Dec. 29, 1964 K. BAUMANN 3,163,118

STARTING UP A STORAGE PUMP OR PUMP-TURBINE

Filed June 11, 1963 3 Sheets-Sheet 1

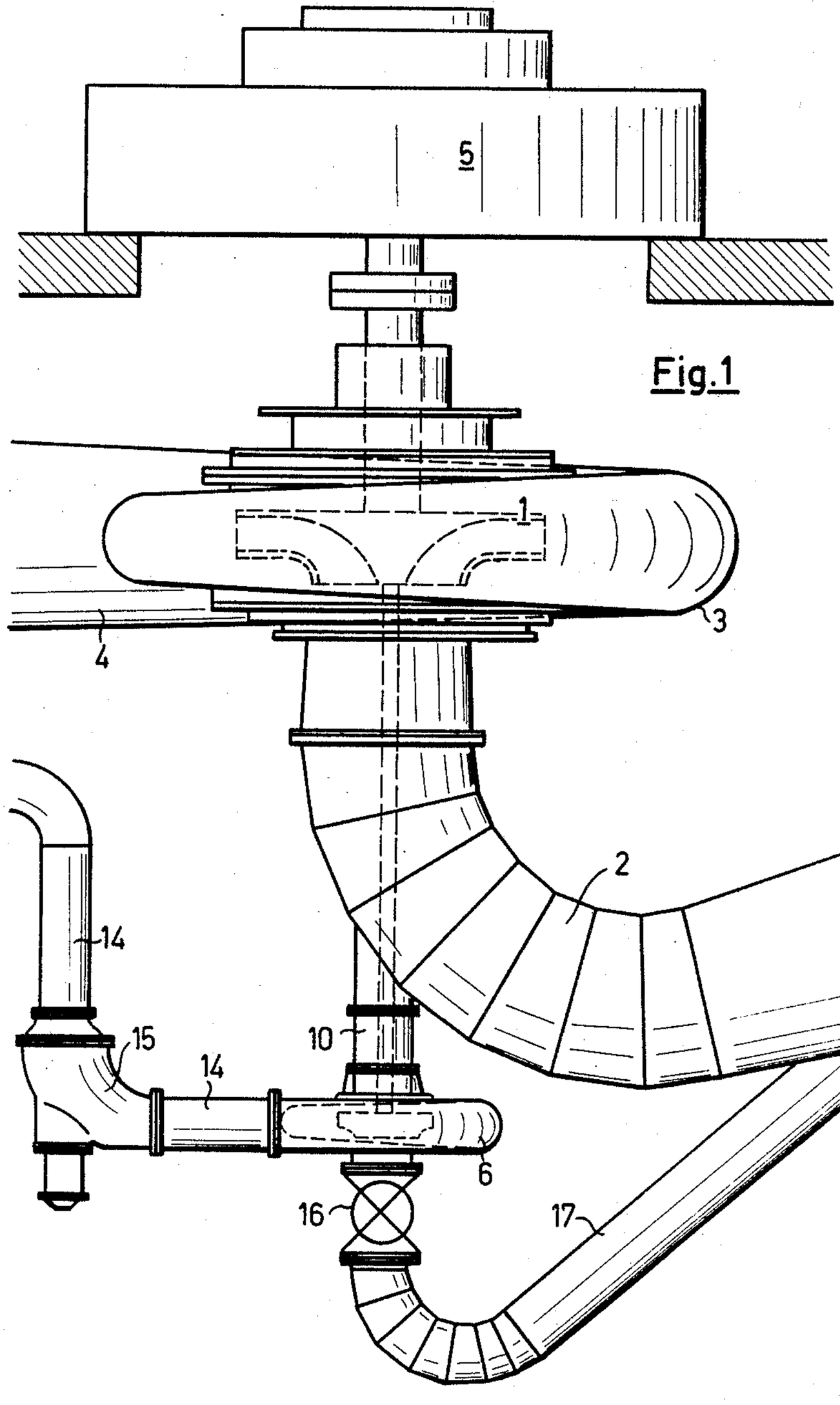

Fig.1

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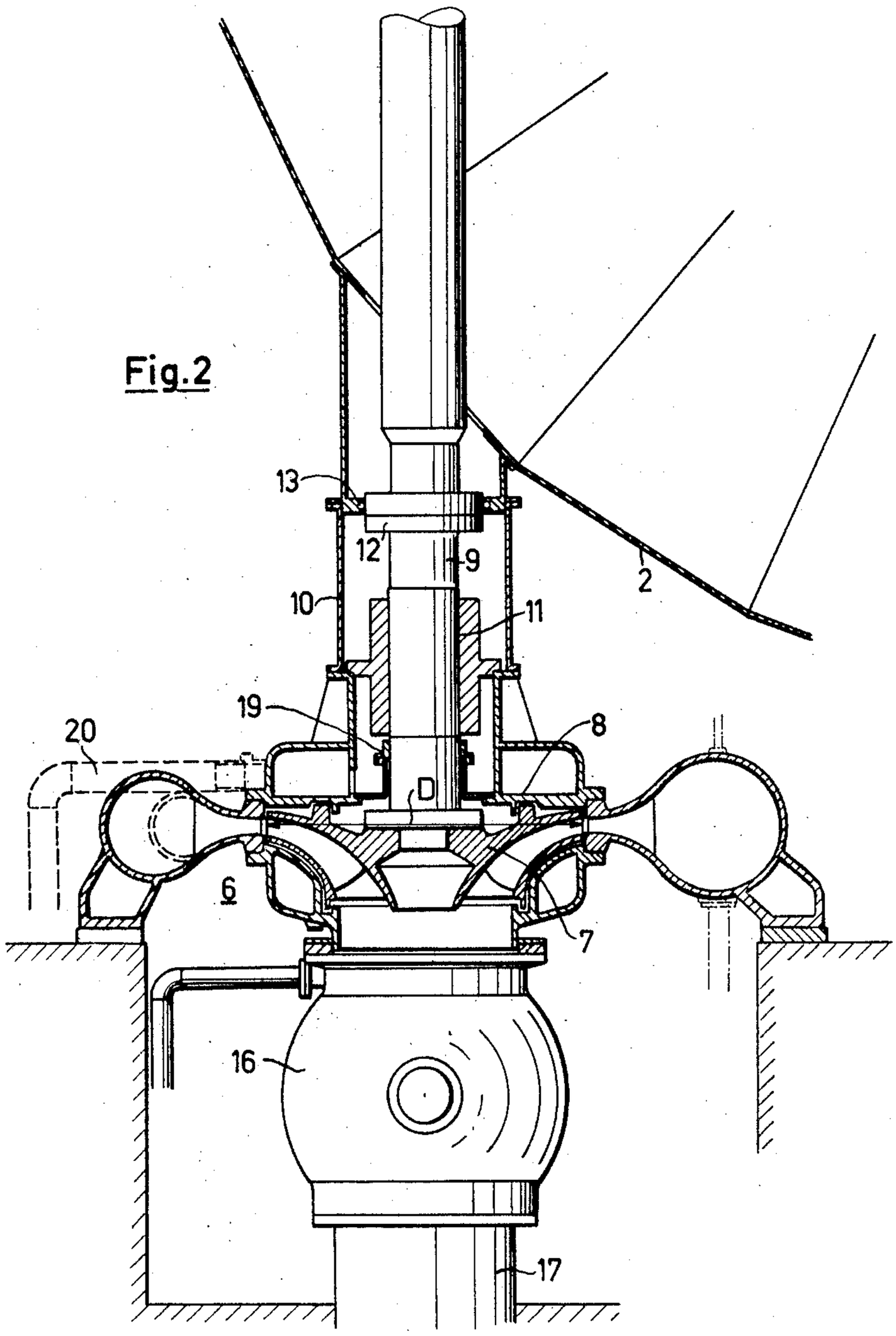
Fig.2



