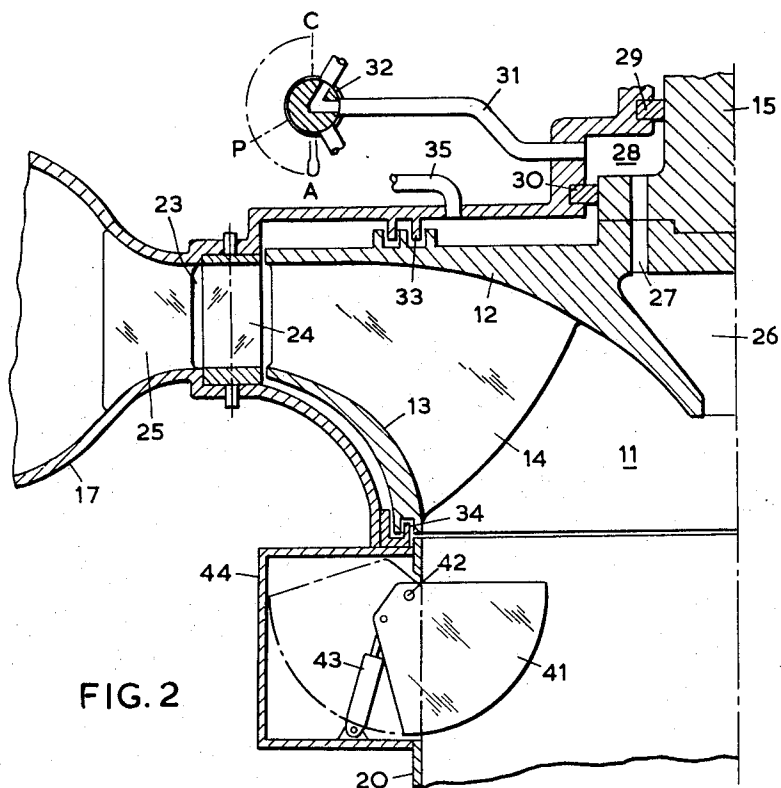
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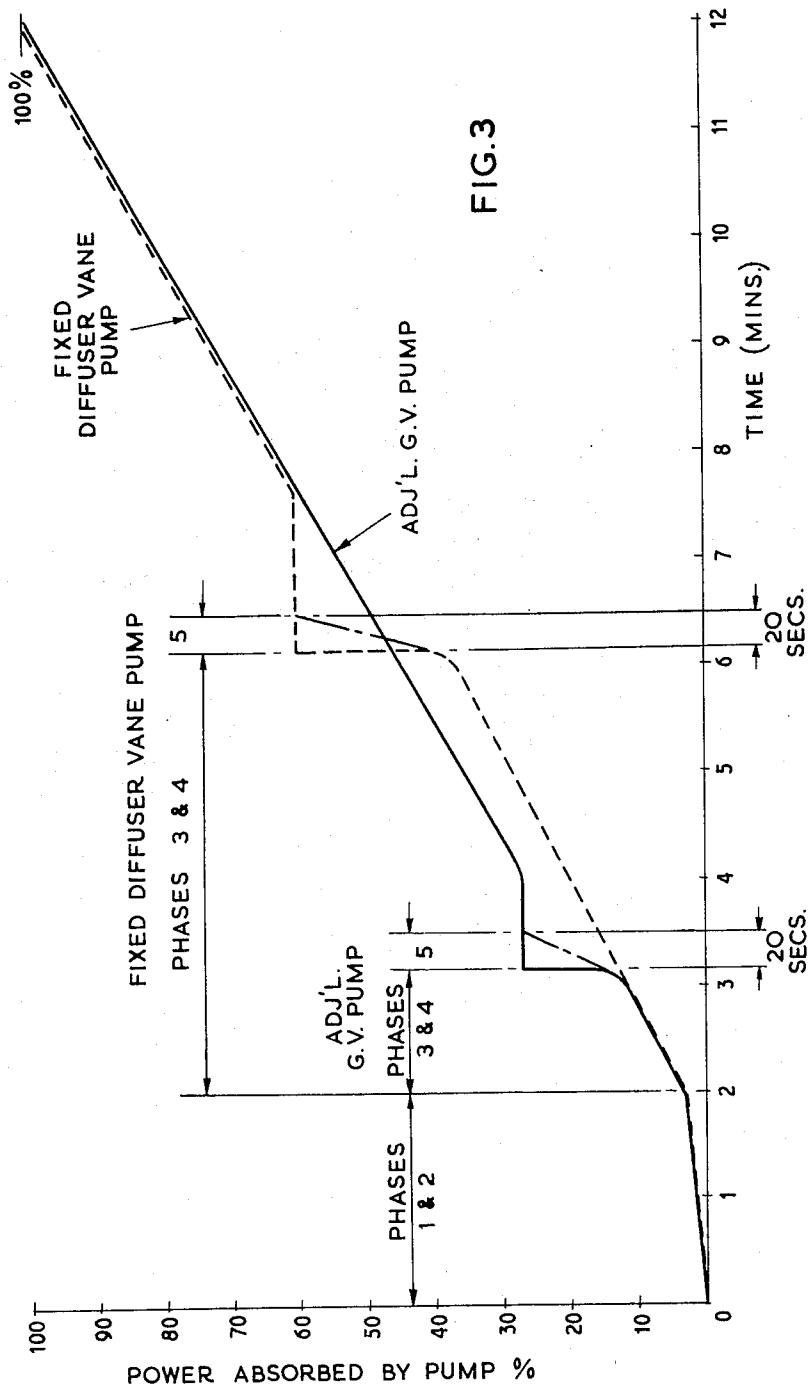
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HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

