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Method for Operating a Heat Pump

The invention relates to a method for operating a heat pump, wherein a fluid is conducted continuously in a fluid circuit, and thermal energy is thereby transferred from a heat source to the fluid in an evaporator, wherein the fluid is at least partially evaporated and is then compressed. The fluid is subsequently at least partially liquefied at a higher temperature level than the heat source for the purpose of releasing thermal energy to a heat sink and is then expanded for the purpose of cooling, wherein, in a partial-load operation, a first partial flow of the fluid is diverted via a first bypass line from the fluid circuit after the compression and before the liquefaction and is fed back to the fluid circuit downstream of the evaporator and before the compression. A method according to the invention is defined in Claim 1.

In heat pumps, thermal energy, i.e. heat, is absorbed from a heat source as a result of the evaporation of a fluid that circulates in the fluid circuit of the heat pump in a working direction and is released into a heat sink. In so doing, the fluid with the absorbed thermal energy is brought to an elevated level of pressure by means of a compressor and is then liquefied at a condensation temperature that is elevated compared to an evaporation temperature. The fluid is expanded in order to return it to its initial state at the end of the circuit, whereby its temperature falls again.

The efficiency of a heat pump is measured by a coefficient of performance (COP), wherein the COP is best expressed by the reciprocal efficiency of a Carnot process. The coefficient of performance corresponds to the ratio of benefit to cost. If the heat pump is used to heat the heat sink, this is equal to the quantity of heat Q_{warm} that is released to the heat sink divided by the energy expended

W_{mech} by the compressor. The greater the difference in magnitude (temperature lift) between the evaporation and condensation temperatures of the fluid, the lower the efficiency of the heat pump.

Ideally, the mass flow rate, the temperature level and the time availability of the heat source are nearly constant in order to ensure the consistent efficiency and performance of the heat pump. If the heat pump is operated with exhaust heat from industrial processes, fluctuations may occur in the three parameters. In these cases, when parameters are reduced, the heat pump must run at partial load to be able to utilize as much of the heat from the heat source as possible. During periods of reduced heat source output, a reduced volumetric flow rate of evaporated fluid flows from the evaporator. If the compressor unit of the heat pump has piston or screw compressors working according to the positive displacement principle, then prior art heat pumps of this type are adapted to the reduced volumetric flow rate of the evaporated fluid during partial-load operation, for example, by adapting the speed of the compressors. However, heat pumps that use exhaust heat from industrial processes often have turbo compressors as compression machines working according to the flow principle. Employing speed control with a frequency converter to adapt the operation of turbo compressors to a reduced volumetric flow rate of the gaseous fluid flowing out of the evaporator is possible only in a limited partial-load range (to approximately 90% of the volumetric flow rate). If the speed were reduced further, the flow on the pressure side of the turbo compressor could collapse, and a so-called surge could occur at the turbo compressor. This must be avoided so that the volumetric flow rate does not fall below a minimum volumetric flow rate that is dependent upon the operating point of the compressor. Providing the turbo compressors with an adjustable angle of attack of the inlet guide vanes (IGV) is also known for adapting the operation of turbo compressors to a reduced volumetric flow rate flowing out of the evaporator. By adjusting the inlet guide vanes, the volumetric flow rate can be throttled to approximately 70% of the volumetric flow rate at a constant pressure ratio. Furthermore, arranging a bypass line with at least one bypass valve is known for adapting the operation of heat pumps to a reduced volumetric flow rate of the fluid flowing out of the evaporator so that the fluid circuit downstream of the compressor unit and upstream of the condenser can be fluidically connected to the fluid circuit downstream of the evaporator and upstream of the compressor unit. The volumetric flow rate passing through the compressor unit can be adjusted by means of a bypass valve. However, the temperature of the suction gas (fluid in the inlet area of the compressor unit) is also increased by the partial flow flowing through the bypass line, and therefore so is the temperature of the compressed gas (fluid at the outlet of the compressor unit). Upper temperature limits are provided for both the fluid itself (due to thermal decomposition above a critical temperature) and the compressor materials (thermal stresses). These can vary depending upon the fluid and materials, wherein the lower of the two temperatures limits the portion of the fluid flow passing over the bypass line and thus also limits the range of the partial-load operation of the heat pump toward a low heat source output. US 2015/285539 A1 discloses a method for operating a heat pump, wherein a fluid is continuously conducted in a fluid circuit, and thermal energy is thereby transferred from a heat source to the fluid in an evaporator, wherein the fluid is at least partially evaporated and subsequently compressed. The fluid is then at least partially liquefied at a higher temperature level than the heat source in order to release thermal energy to a heat sink and is subsequently expanded for the purpose of cooling. After compression and prior to liquefaction, a first partial flow of the fluid is diverted through a first bypass line and returned to the fluid circuit downstream of the evaporator and prior to compression. After the partial liquefaction and upstream of the evaporator, the entire liquid fluid flow is diverted via a second bypass line, which is parallel to the evaporator. A second expansion valve and a second evaporator are arranged in this second bypass line, and so the fluid in the evaporated state is mixed with the first partial flow before compression.

