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[54] **STARTING ARRANGEMENT FOR REVERSIBLE PUMP-TURBINES**

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[51] **Int. Cl.** **F03b 3/10**

[58] **Field of Search** 417/323; 415/53, 122, 500, 415/1; 290/52

[56] **References Cited**

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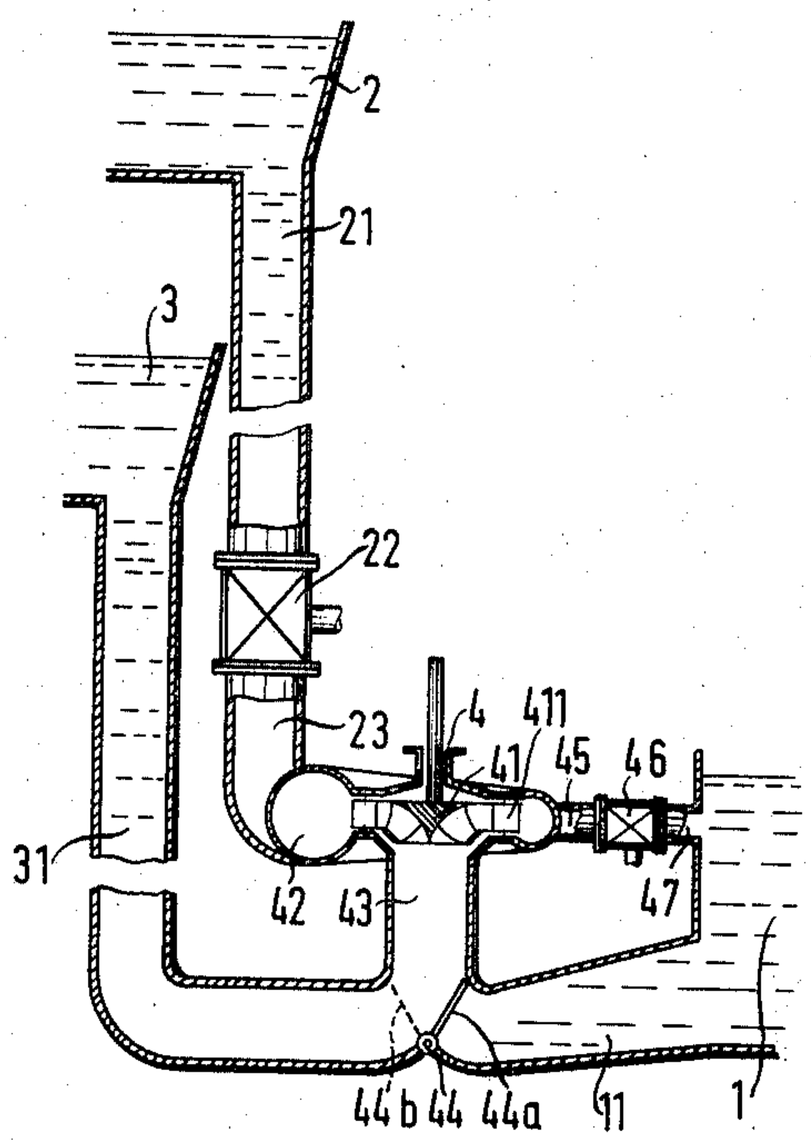
[57] **ABSTRACT**

A pumped-storage system using a reversible turbo pump for generating electricity and for displacing water into an upper reservoir. A reservoir of water at a head sufficient to drive the turbo-pump to a speed enabling it to be motor driven effectively is connected to the turbo pump and drives the latter for starting in the pump mode, the water passing into a tail-water reservoir.

