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(54) **Refrigerating plant with ejector**

(57) The invention relates to a refrigerating plant with ejector, operating with a refrigerant according to a vapour compression cycle and comprising in a main circuit 100A:
- a condenser 110; - a first 111 and a second expansion device 113 positioned downstream of the condenser 110;
- a first receiver of liquid 112 positioned between the two expansion devices in which the refrigerant separates into the liquid phase and the vapour phase; - an evaporator 114 positioned downstream of the second expansion device 113; - at least one primary compressor 115 posi-

tioned downstream of the evaporator 114 and upstream of the condenser 110. The plant comprises in a secondary branch 100B an ejector 116 which takes the refrigerant in output from the condenser as a driving flow and as a driven flow the refrigerant in vapour phase from the first receiver and is connected in output between the evaporator and the condenser. The present invention relates to a refrigerating plant with a triple compression stage, the intermediate stage being realised by means of an ejector.

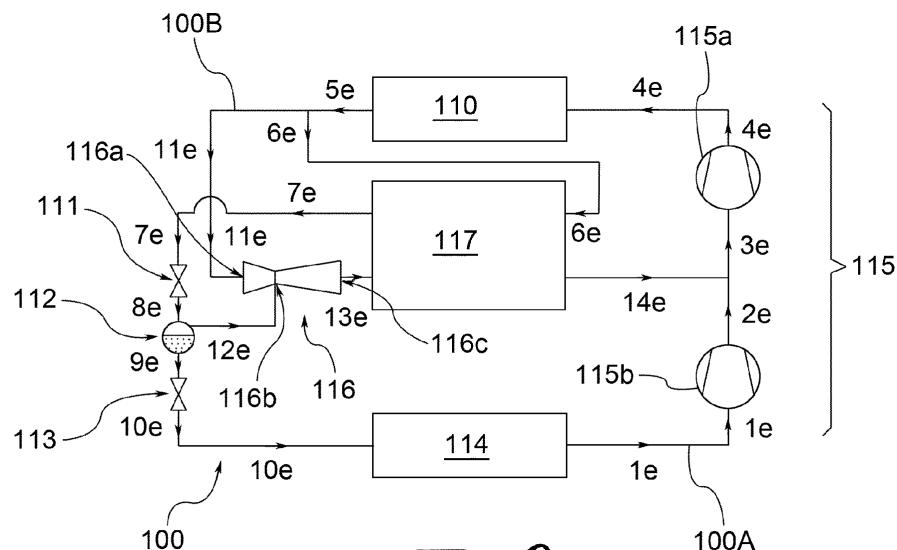


Fig. 9

Description

Field of application

[0001] The present invention relates to a refrigerating plant with ejector,

[0002] The refrigerating plant according to the invention has applications in the refrigerating and air conditioning sectors and possibly also in the more specific heat pump sector.

[0003] In particular, the plant has applications both in refrigerated cabinets with incorporated refrigerator (known in the sector as plug-in cabinets), and in large-sized plants such as refrigerating stations serving a number of refrigerated cabinets in parallel.

State of the art

[0004] As is known, a vapour compression refrigerating plant (or heat pump) of the conventional type makes it possible to transfer heat from a cold source to a hot source by means of a refrigerant fluid operating according to a thermodynamic cycle which provides in sequence for an evaporation stage, a compression stage, a cooling stage and an expansion stage. To such purpose the plant is composed of a closed circuit comprising an evaporator, a compressor, a condenser or gas cooler and an expansion device positioned in series.

[0005] The refrigerant fluid absorbs heat from the cold source (ambient to be cooled) in the evaporator passing to the vapour state. The fluid is then brought to a higher pressure level in the compressor, to transfer heat to the hot source inside the condenser or gas cooler, to return, lastly, to the evaporator flowing through the expansion device.

[0006] The section of circuit comprised between the compressor and the inlet of the expansion device is defined as the high pressure side of the circuit, while the section of circuit comprised between the outlet of the expansion device and the inlet of the compressor is defined, instead, as the low pressure side of the circuit.

[0007] As is known, a compression plant may operate according to a sub-critical cycle or alternatively according to a trans-critical cycle.

[0008] A sub-critical cycle is when the pressure at which heat is transferred to the hot source is below the critical pressure of the refrigerant fluid. In this case, during the cooling stage the refrigerant fluid comes to find itself in (two-phase) conditions of liquid-vapour equilibrium and the heat exchanger performing such stage functions as a condenser. In the high pressure branch of the plant a univocal relationship thus exists between the pressure and the temperature.