The heat pump, which is not part of the invention, is designed for use in the method according to the invention. During partial-load operation of the heat pump, the fluid flowing through the second bypass line is mixed with the fluid flowing via the first bypass line and, in the process, evaporates. By admixing the liquid phase, the temperature of the first partial flow is reduced from the compressed gas temperature to a lower mixing temperature. The second partial flow, which is diverted via the second bypass line and would actually be fed into the evaporator if it were not diverted, is evaporated by means of the first partial flow according to the invention, without the heat source having to be used for this purpose. The mixing preferably takes place within the first bypass line by having the second bypass line open into the first bypass line. However, mixing can also take place within the fluid circuit downstream of the evaporator and upstream of the compressor unit by having the two bypass lines open into the fluid circuit in this area and the partial streams mix with each other there before entering the compressor unit. This alternative variant is especially suitable if the fluid circuit runs downstream of the evaporator to the compressor via a bypass, and an appropriately long path for the mixing of the two partial streams is available in this region of the fluid circuit.

The two bypass lines have at least one valve for partial-load operation, in the case of the first bypass line, and means for metering the flow rate, in the case of the second bypass line. The means for metering the flow rate in the second bypass line can be a pump and/or a valve, for example. The valves and/or the pump can be adjustable and/or controllable and/or regulatable and, for example, can be controlled and/or regulated by a control/regulating device of a heat pump system that comprises the heat pump.

The volumetric flow rates and their ratio to each other can be selected in relation to each other during the partial-load operation of the heat pump such that, at the beginning of, during and at the end of the compression, the form of the fluid is at least saturated vapor to superheated. This prevents slugging on the compressor when turbo compressors are used. The volumetric flow rates and their ratio to each other can be selected in relation to each other during the partial-load operation of the heat pump such that a material- or gas-dependent maximum temperature is not exceeded at the end of compression. This prevents the decomposition of the fluid and prevents damage to the material in the compressor unit due to excessive temperatures. The heat pump can be operated at partial-load operation with a higher volumetric flow rate and is thus especially well-suited for extending the partial-load range in heat pumps with at least one turbo compressor. Care must be taken with a turbo compressor to ensure a sufficiently high volumetric flow rate at the respective operating point of the turbo compressor, which should not fall below an operating point-dependent minimum volumetric flow rate so that the flow toward the pressure side of the compressor does not collapse. If the heat pump is operated with a heat source in which the output significantly fluctuates and can assume particularly low values at times, then according to one exemplary embodiment of the invention, a control/regulation unit can be provided, which, during partial-load operation, adjusts and monitors the volumetric flow rate via the bypass lines as well as the ratio of the two partial flows to each other in such a way that a material- or gas-dependent maximum temperature is not exceeded at the end of the compression process, and the heat pump is deactivated if the heat source output is too low. According to another example that is not claimed in the invention, these steps can be carried out in combination with speed adjustment and/or control and/or regulation of the compressors during the partial-load operation of the heat pump. In the case of turbo compressors, these steps can alternatively or additionally be carried in combination with the adjustment and/or control and/or regulation of the angle of attack of guide vanes.

In the heat pump, the compressor unit may comprise at least one compressor, wherein the compressor is a turbo compressor.

This embodiment is especially well-suited for heat pumps in industrial applications in the power range of more than 500 kW.

It may be possible in a heat pump that the expansion unit comprises at least two expansion devices connected in series, wherein a separator for separating a gas and liquid phase is interposed between the two expansion devices, wherein the second bypass line is fluidically connected to a region of the separator that is configured to accumulate the liquid phase.

The expansion device can be a throttle. A throttle creates a constriction of the flow path, and so the fluid expands while flowing through the constricted section as a result of the reduced pressure. The cross-section of the throttle can be adjustable. The separator that is arranged between the two expansion devices aids in improving the efficiency of the heat pump by supplying at least a part of the separated gaseous phase to the fluid circuit between two compression steps. According to the example not claimed in the invention, the second bypass line is fluidically connected to a region of the separator that is configured to accumulate the liquid phase. The separator can comprise a pressure vessel for separating the gas and liquid phase. The gaseous phase of the fluid accumulates in an upper region of the pressure vessel, and in this region the gaseous fluid can be sucked in through a feed line by the at least one compressor. The second bypass line can branch off from the lower region of the pressure vessel, for example.

The second bypass line can be fluidically connected to a region of the evaporator that is flooded during operation.

This embodiment is also suitable for heat pumps without a separator.

It may also be possible, in a manner 'not according to the invention, that the heat pump comprises means for superheating the fluid flowing out of the evaporator by means of a heat exchanger, which is configured such that it thermally connects fluid that is flowing out of the condenser, before it enters the expansion unit, with fluid flowing out of the evaporator before it enters the compressor unit, wherein the first bypass line opens into the fluid circuit downstream of the heat exchanger, and the second bypass line opens into the first bypass line or likewise into the fluid circuit downstream of the heat exchanger.

This embodiment allows for the use of high-temperature fluids with a positive slope of the condensation curve in a temperature-entropy diagram. In order to avoid entering a range of conditions of the fluid during compression of the fluid (both at full and partial load) in which droplet formation, and thus damage due to droplet impingement in the compressor unit, occurs, the fluid must be superheated before entering the compressor unit. The degree of superheating can be configured for full-load operation by the surface of the heat exchanger. For instance, the two bypass lines can open into the fluid circuit in the outlet area of the heat exchanger. For a start-up phase of the heat pump operation, a heat source with an external energy supply can be connected, which is arranged and configured to transfer heat to the fluid in the fluid circuit downstream of the heat exchanger and upstream of the compressor unit.

The problem addressed by the invention is that of providing a method of the aforementioned type for operating a heat pump, which allows for a range of partial-load operations extended in the direction of low heat source power.

According to the invention, the problem is solved by a method of the aforementioned type for operating a heat pump such that a liquid partial flow is diverted from the fluid circuit via a second bypass line after partial liquefaction and upstream of the evaporator and is mixed with the first partial flow before compression.

