May 25, 1965 H. HULLMANN ETAL 3,185,440

LIMITING THE SPEED OF THE STARTING TURBINE OF A PUMP-TURBINE OR ACCUMULATOR PUMP

Filed Dec. 13, 1963 2 Sheets-Sheet 1

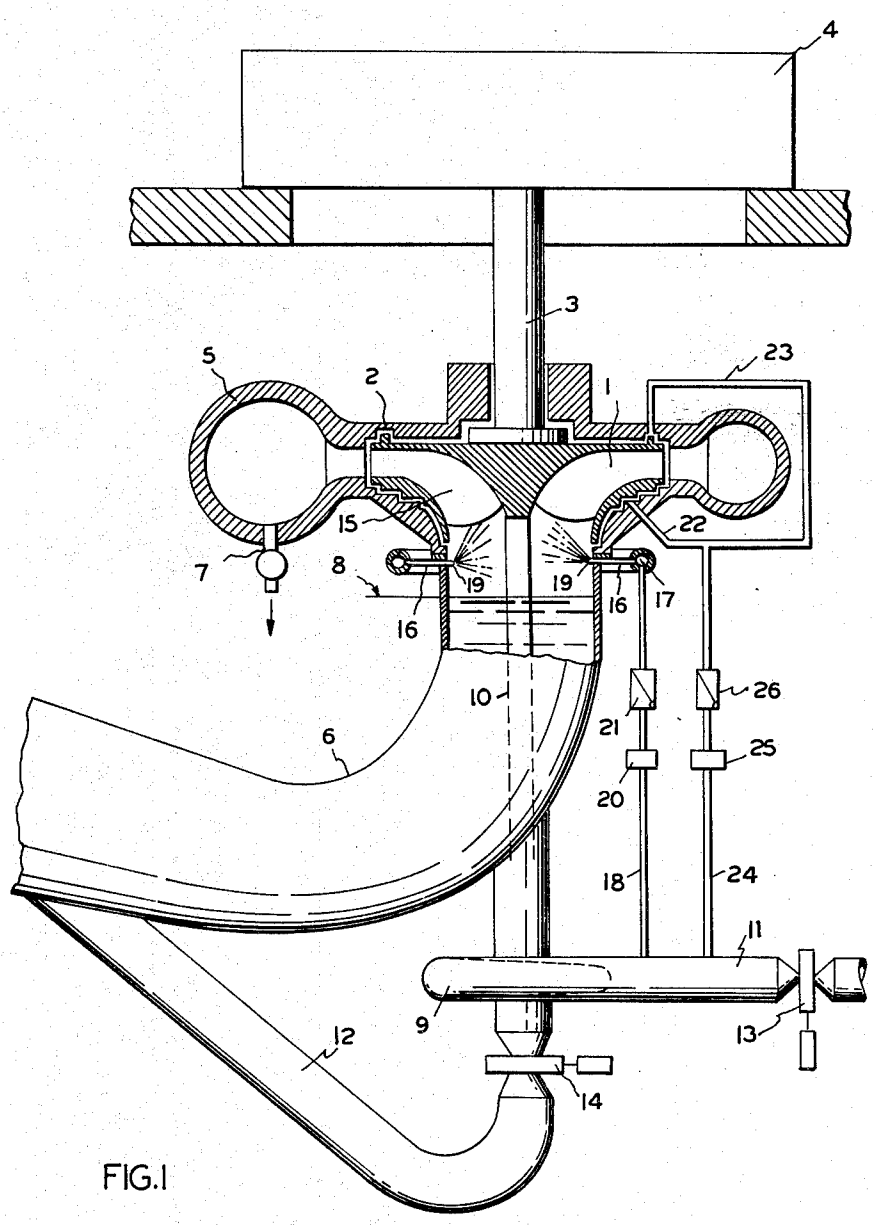

FIG.1

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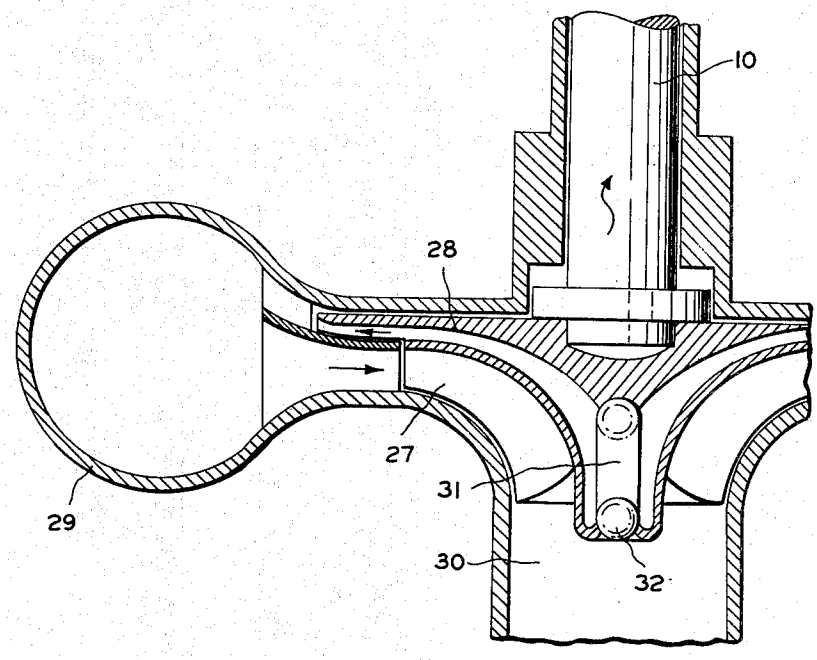