4 Claims, 3 Drawing Figures



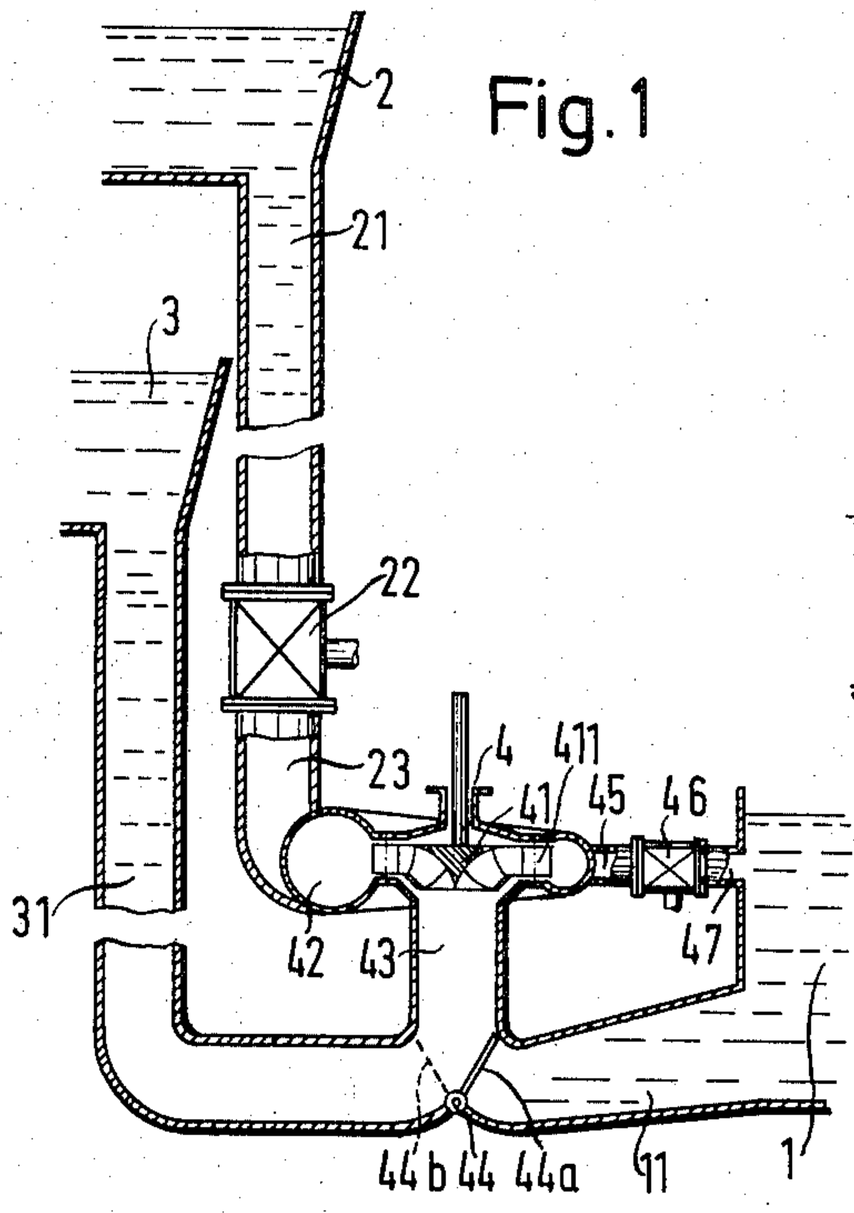


Fig. 1

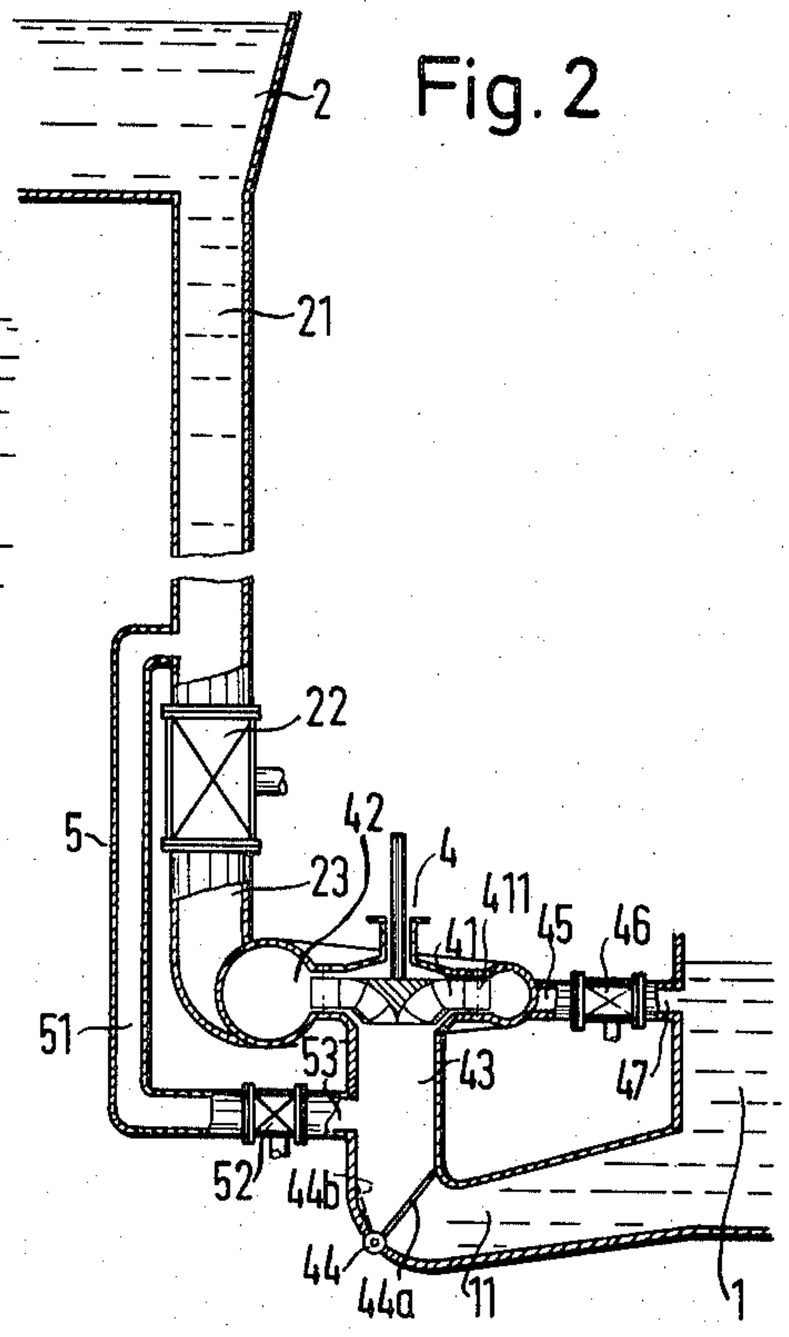


Fig. 2

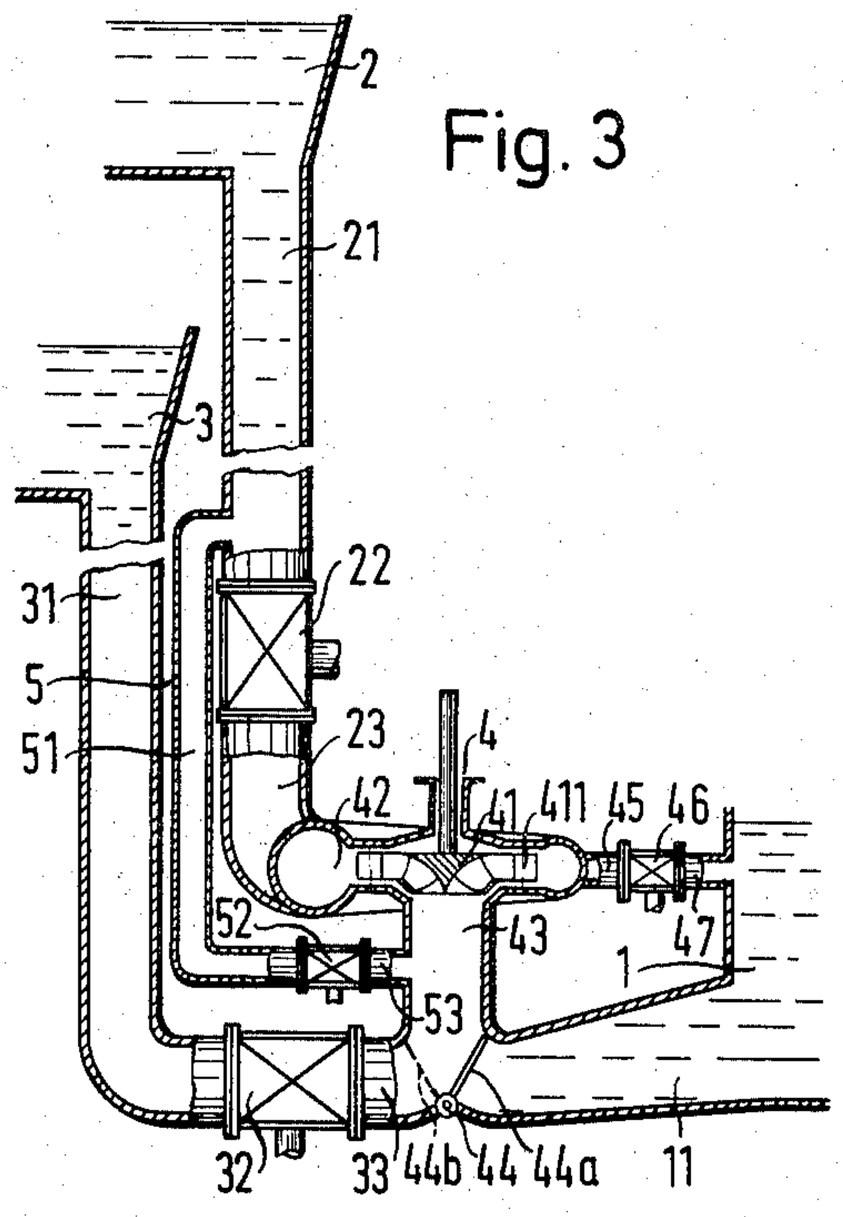


Fig. 3

STARTING ARRANGEMENT FOR REVERSIBLE PUMP-TURBINES

The invention relates to a starting arrangement for reversible pump turbines.

A known technique for rotating a reversible arrangement for a pumping operation in the opposite sense as it rotates in turbine operation, often requires a special starting machine built onto the shaft of the apparatus. Usually, this is a shunt wound three-phase electric motor, but sometimes a special hydraulic turbine is used. As a rule, compressed air is admitted to expel water from the turbine impeller so that it turns in air instead of in water until the start of the aggregate for pumping operation is made possible, because in this way the necessary starting power can be reduced. After the generator has been started in the opposite sense of rotation, it can operate with the auxiliary machine until it reaches the necessary speed, when it is switched over to the mains for operating as a motor. Such a starting arrangement makes the embodiment of the reversible aggregate complicated, it reduces the safety and starting readiness, thereby increasing the cost of the equipment and limiting the economy of the aggregate.