[0009] A trans-critical cycle is when the pressure is higher than the critical pressure of the refrigerant fluid. In this case, during the cooling stage the refrigerant fluid is in super critical (single-phase) conditions and may only undergo cooling without a phase change. The heat ex-

changer which performs such cooling stage functions as a gas cooler and not as a condenser. A univocal relationship cannot therefore exist between the pressure and the temperature in the high pressure branch of the plant, these variables being able to assume values independently of each other.

[0010] The plant solution described above comprises an additional heat exchanger as shown in Figures 1 and 2. More specifically, the refrigerant fluid is compressed (point 2a) by the compressor C, cooled at constant pressure in the condenser/gas cooler D (point 3a) and sub-cooled by a heat exchanger E (Suction Line Heat exchanger, SLHX) to increase its refrigerant capacity (point 4a); the flow of refrigerant is throttled in a throttling device B (point 5a) and sent to the evaporator A (point 6a). In output from the evaporator the refrigerant is superheated (1) to be able to sub-cool the refrigerant in output from the condenser/gas cooler in the SLHX.

[0011] The advantages of this plant solution are as follows:

[0012] - simple configuration with reduced number of components,

[0013] - possibility of using inexpensive components: tube in tube SLHX and capillary tube as throttling device,

[0014] - possibility of introducing a two stage compressor as primary compressor group.

[0015] However, by not providing for the presence of a receiver of liquid, which acts as storage and reservoir, this plant solution has the drawback of not permitting inclusion of a removal system of the steam formed by the throttling (hereinafter simply referred to as "flash gas"), which would permit an improvement in the performance of the cycle.

[0016] In trans-critical CO₂ plants, the receiver of liquid becomes a two-phase receiver and both to avoid the danger of over pressures and to improve the energy performance of the cycle, it is common practice to remove the flash gas with a dedicated removal system which controls the pressure inside the receiver.

[0017] Generally the flash gas is bled, throttled and added to the main flow in output from the evaporator. This solution is however of limited energy efficiency.

[0018] According to a possible alternative plant solution, the flash gas is returned to the high pressure side, upstream of the condenser, by means of an auxiliary compressor, as envisaged for example in the Italian patent IT1351459 in the name of Costan S.p.A.

[0019] More specifically, as shown in Figures 3 and 4, such configuration with auxiliary compressor provides for the subdivision of the throttling process into two stages and the use of a compressor for the extraction of the flash gas vapour which is generated after the first throttling (throttling which brings the refrigerant to an intermediate pressure). The refrigerant (point 3d) passes through the condenser/gas cooler D to be cooled; in output (point 4b) it undergoes a first throttling in a back pressure valve B1 (point 5b), downstream of which a receiver F is located, in which the condition of equilibrium between vapour and

liquid occurs. The two phases are separated. The liquid (point 6b) proceeds towards the evaporator A (point 7b) after being further throttled in a second back pressure valve B2, and subsequently towards the primary compressor C1 (point 1b), while the vapour is compressed in an auxiliary compressor C2 (point 8b). The outlets of the two compressors (points 2b and 9b), are mixed before input to the condenser/gas cooler D (point 3b).

[0020] This plant solution has some advantages:

[0021] - possibility of replacing the traditional systems wherein the flash gas is removed with a throttling device and brought to the conditions (1) and re-compressed in the main compressor group; therefore with an auxiliary compressor system, the main group compresses less flow than the traditional systems with a consequent energy saving.

[0022] - possibility of introducing a two stage compressor as primary compressor group.

[0023] This plant solution has some drawbacks however:

[0024] - compared to the single compression stage configuration it requires an additional compressor, a phase separator and two back pressure valves in place of one, with an increase in costs and plant complexity;

[0025] - difficulty of application to cabinet systems with incorporated refrigerator group (hereinafter simply plug-in): in the auxiliary compressor in fact volumetric flows which may be even 10-20% of those circulating in the primary compressor group may circulate; the reduced sizes of the plug-in systems would require use of auxiliary compressors of such a small size that as of today they cannot be found on the market.

[0026] The need therefore exists in the refrigeration sector to perform a removal of flash gas in a more efficient manner from an operating point of view and in a less expensive and complex manner as regards plant design.

[0027] In general to improve the efficiency of refrigerating plants, plants provided with an ejector have been proposed.