FIG. 2

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LIMITING THE SPEED OF THE STARTING TURBINE OF A PUMP-TURBINE OR ACCUMULATOR PUMP

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14 Claims. (Cl. 253—59)

The runaway speed of a starting turbine, when the latter is economically designed and dimensioned, is in most cases substantially higher than the runaway speed of the pump-turbine or accumulator pump to be started. It could therefore happen that in the event of failure of the control of the starting turbine, the machine to be started would be brought to an unduly high speed, which could lead to the destruction of the machine. The possibility of runaway of the machine set occurs principally when an empty pump-turbine or accumulator pump is started. As a rule, it is uneconomical and technically not always possible to design the machine which is to be started for the runaway speed of the starting turbine.

The invention now relates to a method for limiting the speed of a starting turbine of a hydraulic machine, in particular a pump-turbine or accumulatro pump. According to the invention, in the course of the starting process, and at the latest shortly before the runaway speed of the machine to be started is reached, a braking torque is exerted on the machine set by additional circulation of liquid. In a machine set comprising a pump-turbine or accumulator pump and starting turbine, the invention furthermore relates to a device for carrying out the said method. The said device is so designed that it produces an additional circulation of liquid through the machine set.

FIGS. 1 and 2 of the accompanying drawings each represent in simplified form a construction example of a device for carrying out the method according to the invention. The method will be explained by way of example with reference to this device.

According to FIG. 1, the runner 1 of a pump-turbine 2 is coupled by a shaft 3 to a synchronous electrical machine 4. On the high-pressure side, the pump-turbine 2 has a spiral casing 5 and on the low-pressure side a suction tube 6. The casing of the pump-turbine 2 can be emptied through a pipe 7.

On starting, the water level is lowered to a point 8. A starting turbine 9, connected to the runner 1 of the pump-turbine 2 by a shaft 10, serves for starting. The starting turbine 9 receives water under pressure through a supply connection 11. Its exhaust water flows through a draft tube 12 into the suction tube 6 of the pump-turbine 2. On the inlet side, a shut-off valve 13 is provided in the supply connection 11 and on the outlet side a shut-off valve 14 is provided in the draft tube 12.

In order now to be able to limit the speed of the starting turbine or of the entire machine set on starting of the pump-turbine, the pump-turbine is provided with pressure-water pipes 16 opening into its runner chamber 15, which pipes are connected by an annular pipe 17 and another pipe 18 to a point of the supply connection 11 situated after the shut-off valve 13.

On starting, the shut-off valves 13 and 14 are open, and water under pressure passes through the pipes 18, 17 and 16 to the empty runner chamber 15 of the pump-turbine. The outlets of the pipes 16 are provided with nozzles 19, which spray the water supplied. The runner 1 then rotates in a water-air mixture. By additional liquid circulation, therefore, a braking torque is exerted on the machine set.

The supply of water through the nozzles 19 is so proportioned that the braking torque produced is sufficient to keep the speed of the machine set below the runaway speed of the pump-turbine 2. An adjustable throttling member 20 is incorporated in the pipe 18 for correct proportioning of the quantity of water. A non-return valve 21 furthermore prevents back-flow of water through the pipe 18 after the pump-turbine 2 has been set in operation and the starting turbine 9 has been stopped.

In the arrangement shown in FIG. 1, an additional possibility of exerting a braking torque on the machine set is provided by the fact that the runner gaps and labyrinth gaps of the pump-turbine 2 are connected by pipes 22 and 23 and 24 to the supply connection 11 of the starting turbine. Water under pressure in increased quantity can be supplied through these pipes 22, 23, 24 to the runner gaps and runner labyrinths of the machine which is to be started. This step also provides an additional circulation of liquid with the application of a braking torque on the machine set. A throttling member 25 and non-return valve 26 are incorporated in the pipe 24. These members 25 and 26 serve the same purpose as the members 20 and 21.

The fact that the pipes 18 and 24 are connected to the supply connection 11 of the starting turbine 9 at points situated after the shut-off valve 13 ensures that pressure water is supplied simultaneously to the starting turbine 9 and to the pipes 16, 22, 23 opening into the housing of the pump-turbine 1. Without departing from the general scope of the invention, however, instead of being connected to the inlet of the starting turbine 9, the spray nozzles or the runner gaps or labyrinths may be connected to some other source of water under pressure. In that case, a shut-off valve incorporated in the pressure-water line leading to the runner chamber of the pump-turbine may then be coupled to the operating device of the main shut-off valve of the starting turbine in such a manner that it opens simultaneously with the main shut-off valve.