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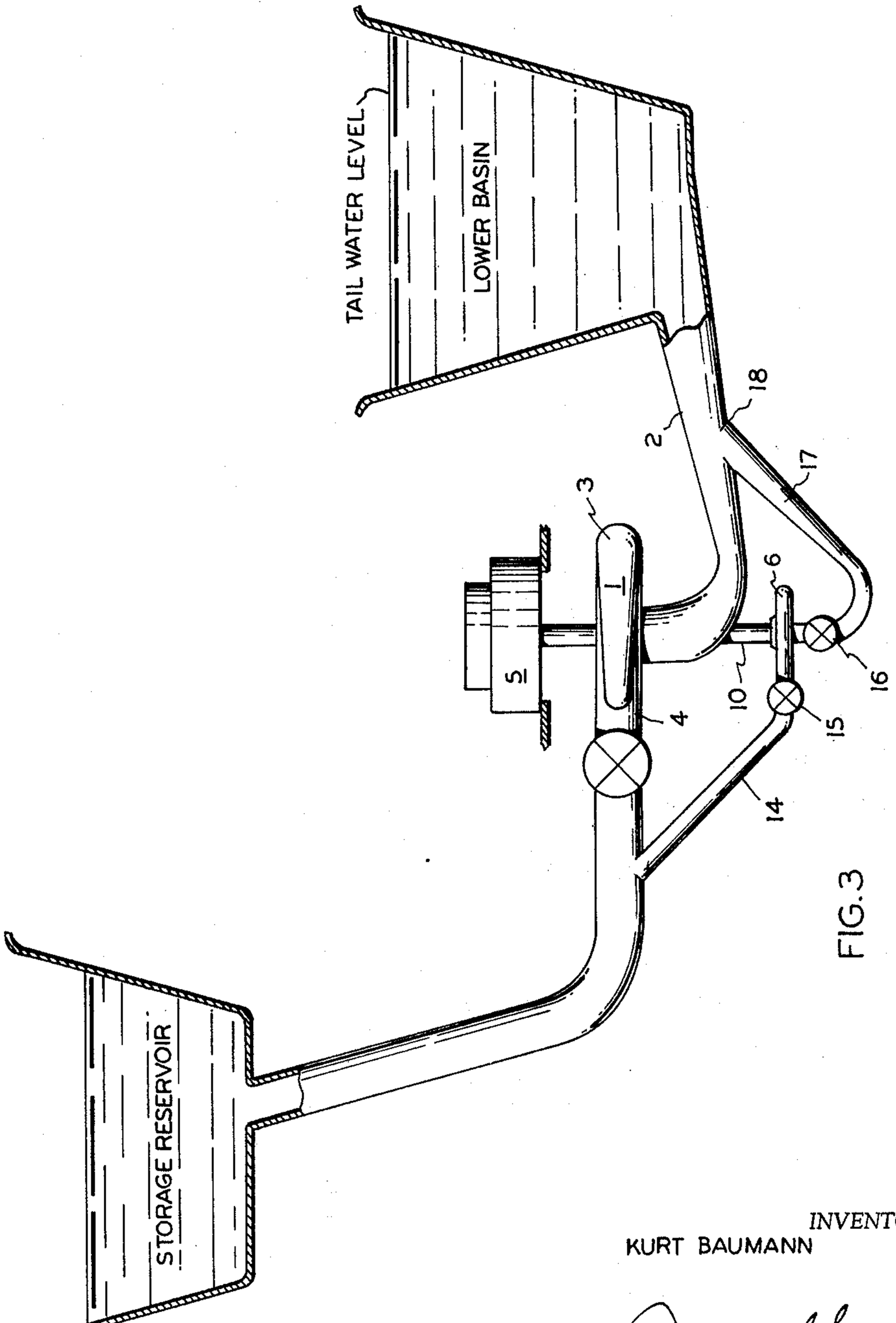

FIG. 3

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STARTING UP A STORAGE PUMP OR PUMP-TURBINE

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11 Claims. (Cl. 103—87)

In pump storage stations, it is known to use as machine set an electrical machine, which can be operated as generator or as motor, and either a turbine and a storage pump adapted to be coupled or uncoupled, or a so-called pump-turbine, that is to say, a hydraulic machine which can be operated as a turbine or as a pump. In the latter case, for turbine operation or pump operation, the reverse direction of rotation is necessary each time, because the hydraulic machine is equipped only with a single, one-stage or multiple-stage runner.

On passing from turbine operation to pump operation, speeding up of the hydraulic machine from stop to synchronous speed is necessary both in the case of the use of a special storage pump and in that of the use of a pump-turbine. In the first case, the storage pump alone must be brought into synchronism with the speed of the electrical machine running as a motor for being coupled to the latter, and in the second case, the pump-turbine must be speeded up together with the electrical machine from stop until the synchronous speed is reached and the electrical machine can be connected to the mains. Heretofore, the starting motor used has been an electric motor or a free-jet water turbine.

