March 1, 1966 D. HARTLAND **3,237,565**

HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

Filed Oct. 7, 1963 5 Sheets-Sheet 1

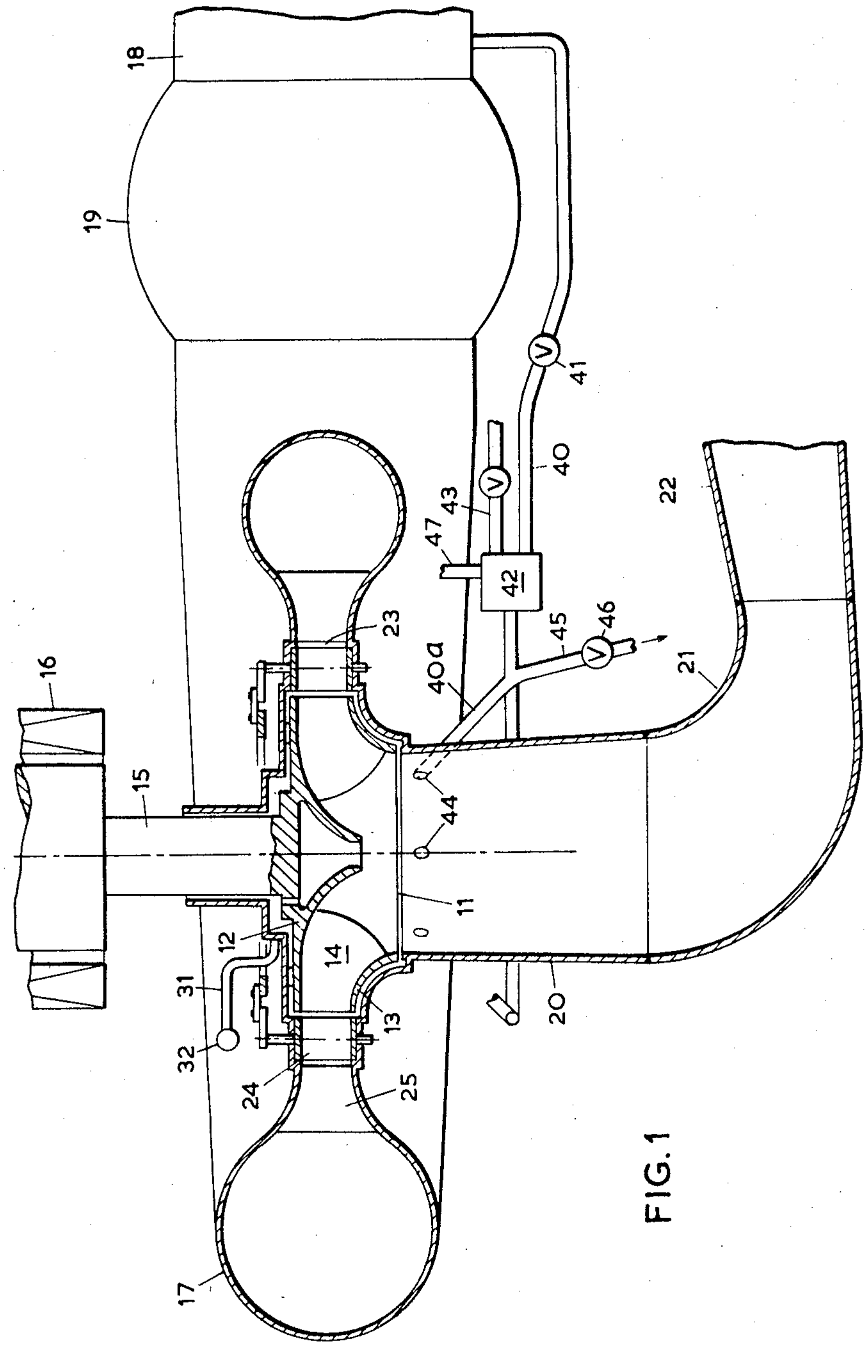

FIG.1

HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

