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(54) Title: HEAT PUMP-REINFORCED SALT-CONCENTRATION-DIFFERENTIAL POWER GENERATION DEVICE USING VAPOUR DIFFERENTIAL PRESSURE ENERGY METHOD UNDER POSITIVE TEMPERATURE DIFFERENCE

(54) 发明名称: 一种热泵强化的正温差下蒸汽压差能法盐差发电装置

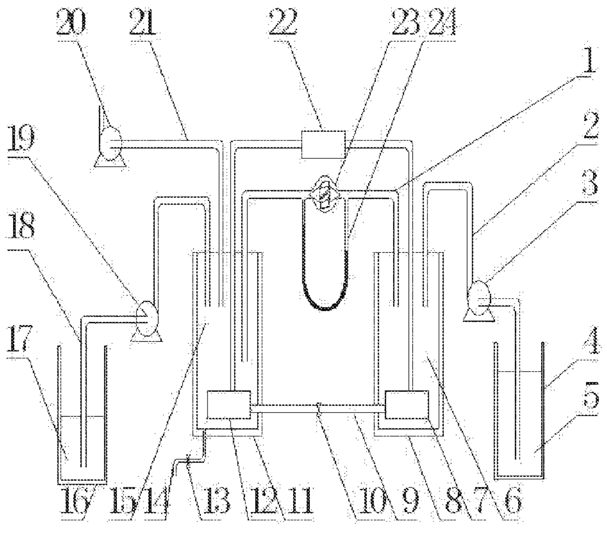

图 1

(57) Abstract: Disclosed is a heat pump-reinforced salt-concentration-differential power generation device using a vapour differential pressure energy method under a positive temperature difference. The power generation device comprises a heat pump heating and circulating device and a salt-concentration-differential power generation device using the vapour differential pressure energy method. The heat pump heating and circulating device comprises a condenser (7), a heat pump pipeline (9), a throttle valve (10), an evaporator (12) and a compressor (22). The salt-concentration-differential power generation device using the vapour differential pressure energy method comprises a low-pressure container (11), a high-pressure container (8), an expander (23), a differential pressure gauge (24)

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and an expander pipeline (11). By the heat pump heating and circulating, heat is absorbed from a concentrated solution so as to lower the temperature of the concentrated solution, the heat is released to a dilute solution so as to increase the temperature of the dilute solution, so that the inverse temperature difference generated by heat absorption through evaporation of water from the dilute solution and heat release through condensation of vapour in the concentrated solution is effectively offset. The positive temperature difference is maintained and enlarged, a positive saturated vapour differential pressure is in turn maintained and enlarged, thereby facilitating the expander (23) to do work. The energy utilization efficiency is high, the loss is small, the cost is cheap, the applicability is good, and the machining is simple and convenient.

(57) 摘要：一种热泵强化的正温差下蒸汽压差能法盐差发电装置，包括热泵加热循环装置和蒸汽压差能法盐差发电装置。所述热泵加热循环装置包括冷凝器(7)、热泵管道(9)、节流阀(10)、蒸发器(12)、压缩机(22)；所述蒸汽压差能法盐差发电装置包括低压容器(11)、高压容器(8)、膨胀机(23)、差压计(24)、膨胀机管道(11)；通过热泵加热循环，在浓溶液中吸热使得浓溶液温度降低，在稀溶液中放热使得稀溶液温度升高，有效的抵消了水在稀溶液中蒸发吸热、水蒸气在浓溶液中冷凝放热产生的逆温差，维持并扩大正温差，进而维持并扩大正的饱和蒸汽压差，对膨胀机(23)做功有促进作用；能量利用效率高，损耗小，成本低廉，适用性好，加工简单方便。

HEAT PUMP-REINFORCED SALINITY-GRADIENT POWER GENERATION DEVICE USING THE VAPOR-PRESSURE DIFFERENCE ENERGY METHOD UNDER POSITIVE TEMPERATURE DIFFERENCE

Technical Field

The present invention relates to the field of salinity-gradient power generation, and in particular, to a heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference.