When the heat pump is in partial-load operation, the fluid flowing via the second bypass line is mixed with the fluid flowing via the first bypass line and evaporates in the process.

As a result of admixing the liquid phase, the temperature of the first partial flow is reduced from the compressed gas temperature to a lower mixing temperature. The second partial flow, which is diverted via the second bypass line and would actually be fed into the evaporator if it were not diverted, is evaporated by means of the first partial flow according to the invention, without the heat source having to be used for this purpose. The mixing preferably takes place within the first bypass line. To this end, the partial flow of liquid can be conducted into the first bypass line, for example by having the second bypass line open into the first bypass line. Additionally or alternatively, however, the mixing can also take place within the fluid circuit downstream of the evaporator and before the compression of the fluid by additionally or alternatively conducting the partial flow of liquid into the fluid circuit downstream of the evaporator and before the compression, for example by having the second bypass line additionally or alternatively open into the fluid circuit in this region.

Owing to the design of the method according to the invention, the heat pump can be operated at a higher volumetric flow rate in partial-load operation and is thus especially well-suited for extending the partial-load range in heat pumps with at least one turbo compressor. Care should be taken in a turbo compressor to ensure a sufficiently high volumetric flow rate at the operating point of each turbo compressor, which should not fall below an operating point-dependent minimum volumetric flow rate so that the flow towards the pressure side of the compressor does not collapse.

According to the invention, when the heat pump is in partial-load operation, the ratio of the first and second partial flow is set and/or controlled and/or regulated in such a way that, at the beginning of, during and at the end of the compression, the form of the fluid is at least saturated vapor to superheated.

This embodiment of the invention prevents damage caused by fluid in the compressor, in particular in a heat pump with at least one turbo compressor. In order to adjust and/or control and/or regulate the ratio of the first and second partial flows during partial-load operation, at least one valve can be provided in the case of the first bypass lines, and means for metering the flow rate, such as a pump and/or a valve, can be provided in the case of the second bypass line. The valves and/or the pump can be adjustable and/or controllable and/or regulatable and can, for example, be controlled and/or regulated by means of a control/regulating device. According to one exemplary embodiment of the invention, the adjustment and/or control and/or regulation of the volumetric flow rate can be carried out in combination with the adjustment and/or control and/or regulation of the speed of the compressors. In turbo compressors according to this exemplary embodiment, these steps can additionally be carried in combination with the adjustment and/or control and/or regulation of the angle of attack of guide vanes.

According to the invention, when the heat pump is in partial-load operation, the ratio of the first and second partial flow is set and/or controlled and/or regulated in such a way that a material- or gas-dependent maximum temperature is not exceeded at the end of the compression.

The invention is suitable for operating heat pumps having a heat source in which the output significantly fluctuates and occasionally requires the heat pump to be operated neat the limit of the operating range of the heat pump. The invention prevents a decomposition of the fluid as well as damage to the material in the at least one compressor used for compression due to excessive temperatures.

Advantageously, it is also possible that, in partial-load operation, the volumetric flow rate of the first and second partial flows is set and/or controlled and/or regulated in such a way that the volumetric flow rate does not fall below a minimum volumetric flow rate that is dependent upon the operating point of the compressor.

This embodiment of the invention is especially well-suited when a heat pump with at least one turbo compressor is used to carry out the method.

It may also be considered advantageous that the liquid partial flow is conducted into the first bypass line and/or into the fluid circuit downstream of the evaporator and before of the compression.

This embodiment of the invention permits the mixing of the two partial streams within the first bypass line and/or within the fluid circuit downstream of the evaporator and before the compression.

The mixing preferably takes place within the first bypass line. To this end, the partial flow of liquid can be conducted into the first bypass line, for example by having the second bypass line open into the first bypass line. Additionally or alternatively, however, the mixing can also take place within the fluid circuit downstream of the evaporator and before the compression of the fluid by additionally or alternatively conducting the partial flow of liquid into the fluid circuit downstream of the evaporator and before the compression, for example by having the second bypass line additionally or alternatively open into the fluid circuit in this region.

A further advantageous embodiment of the invention can provide that the heat pump is operated with a high-temperature fluid whose condensation curve substantially has a positive slope in a temperature-entropy diagram, and, after the liquefaction and before the expansion, the thermal energy of the fluid circuit is transferred to the fluid downstream of the evaporator and before the compression such that, at the beginning of, during and after the compression, the fluid is in a superheated state, wherein, in the partial-load operation, the first partial flow or alternatively both partial flows is/are fed to the fluid circuit after the transfer of the thermal energy.

The advantageous embodiment of the invention permits the heat pump to be operated with high-temperature fluids having a condensation curve with a condensation curve such as this and must therefore be superheated prior to compression in order to prevent damage to the compressor. The transfer of thermal energy can be carried out by means of a heat exchanger. A degree of superheating can be established by the configuration of the heat exchanger surface. For example, it can be selected such that, both at full load and at partial load, the fluid after compression is in a state that maintains a safety margin (temperature difference) from the condensation curve.

Moreover, it can be advantageously provided that the expansion takes place in at least two expansion steps, wherein a gas phase of the fluid is separated from a liquid phase of the fluid, at least between two expansion steps, and the liquid partial flow is diverted from the liquid phase.