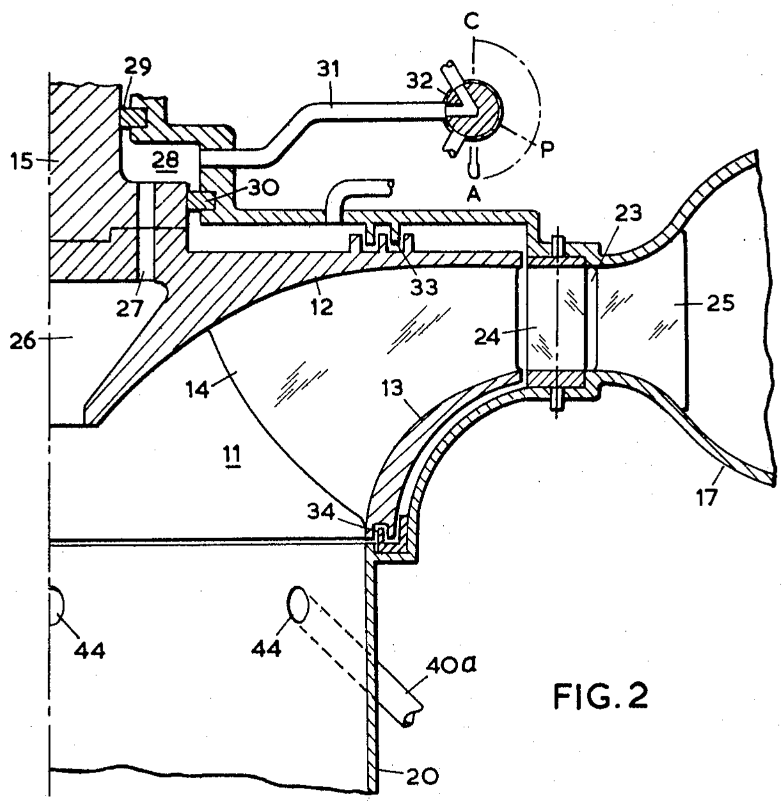

FIG. 2

HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

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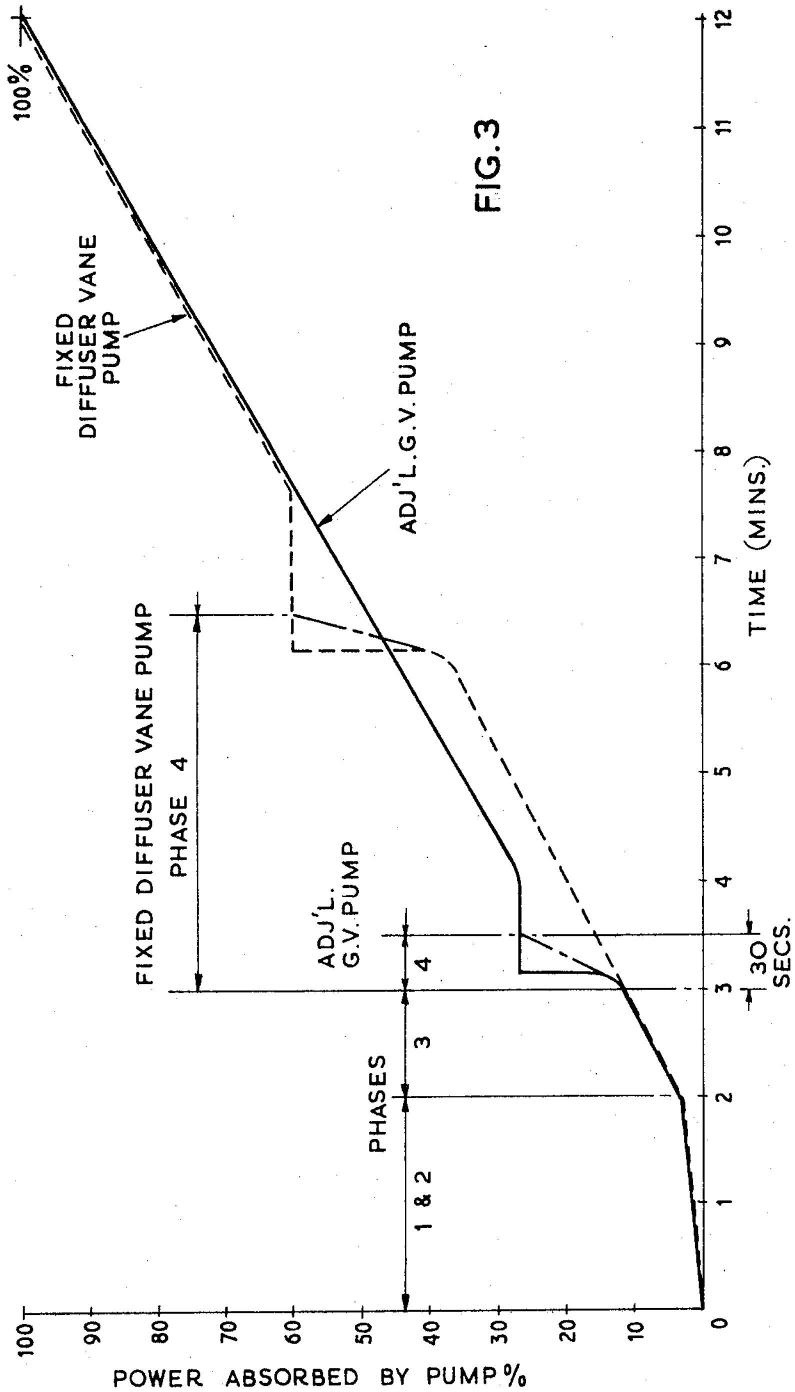

