

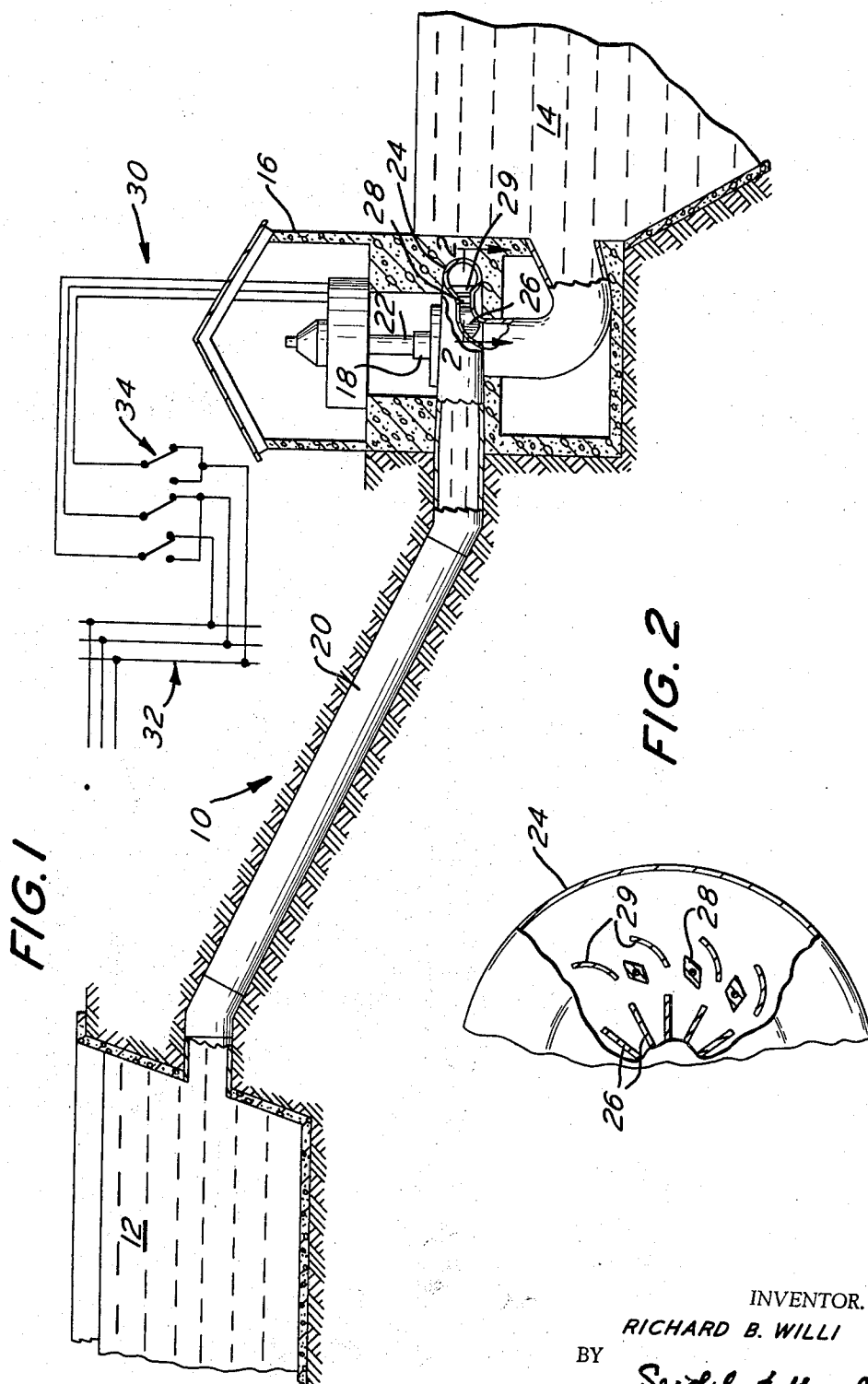
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POWER-ACCUMULATION SYSTEM

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POWER-ACCUMULATION SYSTEM

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ABSTRACT OF THE DISCLOSURE

A power-accumulation system utilizing a pump-turbine which can be operated as a pump wherein water can be delivered up to full pumping head when being operated with a motor-generator turning in a direction as for the generating mode. To accomplish pumping while the pump-turbine shaft is rotated in the generating mode, the wicket gates must be set at an opening less than that required to drive the unit as a turbine at rated speed under no load for a corresponding generating head. Smoothness of operation is greatly enhanced by filling the conduit interconnecting a high and low reservoir in a power-accumulation system in the described manner.

This invention is directed to a power-accumulation system and more particularly to a method of operating a pump-turbine in a power-accumulation system.

The usual power-accumulation system comprises a low level reservoir and a high level reservoir. The low level reservoir is provided with a water supply adequate to fill the reservoir and to provide sufficient make-up water to replace seepage and evaporation losses. The high level reservoir ordinarily will have no natural flow of water into it. An interconnecting pipeline is provided between the high level reservoir and the low level reservoir. At the base of the interconnecting pipeline, a hydroelectric installation is provided, which installation can operate either to generate power as water is passed from the high level reservoir to the low level reservoir or can operate as a pumping unit to deliver and store water in the high reservoir from the low reservoir. The hydraulic unit which can pump water or generate power is known as a pump-turbine.