It must, however, be borne in mind that, as a rule, hydraulic machines, especially when set with the axis vertical, are mounted at a considerable depth below the lowest tail-water level. The use of a free-jet turbine as the starting turbine is then disadvantageous inasmuch as the operating water, which is necessary for starting and which is normally taken from the main pressure pipe of the pump storage set, is discharged into the pump sump of the power station, whence it must be pumped up by special pumps into the lower basin. This disadvantage could certainly be obviated by carrying the discharge pipe of the free-jet turbine housing into the lower basin. To avoid the free-jet runner rotating in the water, it would then be necessary to keep the free-jet turbine housing free from the contiguous tail water by means of compressed air. This would, however, be very troublesome and also costly, due to the high compressed air consumption.

This invention avoids these disadvantages. It relates to an arrangement incorporating a starting turbine for starting up a storage pump or pump-turbine, and it consists in that the starting turbine is constructed as a Francis turbine.

The runner of the starting turbine is here preferably so designed that at the operating speed of the storage pump or pump-turbine, the specific peripheral velocity $K_u=u/\sqrt{2gH}$ of the starting turbine attains at the most the value of about 0.5, with u=peripheral velocity of the runner of the starting turbine, referred to the blade entry diameter, H=net head under which the starting turbine operates and g=acceleration due to gravity.

The specific peripheral velocity, therefore, is always substantially less than the normal specific peripheral velocity of a Francis turbine operating with favourable efficiency. This step affords the advantage that a relatively small machine may be used as the starting turbine, no attempt being made in operation to cover the range of optimum efficiency. In dimensioning the flow cross-sections, it is merely necessary to ensure that the torque necessary for rapid acceleration is obtained.

A constructional example of the subject of the invention is illustrated in simplified form in the accompanying drawings, wherein:

FIG. 1 shows the machine set of a pump storage station with the arrangement for starting it up.

FIG. 2 shows a portion of FIG. 1 on a larger scale with axial longitudinal section through the starting turbine.

FIG. 3 is a schematic diagram of a pump storage station incorporating the machine set of FIG. 1.

The machine set of the pump storage station comprises a vertical-shaft pump-turbine 1 including a draft tube 2 leading to the lower basin, a volute casing 3 and a pressure pipe 4 leading to the storage reservoir, and an electrical machine 5, which is coupled to said turbine and which can function either as a generator or as a motor. Below the draft tube 2 is a starting turbine 6, constructed as a Francis turbine, with runner 7 and housing 8. The runner 7 (FIG. 2) is connected to the runner of the pump-turbine 1 by a driving shaft 9. The driving shaft 9 is surrounded by a water-tight tube 10 connecting the draft tube 2 hydraulically to the housing 8 of the starting turbine 6. Mounted in the tube 10 is a water-lubricated bearing 11 for guiding the driving shaft 9. The provision of a stuffing box at the passage of the pump shaft through the draft tube 2 is here unnecessary. Between the draft tube 2 and bearing 11, the driving shaft 9 is provided with a detachable coupling 12. On the coupling part of the pump shaft is a stoppage seal 13.

The operating water for the starting turbine 6 is taken from the pressure duct 4 of the pump-turbine 1 and is led to the starting turbine 6 through a pipe 14 with built-in adjustable shut-off member 15. A discharge pipe 17, provided with a shut-off member 16, is connected to the starting turbine 6 on the exit side and opens into the draft tube 2 of the pump-turbine 1 at a point 18.

The construction described affords the possibility, after closing the shut-off members 15 and 16 and the stoppage seal 13 at the entry of the shaft into the draft tube 2, and after disconnecting the coupling 12, of removing the starting turbine as a whole without having to empty the draft tube 2 of the pump-turbine 1.

The runner 7 of the starting turbine 6, constructed as a Francis turbine, has a comparatively small inlet diameter D. This diameter D is so dimensioned that on starting the pump-turbine 1 and the electrical machine 5 coupled to it, the peripheral velocity $u=\pi.D.n/60$ (with n=number of revolutions per minute) attains at the most a value of about $0.5\sqrt{2gH}$. The specific peripheral velocity $K_u=u/\sqrt{2gH}$ accordingly is always substantially less than the normal specific peripheral velocity of a Francis turbine operating with favourable efficiency. While disregarding optimum efficiency, therefore, the runner 7 of the starting turbine 6 is so designed that with small dimensions, it attains the high torque development necessary for rapid starting.