FIG. 3

HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

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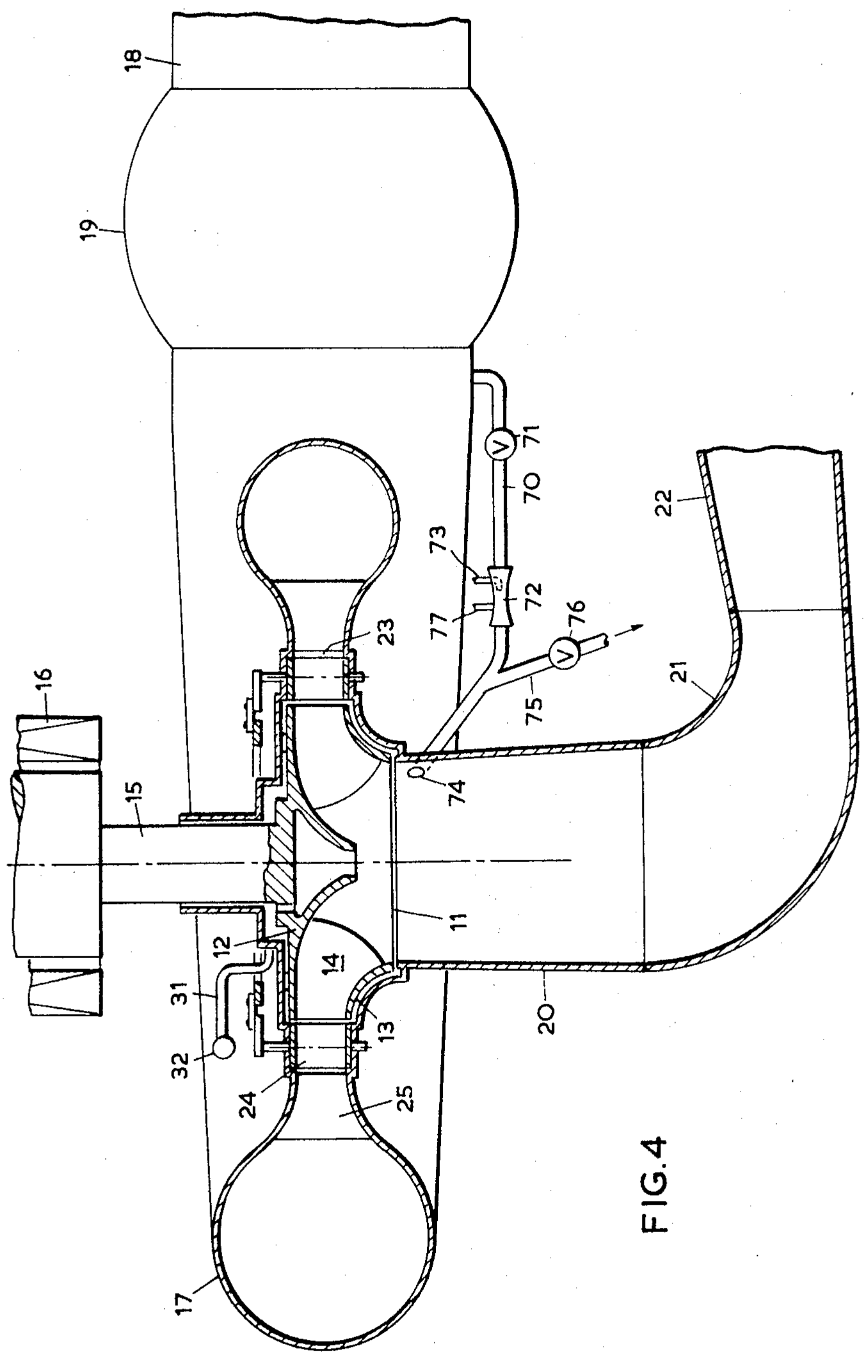

