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(54) **STEAM HEAT PUMP AND LOW-PRESSURE STEAM ENTHALPY SUPPLEMENTING AND PRESSURIZING UTILIZATION METHOD**

(57) The invention discloses an efficient vapor heat pump (VHP) and a method for utilizing low pressure vapor through enthalpy supplement and pressure boost, comprising the following steps: the low pressure vapor is heated into superheated vapor for enthalpy supplement; when a material is heated on a material heater, the pressure boosted and quantity increased saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor is sucked for spraying liquid boost pressure (SLBP), so as to utilize the pressure boosted and quantity increased saturated vapor; further, an artificial tornado is generated from vapor in relevant equipment by reference to the formation theory of tornado in nature and the strong suction force thereof, so as to enhance the suction force and improve thermal efficiency and compression ratio. The vapor heat pump, especially the tornado vapor heat pump (TVHP), has the advantages of high efficiency, low energy consumption, low cost and environmental protection due to small enthalpy difference between low pressure vapor and pressure boosted and quantity increased saturated vapor, less enthalpy supplement of superheated vapor, and high pressure ratio for spraying liquid boost pressure (SLBP). Besides, the low carbon technology is used as a green energy source and thus the TVHP is

widely applied to many fields.

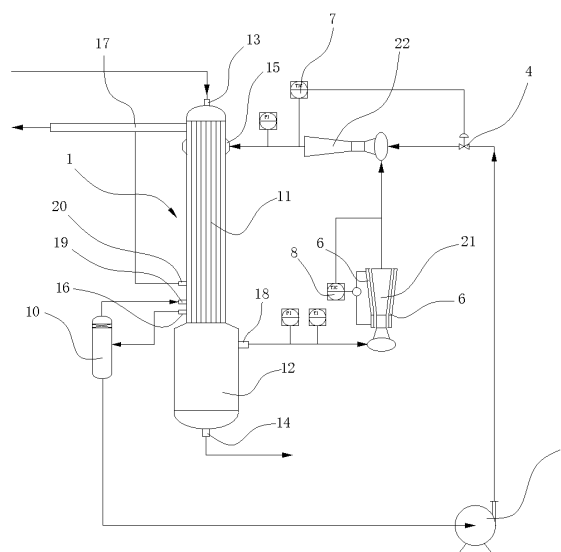


Fig 5

Description**Technical Field**

5 **[0001]** The invention relates to the field of vapor heat pumps (VHP), in particular to a vapor heat pump and a method for utilizing low pressure vapor through enthalpy supplement and pressure boost.

Background

10 **[0002]** As is well-known, the utilization of low pressure vapor or secondary vapor is an important topic in today's green, low-carbon (carbon dioxide emission reduction) and circular economy.

[0003] However, the temperature of the secondary vapor generated during evaporation is always lower than the liquid temperature due to the rising boiling point, which creates technical difficulties for the energy-saving utilization of the secondary vapor.

15 **[0004]** In the prior art, the energy-saving utilization of vapor is generally realized by the following methods.

1. Multi-effect evaporation

[0005] Taking steam as an example, in principle, the multi-effect evaporator uses the latent heat of vaporization of externally supplied vapor for many times. However, whatever happens, the externally supplied vapor enters and flows out of the system in a steam state so that the enthalpy difference of the steam entering and leaving the system is very small. For example, after the saturated steam (1.0MPa(G), 185°C) enters the evaporation system for multi-effect evaporation, it will become 45° C secondary steam and then be discharged from the system, with the enthalpy difference less than 250kJ/kg and the heat utilization rate of the externally supplied vapor less than 9%. Not only that, a large amount of circulating water will be used to condense the secondary steam with the purpose of ensuring the vacuum degree during evaporation. The circulating water consumption as well as other energy consumption decreases the heat utilization rate of second law of thermodynamics.

2. Mechanical vapor recompression (MVR)

30 **[0006]** Taking steam as an example, MVR is an energy-saving technology aiming to reduce the demand for external energy by reusing the energy of the secondary steam. Its working process is to compress the steam (secondary steam) at low temperature through a compressor, increase the temperature, pressure and the enthalpy, and then condensate steam in an evaporator to make full use of the latent heat of steam. Except for start-up, the externally supplied steam is not used in the whole evaporation process, so as to fully utilize the secondary steam, recover latent heat and improve thermal efficiency, thus the economy is equal to 20-effect evaporation. However, one-time investment of MVR is greater than that of multi-effect evaporation, which is generally 1.5 times more than multi-effect evaporation. In addition, special equipment may not be provided and the construction period is relatively short for the multi-effect evaporation; whereas MVR requires a special compressor whose production period is long, so the whole construction period of MVR is three times as long as multi-effect evaporation. Steam is difficult to compress and will eventually be in a superheated state after compressed, of which more than 80% of the energy is consumed for temperature increasing and only less than 20% for pressure increasing. Therefore, the adiabatic compression of saturated steam is very energy consuming. For MVR, the temperature difference between two single-stage compressors (connected in series) is only 16°C (i.e. single-stage temperature rise: 8°C), which limits its application range.

3. Steam-jet heat pump

45 **[0007]** In principle, the steam-jet heat pump requires expanding the externally supplied high-pressure Steam in Laval nozzle (nozzle jet) of the steam ejector to generate supersonic flow so that the pressure energy and phase change energy are converted into kinetic energy of jet flow, so as to drive and eject the secondary steam or low pressure steam, and realize their pressure boosted utilization. After pressure boosted, the pressure of mixed steam is less than that of the externally supplied vapor. The injection driving coefficient is generally less than 1 so that the secondary Steam or low pressure Steam has been rarely used due to very low utilization rate and very high energy consumption.

55 **Summary of the Invention**

[0008] The technical solution to be provided by the invention is to provide a vapor heat pump (VHP) and a method for utilizing low pressure vapor through enthalpy supplement and pressure boost, so as to efficiently utilize the low pressure

vapor.

[0009] The invention provides a method for utilizing low pressure vapor through enthalpy supplement and pressure boost, comprising the following steps:

- 1) the low pressure vapor is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;
- 2) when a material is heated by the high-level thermal energy saturated vapor on a material heater, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor obtained in step 1) is sucked for spraying liquid boost pressure (SLBP), and converted into the pressure boosted and quantity increased saturated vapor, that is, a high-level thermal energy saturated vapor, which is then fed into the material heater for heating the material to achieve the utilization or cyclic utilization.

[0010] Further, an artificial tornado method is used by reference to the formation theory of tornado in nature and its strong suction force, so as to generate tornado vortex in the low pressure vapor for superheating and then spraying-liquid boost pressure or superheating and spraying-liquid boost pressure.

[0011] The method comprises the following steps:

- 1) the low pressure vapor is heated into superheated vapor, or a tornado vortex is generated from the low pressure vapor and then heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at target pressure;
- 2) when the material is heated by the high-level thermal energy saturated vapor on a material heater, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; a tornado vortex is generated from the superheated vapor according to the artificial tornado method for enhancing the suction force; then the superheated vapor is sucked for spraying-liquid boost pressure to generate the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the material heater for heating the material to improve thermal efficiency and pressure ratio, and realize the utilization or cyclic utilization.

[0012] Further, the material heater is an evaporator and the low pressure vapor is secondary vapor, comprising the following steps:

- 1) the secondary vapor formed and discharged from an evaporation chamber of the evaporator is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;
- 2) when the material is heated by the high-level thermal energy saturated vapor in a heating chamber of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor is sucked for spraying-liquid boost pressure, and converted into the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the heating chamber of the evaporator for heating the material, so as to achieve the cyclic utilization.

[0013] Further, the method for utilizing low pressure vapor through enthalpy supplement and pressure boost is realized by a vapor heat pump, comprising a material heater and a superheat and spraying-liquid booster (SHSLB) with a low pressure vapor inlet and a saturated vapor outlet;

the material heater has a saturated vapor inlet in connected with the saturated vapor outlet of the SHSLB;

in step 1), the low pressure vapor flows into the SHSLB and is heated into the superheated vapor; and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure; in step 2), the condensate is sprayed into the SHSLB to convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater for heating the material to archive the utilization or cyclic utilization.

[0014] Further, the vapor heat pump used in the method for utilizing low pressure vapor through enthalpy supplement and pressure boost, is one capable of a tornado vapor heat pump (TVHP), which comprises a material heater and a tornado superheat and spraying-liquid booster (TSHSLB), wherein the TSHSLB has a low pressure vapor inlet and a saturated vapor outlet;

the material heater has a saturated vapor inlet connected with the saturated vapor outlet of the TSHSLB;

in step 1), the low pressure vapor is fed into the TSHSLB and heated into the superheated vapor; and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure; in step 2), when the material is heated by the saturated vapor in the material heater, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; a tornado is generated from the superheated vapor

obtained in step 1) in the TSHSLB for enhancing the suction force; the condensate is sprayed into the TSHSLB to absorb some of enthalpy of the superheated vapor and convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the material heater for heating the material to achieve the utilization or cyclic utilization.

[0015] Further, the SHSLB comprises a superheater (SH) and a spraying-liquid booster (SLB); wherein the SH has a low pressure vapor inlet and a superheated vapor outlet, and the SLB has a superheated vapor inlet and a saturated vapor outlet;

the superheated vapor outlet of the SH is connected with the superheated vapor inlet of the SLB, and the saturated vapor outlet of the SLB is connected with the saturated vapor inlet of the material heater;

in step 1), the low pressure vapor flows through SH and is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

in step 2), the condensate is sprayed into the SLB to convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater for heating the material to archive the utilization or cyclic utilization.

[0016] Further, the SH is a tornado superheater (TSH), the SLB is a tornado spraying-liquid booster (TSLB), and a heater is arranged on the TSH;

in step 1), the low pressure vapor is fed into the TSH to generate a tornado vortex;

meanwhile, in the TSH low pressure vapor is heated into superheated vapor by the heater, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

in step 2), when the material is heated by the saturated vapor in the material heater, the saturated vapor will be condensed to generate a strong suction force; the superheated vapor obtained in step 1) is sucked into the TSLB to generate a tornado vortex for enhancing the suction force; meanwhile, the condensate is sprayed through the nozzle assembly at the direction opposite to the rotating direction of the TSLB tornado vortex, the superheated vapor and the condensate are fully mixed to generate the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater for heating the material to achieve the utilization or cyclic utilization.

[0017] Low pressure vapor is the low-level thermal energy saturated vapor relative to the pressurized high-level thermal energy saturated vapor.

[0018] The material of the invention means evaporable solution or pure liquid, of which the solvent can be either water or organic solvent.

[0019] Taking steam as an example, the method of the invention is based on the principle that saturated steam at different temperature has small enthalpy difference; for example, since the enthalpy difference of saturated steam at 100°C and 120°C is only 29kJ/kg, the secondary steam at 100°C can reach the saturated state at 120°C only through enthalpy supplement of 29kJ/kg and pressure increase. The enthalpy supplement and pressure increase of steam can be performed in many ways such as mechanical vapor recompression (MVR). Steam is difficult to compress and will eventually be in a superheated state, of which more than 80% of the energy is consumed for increase temperature and less than 20% for increase pressure. Therefore, the energy consumption is high.

[0020] The method for utilizing low pressure vapor through enthalpy supplement and pressure boost in the invention is based on the one-to-one correspondence characteristic of temperature, pressure and enthalpy of saturated vapor; that is, given the enthalpy value, the vapor pressure and temperature can be determined. However, the low pressure vapor or secondary vapor can be converted into superheated vapor through enthalpy supplement, but vapor cannot be pressurized. Heat energy and pressure energy are both energy. Under certain conditions, heat energy can be converted into pressure energy such as spraying liquid boost pressure (SLBP), which is an excellent choice.

[0021] Based on the method for utilizing low pressure vapor through enthalpy supplement and pressure boost in the invention, when the material is heated by the saturated vapor, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force. Next, through enthalpy supplement and spraying liquid boost pressure, the low pressure vapor can be converted into the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, so as to utilize the low pressure vapor. In particular, an artificial tornado is generated from vapor in corresponding equipment according to an artificial tornado method, so as to enhance the condensation suction force of vapor and further improve the thermal efficiency and compression ratio. Compared with the traditional method, the invention can effectively reduce the energy consumption and save the cost owing to small enthalpy difference between the low pressure vapor and pressurized saturated vapor, small enthalpy supplement required for superheated vapor, and high efficiency of spraying liquid boost pressure.

[0022] The invention further provides a vapor heat pump, which is not a separate equipment but a device system, comprising a material heater and a SHSLB, wherein the low pressure vapor is heated into superheated vapor in the SHSLB for spraying liquid boost pressure and converted into the pressure boosted and quantity increased saturated vapor; the material heater has a saturated vapor inlet; the SHSLB has a saturated vapor outlet, a low pressure vapor inlet, and a condensate inlet; and the saturated vapor inlet of the material heater is connected with the saturated vapor outlet of the SHSLB.