[0028] The ejector is a machine without moving parts which can be used both as a compressor and as a pump to obtain a raising of the pressure of a fluid by supplying a fluid (of the same type or different) at different pressure and temperature conditions. The ejector works according to a basic principle, according to which when a fluid with a high momentum encounters one with a low momentum, it raises the pressure thereof. The fluid with greater momentum (high pressure) is called the primary flow or driving flow, while the fluid with lesser momentum (low pressure) is called the secondary flow or driven flow. The ejector has a structure with a first converging element, followed by a throat and then by a divergent element (diffuser). The internal energy possessed by the primary flow is transformed into kinetic energy. The effect is to lower the pressure to aspirate the secondary flow. Mixing takes place in the convergent section of the ejector and the speed of the two flows becomes uniform. Downstream, in the throat section, a normal shock wave is

generated which causes a violent transformation from kinetic energy to pressure energy. The outgoing flow obtained is generally a uniform two-phase mixture. The normal shock wave modifies stagnation pressure, lowering it. This reduces the efficiency of the ejector. An alternative to the normal wave is the oblique wave which consists of a less violent transformation which generates a loss of stagnation pressure on the normal component only of the flow crossing it.

[0029] A known plant solution provides for the use of an ejector on the low pressure side (low side) to increase the pressure of the vapour in output from the evaporator thereby reducing the work of the compressor. The plant diagram of this configuration is described in figures 5 and 6. The primary flow (driving flow) in input to the ejector G is the refrigerant in output from the condenser D (gas cooler), while the secondary flow (driven flow) in input to the ejector is the refrigerant in output from the evaporator A. In this configuration, due to the presence of a two-phase liquid-vapour flow at the output of the ejector, a phase separator F needs to be positioned, which separates the saturated liquid to be sent to the back pressure valve B which feeds the evaporator A, from the saturated vapour, to be sent to the compressor C. A plant of this type is described in the British patent GB1132477.

[0030] Another plant solution provides for the use of an ejector on the high pressure side (high side) to increase the pressure of the vapour in output from the compressor thereby reducing the work of said compressor. The plant diagram of this configuration is described in Figures 7 and 8. The primary flow (driving flow) in input to the ejector G is the refrigerant in output from a pump P fed by a fraction of refrigerant (in liquid phase in the case of a sub-critical work cycle, otherwise gaseous for a trans-critical work cycle) in output from the condenser D (gas cooler in the case of a trans-critical work cycle), while the secondary flow (driven flow) in input to the ejector G is the vapour in output from the compressor C. In this configuration, an active component such as the pump P must be provided to enable the primary flow to effectively drive the secondary flow. A plant of this type is described in the US patent US20070101760.

[0031] Plant solutions may also be hypothesised wherein in a simple single stage refrigerating cycle with or without heat exchanger SLHX (Suction Line Heat exchanger) an ejector has been introduced as a pressure recoverer, to reduce the compression ratios developed by the compressor to reduce the consumption of the cycle. Currently none of the solutions proposed have found a practical application in marketed products. Among the main causes is the fact that the ejector is a static device, in other words it has an optimal project design to which predefined input flow (primary and secondary) conditions correspond. Deviations from these optimal conditions lead to a reduction in the efficiency of the ejector and thus of the benefit to the refrigerating cycle. A typical example is the modification of the output temperature from the condenser/gas cooler following variations of the

environmental conditions in which the refrigerating plant works.

Presentation of the invention

[0032] Consequently, the purpose of the present invention is to eliminate or at least attenuate the drawbacks of the prior art mentioned above, by making available a refrigerating plant with ejector, which permits a more efficient removal of the flash gas and which is at the same time also applicable to plug-in cabinets using standard compressors available on the market.

[0033] A further purpose of the present invention is to make available a refrigerating plant with ejector which is simple to make as regards construction and operatively simple to run.

Brief description of the drawings

[0034] The technical characteristics of the invention, according to the aforementioned purposes, can be seen clearly from the contents of the following claims and the advantages thereof will be more clearly comprehensible from the detailed description below, made with reference to the attached drawings, showing one or more embodiments by way of non-limiting examples, wherein:

- Figures 1 and 2 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a vapour compression refrigerating plant of the traditional type, in currently used plug-in cabinets;
- Figures 3 and 4 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a known vapour compression refrigerating plant with removal of the flash gas by means of the auxiliary compressor;
- Figures 5 and 6 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a known vapour compression refrigerating plant with ejector on the low pressure side;
- Figures 7 and 8 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a known vapour compression refrigerating plant with ejector on the high pressure side;
- Figures 9 and 10 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a vapour compression refrigerating plant with ejector for the removal of the flash gas according to a first embodiment of the invention;
- Figures 11 and 12 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a vapour compression refrigerating plant with ejector for the

removal of the flash gas according to a second embodiment of the invention;