FIG.4

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HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

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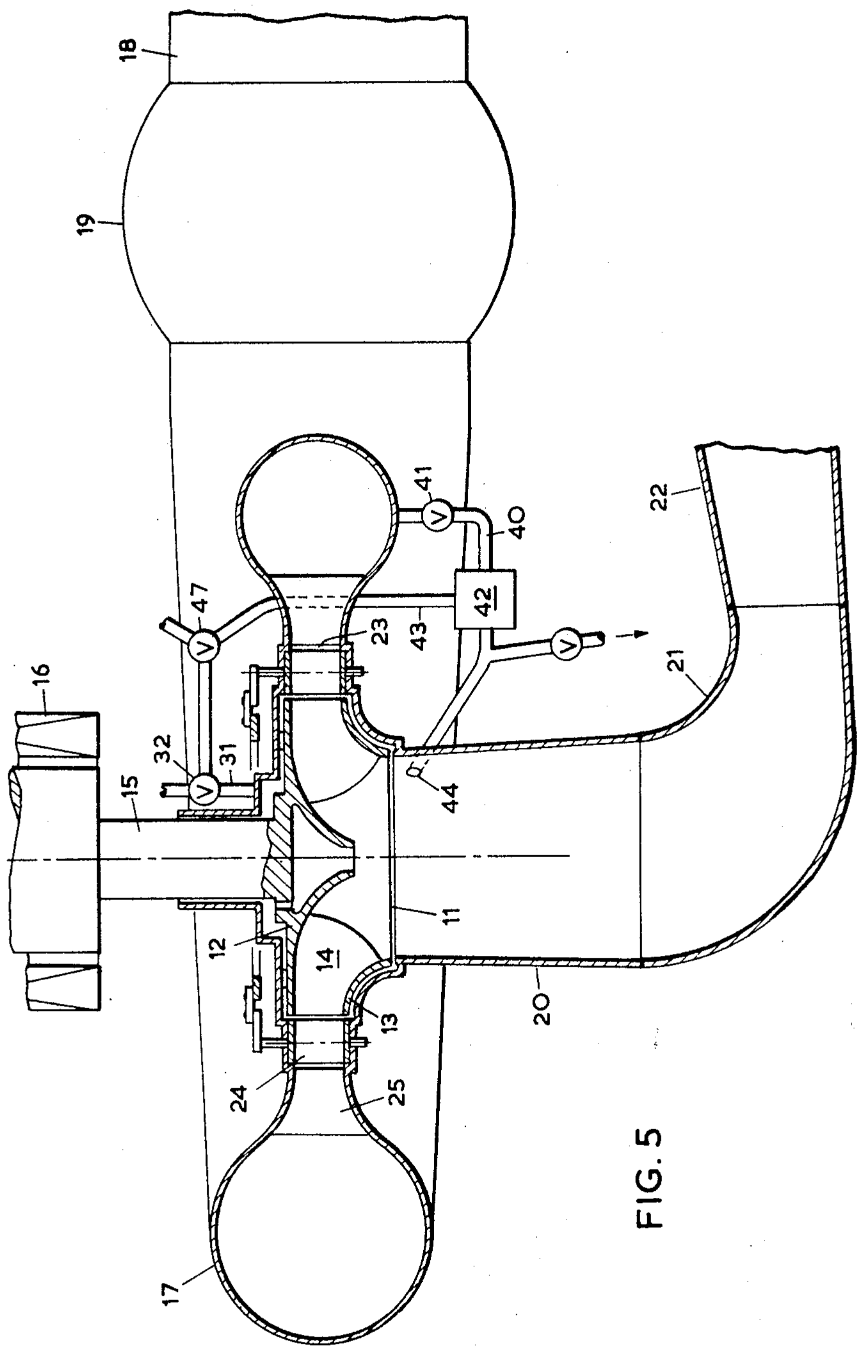