The separation of a gas phase from a liquid phase, which takes place between two expansion steps, aids in improving the efficiency of the heat pump by supplying at least a part of the separated gaseous phase to the fluid circuit between two compression steps. In the embodiment according to the invention, the separated liquid phase, which would otherwise be supplied in its entirety to the evaporator, is partially diverted via the second bypass line as a second partial flow.

It may also be considered advantageous that the liquid partial flow is diverted from a flooded region of the evaporator.

This embodiment of the invention is also well-suited for the operation of heat pumps without separators.

Further advantageous embodiments and advantages of the invention are the subject matter of the description of exemplary embodiments of the invention with reference to the figure in the drawing, wherein the same reference signs refer to components that function in the same way.

The following is shown:

Fig. 1 schematically shows a fluid circuit of a heat pump according to the prior art;

Fig. 2 schematically shows a temperature-entropy diagram of the fluid R134a with a plotted state history during the fluid circuit illustrated in Figure 1 of a heat pump according to the prior art;

Fig. 3 schematically shows a temperature-entropy diagram of a fluid having a condensation curve with a substantially positive slope and a plotted state history of the fluid during passage through the fluid circuit illustrated in Figure 1 of a heat pump according to the prior art;

Fig. 4 schematically shows a fluid circuit of a heat pump that is included in the invention, according to an example; and

Fig. 5 schematically shows a flow chart of a method according to an exemplary embodiment of the invention.

Figure 1 schematically shows a fluid circuit 21 of a heat pump 12 according to the prior art. The fluid 2 is conveyed through the heat pump 12 in a flow direction 11. An evaporator 10 evaporates the fluid while absorbing thermal energy from the heat source 4, and so it assumes a vapor state 1. In this vapor state 1, the fluid 2 enters a compressor unit 7, which comprises a compressor 7a, and is compressed into a compression state 3. In the compression state 3, it flows into a condenser 8 while releasing thermal energy into the heat sink 20 and is converted into a condensed state 5, and it is finally expanded in an expansion unit 9, which comprises an expansion device 9a. As a result, the fluid 2 takes on an expansion state 6, whereupon it is supplied to the evaporator 10. The fluid is thus continuously conveyed through the heat pump 12 in the direction of flow 11 during operation of the heat pump 12, and, in the process, it absorbs heat from the heat source 4 during evaporation in the evaporator 10 and, during liquefaction in the condenser 8, releases thermal energy into the heat sink 20 at a temperature level higher than that of the heat source 4.

Figure 2 shows a temperature-entropy diagram 23, which illustrates an entropy 14 corresponding with the image plane to the right, i.e. on the abscissa axis, and a temperature 13 on the image plane upward, i.e. on the ordinate axis. The temperature-entropy diagram 23 illustrates both a condensation curve 18, a boiling curve 19, and different physical states of a fluid. The condensation curve 18 delimits a gas phase 15 from a two-phase region 16, wherein the fluid is present in both liquid and gaseous states in the two-phase region 16. The boiling curve 19 delimits the two-phase region 16 from a liquid phase 17. The illustrated temperature-entropy diagram 23 shows a condensation curve 18 of a fluid with a substantially negative slope.

Likewise shown schematically in Figure 2 are various thermodynamic states of the fluid that the fluid assumes as it passes through the fluid circuit illustrated in Figure 1 of a heat pump according to the prior art. Starting from the vapor state 1, the compression state 3 is achieved by compression in the flow direction 11. The compression state 3 is within the gas phase 15 and, if it were configured as a turbo compressor, the compressor 7a would therefore not be damaged by slugging as a result of droplet formation in the fluid. The connecting lines illustrated between the individual states are shown in Figure 2 and Figure 3 as straight connecting lines, but they can also deviate from this ideal curve. Starting from the condensed state 3, the condensed state 5, which is on the boiling curve, is set by the condenser 8. Starting from the condensed state 5, the expansion state 6 is achieved by the passage of the fluid through the expansion device 9a, and the vapor state 1 of the fluid is subsequently achieved by supplying energy to the evaporator 10. The circuit of the heat pump 12 is thus closed.

Like Figure 2, Figure 3 shows a temperature-entropy diagram 24, but for a different fluid. The course of the boiling curve 19 and the condensation curve 18 of the fluid delimits a prominently overhanging two-phase region 16, and so the condensation curve 18 has a substantially positive slope. If a fluid of this type is circulated in the fluid circuit of the prior art heat pump illustrated in Figure 1, the compression state 3 will lie within the two-phase region 16. In the case of a turbo compressor, damage caused by slugging can consequently occur in the compressor 7a.

Figure 4 schematically shows a fluid circuit 28 of a heat pump 26 according to an example that is not included in the invention.

A compressor unit 7 with two compressors 7a, 7b is arranged in the fluid circuit 28 downstream of an evaporator 10 in the direction of flow. The compressors 7a and 7b are arranged in series and can be configured as turbo compressors. Downstream of the compressor unit 7, the fluid circuit 28 comprises a condenser 8 and then an expansion unit 9 with two expansion devices 9a, 9b that are arranged in series. The expansion device 9a and/or 9b can be configured as a throttle or, for example, as an expansion valve. The fluid circuit 28 of the heat pump 26 additionally comprises means 34 with a heat exchanger 32 for superheating the fluid flowing out of the evaporator 10. The heat exchanger 32 is designed such that it thermally connects the fluid flowing out of the condenser 8 before entering the expansion unit 9 to the fluid flowing out of the evaporator 10 before entering the compressor unit 7. In addition, a separator 30 for separating a gas and liquid phase is interposed between the two expansion devices 9a and 9b by a gas phase inlet 36 that opens into the fluid circuit 28 between the two compressors 7a and 7b. To ensure sufficient superheating of the fluid that is flowing out of the evaporator 10 during a start-up phase, the means 34 additionally comprise a heating device 38 that can be activated and can be heated by an external energy source 40. For operation at partial load, the heat pump 26 has a first bypass line 42 with a bypass valve 43, and so the fluid circuit 28 downstream of the compressor unit 7 and upstream of the condenser 8 is fluidically connected to the fluid circuit 28 downstream of the evaporator 10 and upstream of the compressor unit 7, as well as a second bypass line 45. The second bypass line has means 46 for metering the flow rate, which are configured as a valve 47. The second bypass line 45 branches off from the separator 30 and opens into the first bypass line 42 such that a liquid phase of the fluid diverted from the separator 30 can be introduced into the first bypass line 42 via the second bypass line 45.