It is the object of the invention to remove these disadvantages in starting reversible turbopump devices for a pumping operation and to create a technically simple and inexpensive starting arrangement for the pumping operation of such apparatus. This task is solved by the starting arrangement according to the invention, in which the aggregate is started for the pumping operation with driving water, whereby the "starting motor" is the impeller itself of the reversible assembly.

The starting arrangement according to the invention is characterized in that on the scroll case of the aggregate it has a slide valve, which is through a corresponding pipeline connected to the tail water, that on the exhaust pipe, which is either in forked manner connected to mean and tail water, or to tail water only, on the bifurcation point or at the knee, is placed a switching-over flap, and that in the case of insertion of the reversible aggregate into a system of two or three storage basins, in which either the head of the tail-water basin or the head of the mean-water basin is too low for the start of the aggregate into pumping operation, a by-pass pipe in the shape of a staring pipe is foreseen as a connection of the penstock with the exhaust pipe.

The system of the invention is shown and described in detail with reference to the accompanying drawing, in which:

FIG. 1 shows in diagrammatic axial cross section assembly a starting scheme for a reversible aggregate in pumping operation with the aid of driving water;

FIG. 2 shows in diagrammatic axial cross section assembly another embodiment of a starting system for pumping operation with the aid of driving water, using an auxiliary pipeline for the start; and

FIG. 3 shows in diagrammatic axial section another embodiment of a starting system of a reversible turbopump with the aid of driving water and using an auxiliary pipe-line in the case that the head of the mean water is not sufficient for obtaining the necessary speed for starting.

The basic elements of the starting arrangement have the same reference numbers in all three embodiments, i.e. the tail-water reservoir **1**, the headwater reservoir **2**, the mean water reservoir **3**, the reversible turbopump **4**, the starting pipeline **5**. Other design elements also are provided with the same reference numerals in all embodiments, when identical elements are in question.

For the sake of clarity, the tail water, the mean water and the headwater will be identified for an embodiment in which the tail water reservoir **1** represents the tail flow channel below a power station, the headwater reservoir **2** represents the storage basin, which has a considerable head over the turbopump or the tail water, and the mean water reservoir **3** is the reservoir above the power station.