FIG. 5

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HYDRAULIC PUMPS AND REVERSIBLE PUMP TURBINES

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13 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 an emulsion of gas and water into the impeller of the pump or reversible pump turbine and for varying the proportions of gas and water so as to vary the density of the emulsion 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 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-conected 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 as 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 thae 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.

A pipe **40** is conected to a source of water under pressure, for example to the delivery pipe **18** as shown. In pumps having adjustable guide vanes **24**, these may be closed and the valve **19** may be open, allowing water under pressure into the spiral casing **17**. In this case the pipe **40** may optionally be connected to the spiral casing **17**.

The pipe **40** contains a valve **41**, by which the flow of water may be controlled, and leads to an emulsifier **42**. Compressed air is fed to the emulsifier **42** through a valve-controlled supply pipe **43** from any convenient source; the emulsifier may be of any known or convenient type, for example one in which the air and water are converted into an emulsion by mechanical means, or of the hydraulically-energised type.

The emulsion passes to a port or ports **44** in the suction tube **20**, the pipe **40*a*** curving upwards towards the port or ports **44** so that the emulsion is directed into the impeller **11**. A branch pipe **45** and valve **46** are provided, to enable the pipe **40*a*** to be drained.

An emulsifying agent, such as a detergent, may be supplied to the emulsifier **42**, for example through pipe **47**.

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. 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. 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 **18**, or from an extraneous source, e.g. through pipes **40**, **40*a***.

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. This third phase may take a further minute.

The three 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.

At the end of the third phase air will be circulated in the suction tube by the exposed parts of the impeller vanes **14**, and in accordance with the invention the density of the circulating medium is progressively changed, so that load may be taken by the pump motor **16** at a controlled rate, in the following manner: an emulsion is injected into the impeller through pipe **40***a*, first at a low density, i.e. with a high ratio of air to water. The density is then gradually increased, preferably by reducing the air supply and maintaining constant the rate of water supply, until the greater part of the impeller **11** and the top of the suction tube **20** is substantially filled with water; the air injected is exhausted to atmosphere in a controlled manner through pipe **31**.

The power absorbed rises from about 10 percent of normal full load to about 27 percent when the impeller is completely filled with water in the case of pumps with adjustable guide vanes, and to about 60 percent in the case of pumps with fixed diffuser vanes. Hitherto this rise took place in a fraction of a second; by use of the invention the rise in power is 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 more than 20 seconds, as shown in chain-dashed lines in FIG. 3.

Finally, in the fifth phase, the adjustable guide vanes **24** (or in pumps with only fixed guide 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 supplies of air and water through pipe **40***a* are shut off in normal operataion.

In an alternative, after the motor **16** is synchronised, the impeller may be filled entirely by means of the injection of emulsion, and the third phase (filling the outer periphery of the impeller) as described above is therefore omitted.

Referring now to FIG. 4, there is shown a modification of the arrangement of FIGS. 1 and 2 in which water is supplied from the delivery pipe **18** through pipe **70**, controlled by valve **71**, to a venturi **72**. Compressed air is fed through pipe **73** to the throat of the venturi or to a distribution manifold at the throat of the venturi, and the emulsion of air and water thus produced is injected into the impeller through port **74**. A drain pipe **75** and valve **76** are provided, and an emulsifying agent, such as Teepol or By-Prox (registered trademarks), may be supplied to the throat of the venturi through a pipe **77**.