Alternatively, the second bypass conduit 45 could branch off from a flooded area 49 instead of from the separator. This alternative course of the second bypass line is not illustrated in the figure.

The ratio of the partial flows flowing via the bypass lines during partial-load operation can be set and/or controlled and/or regulated by means of the valve using means for metering a flow rate in such a way that the fluid is in a form that is at least saturated vapor to superheated at the beginning (vapor state 1b), during (compression states 3a and 3b) and at the end of compression (compression state 3c), and a material- or gas-dependent maximum temperature is not exceeded at the end of the compression process (compression state 3c).

In contrast to the fluid circuit illustrated in Figure 1, the heat pump 26 that is not included in the invention makes it possible for the heat pump to be operated at lower heat source outputs. Moreover, the illustrated exemplary embodiment permits the use of a high-temperature fluid with a positive condensation curve slope in conjunction with a high coefficient of performance.

Figure 5 schematically illustrates in a flow chart an exemplary embodiment of the method according to the invention, wherein a fluid with a condensation curve that has a substantially positive slope in a pressure-enthalpy diagram is selected and used in a preparatory process step VS1 for operating the heat pump.

In a preparatory process step VS2, the superheating of the fluid in the fluid circuit is selected – e.g. by configuring the surface of the heat exchanger – in such a way that the distance to the condensation curve at the compressor end point is at least 10K, in particular 10K to 20K.

In a preparatory process step VS3, data for a partial-load operation, in particular the maximum temperature of the compressed gas that is to be maintained and the operating-point-dependent minimum volumetric flow rates in the compressor unit that are to be maintained, are transferred to a control/regulation unit.

In a process step VS4, a heating device for superheating the fluid is connected during a start-up phase of the operation of the heat pump. In a method step VS5, thermal energy is transferred from a heat source to a fluid in an evaporator, wherein the fluid is at least partially evaporated. In a process step VS6, the fluid is superheated after the transfer of the thermal energy and before compression, and, in the process, the thermal energy of the fluid that is leaving the condenser is extracted before expansion and is transferred to the fluid leaving the evaporator before compression.

In a method step VS7, the fluid is subsequently compressed in a first compression step.

In a method step VS8, the compressed fluid is compressed in a second compression step.

In a method step VS9, the fluid is at least partially liquefied in order to release thermal energy to a heat sink at a temperature level higher than that of the heat source. In a process step VS10, the fluid is expanded for cooling in a first expansion step. In a process step VS11, a gaseous phase of the fluid is separated from a liquid phase of the fluid, and the gaseous fluid is supplied at least in part to the fluid between at least two compression steps. In a process step VS12, the fluid is expanded in a second expansion step and is again supplied to the evaporator, and the fluid circulating in the fluid circuit of the heat pump continuously cycles through process steps VS5 to VS12. If the heat pump is operated in partial-load operation, then process steps VS13 and VS14 are also continuously repeated. In process step VS13, a first partial flow of the fluid is diverted through a first bypass line and returned to the fluid circuit downstream of the evaporator and prior to compression, and a liquid second partial flow is diverted from the fluid circuit through a second bypass line after partial liquefaction and upstream of the evaporator and is mixed with the first partial flow. Furthermore, depending upon the current volumetric flow rate in the vapor state 1a, the current temperature in the compression state 3c and the current volumetric flow rate in the vapor state 1b, the volumetric flow rates through the two bypass lines and their ratio to each other are controlled in such a way that the fluid is in a form that is at least saturated vapor to superheated at the beginning, during and at the end of compression, and the maximum temperature at the end of compression is not exceeded, and the volumetric flow rate does not fall below a minimum volumetric flow rate, which is dependent upon the operating point of the compressor. In process step VS14, a verification is carried out as to whether all of the conditions of process step VS13 can currently be met. If not, then the heat pump is deactivated in process step VS15 because the heat source has insufficient power. If so, then process step VS13 is repeated.

Patentkrav

1. Fremgangsmåde til drift af en varmepumpe, hvorved en fluid føres kontinuerligt i et fluidkredsløb og varmeenergi herved overføres fra en varmekilde til fluiden i en fordamper, hvorved fluiden i det mindste delvist fordampes (VS5) og fluiden derefter komprimeres (VS7, VS8) og derefter med henblik på afgivelse af varmeenergi til en varmeafleder gøres i det mindste delvist flydende (VS9) på et højere temperaturniveau end varmekilden og derefter ekspanderes (VS10, VS12) med henblik på afkøling, og en første delstrøm af fluiden forgrenes fra fluidkredsløbet i en delbelastningsdrift efter komprimeringen og før flydendegørelsen via en første bypass-ledning og føres tilbage igen til fluidkredsløbet nedstrøms af fordamperen og før komprimeringen, og en flydende anden delstrøm forgrenes fra fluidkredsløbet i delbelastningsdriften efter den delvise flydendegørelse og opstrøms af fordamperen via en anden bypass-ledning og blandes med den første delstrøm før komprimeringen,
hvorved
forholdet mellem den første og anden delstrøm indstilles og/eller styres og/eller reguleres på en sådan måde, at fluiden ved begyndelsen, under og ved slutningen af komprimeringen i det mindste er mættet, dampformet til overophedet, og at en materiale- eller gasafhængig maksimumstemperatur ikke overskrides ved slutningen af komprimeringen.

2. Fremgangsmåde ifølge krav 1,
hvorved
volumenstrømmen af den første og anden delstrøm indstilles og/eller styres og/eller reguleres på en sådan måde, at en minimumsvolumenstrøm, der er afhængig af kompressorens driftspunkt, ikke underskrides.

3. Fremgangsmåde ifølge et af kravene 1 eller 2,
hvorved

den flydende delstrøm ledes ind i den første bypass-ledning (42) og/eller ind i fluidkredsløbet nedstrøms af fordamperen (10) og før komprimeringen.

4. Fremgangsmåde ifølge et af kravene 1 til 3,
hvorved
varmepumpen (12, 26) drives med en højtemperaturfluid, hvis dugpunktslinje (18) har i det væsentlige en positiv stigning i et temperatur-over-entropi-diagram (23, 24), og fluidkredsløbets varmeenergi efter flydendegørelsen og før ekspansionen overføres til fluiden nedstrøms af fordamperen og før komprimeringen, således at fluiden er overophedet (VS6) ved begyndelsen af, under og efter komprimeringen, hvorved den første delstrøm eller alternativt begge delstrømme i delbelastningsdriften overføres til fluidkredsløbet efter overførslen af varmeenergien.

5. Fremgangsmåde ifølge et af kravene 1 til 4,
hvorved
ekspansionen sker i mindst to ekspansionstrin, hvorved der mindst mellem to ekspansionstrin separeres (VS11) en gasfase af fluiden fra en flydende fase af fluiden, og den flydende delstrøm forgrenes fra den flydende fase.

6. Fremgangsmåde ifølge et af kravene 1 til 4,
hvorved
den flydende delstrøm forgrenes fra et oversvømmet område af fordamperen.

FIG 1
(Prior Art)

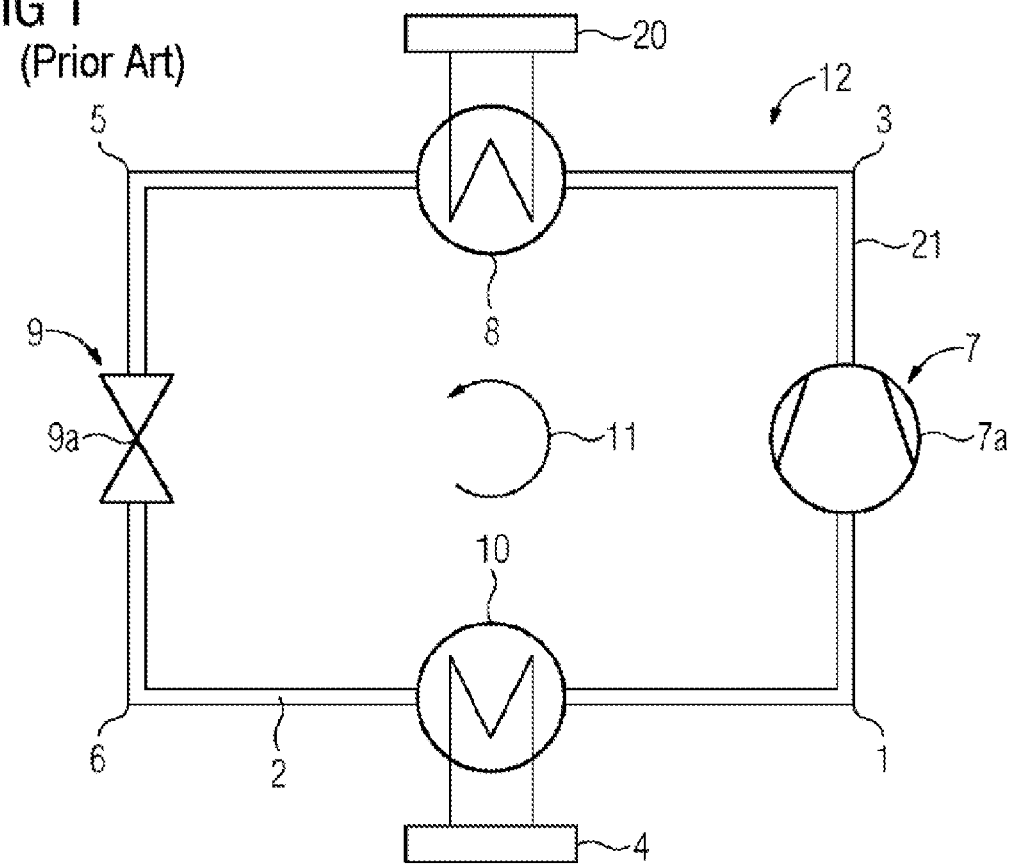


FIG 2
(Prior Art)

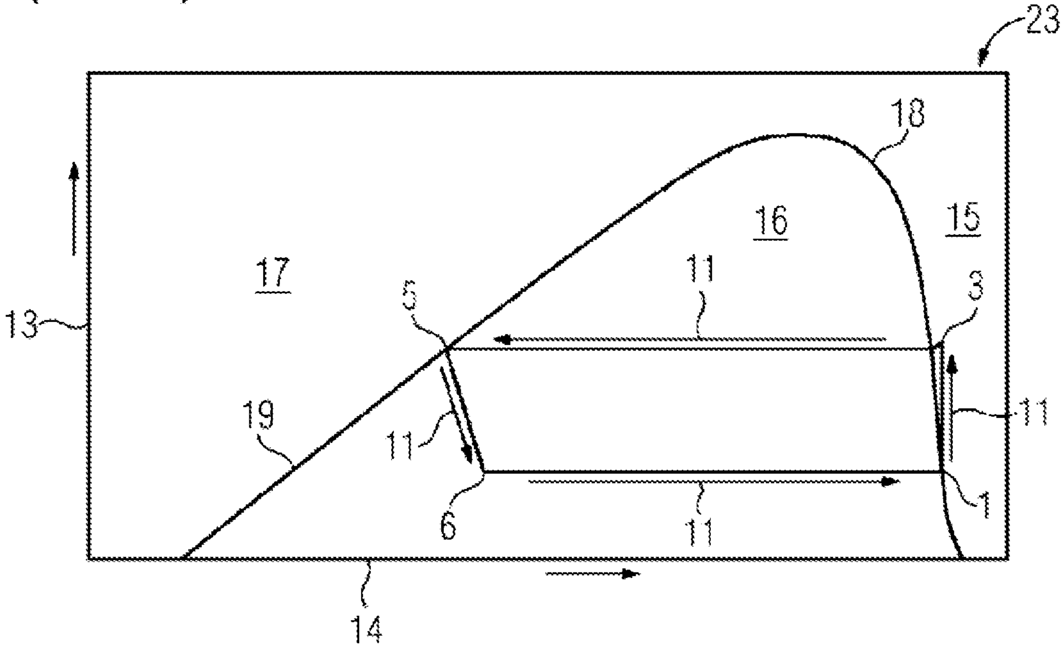


FIG 3
(Prior Art)

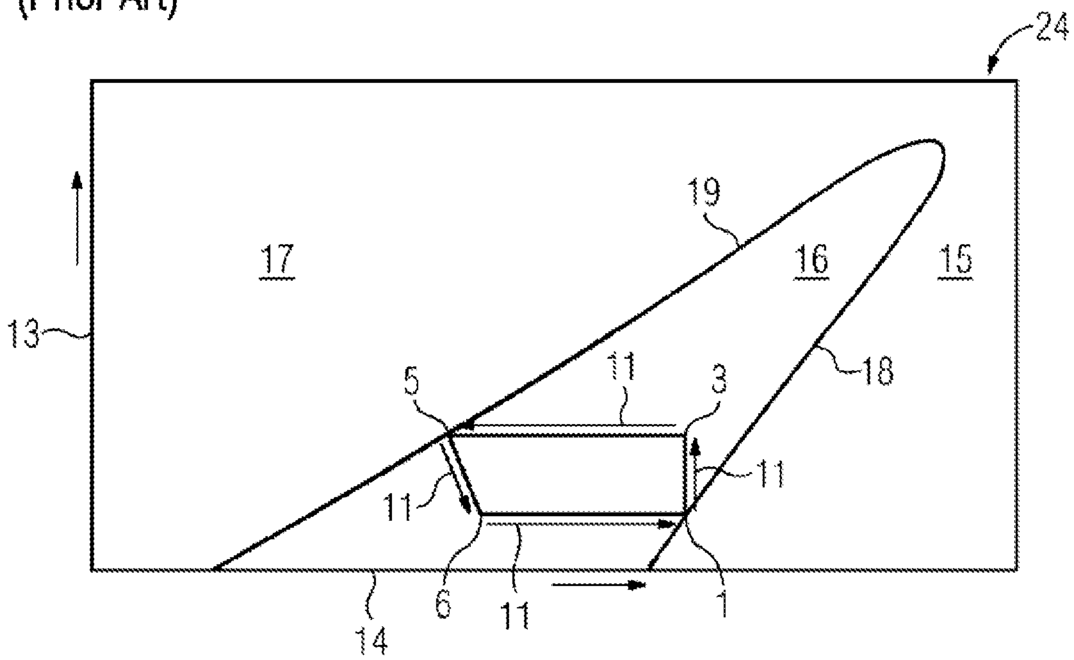


FIG 4

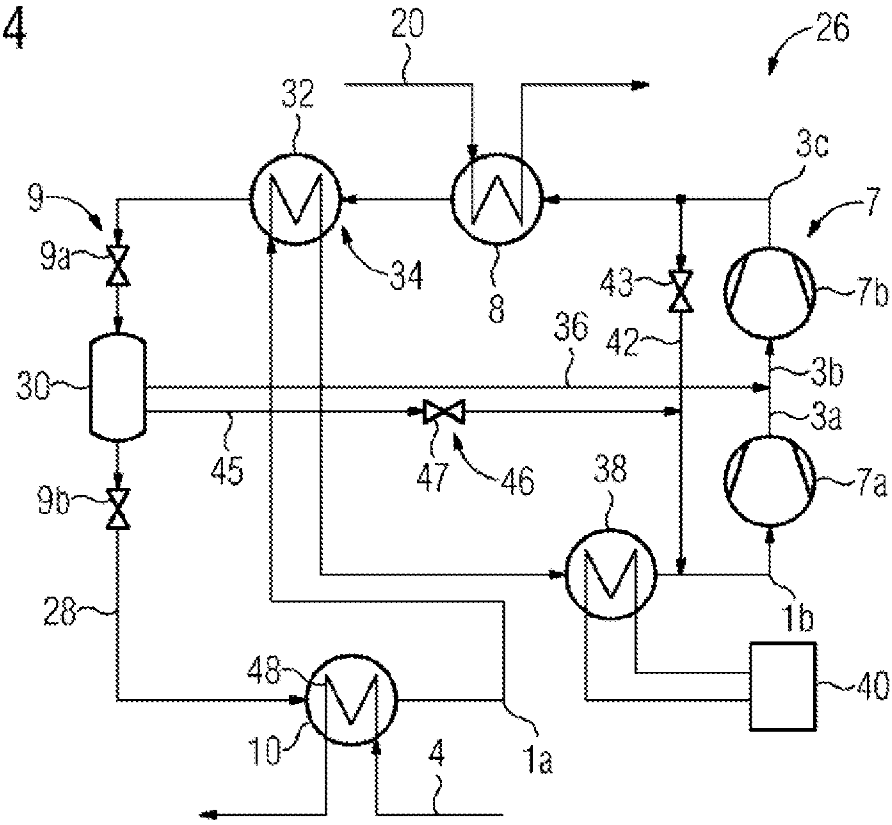
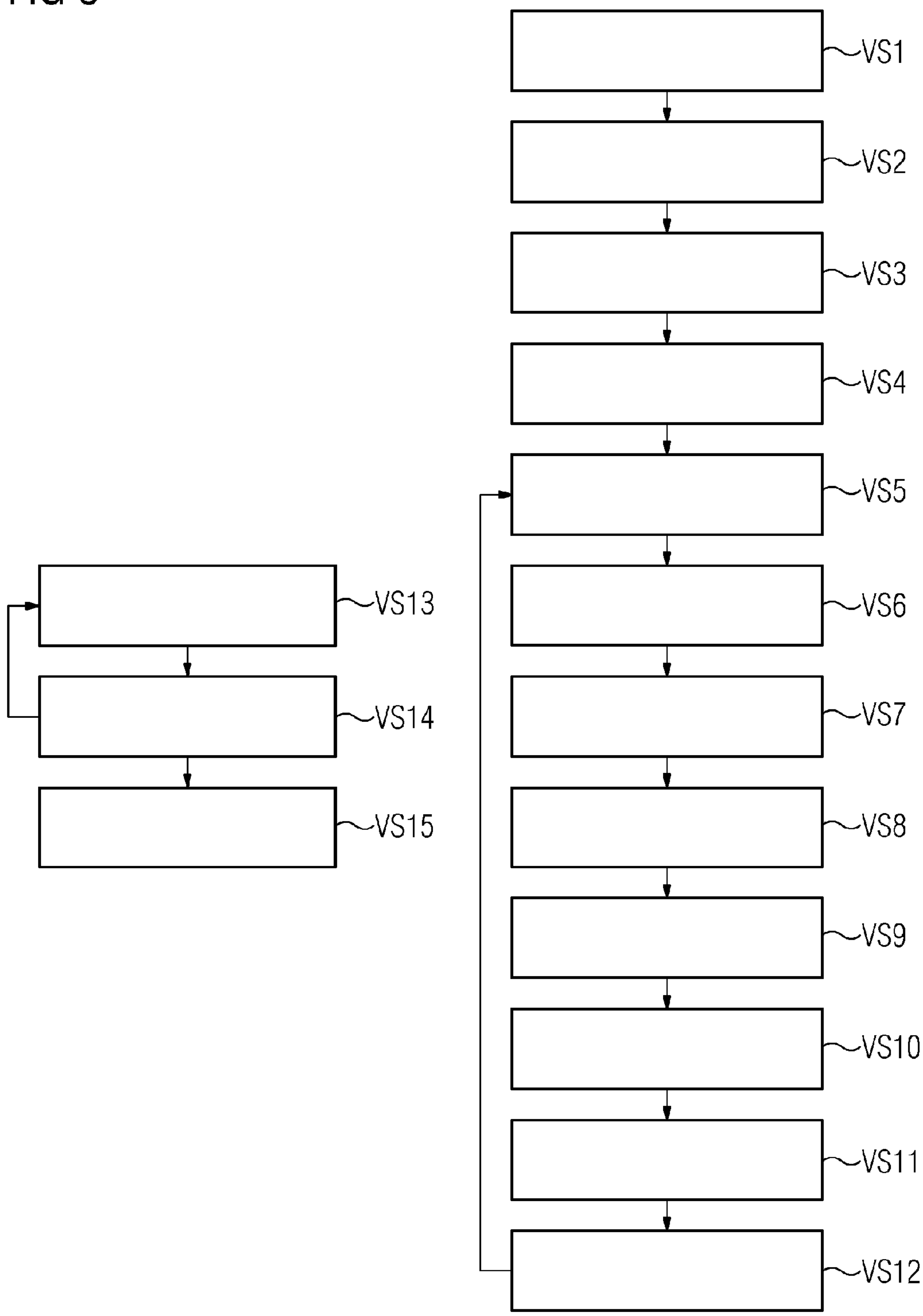


FIG 5


VS1
VS2
VS3
VS4
VS5
VS6
VS7
VS8
VS9
VS10
VS11
VS12
VS13
VS14
VS15