The pump-turbine can be of any suitable type, capacity, or specific speed. It may be similar to a conventional Francis turbine but is not limited thereto. The principle parts of the pump-turbine unit include a casing, draft tube, runner, stay ring, head cover, discharge ring, and wicket gates which are movable in order to control the rate of water flow through the unit. While the structure thereof per se does not constitute a part of my present invention, yet for purposes of defining a component element of the pump-turbine, it will be considered that the pump-turbine embodies the structure of any suitable unit, an example of which is seen in Nagler Patent 1,494,008 which relates to a pump-turbine used in a similar system.

Such a pump-turbine is either driven by or drives an electrical unit which can operate as a synchronous motor or generator. Means are provided for reversing the direction of rotation when the pump-turbine is reversed from the pumping to the generating mode. Electrical equipment and switch gear are provided to adapt the motor-generator to the mode of operation desired, namely pumping with direction of rotation appropriately chosen or generating with a reverse direction of rotation.

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The high level reservoir will usually have no supply of water feeding into it by natural means. Therefore, after an installation is completed it becomes necessary to fill the pipeline which connects the high and low reservoir with water before normal pumping or generating functions can be performed by the pump-turbine. In most installations, this is done either by the use of a small temporary pump or by the use of the main pump-turbine. An example of the use of a booster pump is shown in the Sharp Patent 2,246,472 which is directed to a high level and low level reservoir system.

The use of the main pump-turbine to fill the interconnecting pipeline imposes a severe strain on the pump-turbine since much of the pumping must be performed at very low head and under conditions wherein the flow pattern is quite different from design conditions and therefore the main pump-turbine is subjected to considerable vibration. Pipelines in power-accumulation systems may be quite long, possibly one-half mile to several miles. Therefore, an appreciable amount of time and a substantial quantity of water are involved in filling the pipe.

It is an object of this invention to obviate the need for a separate pump to fill the interconnecting pipeline and to obviate the need for subjecting the main pump-turbine to a period of unduly rough operation.

It is another object of this invention to improve the smoothness of operation of a pump-turbine in a power-accumulation system.

It is another object of this invention to provide an improved method for pumping water to an interconnecting pipeline in a power-accumulation system.

It is another object of this invention to provide a method for pumping water in an interconnecting pipeline in a power-accumulation system which can utilize existing machinery.

Other objects will appear hereinafter.

In accordance with the present invention, it has been found that the pump-turbine can be operated as a pump and water can be delivered up to full pumping head when being operated with a motor-generator turning in a direction as for the generating mode, provided that the wicket gates are set at an opening slightly less than that required to drive the unit as a turbine at rated speed under no load for a corresponding generating head. Furthermore, it has been found that while efficiency when pumping under such conditions is low, smoothness of operation is greatly improved over the alternate condition of pumping with direction of rotation as for the conventional pumping mode. Suitable switching of wiring and controls so that the above-described mode of operation can be obtained is provided in accordance with this invention.

The method is utilized to get the pump-turbine into synchronous condenser mode of operation so that it is ready to generate power on demand. In this mode, the motor-generator is synchronized and rotating at synchronous speed. It operates as a motor to spin the turbine runner in air with the wicket gates closed and with the water level in a draft tube depressed by compressed air. It is necessary to set the pump-turbine below water level so that the runner will be under water for pump operation. In this mode of operation, it is necessary to drain leakage water escaping by the closed wicket gates from the annular chamber between the wicket gates and the outside diameter of the runner. If such escaping water is not drained, the pump-turbine will be subjected to severe

vibration. In order to change from this mode into the generating mode, it is necessary to merely open the wicket gates to an opening greater than the speed no-load position. Prior to opening the wicket gates, the compressed air may be vented from the draft tube so that the runner may spin in water just prior to opening of the wicket gates. Thus, smoother transient operation will be provided.

For the purpose of illustrating the invention, there is shown in the drawings a form which is presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

FIGURE 1 is a diagrammatic sectional elevation of an hydraulic power-accumulation system embodying the features of the present invention.

FIGURE 2 is a partial section view taken along line 2—2 of FIGURE 1.

Referring to the drawings in detail, there is shown in FIGURE 1 a power-accumulation system designated generally as 10.

The power-accumulation system 10 is provided with a high level reservoir 12 and a low level reservoir 14. A power house 16 is positioned adjacent the low level reservoir 14. A pump-turbine 18 is positioned within the power house 16. The power house 16 may be provided with a plurality of pump-turbines as is conventional in power-accumulation systems.