In FIG. **1**, the discharge pipe **11** of tail water reservoir **1** has connected to it an axial portion **43** of an outlet pipe leading into the reversible aggregate **4** in the direction of driving wheel or rotor **41**, which is surrounded by guide vanes **411** and included in the scroll case **42** of the reversible aggregate. The headwater reservoir **2** is connected to inlet of the scroll **42** of reversible turbopump through penstock **21**, slide valve **22** and connection pipe **23**. On the outlet of the turbine scroll case, the connection pipe **45** of slide valve **46** is shown, which is continued by a connection **47** leading into the tail water reservoir **1**. A penstock **31** from the mean water reservoir **3** leads into the connecting portion **43** of the outlet pipe. Between penstock **31** and the discharge pipe **11** of the tail water reservoir, a flap **44** is placed, which can take the position **44a** corresponding to the closed condition of exhaust pipe, or the position **44b** corresponding to the closed condition of the penstock **31** of the mean water reservoir **3**.

In the embodiment shown in FIG. **2**, there is no mean water available, and the aggregate operates only with tail water and headwater. The mean water, which in the embodiment according to FIG. **1** is used only for the start, is in this embodiment replaced by a special starting pipeline **5**. This pipe-line comprises a connection pipe **51** branching off from penstock **21** of the headwater reservoir **2** and leading to slide valve **52**, which is with its connection **53** built into the connecting portion **43** of the discharge pipe of the turbine.

In the embodiment according to FIG. **3**, there are available the tail water reservoir **1**, headwater reservoir **2** and a mean water reservoir **3** which, however, does not possess a sufficient head for starting. According to this embodiment also, between the discharge pipe **21** of headwater and the connecting portion **43** of the discharge pipe there is inserted a starting pipeline **5** comprising all elements described above. According to this embodiment, before the flap **44** there is in the outlet pipe **31** of the mean water reservoir a slide valve **32**, which is by a connection pipe **33** and flap **44** connected to connecting portion **43** of discharge pipe **11**.

In the first and most usual embodiment of a pumped storage station, the headwater from reservoir **2** is conducted through penstock **21**, slide valve **22** and connection pipe **23** into scroll case **42** of the turbine. In this case, the flap **44** must take the position **44b**, closing penstock **31**. The slide valve **46** is closed. The water, having performed its work in the turbine, is through the connecting portion **43** and through the pipe **11** discharged into tail water reservoir **1**.

When starting the aggregate for pumping operation, the slide valve **22** in penstock **21** of headwater reservoir **2** must be closed. Then flap **44** is switched into position **44a**, and water is admitted through penstock **31** of mean water **3**, connecting portion **43** in the direction

of the working wheel into scroll 42 of the reversible aggregate. The has to be opened also slide valve 46 is opened discharging water through connection 45 from turbine scroll into tail water 1. Now the aggregate begins to rotate in the opposite direction to that in the turbine operation. When it has attained the necessary speed of rotation, the generator can be synchronized with the power system, and begins to operate as motor. As soon as the generator operates as motor, flap 44 remains in position 44a, slide valve 46 is closed and valve 22 opened and the aggregate starts pumping water from mean water reservoir 3 through penstock 31 into connecting part 43 of exhaust pipe into the headwater reservoir 2 through scroll 42, slide valve 22 and penstock 21.

In the embodiment according to FIG. 2, the turbine operation proceeds as described for the embodiment according to FIG. 1. The headwater flows through penstock 21, slide valve 22 into scroll 42 of the reversible aggregate, and further through flap 44, which is in position 44*b*, into the tail water reservoir 1. Thereby the slide valve 52 of starting pipe line 5 and slide valve 46 at the outlet of scroll case are closed.

In order to start the aggregate for pumping operation, first slide valve 22 is closed, slide valve 52 opened and flap 44 switched into position 44a. Slide valve 46 is also opened. The headwater now enters through connection pipe 51, which is a part of starting pipe-line 5, passing through slide valve 52, connecting portion 43 of exhaust pipe through working wheel 41 and guide vanes 411, scroll 42 and the connection pipe 45, slide valve 46 and connection pipe 47 into the tail water reservoir 1. Thereby the working wheel 41 rotates in the opposite sense from the turbine operation.