- Figures 13 and 14 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a vapour compression refrigerating plant with ejector for the removal of the flash gas according to a third embodiment of the invention;

- Figures 15 and 16 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a vapour compression refrigerating plant with ejector for the removal of the flash gas according to a fourth embodiment of the invention;

- Figures 17 and 18 respectively show a simplified diagram of a plant and the relative thermodynamic cycle in a pressure-enthalpy P-h diagram of a vapour compression refrigerating plant with ejector for the removal of the flash gas according to a fifth embodiment of the invention.

[0035] The elements or parts of elements common to the embodiments described below will be indicated using the same reference numerals.

Detailed description

[0036] With reference to the figures 9 to 18 reference numeral 100 globally denotes a refrigerating plant with ejector according to the invention.

[0037] The refrigerating plant 100 operates with a refrigerant according to a vapour compression cycle. The cycle may be either sub-critical or trans-critical. In particular CO₂ may be used as the refrigerant.

[0038] According to a general embodiment of the invention, illustrated in the appended Figures 9, 11, 13, 15 and 17, the plant 100 comprises a main circuit 100A and in such main circuit 100A comprises:

- a condenser 110, which acts as a gas cooler in the case in which the cycle is trans-critical;
- a first 111 and a second expansion device 113 positioned downstream of the condenser 110;
- a first receiver of liquid 112 positioned between the two expansion devices 111 and 113, in which the refrigerant separates into the liquid phase and the vapour phase;
- an evaporator 114 positioned downstream of the second expansion device 113; and
- at least one primary compressor 115 positioned downstream of the evaporator 114 and upstream of the condenser 110.

[0039] Preferably, the first and the second expansion devices 111 and 113 are each composed of a back pressure valve.

[0040] The plant 1 comprises an ejector 116 in a secondary branch 100B of the main circuit 100A.

[0041] The ejector 116 is of the converging-diverging type. The structure and functioning of the ejector are known to a person skilled in the art and will not therefore be described in detail.

[0042] The ejector 116 comprises a first inlet 116a for a driving flow, a second inlet 116b for a driven flow and an outlet 116c for ejection of the mixture of the two flows.

[0043] At the first inlet 116a the ejector 116 is fluidically connected to the main circuit in the section downstream of the condenser 110 and upstream of the first expansion device 111 to withdraw a fraction of the flow of refrigerant as the driving flow.

[0044] At the second inlet 116b the ejector is fluidically connected to the first receiver 112 to extract from said receiver as driven flow the vapour phase of the refrigerant (flash gas).

[0045] At the outlet 116c the ejector 116 is fluidically connected to the main circuit in the section between the evaporator 114 and the condenser 110 to discharge the ejected flow of refrigerant.

[0046] Compared to the traditional systems in which the flash gas is throttled and added to the refrigerant in output from the evaporator, in the plant 100 the mass flow processed at the primary compressor (or at the first stage) is reduced with a consequent saving in energy of the refrigerating cycle, thereby performing a more efficient extraction of the flash gas.

[0047] In conjunction with the more efficient extraction of the flash gas, as will be specified further below, unlike the solutions of the prior art which provide for the extraction of the flash gas with an auxiliary compressor, the refrigerating plant 100 according to the invention is not only applicable to refrigerating stations, but also to single plug-in refrigerating cabinets using standard compressors available on the market.

[0048] According to the two embodiments illustrated in Figures 9 and 11, the plant 100 comprises two separate primary compressors: a low pressure one 115b, fluidically connected to the evaporator 114 and a high pressure one 115a, fluidically connected to the condenser 110. The outlet 116c of the ejector 116 is fluidically connected to the main circuit between said two primary compressors 115a, 115b.

[0049] Alternatively, the aforesaid at least one primary compressor may be a two-stage compressor 115, having a first low pressure stage 115b fluidically connected to the evaporator 114 and a second high pressure stage 115a fluidically connected to the condenser 110. The outlet 116c of the ejector 116 is fluidically connected to the main circuit at the compressor 115 between the two compression stages.

[0050] According to a first preferred embodiment, shown in figures 9 and 10, the plant 100 comprises a heat exchanger 117 which thermally connects the section of secondary branch downstream of the outlet 116c of the ejector 116 with the section of main circuit which is comprised between the condenser 110 and the first expansion device 111.