[0023] Further, the SHSLB is a TSHSLB; and TSHSLB comprises a TSHSLB vortex generation superheat section, a TSHSLB acceleration section, a TSHSLB high-speed mixing section and a TSHSLB diffuser section; wherein the TSHSLB vortex generation superheat section has a circular drum or a cylindrical inner cavity, the TSHSLB acceleration section has a conical inner cavity, the TSHSLB high-speed mixing section has a cylindrical inner cavity, and the TSHSLB diffuser section has a conical inner cavity;

the larger diameter end of the conical inner cavity of the TSHSLB acceleration section is connected with a circular drum or a cylindrical inner cavity of the TSHSLB vortex generation superheat section, and the smaller diameter end of the conical inner cavity of the TSHSLB acceleration section is connected with the smaller diameter end of the conical inner cavity of the TSHSLB diffuser section through the cylindrical inner cavity of the TSHSLB high-speed mixing section;

the TSHSLB vortex generation superheat section is provided with a low pressure vapor inlet pipe; the centerline of the low pressure vapor inlet pipe is perpendicular to that of the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section; the low pressure vapor inlet pipe is connected with the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section; and the inner wall of the low pressure vapor inlet pipe is tangent to that of the TSHSLB vortex generation superheat section;

the TSHSLB vortex generation superheat section is provided with a tornado nozzle assembly connected with the inner circular drum or cylindrical cavity of the TSHSLB vortex generation superheat section; the tornado nozzle assembly and the TSHSLB acceleration section are respectively arranged on two opposite sides of the TSHSLB vortex generation superheat section;

the centerline of the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section, the centerline of the conical inner cavity of the TSHSLB acceleration section, the centerline of the cylindrical inner cavity of the TSHSLB high-speed mixing section, the centerline of the conical inner cavity of the TSHSLB diffuser section and the injection centerline of the tornado nozzle assembly are collinear;

a second heater is arranged on the outer surface of the TSHSLB vortex generation superheat section; and the TSHSLB diffuser section is connected with the saturated vapor inlet of the material heater.

[0024] Further, the material heater is an evaporator, and the SHSLB comprises a SH and a SLB;

the SH has a secondary vapor inlet pipe and a superheated vapor outlet; the evaporator comprises a heating chamber and an evaporation chamber; the evaporator has a secondary vapor outlet connected with the evaporation chamber and a saturated vapor inlet connected with the heating chamber; the SLB has a superheated vapor inlet and a saturated vapor outlet; the secondary vapor inlet pipe of the SH is connected with the secondary vapor outlet of the evaporation chamber of the evaporator, and the superheated vapor outlet of the SH is connected with the superheated vapor inlet of the SLB; the saturated vapor outlet of the SLB is connected with the saturated vapor inlet of the heating chamber; the SLB has a nozzle assembly comprising a liquid ejection nozzle arranged in the SLB; and the ejection direction of the liquid ejection nozzle is the same as that of the saturated vapor outlet of the SLB.

[0025] Further, the SH comprises a TSH and a heater; wherein the TSH comprises a tornado vortex generation section, a tornado acceleration section, a high-speed section and a diffuser superheat section; the tornado vortex generation section has a circular drum or a cylindrical inner cavity; the tornado acceleration section has a conical inner cavity; the high-speed section has a cylindrical inner cavity; and the diffuser superheat section has a conical inner cavity;

the larger diameter end of the conical inner cavity of the tornado acceleration section is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section, and the smaller diameter end of the conical inner cavity of the tornado acceleration section is connected with the smaller diameter end of the conical inner cavity of the diffuser superheat section through the cylindrical inner cavity of the high-speed section;

the centerline of the circular drum or cylindrical inner cavity of the tornado vortex generation section, the centerline of the conical inner cavity of the tornado acceleration section, the centerline of the cylindrical inner cavity of the high-speed section and the centerline of the conical inner cavity of the diffuser superheat section are collinear;

a secondary vapor inlet pipe is arranged on the tornado vortex generation section; the centerline of the secondary vapor inlet pipe is perpendicular to that of the circular drum or cylindrical inner cavity of the tornado vortex generation section; the secondary vapor inlet pipe is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section, and the inner wall of the secondary vapor inlet pipe is tangent to that of the tornado vortex generation section;

the heater is arranged on the diffuser superheat section, or on the high-speed section and the diffuser superheat section.

[0026] Further, the SLB is a TSLB comprising a TSLB vortex generation section, a TSLB acceleration section, a TSLB high-speed mixing section and a TSLB diffuser section; the TSLB vortex generation section has a circular drum or cylindrical inner cavity; the TSLB acceleration section has a conical inner cavity; the TSLB high-speed mixing section has a cylindrical inner cavity; and the TSLB diffuser section has a conical inner cavity;

the larger diameter end of the conical inner cavity of the TSLB acceleration section is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section, and the smaller diameter end of the conical inner cavity of the TSLB acceleration section is connected with the smaller diameter end of the conical inner cavity of the TSLB diffuser section through the cylindrical inner cavity of the TSLB high-speed mixing section;

a superheated vapor inlet pipe is arranged on the TSLB vortex generation section; the centerline of the superheated vapor inlet pipe is perpendicular to that of the circular drum or cylindrical inner cavity of the TSLB vortex generation section; the superheated vapor inlet pipe is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section, and the inner wall of the superheated vapor inlet pipe is tangent to that of the TSLB vortex generation section;

the nozzle assembly is arranged on the TSLB vortex generation section and is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section; the nozzle assembly and the TSLB acceleration section are respectively arranged on two opposite sides of the TSLB vortex generation section;

the centerline of the circular drum or cylindrical inner cavity of the TSLB vortex generation section, the centerline of the conical inner cavity of the TSLB acceleration section, the centerline of the cylindrical inner cavity of the TSLB high-speed mixing section, the centerline of the conical inner cavity of the TSLB diffuser section and the injection centerline of the nozzle assembly are collinear;

the outlet of the TSH diffuser section is connected with the TSLB superheated vapor inlet pipe; and the TSLB diffuser section is connected with the saturated vapor inlet of the heating chamber of the evaporator.

[0027] Further, the length-diameter ratio of the cylindrical inner cavity of the TSLB high-speed mixing section is 1-4; 1; and the taper of the conical inner cavity of the TSLB diffuser section is 6-10°.

[0028] Further, the vapor heat pump comprises a condensate discharge tank and a condensate pump; the material heater or evaporator is provided with a condensate outlet connected with the inlet of the condensate discharge tank, wherein the outlet of the condensate discharge tank is connected with the inlet of the condensate pump, and the outlet of the condensate pump is connected with the tornado nozzle assembly or the nozzle assembly so that the heat energy of the condensate can be utilized.

[0029] Further, the vapor heat pump comprises a first temperature control loop, and a control valve is arranged on the connecting pipe between the nozzle assembly of the SLB or the TSLB and the condensate pump;

A temperature sensor for pressure boosted and quantity increased saturated vapor is arranged at the outlet of the SLB or the TSLB, and the valve opening of the control valve is controlled by the first temperature control loop according to the saturated vapor temperature at the outlet of the SLB or the TSLB detected by the temperature sensor for pressure boosted and quantity increased saturated vapor, thereby maintaining stable temperature of the pressure boosted and quantity increased saturated vapor.

[0030] Further, the heater is provided with a second temperature control loop, and a second temperature sensor is arranged at the outlet of the SH or the TSH; and the heating amount of the heater is regulated by the second temperature control loop according to the superheated vapor temperature at the outlet of the SH or the TSH detected by the second temperature sensor to stabilize superheated vapor temperature.

[0031] Further, a control valve is arranged on the connecting pipe between the tornado nozzle assembly of the SHSLB or the TSHSLB and the condensate pump; and the second heater is provided with a temperature regulator;

an temperature automatic selective control loop and a temperature sensor for pressure boosted and quantity increased saturated vapor are arranged at the outlet of the SHSLB or the TSHSLB; the temperature sensor for pressure boosted and quantity increased saturated vapor is connected to the temperature automatic selective control loop; and the valve opening of the control valve as well as the temperature regulator is controlled by the temperature automatic selective control loop to maintain stable temperature of the pressure boosted and quantity increased saturated vapor. The control principle for temperature automatic selective adjustment loop is as follow: if the temperature is higher than set value, the temperature of saturated vapor at the target pressure was reached by increasing the flow rate of condensate and/or reducing the heating amount of the heater; conversely if the temperature is lower than set value, the temperature of saturated vapor at the target pressure was reached by reducing the flow rate of condensate and/or increasing the heating amount of the heater .

[0032] Compared with the prior art, the vapor heat pump of the invention has the following advantages especially when the SHSLB is a TSHSLB or the SHSLB is a combined TSH and TSLB mode for a tornado vapor heat pump (TVHP):

1. For the vapor heat pump of the invention, in particular to the tornado vapor heat pump, when the high level energy vapor is condensed, it will sharply shrink in volume to generate a strong suction force, which is further enhanced by the artificial tornado method (suction pipe effect in daily life), and the low pressure vapor or secondary vapor is heated into the superheated vapor for supplement enthalpy and spraying liquid boost pressure (SLBP) based on the uniquely structured TSH, TSLB or TSHSLB, so as to utilize the low pressure vapor or secondary vapor. The energy consumption of the TVHP is lower than that of multi-effect evaporation and steam-jet heat pump, or at least twice lower than that of the mechanical vapor recompression (MVR), due to the small enthalpy difference of saturated vapor at different temperature, thus small enthalpy supplement is needed ,but high pressure ratio for spraying liquid boost pressure is reached. Further, the theoretical thermal efficiency of the tornado vapor heat pump is as high as more than 90%, and the low carbon technology means a green energy source. No externally supplied vapor is needed in the whole process except start-up. If a vacuum device is equipped, even no externally supplied vapor is

needed during the start-up; which means that energy sources for generating externally supplied vapor, such as coal and oil, are saved, carbon dioxide and other harmful gases are not generated, and waste residue and waste liquid are not discharged at the same time. This technology will play an excellent role in today's green, low-carbon economy (carbon dioxide emission reduction) and circular economy.

2. The vapor heat pump of the invention, especially the tornado vapor heat pump is structurally simple, low in material requirement and convenient to manufacture at low cost. Thus, the investment on TVHP is lower than that on MVR and even multi-effect evaporation. Moreover, the TVHP has shorter construction period than MVR and even multi-effect evaporation.

3. The vapor heat pump of the invention, especially the tornado vapor heat pump heats the material by the pressure boosted and quantity increased saturated vapor. Different from the multi-effect evaporation, the system will not discharge the secondary vapor when the saturated vapor is condensed, which saves a large amount of circulating water required by the multi-effect evaporation to condense the secondary vapor.

4. The vapor heat pump of the invention, especially the tornado vapor heat pump has no rotating parts, which avoids the noise and environmental pollution.

Brief Description of the Attached Drawings

[0033]

Fig. 1 is a constitution schematic diagram of a device system when the vapor heat pump (VHP) in an example of the invention comprises a material heater and a superheat and spraying-liquid booster (SHSLB);

Fig. 2 is a constitution schematic diagram of the vapor heat pump (VHP) comprises a material heater which is an evaporator, a superheat and spraying-liquid booster (SHSLB);

Fig. 3 is a structural schematic diagram of the tornado superheat and spraying-liquid booster (TSHSLB) in an example of the invention;

Fig. 4 is a constitution schematic diagram of a device system when the vapor heat pump (VHP) in an example of the invention comprises a material heater, a superheater (SH) and a spraying-liquid booster (SLB);

Fig. 5 is a constitution schematic diagram of the vapor heat pump comprises a material heater which is an evaporator, a superheater (SH) and a spraying-liquid booster (SLB);

Fig. 6 is a perspective view of the tornado superheater (TSH) in an example of the invention;

Fig. 7 is a front view of the tornado superheater (TSH) in an example of the invention;

Fig. 8 is a section view of the tornado superheater (TSH) in an example of the invention;

Fig. 9 is a section view of Fig. 7 in A-A direction;

Fig. 10 is a perspective view of the tornado spraying-liquid booster (TSLB) in an example of the invention;

Fig. 11 is a front view of the tornado spraying-liquid booster (TSLB) in an example of the invention;

Fig. 12 is a section view of the tornado spraying-liquid booster (TSLB) in an example of the invention;

Fig. 13 is a section view of Fig. 11 in A-A direction;

[0034] As shown in the Fig., 1- material heater, 11- heating chamber, 12- evaporation chamber, 13- evaporable solution inlet, 14- concentrated solution outlet, 15- saturated vapor inlet, 16- condensate outlet, 17- vent nozzle 18- secondary vapor outlet, 19- flash vapor inlet, 20- second vent nozzle, 2- superheat and spraying-liquid booster (SHSLB), 202- TSHSLB vortex generation superheat section, 203- TSHSLB acceleration section, 204- TSHSLB high-speed mixing section, 205- TSHSLB diffuser section, 206- tornado nozzle assembly, 207- second heater, 21- superheater (SH), 212- tornado vortex generation section, 213- tornado acceleration section, 214- high-speed section, 215- diffuser superheat section, 22- spraying-liquid pressure booster (SLB), 221- superheated vapor inlet pipe, 222- TSLB vortex generation section, 223- TSLB acceleration section, 224- TSLB high-speed mixing section, 225- TSLB diffuser section, 226- nozzle assembly, 3- condensate pump, 4- control valve, 5- temperature automatic selective control loop, 6- heater, 7- first temperature control loop, 8- second temperature control loop, 9- low pressure vapor pipe, 10- condensate discharge tank.

