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[54] **REVERSIBLE MULTI-STAGE HYDRAULIC MACHINE**

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[51] **Int. Cl.** **F01d 13/02,** F01d 1/30, F01d 1/00

[58] **Field of Search** ..... 415/152, 153, 154, 500, 415/127, 128, 99, 219 C, 166, 148, 151, 158, 199 A

[56] **References Cited**

UNITED STATES PATENTS

245,590	3/1884	Sherck	415/166
518,795	4/1944	Staples	415/166
2,219,098	10/1940	Borer	415/100
2,996,995	8/1961	Culaud	415/500
3,226,083	12/1965	Braikevitch et al.	415/500
3,433,165	3/1969	Hosnedl et al.	415/500
3,794,456	2/1974	Jelusie	415/153

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[57] **ABSTRACT**

A reversible multi-stage hydraulic machine having a minimum of three stages where the wheels are disposed on a common shaft; one of the wheels is disposed with its suction aperture directed on the opposite side to the suction apertures of the wheels of the other stages and is arranged back to back to its adjacent wheel; jointly and simultaneously regulable distributors are arranged each on the periphery of the wheels arranged each other back to back; a set of obturators in the machine makes it possible for at least one stage to be put out of action.

5 Claims, 4 Drawing Figures

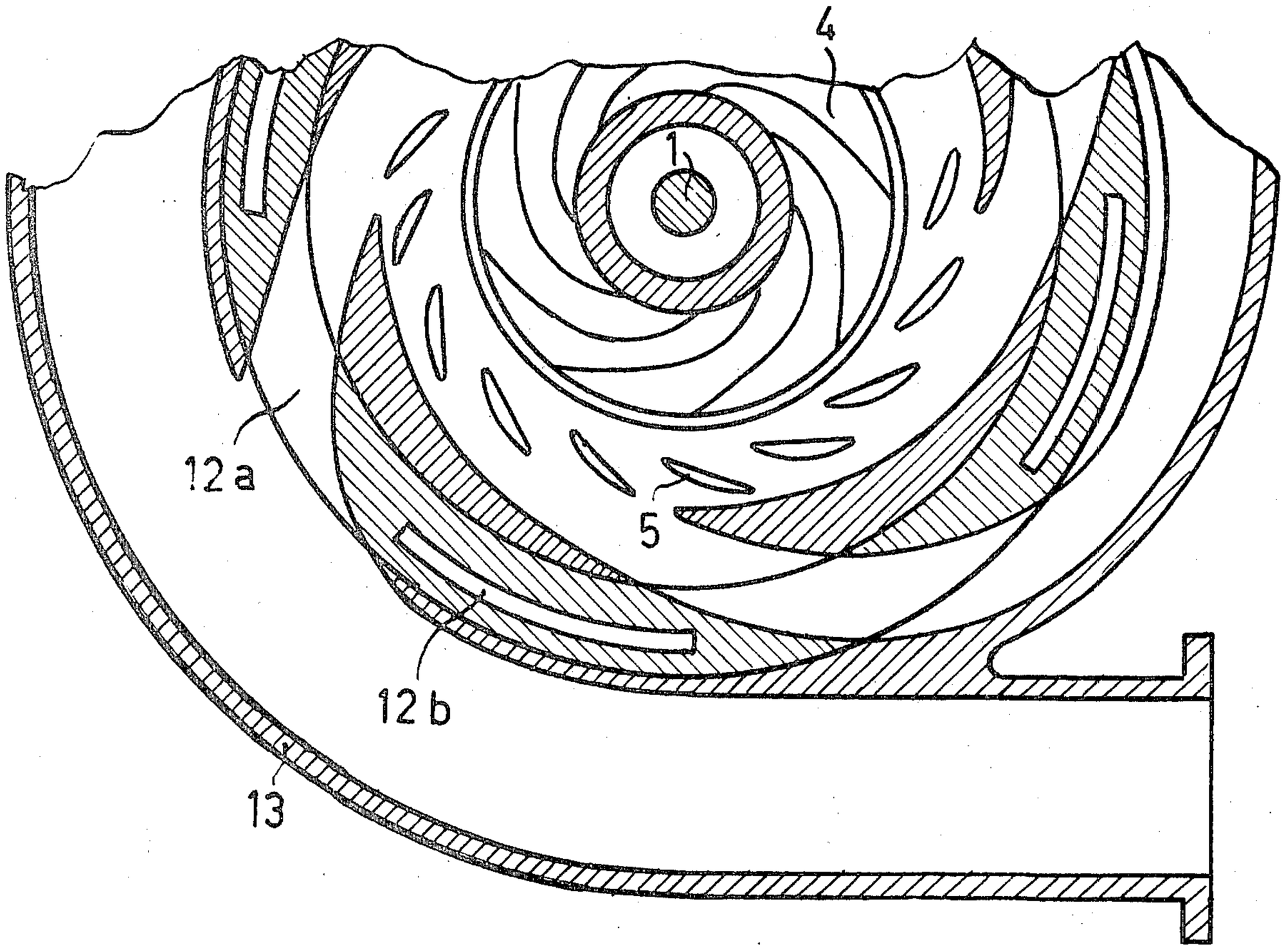


Fig.1

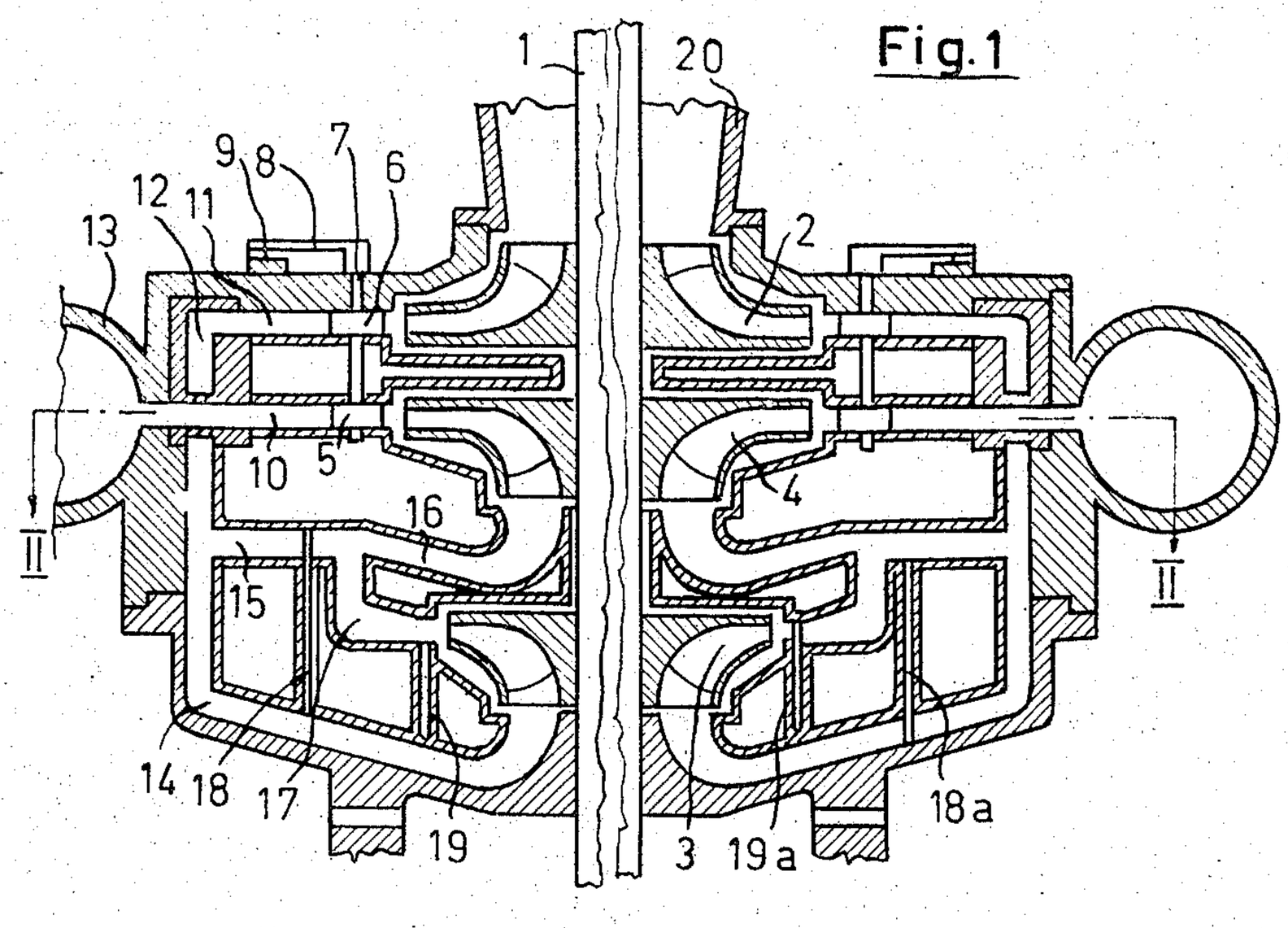

1
20
9
8
7
6
12
11
13
2
10
5
16
4
II
II
15
14
18
17
19
3
19a
18a

Fig.2

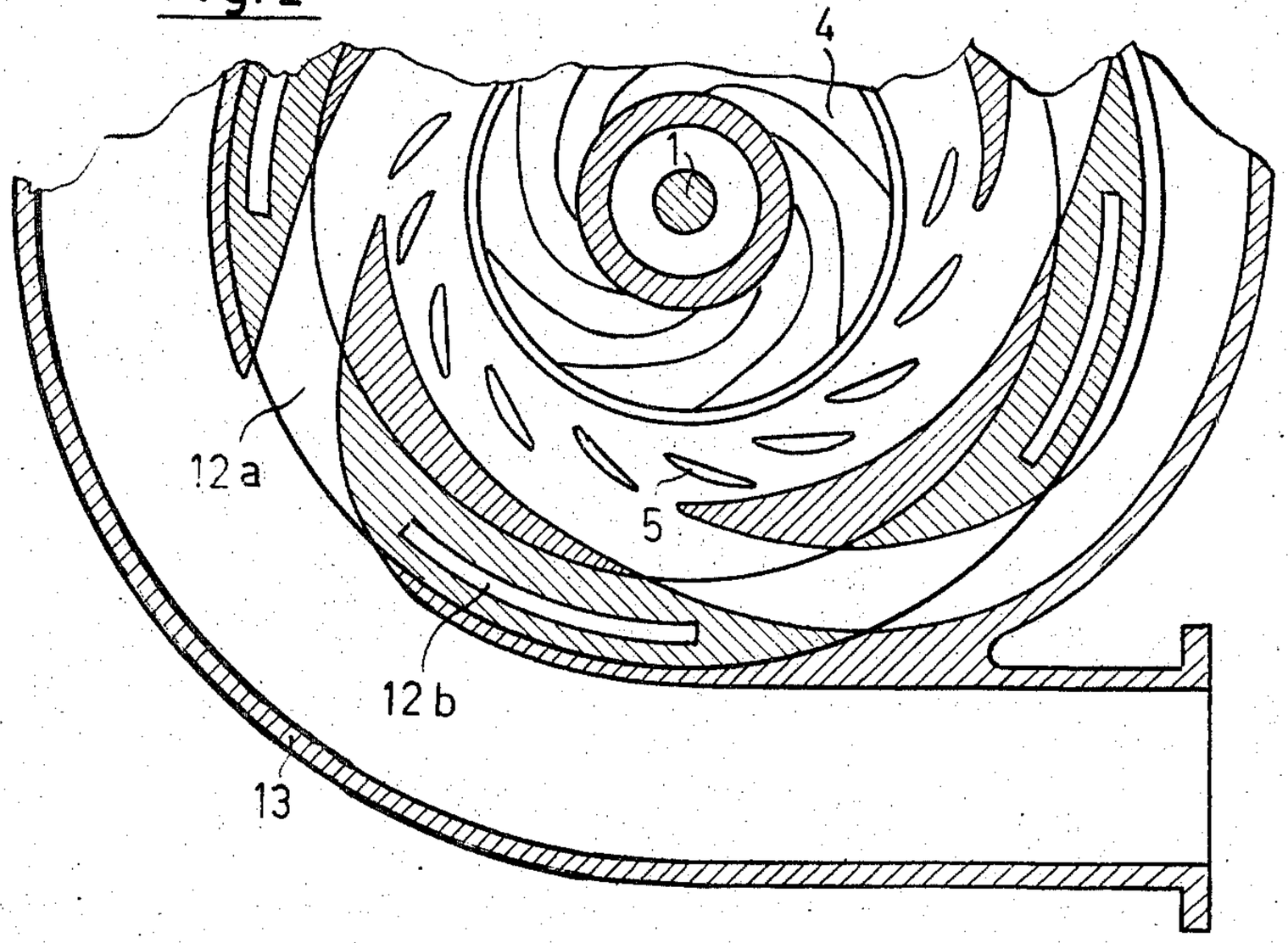

4
1
12a
5
12b
13

Fig. 3

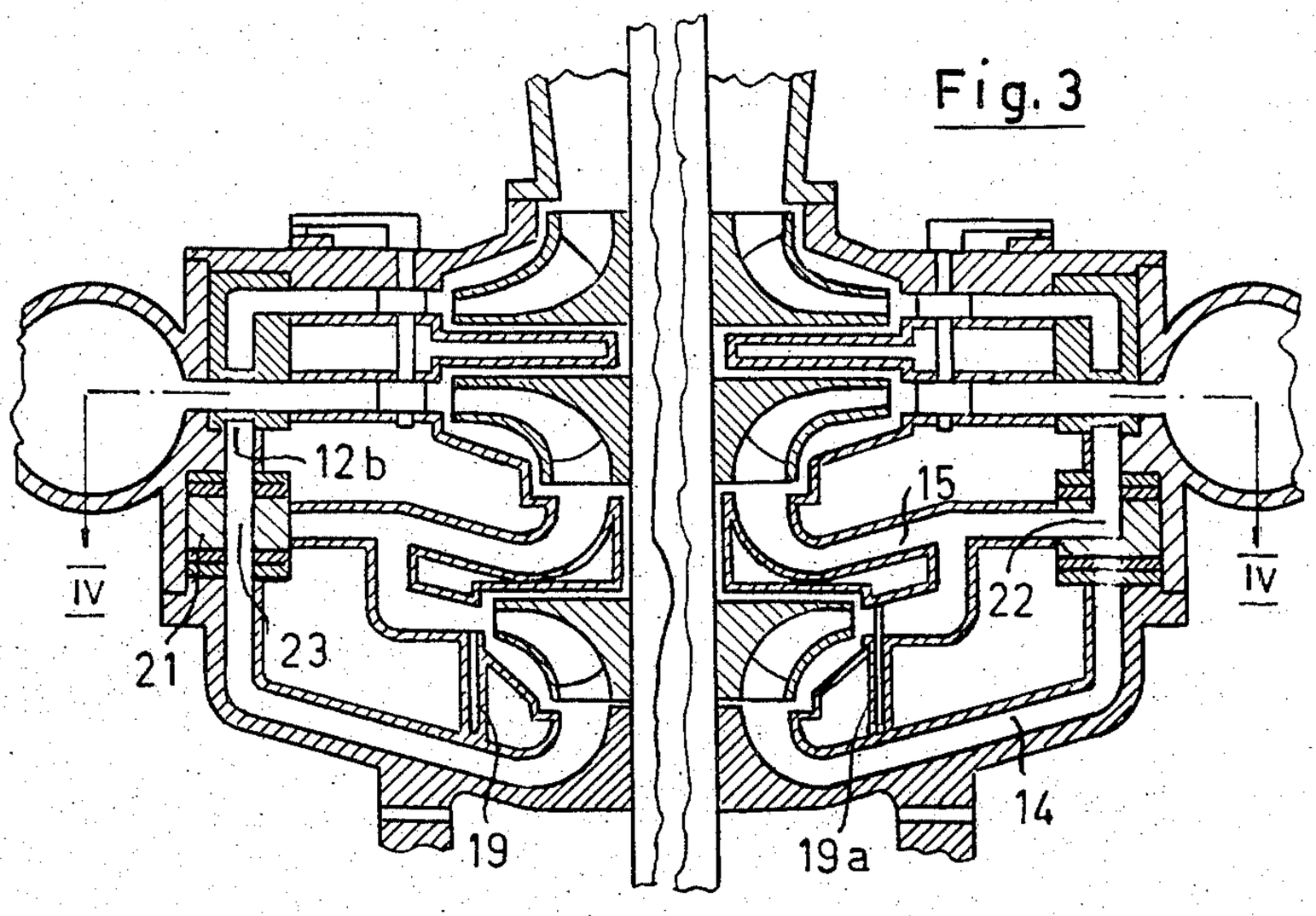
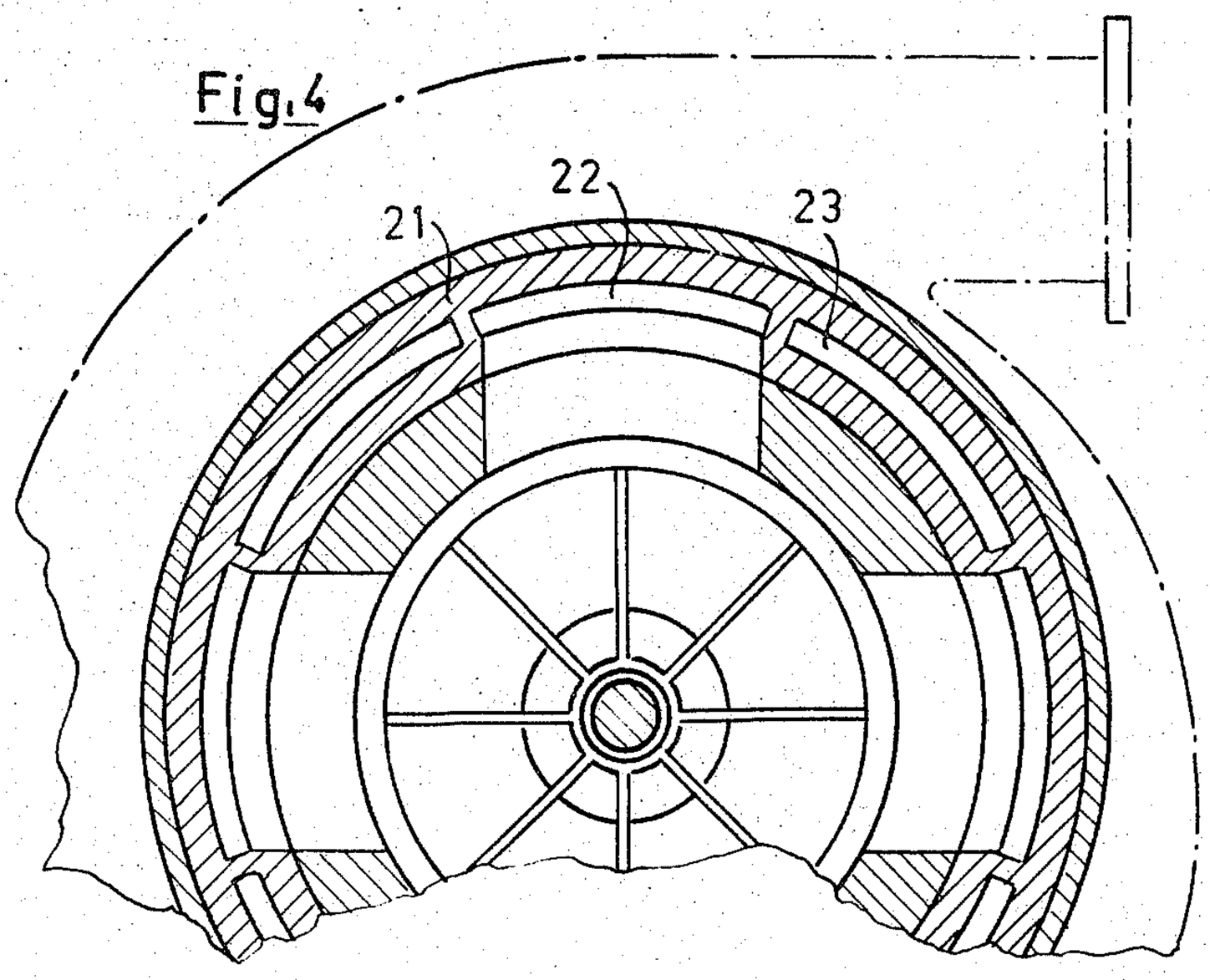