[0051] In particular, such heat exchanger 117 could be of the type with concentric tubes.

[0052] The functioning of the plant 100 with reference to Figures 9 and 10 will be now described in detail. The alphanumeric references from 1e to 14e identify the various sections of the plant in the pressure-enthalpy diagram P-h of Figure 10.

[0053] In output from the condenser 110 (point 5e), the refrigerant is divided; one fraction (secondary flow) is bled (11e) and introduced into the ejector 116 as a driving flow. The high energy possessed by the refrigerant in the conditions (11e) is used to aspirate the "flash gas" (12e). The divergent element of the ejector permits a re-compression in output (13e). The refrigerant in output from the ejector being biphasic, the introduction of the heat exchanger 117 (IHx, Internal Heat Exchanger) makes it possible to exploit the complete evaporation of it (13e) to sub-cool the refrigerant of the primary flow in output from the condenser 110 (point 6e) as far as the input conditions (point 7e) in the back pressure valve; after the heat exchanger 117 the secondary flow of refrigerant completes the evaporation before introduction into the compressor (point 3e). The primary flow is preferably throttled in a back pressure valve 111 (point 8e) enters the receiver, is bled in liquid phase (point 9e) and then throttled in the back pressure valve 113 (point 10e). After complete evaporation in the evaporator 114 (point 1e) the primary flow is compressed in the low pressure compressor 115b (point 2e), mixed with the flash gas (point 3e) and then compressed in the high pressure compressor 115a (point 4e).

[0054] The plant configuration according to the aforesaid first embodiment, firstly makes it possible to remove the flash gas in a less complicated manner as regards the plant compared to the solutions of the prior art with auxiliary compressors. In general in fact an ejector is less complex than a compressor.

[0055] As already said, compared to the systems in which the flash gas is throttled and added to the refrigerant in output from the evaporator, in the plant 100 described above the mass flow processed at the first stage of compression is reduced with a consequent saving in energy of the refrigerating cycle.

[0056] The presence of the heat exchanger 117 makes it possible to greatly sub cool the (primary) flow of refrigerant, reducing the content of vapour in output from the back pressure valve 111. The flow of flash gas bled from the ejector is reduced while, for the same enthalpic difference at the evaporator and same refrigerating power demand, the flow of refrigerant at the first compression stage is constant. As a result, the flow of refrigerant which is processed by the second compression stage (the sum of that of the first stage and of that of flash gas) decreases, with a consequent improvement in performance of the cycle.

[0057] The plant configuration comprises components with a reduced economic impact. The ejector and the heat exchanger 117 (1HX) are in fact devices of limited

cost. This makes the first embodiment of the plant 100 particularly suitable for plug-in cabinets also, in which a low economic impact is essential.

[0058] According to a second preferred embodiment, shown in figures 11 and 12, the plant 100 comprises a second receiver of liquid 119, inserted fluidically in the section of secondary branch downstream of the outlet 116c of the ejector 116. In said second receiver 119 the flow of ejected refrigerant separates into the liquid phase and the vapour phase.

[0059] More specifically, said second receiver 119 is fluidically connected to the main circuit by means of a third expansion device 120 in the section comprised between the second expansion device 113 and the evaporator 114 to recirculate the liquid phase in the main circuit 100A. The vapour phase is aspirated by the second high pressure stage 115a of the two-stage compressor 115 or by the high pressure compressor 115a.

[0060] The functioning of the plant 100 with reference to Figures 11 and 12 will be now described in detail. The alphanumerical references from 1f to 16f identify the various sections of the plant in the pressure-enthalpy diagram P-h of Figure 12.

[0061] The refrigerant in output from the ejector 116 (point 12f) is in two-phase conditions. The second receiver of liquid 119 makes it possible to exploit the refrigerant power contained in the liquid fraction. In the receiver 119 the phases are separated. The liquid (point 13f) is bled and throttled (point 14f) in the third expansion device 120 and then added to the main flow (point 9f) to reach the evaporator after a mixing (conditions point 15f). Diverse-ly, the vapour (point 16e) is added to the gas in output from the first compression stage or from the low pressure compressor 115b (point 2f) and the mixed fluid (point 3f) is compressed in the second compression stage or by the high pressure compressor (point 4f). The primary flow is throttled in a back pressure valve 111 (point 7f) and enters the first receiver 112. From here it is bled in liquid phase (point 8f) and then throttled in the back pressure valve 113 (point 9f). After mixing with the secondary flow in liquid phase, complete evaporation takes place in the evaporator 114 (point 1f). The refrigerant is then compressed at the first compression stage or by the low pressure compressor 115b (point 2f).