Detailed Description of the Preferred Embodiment

[0035] Taking steam as an example, there is a one-to-one corresponding relationship among temperature, pressure and enthalpy for dry saturated steam (usually known as saturated steam) with dryness $X=1.00$ and superheat degree of 0. In other words, given the enthalpy value, the pressure and temperature of saturated steam can be determined. The state parameters of saturated steam and water (condensate) are summarized in Table 1.

Table 1 Parameters of saturated steam and water (condensate) at different temperature

Saturated steam					Water (condensate)	
Temperature t °C	Pressure P kPa	Enthalpy i kJ/kg	Latentheat r kJ/kg	Specific volume v" m³/kg	Specific volume v' m³/kg	Enthalpy i' kJ/kg
160	638.58	2758	2083	0.3068	0.0011021	675
140	373.40	2734	2145	0.5087	0.0010798	589
120	205.14	2706	2203	0.8917	0.0010603	503
100	104.69	2677	2257	1.673	0.0010435	420
80	48.93	2643	2308	3.409	0.0010290	335
60	20.58	2609	2358	7.678	0.0010171	251
40	7.62	2574	2406	19.55	0.0010079	168
20	2.41	2537	2454	57.84	0.0010018	83

[0036] It can be seen from Table 1 that the enthalpy difference of saturated steam at different temperature is very small. Therefore, to reuse the low pressure steam or secondary steam through enthalpy supplement and pressure boost will be a perfect choice.

[0037] For example, since the enthalpy difference between 100°C and 120°C saturated steam is only 2706-2677=29kJ/kg, the 100°C low pressure vapor or secondary vapor can reach the 120°C saturation state steam and reused through enthalpy supplement of 29kJ/kg and pressure boosting based on the technology of the invention.

[0038] Moreover, the enthalpy supplement method is to heat the low pressure steam or secondary steam into superheated steam for enthalpy supplement, and the formula is as follows:

$$\begin{aligned}
 i''_2 &= i'' + q \\
 &= i'' + C_{pm} \Delta t \\
 &= i'' + C_{pm} (t_2 - t)
 \end{aligned}$$

[0039] Where: i''_2 - enthalpy of superheated steam, i - enthalpy of low pressure saturation steam or secondary steam, q - amount of heat supplemented by heating 1kg of saturated steam to a certain superheat degree, C_{pm} - average specific heat of superheated steam, Δt - superheat degree, t_2 - superheated steam temperature, t - temperature of low-pressure steam or secondary steam.

[0040] It can be seen from the formula that the enthalpy of superheated steam increases with the amount of heat supplemented, superheat degree or superheated steam temperature, which is the mode and principle of enthalpy supplement of the superheated steam. In addition, the superheated steam cannot be pressure increased during enthalpy supplement. However, heat energy and pressure energy are both energy. Under certain conditions, heat energy can be converted into pressure energy by spraying liquid boost pressure, will be a perfect choice. In general, the enthalpy supplement requirements can be met by exceeding the high-level thermal energy saturated steam temperature at the target pressure; and the principle of superheated steam rising is the same as that of hot air balloon rising.

[0041] Importantly, the spraying liquid boost pressure of the invention is different from adiabatic compression, of which steam will eventually be in a superheated state because more than 80% of the energy is consumed for temperature increase and less than 20% of the energy is used for pressure increase; meanwhile, it is also different from isothermal compression. Despite low energy consumption compared with adiabatic compression, the isothermal compression of gas will release heat to the outside, i.e. the compression heat shall be taken away by cooling water or air, resulting in a decrease in enthalpy of energy. The characteristics of spraying liquid boost pressure lie in that the pressure boosted or compressed vapor is the pressure boosted saturated vapor instead of superheated vapor, and no heat is released so as not to reduce the enthalpy value. Instead, the system acquires heat from the outside, i.e. spraying liquid heat; thus the spraying liquid absorbs this part of enthalpy higher than the temperature of pressure boosted saturated vapor and becomes the incremental saturated vapor. In a word, the purpose of spraying liquid boost pressure is to convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, with low energy consumption and large pressure ratio.

[0042] There is another important basis, that is, when the material is heated by the high-level thermal energy saturated

steam in a material heater or an evaporator, the saturated steam will be condensed and sharply shrink in volume to generate a strong suction force.

[0043] Taking the saturated steam at 1000kg, 120°C and 205.14kPa as an example, it can be seen from Table 1 that the specific volumes of saturated steam and condensate are $v''=0.8917 \text{ m}^3/\text{kg}$, and $v'=0.0010603 \text{ m}^3/\text{kg}$ respectively; saturated steam volume $V''=1000 \times 0.8917=891.7 \text{ m}^3$, condensate volume $V'=1000 \times 0.0010603=1.06 \text{ m}^3$; after the saturated steam is condensed into condensate, its volume decreases by $891.7/1.06=841$ times;

[0044] Taking the saturated steam at 1000kg, 60°C and 20.58kPa as an example, it can be seen from Table 1 that the specific volumes of saturated steam and condensate are $v''=7.678 \text{ m}^3/\text{kg}$, and $v'=0.0010171 \text{ m}^3/\text{kg}$ respectively; saturated steam volume $V''=1000 \times 7.678=7687 \text{ m}^3$, condensate volume $V'=1000 \times 0.0010171=1.0171 \text{ m}^3$; after the saturated steam is condensed into condensate, its volume decreases by $7687/1.0171=7558$ times;

[0045] More importantly, natural tornadoes easily "lifted" a 110,000-kilogram large oil storage tank to a height of 15m and flung it 120m away; even natural tornadoes water absorption height of more than 200m and a potential energy which is equal to 20 atmospheres were observed.

[0046] Therefore, according to the invention, an artificial tornado is generated in relevant equipment by reference to the formation principle of tornado in nature and its strong suction to further enhance the strong suction force generated during condensation and sharp volume reduction of vapor, so as to improve the thermal efficiency and compression ratio.

[0047] The technical scheme provided by the invention is a vapor heat pump and a method for utilizing low pressure vapor through enthalpy supplement and pressure boost.

[0048] The invention will be further described in combination with attached drawings and example.

[0049] The method for utilizing low pressure vapor through enthalpy supplement and pressure boost comprises the following steps:

1) the low pressure vapor is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

2) when the material is heated by the high-level thermal energy saturated vapor on a material heater 1, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor obtained in step 1) is sucked for spraying liquid boost pressure, and converted into the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the material heater 1 for heating the material to achieve the utilization or cyclic utilization.

[0050] In particular, in step 1), the low pressure vapor may be the secondary vapor generated in the evaporator, or the industrial by-product vapor, the waste heat boiler steam, etc.

the low pressure vapor is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at target pressure; in particular, the superheated vapor shall be at 2-30°C higher than the high-level thermal energy saturated vapor

[0051] In step 1), the low pressure vapor can be directly heated, or heated by an external heater after being made into tornadoes according to the principle of artificial tornadoes.

[0052] The material heater 1 in step 2) refers to the equipment where the material can be heated by vapor; and the material heater may be an evaporator, a heat exchanger, a heater, etc. Meanwhile, when the saturated vapor is condensed in step 2, it will sharply shrink in volume to generate a strong suction force so that the superheated vapor obtained in step 1) can be sucked for spraying liquid boost pressure. Alternatively, under the action of the strong suction force generated when the saturated vapor is condensed and sharply shrinks in volume, a tornado vortex is generated from the superheated vapor for spraying liquid boost pressure.

[0053] In particular, when the low pressure vapor is secondary vapor in the above method, the material heater 1 is an evaporator. The method comprises the following steps:

1) the secondary vapor formed and discharged from an evaporation chamber 12 of the evaporator is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

2) when the material is heated by the high-level thermal energy saturated vapor in a heating chamber 11 of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor is sucked for spraying-liquid boost pressure and converted into the high-level thermal energy saturated vapor, which is then fed into the heating chamber 11 of the evaporator for heating the material, so as to achieve the cyclic utilization. The heated material is an evaporable solution or pure liquid

[0054] In the above-mentioned method for utilizing low pressure vapor through enthalpy supplement and pressure boost, the superheat and spraying liquid boost pressure of low pressure vapor can be realized through many ways; for example, a heater or a heat exchanger can be used in the process of heating the low pressure vapor; or the diffuser

and booster can be directly used in the process of pressurizing the low pressure vapor.

[0055] The method for utilizing low pressure vapor through enthalpy supplement and pressure boost is a preferred embodiment, adopting a vapor heat pump comprising a material heater 1 and a SHSLB 2; wherein the SHSLB2 has a saturated vapor outlet and a low pressure vapor inlet;

the material heater 1 has a saturated vapor inlet in connected with the saturated vapor outlet of the SHSLB2;

in step 1), the low pressure vapor is heated into the superheated vapor in the SHSLB2; and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

in step 2), the condensate is sprayed into the SHSLB2 at 3-16m/s to convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater 1 for heating the material to archive the utilization or cyclic utilization.

[0056] For the method for utilizing the secondary vapor through enthalpy supplement and pressure boost, the SHSLB2 can be an integrated combination mode of a common heater and a diffuser, or a separate connection combination of the common heater and the diffuser.

[0057] For example, the SHSLB2 is used for easy installation. Further, in order to improve the efficiency of superheat and spraying liquid boost pressure of secondary vapor, the SHSLB2 is a TSHSLB capable of realizing enthalpy supplement and spraying liquid boost pressure of secondary vapor.

in step 1), the secondary vapor formed in an evaporation chamber of the evaporator is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

in step 2), when the evaporable solution or pure liquid is heated by the saturated vapor in the heating chamber of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; a tornado is generated from the superheated vapor obtained in step 1) in the TSHSLB for enhancing the suction force, with the central speed of the tornado vortex more than 200m/s; meanwhile, the condensate is sprayed through the nozzle assembly 206 at 3-16m/s and at the rotating direction opposite to that of the tornado vortex in the TSHSLB; the superheated vapor and the condensate are fully mixed to generate the pressure boosted and quantity increased saturated vapor, which is then fed into the heating chamber of the evaporator for heating the material to achieve the cyclic utilization.

[0058] In order to facilitate the separate adjustment of superheat and spraying liquid boost pressure of the low pressure vapor, the SHSLB2 preferably comprises a SH21 and a SLB22; wherein the SH21 has a low pressure vapor inlet and a superheated vapor outlet, and the SLB22 has a superheated vapor inlet and a saturated vapor outlet.

the superheated vapor outlet of the SH21 is connected with the superheated vapor inlet of the SLB22, and the saturated vapor outlet of the SLB22 is connected with the saturated vapor inlet of the material heater 1;

in step 1), the low pressure vapor is heated into the superheated vapor in the SH21; and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

in step 2), the condensate is sprayed into the SLB22 at 3-16m/s to convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater 1 for heating the material to archive the utilization or cyclic utilization.

[0059] In order to improve the efficiency of superheat and spraying-liquid boost pressure of the low pressure vapor, the SHSLB2 further comprises a SH21 and a SLB22; wherein the SH21 is a TSH through which a tornado vortex can be generated from vapor, and the SLB22 is a TSLB through which a tornado vortex can be generated from vapor, and TSH is provided with a heater 6 for heating vapor;

in step 1), the low pressure vapor is fed into the TSH to generate a tornado vortex;

meanwhile, the TSH low pressure vapor is heated into superheated vapor by the heater 6 arranged on the TSH, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

in step 2), when the material is heated by the saturated vapor in the material heater 1, the saturated vapor will be condensed to generate a strong suction force so that the superheated vapor obtained in step 1) is sucked into the TSLB for spraying-liquid boost pressure and changed into a tornado vortex for enhancing the suction force; meanwhile, the condensate is sprayed through the nozzle assembly 226 at the direction opposite to the rotating direction of the TSLB tornado vortex; the superheated vapor and the condensate are fully mixed to generate the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater 1 for heating the material to achieve the utilization or cyclic utilization.

Example 1

[0060] As shown in Fig. 2, the method for utilizing low pressure vapor through enthalpy supplement and pressure boost, adopting a vapor heat pump comprising a material heater 1 and a SHSLB2, wherein the material heater 1 is an evaporator comprising an evaporation chamber 12 and a heating chamber 11; and the secondary vapor outlet 18 of the evaporation chamber 12, the SHSLB2, and the saturated vapor inlet 15 of the heating chamber 11 are sequentially

connected.

[0061] Comprising following steps:

1) the secondary vapor discharged from the secondary vapor outlet 18 of the evaporation chamber 12 is fed into the SHSLB2 so that the secondary vapor is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of saturated vapor at the target pressure.

2) when the evaporable solution or pure liquid is heated by the saturated vapor in the heating chamber 11 of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; at the same time, the condensate is sprayed into the SHSLB2 to absorb the excess enthalpy in the superheated vapor and converted into the pressure boosted and quantity increased high-level thermal energy saturated vapor, which is then fed into the heating chamber 11 of the evaporator for heating the evaporable solution or pure liquid to realize the cyclic utilization.

Example 2

[0062] As shown in Fig. 5, the method for utilizing low pressure vapor through enthalpy supplement and pressure boost, adopting a vapor heat pump comprising a material heater 1 and a SHSLB2, wherein the material heater 1 is an evaporator comprising an evaporation chamber 12 and a heating chamber 11; the SHSLB2 comprised a SH21 and a SLB22; and the secondary vapor outlet 18 of the evaporation chamber 12, the SH21, the SLB22 and the saturated vapor inlet 15 of the heating chamber 11 are sequentially connected.

[0063] The method further comprises the following steps:

1) after discharged from the secondary vapor outlet 18 of the evaporation chamber 12, the secondary vapor is fed into the SH21, the secondary vapor is heated into superheated vapor and the superheated vapor shall be at a temperature higher than that of saturated vapor at the target pressure;

2) when the evaporable solution or pure liquid is heated by the saturated vapor in the heating chamber 11 of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor obtained in step 1) is sucked into the SLB22; at the same time, the condensate is sprayed into the SLB22 to convert the superheated vapor into the pressure boosted and quantity increased high-level thermal energy saturated vapor, which is then fed into the heating chamber 11 of the evaporator for heating the evaporable solution or pure liquid to realize the cyclic utilization.

[0064] In particular, the SH21 is a heat exchanger and the SLB22 is a diffuser.

Example 3

[0065] As shown in Fig. 2, the method for utilizing low pressure vapor through enthalpy supplement and pressure boost, adopting a vapor heat pump, in particular to a tornado vapor heat pump comprising an evaporator and a TSHSLB, wherein the evaporator comprised an evaporation chamber 12 and a heating chamber 11; and the secondary vapor outlet 18 of the evaporation chamber 12, the TSHSLB, and the saturated vapor inlet 15 of the heating chamber 11 are sequentially connected.

[0066] The method comprises the following steps:

1) the secondary vapor discharged from the secondary vapor outlet 18 of the evaporation chamber 12 is fed into the TSHSLB so that a tornado vortex is generated from the secondary vapor, with the central wind speed more than 200m/s;

at the same time, the secondary vapor is heated into the superheated vapor, and the superheated vapor shall be at a temperature higher than that of saturated vapor at the target pressure;

2) when the evaporable solution or pure liquid is heated by the saturated vapor in the heating chamber 11, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; the artificial tornado method is used to enhance the suction force so that the superheated vapor obtained in step 1) is sucked into the TSHSLB for spraying-liquid boost pressure; meanwhile, the condensate is sprayed into the TSHSLB through the nozzle assembly 206 at the rotating direction opposite to that of the superheated vapor; after the superheated vapor and the condensate are fully mixed, the condensate absorbed part of the enthalpy of superheated vapor and is converted into the pressure boosted and quantity increased high-level thermal energy saturated vapor, which is then fed into the heating chamber 11 of the evaporator via the saturated vapor inlet 15 for heating the evaporable solution or pure liquid to achieve the cyclic utilization.

[0067] In particular, as shown in Fig. 3, in the tornado vapor heat pump, the SHSLB2 is a TSHSLB comprising a TSHSLB vortex generation superheat section 202, a TSHSLB acceleration section 203, a TSHSLB high-speed mixing section 204 and a TSHSLB diffuser section 205; wherein the TSHSLB vortex generation superheat section 202 has a circular drum or a cylindrical inner cavity, the TSHSLB acceleration section 203 has a conical inner cavity, the TSHSLB high-speed mixing section 204 has a cylindrical inner cavity, and the TSHSLB diffuser section 205 has a conical inner cavity;

the larger diameter end of the conical inner cavity of the TSHSLB acceleration section 203 is connected with the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section 202, and the smaller diameter end of the conical inner cavity of the TSHSLB acceleration section 203 is connected with the smaller diameter end of the conical inner cavity of the TSHSLB diffuser section 205 through the cylindrical inner cavity of the TSHSLB high-speed mixing section 204;

the TSHSLB vortex generation superheat section is provided with a secondary vapor inlet pipe 201; the centerline of the secondary vapor inlet pipe 201 is perpendicular to that of the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section 202; the secondary vapor inlet pipe 201 is connected with the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section 202; and the inner wall of the secondary vapor inlet pipe 201 is tangent to that of the TSHSLB vortex generation superheat section 202;

the TSHSLB vortex generation superheat section 202 is provided with a tornado nozzle assembly 206 in connected with a circular drum or a cylindrical inner cavity of the TSHSLB vortex generation superheat section 202; the tornado nozzle assembly 206 and the TSHSLB acceleration section 203 are respectively arranged on two opposite sides of the TSHSLB vortex generation superheat section 202;

the centerline of the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section 202, the centerline of the conical inner cavity of the TSHSLB acceleration section 203, the centerline of the cylindrical inner cavity of the TSHSLB high-speed mixing section 204, the centerline of the conical inner cavity of the TSHSLB diffuser section 205 and the injection centerline of the tornado nozzle assembly 206 are collinear;

a second heater 207 is arranged on the outer surface of the TSHSLB vortex generation superheat section 202; the diffuser section 205 is connected with the saturated vapor inlet 15 of the heating chamber 11 of the evaporator.

[0068] In step 1), the secondary vapor is heated into the superheated vapor on the TSHSLB vortex generation superheat section 202.

[0069] In step 2), the condensate is sprayed into the TSHSLB to convert the superheated secondary vapor into the pressure boosted and quantity increased high-level thermal energy saturated vapor.

Example 4

[0070] As shown in Fig. 5, the method for utilizing low pressure vapor through enthalpy supplement and pressure boost, adopting a vapor heat pump, in particular to a tornado vapor heat pump comprising a material heater 1, a SH21 and a SLB22; wherein the material heater 1 is an evaporator, the SH21 is a TSH and the SLB22 is a TSLB; the evaporator comprised an evaporation chamber 12 and a heating chamber 11; the secondary vapor outlet 18 of the evaporation chamber 12, the TSH, the TSLB and the saturated vapor inlet 15 of the heating chamber 11 are sequentially connected; a tornado vortex is generated from vapor in the TSH; and a heater 6 is arranged on the TSH for heating vapor.

[0071] Further, comprising following steps:

1) the secondary vapor discharged from the secondary vapor outlet 18 of the evaporation chamber 12 is fed into the TSH so that a tornado vortex is generated from the secondary vapor, with the central wind speed more than 100m/s;

at the same time, the heater 6 on the TSH is started to heat the secondary vapor into superheated vapor, and the discharged superheated vapor shall be at a temperature higher than that of the saturated vapor at the target pressure;

2) when the evaporable solution or pure liquid is heated by the saturated vapor in the heating chamber 11 of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; the artificial tornado method is used to enhance the suction force so that the superheated vapor obtained in step 1) is sucked into the TSLB for spraying liquid boost pressure, and then changed into a tornado vortex, with the central speed more than 200m/s, which is comparable to and even surpassed the strongest tornado in nature; meanwhile, the condensate is sprayed through the nozzle assembly 206 at the rotating direction opposite to that of the tornado vortex in the TSLB; after the superheated vapor and the condensate are fully mixed, the condensate absorbed part of the enthalpy of superheated vapor and is converted into the pressure boosted and quantity increased high-level thermal energy saturated vapor, which is then fed into the heating chamber 11 of the evaporator via the saturated vapor inlet 15 for heating the evaporable solution or pure liquid to achieve the cyclic utilization.

Example 5

[0072] In this example, the method for utilizing low pressure vapor through enthalpy supplement and pressure boost, adopting a vapor heat pump, in particular to a tornado vapor heat pump comprising a material heater 1, a SH21 and a SLB22; wherein the material heater 1 is an evaporator, the SH21 is a TSH and the SLB22 is a TSLB; the SH21 comprised a TSH and a heater 6; wherein the TSH comprised a tornado vortex generation section 212, a tornado acceleration section 213, a high-speed section 214 and a diffuser superheat section 215; the tornado vortex generation section 212 has a circular drum or a cylindrical inner cavity; the tornado acceleration section 213 has a conical inner cavity; the high-speed section 214 has a cylindrical inner cavity; and the diffuser superheat section 215 has a conical inner cavity; the larger diameter end of the conical inner cavity of the tornado acceleration section 213 is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section 212, and the smaller diameter end of the conical inner cavity of the tornado acceleration section 213 is connected with the smaller diameter end of the conical inner cavity of the diffuser superheat section 215 through the cylindrical inner cavity of the high-speed section 214; the centerline of the circular drum or cylindrical inner cavity of the tornado vortex generation section 212, the centerline of the conical inner cavity of the tornado acceleration section 213, the centerline of the cylindrical inner cavity of the high-speed section 214 and the centerline of the conical inner cavity of the diffuser superheat section 215 are collinear; a secondary vapor inlet pipe 211 is arranged on the tornado vortex generation section 212; the centerline of the secondary vapor inlet pipe 211 is perpendicular to that of the circular drum or cylindrical inner cavity of the tornado vortex generation section 212; the secondary vapor inlet pipe 211 is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section 212, and the inner wall of the secondary vapor inlet pipe 211 is tangent to that of the tornado vortex generation section 212; the heater 6 is arranged on the diffuser superheat section 215, or on the high-speed section 214 and the diffuser superheat section 215. the SLB22 is a TSLB comprising a TSLB vortex generation section 222, a TSLB acceleration section 223, a TSLB high-speed mixing section 224 and a TSLB diffuser section 225; the TSLB vortex generation section 222 has a circular drum or a cylindrical inner cavity; the TSLB acceleration section 223 has a conical inner cavity; the TSLB high-speed mixing section 224 has a cylindrical inner cavity; and the TSLB diffuser section 225 has a conical inner cavity; the larger diameter end of the conical inner cavity of the TSLB acceleration section 223 is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222, and the smaller diameter end of the conical inner cavity of the TSLB acceleration section 223 is connected with the smaller diameter end of the conical inner cavity of the TSLB diffuser section 225 through the cylindrical inner cavity of the high-speed mixing section 224; a superheated vapor inlet pipe 221 is arranged on the TSLB vortex generation section 222; the centerline of the superheated vapor inlet pipe 221 is perpendicular to that of the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222; the superheated vapor inlet pipe 221 is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222, and the inner wall of the superheated vapor inlet pipe 221 is tangent to that of the TSLB vortex generation section 222; the nozzle assembly 226 is arranged on the TSLB vortex generation section 222 and is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222; the nozzle assembly 226 and the TSLB acceleration section 223 are respectively arranged on two opposite sides of the TSLB vortex generation section 222; the centerline of the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222, the centerline of the conical inner cavity of the TSLB acceleration section 223, the centerline of the cylindrical inner cavity of the TSLB high-speed mixing section 224, the centerline of the conical inner cavity of the TSLB diffuser section 225 and the injection centerline of the nozzle assembly 226 are collinear; the evaporator comprised an evaporation chamber 12 and a heating chamber 11; the secondary vapor outlet 18 of the evaporation chamber 12, the TSH, the TSLB, and the saturated vapor inlet 15 of the heating chamber 11 are sequentially connected.

[0073] The method for utilizing low pressure vapor through enthalpy supplement and pressure boost in the example, comprising following steps:

- 1) the secondary vapor discharged from the secondary vapor outlet 18 of the evaporation chamber 12 is fed into the TSH so that a tornado vortex is generated from the secondary vapor, with the central wind speed more than 100m/s;
- at the same time, the heater 6 on the TSH is started to heat the secondary vapor into superheated vapor, and the discharged superheated vapor shall be at a temperature higher than that of the saturated vapor at the target pressure;
- 2) when the evaporable solution or pure liquid is heated by the saturated vapor in the heating chamber 11 of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; an artificial tornado method is used to enhance the suction force so that the superheated vapor obtained in step 1)

is sucked into the TSLB and then converted into a tornado vortex, with the central speed more than 200m/s, which is comparable to and even surpassed the strongest tornado in nature; meanwhile, the condensate is sprayed into the TSLB through the nozzle assembly 226 at the rotating direction opposite to that of the tornado vortex in the TSLB; after the superheated vapor and the condensate are fully mixed, the condensate absorbed part of the enthalpy of superheated vapor and is converted into the pressure boosted and quantity increased high-level thermal energy saturated vapor, which is then fed into the heating chamber 11 of the evaporator via the saturated vapor inlet 15 for heating the evaporable solution or pure liquid to achieve the cyclic utilization.

[0074] In the device system of the tornado vapor heat pump, the method, technique, system and regulation of using artificial tornadoes (without destructive effect) are as follows: the solution in the evaporation chamber of the evaporator is evaporated to generate the secondary vapor (low-level thermal energy vapor), which is discharged from the outlet 18, entered the secondary vapor inlet pipe 211 of the TSH, and then tangentially flowed into the vortex generation section 212 to generate the initial tornado vortex. Next, the tornado vortex is accelerated in the acceleration section 213 with the central wind speed more than 100 m/s, thus creating favorable conditions for the superheating of the secondary vapor. The secondary vapor is superheated by the heater 6 into the superheated vapor for enthalpy supplement in the high-speed section 214 and the diffuser superheat section 215. In general, the enthalpy supplement is satisfactory when the superheated vapor temperature exceeded the temperature of saturated vapor at the target pressure. The superheated vapor can reach the required superheat degree by adjusting the heat supply amount of the heater 6 at the outlet of the diffuser superheat section 215 of the TSH. The rising principle of superheated vapor is similar to that of a hot air balloon, and produced corresponding suction force (or pumping force) to the secondary vapor at the same time. The superheated vapor at the outlet of the diffuser superheat section 215 can only be used for enthalpy supplement rather than pressure boosting according to the nature of the superheated vapor.

[0075] The superheated vapor at the outlet of the diffuser superheat section 215 entered the TSLB superheated vapor inlet pipe 221 by means of its lift force, and then tangentially flowed into the TSLB vortex generation section 222 to generate an initial tornado vortex. The circular drum or cylindrical shell is required for the TSLB vortex generation section, and its diameter can allow the superheated vapor to enter and boosted pressure at the outlet. Its tornado vortex is accelerated in the TSLB acceleration section 223, with the central wind speed more than 200 m/s, thus creating favorable conditions for the spraying liquid boost pressure of the superheated vapor. The counter-rotating condensate is sprayed through the nozzle assembly 226 and mixed with the superheated vapor violently at high speed, so as to generate a strong suction force under the combined action of the circulation area, diffuser, spraying liquid boost pressure and vapor condensation. The tornado formation method is used to enhance the suction force so that the superheated vapor is converted into the pressure boosted and quantity increased high-level thermal energy saturated vapor, and then flowed out of the TSLB diffuser section 225. Since the saturated vapor can reach the required temperature by controlling the flow rate of condensate, the spraying liquid boost pressure technology can avoid the situation that over 80% of the energy consumed by conventional technology, namely adiabatic compression is consumed for temperature increasing. The high-level thermal energy saturated vapor entered the heating chamber of the evaporator through the inlet pipe 15 for heating the solution to be evaporated, and changing itself into condensate after releasing latent heat. During this process, the saturated vapor sharply shrank in volume to generate a strong suction force, which is also the motive power of the tornado vapor heat pump. Therefore, the secondary vapor (low-level thermal energy vapor) can be changed into the high-level thermal energy saturated vapor for reuse.

[0076] To sum up, the SHSLB2 was a TSHSLB in example 3, and the SHSLB2 is a combination of a TSH and a TSLB in example 5.

[0077] Among them, the TSHSLB in example 3 has basically the same structure as that of the TSLB in example 5. In example 3, the TSH in example 5 is not provided, the second heater 207 is arranged on the TSLB vortex generation section 222 to act as the TSHSLB, and the rest remained unchanged. The method in example 5 differs from that in example 3 in that: in example 3, the TSH is not provided; the secondary vapor discharged from the secondary vapor outlet 18 of the evaporation chamber 12 is directly fed into the TSHSLB, and the temperature of saturated vapor at its outlet is controlled by an temperature automatic selective adjustment loop. In particular, if the temperature is higher than set value, the temperature of saturated vapor at the target pressure is reached by increasing the flow rate of condensate and/or reducing the heating amount of the second heater 207; conversely if the temperature is lower than set value, the temperature of saturated vapor at the target pressure is reached by reducing the flow rate of condensate and/or increasing the heating amount of the second heater 207.

[0078] To sum up, the invention provides a method for utilizing low pressure vapor through enthalpy supplement and pressure boost, adopting a tornado vapor heat pump system. Thus, in the process of changing the secondary vapor into the saturated vapor through enthalpy supplement and spraying liquid boost pressure, the strong suction force formed through the self-condensation of saturated vapor during heating in the evaporator can be provided for forming a tornado, and the suction force further enhanced by the artificial tornado for enthalpy supplement and spraying liquid boost pressure, so as to realize the cyclic utilization of secondary vapor. This method has low energy consumption due to small enthalpy

difference of saturated vapor at different temperature, thus small enthalpy supplement heat is needed, but large suction force and high pressure ratio for spraying liquid boost pressure is reached, so it can achieve the goal of the energy save and emission reduction.

Example 6

[0079] Based on Example 1 to Example 5, as shown in Fig. 1 and Fig. 4, the secondary vapor is replaced with the low pressure vapor, the evaporator is replaced with the material heater 1, the corresponding vapor heat pump and the method for utilizing low pressure vapor through enthalpy supplement and pressure boost remained unchanged, and low pressure vapor is fed through the low pressure vapor pipe 9.

Example 7

[0080] The vapor heat pump is a tornado vapor heat pump, comprising a material heater 1 and a SHSLB2; wherein the SHSLB2 comprised a SH21 and a SLB22; the SH21 is a TSH as shown in Fig. 6 to Fig. 9; the TSH comprised a tornado vortex generation section 212, a tornado acceleration section 213, a high-speed section 214 and a diffuser superheat section 215; the tornado vortex generation section 212 has a circular drum or a cylindrical inner cavity; the tornado acceleration section 213 has a conical inner cavity; the high-speed section 214 has a cylindrical inner cavity; and the diffuser superheat section 215 has a conical inner cavity;

the larger diameter end of the conical inner cavity of the tornado acceleration section 213 is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section 212, and the smaller diameter end of the conical inner cavity of the tornado acceleration section 213 is connected with the smaller diameter end of the conical inner cavity of the diffuser superheat section 215 through the cylindrical inner cavity of the high-speed section 214;

the centerline of the circular drum or cylindrical inner cavity of the tornado vortex generation section 212, the centerline of the conical inner cavity of the tornado acceleration section 213, the centerline of the cylindrical inner cavity of the high-speed section 214 and the centerline of the conical inner cavity of the diffuser superheat section 215 are collinear; a low pressure vapor inlet pipe 211 is arranged on the tornado vortex generation section 212; the centerline of the low pressure vapor inlet pipe 211 is perpendicular to that of the circular drum or cylindrical inner cavity of the tornado vortex generation section 212; the low pressure vapor inlet pipe 211 is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section 212, and the inner wall of the low pressure vapor inlet pipe 211 is tangent to that of the tornado vortex generation section 212; the heater 6 is arranged on the diffuser superheat section 215, or on the high-speed section 214 and the diffuser superheat section 215.

[0081] In particular, the length-diameter ratio of the cylindrical inner cavity of the high-speed section 214 is 1.5 - 4:1 and the taper of the conical inner cavity of the diffuser superheat section 215 is set at 2° - 8°.

[0082] Principle of heating low pressure vapor into superheated vapor in TSH:

After entering the low pressure vapor inlet pipe 211 of the TSH via the low pressure vapor pipe, low pressure vapor (low-level thermal energy vapor) tangentially flowed into the tornado vortex generation section 212, and is formed into an initial tornado vortex. Then, the tornado vortex is accelerated in the tornado acceleration section 213, with the central wind speed more than 100 m/s, thus creating favorable internal conditions for the heating and superheating of the low pressure vapor. The low pressure vapor is heated into superheated vapor by the heater 6 for enthalpy supplement in the high-speed section 214 and the diffuser superheat section 215. In general, the enthalpy supplement can be satisfactory when the superheated vapor temperature exceeded the saturated vapor temperature at the target pressure. The superheated vapor can reach the superheat degree by adjusting the heat supply amount of the heater 6 at the outlet of the diffuser superheat section 215. The principle of superheated vapor discharging is similar to that of a hot air balloon, and corresponding suction force (or pumping force) will be produced for the secondary vapor in the above process. The superheated vapor at the outlet of the diffuser superheat section 215 can only be used for enthalpy supplement rather than pressure boosting according to the property of superheated vapor.

Example 8

[0083] The vapor heat pump is a tornado vapor heat pump, comprising a material heater 1 and a SHSLB2; wherein the SHSLB2 comprised a SH21 and a SLB22; the SH21 is a TSH; the SLB22 is a TSLB as shown in Fig. 10 to Fig. 13; the TSLB comprised a TSLB vortex generation section 222, a TSLB acceleration section 223, a TSLB high-speed mixing section 224 and a TSLB diffuser section 225; the TSLB vortex generation section 222 has a circular drum or a cylindrical inner cavity; the TSLB acceleration section 223 has a conical inner cavity; the TSLB high-speed mixing section 224 has a cylindrical inner cavity; and the TSLB diffuser section 225 has a conical inner cavity;

the larger diameter end of the conical inner cavity of the TSLB acceleration section 223 is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222, and the smaller diameter end of the conical

inner cavity of the TSLB acceleration section 223 is connected with the smaller diameter end of the conical inner cavity of the TSLB diffuser section 225 through the cylindrical inner cavity of the high-speed mixing section 224;

a superheated vapor inlet pipe 221 is arranged on the TSLB vortex generation section 222; the centerline of the superheated vapor inlet pipe 221 is perpendicular to that of the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222; the superheated vapor inlet pipe 221 is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222, and the inner wall of the superheated vapor inlet pipe 221 is tangent to that of the TSLB vortex generation section 222;

the nozzle assembly 226 is arranged on the TSLB vortex generation section 222 and connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222; the nozzle assembly 226 and the TSLB acceleration section 223 are respectively arranged on two opposite sides of the TSLB vortex generation section 222;

the centerline of the circular drum or cylindrical inner cavity of the TSLB vortex generation section 222, the centerline of the conical inner cavity of the TSLB acceleration section 223, the centerline of the cylindrical inner cavity of the TSLB high-speed mixing section 224, the centerline of the conical inner cavity of the TSLB diffuser section 225 and the injection centerline of the nozzle assembly 226 are collinear;

the outlet of the TSH diffuser superheat section 215 is connected with the TSLB superheated vapor inlet pipe 221; and the TSLB diffuser section 225 is connected with the saturated vapor inlet of the material heater 1.

[0084] In particular, the length-diameter ratio of the cylindrical inner cavity of the TSLB high-speed mixing section 224 is 1~4: 1; and the taper of the conical inner cavity of the TSLB diffuser section 225 is 6~10°.

[0085] Principle of spraying liquid boost pressure for the superheated vapor in TSLB:

The superheated vapor at the outlet of the TSH diffuser superheat section 215 entered the TSLB superheated vapor inlet pipe 221 due to its lift force, and then tangentially flowed into the TSLB vortex generation section 222 to generate an initial tornado vortex. Requirements for the TSLB vortex generation section: the diameter of a circular drum or cylindrical shell can allow the superheated vapor to enter and be pressure boosted at the outlet. The tornado vortex is accelerated in the TSLB acceleration section 223, with the central wind speed more than 200 m/s, thus creating favorable internal conditions for the spraying liquid boost pressure of the superheated vapor. The counter-rotating condensate is sprayed through the nozzle assembly 226 and mixed with the TSLB tornado vortex violently at high speed to generate a strong suction force under the combined action of the circulation area, diffuser, spraying liquid boost pressure and vapor condensation, which is enhanced by the tornado formation method so that the pressure boosted and quantity increased high-level thermal energy saturated vapor flowed out of the diffuser section 225. The saturated vapor can reach the required temperature by controlling the flow rate of condensate. As a result, based on the spraying liquid boost pressure technology, over 80% of the energy consumed by conventional technology, namely adiabatic compression will not be consumed for temperature increasing. Moreover, the high-level thermal energy saturated vapor entered the material heater 1 for heating the material, and released latent heat in this process, then can be changed into condensate. Therefore, the saturated vapor sharply shrank in volume to generate a strong suction force, that is the power of the tornado vapor heat pump, so as to change the low pressure vapor into the high-level thermal energy saturated vapor through tornado superheat and spraying liquid boost pressure for reuse.

Example 9

[0086] To utilize the heat energy of condensate, as shown in Fig. 1, 2, 4 and 5, the vapor heat pump further comprised a condensate discharge tank 10 and a condensate pump 3;

the condensate outlet 16 of the evaporator or the condensate outlet of the material heater 1 is connected with the inlet of the condensate discharge tank 10, the condensate outlet of the condensate discharge tank 10 is connected with the inlet of the condensate pump 3, and the outlet of the condensate pump 3 is connected with the tornado nozzle assembly 206 or the nozzle assembly 226.

[0087] The condensate in the condensate discharge tank 10 is pumped out and pressurized by the condensate pump 3, and then sprayed into the SHSLB2, the TSHSLB, the SLB22 and the TSLB through the tornado nozzle assembly 206 or the nozzle assembly 226 respectively, so as to change the superheated vapor into the pressure boosted and quantity increased saturated vapor, and achieve the purpose of utilizing condensate heat energy and saving cost.

Example 10

[0088] In order to ensure that low pressure vapor or secondary vapor is changed into the pressure boosted and quantity increased saturated vapor after tornado superheat and spraying-liquid boost pressure, as shown in Fig. 4 and 5, the vapor heat pump further comprised a first temperature control loop 7; and a control valve 4 is arranged on the connecting pipe between the condensate pump 3 and the nozzle assembly 226 of the SLB22 or the TSLB;

a temperature sensor is arranged at the outlet of the SLB22 or the TSLB, and the valve opening of the control valve 4 is controlled according to the vapor temperature at the outlet of the SLB22 or the TSLB by the first temperature control

loop 7, so as to regulate the flow rate of condensate and maintain stable temperature of the pressure boosted and quantity increased saturated vapor. In particular, the first temperature control loop 7 can be of DCS centralized control.

[0089] In order to adjust the superheat temperature when the low pressure vapor or secondary vapor passes through the SH21 or the TSH, further, the heater 6 is provided with a second temperature control loop 8, and a second temperature sensor is arranged at the outlet of the SH21 or the TSH; the heating amount of the heater 6 is adjusted by the second temperature control loop 8 according to the temperature of the superheated vapor at the outlet of the SH21 or the TSH detected by the second temperature sensor to maintain stable temperature of the superheated vapor. The second temperature control loop 8 can be of DCS centralized control.

[0090] In order to ensure that the low pressure vapor or secondary vapor is changed into the pressure boosted and quantity increased saturated vapor through enthalpy supplement and spraying-liquid boost pressure, as shown in Fig. 1 and 2, the vapor heat pump further comprised a temperature automatic selective control loop 5 arranged at the outlet of the SHSLB2 or the TSHSLB. The pressure boosted and quantity increased saturated vapor temperature sensor is arranged at the outlet of the SHSLB2 or the TSHSLB. If the temperature is higher than set value, the pressure boosted and quantity increased saturated vapor temperature is reached by adjusting the valve opening of the control valve 4 and the spraying-liquid amount; conversely, If the temperature is lower than set value the pressure boosted and quantity increased saturated vapor temperature is reached by selectively adjusting the heating amount of the heater 207. The temperature automatic selective control loop can be of DCS centralized control.

[0091] In conclusion, compared with the prior art, the vapor heat pump and the method for utilizing low pressure vapor through enthalpy supplement and pressure boost in the Examples 1 to 10, especially the more efficient tornado vapor heat pump(TVHP), have the following advantages:

1. According to the tornado vapor heat pump provided by the invention, the high-level thermal energy saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force, which is further enhanced by the artificial tornado method (suction pipe effect in daily life), and the low pressure vapor or secondary vapor is heated into the superheated vapor for enthalpy supplement and spraying liquid boost pressure (SLBP) based on the uniquely structured TSH, TSLB or TSHSLB, so as to utilize the low pressure vapor or secondary vapor. The energy consumption of the TVHP is lower than that of multi-effect evaporation and steam-jet heat pump, or at least twice lower than that of the mechanical vapor recompression (MVR), due to the small enthalpy difference of saturated vapor at different temperature, thus small enthalpy supplement is needed, but high pressure ratio for spraying liquid boost pressure is reached. Further, the theoretical thermal efficiency of the tornado vapor heat pump is as high as more than 90%, and the low carbon technology means a green energy source. Even No externally supplied vapor is needed in the whole process except start-up. If a vacuum device is equipped, no externally supplied vapor during the start-up; which means that energy sources for generating externally supplied vapor, such as coal and oil, are saved, carbon dioxide and other harmful gases are not generated, and waste residue and waste liquid are not discharged at the same time. This technology will play an excellent role in today's green, low-carbon economy (carbon dioxide emission reduction) and circular economy.

2. The tornado vapor heat pump of the invention is structurally simple, low in material requirement and convenient to manufacture at low cost. Thus, the investment on TVHP is lower than that on MVR and even multi-effect evaporation. Moreover, the TVHP has shorter construction period than MVR and even multi-effect evaporation.

3. The tornado vapor heat pump of the invention heats the material by the pressure boosted and quantity increased saturated vapor. Different from the multi-effect evaporation, the system will not discharge the secondary vapor but instead recycling use it without cooling water consumption, which saves a large amount of circulating water required to condense the secondary vapor.

4. The tornado vapor heat pump of the invention has no rotating parts, which avoids the noise and environmental pollution.

5. The vapor heat pump and the method for utilizing low pressure vapor through enthalpy supplement and pressure boost in the invention, in particular to the tornado vapor heat pump, take the vapor as the solvent vapor, which comprises steam, and vast elementary substance, organic solvent vapor and etc., and thus are widely used.

Claims

1. A method for utilizing low pressure vapor through enthalpy supplement and pressure boost, **characterized by** comprising the following steps:

1) the low pressure vapor is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

2) when a material is heated by the high-level thermal energy saturated vapor in a material heater (1), the

saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor obtained in step 1) is sucked for spraying liquid boost pressure (SLBP), and converted into pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the material heater (1) for heating the material to achieve the utilization or cyclic utilization.

- 5
2. The method according to claim 1, **characterized in that** an artificial tornado method is used by reference to the formation theory of tornado in nature and strong suction force thereof, so as to generate tornado vortex in the low pressure vapor for superheating and then spraying-liquid boost pressure or for superheating and spraying-liquid boost pressure.
- 10 comprising the following steps:

1) a tornado vortex is generated from the low pressure vapor and heated into superheated vapor; and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

15 2) when a material is heated by the high-level thermal energy saturated vapor on a material heater (1), the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; based on the artificial tornado method, a tornado vortex is generated from the superheated vapor for enhancing the suction force so that the superheated vapor is sucked for spraying-liquid boost pressure, so as to form the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the material heater (1) for heating the material to improve thermal efficiency and boosted pressure ratio, and realize the utilization or cyclic utilization.

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3. The method according to claim 1, **characterized in that** the material heater (1) is an evaporator and the low pressure vapor is secondary vapor, comprising the following steps:
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1) the secondary vapor formed and discharged from an evaporation chamber (12) of the evaporator is heated into superheated vapor, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

30 2) when a material is heated by the high-level thermal energy saturated vapor in a heating chamber (11) of the evaporator, the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force so that the superheated vapor is sucked for spraying-liquid boost pressure, and generates the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the heating chamber (11) of the evaporator for heating the material, so as to achieve the cyclic utilization.

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4. The method according to claim 1, **characterized in that** a vapor heat pump (VHP) is used and comprises a material heater (1) and a superheat and spraying-liquid booster (2) (SHSLB(2)); and the SHSLB(2) has a low pressure vapor inlet and a saturated vapor outlet;

The material heater (1) has a saturated vapor inlet connected with a saturated vapor outlet of the SHSLB(2);

40 in step 1), the low pressure vapor is heated into superheated vapor in the SHSLB(2), and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure; in step 2), the condensate is sprayed into the SHSLB(2) to convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater (1) for heating the material to archive the utilization or cyclic utilization.

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5. The method according to claim 4, **characterized in that** the vapor heat pump is a tornado vapor heat pump (TVHP) comprising a material heater (1) and a tornado superheat and spraying-liquid booster (TSHSLB), wherein the TSHSLB has a low pressure vapor inlet and a saturated vapor outlet;

the material heat (1) has a saturated vapor inlet connected with the saturated vapor outlet of the TSHSLB;

50 in step 1), the low pressure vapor is fed into the TSHSLB and heated into the superheated vapor by a heater (207) arranged on the outer surface of the TSHSLB; and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure;

in step 2), when the material is heated by the saturated vapor in the material heater (1), the saturated vapor will be condensed and sharply shrink in volume to generate a strong suction force; a tornado is generated and accelerated from the superheated vapor obtained in step 1) in the TSHSLB for enhancing the suction force; the condensate is sprayed into the TSHSLB to absorb some of enthalpy of the superheated vapor, and convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, that is, the high-level thermal energy saturated vapor, which is then fed into the material heater (1) for heating the material to achieve the utilization or cyclic utilization.

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6. The method according to claim 4, **characterized in that** the SHSLB(2) comprises a superheater (21) (SH (21)) and a spraying-liquid booster (22) (SLB(22)); wherein the SH(21) has a low pressure vapor inlet and a superheated vapor outlet, and the SLB(22) has a superheated vapor inlet and a saturated vapor outlet; the superheated vapor outlet of the SH(21) is connected with the superheated vapor inlet of the SLB(22), and the saturated vapor outlet of the SLB(22) is connected with the saturated vapor inlet of the material heater (1); in step 1), the low pressure vapor is heated into superheated vapor in the SH(21), and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure; in step 2), the condensate is sprayed into the SLB(22) to convert the superheated vapor into the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater (1) for heating the material to archive the utilization or cyclic utilization.
7. The method according to claim 6, **characterized in that** the SH(21) is a tornado superheater (TSH), the SLB(22) is a tornado spraying-liquid booster (TSLB), and a heater (6) is arranged on the TSH; in step 1), the low pressure vapor is fed into the TSH to generate a tornado vortex; meanwhile, the low pressure vapor is heated into superheated vapor by the heater (6) and then discharged, and the superheated vapor shall be at a temperature higher than that of the high-level thermal energy saturated vapor at the target pressure; in step 2), when the material is heated by the saturated vapor in the material heater (1), the saturated vapor will be condensed to generate a strong suction force; the superheated vapor obtained in step 1) is sucked into the TSLB to generate a tornado vortex for enhancing the suction force; meanwhile, the condensate is sprayed through the nozzle assembly (226) at the direction opposite to the rotating direction of the TSLB tornado vortex, and the superheated vapor and the condensate are fully mixed to form the pressure boosted and quantity increased saturated vapor, which is then fed into the material heater (1) for heating the material to achieve the utilization or cyclic utilization.
8. A vapor heat pump used for realizing the method for utilizing low pressure vapor through enthalpy supplement and pressure boost according to claims 1, 2, 3, 4, 5, 6 or 7, **characterized by** comprising a material heater (1) and a SHSLB(2); wherein the low pressure vapor is heated into superheated vapor in the SHSLB(2) for spraying liquid boost pressure to generate the pressure boosted and quantity increased saturated vapor; the material heater (1) has a saturated vapor inlet and the SHSLB(2) has a saturated vapor outlet, a low pressure vapor inlet, and a condensate inlet; and the saturated vapor inlet of the material heater (1) is connected with the saturated vapor outlet of the SHSLB(2).
9. The vapor heat pump according to claim 8, **characterized in that** the SHSLB(2) is a tornado superheat and spraying-liquid booster (TSHSLB); and the TSHSLB comprises a TSHSLB vortex generation superheat section (202), a TSHSLB acceleration section (203), a TSHSLB high-speed mixing section (204) and a TSHSLB diffuser section (205); wherein the TSHSLB vortex generation superheat section (202) has a circular drum or a cylindrical inner cavity, the TSHSLB acceleration section (203) has a conical inner cavity, the TSHSLB high-speed mixing section (204) has a cylindrical inner cavity, and the TSHSLB diffuser section (205) has a conical inner cavity; the larger diameter end of the conical inner cavity of the TSHSLB acceleration section (203) is connected with the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section (202), and the smaller diameter end of the conical inner cavity of the TSHSLB acceleration section (203) is connected with the smaller diameter end of the conical inner cavity of the TSHSLB diffuser section (205) through the cylindrical inner cavity of the TSHSLB high-speed mixing section (204); the TSHSLB vortex generation superheat section is provided with a low pressure vapor inlet pipe (201); the centerline of the low pressure vapor inlet pipe (201) is perpendicular to that of the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section (202); the low pressure vapor inlet pipe (201) is connected with the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section (202); and the inner wall of the low pressure vapor inlet pipe (201) is tangent to that of the TSHSLB vortex generation superheat section (202); the TSHSLB vortex generation superheat section (202) is provided with a tornado nozzle assembly (206) in connected with the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section (202); the tornado nozzle assembly (206) and the TSHSLB acceleration section (203) are respectively arranged on two opposite sides of the TSHSLB vortex generation superheat section (202); the centerline of the circular drum or cylindrical inner cavity of the TSHSLB vortex generation superheat section (202), the centerline of the conical inner cavity of the TSHSLB acceleration section (203), the centerline of the cylindrical inner cavity of the TSHSLB high-speed mixing section (204), the centerline of the conical inner cavity of the TSHSLB diffuser section (205) and the injection centerline of the tornado nozzle assembly (206) are collinear; a second heater (207) is arranged on the outer surface of the TSHSLB vortex generation superheat section (202);

the TSHSLB diffuser section (205) is connected with the saturated vapor inlet of the material heater (1).

10. The vapor heat pump according to claim 8, **characterized in that** the material heater (1) is an evaporator, and the SHSLB(2) comprises a SH(21) and a SLB (22);

The SH(21) has a secondary vapor inlet pipe and a superheated vapor outlet; the evaporator comprises a heating chamber (11) and an evaporation chamber (12); the evaporator has a secondary vapor outlet (18) in connected with the evaporation chamber (12) and a saturated vapor inlet (15) in connected with the heating chamber (11); the SLB(22) has a superheated vapor inlet and a saturated vapor outlet; the secondary vapor outlet (18) of the evaporation chamber (12) of the evaporator is connected with the secondary vapor inlet pipe of the SH(21), and the superheated vapor outlet of the SH(21) is connected with the superheated vapor inlet of the SLB(22); the saturated vapor outlet of the SLB(22) is connected with the saturated vapor inlet (15) of the heating chamber (11); the SLB(22) has a nozzle assembly (226) comprising a liquid ejection arranged in the SLB(22); and the ejection direction of the liquid ejection nozzle is the same as that of the saturated vapor outlet of the SLB(22).

11. The vapor heat pump according to claim 10, **characterized in that** the SH(21) comprises a TSH and a heater (6); wherein the TSH comprises a tornado vortex generation section (212), a tornado acceleration section (213), a high-speed section (214), and a diffuser superheat section (215); the tornado vortex generation section (212) has a circular drum or a cylindrical inner cavity; the tornado acceleration section (213) has a conical inner cavity; the high-speed section (214) has a cylindrical inner cavity; and the diffuser superheat section (215) has a conical inner cavity; the larger diameter end of the conical inner cavity of the tornado acceleration section (213) is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section (212), and the smaller diameter end of the conical inner cavity of the tornado acceleration section (213) is connected with the smaller diameter end of the conical inner cavity of the diffuser superheat section (215) through the cylindrical inner cavity of the high-speed section (214);

the centerline of the circular drum or cylindrical inner cavity of the tornado vortex generation section (212), the centerline of the conical inner cavity of the tornado acceleration section (213), the centerline of the cylindrical inner cavity of the high-speed section (214) and the centerline of the conical inner cavity of the diffuser superheat section (215) are collinear;

a secondary vapor inlet pipe (211) is arranged on the tornado vortex generation section (212); the centerline of the secondary vapor inlet pipe (211) is perpendicular to that of the circular drum or cylindrical inner cavity of the tornado vortex generation section (212); the secondary vapor inlet pipe (211) is connected with the circular drum or cylindrical inner cavity of the tornado vortex generation section (212), and the inner wall of the secondary vapor inlet pipe (211) is tangent to that of the tornado vortex generation section (212);

the heater (6) is arranged on the diffuser superheat section (215), or on the high-speed section (214) and the diffuser superheat section (215).

12. The vapor heat pump according to claim 10, **characterized in that** the SLB(22) is a TSLB; the TSLB comprises a TSLB vortex generation section (222), a TSLB acceleration section (223), a TSLB high-speed mixing section (224) and a TSLB diffuser section (225); the TSLB vortex generation section (222) has a circular drum or a cylindrical inner cavity; the TSLB acceleration section (223) has a conical inner cavity; the TSLB high-speed mixing section (224) has a cylindrical inner cavity; and the TSLB diffuser section (225) has a conical inner cavity;

the larger diameter end of the conical inner cavity of the TSLB acceleration section (223) is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section (222), and the smaller diameter end of the conical inner cavity of the TSLB acceleration section (223) is connected with the smaller diameter end of the conical inner cavity of the TSLB diffuser section (225) through the cylindrical inner cavity of the TSLB high-speed mixing section (224);

a superheated vapor inlet pipe (221) is arranged on the TSLB vortex generation section (222); the centerline of the superheated vapor inlet pipe (221) is perpendicular to that of the circular drum or cylindrical inner cavity of the TSLB vortex generation section (222); the superheated vapor inlet pipe (221) is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section (222), and the inner wall of the superheated vapor inlet pipe (221) is tangent to that of the TSLB vortex generation section (222);

the nozzle assembly (226) is arranged on the TSLB vortex generation section (222) and is connected with the circular drum or cylindrical inner cavity of the TSLB vortex generation section (222); the nozzle assembly (226) and the TSLB acceleration section (223) are respectively arranged on two opposite sides of the TSLB vortex generation section (222);

the centerline of the circular drum or cylindrical inner cavity of the TSLB vortex generation section (222), the centerline of the conical inner cavity of the TSLB acceleration section (223), the centerline of the cylindrical inner cavity of the TSLB high-speed mixing section (224), the centerline of the conical inner cavity of the TSLB diffuser section (225)

and the injection centerline of the nozzle assembly (226) are collinear;
 the secondary vapor outlet (18) of the evaporation chamber (12) of the evaporator is connected with the secondary
 vapor inlet pipe (211) of the TSH, and the outlet of the TSH diffuser superheat section (215) is connected with the
 TSLB superheated vapor inlet pipe (221); and the outlet of the TSLB diffuser section (225) is connected with the
 saturated vapor inlet (15) of the heating chamber (11) of the evaporator.

13. The vapor heat pump according to claim 12, **characterized in that** the length-diameter ratio of the cylindrical inner
 cavity of the TSLB high-speed mixing section (224) is 1-4: 1; and the taper of the conical inner cavity of the TSLB
 diffuser section (225) is 6-10°.

14. The vapor heat pump according to claim 8,9,10,11,12 or 13, **characterized by** further comprising a condensate
 discharge tank (10) and a condensate pump (3);
 the material heater (1) is provided with a condensate outlet in connected with the inlet of the condensate discharge
 tank (10), wherein the outlet of the condensate discharge tank (10) is connected with the inlet of the condensate
 pump (3), and the outlet of the condensate pump (3) is connected with the tornado nozzle assembly (206) so that
 the heat energy of the condensate can be utilized.

15. The vapor heat pump according to claim 10,11 or 12, **characterized by** further comprising a first temperature control
 loop (7) and a control valve (4) arranged on the connecting pipe between the nozzle assembly (226) of the SLB(22)
 or the TSLB and the condensate pump (3);
 the outlet of the SLB(22) or the TSLB is provided with a pressure boosted and quantity increased saturated vapor
 temperature sensor, and the valve opening of the control valve (4) is controlled by the first temperature control loop
 (7) according to the vapor temperature at the outlet of the SLB(22) or the TSLB detected by the pressure boosted
 and quantity increased saturated vapor temperature sensor, thereby adjusting the condensate flow rate and stabi-
 lizing pressure boosted and quantity increased saturated vapor temperature.

16. The vapor heat pump according to claim 10,11 or 12, **characterized in that** the heater (6) is provided with a second
 temperature control loop (8), and a second temperature sensor is arranged at the outlet of the SH(21) or the TSH;
 and the second temperature control loop (8) may adjust the heating amount of the heater (6) according to the
 superheated vapor temperature at the outlet of the SH(21) or the TSH detected by the second temperature sensor
 to realize stable superheated temperature.

17. The vapor heat pump according to claim 9, **characterized in that** a control valve (4) is arranged on the connecting
 pipe between the tornado nozzle assembly (206) and the condensate pump (3); and the second heater (207) is
 provided with a temperature regulator;
 an temperature automatic selective control loop (5) and a temperature sensor for pressure boosted and quantity
 increased saturated vapor are arranged on the outlet of the SHSLB(2) or the TSHSLB; the temperature sensor for
 pressure boosted and quantity increased saturated vapor is connected to the temperature automatic selective control
 loop (5); and the valve opening of the control valve (4) as well as the temperature regulator is controlled by the
 temperature automatic selective control loop (5) to maintain stable temperature of the pressure boosted and quantity
 increased saturated vapor.

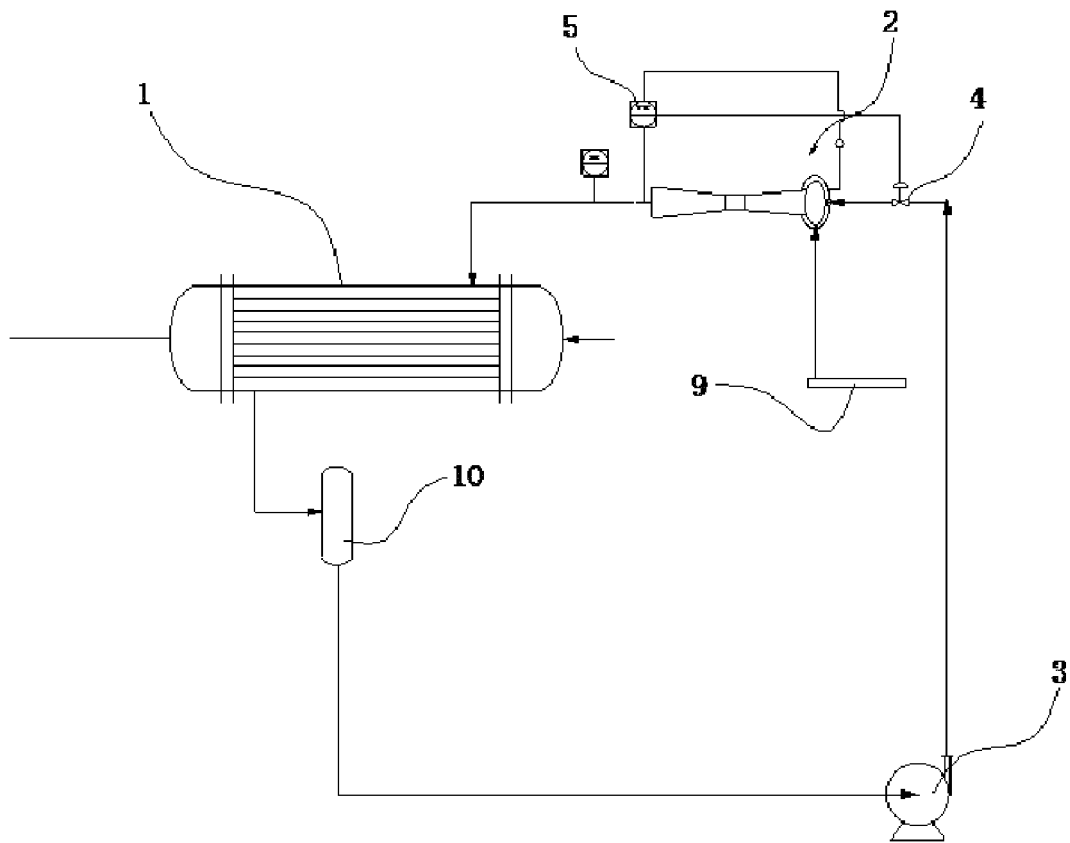


Fig 1

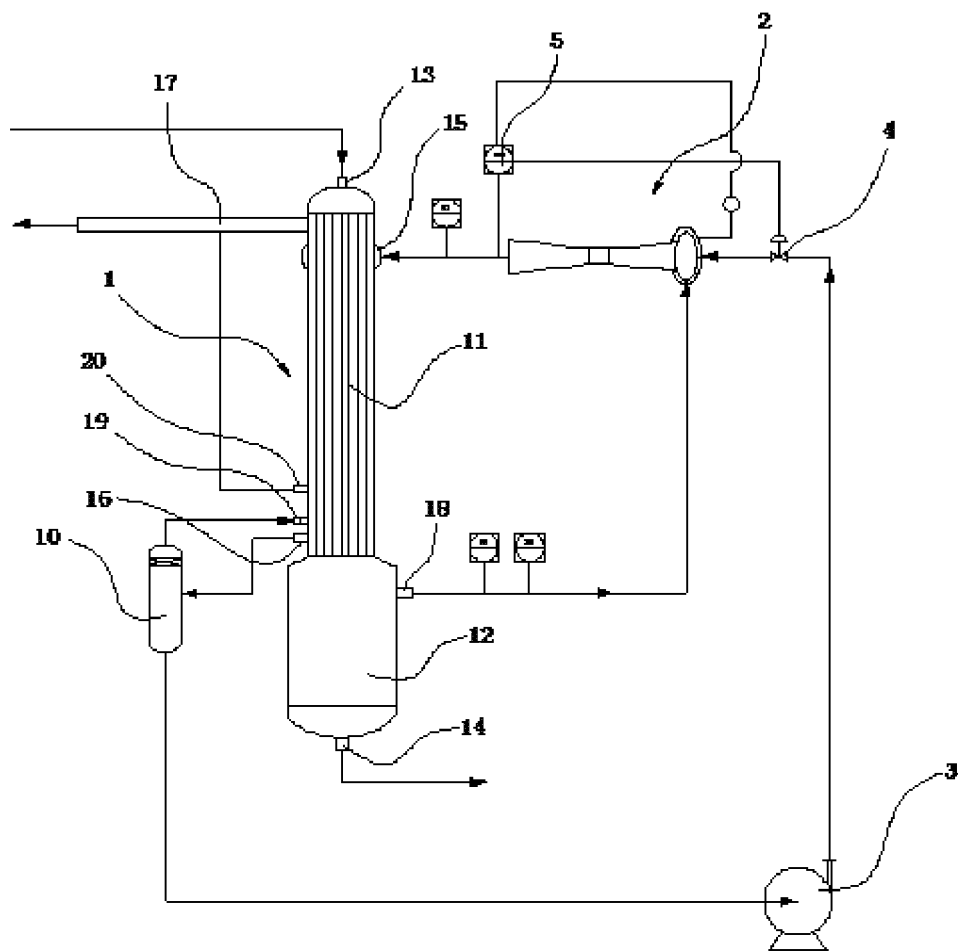


Fig 2

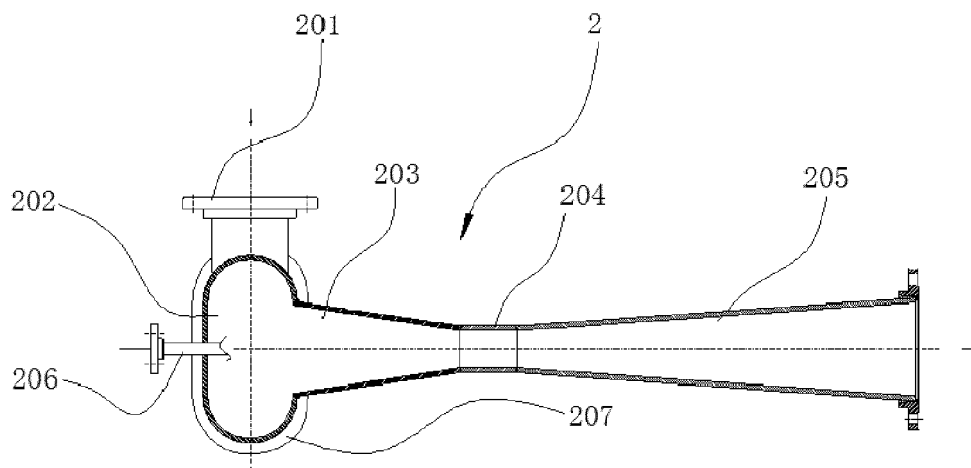


Fig 3

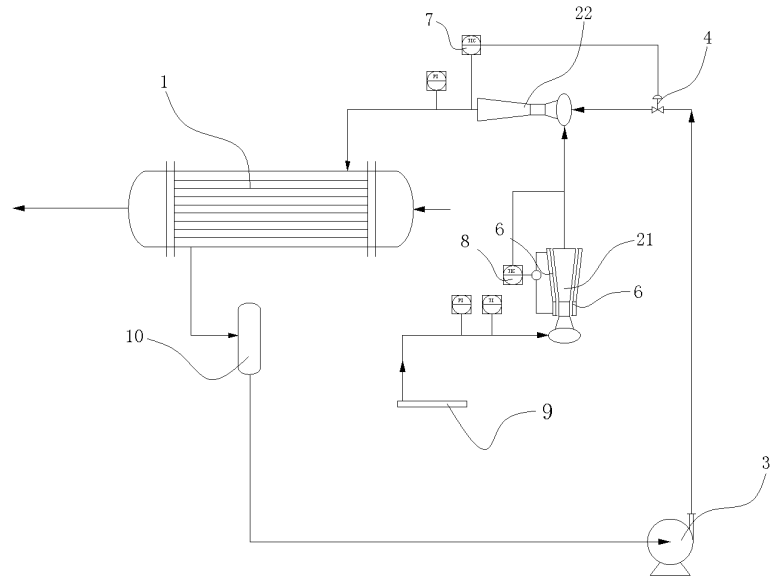


Fig 4

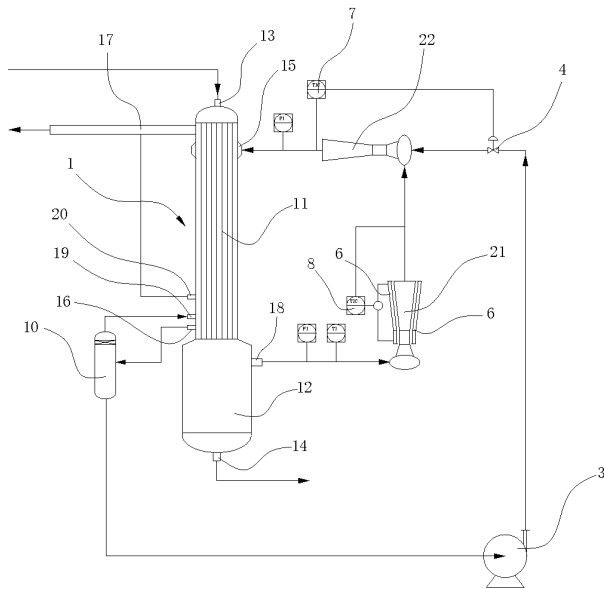


Fig 5

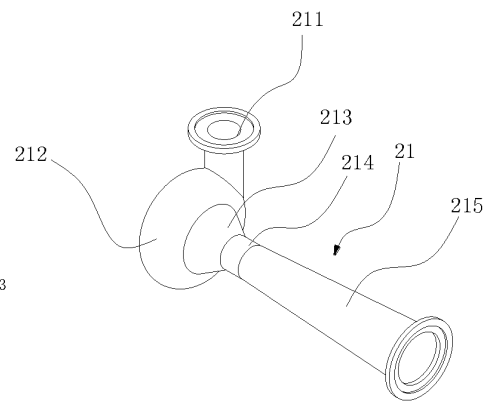


Fig 6

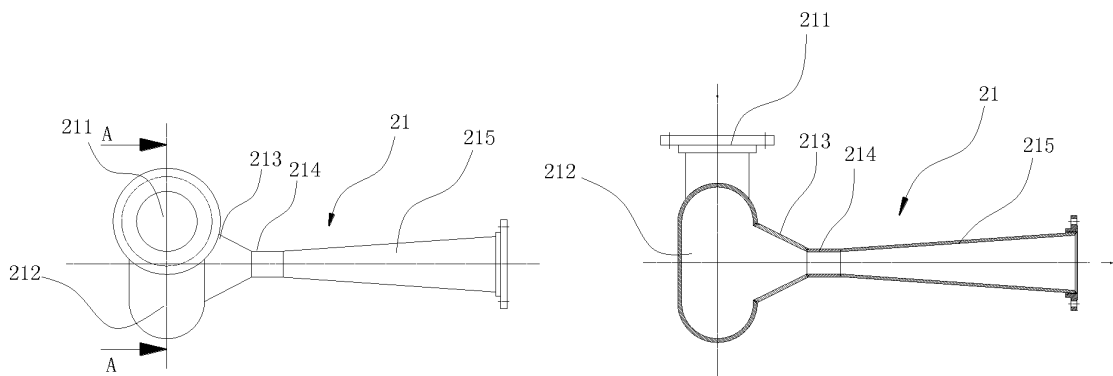


Fig 7

Fig 8

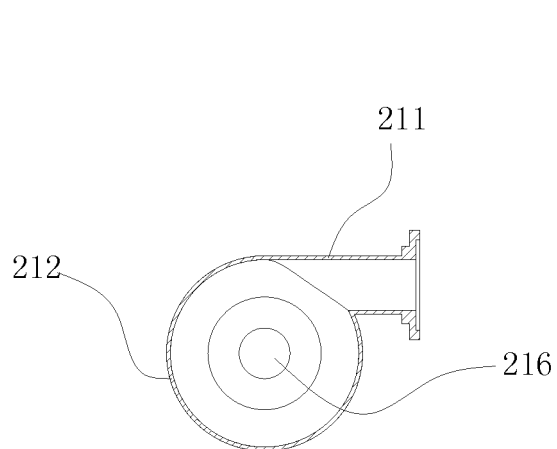


Fig 9

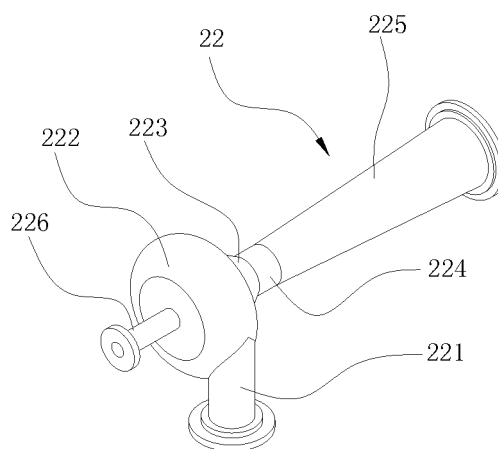


Fig 10

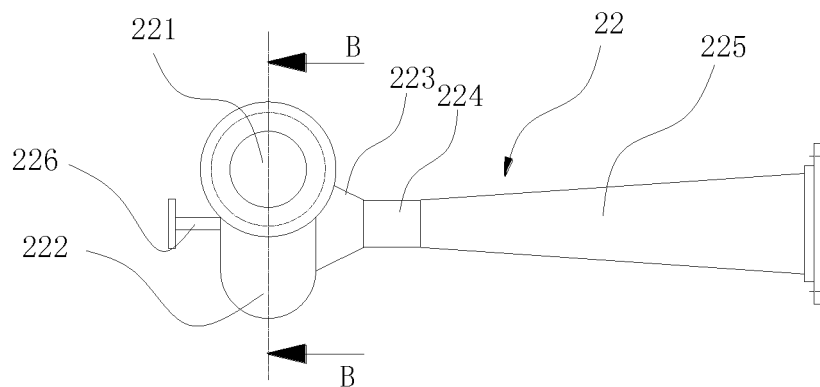


Fig 11

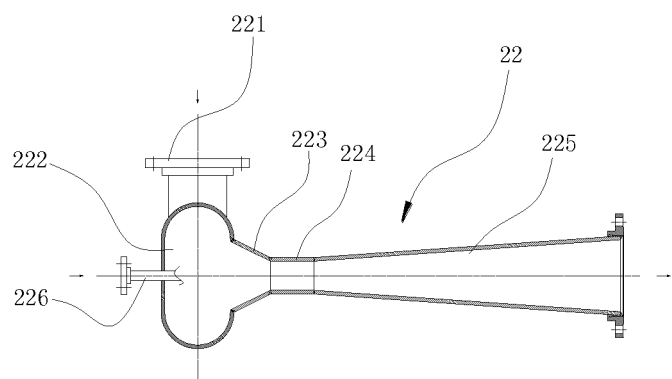


Fig 12

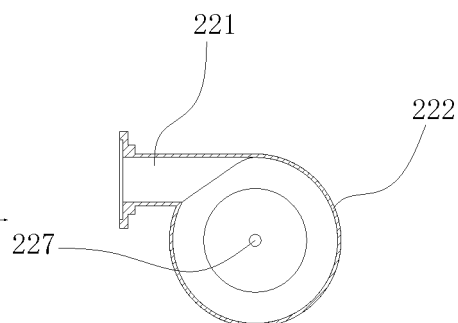


Fig 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/112817

A. CLASSIFICATION OF SUBJECT MATTER

F22G 1/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F22G; F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, EPODOC, WPI: 低压蒸气, 低压蒸汽, 过热, 喷液, 喷射, 增压, 加热, 物料, jet, injection, vapour, steam, superheat,
overheating, pressure, heating, material

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 106765049 A (SICHUAN UNIVERSITY) 31 May 2017 (31.05.2017), description, paragraphs [0091]-[0218], and figures 1-13	1-17
X	CN 202902754 U (SHIJIAZHUANG GONGDA CHEMICAL INDUSTRY EQUIPMENT CO., LTD.) 24 April 2013 (24.04.2013), description, paragraphs [0020]-[0034], and figure 1	1
A	DE 3541418 A1 (STEIMMUELLER GMBH L & C) 27 May 1987 (27.05.1987), entire document	1-17
A	WO 2007144285 A2 (SIEMENS AG et al.) 21 December 2007 (21.12.2007), entire document	1-17
A	CN 101432571 A (EASTMAN CHEMICAL CO.) 13 May 2009 (13.05.2009), entire document	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search 15 January 2018	Date of mailing of the international search report 12 February 2018
Name and mailing address of the ISA State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No. (86-10) 62019451	Authorized officer WANG, Ying Telephone No. (86-10) 62084892

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT Information on patent family members

International application No.
PCT/CN2017/112817

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 106765049 A	31 May 2017	None	
CN 202902754 U	24 April 2013	None	
DE 3541418 A1	27 May 1987	EP 0223985 A1	03 June 1987
WO 2007144285 A2	21 December 2007	DE 102006028007 A1	20 December 2007
		WO 2007144285 A3	23 June 2011
CN 101432571 A	13 May 2009	EP 2010821 A2	07 January 2009
		JP 2009535596 A	01 October 2009
		MX 2008013330 A	06 March 2009
		WO 2007127056 A2	08 November 2007
		US 2007245736 A1	25 October 2007
		WO 2007127056 A3	06 November 2008
		CA 2645769 A1	08 November 2007
		AU 2007243622 A1	08 November 2007