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54 **Hydro-electrical power plant.**

57 The invention relates to a hydro-electrical power plant and a method for generating electrical energy from hydraulic energy using the hydro-electrical power plant. The hydro-electrical power plant comprises a circulation system and a piston for displacing a hydraulic medium through the circulation system. The piston is provided with an adjustment device which is arranged for adjusting the ratio between the buoyancy of the piston and the weight of the piston.

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Hydro-electrical power plant

BACKGROUND

The invention relates to a hydro-electrical power plant, in particular a hydro-electrical power plant for
5 generating electricity for metropolitan areas.

An example of a known hydro-electrical power plant is a dam which generates electricity from water which is collected in a large reservoir. The dam provides electricity from a renewable energy source against
10 relatively low costs and virtually no harmful emissions when compared to traditional, fossil fuel power plants. However, dams and the associated reservoirs have a large impact on the environment and can typically not be constructed close to the metropolitan area for which the
15 electricity is intended.

It is an object of the present invention to provide an alternative hydro-electrical power plant.

20 SUMMARY OF THE INVENTION

According to a first aspect, the invention provides a hydro-electrical power plant comprising a circulation system for circulating a hydraulic medium,

wherein the circulation system comprises an upright piston chamber with a circumferential wall, a top and a bottom which bound a piston chamber volume for receiving the hydraulic medium, wherein the circulation system further
5 comprises at least one return channel which is in fluid communication with the piston chamber volume at the top and at the bottom of the piston chamber to form a closed path of circulation, wherein the circulation system is provided with a piston which is arranged to be submerged in the
10 hydraulic medium in the piston chamber volume, wherein the piston is moveable within the piston chamber for displacing the hydraulic medium through the circulation system, wherein the power plant comprises a converter which is placed in the circulation path for converting the hydraulic
15 energy of the circulating hydraulic medium into electrical energy, wherein the piston is provided with an adjustment device which is arranged for adjusting the ratio between the buoyancy of the piston when it is submerged in the hydraulic medium and the weight of the piston.

20 Thus, a hydro-electrical power plant is provided which can form an alternative for traditional, fossil fuel power plants and high impact dams. By adjusting the ratio between the buoyancy and the weight of the piston, the piston can be moved through the piston chamber, thereby
25 causing a circulation of hydraulic medium which can effectively be converted by the converter into electrical energy.

In an embodiment the adjustment device is arranged for adjusting the ratio to a first ratio in which
30 the buoyancy of the piston is smaller or less than the weight of the piston and a second ratio in which the buoyancy of the piston is greater or more than the weight of the piston. The first ratio can cause the piston to sink or descent in a downstroke through the piston chamber. The
35 second ratio can cause the piston to rise or ascent in an upstroke through the piston chamber.

In an embodiment the adjustment device is

arranged for adjusting the buoyancy of the piston. By adjusting the buoyancy of the piston, the weight of piston can remain substantially constant.

In an embodiment the adjustment device is
5 arranged for contracting the overall piston volume and for expanding the overall piston volume. Adjustment of the overall piston volume can effectively change the buoyancy of the piston, as the weight of the hydraulic medium that would normally occupy the overall piston volume is
10 proportional to the buoyancy force acting on the piston.

In an embodiment the piston comprises a first piston member and a second piston member which define or enclose at least part of the overall piston volume, wherein the adjustment device is coupled to the piston members for
15 moving the piston members relative to each other to adjust the overall piston volume. The mutual positions of the piston members can alter the outer shape of the piston and the piston volume enclosed with said outer shape.

In an embodiment the piston comprises a third
20 piston member which is arranged between the first piston member and the second piston member, wherein the third piston member defines or encloses at least part of the overall piston volume, wherein the adjustment device is attached to the third piston member for moving the first
25 piston member and the second piston member with respect to the third piston member. The third piston member can function as a housing for the adjustment device and can provide space for the first piston member and the second piston member to move inwards or outwards with respect to
30 the third piston member, to allow for the change in piston volume to occur.

In an embodiment the adjustment device comprises a threaded spindle and a drive for driving the spindle, wherein at least the first piston member engages onto and
35 is arranged to be moved by the spindle via an internal thread or a ball-screw spindle transmission. Preferably, the spindle is provided with opposite threads, wherein the

second piston member engages onto and is arranged to be moved in an opposite direction by the spindle via an internal thread or a ball-screw spindle transmission. In this manner, a relatively high transmission ratio can be achieved between the drive and the piston members to be moved, so that the forces of the hydraulic medium acting on the piston can be countered. The spindle can form a relatively compact transmission between the drive and the piston members to be moved, with a relatively small amount of moving parts.

In an embodiment the adjustment device comprises a mass which is suspended in the piston and a drive for rotating the mass, wherein the adjustment device is provided with a helical transmission which is arranged to travel over a helical travel path along the outer surface of the mass as it is rotated, wherein the helical transmission is arranged for converting the rotation of the mass into a linear movement of the first piston member with respect to the second piston member. In this manner, a relatively high transmission ratio can be achieved between the drive and the piston members to be moved. The weight of the mass can also aid the operation of the transmission.

In an embodiment the adjustment device is provided with a first diaphragm spring between the first piston member and the third piston member and a drive for controlling the first diaphragm spring to act as a lever between the first piston member and the third piston member. Preferably, the adjustment device is provided with a second diaphragm spring between the second piston member and the third piston member and a drive for controlling the second diaphragm spring to act as a lever between the second piston member and the third piston member. In this manner, a relatively high transmission ratio can be achieved between the drive and the piston members to be moved.

In an embodiment the adjustment device is arranged for adjusting the weight of the piston. The

overall piston volume can thus remain substantially constant.

In an embodiment the adjustment device comprises a ballast chamber and a first valve and/or a second valve
5 for allowing the hydraulic medium outside of the piston to flow into ballast chamber and for allowing hydraulic medium inside the ballast chamber to flow out of the ballast chamber, respectively. Depending on the level of hydraulic medium in the ballast chamber, the weight of the piston can
10 be increased or decreased.

In an embodiment the adjustment device comprises a skirt for trapping a gas underneath the piston. The gas can occupy a volume that was previously occupied by hydraulic medium, thereby increasing the overall volume of
15 the piston.

In an embodiment the piston is placed circumferentially in substantially sealing abutment with the circumferential wall of the piston chamber. In this manner, the piston can divide or fluidically separate the
20 piston chamber volume in a section underneath the piston and a section above the piston.

In an embodiment the piston is a free piston, which is preferably arranged to be moveable in the piston chamber without any fixed connection to the rest of the
25 power plant. The piston can thus freely move within the piston chamber between the top and the bottom without hindrance by other parts of the power plant.

In an embodiment the adjustment device is arranged for moving the piston in a reciprocating manner in
30 a downstroke and an upstroke by alternating the first ratio and the second ratio, respectively, wherein during the downstroke, the direction of circulation is opposite to the direction of circulation during the upstroke, wherein the converter is arranged for converting the hydraulic energy
35 of the hydraulic medium that is being displaced through the circulation system into electrical energy during both the downstroke and the upstroke. In this manner, the generation

of electrical energy can be kept substantially constant and is not interrupted by a passive upstroke.

In an embodiment the power plant is provided with a valve assembly for inverting the flow to and from the
5 converter. The valve assembly can ensure that the flow always correctly enters and leaves the converter, despite of the direction of circulation in the circulation system. Thus, the converter can be optimized for one flow direction.

10 In an embodiment the converter is a turbine, preferably a Kaplan turbine, most preferably a Kaplan turbine of the bulb or tubular type. A turbine, in particular a Kaplan turbine, is able to efficiently convert hydraulic energy from the flow of hydraulic medium into
15 mechanical energy, and eventually electrical energy.

In an embodiment the piston builds up kinetic energy when moving through the piston chamber, wherein the power plant is provided with an energy absorption unit for absorbing the kinetic energy of the moving piston when the
20 piston reaches the bottom or the top of the piston chamber, wherein the energy absorption unit is arranged for storing the absorbed kinetic energy, preferably as hydraulic energy. The absorbed kinetic energy can be reused in other parts of the power plant, for example for controlling the
25 valve assembly or for driving the adjustment device of the piston.

In an embodiment the energy absorption unit is arranged at the piston. Thus, the absorbed kinetic energy can be stored internally in the piston and can be reused
30 for driving the adjustment device directly at the piston.

In an embodiment the power plant comprises a plurality of return channels which are integrated in the circumferential wall of the piston chamber. By integrating the return channels in the circumferential wall, a compact
35 construction can be achieved, in which the piston chamber and the return channels can be constructed simultaneous.

According to a second aspect, the invention

provides a method for generating electrical energy from hydraulic energy using the aforementioned hydro-electrical power plant, wherein the method comprises a step of adjusting the ratio between the buoyancy and the weight of the piston. By adjusting the ratio between the buoyancy and the weight of the piston, the piston can be moved through the piston chamber, thereby causing a circulation of hydraulic medium which can effectively be converted by the converter into electrical energy.

10 In an embodiment the step of adjusting the ratio involves alternating between a first ratio and a second ratio, wherein in the first ratio the buoyancy of the piston is smaller or less than the weight of the piston and wherein in the second ratio the buoyancy of the piston is greater or more than the weight of the piston. The first ratio can cause the piston to sink or descent in a downstroke through the piston chamber. The second ratio can cause the piston to rise or ascent in an upstroke through the piston chamber.

20 In an embodiment the buoyancy of the piston is adjusted. By adjusting the buoyancy of the piston, the weight of piston can remain substantially constant.

In an embodiment the piston volume is reduced to reduce the buoyancy of the piston and wherein the piston volume is expanded to increase the buoyancy of the piston. Adjustment of the overall piston volume can effectively change the buoyancy of the piston.

30 In an embodiment the weight of the piston is adjusted. By adjusting the weight of the piston, the overall piston volume can remain substantially constant.

In an embodiment the method comprises a step of storing thermal energy into the hydraulic medium that is circulated through the circulating system. The large volume of the hydraulic medium can be particularly suitable for temporarily storing thermal energy.

In an embodiment the method comprises the step of delivering the hydraulic medium from the circulating system

to external systems, such as for district heating, for
hygienic purposes, for agricultural purposes or for water
consumption, wherein the method preferably comprises a
purification step of purifying the hydraulic medium prior
5 to delivery to the external systems. The hydro-electrical
power plant can thus serve a dual purpose, in the sense
that it can provide electrical energy as well as a
hydraulic medium to metropolitan or urban areas.

The various aspects and features described and
10 shown in the specification can be applied, individually,
wherever possible. These individual aspects, in particular
the aspects and features described in the attached
dependent claims, can be made subject of divisional patent
applications.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be elucidated on the basis of
20 an exemplary embodiment shown in the attached schematic
drawings, in which:

figures 1 and 2 show cross sectional side views
of a hydro-electrical power plant according to a first
exemplary embodiment of the invention, with a piston in a
25 downstroke and an upstroke, respectively;

figures 3 and 4 shows cross sectional top views
of the power plant according to the line III - III in
figure 1 and the line IV - IV in figure 2, respectively;

figure 5 shows a cross sectional side view of the
30 piston according to figures 1-4; and

figures 6-9 show cross sectional side views of
various alternative pistons according to alternative
embodiments of the invention.

35

DETAILED DESCRIPTION OF THE INVENTION

Figures 1-4 show a hydro-electrical power generator or a hydro-electrical power plant 1 according to an exemplary embodiment of the invention, in particular for generating electrical energy for urban or metropolitan areas. The hydro-electrical power plant 1 comprises a circulation system for circulating a hydraulic medium M and a converter 6 for converting the hydraulic energy of the circulating hydraulic medium M into electrical energy. The circulation system comprises a piston 8 which causes or drives the circulation of the hydraulic medium M. Several embodiments of the piston 8 will be described. However, first the general layout of the hydro-electrical power plant 1 is elucidated by the description below.

As shown in figure 1, the circulation system of the power plant 1 comprises a vertically upright piston chamber 2. The piston chamber 2 is provided with a circumferential wall 20 with a substantially vertical, longitudinal center axis S. In this exemplary embodiment, the circumferential wall 20 is substantially circular, such that the piston chamber 2 can be considered to be of cylindrical shape. Alternatively, the shape of the piston chamber 2 can be any prism having a constant cross section considered perpendicular to the center axis S. The circumferential wall 20 preferably has a height or length L in the range of approximately fifty meters up to or exceeding two-hundred meters. The outside diameter of the circumferential wall 20 is preferably in the range of approximately five meters up to or exceeding fifty meters. To accommodate such large dimensions without compromising the environment, the piston chamber 2 is preferably at least partially located under ground level G, for example in an underground, man-made shaft. The circumferential wall 20 is formed via a caisson method wherein the circumferential wall 20 is constructed with the help of a sliding form while simultaneously sinking the piston chamber 2 in the man-made shaft.

The piston chamber 2 is further provided with a

bottom 21 at the bottom end of the circumferential wall 20 and a top 25 at the top end of the circumferential wall 20. Together, the circumferential wall 20, the bottom 21 and the top 25 form, confine or bound a piston chamber volume H. The piston chamber volume H is almost completely or completely filled with the hydraulic medium M. In this example, the hydraulic medium M is water, preferably water that is provided and/or replenished by a renewable source such as run-off water, rainwater basins, groundwater, water from rivers and canals or precipitation from a precipitation cycle. Alternatively, the water can be provided from the water mains, for example during startup. As shown in figure 1, the bottom 21 comprises a bottom wall 22 with a first annular distribution channel 23 which is fluidically connected or in fluid communication with the piston chamber volume H at or near the bottom of the piston chamber 2. As shown in figures 1 and 3, the top 25 comprises a dome 26 with a center servicing passage 27, that can be opened for inspection or maintenance. The top 25 is further provided with a second annular distribution channel 28 which extends circumferentially around the outside of the dome 26 at or near the top of the piston chamber 2.

As shown in figure 1, the power plant 1 is provided with a plurality of mutually parallel, longitudinal return channels 3 which are integrally formed in the circumferential wall 20. The return channels 3 are evenly distributed in the circumferential direction about the center axis S. Alternatively, the power plant 1 can be provided with a single return channel (not shown) or one or more return channels being arranged separately of the circumferential wall 20 of the piston chamber 2. However, the integrated return channels 3 are preferred because this allows for compact and simultaneous construction of both the circumferential wall 20 and the return channels 3. The return channels 3 extend through the full length L of the circumferential wall 20. They are in fluid communication

with the first distribution channel 23 at the bottom end and the top end of the circumferential wall 20 at or near the bottom 21 and with the second distribution channel 28 at or near the top 25, respectively.

5 In this exemplary embodiment, the first distribution channel 23 directly debouches into the piston chamber volume H. The second distribution channel 28 does not directly debouch into the piston chamber volume H. Instead, the distribution channel 28 is operationally in
10 fluid communication with the piston chamber volume H via a valve assembly 4, a tube assembly 5 and the converter 6. Alternatively, the valve assembly 4, the tube assembly 5 and the converter 6 can be arranged at any position along the return channels 3, for example at halfway of the length
15 L of the circumferential wall 20 or at bottom 21. In the latter case, the second distribution channel 28 would be in direct fluid communication with the piston chamber volume H, while the first distribution channel 23 would be not directly debouch into the piston chamber volume H. In the
20 case of the piston chamber 2 being largely arranged underground, the upper position is preferred as it provides easy access for inspection or maintenance.

As shown in figure 3, the valve assembly 4 comprises a first valve element in the form of a first
25 valve block 40 and a second valve element in the form of a second valve block 44. The first valve block 40 comprises a first passageway 41 which is in fluid communication with the second distribution channel 28 and a second passageway 42 which is in fluid communication with the piston chamber
30 volume H at or near the top of the piston chamber 2. The first valve block 40 is provided with a concave sliding surface 43 facing towards the second valve block 44. The passageways 41, 42 extend separately through the first valve block 40 and debouch separately at the concave
35 sliding surface 43.

The second valve block 44 comprises an first inlet port 45, a second inlet port 47 and an outlet port 46

arranged between the inlet ports 45, 47. The second valve block 44 is provided with a convex sliding surface 48 that faces towards the first valve block 40. The ports 45-47 extend separately through the first valve block 40 and debouch separately at the convex sliding surface 48. The concave sliding surface 43 of the first valve block 40 and the convex sliding surface 48 of the second valve block 44 are complementary shaped with respect to each other. The sliding surfaces 43, 48 are shaped as circular segments with the same radii, such that the second valve block 44 can be driven by a drive (not shown) to slideably rotate with respect to the first valve block 40 about the center of the circular segments between a first valve position as shown in figure 3 and a second valve position as shown in figure 4.

In the situation as shown in figure 3, the second valve block 44 is arranged in the first valve position with respect to the first valve block 40. In this first valve position, the first passageway 41 is aligned with and in fluid communication with the first inlet port 45. The second passageway 42 is aligned with and in fluid communication with the outlet port 46. The second inlet port 47 is arranged in a blind position, straight opposite to a blind surface of the first sliding surface 43. In figure 4, the situation is shown wherein the second valve block 44 has been rotated in a rotational direction R to the second valve position. In the second valve position, the first passageway 41 is aligned with and in fluid communication with the outlet port 46. The second passageway 42 is aligned with and in fluid communication with the second inlet port 47. The first inlet port 45 is now arranged in a blind position, straight opposite to a blind surface of the first sliding surface 43.

As shown in figure 3, the power plant 1 further comprises a tube assembly 5 with a first inflow tube 51, a second inflow tube 53 and an outflow tube 52 arranged between the inflow tubes 51, 53. The first inflow tube 51,

the outflow tube 52 and the second inflow tube 53 are separately in fluid communication with the first inlet port 45, the outlet port 46 and the second inlet port 47, respectively. The tube assembly 5 is provided with a first
5 end piece 54 that fluidically connects the first inflow tube 51 to the outflow tube 52 and a second end piece 55 that fluidically connects the second inflow tube 53 to the outflow tube 52.

As shown in figure 1, the return channels 3 are
10 in fluid communication with the piston chamber 2 at the bottom 21 and the top 25 to form a substantially closed loop, a closed circuit or a closed path of hydraulic circulation. The valve block 4 and the tube assembly 5 are arranged in the path of circulation and direct the flow of
15 hydraulic medium M to the converter 6 which is arranged in the outflow tube 52 of the tube assembly 5. In an alternative embodiment (not shown), the tube assembly 5 can be provided with a single inflow tube arranged between two outflow tubes, wherein the converter 6 would be arranged in
20 the single inflow tube and wherein the hydraulic medium M would flow into tube assembly 5 via the single inflow tube and would be directed through one of the outflow tube depending on the valve position of the valve assembly. In the exemplary embodiment as shown in figure 3, the
25 converter 6 comprises a Kaplan turbine with a turbine wheel or runner 61 which is coupled, via a shaft, to a gearbox 62. The Kaplan turbine is of the bulb type or tubular type, in which the runner 61 and the gearbox 62 are axially arranged within the outflow tube 52. The gearbox 62 is
30 provided with an angular transmission which is coupled, via a shaft 63, to a direct drive generator and flywheel assembly 64 which can temporarily store the mechanical energy and eventually convert it to electrical energy.

As shown in figure 3, the power plant 1 further
35 comprises an expansion vessel 7 with a housing 70, an expansion volume 71 and an expansion tube 72 which connects the expansion volume 71 in fluid communication with the

piston chamber volume H via the center servicing passage 27. The expansion vessel 7 is hydraulically controlled to keep the pressure of the hydraulic medium M within the power plant 1 constant during operation of the plant 1.

5 Figures 1-5 show the piston 8 according to the first exemplary embodiment of the invention. The piston 8 is arranged to alternately move in a downstroke and an upstroke through the piston chamber 2. The vertical orientation of the piston chamber 2 ensures that there is
10 no or little friction between the piston 8 and the circumferential wall 20 as the piston 8 moves through the piston chamber 2. During the downstroke and the upstroke, the piston 8 is not fixedly connected to the rest of the power plant 1, neither by a crank arm or any other parts
15 which would typically be associated with a piston for transferring mechanical energy onto a piston. As such, the piston 8 can be considered as a free piston. Optionally, an umbilical cable (not shown) can be provided between the piston 8 and the piston chamber 2 to supply hydraulic fluid
20 or electricity to the piston 8, or to send control signal to or receive control signals from the piston 8. The umbilical cable should however be arranged in such a manner as not to hinder the movement of the piston 8 through the piston chamber 2.

25 The piston 8 comprises a first piston member 81 in the form of a first cylindrical extension and a second piston member 82 in the form of a second cylindrical extension, both extending from opposite sides of a center,
30 third piston member 83. The first piston member 81 and the second piston member 82 are provided with a first internal thread 86 and a second internal thread 87, respectively. The third piston member 83 is formed by a cylindrical center section with a first dome 84 at one end and a second dome 85 at the other end. The shape of the domes 84, 85
35 allows the piston 8 to withstand the pressure of the hydraulic medium M, in particular when the piston 8 is at the bottom 21 of the piston chamber 2. The center section

comprises a series of subsequent annular seals (not shown) which are arranged to be circumferentially placed in sealing abutment with the cylindrical wall 20 of the piston chamber 2. The seals of the piston 8 divide the piston chamber volume H in a section above the piston 8 and a second below the piston 8. Depending on the direction of the stroke of the piston 8, one of the sections is a section which is gradually compressed, while the other section is gradually expanding.

10 Together, the first piston member 81, the second piston member 82 and the third piston member 83 define, bound or enclose an overall piston volume V. The piston volume V determines the buoyancy force that is exerted on the piston 8 when the piston 8 is submerged in the hydraulic medium M. The piston 8 furthermore has an overall weight, i.e. the force acting on the piston 8 under gravity.

As shown in figure 5, the piston 8 is provided with an adjustment device 9 which is arranged for adjusting the buoyancy of the piston 8 when it is submerged in the hydraulic medium M. The adjustment device 9 comprises a spindle 90 which extends through the center of the third piston member 83, parallel to and at the center axis S of the piston chamber 2, between the first piston member 81 and the second piston member 82. The spindle 90 is provided with a first external thread 91 on one end and an opposite second external thread 92 on the other end. The spindle 90 is coupled to a drive, preferably a hydraulic drive (not shown), to be driven in a rotational direction K about the center axis S.

The first piston member 81 and the second piston member 82 are concentrically arranged on opposite ends of the spindle 90, with their internal threads 86, 87 engaging onto external threads 91, 92 of the spindle 90. Alternatively, the first piston member 81 and the second piston member 82 engage onto the spindle 90 via a ball-screw spindle type transmission (not shown). When the

spindle 90 is driven in the rotational direction K, the rotation is converted into a linear movement of the first piston member 81 and the second piston member 82, parallel to the center axis S. The first piston member 81 and the second piston member 82 can be driven apart in the expansion direction P or retracted towards each other in the contraction direction T. The expanded state of the first piston member 81 and the second piston member 82 is schematically indicated with dashed lines. In the expanded state, the first piston member 81 and the second piston member 82 are extended linearly over an expansion distance X, thereby increasing the overall piston volume V of the piston 8 with respect to the overall piston volume V in the contracted state.

As shown in figure 5, the piston 8 comprises a first energy absorption unit 88 and a second energy absorption unit 89, arranged on opposite sides of the piston 8. In this particular embodiment, the first energy absorption unit 88 is arranged at the distal end of the first piston member 81. The second energy absorption unit 89 is arranged at the distal end of the second piston member 82. The energy absorption units 88, 89 are provided with one or a plurality of hydraulic ram cylinders, which are arranged for absorbing the kinetic energy as the piston 8 approaches or reaches the bottom 21 and the top 25 of the piston chamber 2. The kinetic energy that is absorbed by the ram cylinders is stored in a hydraulic accumulator or a set of hydraulic accumulators (not shown). The stored hydraulic energy in the hydraulic accumulators can subsequently be used to power the drive of the adjustment device 9.

Alternatively, the energy absorption units 88, 89 can be arranged externally with respect to the piston 90, for example at the bottom 21 and the top 25 of the piston chamber 10. In such an embodiment, the piston 8 would come into abutment with the energy absorption units at the bottom 21 and the top 25, respectively, which would cause

the energy absorption units to absorb the kinetic energy of the piston 8 and store the absorbed kinetic energy externally with respect to the piston 8. The energy absorption units 88, 89 would then merely serve as brakes to slow down the downstroke or upstroke of the piston 8. The piston 8 would require a separate power source within the piston 8 or the aforementioned, optional umbilical cable feeding alternative power or the absorbed kinetic energy from the energy absorption units 88, 89 to the piston 8.

The method for generating electricity with the aforementioned power plant 1 according to the first embodiment of the invention will be elucidated below on the basis of figures 1-4, and with occasional reference to figure 5.

Figures 1 and 3 show the situation wherein the power plant 1 is ready for generating electricity during a downstroke of the piston 8. In the situation as shown in figure 1, the piston 8 is descending during the downstroke. The valve assembly 4 is in the first valve position, wherein the first inflow tube 51 is in fluid communication with the return channels 3 via the first passageway 41 and wherein the outflow tube 52 is in fluid communication with the piston chamber 2 via the second passageway 42.

The adjustment device 9 of the piston 8, as shown in figure 5, has been driven to move the first piston member 81 and the second piston member 82 inwards towards each other in the contraction direction T. The adjustment device 9 can be powered by hydraulic energy that has been stored in the piston 8 by the energy absorption units 88, 89 during previous strokes of the piston 8. At startup or during operation, the hydraulic energy stored in the piston 8 can be supplemented by feeding hydraulic energy via the optional umbilical cable or by temporarily docking the piston 8 at the top in proximity to the servicing passage 27. As a result of the contraction of the first piston member 81 and the second piston member 82, the

overall piston volume V of the piston 8 is reduced. Hydraulic medium M is transferred from the expansion vessel 7 to the piston chamber volume H to compensate for the change in piston volume V .

5 According to Archimedes' principle, the buoyancy force exerted on the piston 8 by the hydraulic medium M is proportional to the weight of the hydraulic medium M that would otherwise occupy the overall piston volume V . Thus, by reducing the overall piston volume V , less hydraulic
10 medium M is displaced by the piston 8 and the buoyancy of the piston 8 is reduced. To achieve descend, the ratio between the buoyancy and the weight of the piston 8 is reduced to a first ratio wherein the buoyancy is smaller or less than the weight of the piston 8. As a result, the
15 piston 8 will tend to descend or sink in the piston chamber 2 and the piston 8 will start to build up kinetic energy in a downward direction.

 During the downstroke of the piston 8, the section of the piston chamber volume H underneath the
20 piston 8 will be compressed while the section of the piston chamber volume H above the piston 8 is expanding. The hydraulic medium M underneath the piston 8 will be compressed by the piston 8 in a downward direction as indicated with arrows A . The hydraulic medium M is
25 subsequently forced out of the piston chamber volume H via the first distribution channel 23, which distributes the hydraulic medium M over the plurality of return channels 3. The hydraulic medium M is returned upwards, as indicated with flow arrows B , towards the second distribution channel
30 28.

 Figure 3 shows how the hydraulic medium M is returned to the top 25 via the plurality of return channel 3. The hydraulic medium M is collected in the second distribution channel 28 and subsequently forced through the
35 first passageway 41 and the first inlet port 45 of the valve assembly 4 into the first inflow tube 51 tube assembly 5, as indicated with flow arrows C . The flow C of

hydraulic medium M is then redirected by the first end piece 54 towards the outflow tube 52. In the outflow tube 52, the flow C of hydraulic medium M powers the converter 6, which converts the hydraulic energy of the hydraulic medium M into mechanical energy, and eventually into electrical energy. The flow C of hydraulic medium M leaves the outflow tube 52 of the tube assembly 5 via the outlet port 46 and the second passageway 42 of the valve assembly 4 and is subsequently allowed to enter the piston chamber volume H again at the top 25, above the descending piston 8. When the hydraulic medium M enters the piston chamber 2 again at the top 25, the hydraulic medium M has completed a full circulation in a path of circulation through the circulation system, as indicated with arrows A, B and C.

The downstroke of the piston 8 is continued until the piston 8 arrives at the bottom 21 of the piston chamber 2. When the piston 8 approaches the bottom 21, the speed of the descending piston 8 can be reduced by already moving the valve assembly 4 from the first position, partly into the second position. As a result, the passageways 41, 42 are slightly choked, thereby reducing the flow of hydraulic medium M and increasing the pressure of the hydraulic medium M underneath the piston 8, thereby slowing down the piston 8. Eventually, the first absorption unit 88 will come into abutment with the bottom wall 22. The ram cylinders of the first absorption unit 88 will absorb the kinetic energy of the piston 8 and - at the same time - slow down the descent of the piston 8. The absorbed kinetic energy is stored in the hydraulic accumulator of the first energy absorption unit 88 as hydraulic energy. At this moment, the downstroke of the piston 8 can be inverted into an upstroke in a manner which will be described hereafter.

The inversion of the downstroke of the piston 8 into an upstroke will cause the hydraulic medium M to circulate in an opposite direction of circulation. However, the converter 6 is typically optimized for one direction of circulation. Thus, shortly prior to, at the same time or

shortly after inversion of the downstroke into an upstroke, the valve assembly 4 has to be operated so that the flow of hydraulic medium M from the piston chamber 2 and the return channels 3 to the tube assembly 5 and the converter 6 is
5 inverted with respect to the situation as shown in figure 3.

Figure 4 shows the situation after the second valve block 44 of the valve assembly 4 has been rotated in the rotational direction R with respect to the first valve
10 block 40 to the second valve position. The second inflow channel 53 of the tube assembly 5 is now in fluid communication with the piston chamber 2 via the second passageway 42, while the outflow channel 52 is in fluid communication with the return channels 3 via the first
15 passageway 41. During the inversion of the downstroke into the upstroke, the flow of the hydraulic medium M to the tube assembly 5 is shortly interrupted, at which time the flywheel 64 as shown in figures 1 can compensate for the temporary interruption in the circulation. In this manner
20 it can be achieved that the circulating hydraulic medium M always enters the switch assembly 5 via one of the inflow channels 51, 53 and exits the switch assembly 5 via the outflow channel 52, despite the alternating directions of circulation of the hydraulic medium M through the
25 circulation system. Thus the converter 6 can be optimized for one direction of circulation. The power plant 1 is now ready for generating electricity during the upstroke of the piston 8.

Figure 2 shows the situation wherein the piston 8
30 is ascending during the upstroke. The adjustment device 9, as shown in figure 5, has been driven to move the first piston member 81 and the second piston member 82 apart in the expansion direction P. As a result of the expansion of the first piston member 81 and the second piston member 82,
35 the overall piston volume V of the piston 8 is increased again. Hydraulic medium M is transferred from the piston chamber volume H to the expansion vessel 7 to compensate

for the change in piston volume V .

By increasing the overall piston volume V , more hydraulic medium M is displaced by the piston 8 and the buoyancy of the piston 8 is increased. To achieve ascend, the ratio between the buoyancy and the weight of the piston 8 is increased to a second ratio wherein the buoyancy is greater or more than the weight of the piston 8. As a result, the piston 8 will tend to ascend or rise in the piston chamber 2 and the piston 8 will start to build up kinetic energy in an upward direction. During the upstroke of the piston 8, the section of the piston chamber volume H above the piston 8 will be compressed, while the section of the piston chamber volume H underneath the piston 8 is expanding. The hydraulic medium M will be compressed by the piston 8 in an upward direction as indicated with arrows D .

As shown in figure 4, the hydraulic medium M is subsequently forced out of the piston chamber volume H via the second passageway 42 of the first valve block 40, which debouches via the second inlet port 47 of the second valve block 44 into the second inflow tube 53 of the tube assembly 5. The flow of the hydraulic medium M through the second inflow tube 53 is indicated with flow arrows E . The flow E of hydraulic medium M is then redirected by the second end piece 55 towards the outflow tube 52. In the outflow tube 52, the flow E of hydraulic medium M again powers the converter 6, which converts the hydraulic energy of the hydraulic medium M into mechanical energy, and eventually into electrical energy. The flow E of hydraulic medium M leaves the outflow tube 52 of the tube assembly 5 via the outlet port 46 of the second valve block 44 and the second passageway 42 of the first valve block 40 and is subsequently collected in the second distribution channel 28.

As shown in figure 2, the hydraulic medium M is distributed by the second distribution channel 28 over the plurality of return channels 3. The hydraulic medium M flows in a downward flow direction F towards the first

distribution channel 23 at the bottom 21 of the piston chamber 2. The hydraulic medium M is collected in the distribution channel 23. The hydraulic medium M is subsequently allowed to enter the piston chamber 2 again at the bottom 21 underneath the ascending piston 8. When the hydraulic medium M enters the piston chamber 2 again at the bottom 21, the hydraulic medium M has completed a full circulation in a path of circulation through the circulation system, as indicated with arrows D, E and F. The circulation occurs in an opposite direction of circulation with respect to the circulation as shown in figure 1.

The upstroke of the piston 8 is continued until the piston 8 arrives at the top 25 of the piston chamber 2. When the piston 8 approaches the top 25, the speed of the ascending piston 8 can be reduced by already moving the valve assembly 4 from the second position, partly into the first position. As a result, the passageways 41, 42 are slightly choked, thereby reducing the flow of hydraulic medium M and increasing the pressure of the hydraulic medium M above the piston 8, thereby slowing down the piston 8. Eventually, the second absorption unit 89 will come into abutment with the dome 22. The ram cylinders of the second absorption unit 89 will absorb the kinetic energy of the piston 8 and - at the same time - slow down the ascent of the piston 8. The absorbed kinetic energy is stored in the hydraulic accumulator of the second energy absorption unit 89 as hydraulic energy. At this moment, the upstroke of the piston 8 can be inverted into a downstroke, after which the aforementioned method will repeat itself.

The hydraulic medium M is being circulated through the circulation system in alternating directions of circulation. Due to the gravitational forces acting on the hydraulic medium M and the cohesion of the hydraulic medium M, only a minimal amount of kinetic energy from the piston 8 is required to sustain the circulation. As a result, only a minimal variation between the first ratio and the second

ratio is required to achieve enough buoyancy force or weight force to start the circulation.

It will be apparent to one skilled in the art that adjusting the ratio between the buoyancy and the weight of the piston 8 can be achieved in many different ways. The following description illustrated various alternative embodiments of the piston 8 as shown in figure 5, which can replace the piston 8 in the power plant 1 as shown in figures 1-4. The alternative embodiments are by no means intended to limit the scope of the invention.

Figure 6 shows an alternative piston 108 according to a second embodiment of the invention. Similarly to the piston 8 according to figure 5, the volume V of the alternative piston 108 can be adjusted by an alternative adjustment device 109.

The alternative piston 108 comprises a first piston member 181 in the form of a first dome, a second piston member 182 in the form of a second dome and a third piston member 183 in the form of a cylindrical center section that is arranged between the first piston member 181 and the second piston member 182. The center section is assembled of a plurality of annular ring members 184, which are placed in sealing abutment on top of each other. Each ring member 184 is provided with a circumferentially extending, rubber seal (not shown) which is arranged to be placed in substantially sealing abutment with the circumferential wall 20 of the piston chamber 2. Together, the first piston member 181, the second piston member 182 and the third piston member 183 define the overall piston volume V. The piston 108 is provided with a first energy absorption unit 188 and a second energy absorption unit 189 which function in the same way as the energy absorption units 88, 89 of the piston 8 according to the first embodiment.

The alternative adjustment device 109 is arranged within the third piston member 183 between the first piston member 181 and the second piston member 182 and is arranged

for moving the first piston member 181 towards and away from the second piston member 182. For this purpose, the adjustment device 109 comprises a solid mass 190 which can be lowered and raised along the center axis S. The weight
5 of the mass 190 is used to aid the operation of the adjustment device 109. The mass 190 has a dome-like shape with a convex outer surface. The adjustment device 109 is provided with a plurality of guide arms 191 which are rotatably coupled to the second piston member 182 and which
10 are evenly distributed in the circumferential direction around the convex outer surface of the mass 190. Each guide arm 191 has a curvature that matches the curvature of the mass 190 and reaches underneath the mass 190 to suspend the mass 190 with respect to the second piston member 182. The
15 guide arms 191 are provided with guide wheels 192 which are arranged to travel or roll over the outer surface of the mass 190 along a helical travel path.

The plurality of guide arms 191 are connected, via first hinges 193, to an equal number of legs 194,
20 arranged circumferentially about the center axis S. The legs 194 are connected, via second hinges 195, to the first piston member 181. Together, the guide arms 191, the guide wheels 192, the first hinges 193, the legs 194 and the second hinges 195 form a helical transmission between the
25 second piston member 182 and the first piston member 181, which transmission is arranged for converting the rotary motion of the mass 190 into a linear motion of the first piston member 191 with respect to the second piston member 182.

30 The alternative piston 108 is controlled by a hydraulic drive (not shown), which is powered by the hydraulic energy from the energy absorption units 188, 189. The drive drives the mass 190 in a rotational direction K about the center axis S. As the mass 190 rotates between
35 the guide arms 191, the guide wheels 194 travel along the helical travel path over the outer surface of the mass 190, thereby biasing the mass 190 to move downwards or upwards,

depending on the direction of rotation K. When the mass 190 moves downwards, the guide arms 191 are deflecting or rotated outwards in a radial direction, as schematically indicated with dashed lines. When the mass 190 is rotated
5 in an opposite direction of rotation K, the guide arms 191 are allowed to return to their initial positions. The movement of the guide arms 191 is mechanically transferred, via the legs 194, to the first piston member 181. The first piston member 181 will be moved by the legs 194 over an
10 expansion distance X between an expanded state, as schematically shown with dashed lines, and the initial contracted state as shown in figure 6. The overall piston volume V is greater in the expanded state when compared to the contracted state.

15 Figure 7 shows a further alternative piston 208 according to a third embodiment of the invention. Similarly to the piston 8 according to figure 5 and the alternative piston 108 according to figure 6, the volume V of the further alternative piston 208 can be adjusted by a further
20 alternative adjustment device 209.

The further alternative piston 208 comprises a first piston member 281 in the form of a first dome, a second piston member 282 in the form of a second dome and a third piston member 283 in the form of a cylindrical center
25 section that is arranged between the first piston member 281 and the second piston member 282. The center section is assembled of annular rings 284 similar in form and function to the annular rings 184 as described in relation to the alternative piston 108 according to figure 6. The seals are
30 arranged to be placed in substantially sealing abutment with the circumferential wall 20 of the piston chamber 2. Together, the first piston member 281, the second piston member 282 and the third piston member 283 define the overall piston volume V. The piston 208 is provided with a
35 first energy absorption unit 288 and a second energy absorption unit 289 which function in the same way as the energy absorption units 88, 89 of the piston 8 according to

the first embodiment.

The alternative adjustment device 209 comprises a hydraulic drive 290 which is concentrically arranged within the third piston member 283, substantially in the middle
5 between the first piston member 281 and the second piston member 282. The hydraulic drive 290 comprises a plurality of hydraulic rams 291 which can be expanded and contracted in the expansion direction P and the contraction direction T, respectively, parallel to the center axis S. The
10 alternative adjustment device 209 is provided with a first set of control wires 292 and a second set of control wires 293 which are connected to opposite sides of the hydraulic rams 291.

The alternative adjustment device 209 further
15 comprises a first diaphragm spring 294 between the first piston member 281 and the third piston member 283 and a second diaphragm spring 295 between the second piston member 282 and the third piston member 283. Each diaphragm spring 294, 295 is provided with a plurality of radially
20 extending spring sections 296. The spring sections 296 are pie shaped and taper in the direction of the center axis S. Each spring section 296 is provided with a pulley 297 at the radially inner end, close to the center axis S, a first hinge 298 at the radially outer end and a second hinge 299
25 at a distance from the first hinge 298, between the first hinge 298 and the pulley 297. The spring sections 296 of the first diaphragm spring 294 and the second diaphragm spring 295 are rotatably coupled to the first piston member 281 and the second piston member 282, respectively, at the
30 first hinges 298. The diaphragm springs 294, 295 are interconnected by vertical wall members 285, which extend between each of the spring sections 296 of both diaphragm springs 294, 295. The spring sections 296 are rotatably coupled to the vertical wall members 285 at the second
35 hinges 299. The control wires 292, 293 are fixed at one end to the hydraulic drive 290, subsequently run over the pulleys 297 of the respective diaphragm spring assemblies

294, 295 and are fixed at the other end to the spring sections 296, somewhere along the radial length of the spring sections 296.

When the hydraulic rams 291 are contracted, both
5 sets of control wires 292, 293 are simultaneously pulled by the hydraulic drive 290. The pulleys 297 at the radially inner ends of the spring sections 296 are pulled towards the hydraulic drive 290, causing a rotation of the spring sections 296 about the second hinges 299, as indicated with
10 arrows Z. Now, the diaphragm spring assemblies 294, 295 will act as levers between the respective piston members 281-283, in the sense that the first hinges 298 at the radially outer ends of the diaphragm spring assemblies 294, 295 will be moved in opposite directions with respect to
15 the pulleys 297 at the center of the diaphragm spring assemblies 294, 295. The first piston member 281 and the second piston member 282, which are attached to the spring sections 296 at the first hinges 298, will be moved in their respective expansion directions P over the expansion
20 distance X. The expanded state of the first piston member 281 and the second piston member 282 is shown schematically with dashed lines. The overall piston volume V is increased in the expanded state.

When the hydraulic rams 291 are expanded, both
25 sets of control wires 292, 293 are paid out again. The pressure of the hydraulic medium M acting on the first piston member 281 and the second piston member 282 keeps the piston 208 under constant pressure to return in the contraction direction T to its contracted state. Thus, as
30 soon as the control wires 292, 293 are paid out, the diaphragm spring assemblies 294, 295 are allowed to rotate back to their initial orientation as shown in figure 7.

Figure 8 shows a further alternative piston 308 according to a fourth embodiment of the invention. Contrary
35 to the previously discussed pistons 8, 108, 208, this further alternative piston 308 does not have means for adjusting its volume V. Instead, the further alternative

piston 308 has a further alternative adjustment device 309 for adjusting the weight or density of the piston 308.

The further alternative piston 308 comprises a first piston member 381 in the form of a dome, a second piston member 382 in the form of a dome and a third piston member 383 in the form of a center section between the first piston member 381 and the second piston member 382. The center section is assembled of annular rings 384 similar in form and function to the annular rings 184 as described in relation to the alternative piston 108 according to figure 6. The piston 308 is also provided with a first energy absorption unit 388 and a second energy absorption unit 389 which again function in the same way as the energy absorption units 88, 89 of the piston 8 according to the first embodiment.

The further alternative adjustment device 309 comprises a ballast tank or ballast chamber 390. In this exemplary embodiment, the ballast chamber 390 is bound at the bottom by the first piston member 381, circumferentially by an annular ring 391 similar to the annular rings 384 and at the top by a displaceable wall 392. The displaceable wall 392 is mounted on a plurality of hydraulic cylinders 393 which are fixedly attached to the third piston member 383 for moving the displaceable wall 392 with respect to the third piston member 383. The piston 308 is provided with a hollow, center shaft 394 in order to provide a fixed distance between the first piston member 381 and the second piston member 382. The piston 308 is provided with a first valve 395 and a second valve 396, which are both in fluid communication with the ballast chamber 390 and which can be independently opened or closed. The first valve 395 acts as an inlet valve for allowing hydraulic medium M to flow into the ballast chamber 390. The second valve 396 acts as an outlet valve for allowing hydraulic medium M to flow out of the ballast chamber 390. Alternatively, both inflow and outflow can be combined in one valve (not shown).

Hydraulic medium M is drawn in when the hydraulic cylinders 393 and the displaceable wall 392 attached thereto are retracted, causing an under pressure in the ballast chamber 390. The first valve 395 is opened, allowing hydraulic medium M to flow into the ballast chamber 390 from outside of the piston 308. The largest possible volume of the ballast chamber 390 is chosen such that, when completely filled with hydraulic medium M, the a first ratio between the weight and the buoyancy of the piston 308 is achieved wherein the weight of the piston 308 is larger than the buoyancy of the piston 308. As a result, the piston 308 will tend to sink in the piston chamber 2 as shown in figure 1.

When the further alternative piston 308 reaches the bottom 21 of the piston chamber 2, the hydraulic cylinders 393 are expanded again. The displaceable wall 392 is moved inwards, thereby compressing the ballast chamber 390 and forcing the hydraulic medium M out of the ballast chamber 390 via the second valve 396 into the piston chamber volume H around the piston 308. Eventually, enough hydraulic medium M is forced out of the ballast chamber 390 so that the ratio between the weight and the buoyancy of the piston 308 is tipped over again to the second ratio, wherein the buoyancy of the piston 308 is greater or more than the weight of the piston 308. As a result, the piston 308 will tend to rise in the piston chamber 2.

As shown in figure 8, the further alternative piston 308 is provided with a plurality of additional hydraulic power units 398. The power units 398 are provided with pressure bags 399 which are filled with a hydraulic drive fluid. The hydraulic power units 398 are in fluid communication with the outside hydraulic medium M, so that the pressure of the outside hydraulic medium M can be transferred onto the pressure bags 399. The pressure outside of the piston 308 increases proportionally with its depth. As a result, the hydraulic drive fluid in the pressure bags 399 is pressurized as the piston 308

descents. The pressurized hydraulic drive fluid can be released into the hydraulic cylinders 393 together with the hydraulic energy that is received from the energy absorption units 388, 389.

5 Alternatively, the pressurized drive fluid can be utilized for driving a hydraulic motor or a hydraulic pump (not shown). The motor or pump can deliver a certain volume of hydraulic fluid at a higher pressure to the hydraulic cylinders 393. The hydraulic power units 398 are
10 particularly effective during the inversion from the downstroke into the upstroke, as that is the moment at which the piston 308 is at its lowest point of descent and the pressure on the piston 308 is the greatest. After the hydraulic power from the drive fluid has been utilized, the
15 drive fluid is stored in a storage tank (not shown). As the pressure of the hydraulic medium M onto the pressure bags 399 decreases to almost ambient pressure when the piston 308 ascends, the stored drive fluid is allowed to enter the pressure bags 399 again. Now, the piston 308 is ready for
20 the subsequent downstroke. It will be apparent to one skilled in the art that the aforementioned hydraulic power units 398 can also be installed in or on the previously discussed pistons 8, 108, 208.

 Figure 9 shows a further alternative piston 408
25 according to a fifth embodiment of the invention. This further alternative piston 408 again features an adjustment of the piston volume V, however, this time by means of a further alternative adjustment device 409 that introduces a gas to the piston 408.

30 The further alternative piston 408 according to the fifth embodiment of the invention is substantially similar in construction as the piston 308 according to the fourth embodiment of the invention. As such, the further alternative piston 408 comprises piston members 481-483
35 with annular rings 483 and energy absorption units 488, 489.

 The further alternative piston 408 according to

the fifth embodiment of the invention differs from the previously described pistons 8, 108, 208, 308 in that its adjustment device 409 is provided with a wall or skirt 492 which extends circumferentially around the dome shape of the first piston member 481. The skirt 492 encloses a gas volume 493 around the dome shape of the first piston member 481. When gas is trapped underneath the skirt 492 in the gas volume 493 and the pressure of the gas exceeds the surrounding pressure of the hydraulic medium M, the gas will take the place of the hydraulic medium M that would otherwise occupy the gas volume 493. Thus, by supplying gas to or removing gas from gas volume 493, the overall piston volume V, including the gas volume 493 can be adjusted so that the ratio between the buoyancy and the weight of the piston 408 can be adjusted between the first ratio and the second ratio.

The gas can be supplied to and removed from the gas volume 492 by external means, for example by an injector (not shown) arranged at the bottom 21 of the piston chamber 2 of figure 1 and a suction nozzle (not shown) arranged near the top 25 of the piston chamber 2 of figure 1. Preferably, the gas is supplied to and removed from the gas volume 492 by an automated system arranged within the hydro-electric power plant 1. Such an automated system for example comprises a carousel (not shown) at the servicing passage 27 for dispensing a heat cartridge 390, as shown in figure 9 into the piston 408 when the piston is at the top 25. The piston 408 comprises a boiling liquid expanding vapour explosion reactor or BLEVE reactor 491 which is filled with a phase changing medium. The heat cartridge 490 is inserted into the reactor 491 in the insertion direction Q.

Once the piston 408 approaches the bottom 21 of the piston chamber 2, the heat cartridge 490 is controlled to transfers its heat to the phase changing medium in the reactor 491. The phase changing medium is heated so that it changes from a liquid phase to a gas phase. As a result of

the phase change, the pressure in the reactor 491 increases. The pressurized phase changing medium is allowed to escape the reactor 491 via a nozzle (not shown) at the bottom of the reactor 491. The escape of the phase changing
5 medium in the gas phase from the reactor 491 is schematically indicated with escaping arrows U. The phase changing medium is collected underneath the skirt 492 of the piston 408 to form the gas volume 493. As its pressure is greater than the pressure of the surrounding hydraulic
10 medium M, it displaces the hydraulic medium M and increases the piston volume V. Thus, the buoyancy of the piston 408 is increased and the piston 408 will start its upstroke. As the piston 408 approaches the top 25, the phase changing medium has cooled down so that it condensates and returns
15 to a liquid phase with a pressure lower or equal to the surrounding hydraulic medium M. As a result, the piston volume V is decreased again and the piston 408 will start its downstroke. At the beginning of each downstroke, the previously inserted heat cartridge 490 is removed from the
20 piston 408 and a subsequent, recharged heat cartridge 490 is inserted at the top 25 by the carrousel.

Apart from generating electricity, the large capacity of the piston chamber volume H and the large volume of the hydraulic medium M contained in the power
25 plant 1 can be utilized for effective temporary storage of thermal energy, such as heat for district heating. The thermal energy can be transferred to the hydraulic medium M by various known types of heat exchangers. These heat exchangers preferably receive their thermal energy from the
30 hydro-electric power plant 1 itself in situation where there is an overflow of electrical energy due to a dip in energy consumption, or from renewable sources, such as from a concentrated solar energy plant (not shown).

Apart from generating electricity and storing
35 thermal energy in the hydraulic medium M, the hydro-electric power plant 1 can, in case water is used as a hydraulic medium M, supply water for consumption, for

hygienic purposes, for agricultural purposes or for district heating systems that use water as a carrier of thermal energy. The water can be taken from expansion vessel 7, that can be enlarged for this purpose. Additional
5 purification and quality control equipment can be installed in order to guarantee water quality and water safety before supplied for consumption purposes.

It is to be understood that the above description is included to illustrate the operation of the preferred
10 embodiments and is not meant to limit the scope of the invention. From the above discussion, many variations will be apparent to one skilled in the art that would yet be encompassed by the scope of the present invention.

C O N C L U S I E S

1. Hydro-elektrische krachtcentrale omfattende een circulatiesysteem voor het circuleren van een hydraulisch medium, waarbij het circulatiesysteem een opstaande zuigerkamer omvat met een omtrekswand, een
5 bovenkant en een onderkant welke een zuigerkamervolume begrenzen voor het ontvangen van het hydraulische medium, waarbij het circulatiesysteem verder ten minste één retourkanaal omvat welke in fluïdum verbinding staat met het
10 zuigerkamervolume aan de bovenkant en de onderkant van de zuigerkamer teneinde een gesloten circulatiebaan te vormen, waarbij het circulatiesysteem is voorzien van een zuiger welke is ingericht teneinde te worden ondergedompeld in het hydraulische medium in het zuigerkamervolume, waarbij de
15 zuiger beweegbaar is binnen de zuigerkamer voor het verplaatsen van het hydraulische medium door het circulatiesysteem, waarbij de krachtcentrale een omzetter omvat welke is geplaatst in de circulatiebaan voor het omzetten van de hydraulische energie van het circulerende hydraulische medium in elektrische energie, waarbij de
20 zuiger is voorzien van een aanpasinrichting welke is ingericht voor het aanpassen van de verhouding tussen het drijfvermogen van de zuiger wanneer deze is ondergedompeld is in het hydraulische medium en het gewicht van de zuiger.

2. Krachtcentrale volgens conclusie 1, waarbij de
25 aanpasinrichting is ingericht voor het aanpassen van de verhouding naar een eerste verhouding waarin het drijfvermogen van de zuiger kleiner is dan het gewicht van de zuiger en een tweede verhouding waarin het drijfvermogen van de zuiger groter is dan het gewicht van de zuiger.

30 3. Krachtcentrale volgens conclusie 1 of 2, waarbij de aanpasinrichting is ingericht voor het aanpassen van het drijfvermogen van de zuiger.

4. Krachtcentrale volgens conclusie 3, waarbij de aanpasinrichting is ingericht voor het samentrekken van het algehele zuigervolume en voor het expanderen van het algehele zuigervolume.

5 5. Krachtcentrale volgens conclusie 4, waarbij de zuiger een eerste zuigerdeel en een tweede zuigerdeel omvat welke ten minste een gedeelte van het algehele zuigervolume bepalen of omsluiten, waarbij de aanpasinrichting gekoppeld is met de zuigerdelen voor het relatief ten opzichte van
10 elkaar bewegen van de zuigerdelen teneinde het algehele zuigervolume aan te passen.

6. Krachtcentrale volgens conclusie 5, waarbij de zuiger een derde zuigerdeel omvat welke is aangebracht tussen het eerste zuigerdeel en het tweede zuigerdeel,
15 waarbij het derde zuigerdeel ten minste een deel van het zuigervolume bepaalt of omsluit, waarbij de aanpasinrichting is bevestigd aan het derde zuigerdeel voor het bewegen van het eerste zuigerdeel en het tweede zuigerdeel ten opzichte van het derde zuigerdeel.

20 7. Krachtcentrale volgens conclusie 5 of 6, waarbij de aanpasinrichting een spindel omvat die van schroefdraad is voorzien en een aandrijving voor het aandrijven van de spindel, waarbij ten minste het eerste zuigerdeel aangrijpt op en is ingericht teneinde te worden
25 bewogen door de spindel via een inwendige schroefdraad of een kogelomloop spindel overbrenging.

8. Krachtcentrale volgens conclusie 7, waarbij de spindel is voorzien van tegengestelde schroefdraden, waarbij het tweede zuigerdeel aangrijpt op en is ingericht teneinde
30 te worden bewogen in een tegengestelde richting door de spindel via een inwendige schroefdraad of een kogelomloop spindel overbrenging.

9. Krachtcentrale volgens conclusie 5 of 6, waarbij de aanpasinrichting een massa omvat welke is
35 opgehangen in de zuiger en een aandrijving voor het roteren van de massa, waarbij de aanpasinrichting is voorzien van een schroeflijnvormige overbrenging welke is ingericht

teneinde over een schroeflijnvormige bewegingsbaan langs het buitenoppervlak van de massa te bewegen terwijl de massa geroteerd wordt, waarbij de schroeflijnvormige overbrenging is ingericht voor het omzetten van de rotatie van de massa
5 in een lineaire verplaatsing van het eerste zuigerdeel ten opzichte van het tweede zuigerdeel.

10 10. Krachtcentrale volgens conclusie 6, waarbij de aanpasinrichting is voorzien van een eerste diafragma veer tussen het eerste zuigerdeel en het derde zuigerdeel en een aandrijving voor het aansturen van de eerste diafragma veer teneinde zich te gedragen als een hefboom tussen het eerste zuigerdeel en het derde zuigerdeel.

15 11. Krachtcentrale volgens conclusie 10, waarbij de aanpasinrichting is voorzien van een tweede diafragma veer tussen het tweede zuigerdeel en het derde zuigerdeel en een aandrijving voor het aansturen van de tweede diafragma veer teneinde zich te gedragen als een hefboom tussen het tweede zuigerdeel en het derde zuigerdeel.

20 12. Krachtcentrale volgens conclusie 1 of 2, waarbij de aanpasinrichting is ingericht voor het aanpassen van het gewicht van de zuiger.

25 13. Krachtcentrale volgens conclusie 12, waarbij de aanpasinrichting een ballastkamer omvat en een eerste klep en/of een tweede klep voor het toelaten van respectievelijk een instroom in de ballastkamer van het hydraulische medium buiten de zuiger en voor het toelaten van een uitstroom uit de ballastkamer van het hydraulische medium binnen de ballastkamer.

30 14. Krachtcentrale volgens één der voorgaande conclusies, waarbij de aanpasinrichting een rok omvat voor het opsluiten van een gas onder de zuiger.

35 15. Krachtcentrale volgens één der voorgaande conclusies, waarbij de zuiger in de omtreksrichting in in hoofdzaak afdichtende aanligging met de omtrekswand van de zuigerkamer is geplaatst.

16. Krachtcentrale volgens één der voorgaande conclusies, waarbij de zuiger een vrije zuiger is, welke bij

voorkeur is ingericht teneinde beweegbaar te zijn in de zuigerkamer zonder enige vaste verbinding met de rest van de krachtcentrale.

17. Krachtcentrale volgens één der voorgaande
5 conclusies, waarbij de aanpasinrichting is ingericht voor het bewegen van de zuiger op een heen en weer gaande manier in een neergaande slag of een opgaande slag door het afwisselen van respectievelijk de eerste verhouding en de tweede verhouding, waarbij gedurende de neergaande slag, de
10 richting van circulatie tegengesteld is aan de richting van circulatie gedurende de opgaande slag, waarbij de omzetter is ingericht voor het omzetten van de hydraulische energie van het hydraulische medium dat wordt verplaatst door het circulatiesysteem in elektrische energie gedurende zowel de
15 neergaande slag als de opgaande slag.

18. Krachtcentrale volgens conclusie 17, waarbij de krachtcentrale is voorzien van een kleppensamenstel voor het omkeren van de stroom naar en vanaf de omzetter.

19. Krachtcentrale volgens één der voorgaande
20 conclusies, waarbij de omzetter een turbine is, bij voorkeur een Kaplan turbine, bij meeste voorkeur een Kaplan turbine van het bulb- of buistype.

20. Krachtcentrale volgens één der voorgaande
conclusies, waarbij de zuiger kinetische energie opbouwt
25 wanneer deze beweegt door de zuigerkamer, waarbij de krachtcentrale is voorzien van een energie absorbeereenheid voor het absorberen van de kinetische energie van de bewegende zuiger wanneer de zuiger de onderkant of de bovenkant van de zuigerkamer bereikt, waarbij de energie
30 absorbeereenheid is ingericht voor het opslaan van de geabsorbeerde kinetische energie, bij voorkeur als hydraulische energie.

21. Krachtcentrale volgens conclusie 20, waarbij de energie absorbeereenheid is aangebracht bij de zuiger.

35 22. Krachtcentrale volgens één der voorgaande conclusies, waarbij de krachtcentrale een meervoud van retourkanalen omvat welke geïntegreerd zijn in de

omtrekswand van de zuigerkamer.

23. Werkwijze voor het genereren van elektrische energie vanuit hydraulische energie met gebruikmaking van een hydro-elektrische krachtcentrale volgens één der
5 voorgaande conclusies, waarbij de werkwijze de stap omvat van het aanpassen van de verhouding tussen het drijfvermogen en het gewicht van de zuiger.

24. Werkwijze volgens conclusie 23, waarbij de stap van het aanpassen van de verhouding het afwisselen
10 behelst tussen de eerste verhouding en de tweede verhouding, waarbij in de eerste verhouding het drijfvermogen van de zuiger kleiner is dan het gewicht van de zuiger en waarbij in de tweede verhouding het drijfvermogen van de zuiger groter is dan het gewicht van de zuiger.

15 25. Werkwijze volgens conclusie 23 of 24, waarbij het drijfvermogen van de zuiger wordt aangepast.

26. Werkwijze volgens conclusie 25, waarbij het zuigervolume gereduceerd wordt teneinde het drijfvermogen van de zuiger te reduceren en waarbij het zuigervolume
20 geëxpandeerd wordt teneinde het drijfvermogen van de zuiger te laten toenemen.

27. Werkwijze volgens conclusie 23 of 24, waarbij het gewicht van de zuiger wordt aangepast.

28. Werkwijze volgens één der conclusies 23-27,
25 waarbij de werkwijze een stap omvat van het opslaan van thermische energie in het hydraulische medium dat gecirculeerd wordt door het circulatiesysteem.

29. Werkwijze volgens één der conclusies 23-28, waarbij de werkwijze de stap omvat van het afleveren van het
30 hydraulische medium vanuit het circulatiesysteem aan externe systemen, zoals voor stadsverwarming, voor hygiënische doeleinden, voor agrarische doeleinden of voor waterconsumptie, waarbij de werkwijze bij voorkeur een purificatie stap van het zuiveren van het hydraulische
35 medium omvat voorafgaande aan het afleveren aan de externe systemen.

30. Krachtcentrale omvattende één of meer

maatregelen zoals beschreven in de bijgevoegde beschrijving of zoals getoond in de bijgevoegde tekeningen.

31. Werkwijze omvattende één of meer maatregelen en/of één of meer stappen zoals beschreven in de bijgevoegde
5 beschrijving of zoals getoond in de bijgevoegde tekeningen.

-o-o-o-o-o-o-o-o-

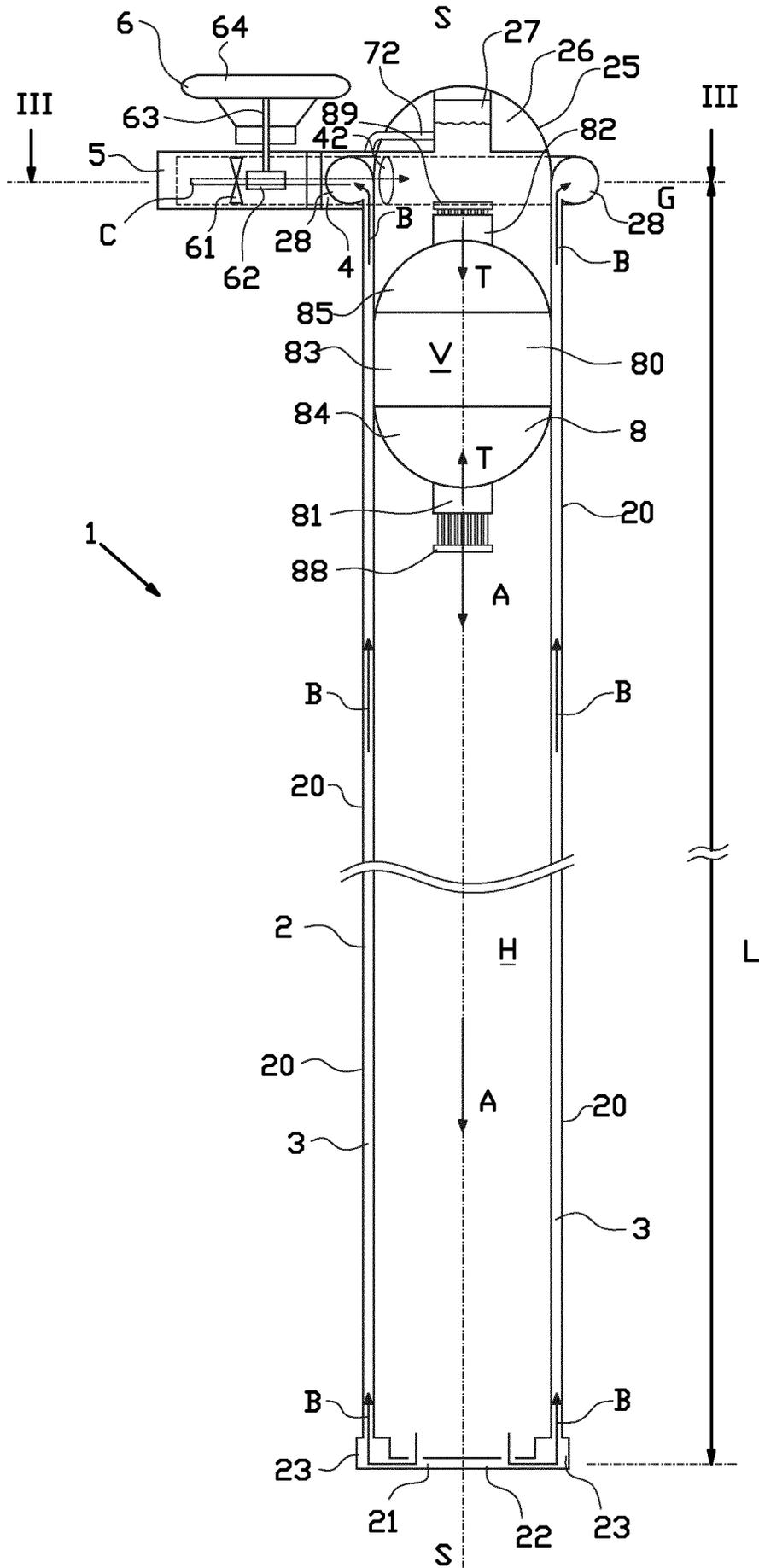


FIG. 1

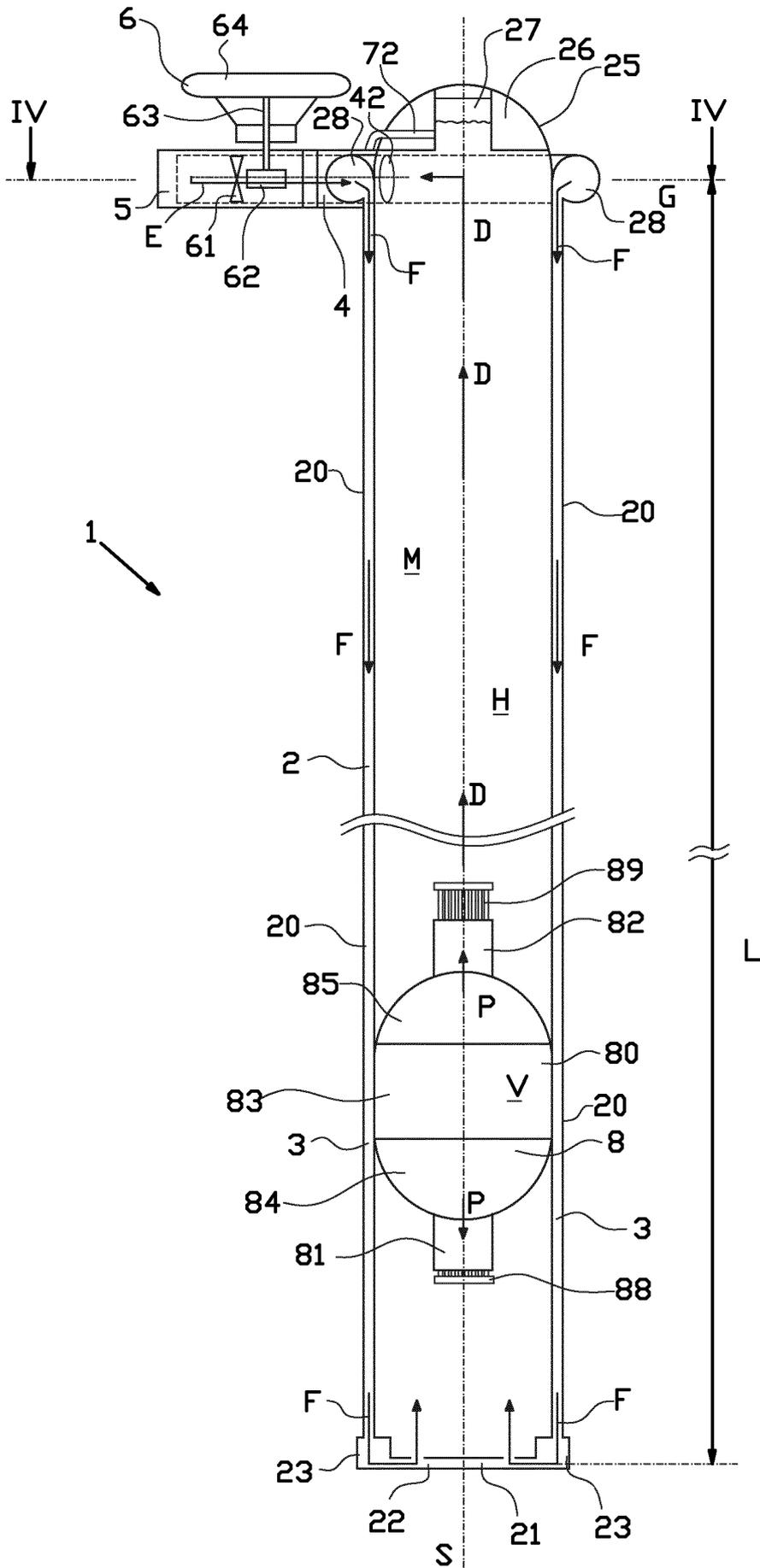


FIG. 2

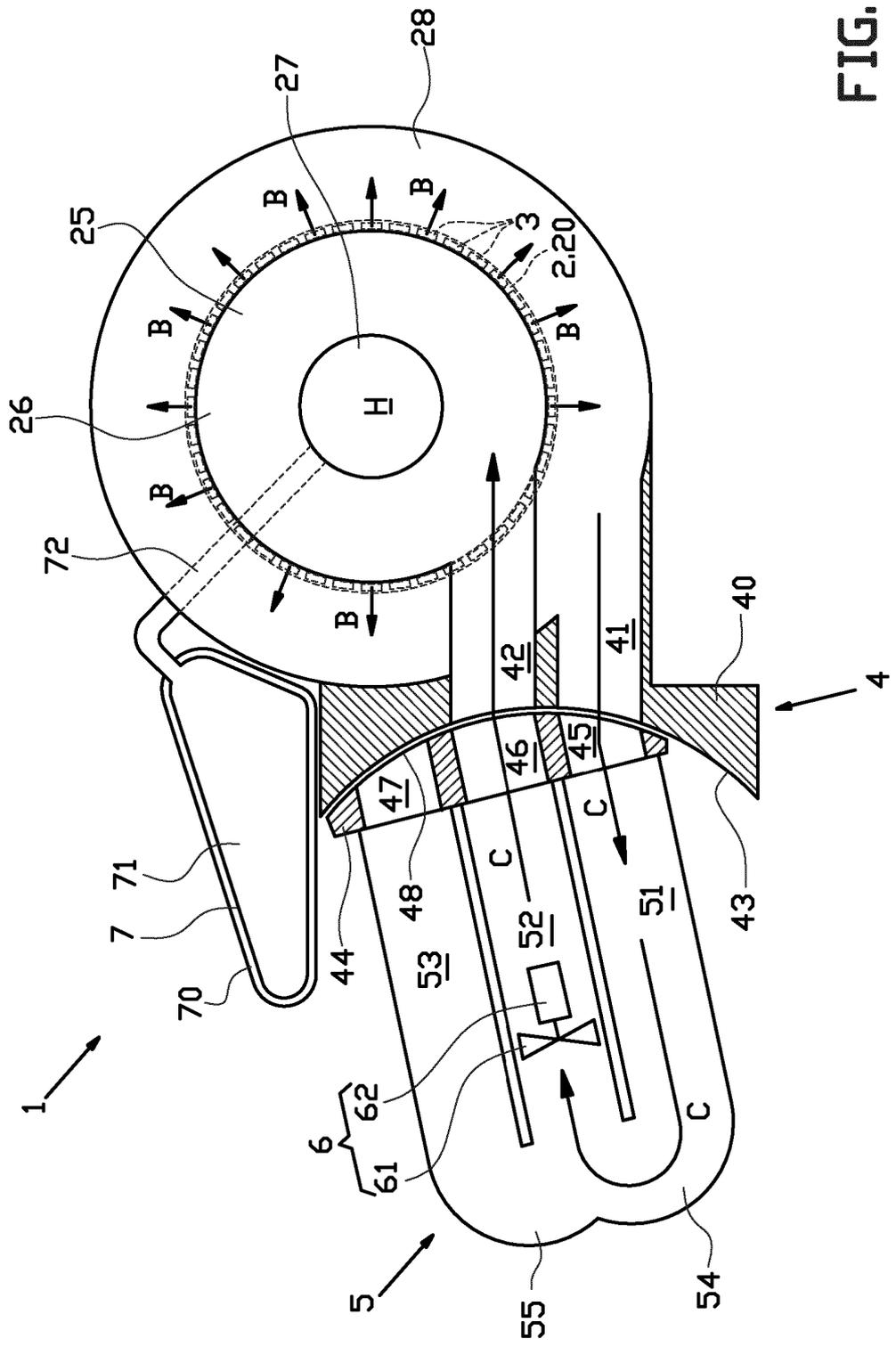


FIG. 3

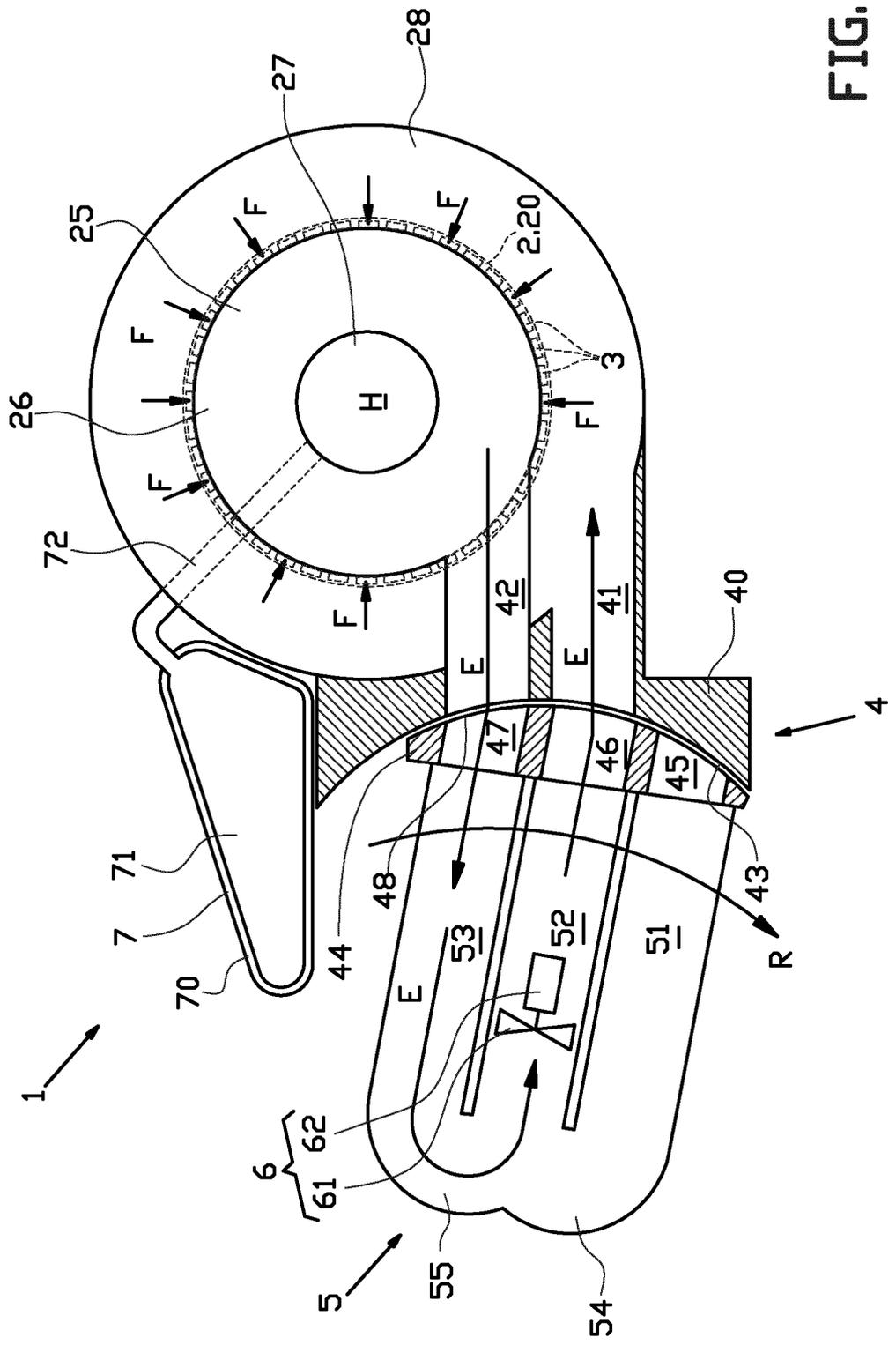


FIG. 4

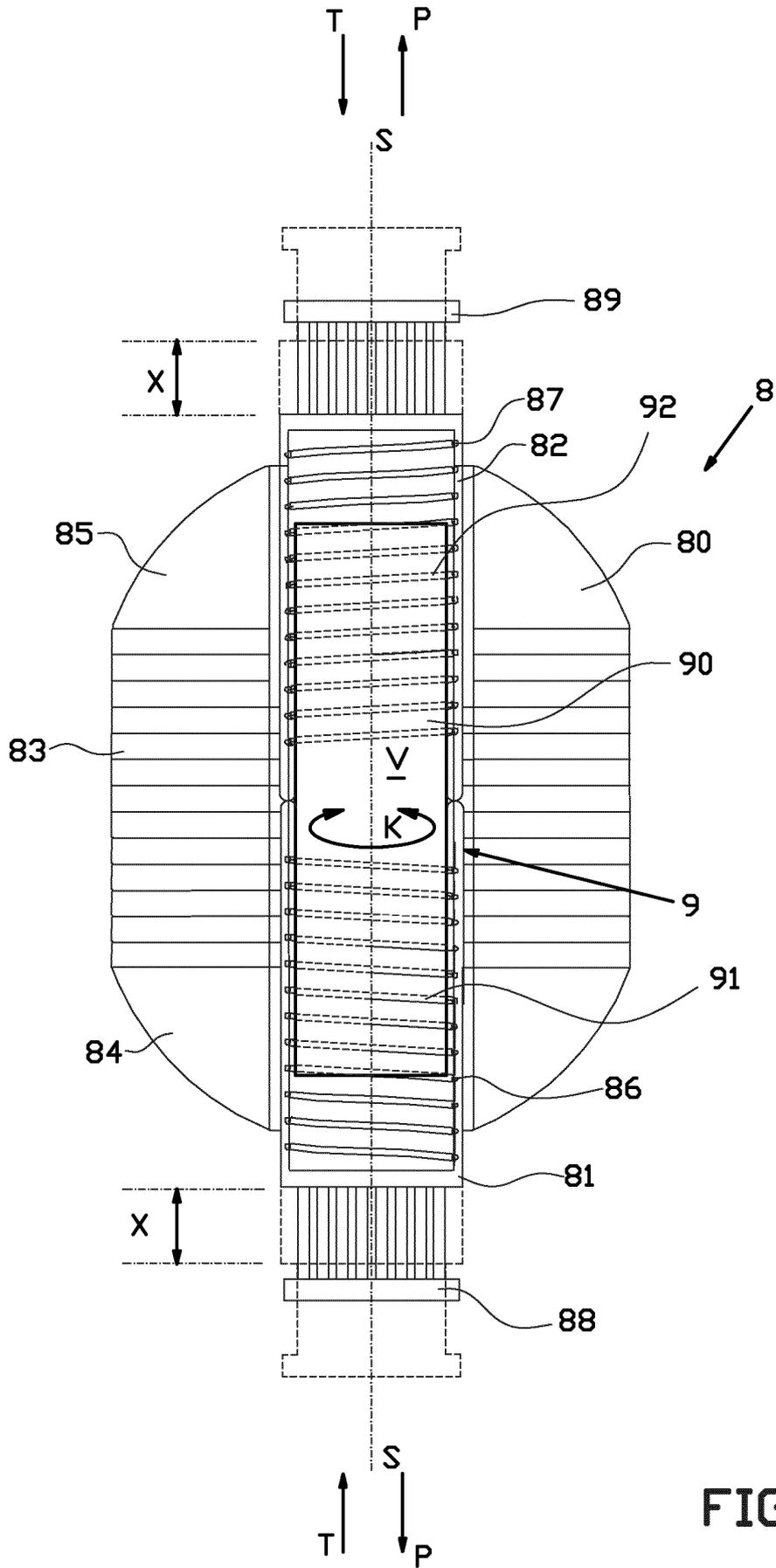


FIG. 5

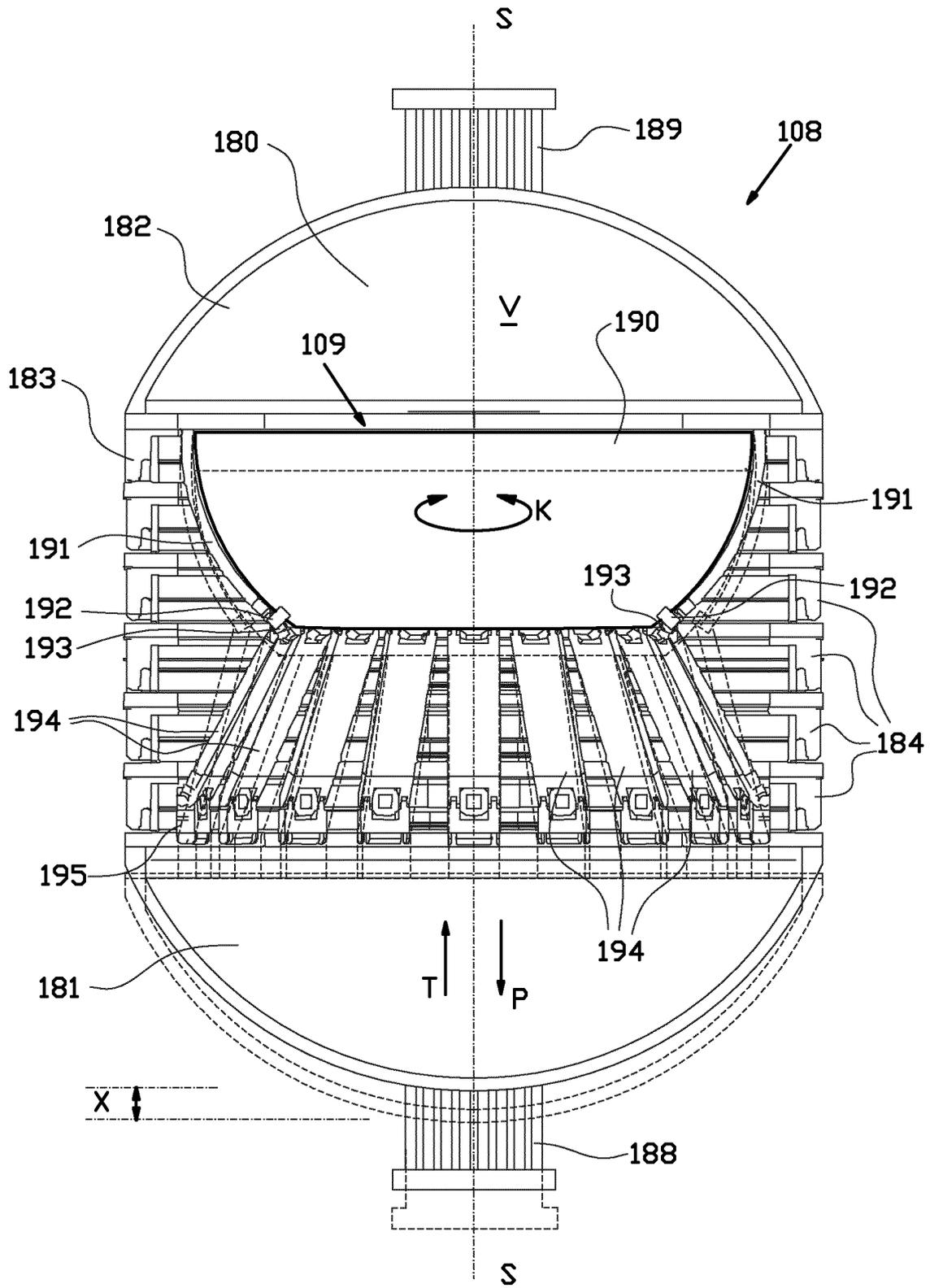


FIG. 6

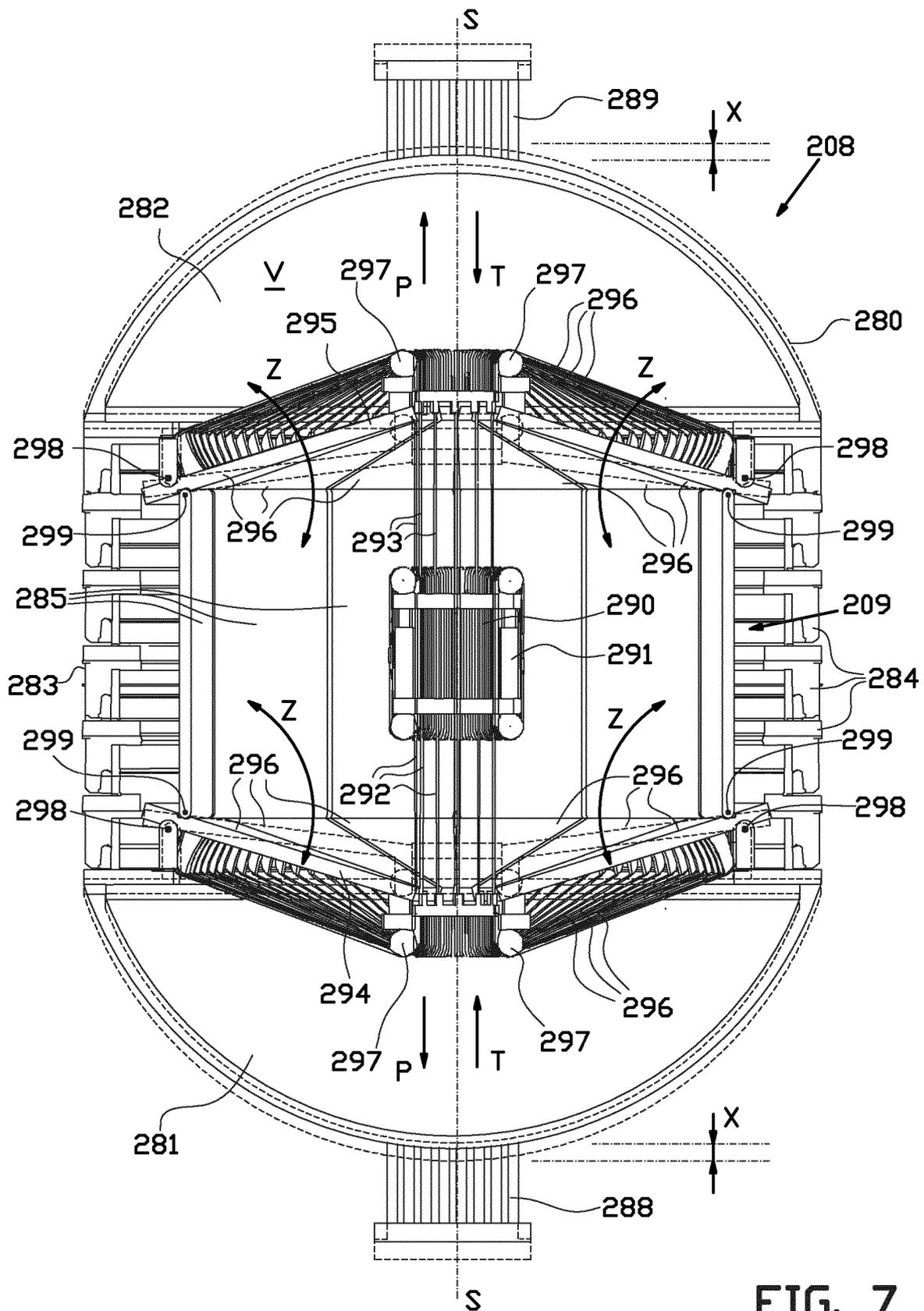


FIG. 7

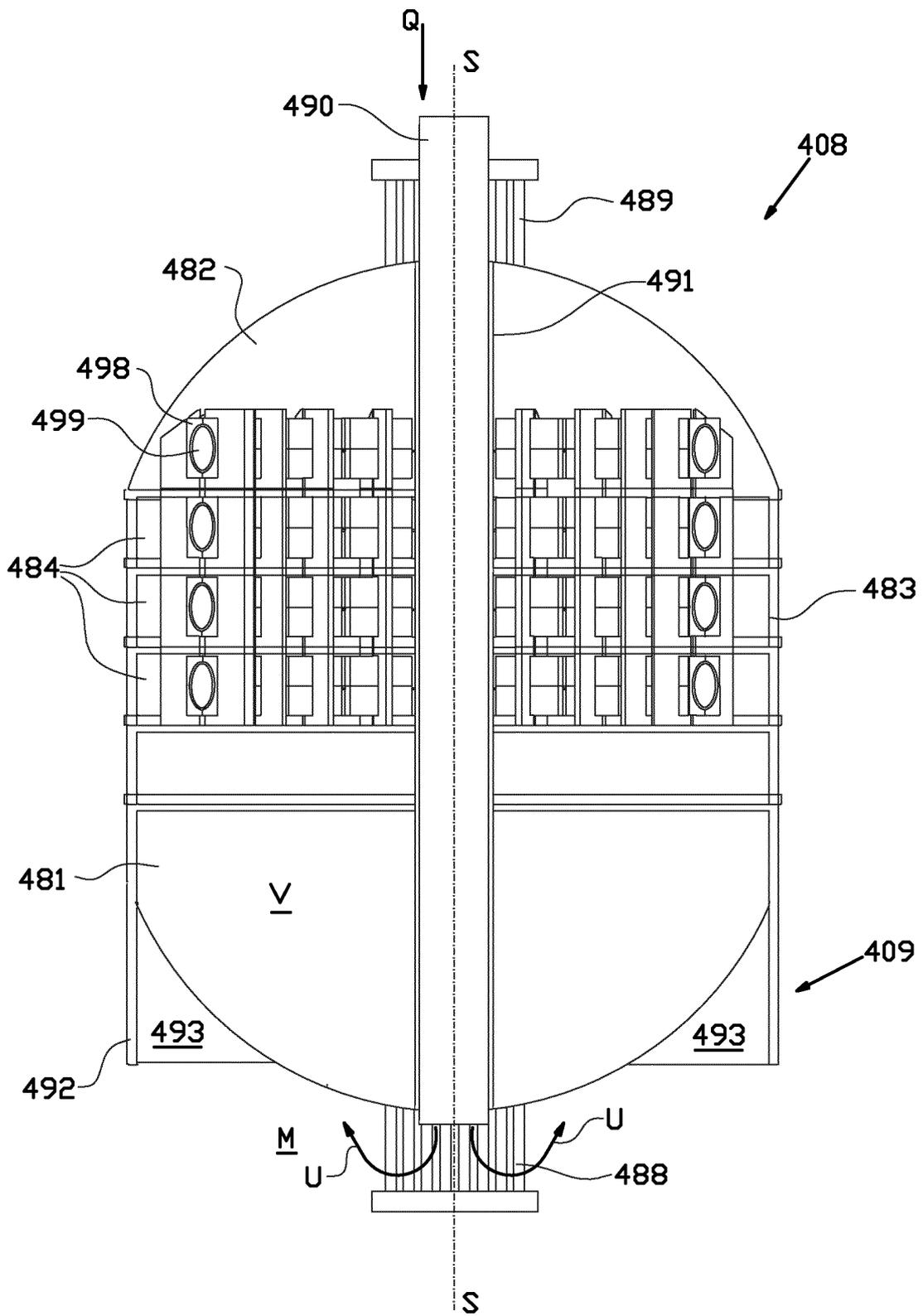


FIG. 9



ONDERZOEKSRAPPORT

BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

| RELEVANTE LITERATUUR | | | |
|---|--|---|--------------------------------------|
| Categorie | Literatuur met, voor zover nodig, aanduiding van speciaal van belang zijnde tekstgedeelten of figuren. | Van belang voor conclusie(s) nr: | Classificatie (IPC) |
| X | WO 2010/105389 A1 (TIAN XIAOHONG [CN]) 23 september 2010 (2010-09-23) | 1-3,12, 13,15, 16,19, 23-25, 27,30,31 | INV. F03B17/00 F03B17/04 |
| Y | * samenvatting; figuren 1-4 * ----- | 4,5 | |
| Y | GB 2 430 471 A (COONAN BLAISE [GB]) 28 maart 2007 (2007-03-28) * bladzijde 1, alinea 8 - bladzijde 2, alinea 1; figuren 1-13 * ----- | 1-11 | |
| A | DE 10 2011 018425 A1 (BRINKER KARL-HEINZ [DE]) 22 november 2012 (2012-11-22) * alinea's [0004] - [0012]; figuren 1-6 * ----- | 1 | |
| A | US 6 945 042 B1 (WALCKNER JAMES R [US]) 20 september 2005 (2005-09-20) * kolom 6, regel 31 - kolom 8, regel 22; figuren 1-6 * ----- | | |
| | | | Onderzochte gebieden van de techniek |
| | | | F03B |
| Indien gewijzigde conclusies zijn ingediend, heeft dit rapport betrekking op de conclusies ingediend op: | | | |
| Plaats van onderzoek: München | Datum waarop het onderzoek werd voltooid: 8 augustus 2013 | Bevoegd ambtenaar: Jucker, Chava | |
| <p>¹ CATEGORIE VAN DE VERMELDE LITERATUUR</p> <p>X: de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur Y: de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht A: niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft O: niet-schriftelijke stand van de techniek P: tussen de voorangsdatum en de indieningsdatum gepubliceerde literatuur</p> <p>T: na de indieningsdatum of de voorangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvraag, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding E: eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven D: in de octrooiaanvraag vermeld L: om andere redenen vermelde literatuur &: lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie</p> | | | |

**AANHANGSEL BEHORENDE BIJ HET RAPPORT BETREFFENDE
HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK,
UITGEVOERD IN DE OCTROOIAANVRAGE NR.**

NO 138542
NL 2009930

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooischriften genoemd in het rapport.

De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door het Bureau voor de Industriële eigendom gegarandeerd; de gegevens worden verstrekt voor informatiedoeleinden.

08-08-2013

| In het rapport genoemd octrooigeschrift | Datum van publicatie | Overeenkomend(e) geschrift(en) | Datum van publicatie |
|--|-------------------------|------------------------------------|--------------------------|
| WO 2010105389 A1 | 23-09-2010 | CN 101514669 A WO 2010105389 A1 | 26-08-2009 23-09-2010 |
| GB 2430471 A | 28-03-2007 | GEEN | |
| DE 102011018425 A1 | 22-11-2012 | GEEN | |
| US 6945042 B1 | 20-09-2005 | US 6945042 B1 WO 2006025936 A1 | 20-09-2005 09-03-2006 |



OCTROOICENTRUM NEDERLAND

SCHRIFTELIJKE OPINIE

| | | | |
|---|-------------------------------|----------------|-----------------------------|
| DOSSIER NUMMER NO138542 | INDIENINGSDATUM 04.12.2012 | VOORRANGSDATUM | AANVRAAGNUMMER NL2009930 |
| CLASSIFICATIE INV. F03B17/00 F03B17/04 | | | |
| AANVRAGER Leegwater C.V. | | | |

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

- Onderdeel I Basis van de schriftelijke opinie
- Onderdeel II Voorrang
- Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
- Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding
- Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
- Onderdeel VI Andere geciteerde documenten
- Onderdeel VII Overige gebreken
- Onderdeel VIII Overige opmerkingen

| | |
|--|--|
| | DE BEVOEGDE AMBTENAAR Jucker, Chava |
|--|--|

SCHRIFTELIJKE OPINIE

Aanvraag nr.:

NL2009930

Onderdeel I Basis van de Schriftelijke Opinie

1. Deze schriftelijke opinie is opgesteld op basis van de meest recente conclusies ingediend voor aanvang van het onderzoek.
2. Met betrekking tot **nucleotide en/of aminozuur sequenties** die genoemd worden in de aanvraag en relevant zijn voor de uitvinding zoals beschreven in de conclusies, is dit onderzoek gedaan op basis van:
 - a. type materiaal:
 - sequentie opsomming
 - tabel met betrekking tot de sequentie lijst
 - b. vorm van het materiaal:
 - op papier
 - in elektronische vorm
 - c. moment van indiening/aanlevering:
 - opgenomen in de aanvraag zoals ingediend
 - samen met de aanvraag elektronisch ingediend
 - later aangeleverd voor het onderzoek
3. In geval er meer dan één versie of kopie van een sequentie opsomming of tabel met betrekking op een sequentie is ingediend of aangeleverd, zijn de benodigde verklaringen ingediend dat de informatie in de latere of additionele kopieën identiek is aan de aanvraag zoals ingediend of niet meer informatie bevatten dan de aanvraag zoals oorspronkelijk werd ingediend.
4. Overige opmerkingen:

Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk

De vraag of de uitvinding in de aanvraag nieuw, inventief en industrieel toepasbaar is, wordt niet behandeld in deze schriftelijke opinie met betrekking tot:

- de gehele aanvraag
- conclusies 30, 31

omdat:

- deze aanvraag of deze conclusies , betrekking hebben op materie waarvoor het niet zinvol is een schriftelijke opinie op te stellen.
- de beschrijving, figuren of deze conclusies 30, 31, , zo onduidelijk zijn dat het niet zinvol is een schriftelijke opinie op te stellen.

Zie aparte bladzijde

- deze conclusies , onvoldoende steun vinden in de beschrijving waardoor het niet zinvol is een schriftelijke opinie op te stellen.
- geen onderzoek naar de stand van de techniek is uitgevoerd voor deze conclusies .
- een zinvolle schriftelijke opinie niet opgesteld kon worden omdat de sequentie opsomming niet beschikbaar was in het juiste formaat, of in het geheel niet beschikbaar was (WIPO ST25).
- een zinvolle schriftelijke opinie niet opgesteld kon worden zonder de tabellen met betrekking tot de sequentie opsommingen; of deze tabellen waren niet beschikbaar in elektronische vorm.
- Zie aparte bladzijde

Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid

1. Verklaring

| | |
|----------------------------|--|
| Nieuwheid | Ja: Conclusies 4-11, 14, 17, 18, 20-22, 26, 28, 29 Nee: Conclusies 1-3, 12, 13, 15, 16, 19, 23-25, 27 |
| Inventiviteit | Ja: Conclusies 6-11, 14, 17, 18, 20-22, 26, 28, 29 Nee: Conclusies 1-5, 12, 13, 15, 16, 19, 23-25, 27 |
| Industriële toepasbaarheid | Ja: Conclusies 1-29 Nee: Conclusies |

2. Citaties en toelichting:

Zie aparte bladzijde

SCHRIFTELIJKE OPINIE

Aanvraag nr.:
NL2009930

Onderdeel VIII Overige opmerkingen

De volgende opmerkingen met betrekking tot de duidelijkheid van de conclusies, beschrijving, en figuren, of met betrekking tot de vraag of de conclusies nawerkbaar zijn, worden gemaakt:

Zie aparte bladzijde

Re Item III

Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

Claims 30 and 31 are so broadly formulated that it is unclear what exactly their scope is, thereby rendering the definition of the subject-matter of said claim unclear. For this reason it is not possible to give an opinion on novelty, inventive step and industrial applicability.

-

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following documents:

- D1 WO 2010/105389 A1 (TIAN XIAOHONG [CN]) 23 september 2010
- D2 GB 2 430 471 A (COONAN BLAISE [GB]) 28 maart 2007

2 LACK OF NOVELTY

The present application does not meet the criteria of patentability, because the subject-matter of independent claims 1 and 23 is not new.

2.1 D1 discloses (see e.g. abstract, figures 1-4) "Hydro-elektrische krachtcentrale omvattende een circulatiesysteem voor het circuleren van een hydraulisch medium, waarbij het circulatiesysteem een opstaande zuigerkamer (10) omvat met een omtrekswand, een bovenkant en een onderkant welke een zuigerkamervolume begrenzen voor het ontvangen van het hydraulische medium, waarbij het circulatiesysteem verder ten minste één retourkanaal (22) omvat welke in fluïdum verbinding staat met het zuigerkamervolume (10) aan de bovenkant en de onderkant van de zuigerkamer teneinde een gesloten circulatiebaan te vormen, waarbij het circulatiesysteem is voorzien van een zuiger (14, 18, 19) welke is ingericht teneinde te worden ondergedompeld in het hydraulische medium in het zuigerkamervolume (10), waarbij de zuiger (14, 18, 19) beweegbaar is binnen de zuigerkamer (10) voor het verplaatsen van het hydraulische medium door het circulatiesysteem, waarbij de krachtcentrale een omzetter (12) omvat welke is geplaatst in de circulatiebaan voor het omzetten van de hydraulische energie van het circulerende hydraulische medium in elektrische energie, waarbij de zuiger

(14, 18, 19) is voorzien van een aanpasinrichting (13) welke is ingericht voor het aanpassen van de verhouding tussen het drijfvermogen van de zuiger wanneer deze is ondergedompeld is in het hydraulische medium en het gewicht van de zuiger".

- 2.2 Independent claim 1 is therefore not new. The same reasoning applies mutatis mutandis for the corresponding independent method claim 23, which therefore is also not new.

3 DEPENDENT CLAIMS

- 3.1 Dependent claims 2-5, 12, 13, 15, 16, 19, 24, 25, 27 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step, see document D1 which discloses all the technical features of dependent claims 2, 3, 12, 13, 15, 16, 19, 24, 25, 27 (see e.g. abstract and figures 1-4), and document D2 which discloses the features of varying the volume of the piston body (see e.g. page 1, paragraph 7 - page 2, paragraph 1; figures 1-13) which the skilled person would adapt into the device of D1 without an inventive step in order to solve the problem of an alternative way to vary the buoyancy/weight ratio.
- 3.2 The combination of the features of dependent claims 6-11, 14, 17, 18, 20-22, 26, 28, 29 is neither known from, nor rendered obvious by, the available prior art. The reasons are as follows: There is no hint in the prior art to adjust the device of D1 in order to arrive at the technical subject-matter of those claims.

Re Item VIII

Certain observations on the application

Claims 30 and 31 are so broadly formulated that it is unclear what exactly their scope is, thereby rendering the definition of the subject-matter of said claim unclear. Therefore these claims should be removed from the application.