After the machine set 1–5 has been speeded up and the electrical machine has been connected to the mains, the two shut-off members 15 and 16 are closed and the housing 8 of the starting turbine 6 is emptied. A splash ring 19 is mounted on the shart 9 below the water-lubricated bearing 11 for preventing the entry of leakage water into the housing 8 during operation with the housing 8 empty. The leakage water thrown off by the splash ring 19 is discharged through a pipe 20.

As will be appreciated from FIG. 2, the starting turbine 6 has no adjustable guide blade system. Instead, for regulating the quantity of water of the starting turbine 6, use is made of the adjustable shut-off member 15 incorporated in its water path.

The arrangement described can, in principle, be used in the same way if, instead of the pump-turbine 1, a storage pump is used, that is to say, a hydraulic machine which can be used only as a pump, and which, on starting up, is to be brought by the starting turbine from stoppage to synchronous speed so that it can be coupled to an electrical machine.

What is claimed is:

1. In combination a pump storage station including a water storage reservoir, a water basin at a lower elevation than the storage reservoir, a pump located below the minimum water level in the basin and arranged to transfer water from the basin to the storage reservoir, and a synchronous electrical machine adapted to drive the pump; a starting turbine of the Francis type connected in driving relation with the pump; and means defining a flow path leading from the storage reservoir to the basin through the Francis turbine.

2. The combination defined in claim 1 in which the pump is provided with a draft tube leading from its inlet to the basin; and that part of said flow path between the Francis turbine and the basin includes a portion of the draft tube.

3. The combination defined in claim 1 in which the pump is arranged with vertical axis and has a curved draft tube on its underside; the starting turbine being disposed below said draft tube and having a driving shaft traversing said draft tube; a water-tight tube being further arranged to surround said shaft while connecting the starting turbine to the draft tube; and a water-lubricated bearing for said shaft being mounted in said water-tight tube.

4. The combination defined in claim 3 in which a splash ring is mounted on said driving shaft below the water-lubricated bearing so as to prevent entry of leakage water from the draft tube of the pump into the housing of the starting turbine during operation with said housing emptied.

5. The combination defined in claim 4 in which the driving shaft has a detachable coupling between the draft tube of the pump and the bearing.

6. The combination defined in claim 12 in which the starting turbine has only fixed guide vanes; and which includes an adjustable shut-off member for the through-flowing water located in said flow path between the storage reservoir and the starting turbine.

7. The combination defined in claim 1 in which said starting turbine has a runner dimensioned in such a manner that, at the operating speed of the pump, the specific peripheral velocity $K_u=u/\sqrt{2gH}$ of the starting turbine attains at the most the value of about 0.5, that is to say, it is always substantially less than the normal specific peripheral velocity of a Francis turbine operating with favourable efficiency.

8. In combination a vertical axis storage water pump which, in operation, is to be driven by a synchronous electric machine, comprising a housing; an impeller in said housing; a curved draft tube for the water to be pumped connected to the underside of said housing; an outlet connection for the pumped water; and a starting turbine of the Francis type comprising a housing arranged below said draft tube and coaxially with the pump; a runner in said turbine housing; a driving shaft connecting said turbine runner with the pump impeller while traversing said draft tube; an inlet connection for the turbine operating water; a discharge connection adjoining the underside of said turbine housing; and a water-tight tubular member surrounding said driving shaft and connecting the draft tube with the turbine housing; the runner of said starting turbine being dimensioned in such a manner that, at the operating speed of the pump, the specific peripheral velocity $K_u=u/\sqrt{2gH}$ of the starting turbine attains at the most the value of about 0.5, so that it is always substantially less than the normal specific peripheral velocity of a Francis turbine operating with favourable efficiency.

9. The combination defined in claim 8 in which the discharge connection of the starting turbine opens into the draft tube of the pump.

10. The combination defined in claim 8 in which the tubular member which surrounds the driving shaft contains a water-lubricated guide bearing for the driving shaft.

11. The combination defined in claim 8 in which at least one of the turbine inlet and discharge connections has a built in adjustable shut-off member.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,163,118 December 29, 1964

Kurt Baumann

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 42, for the claim reference numeral "12" read -- 1 --.

Signed and sealed this 27th day of April 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents