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(54) **Title**: HIGH EFFICIENCY POWER PLANTS

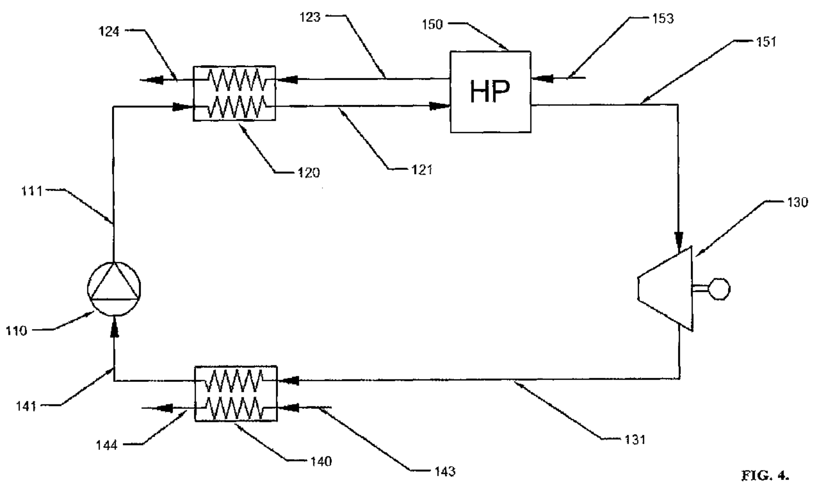

FIG. 4.

(57) **Abstract**: A Rankine cycle including pump (110), evaporator (120), turbine (130) and condenser (140) further includes a heat pump (150) arrangement for enhancing the efficiency of the cycle.

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High Efficiency Power Plants

Technical Field

This invention relates to the generation of energy. More particularly, this invention relates to a method of transforming thermal energy into mechanical energy. The invention further relates to a method of improving the heat utilization efficiency in a thermodynamic cycle and thus to a new thermodynamic cycle utilizing the method.

Background Art

In Rankine cycle, a major portion of the heat in the cycle is rejected to the cooling water, which results in thermal pollution of the environment and a higher energy loss.

FIG. 1 shows a simplified schematic diagram of the Rankine cycle, Water enters the pump 110 as saturated liquid and is compressed to a higher pressure to enters evaporator 120 via line 111, it superheated and leaves as superheated vapor, the evaporator 120 is continuously heated through line 123, hot stream 123 could be any source of heat such as combustion gases, nuclear reactors, etc., which leaves the evaporator via line 124, the superheated vapor enters the turbine 130 via line 121, where it expanded to generate electricity, The pressure and the temperature of steam drop during this process, The steam at low pressure and temperature leaves the turbine 130 via line 131 and enters the condenser 140, which is continuously cooled through cold stream 143. Cold stream 143 could be any source of convenient coolant such as cooling tower water, seawater, river water, or dry air, etc., which leaves the condenser 140 at a higher temperature via line 144, The condensate water leaves the condenser 140 to the pump 110 via line 141.

Many improvements had patented by Kaline, Due to Al-Mayahi There are numerous prior patents relating to variations of the Kalina cycle, including U.S. Pat. No. 4,346,561, U.S. Pat. No. 4,489,563, U.S. Pat. No. 4,548,043, U.S. Pat. No. 4,586,340, U.S. Pat. No. 4,732,005, U.S. Pat. No. 4,763,480, U.S. Pat. No. 4,899,545, U.S. Pat. No. 5,029,444, U.S. Pat. No. 5,095,708, U.S. Pat. No. 5,822,990, U.S. Pat. No. 5,950,433, U.S. Pat. No. 6,735,948, U.S. Pat. No. 6,769,256, U.S. Pat. No. 6,820,421, U.S. Pat. No. 6,829,895, U.S. Pat. No. 6,910,334, U.S. Pat. No. 6,923,000, U.S. Pat. No. 6,941,757 and U.S. Pat. No. 6,968,690.

FIG. 2 shows a simplified schematic for a conventional Kalina Cycle. The mixed working fluid, which is water-ammonia pumped in pump 210 to enter exchanger 220 via line 211 to be heated, then enter the recuperator 230 via line 221 to exchange heat, then leave the recuperator 230 to pass through line 231 to enter the evaporator 270 to be evaporated by exchanging heat with a heating source working fluid flowing from line 273 into evaporator 270 and then out line 274. The mixed working fluid has a boiling point dependent on concentration, passes as a mixture of water and vapor from the evaporator 270 through line 271 to be partially separated in a separator 240. The richer vapor component 243 passes to a turbine 250 for generation of electricity, while the leaner liquid component 241 passes via a recuperator heat exchanger 230 into line 233 and through a throttle valve 260, which reduces its pressure, to rejoin the richer stream 251 downstream of the turbine 250 at line 263 then pass through the heat exchanger 220 and from line 223 into a condenser 280, where vapors condense to liquid in heat exchange with a cold stream line 283 and then out line 284. The condensated mixture is then return back to pump 210 via line 281.

An Improvements is patent by Al-Mayahi using an energy recovery device, Pat US20110051880.

FIG. 3 is a schematic diagram of the Mayahi cycle. The mixed working fluid, which is water-ammonia pumped in pump 310, to enter an energy recovery device (ERD), such as energy recovery turbine (ERT) 320 via line 311, In the ERT 320, an apparatus commonly employed in reverse osmosis desalination plants, and the high pressure of one liquid is transferred to another. Here the high pressure of the flow from the evaporator/generator 350 in line 343 is transferred to the lower pressure flow from the condenser/absorber 370 in line 311, the lowered pressure flow from the evaporator 350 in line 323 passing to the condenser 370 in this example being employed for the spray via line 333. Because the low pressure of the condenser flow has already been increased by pressure exchange in the ERT 320, the pump 310 serves only an auxiliary purpose to increase the pressure of the stream in line 371 to higher pressure in line 321, and so does not need to be a high pressure pump. The mixed working fluid with high pressured in line 321 is then enter exchanger 330 to be heated, then enter the recuperator 340 via line 331 to exchange heat, then leave the recuperator 340 to pass through line 341 to enter the generator/evaporator 350 to be evaporated by exchanging heat with a heating source working fluid flowing from line 353 into evaporator 250 and then out line 354. Ammonia has a low boiling point, it evaporated and pass through line 351 to the turbine 360 to expand an generate electricity, then pass through heat exchanger 330 via line 361 to exchange heat with the mixture from line 321, and then back to the condenser/absorber 370 via line 333, where condense to liquid in heat exchange with a cold stream line 373 and then out line 374.

Disclosure of invention

In Rankine cycle, the working fluid enters the pump as saturated liquid, and pressurized to the operation pressure of the boiler, the working fluid temperature is increased until it reached the operation pressure boiling temperature, then the enthalpy increased at constant temperature until it reach the "saturated vapor state", then it superheated, and the temperature increased. The superheated vapor enters the turbine, where it expand producing work.

The p-h diagram shows that the energy that used to superheated the working fluid, after it reach the "saturation vapor state", is "close" to the work gained by expansion in turbine, and the work gained in turbine increased by increasing the operation pressure in boiler, and so the boiling temperature.

By Increasing the operation pressure at boiler, and so the boiling temperature to temperature "close" to the "heat source", and then superheating the working fluid at temperature higher than the heat source temperature, or temperature that can be achieved by the heat source or by exchanging with the heat source, by using a heat pump to transfer heat from the heat source to a higher temperature and exchanging with the working fluid to superheat it before expanding in turbine, will increase the gained work, and so the efficiency.

FIG. 4 showing a modified Rankine cycle in accordance with various embodiments of the present invention, Water enters the pump 110 as saturated liquid and is compressed to a higher pressure to enters evaporator 120 via line 111, the evaporator 120 is continuously heated by exchanging heat with a hot stream flowing from line 123 into evaporator 120 and then out line 124. The working fluid is boiled and leaves, at "saturated vapor state", or as superheated vapor, to enter the heat pump 150 via line 121, the heat pump superheat the working fluid to temperature higher than the heat source, or higher than temperature that can be achieved by exchanging heat with the heat source, by transferring, heat from heat source line 153 to 123, to the working fluid. The superheated vapor enters the turbine 130 via line 151, where it expanded to generate electricity, the pressure and the temperature of steam drop during this process, the steam at low pressure and temperature leaves the turbine 130 via line 131 and enters the condenser 140, which is continuously cooled through cold stream flowing from line 143 into condenser 140 and then out line 144. The condensate water leaves the condenser 140 back to the pump 110 via line 141.

Brief Description of Drawings

FIG. 1 is a schematic diagram of the Rankine cycle.

FIG. 2 is a schematic diagram of the Kalina cycle.

FIG. 3 is a schematic diagram of the Mayahi cycle.

FIG. 4 showing a modified Rankine cycle in accordance with various embodiments of the present invention

FIG. 5 showing a modified Kalina cycle in accordance with various embodiments of the present invention.

FIG. 6 showing a modified Al-Mayahi cycle in accordance with various embodiments of the present invention.

FIG. 7 is a schematic diagram of the Design showing the optimization of Rankine in accordance with various embodiments of the present invention.

FIG. 8 is a schematic diagram of a design 1 of a heat pump that transfer heat from heat source with constant temperature to a gradual one.

FIG. 9 is a schematic diagram of the Design 2 of a heat pump that transfer heat from heat source with constant temperature to a gradual one.

FIG. 10 is a schematic diagram of the Design 3 of a heat pump that transfer heat from heat source with constant temperature to a gradual one.

FIG. 11 is a graph in p-h diagram shows the difference between Rankine cycle, and the modified Rankine cycle in accordance with various embodiments of the present invention.

Detailed Description

In Rankine cycle, the working fluid enters the pump as saturated liquid, and pressurized to the operation pressure of the boiler, the working fluid temperature is increased until it reached the operation pressure boiling temperature, then the enthalpy increased at constant temperature until it reach the "saturated vapor state", then it superheated, and the temperature increased. The superheated vapor enters the turbine, where it expand producing work.

The p-h diagram shows that the energy that used to superheated the working fluid, after it reach the "saturation vapor state", is "close" to the work gained by expansion in turbine, and the work gained in turbine increased by increasing the operation pressure in boiler, and so the boiling temperature.

By Increasing the operation pressure at boiler, and so the boiling temperature to temperature "close" to the "heat source", and then superheating the working fluid at temperature higher than the heat source temperature, or temperature that can be achieved by the heat source or by exchanging with the heat source, by using a heat pump to transfer heat from the heat source to a higher temperature and exchanging with the working fluid to superheat it before expanding in turbine, will increase the gained work, and so the efficiency.

FIG. 4 showing a modified Rankine cycle in accordance with various embodiments of the present invention, Water enters the pump 110 as saturated liquid and is compressed to a higher pressure to enters evaporator 120 via line 111, the evaporator 120 is continuously heated by exchanging heat with a hot stream flowing from line 123 into evaporator 120 and then out line 124. The working fluid is boiled and leaves, at "saturated vapor state", or as superheated vapor, to enter the heat pump 150 via line 121, the heat pump superheat the working fluid to temperature higher than the heat source, or higher than temperature that can be achieved by exchanging heat with the heat source, by transferring, heat from heat source line 153 to 123, to the working fluid. The superheated vapor enters the turbine 130 via line 151, where it expanded to generate electricity, the pressure and the temperature of steam drop during this process, the steam at low pressure and temperature leaves the turbine 130 via line 131 and enters the condenser 140, which is continuously cooled through cold stream flowing from line 143 into condenser 140 and then out line 144. The condensate water leaves the condenser 140 back to the pump 110 via line 141.

FIG. 5 showing a modified Kalina cycle in accordance with various embodiments of the present invention. The mixed working fluid, which is water-ammonia pumped in pump 210 to enter exchanger 220 via line 211 to be heated, then enter the recuperator 230 via line 221 to exchange heat, then leave the recuperator 230 to pass through line 231 to enter the evaporator 270 to be evaporated by exchanging heat with a hot stream flowing from line 273 into evaporator 270 and then out line 274. The mixed working fluid has a boiling point dependent on concentration, passes as a mixture of water and vapor from the evaporator 270 through line 271 to be partially separated in a separator 240. The richer vapor component 243 that have temperature equal to the maximum temperature that can achieved, by exchanging with the heat source line, enters the heat pump 290 to be superheated to temperature "higher" than the temperature that can achieved by exchanged with the heat source, in some designs that the working vapor in line 243 does not reach the maximum temperature that can be achieved by exchanging with the heat source, it should superheated by the heat source before enters the heat pump. The working fluid is then pass to the turbine 250 via line 291 for generation of electricity, while the leaner liquid component 241 passes via a recuperator heat exchanger 230 into line 233 and through a throttle valve 260, which reduces its pressure, and leave to line 261 to rejoin the richer stream 251 downstream of the turbine 250 at line 263 then pass through the heat exchanger 220, then leaves it to line 223 to enters the condenser 280, where vapors condense to liquid in heat exchange with a cold stream line 283 and then out line 284. The condensated mixture is then return back to pump 210 via line 281.

FIG. 6 showing a modified Al-Mayahi cycle in accordance with various embodiments of the present invention. The mixed working fluid, which is water-ammonia pumped in pump 310, to enter an energy recovery device (ERD), such as energy recovery turbine (ERT) 320 via line 311, In the ERT 320, the high pressure of one liquid is transferred to another. Here the high pressure of the flow from the generator/evaporator 350 in line 343 is transferred to the lower pressure flow from the condenser 370 in line 311, the lowered pressure flow from the generator/evaporator 350 in line 323 passing to the condenser 370 is being employed for the spray via line 333. Because the low pressure of the condenser flow has already been increased by pressure exchange in the ERT 320, the pump 310 serves only an auxiliary purpose to increase the pressure of the stream in line 371 to higher pressure in line 321, and so does not need to be a high pressure pump. The mixed working fluid with high pressured in line 321 is then enter exchanger 330 to be heated, then enter the recuperator 340 via line 331 to exchange heat, then leave the recuperator

340 to pass through line 341 to enter the generator/evaporator 350 to be evaporated by exchanging heat with the hot stream from line 353 into evaporator 350 and then out line 354. Ammonia has a low boiling point, it evaporated/superheated to the maximum temperature that can achieved by the exchanging with the heat source line, pass through line 351 to enter the heat pump 380 to be superheated to temperature "higher" than the temperature that can achieved by exchanged with the heat source, by transferring, heat from heat source line 383 to 353, to the working fluid, in some designs that the working vapor in line 351 does not reach the maximum temperature that can be achieved by exchanging with the heat source, so it should superheated by the heat source before enters the heat pump, then pass to the turbine 360 via line 381 for generation of electricity, then pass through heat exchanger 330 via line 361 to exchange heat with the mixture from line 321, and then back to the condenser/absorber 370 via line 333, where condense to liquid in heat exchange with a cold stream line 373 and then out line 374.

The optimization that can be achieved by this method need to redesign the heat pump, and modify the cycle for example in Rankine cycle. When designing a normal Rankine cycle we choose a boiler pressure that allow working fluid to be superheated and expanded in turbine and stay in the dray region, that enforce the designer to select a pressure that allow a very low boiling temperature than the heat source, said we have source that can supply heat at temperature 150 C, designer can select operation pressure for boiler equal to 0.1 bar, so the boiling temperature at this pressure will be around 50 C, But by applying this method, we can chose a higher pressure said 1.5 bar, and boiling temperature 110 C, and superheated the working fluid to temperature equal to 150, then using the heat pump to get a higher temperature say 250 C, and to achieve higher efficiency, we should re-design the heat pump so it transfer the heat from the heat source with constant temperature say 150, to the working vapor that need a gradual temperature from 150 to 250, Fig. 7, 8, and 8 show three designs, of that heat pump, and also we can use a heat pump that contains many units where each unit pump heat from the heat source to a different temperature, said unit 1 pump from 150 C to 160, unit 2 pump from 150 to 170, etc., and it can also contains a unit that pump heat from 150 to 200, and other are a cascading units can pump heat from 200 to a higher said from 200 to 210, etc. the design of the heat pump depends on the heat pump working fluids, and in p-h diagram of working fluid. In Fig. 11, it can be noticed that when the Rankin cycle working fluid expands in turbine it reach the wet region at temperature and pressure higher than the condenser temperature and pressure, so to get a higher efficiency we should superheat the working fluid by the heat source, to reach the maximum temperature that can be achieved by exchanging, then superheated in the heat pump, before expanding in the second turbine.

In some cases heat pump should transfer heat from heat constant/gradual heat source, to a gradual temperature, said a solar collector where having a fluid water at pressure 1 bar and boiling temperature 100 C, but the fluid in the collector is superheated to reach temperature higher than 100 C, said 150, in this case to achieve a higher efficiency we have to design the boiler to works at pressure close to 1 bar, and superheat the Rankine cycle working fluid to temperature close to 150, then transfer heat from the hot stream source from 100 C – 150 C by the heat pump to supply heat to the working fluid with a gradual temperature from 150 C – 250 C.

FIG. 7 is a schematic diagram of the Design showing the optimization of Rankine in accordance with various embodiments of the present invention, Water enters the pump 110 as saturated liquid and is compressed to a higher pressure of the first stage to leave at line 111 to join line 116 in line 112 to enters evaporator 120, the evaporator 120 is continuously heated by exchanging heat with a hot stream flowing from line 123 into evaporator 120 and then out line 124. The working fluid is boiled and leaves, at "saturated vapor state", or as superheated vapor, with temperature equal to the maximum temperature that can achieved by exchanging with the hot stream to enter the heat pump 150 via line 121, the heat pump superheat the working fluid to temperature higher than the heat source, or higher than temperature that can be achieved by exchanging heat with the heat source, by transferring, heat from heat source line 153 to 123, to the working fluid. The superheated vapor enters the first turbine 160 via line 151, where it expanded to generate electricity, the pressure and the temperature of steam drop during this process, the steam at low pressure and temperature leaves the turbine 160 via line 161, the line 161 splits into line 162, and 163 where both enter the heat pump 190 to transfer heat from line 162 to higher temperature to superheat the working fluid in line 163. The fluid in line 162 condensate and leave the heat pump 190 as saturated liquid via line 192 to be pumped to the pressure of the first stage in pump 115 and leave in line 116 to join line 111, in line 112 before entering the heat exchange/boiler 120. The fluid in line 163 is superheated in the heat pump and leaves it to the line 191 to enter heat exchange / boiler 170. The heat pump 190 is optional and it can increase the efficiency when difference between boiling temprature before expanding the turbine 160, and after expanding is high, but when that difference is low it will decrease the efficiency so we can not use it with low difference so in this case the working fluid in line 161 will directly enters the heat exchanger 170 directly. In heat exchanger 170, the working fluid exchange heat with heat source, where it superheated to the maximum temperature that can achieved by the exchanging with the hot stream flowing from line 173 into evaporator 170 and then out line 153, then the working fluid vapor enters the heat pump 180 via line 171, to superheated to temperature higher than the heat source, or higher than temperature that can be achieved by exchanging heat with the heat source, by transferring, heat from heat source line 183 to 173, to the working fluid before enters the second turbine 130 via line 181, wherein it expand to produce work/electricity, then pass though line 131 to enter the condenser 140, which is continuously cooled through cold stream flowing from line 143 into condenser 140 and then out line 144. The condensated water leaves the condenser 140 back to the pump 110 via line 141.

FIG. 8 is a schematic diagram of a design 1 of a heat pump that transfer heat from heat source with constant temperature to a gradual one. The heat pump is a device transferring heat from lower temperature medium to a higher temperature one. The working fluid at saturated vapor state is compressed in pump/compressor 810 to the working pressure in first stage, the compression process is also superheat the working fluid, for fluids that has a higher specific heat, when it compressed at vapor state it superheated to a "higher" temperature, exchanging this heat with the higher temperature medium, to which is aimed to transfer heat is leading to a higher coefficient of performance (COP), the working fluid enter condenser 820 to loss heat by exchanging with the higher temperature medium, and leave to line 821 at saturated vapor state, then it splitted into two lines, line 823, and line 852 to enters the pump/compressor 850 to be compressed to the working pressure in this second stage, then enter condenser 860 via line 851, it loss heat by exchanging heat with the higher temperature medium, and leave the compressor 860 to enter the throttle 870 via line 861, where it loss pressure and return back to pressure of the previous stage, it leaves in line 871, and rejoin the line 823 in line 832 to enter the condenser 830 where it loss/exchange heat with the higher temperature medium, and then leaves at line 831 to enter the throttle 840, where it loss pressure then enter evaporator 880 via line 841, where it heated from the lower temperature heating source to the reach the saturated vapor state and back to compressor 810 via line 881. The evaporator 880 is continuously heated from the lower temperature heating source flowing from line 883 to 884. The higher temperature medium is first enter the condenser 830 via line 833 to be heated to a higher temperature and leave to enter the condenser 820 via line 834 to heated to a temperature equal or higher than the previous condenser, then leave to enter condenser 860 to heated to temperature higher than temperature in condenser 830, then leave via line 864.

FIG. 9 is a schematic diagram of a design 2 of a heat pump that transfer heat from heat source with constant temperature to a gradual one. The working fluid at saturated vapor state is compressed in pump/compressor 810 to the working pressure in first stage, and leaves via line 811, the compression process is also superheat the working fluid, so to return the fluid to the saturated state point, it mix with fluid from second stage at liquid-vapor state, the line 811 is join with line 873 in line 812 which is then splitted into two lines 852, and line 823, which joined with line 874 in line 832 to enter the condenser 830 where it loss/exchange heat and leaves to line 831 to enter the throttle 840, where it loss pressure then enter evaporator 880 via line 841, where it heated from the low temperature heating source to the reach the saturated vapor state and back to compressor 810 via line 881. The evaporator 880 is continuously heated from the low temperature heating source flowing from line 883 to 884. The working fluid in line 852 enters the pump/compressor 850 to be compressed the working pressure in this second stage, then enter condenser 860 via line 851, it loss heat by exchanging heat with the higher temperature medium, and leave the compressor 860 to enter the throttle 870 via line 861, where it loss pressure and return back to pressure of the previous stage, it leaves in line 871, and splitted into two lines, line 873, and 874. The higher temperature medium is first enter the condenser 830 via line 833 to be heated to a higher temperature then leaves to enter condenser 860 via line 834 to be heated to temperature higher than temperature in condenser 830, then leaves via line 864.

FIG. 10 is a schematic diagram of a design 3 of a heat pump that transfer heat from heat source with constant temperature to a gradual one. The working fluid at saturated vapor state is compressed in pump/compressor 810 to the working pressure in first stage, and leaves via line 811 which then splitted into two lines 814, and 815. The line 815 join line 874 in line 832 to enter the condenser 830 where it loss/exchange heat leaves at line 831 to enter the throttle 840, where it loss pressure then enter evaporator 880 via line 841, where it heated from the heating source to the reach the saturated vapor state and back to compressor 810 via line 881. The evaporator 880 is continuously heated from the low temperature heating source flowing from line 883 to 884. The line 814 is join with line 873 in line 852, to return the working fluid to the saturated state point before it enters the pump/compressor 850 to be compressed to the working pressure in this second stage, then enter condenser 860 via line 851, it loss heat by exchanging heat with the higher temperature medium, and leave the compressor 860 to enter the throttle 870 via line 861, where it loss pressure and return back to pressure of the previous stage, it leaves in line 871, which is then splitted into two lines, line 873, and 874. The higher temperature medium is first enter the condenser 830 via line 833 to be heated to a higher temperature then leaves to enter condenser 860 via line 834 to be heated to temperature higher than temperature in condenser 830, then leaves via line 864.

FIG. 11 is a graph in p-h diagram shows the difference between Rankine cycle, and the modified Rankine cycle in accordance with various embodiments of the present invention. For low heat source temperature that supply 150 C, In Rankine cycle, Fig. 1. the saturated working fluid water at point 1 is pumped to the working pressure to reach point 2, then boiled at boiler and superheated to reach point 3, then expanded to point 4 in turbine, to produce work, then condensate to return back to point 1. In Modified-Rankine cycle Fig. 7. Wherein a heat pump is used to transfer heat from constant temperature heat source 150 to gradual temperature 150-250, a redesign is made, so the saturated working fluid water at point 1 is pumped to the working pressure to reach the point 5 which have a pressure higher than the point 2, to boiled at boiler and superheated to reach point 6 that has the same temperature like point 3, but higher pressure, then superheated in heat pump to reach the point 7, then expanded in the first turbine to point 8, and because the difference between the boiling temperature before and after turbine is low, the heat pump 190 is removed, and the working fluid is then superheated by the heat source to point 9 that has the same temperature like points 3, and 6, but higher pressure than point 3 and lower pressure than point 6, and superheated in heat pump to point 10 before it expanded in the next turbine.

We can notice that “all” heat we add by the heat pump, we gained as work in turbine “plus” the work due to the increasing in pressure of boiler which equal to (h6-h8).

Claims

1. A method of superheating the working fluid to temperature higher than the “heat source”, or higher than the temperature which can be achieved by the heat source or by exchanging with the heat source, it comprise the steps of transferring heat from heat source to a higher temperature through a heat pump system, to superheating the working fluid.

2. A method of superheating the working fluid by transfer heat from the working fluid to higher temperature to superheat the working fluid.

   3. A method of claim 1, 2 wherein the heat pump superheating the working fluid after it reach the maximum temperature that can be achieved by heat source, or by exchanging with the heat source.

   4. A method of claim 1, 2 wherein the heat pump superheating the working fluid after it reach the saturation vapor state.

   5. A method of claim 1, 2 wherein the heat pump superheating the working fluid before it reach the saturation vapor state.

   6. A method of claim 1, 2 wherein the heat pump transfer heat from constant temperature heat source to a constant temperature to superheat the working fluid.

   7. A method of claim 1, 2 wherein the heat pump transfer heat from constant temperature heat source to a gradual temperature to superheat the working fluid.

   8. A method of claim 1, 2 wherein the heat pump transfer heat from gradual temperature heat source to a constant temperature to superheat the working fluid.

   9. A method of claim 1, 2 wherein the heat pump transfer heat from gradual temperature heat source to a gradual temperature to superheat the working fluid.

10. A method of claim 1, 2 wherein the heat pump transfer heat from constant temperature heat source to a gradual temperature one, said it transfer heat from heat source with having constant temperature equal to 150 C, to supply heat with gradual temperature from 150 C to 300 C.

11. Claim 2, the working fluid which heat is transferred from it, is considered the heat source supplied to the heat pump at this stage.

12. A heat engine system having a heat pump system.

13. A heat engine system having a heat pump to superheating the working fluid before expanding.

AMENDED CLAIMS
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1- A Heat pump "A" that combines many stage to transfer heat from low temperature medium to high temperature medium wherein

The working fluid at saturated vapor stage in last stage at line LA1.1 is compressed then rejects heat to the high temperature medium through a heat exchanger HXA1 is then expanded in expansion valve and leaves at line LA1.2;

The working fluid at saturated vapor stage in the previous stage is compressed before rejecting heat to the high temperature medium through a heat exchanger HXA2.1 until the working fluid reaches the saturated vapor stage then is split into two lines LA1.1 and LA22;

The LA1.2 joins LA22 at line LA2 before rejecting heat to the high temperature medium through a heat exchanger HXA2.2;

The high temperature medium passes through heat exchangers HXA2.2, HXA2.1, and HXA1 respectively.

2- A Heat pump "B" that combine many stage wherein

The working fluid at saturated vapor stage in last stage at line LB1.1 is compressed before rejecting heat to the high temperature medium through a heat exchanger HXB1 then is expanded in expansion valve before being split into two lines LB11, and LB12;

The line LB11 joins the working fluid of the previous stage - after it is compressed - at line LB2.1 then it is split into two lines LB1.1 and LB22;

The LB12 join LB22 at line LB2.2 before rejects heat to the high temperature medium through a heat exchanger HXB2;

The high temperature medium passes through heat exchangers HXB2, and HXB1 respectively.

3- A Heat pump "C" that combine many stages wherein

The working fluid in the last stage at super-heated vapor stage rejects heat to the high temperature medium through a heat exchanger HXC1 is then expanded via expansion valve before being split into two lines LC11 and LC12;

The working fluid at previous stage is split into two lines LC21 and LC22 after it is compressed;

The line LC11 joins LC21 and to the compressor in the last stage, while the line LC12 joins LC22 at line LC2 then rejects heat to the high temperature medium through a heat exchanger HXC2;

The high temperature medium passes through heat exchangers HXC2, and HXC1 respectively.

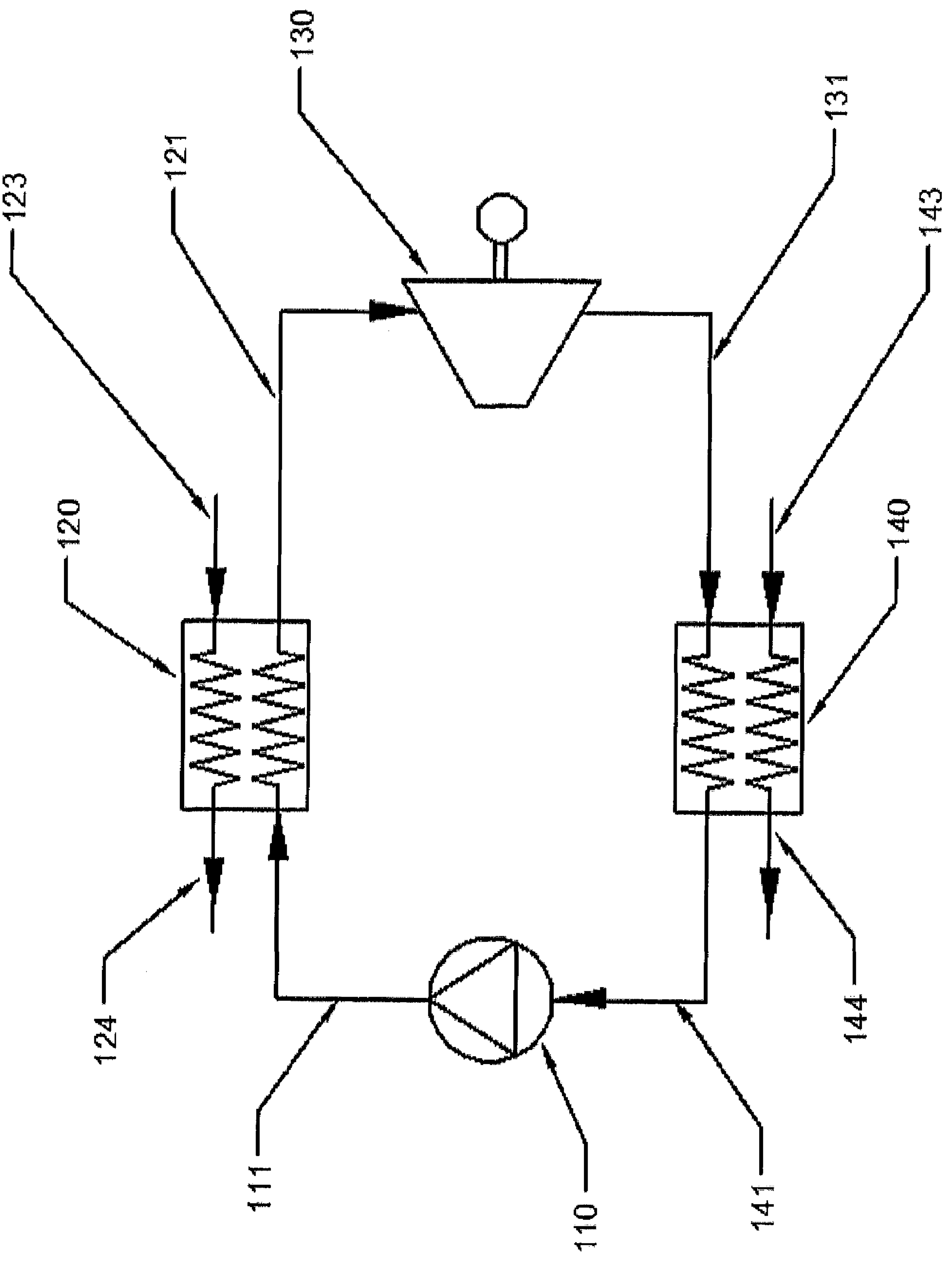

FIG. 1.

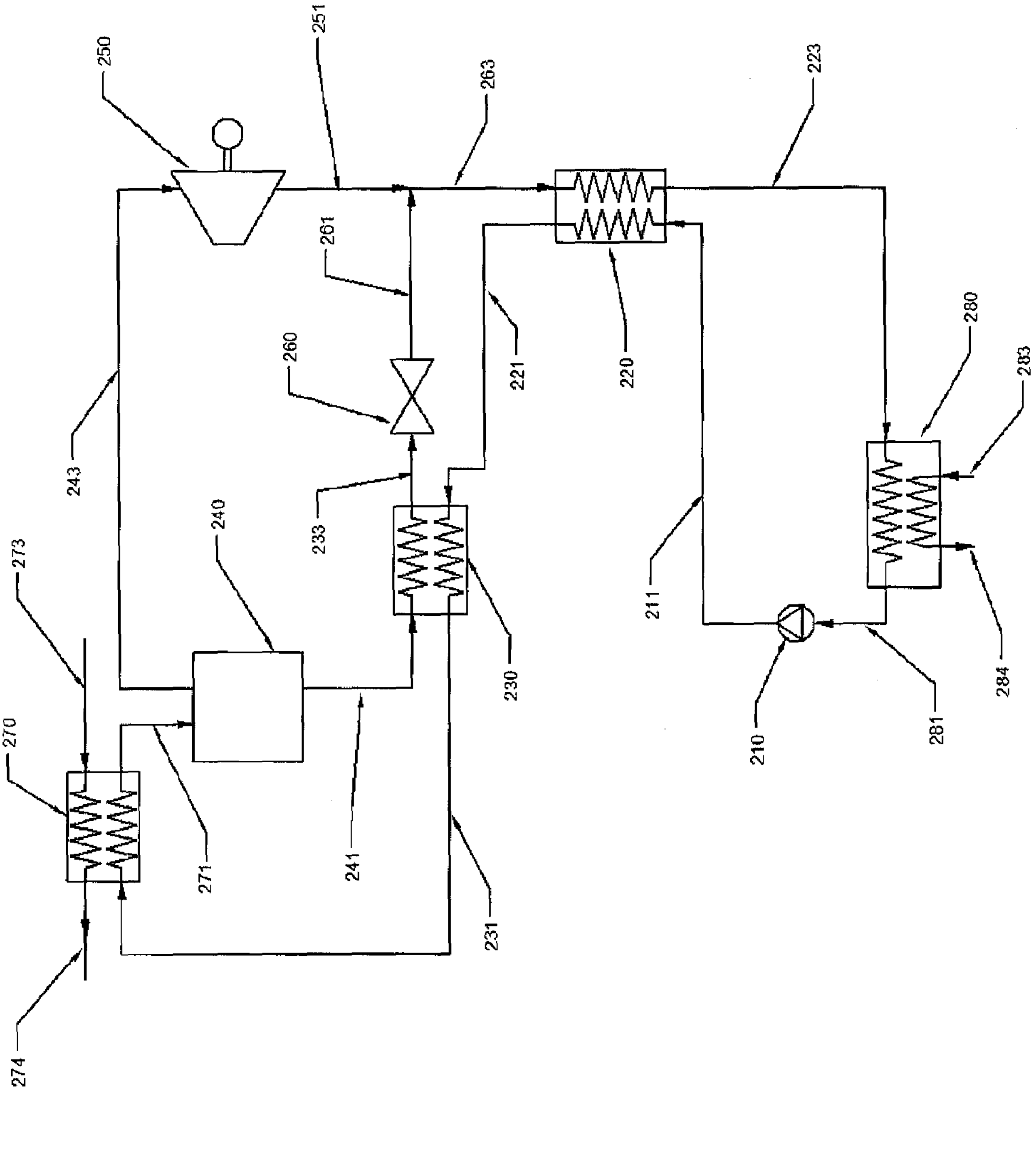
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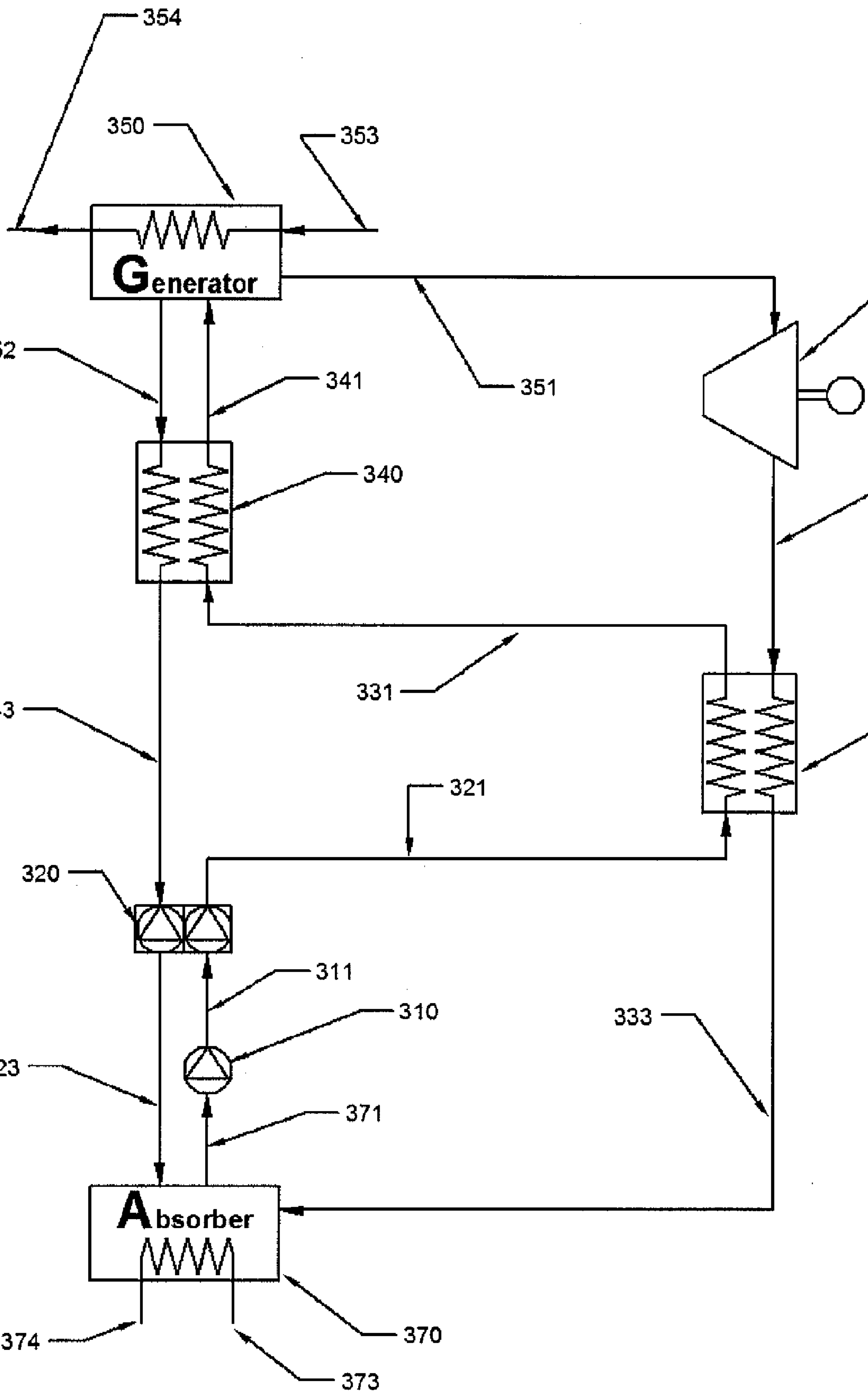
FIG. 2.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Absorber
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370
373

FIG. 3.

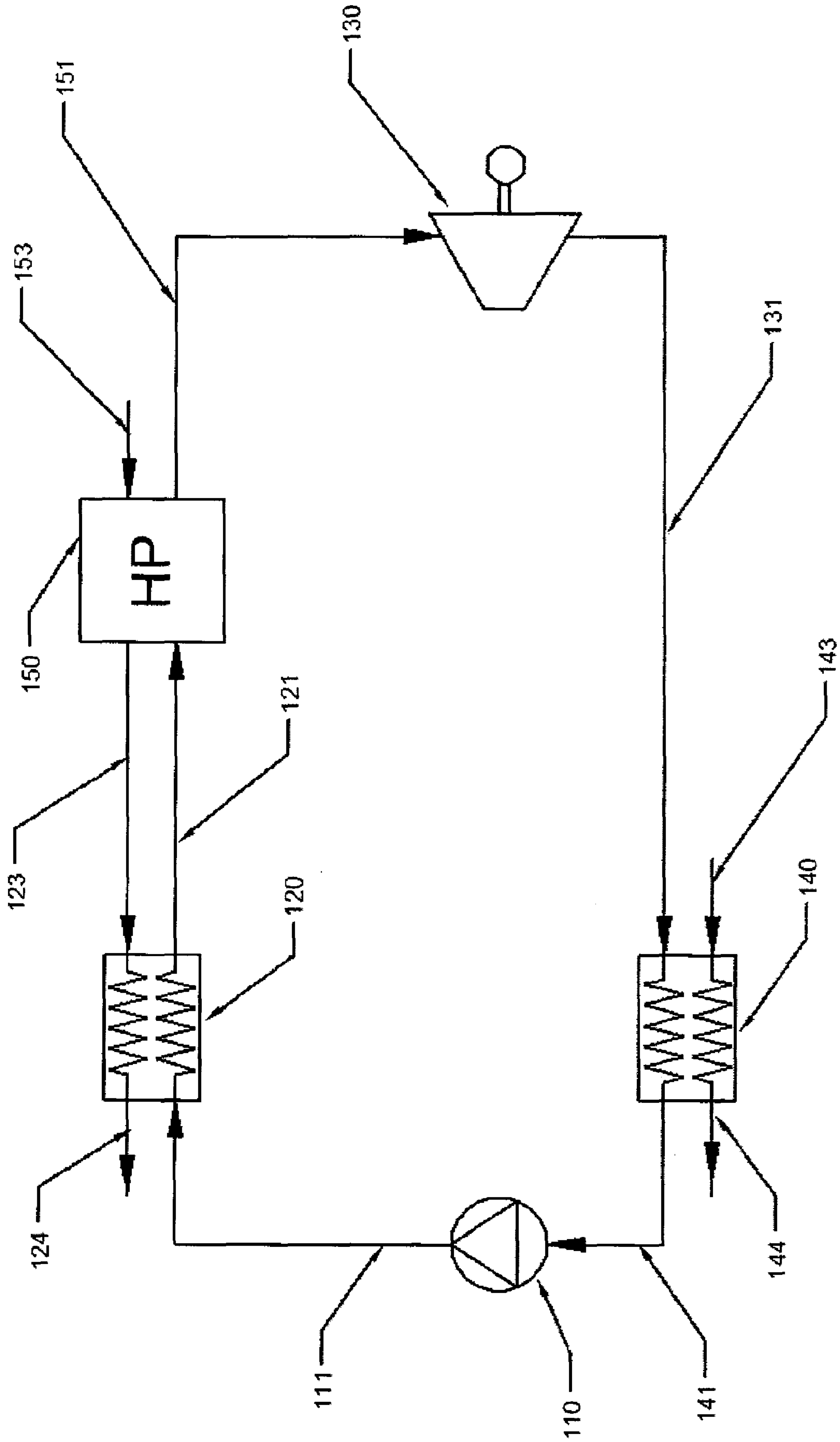

FIG. 4.

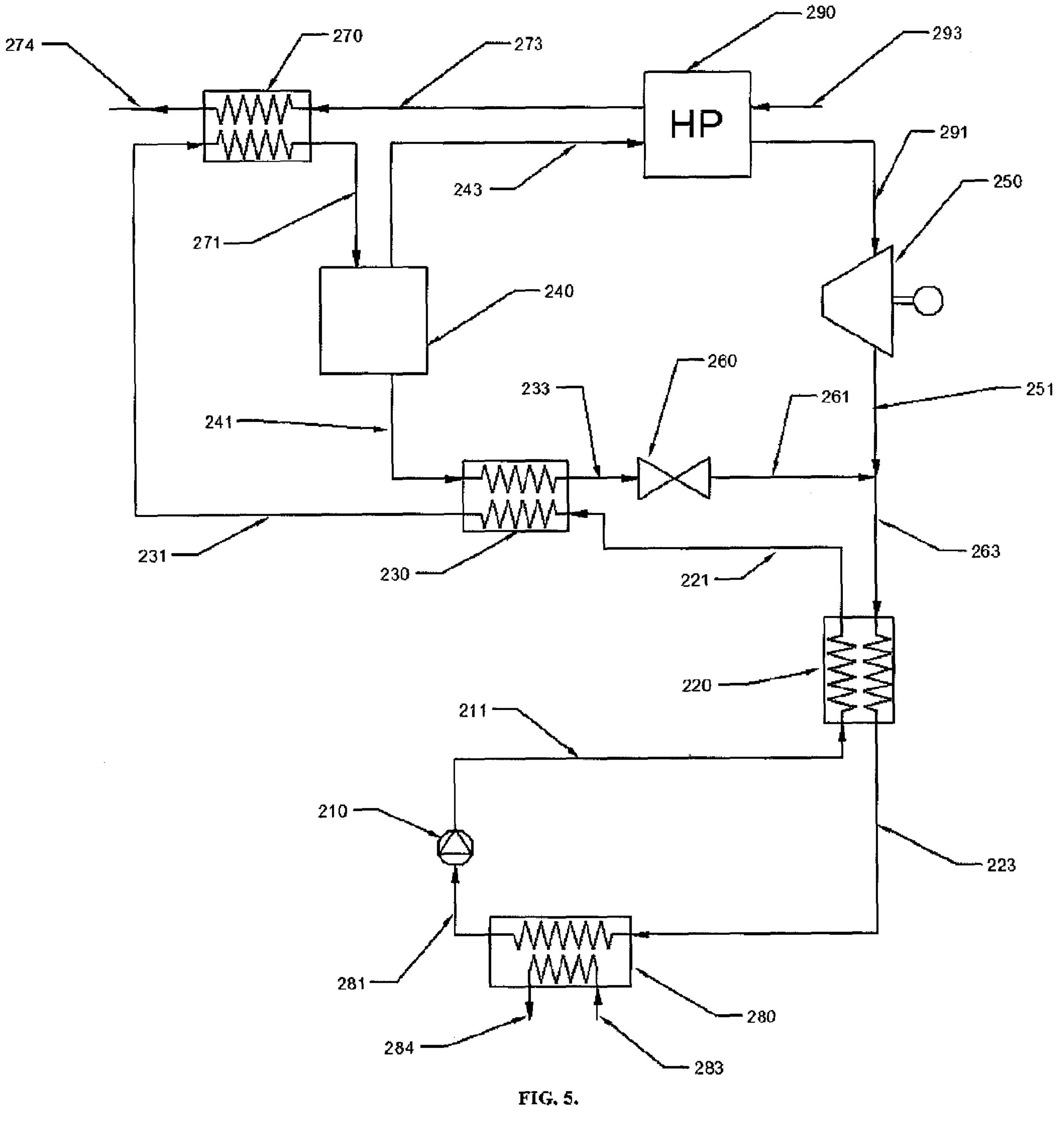
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FIG. 5.

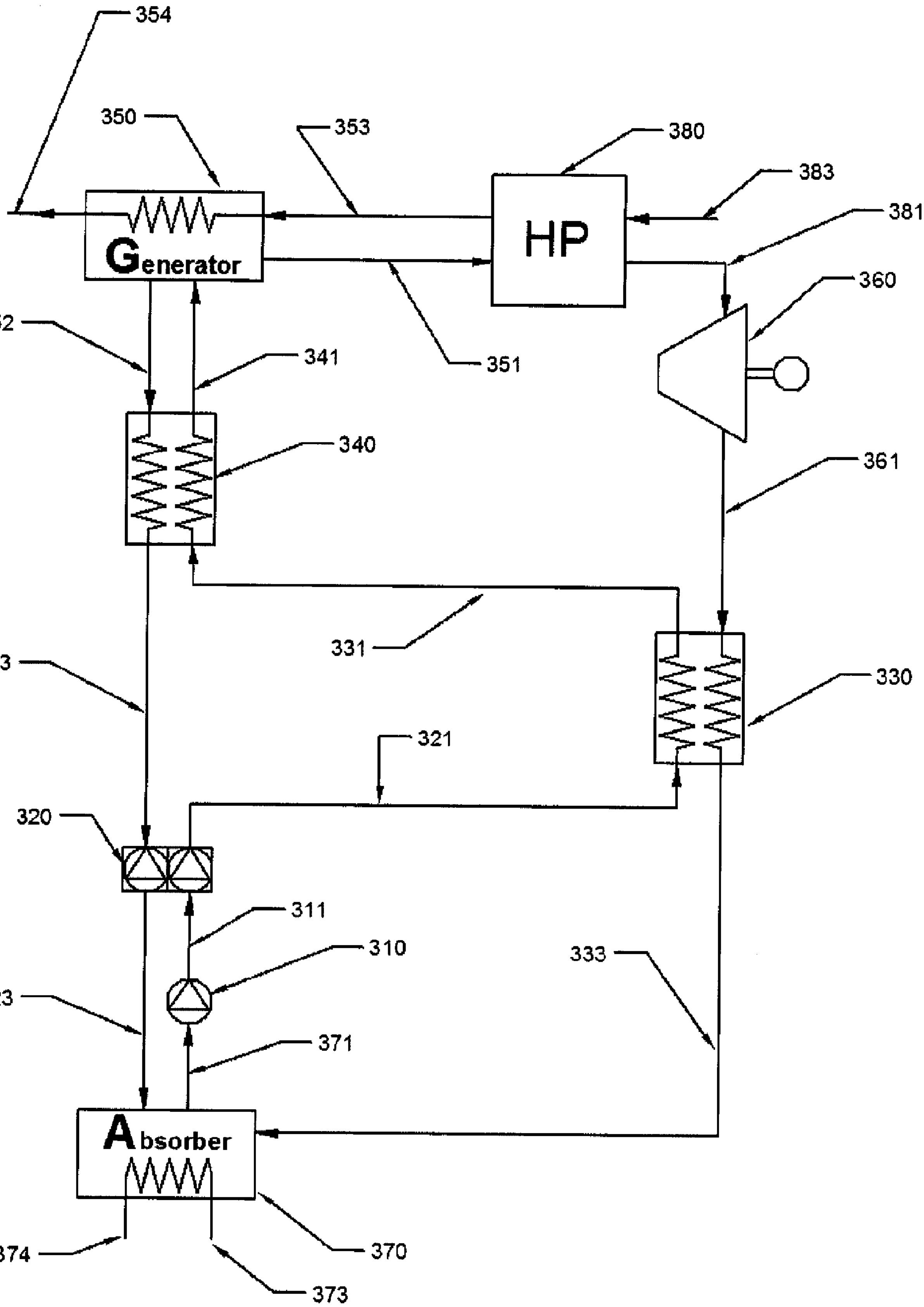
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FIG. 6.

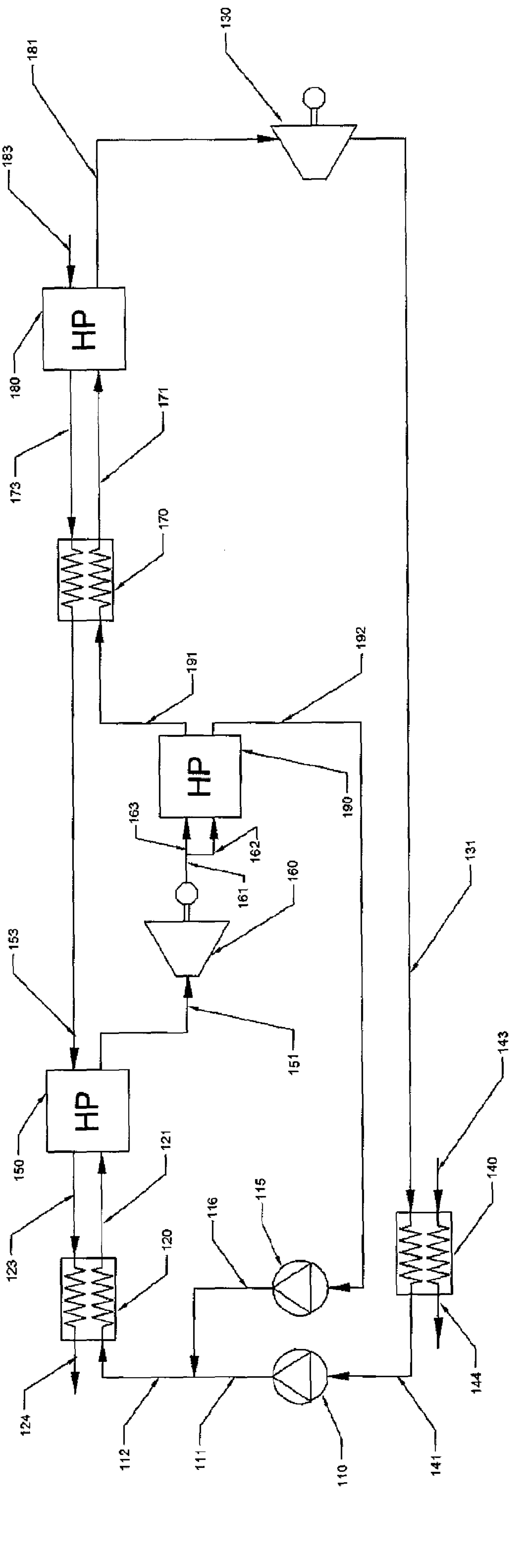
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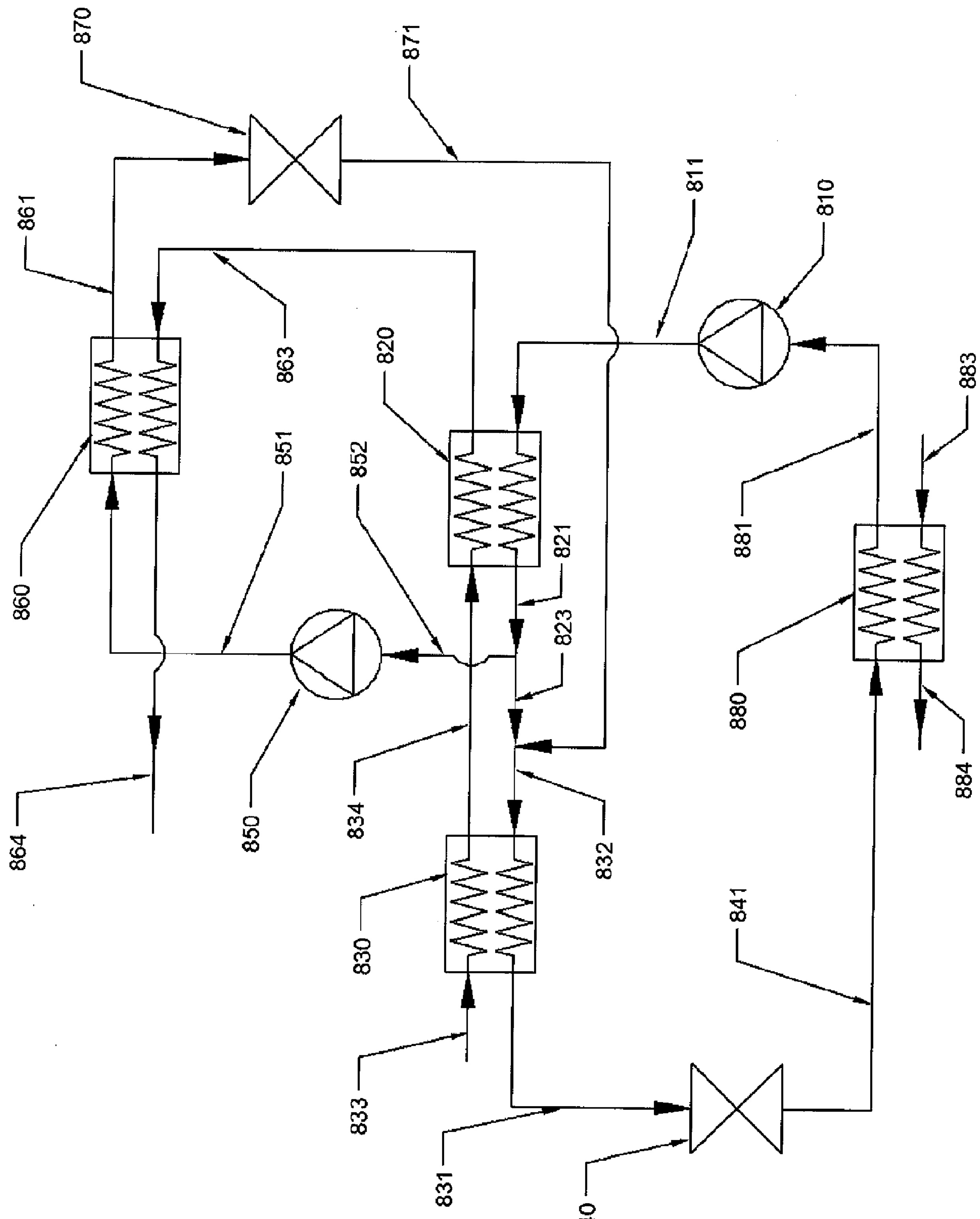
FIG. 7.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841
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831
840

FIG. 8.

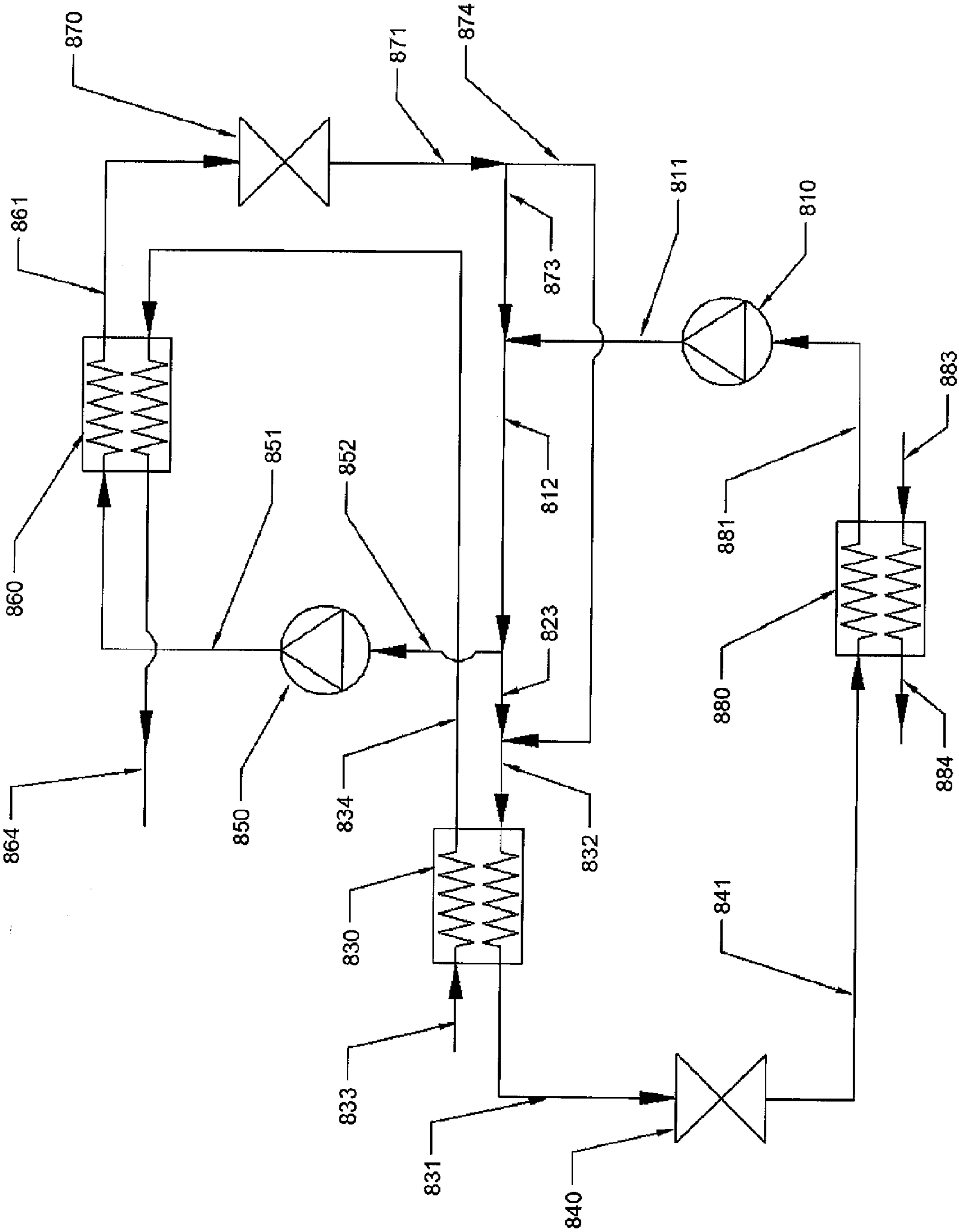
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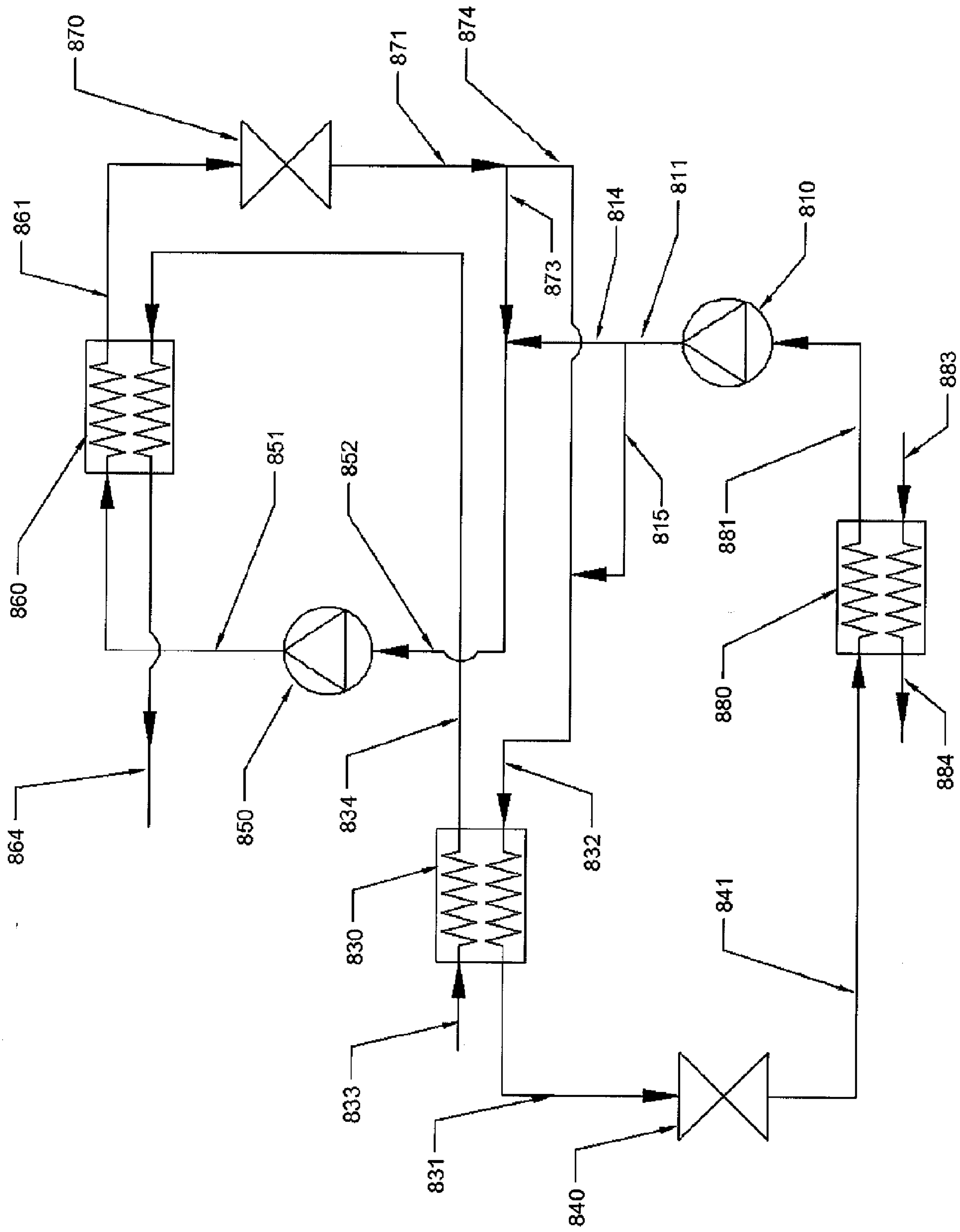
FIG. 9.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831
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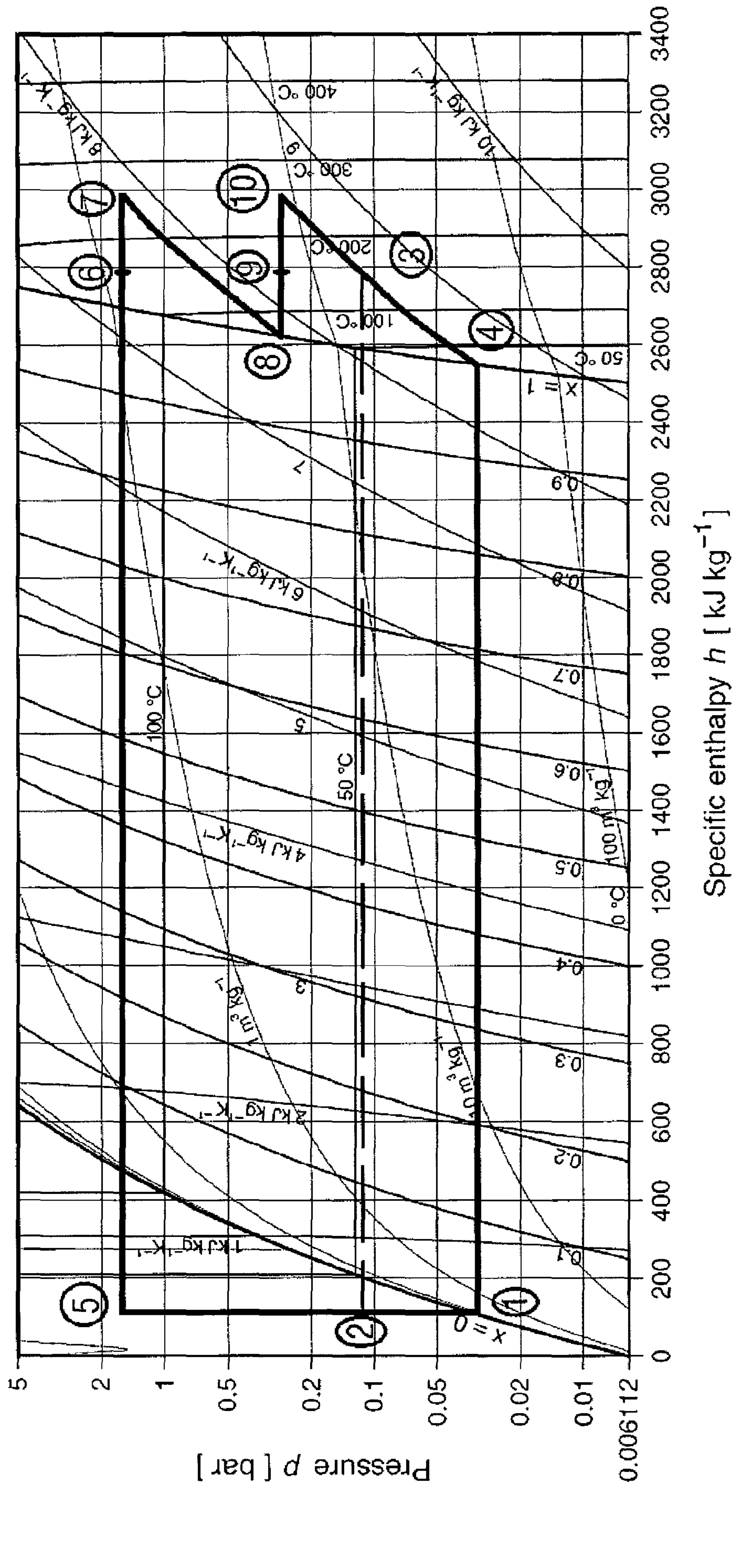
FIG. 10.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Specific enthalpy h [kJ kg^{-1}]
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x = 1
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50 °C
0 °C
200 °C
300 °C
400 °C
1 kJ kg^{-1}K^{-1}
2 kJ kg^{-1}K^{-1}
4 kJ kg^{-1}K^{-1}
6 kJ kg^{-1}K^{-1}
8 kJ kg^{-1}K^{-1}
10 kJ kg^{-1}K^{-1}
1 m^3 kg^{-1}
10 m^3 kg^{-1}
100 m^3 kg^{-1}
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0.2
0.3
0.4
0.5
0.6
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0.8
0.9
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FIG. 11.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EG2014/000014

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01K17/00 F01K25/06
ADD.

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)
F01K

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/324892 A1 (TAI CHANG-HSIEN [TW] ET AL) 27 December 2012 (2012-12-27) paragraphs [0019] - [0023]; figure 8 -----	1-13
X	WO 2013/171333 A2 (ATALLA NAJI AMIN [GB]) 21 November 2013 (2013-11-21) page 26, lines 9-27; figure 7 -----	1-13
X	US 6 769 256 B1 (KALINA ALEXANDER I [US]) 3 August 2004 (2004-08-03) paragraphs [0020] - [0021]; figures -----	1-13
X	US 2011/252796 A1 (BURKHART JAMES A [US]) 20 October 2011 (2011-10-20) paragraphs [0006], [0008], [0012], [0073] - [0074], [0094]; figures 1,3,5,14,18 -----	1-13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"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

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 November 2014	18/11/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Henkes, Roeland

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EG2014/000014

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2013171333 A2	21-11-2013
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		NI 200500131 A	17-02-2006
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		US 2004148935 A1	05-08-2004
US 2011252796 A1	20-10-2011	NONE	