Referring to FIG. 5, a further modification of the arrangement of FIGS. 1 and 2 is shown, in which instead of the pipe **43** being connected to an external source of compressed air, it is supplied with air exhausted from the impeller space through pipe **31**. A two-way valve **47** is provided to enable the pipe **31** alternatively to be vented to atmosphere or connected to pipe **43**.

It will be apparent that various combinations are possible within the scope of the invention; for example the air supply pipe **73** (FIG. 4) of the venturi **72** may be connected to be supplied with air exhausted from the impeller space through pipe **31**.

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,
- a delivery tube mounted on said casing downstream of said impeller,
- control means mounted on said casing for causing said liquid to flow along the suction tube towards said impeller at a controlle rate,
- an emulsifier connected to a source of both gas and liquid for generating an emulsion therefrom,
- means for injecting said emulsion into said suction tube adjacent said impeller during the controlled flow of said liquid thereto, and
- means for varying the proportions of gas and liquid in said emulsifier during the injection of said emulsion.

2. A hydraulic machine according to claim **1**, wherein said control means comprises
- a valve selectively operable to introduce a gas into said impeller, and
- means for exhausting said gas from said impeller whereby to permit said liquid to flow along the suction tube towards said impeller.

3. A hydraulic machine according to claim **2**, wherein said emulsifier comprises,
- a venturi tube having an inlet, a throat and an outlet, and
- a first pipe connecting said inlet to a liquid pressure source,
- a second pipe connecting said throat to a gas pressure source, and
- a third pipe connecting said outlet to said suction tube.

4. A hydraulic machine according to claim **3**, wherein said gas pressure source is the said gas exhausted from said impeller as the said liquid flows along the suction tube.

5. A hydraulic machine according to claim **3**, wherein said emulsifier further comprises
- a fourth pipe connecting said throat to a source of an emulsifying agent.

6. A hydraulic machine comprising,
- a casing,
- an impeller mounted for rotation in said casing,
- a suction tube communication with a liquid reservoir and connected to said casing upstream of the impeller,
- a spirally-wound delivery tube connected to said casing downstream of said impeller,
- valve means mounted on said casing and movable between a first position for introducing gas into said impeller and a second position for exhausting said gas therefrom whereby to cause said liquid to flow along the suction tube towards said impeller at a controlled rate,
- an emulsifier connected both to a source of gas, and a source of liquid, for generating an emulsion therefrom,
- means for injecting said emulsion into said suction tube towards said impeller during the controlled flow of said liquid thereto, and
- means for varying the proportions of gas and liquid in said emulsifier during the injection of said emulsion.

7. A hydraulic machine according to claim **6**, comprising means for supplying an emulsifying agent to said emulsifier.

8. A hydraulic machine according to claim **7**, wherein said emulsifier comprises,
- a venturi having an inlet and a throat, and
- means for supplying liquid to said inlet and for supplying gas to said throat to generate said emulsion.

9. A hydraulic machine according to claim **6**, wherein said emulsion is generated in said emulsifier by mechanical means.

10. A hydraulic machine comprising
a casing,
an impeller having a leading edge and a trailing edge,
means mounting said impeller for rotation in said casing,
a first tube mounted on said casing and communicating at one end with the leading edge of said impeller and at the other end with a water supply,
a second tube mounted on said casing and communicating with the trailing edge of said impeller,
a control valve mounted on said casing and selectively operable to permit water to advance along said first tube towards said impeller at a controlled rate,
an emulsifier connected to a source of air and a source of water for generating an aerated emulsion from said water,
a conduit connected between said emulsifier and said first tube for directing said aerated emulsion towards said impeller during the controlled flow of water thereto, and
means for varying the proportions of water and air supplied to said emulsifier from said sources.

11. A hydraulic machine according to claim 10, wherein the said means for varying the proportions of water and air supplied to said emulsifier varies the density of said emulsion from a low value when said water initially impinges upon said impeller to a high value when said water substantially fills said impeller.

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

13. A hydraulic machine according to claim 11, wherein said machine is operative as a reversible pump-turbine.

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