After having switched over the generator for motor operation, slide valve 52 is closed, flap 44 switched into position 44b, slide valve 46 closed, slide valve 22 opened; then the aggregate in pumping operation will deliver tail water to the headwater basin 2.

In the embodiment according to FIG. 3 in turbine operation, the operation proceeds in the same way as described for the embodiment according to FIGS. 1 or 2.

In order to start the turbopump for pumping operation, first slide valve 22 is closed, flap 44 switched into position 44a, slide valve 32 closed, and starting accomplished by means of headwater admitted through pipeline 5 through opened slide valve 52, connection 53 and connecting portion 43 of exhaust pipe; the water then flows to the scroll, then through working wheel 41 and opened slide valve 46 into the tail water reservoir 1. After starting is accomplished, whereby flap 44 remains in position 44a, slide valves 52 and 46 are closed and water is pumped from mean water basin 3 through opened slide valve 32, the reversible turbopump 4 and opened slide valve 22 into headwater basin 2.

When, the turbopump is used in a pumping operation mean water from a basin above the power station is pumped in to the upper storage basin, when a surplus of electric energy is available. In the embodiment of FIG. 2, water is pumped up even from the tail-water channel.

The aggregate is operated according to the embodiment shown in FIG. 3 when the head of mean water basin 3 at the station is too low for driving the turbopump in the pumping operation. In this case, headwater 2 is used for starting and, consequently, it is unavoidable in this case to provide a slide valve 32 in mean-water penstock 31.

It should also be noted that slide valve 46 at the outlet from the scroll in the tail-water zone must be so shaped that the highest possible starting speed of aggregate can be obtained. Thereby experiments have shown that it is not necessary to obtain the rated speed of the turbopump if this is not attainable due to an insufficient head, but that a speed suffices which permits switching over the generator into motor operation. In most cases, the slide valve 46 is already built in to all turbopumps for preventing the water hammer in turbine or pumping operation. The essential aim of this slide valve is that it must be open for pumping operation to permit starting, while normally this slide valve is closed except when there appear effects of water hammer. It is clear that the slide valve can also be opened manually. Its design permits obtaining the necessary number of revolutions when starting the turbopump for pumping operation.

The advantage of the starting arrangement of a reversible turbopump for pumping operation according to the invention lies in that the working wheel of the reversible turbopump itself is used as the starting motor and that no special hydraulic, electric or other starting motor is necessary.

In the sense of the invention it is, further, possible to utilize advantageously the existing equipment of previously built installations. Due to the advantages mentioned. The arrangements according to the invention are substantially cheaper with regard to investment costs, as well as for operation and maintenance, when compared to arrangements of reversible turbopumps known to-date.

I claim:

1. A pumped-storage system, comprising:

a reversible turbo pump having a rotor connectible with a motor/generator, and a scroll provided with a lateral inlet, a lateral outlet and an axially extending discharge duct;

an upper reservoir disposed above said turbo pump and having a first conduit connected with said inlet;

a lower reservoir disposed below said turbo pump and connected to said duct;

a second conduit connecting said outlet with said lower reservoir;

a first valve in said first conduit and a second valve in said duct adapted to be opened to drive said rotor hydraulically in one sense upon passage of water from said upper reservoir into said lower reservoir through said turbo pump; and

means for supplying water to said duct at a head greater than that of said lower reservoir, and a third valve in said second conduit openable upon the supply of water at said greater head for passing water through said turbo pump to drive said rotor hydraulically in the opposite sense at a speed sufficient to enable motor operation of said pump to pump water from said lower reservoir.

2. The system defined in claim 1 wherein said means includes a mean-water reservoir at a level above that of said lower reservoir and below that of said upper reservoir, and a penstock connecting said mean-water reservoir to said duct, said second valve being a flap displaceable to communicate said duct selectively with said penstock and with said lower reservoir.

3. The system defined in claim 2 wherein said means further includes a pipe connected between said upper reservoir head of said first valve and said duct head of said second valve, and a fourth valve in said pipe openable for the starting of said turbo pump in a pumping mode of operation.

4. The system defined in claim 1 wherein said means includes a pipe connected between said upper reservoir ahead of said first valve and said conduit ahead of said second valve, and a fourth valve in said pipe openable to start said rotor in said opposite sense.

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