Technical Background

As the society progresses and the global economy develops rapidly, people have increasing demand for energy sources. In view of the current development of global energy sources, fossil energy sources will still dominate for a long time in the future. However, fossil energy sources are nonrenewable energy sources and may suffer from a series of problems such as exhaustion and environmental pollution. This gives rise to an urgent need for people to search for new energy sources to replace fossil energy sources. Oceans are inexhaustible sources of abundant ocean energies. The ocean energy sources usually refer to renewable natural energy sources stored in oceans, and the major one of the renewable natural energy sources is salinity gradient energy based on seawater. Salinity gradient energy is a kind of energy obtained from an electrochemical potential difference between seawater and fresh water or two types of seawater that have different salt concentrations, and mainly exists in regions where rivers and seas meet. In terms of characteristics, for example, there is a huge amount of salinity gradient energy, and salinity gradient energy is clean and renewable. In addition, salinity gradient energy may also be harnessed at salt lakes and underground salt mines with abundant fresh water. Salinity gradient energy is a renewable energy source with the largest energy density among ocean energies. Generally, an electrochemical potential difference between seawater (the salinity is 3.5%) and river water is equivalent to a 240-meter water level difference. Salinity gradient energy sources are abundant in oceans. It is estimated that there is 2.6 TW of usable salinity gradient energy on the earth. The amount of salinity gradient energy is even larger than that of temperature difference energy. It is calculated that in China, the annual runoff of coastal rivers is about 1.7×10^{12} m^3 to 1.8×10^{12} m^3, the annual runoff of major rivers is about 1.5×10^{12} m^3 to 1.6×10^{12} m^3, the reserves of coastal salinity gradient energy sources are about 3.9×10^{18} J, and the theoretical power is about 1.25×10^{11} W. The amount of coastal energy sources in the estuaries of the Yangtze River and rivers south to the Yangtze River accounts for 92.5% of the total amount in China, and the theoretical power is estimated to be 0.86×10^{11} W. In particular, the runoff in the estuary of the Yangtze River is 2.2×10^{4} m^3/s, and the power that can be generated is 5.2×10^{10} W. In addition, some inland salt lakes in Qinghai province etc. of China may also be utilized.

Currently, the forms of salinity-gradient power generation mainly include: pressure retarded osmosis, reverse electrodialysis, vapor-pressure difference, electrochemical capacitance, and the like. Pressure retarded osmosis and reverse electrodialysis are the most researched forms. The principle of the vapor-pressure difference energy method is: A vapor pressure difference between salt solutions with different concentrations is used to drive a turbine to generate power. The biggest advantage of the method is that the dependence on osmotic membranes is avoided. However, because of low temperature, low evaporation, and excessively small pressure differences, at the room temperature, a vapor pressure difference between seawater with a concentration of 3.45% and fresh water is only 10 mmHg to 20 mmHg. Therefore, the diameter of a turbine needs to be very large to ensure reasonable power generation. Furthermore, the evaporation of water on an upper surface on the side of a dilute solution causes gradual decrease of the temperature. When moisture reaches an upper surface on the side of a concentrated solution, because of heat release through condensation, the temperature rises, and a negative temperature difference is gradually formed, which suppresses the effect of a positive pressure difference. If the concentrated solution has a temperature increase of 0.5°C through condensation of water vapor, the positive pressure difference is canceled. Therefore, it is exceedingly difficult to utilize salinity-gradient power generation using a vapor-pressure difference energy method.

Summary of Invention

Technical problem: An objective of the present invention is to rectify the defect in the prior art, and to provide a heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference, by means of which, a negative temperature difference is eliminated, a positive temperature difference is increased, a pressure difference is increased, an expander does more work, the energy utilization efficiency is high, the loss is small, the costs are low, and the processing is simple and convenient.

Technical solution: A heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference in the present invention includes a heat pump heating cycling device and a salinity-gradient power generation device using the vapor-pressure difference energy method.

The heat pump heating cycling device includes a condenser, a heat pump pipe, a throttle valve, an evaporator, and a compressor. The condenser, the throttle valve, the evaporator, and the compressor are sequentially connected by the heat pump pipe and form a cycling device.

The salinity-gradient power generation device using a vapor-pressure difference energy method includes a low-pressure container, a high-pressure container, the expander, a differential pressure gauge, and an expander pipe. The low-pressure container is connected to the high-pressure container through the expander pipe. The expander is disposed in the expander pipe. The differential pressure gauge is disposed between an outlet and an inlet of the expander.

The evaporator is disposed inside the low-pressure container, and a concentrated solution is filled inside the low-pressure container. The condenser is disposed inside the high-pressure container, and a dilute solution is filled inside the high-pressure container.

The concentrated solution is a saturated lithium bromide solution or a saturated sodium chloride solution. The dilute solution is a solution with a concentration less than 10%.

Preferably, the salinity-gradient power generation device using the vapor-pressure difference energy method further includes a dilute solution container, a dilute solution supplement, a dilute solution pump, a dilute solution pump pipe, a concentrated solution container, a concentrated solution supplement, a concentrated solution pump, and a concentrated solution pump pipe.

The dilute solution supplement is placed inside the dilute solution container. The dilute solution container is connected to the high-pressure container through the dilute solution pump pipe. The dilute solution pump is disposed in the dilute solution pump pipe.

The concentrated solution supplement is placed inside the concentrated solution container. The concentrated solution container is connected to the low-pressure container through the concentrated solution pump pipe. The concentrated solution pump is disposed in the concentrated solution pump pipe.

Preferably, the salinity-gradient power generation device using a vapor-pressure difference energy method further includes a vacuum pump. The vacuum pump is connected to the low-pressure container through a vacuum pump pipe.

Preferably, a liquid discharge pipe is disposed at the bottom of the low-pressure container, and a valve is disposed in the liquid discharge pipe.

Preferably, the throttle valve is disposed in the heat pump pipe connecting the condenser and the evaporator.

Beneficial effect: For the heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference of the present invention, by a heat pump heating cycle, heat is absorbed from a concentrated solution to lower the temperature of the concentrated solution, and heat is released to a dilute solution to increase the temperature of the dilute solution, so that a negative temperature difference generated by heat absorption through evaporation of water in the dilute solution and heat release through condensation of water vapor in the concentrated solution is effectively canceled, so as to maintain and increase a positive temperature difference, and to further maintain and increase a positive saturated vapor pressure difference, thereby making it easier for the expander to do work. The energy utilization efficiency is high, the loss is small, the costs are low, the applicability is desirable, and the processing is simple and convenient.

Brief Description of Drawings:

FIG. 1 is a schematic structural diagram according to the present invention.

Description of Embodiments

The present invention is further described below with reference to the embodiments in the accompanying drawings:

As shown in FIG. 1, a heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference of the present invention includes a heat pump heating cycling device and a salinity-gradient power generation device using the vapor-pressure difference energy method, and is mainly formed of an expander pipe 1, a dilute solution pump pipe 2, a dilute solution pump 3, a dilute solution container 4, a dilute solution supplement 5, a dilute solution 6, a condenser 7, a high-pressure container 8, a heat pump pipe 9, a throttle valve 10, a low-pressure container 11, an evaporator 12, a valve 13, a liquid discharge pipe 14, a concentrated solution 15, a concentrated solution container 16, a concentrated solution supplement 17, a concentrated solution pump pipe 18, a concentrated solution pump 19, a vacuum pump 20, a vacuum pump pipe 21, a compressor 22, an expander 23, and a differential pressure gauge 24.

The heat pump heating cycling device includes the condenser 7, the heat pump pipe 9, the throttle valve 10, the evaporator 12, and the compressor 22. The condenser 7, the throttle valve 10, the evaporator 12, and the compressor 22 are sequentially connected by the heat pump pipe 9 and form a cycling device. The salinity-gradient power generation device using the vapor-pressure difference energy method includes the low-pressure container 11, the high-pressure container 8, the expander 23, the differential pressure gauge 24, and the expander pipe 1. The low-pressure container 11 is connected to the high-pressure container 8 through the expander pipe 1. The expander 23 is disposed in the expander pipe 1. The differential pressure gauge 24 is disposed in the expander pipe 1. The differential pressure gauge 24 is disposed between an outlet and an inlet of the expander 23. The evaporator 12 is disposed inside the low-pressure container 11, and the concentrated solution 15 is filled inside the low-pressure container 11. The condenser 7 is disposed inside the high-pressure container 8, and the dilute solution 6 is filled inside the high-pressure container 8. The concentrated solution 15 is a saturated lithium bromide solution or a saturated sodium chloride solution. The dilute solution 6 is a solution with a concentration less than 10%.

The condenser 7 is placed in the dilute solution 6 to heat the dilute solution 6, and the evaporator 12 is placed in the concentrated solution 15 to cool the concentrated solution 15. The compressor 22 is driven by an external motor. The heat pump pipe sequentially connects the compressor 22, the condenser 7, the throttle valve 10, and the evaporator 12 to form a heat pump heating cycle.

The salinity-gradient power generation device using a vapor-pressure difference energy method further includes the dilute solution container 4, the dilute solution supplement 5, the dilute solution pump 3, the dilute solution pump pipe 2, the concentrated solution container 16, the concentrated solution supplement 17, the concentrated solution pump 19, and the concentrated solution pump pipe 18. The dilute solution supplement 5 is provided inside the dilute solution container 4. The dilute solution container 4 is connected to the high-pressure container 8 through the dilute solution pump pipe 2. The dilute solution pump 3 is disposed in the dilute solution pump pipe 2. The concentrated solution supplement 17 is provided inside the concentrated solution container 16. The concentrated solution container 16 is connected to the low-pressure container 11 through the concentrated solution pump pipe 18. The concentrated solution pump 19 is disposed in the concentrated solution pump pipe 18.

The salinity-gradient power generation device using the vapor-pressure difference energy method further includes the vacuum pump 20. The vacuum pump 20 is connected to the low-pressure container 11 by the vacuum pump pipe 21. The liquid discharge pipe 14 is disposed at the bottom of the low-pressure container 11. The valve 13 is disposed in the liquid discharge pipe 14. The throttle valve 10 is disposed in the heat pump pipe 9 connecting the condenser 7 and the evaporator 12.

In a salinity-gradient power generation loop using a vapor-pressure difference energy method, the dilute solution 6 is filled inside the high-pressure container 8, and the dilute solution supplement 5 is filled in the dilute solution container 4. The dilute solution pump 3 adds the dilute solution supplement 5 in the dilute solution container 4 to the high-pressure container 8. The concentrated solution 15 is filled in the low-pressure container 11. The concentrated solution supplement 17 is filled in the concentrated solution container 16. The concentrated solution pump 19 adds the concentrated solution supplement 17 in the concentrated solution container 16 to the low-pressure container 11. Moreover, the low-pressure container 11 is connected to the vacuum pump 20 through the vacuum pump pipe 21, to maintain an internal vacuum condition. The bottom of the low-pressure container 11 is connected to the valve 13 to adjust the liquid discharge pipe 14. The high-pressure container 8 and the low-pressure container 11 are connected to the expander 23 through the expander pipe 1. The expander 23 is located between the low-pressure container 11 and the high-pressure container 8. The differential pressure gauge 24 is located on two sides of the expander 23. In this way, the entire salinity-gradient power generation loop using the vapor-pressure difference energy method is formed.

At a same temperature condition, the dilute solution 6 filled in the high-pressure container 8 evaporates more easily than the concentrated solution 15 in the low-pressure container 11. The vacuum pump 20 creates a vacuum condition for the low-pressure container 11, to enable the pressure in the high-pressure container 8 to be higher than the pressure in the low-pressure container 11. Under the effect of a pressure difference, water vapor in the high-pressure container 8 passes through the expander pipe 1 to drive the expander 23 to rotate and generate power. The water vapor then enters the low-pressure container 11, and condenses on the surface of the concentrated solution 15 in the low-pressure container 11 to release heat. As the device keeps operating, the dilute solution 6 in the high-pressure container 8 is reduced due to the evaporation of water. The dilute solution pump 3 adds the dilute solution supplement 5 to the high-pressure container 8 through the dilute solution pump pipe 2 to keep a liquid level of the dilute solution 6 in the high-pressure container 8 unchanged. Similarly, because the water vapor condenses on the surface of the concentrated solution 15 in the low-pressure container 11, the concentrated solution 15 is diluted to a reduced concentration. The diluted concentrated solution 15 is quantitatively discharged out of the low-pressure container 11 through the liquid discharge pipe 14 in time. The concentrated solution pump 19 quantitatively adds the concentrated solution supplement 17 to the low-pressure container 11 through the concentrated solution pump pipe 18, to keep the concentration of the concentrated solution 15 in the low-pressure container 11 unchanged. Moreover, because of heat absorption through evaporation of water in the dilute solution 6, the temperature in the high-pressure container 8 gradually decreases. The water vapor in the concentrated solution 15 condenses to release heat, so that the temperature in the low-pressure container 11 gradually increases. As a result, the temperature in the high-pressure container 8 is lower than the temperature in the low-pressure container 11. A negative temperature difference in the high-pressure container 8 mitigates the effect of a positive pressure difference, causing the expander 23 to do less work. The evaporator 12 is placed in the concentrated solution 15 in the low-pressure container 11, and the condenser 7 is placed in the dilute solution 6 in the high-pressure container 8. The evaporator 12 and the condenser 7 are connected to the compressor 22 and the throttle valve 10 through the heat pump pipe 9, to form the heat pump heating cycle. The working fluid in the heat pump heating cycle absorbs heat and evaporates in the evaporator 12, to further lower the temperature in the concentrated solution 15 to facilitate the condensation of water vapor on the surface of the concentrated solution 15, so that the pressure in the low-pressure container 11 is further decreased. The working fluid in the heat pump heating cycle is cooled in the condenser 7 and releases heat, to increase the temperature of the dilute solution 6 to facilitate the evaporation of water on the surface of the dilute solution 6, so that the pressure in the high-pressure container 8 is further increased. Not only the negative temperature difference generated by heat absorption through evaporation of water in the dilute solution 6 and heat release through condensation of water vapor in the concentrated solution 15 is canceled, but also a positive temperature difference can be generated, thereby further increasing a pressure difference, making it easier for the expander 23 to do work, enhancing salinity-gradient power generation using the vapor-pressure difference energy method, and improving the system power.

For the heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference of the present invention, by a heat pump heating cycle, heat is absorbed from a concentrated solution to lower the temperature of the concentrated solution, and heat is released to a dilute solution to increase the temperature of the dilute solution, so that a negative temperature difference generated by heat absorption through evaporation of water in the dilute solution and heat release through condensation of water vapor in the concentrated solution is effectively canceled, so as to maintain and increase a positive temperature difference, and to further maintain and increase a positive saturated vapor pressure difference, thereby making it easier for the expander to do work. The energy utilization efficiency is high, the loss is small, the costs are low, the applicability is desirable, and the processing is simple and convenient.

CLAIMS

1. A heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference, comprising a heat pump heating cycling device and a salinity-gradient power generation device using the vapor-pressure difference energy method, wherein

the heat pump heating cycling device comprises a condenser (7), a heat pump pipe (9), an evaporator (12), and a compressor (22), and the condenser (7), the evaporator (12), and the compressor (22) are sequentially connected by the heat pump pipe (9) and form a cycling device;

the salinity-gradient power generation device using the vapor-pressure difference energy method comprises a low-pressure container (11), a high-pressure container (8), an expander (23), a differential pressure gauge (24), and an expander pipe (1); and the low-pressure container (11) is connected to the high-pressure container (8) through the expander pipe (1), the expander (23) is disposed in the expander pipe (1), and the differential pressure gauge (24) is disposed between an outlet and an inlet of the expander (23);

the evaporator (12) is disposed inside the low-pressure container (11), and a concentrated solution (15) is filled inside the low-pressure container (11); and the condenser (7) is disposed inside the high-pressure container (8), and a dilute solution (6) is filled inside the high-pressure container (8); and

the concentrated solution (15) is a saturated lithium bromide solution or a saturated sodium chloride solution; and the dilute solution (6) is a solution with a concentration less than 10%.

2. The heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference according to claim 1, wherein the salinity-gradient power generation device using the

vapor-pressure difference energy method further comprises a dilute solution container (4), a dilute solution supplement (5), a dilute solution pump (3), a dilute solution pump pipe (2), a concentrated solution container (16), a concentrated solution supplement (17), a concentrated solution pump (19), and a concentrated solution pump pipe (18);

the dilute solution supplement (5) is placed inside the dilute solution container (4), the dilute solution container (4) is connected to the high-pressure container (8) through the dilute solution pump pipe (2), and the dilute solution pump (3) is disposed in the dilute solution pump pipe (2); and

the concentrated solution supplement (17) is placed inside the concentrated solution container (16), the concentrated solution container (16) is connected to the low-pressure container (11) through the concentrated solution pump pipe (18), and the concentrated solution pump (19) is disposed in the concentrated solution pump pipe (18).

3. The heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference according to claim 1, wherein the salinity-gradient power generation device using the vapor-pressure difference energy method further comprises a vacuum pump (20), and the vacuum pump (20) is connected to the low-pressure container (11) through a vacuum pump pipe (21).

4. The heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference according to claim 1, wherein a liquid discharge pipe (14) is disposed at the bottom of the low-pressure container (11), and a valve (13) is disposed in the liquid discharge pipe (14).

5. The heat pump-reinforced salinity-gradient power generation device using a vapor-pressure difference energy method under a positive temperature difference

according to claim 1, wherein a throttle valve (10) is disposed in the heat pump pipe (9) connecting the condenser (7) and the evaporator (12).

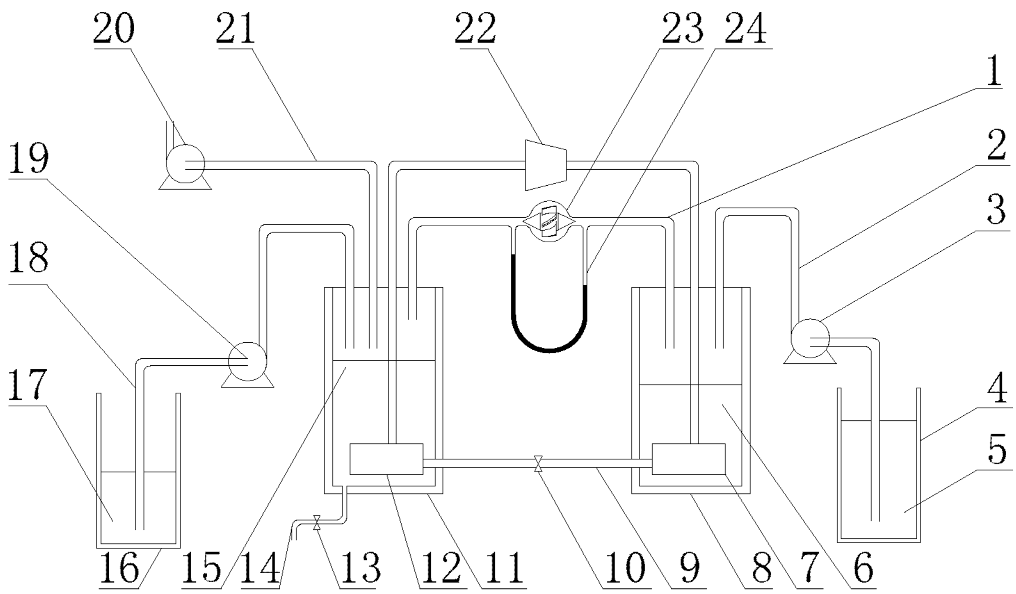

FIG. 1