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12 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 suppressing at least partially the circulation of water in the suction tube immediately upstream of the impeller 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;

FIG. 2 is a detailed view of part of FIG. 1 showing a hydraulic pump or reversible pump turbine in accordance with the invention;

FIG. 3 is a graph plotting power absorbed against time;

FIG. 4 shows another embodiment of hydraulic pump or reversible pump turbine in accordance with the invention; and

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

Referring to FIGS. 1 and 2, 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 a rotary valve 32 in position A, as shown connected to a source of pressurised or compressed air in position P of the valve 32, or closed off in position C of this valve.

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 draft tube 20. A drainpipe 35 is provided between the sealing ring 30 and the labyrinth seal 33 through which any leakage is drained off.

A number of retractable baffles are provided at the top of the suction tube 20, each consisting of a sector-shaped plate 41 mounted to pivot about a pin 42 by means of a hydraulic jack 43. In their extended positions the baffles project through slots in the suction tube wall 20 approximately across a quarter of the diameter of the suction tube, and in their retracted position the baffles lie in the position shown in chain-dashed lines and are housed in an annular chamber 44 or a series of radially-extending chambers secured to the outside of the suction tube wall. The pins 42 are tangential to the suction tube, seen in plan view, and there may be four, six, or any convenient number of baffles. The baffles 41 may be axial of the suction tube, or they may be set at an angle to the axial direction.

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 phases rises from zero to about 3 percent of the normal full load, and they may take, for example, two minutes (see FIG. 3).

In FIG. 3 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.

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. This 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 inward 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.

The baffles 41 should be extended at least by the time that the third phase, just described, is completed. This phase may take a further minute.

More of the air from the suction tube 20 is then exhausted through pipe 31, allowing water partially to fill the eye of the impeller 11, which produces a weak vortex in the suction tube. 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 into the vanes of the impeller, produces a sudden rise in the power absorbed, and is caused by a rapid change in the flow regime in the suction tube. Once this phase is initiated, it is 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. 3). It has been found that by use of baffles 41, which destroy the circumferential component of the vortex adjacent the suction tube wall, 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. 3.

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 baffles 41 are retracted for normal operation.

Referring now to FIG. 4, there is shown a modification of the arrangement of FIGS. 1 and 2 particularly suitable for pumps and for reversible pump turbines where the utmost efficiency in turbine operation is not essential. In this embodiment, instead of retractable baffles 41, fixed baffles 51 are provided extending diametrically across the suction tube. In the embodiment shown two baffles are provided at right angles to one another.

Referring to FIG. 5, yet another arrangement is shown in which fixed vanes 61 are provided which project radially inward from the wall of the suction tube 20.

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

1. In a hydraulic machine having 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, and a plurality of baffles mounted on and extending inwardly of said suction tube, the method of starting said machine comprising the steps of,

introducing a gas into the impeller to arrest the advance of said liquid along the suction tube, rotating said impeller, and exhausting said gas from said impeller at a controlled rate to permit and govern the advance of said liquid along the suction tube into said impeller whereby the load imposed by said liquid on said impeller increases gradually from no-load towards full-load conditions.

2. In a hydraulic machine according to claim 1, the additional step of, retracting the baffles from the liquid flow path along the suction tube when said liquid has advanced into said impeller.

3. A method of starting a hydraulic machine having a

rotatable impeller and a suction tube upstream of said impeller for receiving water from a reservoir, comprising the steps of,

introducing air into said impeller to maintain said water in said suction tube at a level remote from said impeller,

rotating said impeller,

exhausting the air from said impeller at a controlled rate to permit said water to advance along the suction tube towards the impeller and displace the air whereby the load imposed by the water on said impeller increases gradually from no-load towards full-load conditions, and

impeding circulatory motion of said water in the suction tube adjacent said impeller during the said steps.

4. A method according to claim 3, in which the circulatory motion of said water is impeded only during the said steps performed during the starting operation.

5. A method according to claim 3, wherein said air is above atmospheric pressure.

6. A method according to claim 3, wherein said air is below atmospheric pressure.

7. In a hydraulic machine having an impeller and a suction tube mounted upstream of said impeller for receiving water from a reservoir, the method of controlling the advance of water along the suction tube into the impeller space during the period in which the machine is started, comprising the steps of,

initially introducing air into said impeller space to restrain the water from entering said space,

rotating said impeller,

exhausting the air from said space to advance the water along the suction tube and displace the air from said space whereby the load imposed upon said impeller by the water is only gradually increased, and substantially preventing rotational motion of said water during its advance along the suction tube during the said period.

8. 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 a plurality of baffles mounted on and extending inwardly of said suction tube adjacent said impeller for suppressing at least partially, the circulatory component of said liquid during entry thereof into said impeller.

9. A hydraulic machine according to claim 8, comprising control means selectively operable to retract said baffles from the liquid flow path along said suction tube.

10. A hydraulic machine according to claim 9, wherein said baffles lie in planes containing the axis of said suction tube.

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

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

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