[0062] The plant configuration according to the afore-said second embodiment also makes it possible to remove the flash gas in a less complicated manner as regards the plant design compared to the solutions of the prior art with auxiliary compressors. Compared to the first configuration the addition of a receiver is envisaged, the complexity of which is however inferior to that of a compressor. Even though compared to the first embodiment the plant configuration is complicated by the addition of further elements (i.e. second receiver and third expansion device), the low economic impact thereof makes the configuration of interest also for small sized applications such as plug-in cabinets.

[0063] The plant configuration according to the afore-

said second embodiment also permits a reduction of the mass flow processed at the first stage of compression with a consequent saving in energy of the refrigerating cycle, despite in a less relevant manner than with the first embodiment.

[0064] In addition, the separation of the liquid-vapour phases in the second receiver 119 - after the ejector- makes it possible to recover refrigerant power and thus to improve the performance of the refrigerating cycle.

[0065] According to three alternative embodiments (third, fourth and fifth embodiments) shown in figures 13 to 18, which will be described in more detail below, the secondary branch 100B which the ejector 116 is inserted in may be connected to the main circuit 100A downstream of the aforesaid at least one primary compressor 115 and upstream of the condenser 110.

[0066] Advantageously, the aforesaid at least one primary compressor 115 may be a single stage compressor or a two-stage compressor (with a first low pressure stage and a second high pressure stage). Alternatively the plant 100 may comprise two primary compressors connected in series, of which one low pressure and one high pressure. In all three embodiments, the secondary branch 100B which the ejector 116 is inserted in is connected to the main circuit 100A downstream of the primary compressor or compressors 115. In other words, the secondary branch is connected in the high pressure part of the main circuit 100A, i.e. in the part which is at the input pressure to the condenser 110.

[0067] According to a third and fourth embodiment, respectively shown in Figures 13-14 and in Figures 15-16, the plant 100 comprises at least one auxiliary compressor 118 inserted fluidically in the secondary branch downstream of the outlet of the ejector 116. Operatively, said auxiliary compressor 118 raises the pressure of the flow in output from the ejector to the same pressure level as the refrigerant in input to the condenser 110.

[0068] More specifically, according to the third embodiment (Figures 13 and 14), the plant 100 comprises a heat exchanger 117 which thermally connects the section of secondary branch downstream of the outlet 116c of the ejector 116 and upstream of the auxiliary compressor 118 with the section of main circuit which is comprised between the condenser 110 and the first expansion device 111.

[0069] The functioning of the plant 100 with reference to Figures 13 and 14 will be now described in detail. The alphanumerical references from 1g to 14g identify the various sections of the plant in the pressure-enthalpy diagram P-h of Figure 14.

[0070] From the flow in output from the condenser 110 (point 4g) a fraction is bled (point 10g) and introduced into the ejector 116 as a driving flow. The high energy possessed by the refrigerant in the conditions of the point 10g is used to aspirate the "flash gas" (point 11g). The divergent element of the ejector permits a re-compression in output (point 12g). The refrigerant in output from the ejector 116 is biphasic. The heat exchanger 117 (IHx)

makes it possible to exploit the complete evaporation (point 13g) to sub-cool the refrigerant of the main flow in output from the condenser 110 (point 5g) as far as the conditions of the point 6g. The vapour in output from the exchanger 117 (point 13g) undergoes a compression with the auxiliary compressor 118 as far as the high pressure conditions of the circuit (point 14g), where it mixes with the main flow (point 2g) entering the condenser 110 at the conditions of point 3g. The primary flow is throttled in a back pressure valve 111 (point 7g), enters the first receiver 112. Here the refrigerant is bled in liquid phase (point 8g) and throttled in the back pressure valve 13 (point 9g). After complete evaporation in the evaporator 114 (point 1g) the refrigerant is compressed in the primary compressor 115 (point 2g) and mixed with the flash gas (point 3g).

[0071] Compared to the traditional plants in which the flash gas is throttled and added to the refrigerant in output from the evaporator, the plant configuration according to the aforesaid third embodiment also permits a reduction of the mass flow processed by the primary compressor with consequent saving in energy of the refrigerating cycle.