Fig. 4



REVERSIBLE MULTI-STAGE HYDRAULIC MACHINE

BACKGROUND OF THE INVENTION

The present invention relates to a reversible hydraulic machine having a minimum of three stages, and so designed as to be able to put one or more stages out of service at will, the wheels in the said machine being disposed on the common shaft.

In general, reversible hydraulic machines coupled to an alternator-motor and rotating at the same angular velocity in both directions of rotation reach their conditions of maximum efficency as turbines with heads which are from 20 to 40 percent greater than the elevation heights obtained under maximum efficency conditions during pumping; consequently, a reversible single-stage hydraulic machine cannot generally be so dimensioned as to operate as a turbine in the head range corresponding to its optimum efficiency. This results in a regrettable loss of energy which often justifies having recourse to ternary or isogyre solutions these utilising two wheels with different traces and situated each on separate passage of flow for conditions of operation as a turbine or as a pump.

When the high heads make it necessary to utilise a multi-stage machine, it becomes possible to overcome this disadvantage by a constructional design making it possible to put a larger number of stages into operation for working as a pump than for working as a turbine. Judicious selection of the individual blading traces of the various wheels then makes it possible to adapt the machine to installation conditions, so that it operates close to optimum efficiency, both as a turbine and as a pump.

Wheels required to operate under turbine conditions are preferably fed by means of a directable distributor. Under any head this device makes it possible to adjust the flow while retaining the highest possible efficiency. A simplification consists in providing distributors only for some of the wheels during turbine operation. However, the distribution of the head over the stages is hereby unbalanced, which is detrimental to efficiency and makes it necessary to limit the range of adjustment.

SUMMARY OF THE INVENTION

The object of the present invention is to achieve greater efficiency in reversible multi-stage hydraulic machines initially described, accompanied by better distribution of the head over the under turbine conditions required stages.

According to the present invention, this object is achieved in the case of a reversible multi-stage hydraulic machine comprising at least three stages in which the wheels are disposed on a common shaft by disposing at least one of the wheels with its suction aperture directed on the opposite side to the suction apertures of the wheels of the other stages and by arranging this wheel back to back to the wheel in the adjacent stage, further by disposing a set of obturators in the machine for putting at least one of the stages out of action, and more further by arranging each one regulable distributor in the two adjacent stages in which said wheel are arranged each other back to back and the distributors being regulable jointly and simultaneously.

According to the present invention at least one of the set of obturators for putting at least one stage out of action is of the cylindrical type commonly known as a sleeve valve.

It is advantageous if one of the obturators is a double-action sleeve valve.

As one of the obturators a double-action rotary obturator too is shown in one of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawings illustrate diagrammatically and by way of example one form of construction of the machine according to the invention, and also a variant.

FIG. **1** is a view thereof in longitudinal section, whereby on the left the machine being adjusted for the pump- and on the right for the turbine operating is shown.

FIG. **2** is a view thereof in cross-section on the line II—II in FIG. **1.**

FIG. **3** is a view in longitudinal section, similar to FIG. **1,** of the variant, showing a machine equipped with a set of different obturators, whereby on the left the machine being adjusted for the pump- and on the right for the turbine operating is shown.