A conduit 20 interconnects the high level reservoir 12 and the low level reservoir 14. The conduit 20 in an actual system may be several miles in length. The pump-turbine 18 is provided with a runner shaft 22 which extends towards the opening in the bottom of the conduit 20. The pump-turbine 18 may be of the Francis type or may be of any other suitable design. The pump-turbine 18 is provided with a spiral casing 24 through which the water in the system flows. A plurality of runner blades 26 are attached to the runner shaft 22. The preferred type of runner blade is that which is utilized in a conventional centrifugal pump.

A plurality of wicket gates 28 are positioned adjacent the runner blades 26. The wicket gate 28 are movable between open and closed positions as is conventional in pump-turbines of this type. A stay ring having stay ring vanes 29 is positioned within the spiral casing 24 in a conventional manner.

Appropriate wiring 30 is attached to the pump-turbine 18 to provide for the reversal of rotation of the runner shaft 22 when the operation of the pump-turbine 18 is to be changed from pumping to generating mode or vice versa. The wiring 30 is connected to a plurality of reversing switches 34 which are connected to a plurality of bus-bars 32. Appropriate power is provided for the bus-bars 32 as is conventional and need not be further discussed here. The switches 34 may be operated manually or automatic controls may be provided for their operation.

The method of this invention is performed in the following manner. Upon initial installation of the power-accumulation system 10, it is readily apparent that the conduit 20 which interconnects the high level reservoir 12 and the low level reservoir 14, as well as the high level reservoir 12 will have no water therein. Thus, it is necessary to pump water from the low level reservoir 14 into the conduit 20 and thereafter into the high level reservoir 12. Normally, pumping is achieved by rotating the runner shaft 22 of the pump-turbine 18 in the normal pumping direction with the wicket gates 28 fully open. Thereafter, when it is desired to operate the pump-turbine 18 as a turbine, the direction of rotation of the runner shaft 22 will be reversed and the wicket gates 28 will be rotated until they are approximately 68 percent closed. Thereafter, the pump-turbine 18 is operated as a turbine.

In utilizing the method of this invention, the wicket gates 28 are from 75 percent to 95 percent closed. There-

after, the runner shaft 22 is rotated in the direction of rotation which is normally used when the pump-turbine 18 is operated as a turbine. Thereafter, the pump-turbine 18 will pump water from the low level reservoir 14 into the conduit 20 until the water is delivered up to full pumping head. Thereafter, the wicket gates 28 can be fully opened and the direction of rotation of the shaft 22 reversed and the pump-turbine can then be operated in the normal pumping mode. The use of the method heretofore described eliminates the strain on the pump-turbine which results from pumping at very low head wherein the flow pattern is significantly different from design conditions and subjects the unit to considerable vibration. It is readily apparent that when the runner shaft 22 of the pump-turbine 18 is driven by the motor-generator in a direction of rotation as for generating, the pumping action occurs with the wicket gates open an amount less than required to achieve rated speed under no load when operating as a turbine under the same head. After the conduit 20 has been filled with water, the pump-turbine 18 can be operated in the conventional manner.

As a specific example of the operation of the method of this invention, pumping may be achieved during the operation of a reversible pump-turbine unit rotating in a direction for turbine operation wherein the wicket gates are between 75 and 95 percent closed, the water may be pumped to a head of 727 feet. The unit may have a runner-tip diameter of 221 inches with a design to operate as a pump in a conventional direction of rotation at a speed of 240 revolutions per minute between heads of 656 and 780. At this condition of head, if the wicket gates were 68 percent closed the unit would be driven at a speed of 240 revolutions per minute under no load and, larger gate openings would generate power to be absorbed by the electrical unit.

Thus, it is readily observed that an improved and totally unexpected method is provided by this invention wherein a pump-turbine unit can be utilized in a power-accumulation system for initially filling an interconnecting pipeline between the low level reservoir and a high level reservoir in such system without the use of a temporary pump and without the imposition of a severe strain on the pump-turbine.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. A method of filling a conduit in a power-accumulation system comprising the steps of positioning a pump-turbine in the conduit between a high reservoir and a low reservoir, particularly closing the wicket gates so that said gates are at least seventy-five percent closed, rotating the pump-turbine in the direction of rotation which is normally used to generate power and pumping water through said conduit from the low reservoir to the high reservoir while said pump-turbine is rotating in said direction.

2. A method of filling an empty conduit as set forth in claim 1 wherein said step of partially closing the wicket gates includes partially closing said gates so that said gates are no more than ninety-five percent closed.

3. A method of filling an empty conduit as set forth in claim 2 including the step of reversing the direction of rotation of said pump-turbine and opening said wicket gates for normal pumping operation after a sufficient head has been attained.

4. In a power accumulation system having a pump-turbine which has a runner shaft which shaft has a first direction of rotation for pumping operation and a second direction of rotation for turbine operation, a method comprising the steps of: rotating the pump-turbine in the second direction of rotation, closing the wicket gates so that

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said gates are between seventy-five percent and ninety-five percent closed, and thereafter pumping with said pump-turbine shaft rotating in said second direction.

5. The method as set forth in claim 1 including the steps of: pumping in said first direction of rotation after a sufficient head has been attained and opening said wicket gates when pumping in said first direction of rotation.

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