[0072] The presence of the heat exchanger 117 makes it possible to greatly sub cool the flow (primary) of refrigerant, reducing the content of vapour in output from the back pressure valve 111. The flow of flash gas bled from the ejector is reduced while, for the same enthalpic difference at the evaporator and refrigerant power demand, the flow of refrigerant at the first compression stage is constant. As a result, the flow of refrigerant which is processed by the second compression stage (sum of that of the first stage and of that of flash gas) decreases with a consequent improvement in performance of the cycle.

[0073] Compared to the solution of the art with removal of the flash gas with an auxiliary compressor, but without an ejector, with the configuration according to the third embodiment of the invention much higher ratios of the volumetric flow of the secondary flow (flash gas) to the volumetric flow of the primary flow are registered.

[0074] This entails a double advantage:

[0075] - there is no longer a primary compressor and an auxiliary compressor of an exaggeratedly different size from one another; they are, on the contrary, approximately equivalent;

[0076] - the plant configuration proves adaptable for both large sizes (refrigerating stations) and for small sizes (plug-in cabinets), in fact it is no longer unthinkable to find compressors commercially available structured to operate in the condition of the auxiliary compressor.

[0077] Advantageously, compared to the solution of the prior art with auxiliary compressor, the auxiliary compressor works less given that part of the pressure difference is given by the ejector.

[0078] Compared to the solution of the prior art with auxiliary compressor, the plant diagram of the aforesaid third embodiment is further complicated by the presence of the ejector and of the heat exchanger IHX. However,

these two components have a relatively low economic impact. In any case, as already said, the possibility of using commercial compressors for the auxiliary compressor makes the plant 100 according to said third embodiment also applicable to plug-in cabinets.

[0079] More specifically, according to the fourth embodiment (Figures 15 and 16), the plant 100 comprises a second receiver of liquid 119 inserted fluidically in the section of secondary branch downstream of the outlet 116c of the ejector 116 and upstream of the auxiliary compressor 118. In said second receiver 119 the flow of refrigerant in output from the ejector separates into the liquid phase and the vapour phase. The second receiver 119 is fluidically connected to the main circuit 100A by means of a third expansion device 120 in the section comprised between the second expansion device 113 and the evaporator 114 to recirculate the liquid phase in the main circuit. The vapour phase is aspirated by the auxiliary compressor 118.

[0080] The functioning of the plant 100 with reference to Figures 15 and 16 will be now described in detail. The alphanumerical references from 1h to 16hg identify the various sections of the plant in the pressure-enthalpy diagram P-h of Figure 16.

[0081] From the flow in output from the condenser 110 (point 4h) a fraction of refrigerant is bled (point 9h) and then introduced into the ejector 116 as a driving flow. The high energy possessed by the refrigerant in the conditions of the point 9h is used to aspirate the "flash gas" (point 10h). The divergent element of the ejector permits a re-compression in output (point 11h). The refrigerant in output from the ejector 116 (point 11h) is in two-phase conditions. The second receiver of liquid 119 placed downstream of the ejector 116 (point 11h) makes it possible to separate the two liquid and vapour phases and thus exploit the refrigerant power contained in the liquid fraction. The liquid (point 12hf) is bled and throttled (point 13h) and then added to the main flow (point 8h) to reach, after mixing, the evaporator at the conditions of point 14h. The vapour (point 15h) is compressed by the auxiliary compressor 118 and returned to a condition of high pressure (point 16h) and added to the gas in output from the primary compressor (point 2h). The primary flow, instead, is throttled in a back pressure valve 111 (point 6h) and enters the first receiver 112. From here it is bled in liquid phase (point 7h) and then throttled in the back pressure valve 113 (point 8h). After mixing with the secondary flow (point 14h), complete evaporation is performed in the evaporator 114 (point 1h) and it is introduced into the primary compressor 115.

[0082] Compared to the traditional plants, in which the flash gas is throttled and added to the refrigerant in output from the evaporator, the plant configuration according to the aforesaid fourth embodiment also permits a reduction of the mass flow processed by the primary compressor with consequent saving in energy of the refrigerating cycle, despite in a less relevant manner than the first embodiment of the invention.

[0083] Compared to the solution of the art with removal of the flash gas with an auxiliary compressor, but without an ejector, with the configuration according to the aforesaid fourth embodiment of the invention - similarly to the third embodiment - much higher ratios of the volumetric flow of the secondary flow (flash gas) to the volumetric flow of the primary flow are registered. This entails a double advantage:

- there is no longer a primary compressor and an auxiliary compressor of an exaggeratedly different size from one another; they are, on the contrary, approximately equivalent;
- the plant configuration proves adaptable for both large sizes (refrigerating stations) and for small sizes (plug-in cabinets), in fact it is no longer unthinkable to find compressors commercially available structured to operate in the conditions of the auxiliary compressor.