FIG. **4** is a view thereof in cross-section on the line IV—IV in FIG. **3.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The machine shown in FIG. **1** and **2** comprises a shaft **1** which is carried by bearings (not shown) and on which are disposed three wheels numbered **2, 3** and **4**; the suction aperture of the wheel **2** is directed on the opposite side to the suction apertures of the wheels **3** and **4** (its blading is arranged accordingly) and this wheel **2** is arranged back to back to the wheel **4** which is in the adjacent stage relatively to the wheel **2.**

Two distributors **5** and **6,** each of which is formed of a series of movable blades, are each one disposed on the periphery of the wheels **4** and **2** respectively. These last two wheels **4** and **2** have their suction apertures in opposition, so that the distributors **5** and **6** are relatively very closely adjacent. Shafts **7** each carry a guide blade of the distributor **5** and a guide blade of the distributor **6.** Connecting rods **8** mounted on the shafts **7** and driven in known manner by the single and common regulating ring **9** permits simultaneous adjustment of the angular position of all the blades of the distributors **5** and **6,** thus effecting simultaneous adjustment of the admission of water to the wheels **4** and **2** of the machine and a balanced distribution of the head over the wheels **4** and **2.**

Ducts **10** and **11** situated beyond the distributors **5** and **6,** in relation to the wheels **4** and **2,** are formed in such a manner as to lead to a crossing part **12.** This part, of known shape, enables the ducts **10** to lead to a spiral casing **13** by way of a path **12a,** while the ducts **11** pass through apertures **12b** in the part **12,** these apertures bringing them into communication with the remainder of the machine.

Beyond the apertures **12b,** these ducts are divided into two branches **14** and **15.** The branch **14** rejoins the suction aperture of the wheel **3.** The branch **15** is directed towards the suction aperture of the wheel **4** to which it leads through a duct **16** after passing the junction of a return duct **17** of the wheel **3.**

The ducts **14** and **15** can be alternately closed by an obturator **18** shown in FIG. **1** in the form of a double-action sleeve valve. Another sleeve valve **19** disposed on the periphery of the wheel **3** can at will close the return duct **17.**

Taking these arrangements into account, the machine is designed to operate as a turbine with the two stages corresponding to the wheels **4** and **2** only, and to operate as a pump with the three stages on action.

During operation as a turbine, the valves **18** and **19** are situated in the positions shown in the right part of FIG. **1,** bearing the references **18***a* and **19***a*. The wheel **3** is then put out of action and emptied by a usual type of device (not shown) in order to avoid a loss of energy through splashing.

After the opening of a check valve (not shown), the water under pressure enters the spiral casing **13.** The water then flows into the ducts **12***a*, **10,** passes through the distributor **5,** which has been opened to the desired position to feed the wheel **4.** After escaping from the suction aperture of the latter, the water is guided through the successive duct elements **16, 15, 12***b*, and **11,** to the distributor **6** which feeds the wheel **2.** After passing through the latter, the water escapes from the machine through the suction tube **20.** The wheel **2,** which is assumed to have the same arrangement as the wheel **4** (except for the direction of rotation), being fed by a distributor **6** located under the same driving means, namely the single and common regulating ring **9,** as the distributor **5,** this results in a conversion of energy which is also distributed over the two wheels and the range of adjustment will be as wide as that is normally possible with a single-stage Francis turbine.

For operation as a pump the machine is driven in the opposite direction of rotation to that for turbine operation. The valves **18** and **19** are in the positions shown in the left part of FIG. **1.** The wheel **3** is then inserted into the water circuit and must previously be refilled either before the pump is put into operation or at least during the opening of the (not shown) check valve isolating the machine from the (not shown) penstock. The two distributors **5** and **6** are kept in a predetermined open position, defined in dependance on the delivery head.

The water drawn in by the wheel **2** is successively passed to the wheel **3** and then to the wheel **4** through ducts for which the free passage is determined by the valves and attains a delivery head enabling it to escape through the spiral casing **13** in the direction of the delivery pipe of the pump-turbine plant.

The trace of the wheel **3** is generally different from that of the wheels **2** and **4.** The portions of the delivery head treated by the wheels **2** and **4** are equal, and that treated by the wheel **3** supplies the make-up ensuring operation with optimum efficiency, taking into account the range of variation of the upstream and downstream pond levels of the pump-turbine plant.