As apparatus for producing an additional liquid circulation through the machine set, it is also possible to provide a centrifugal pump acting as circulation pump and speed limiting pump and mechanically coupled to the starting turbine. This circulation pump should then be so designed that it begins to deliver on exceeding a speed below the runaway speed of the machine which is to be started and then absorbs part of the driving torque of the starting turbine.

FIG. 2 shows such an embodiment. The starting turbine is constructed as Francis turbine. 27 is the runner of the starting turbine and 28 the runner of the circulating pump. The runner 28 of the circulating pump is built directly on to the runner 27 of the starting turbine on the coupling side. Connected thereto is the driving shaft 10 for the pump-turbine or accumulator pump to be driven, which is not shown.

The working water flows to the runner 27 of the starting turbine through a spiral casing 29 and flows away through a draft tube 30. The suction side of the circulating pump 28 is connected to the outlet chamber of the starting turbine, that is to say to the draft tube 30 by a passage 31 passing through the runner hub of the starting turbine. The spiral casing 29 acts as pressure casing common to the starting turbine and circulating pump, that is to say, it forms the inlet chamber for the starting turbine and the outlet chamber for the circulating pump.

The runner 28 of the circulation pump is so designed that it begins to deliver on exceeding a predetermined speed below the runaway speed of the machine to be started, but advantageously only above the working speed of the machine to be started. Incorporated in the passage 31 as closure member is a non-return valve 32, which,

below said speed, prevents back-flow of water through the runner **28** of the circulating pump opposite to the delivery direction.

As soon as the speed at which the runner **28** of the circulating pump produces the necessary pressure for the delivery of water is exceeded, the non-return valve **32** opens automatically and the circulating pump begins to pump water from the discharge chamber of the starting turbine to the inlet chamber thereof and thus to circulate it additionally while exercising a braking torque on the machine set.

What is claimed is:

1. In combination a machine set comprising a hydraulic machine having a housing and a runner in said housing, and a starting turbine drivingly connected with said runner of the hydraulic machine, said starting turbine having a supply connection for driving water including a shut-off valve, and a speed limiting device comprising at least one pipe issuing from a point of said supply connection situated after said shut-off valve and opening into said housing of the hydraulic machine so as to withdraw water from said supply connection and to direct it toward the runner of said hydraulic machine.

2. The combination defined in claim 1 in which said pipe is provided with a throttling member.

3. The combination defined in claim 1 in which said pipe is provided with a non-return valve.

4. In combination a machine set comprising an hydraulic machine having a housing and a runner in said housing, and a starting turbine having a runner drivingly connected with the runner of said hydraulic machine and means defining a flow passage for driving water through said starting turbine, comprising a supply connection including a shut-off valve and a discharge connection for the water leaving the runner of the starting turbine; and a speed limiting device comprising a flow connection, issuing from said flow passage at a point downstream from said shut-off valve, for deriving part of the driving water of the starting turbine; and means, effective when the speed of the machine reaches a speed which approaches the runaway speed of the hydraulic machine, causing the derived water to exert a hydro-dynamic drag on the machine set.

5. The combination defined in claim 4 in which the means causing the derived water to exert a hydro-dynamic drag on the machine set comprises means to direct the derived water from said flow connection toward the runner of said hydraulic machine.

6. The combination defined in claim 5 in which part of the runner of said hydraulic machine defines with the housing a sealing gap and said flow connection opens into said sealing gap.

7. The combination defined in claim 5 in which said flow connection opens into the housing at a point situated on the low pressure side of the runner so as to direct the water toward the runner.

8. The combination defined in claim 4 in which the means causing the derived water to exert a hydro-dynamic drag on the machine set comprises a centrifugal pump connected to be driven by said starting turbine and in which said flow connection opens into the inlet side of said centrifugal pump, said centrifugal pump being effective to deliver water only when its speed exceeds a speed which approaches the runaway speed of said hydraulic machine.

9. The combination defined in claim 8 in which a shut-off valve is incorporated in the liquid flow path of the centrifugal pump; said shut-off valve being designed so as to open automatically when a predetermined speed below the runaway speed of the hydraulic machine is exceeded.

10. The combination defined in claim 9 in which the shut-off valve incorporated in the liquid flow path of the centrifugal pump is a non-return valve designed to open as soon as the liquid pressure produced by the speed limiting pump has reached a predetermined value.

11. The combination defined in claim 8 in which the suction side of the centrifugal pump is connected to the discharge side of the starting turbine and the pressure side of the centrifugal pump is connected to the inlet side of the starting turbine.

12. The combination defined in claim 11 in which the starting turbine is constructed as a Francis turbine and the runner of the centrifugal pump is built directly on the runner of the starting turbine.

13. The combination defined in claim 12 in which the starting turbine and the centrifugal pump have on the pressure side a spiral casing common to both.

14. The combination defined in claim 12 in which for the connection of the suction side of the centrifugal pump with the discharge side of the starting turbine a passage is provided which passes through the runner of the starting turbine, a non-return valve being incorporated in said passage.

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