In the variant illustrated in FIGS. **3** and **4** the sleeve valve **18** is replaced by a rotary obturator **21** composed of a ring provided alternately with apertures **22** having a bent passage and apertures **23** having a direct passage. An operating device (not shown) makes it possible to turn the obturator one step in one direction or the other, so as to cause the ducts **12***b* to coincide either with the apertures **22** or with the apertures **23** of this obturator.

It is seen that if the apertures **22** are fed by the ducts **12***b*, the conditions supplied by the sleeve valve in the position **18***a* in FIG. **1** are once again exactly obtained, the ducts **15** are fed while the ducts **14** are obturated, and the machine is ready for operation as a turbine, provided that the sleeve valve **19***a* is closed as previously.

If the apertures **23** are fed by the ducts **12***b*, the situation corresponding to the position **18** in FIG. **1** of the sleeve valve is found once again, the ducts **14** are fed and the ducts **15** are closed; the machine is ready to operate as a pump, provided that the sleeve valve **19** is opened as previously.

Numerous other modifications of the embodiment described and illustrated in the drawing can be contemplated.

In particular, stages may be added on either side of the set of wheels **3, 4, 2,** the wheel or wheels added at the side of the wheel **3** having its or their suction apertures directed in the same direction as those of the wheels **3** and **4,** while the wheels added at the side of the wheel **2** have their suction apertures directed in the same direction as those of the latter.

Obviously, particularly in the case of machines having a large number of stages, it is possible to provide obturators enabling a group of a plurality of stages to be put out of action.

The arrrangement of the wheels of the hydraulic machines described above permits a substantial simplification of the simulataneous operation of two distributors **5** and **6** placed on two contiguous stages in which the wheels **2** and **4** have their suction apertures in position and are arranged each other back to back. Furthermore, they make it possible to put out of action a stage or group of stages with the aid of obturators of various kinds incorporated in the machine.

Finally, the fact that one or more wheels of the machine are situated with their suction apertures directed in opposite directions make it possible to reduce the axial thrusts and the differences in pressure at the joints, thus improving efficiency.

I claim:

1. A reversible hydraulic machine including

a. a pump-turbine part having at least two stages, and a pump part having at least one stage,

b. each stage including an impeller, and the impellers being coupled to a common shaft,

c. the impellers of said two stages of the pump-turbine part being arranged in juxtaposition and back-to-back with their suction apertures facing in opposite directions;

d. two sets of distributors with adjustable stator blades, one being associated with each of said two stages of the pump-turbine part;

e. common regulating means for simultaneously adjusting the setting of both sets of blades; and

f. passage means interconnecting the stages and containing obturator means for selectively putting out of action the pump part,

g. the obturator means having a first setting in which it causes water being pumped to flow from a suction tube to a spiral casing of the machine through a path which leads serially through one stage of the pump-turbine, the pump, and the other stage of the pump-turbine, and a second setting in which it causes water acting as power medium to flow from the spiral casing to the suction tube of the machine

through a part which leads serially through said two stages of the pump-turbine part and is isolated from the pump part.

2. A machine as defined in claim 1 in which the obtruator means includes a reciprocable sleeve valve.

3. A machine as defined in claim 2 in which

a. the passage means includes a first passage which connects the periphery of one impeller of the pump-turbine part with the suction aperture of the other impeller of that part, and second and third passages which connect the suction aperture and periphery, respectively, of the impeller of the pump part with spaced points along the first passage; and

b. said sleeve valve is of the double-acting type and has a first position in which it opens the first passage and closes the second passage, and a second position in which it closes the first passage at a location intermediate the junctions of this passage

with the second and third passages and opens the second passage.

4. A machine as defined in claim 1 in which the obturator means includes a rotary valve.

5. A machine as defined in claim 4 in which

a. the passage means includes a first passage connected with the periphery of the first impeller of the pump-turbine part, a second passage connected with the suction aperture of the other impeller of the pump-turbine part, and a third passage connected with the suction aperture of the impeller of the pump part, these passages leading to the rotary valve; and

b. said rotary valve is of the double-acting type and has two positions in which, respectively, it connects the first passage with the second and third passages.

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