[0084] Advantageously, compared to the solution of the prior art with auxiliary compressor, the auxiliary compressor works less given that part of the pressure difference is given by the ejector.

[0085] The separation of the phases in the second receiver 119 (downstream of the ejector) permits a recovery of refrigerating power with consequent improvement of the performance of the refrigerating cycle.

[0086] More specifically, according to the fifth embodiment (Figures 17 and 18), the plant 100 comprises at least one pump 121 fluidically inserted in the aforesaid secondary branch 100B upstream of the first inlet 116a of the ejector 116. The pump 121 raises the pressure of the driving flow of the ejector 116 so that the pressure of the flow ejected is the equivalent to that of the refrigerant in input to the condenser 110.

[0087] The functioning of the plant 100 with reference to figures 17 and 18 will be now described in detail. The alphanumerical references from 1i to 12i identify the various sections of the plant in the pressure-enthalpy diagram P-h of Figure 18.

[0088] In this configuration the energy of the refrigerant is increased which, after coming out of the condenser 110 (point 4i), is bled from the main flow (point 9i), as far as the conditions of point 10i, by means of a pump 121 (in particular hydraulic) to be fed to the ejector 116 as a driving flow. The pump operates 121 in such a way that the driving flow has a pressure level such that, not only is it able to bleed the flash gas (point 11i), but it is also able to make the flow in output from the ejector (point 12i) have a pressure equal to that of the main flow in output from the compressor 115 (point 2i); the two flows are mixed and enter the condenser (110) (point 3i). The main flow (point 5i) is throttled in a back pressure valve 111 (point 6i) and collected in the first receiver 112. From here the refrigerant is bled in liquid phase (point 7i) and throttled in the main expansion device 113 (point 8i). After completing the evaporation in the evaporator, the refrigerant enters the compressor (point 1i). As already said the vapour phase present in the first receiver 112 is aspirated as driven fluid by the ejector 116.

erant enters the compressor (point 1i). As already said the vapour phase present in the first receiver 112 is aspirated as driven fluid by the ejector 116.

[0089] Compared to the traditional plants, in which the flash gas is throttled and added to the refrigerant in output from the evaporator, the plant configuration according to the aforesaid fifth embodiment also permits a reduction of the mass flow processed by the primary compressor with consequent saving in energy of the refrigerating cycle.

[0090] Compared to the configurations according to the invention (third and fourth embodiment) with auxiliary compressor, there is a reduction of consumption in that for the same pressure difference a pump consumes less than a compressor.

[0091] In this fifth embodiment the auxiliary compressor is replaced with two components, the ejector and the pump, with consequent complication of the plant. These two components are however relatively inexpensive. In this particular configuration too, the plant thus proves adaptable for both large sized plants (refrigerating stations) and small sized plants (plug-in cabinets).

[0092] The invention makes it possible to achieve several advantages which have been expounded in the description.

[0093] The refrigerating plant 100 with ejector according to the invention permits a more efficient removal of the flash gas and is at the same time also applicable to plug-in cabinets using standard compressors available on the market.

[0094] The refrigerating plants 100 is constructionally simple to make and operatively simple to run.

[0095] The invention thus conceived thereby achieves the intended objectives.

[0096] Obviously, its practical embodiments may assume forms and configurations different from those described while remaining within the scope of protection of the invention.

[0097] Furthermore, all the parts may be replaced with technically equivalent parts and the dimensions, shapes and materials used may be varied as required.

Claims

1. Refrigerating plant with ejector, operating with a refrigerator according to a vapour compression cycle and comprising in a main circuit (100A):

- a condenser (110); - a first (111) and a second expansion device (113) positioned downstream of the condenser (110); - a first receiver of liquid (112) positioned between the two expansion devices (111;113) in which the refrigerant separates into the liquid phase and the vapour phase;
- an evaporator (114) positioned downstream of the second expansion device (113); - at least one primary compressor (115) positioned down-

stream of the evaporator (114) and upstream of the condenser (110).

characterised in that it comprises in a secondary branch (100B) of said main circuit (100A) an ejector (116) which comprises a first inlet (116a) for a driving flow, a second inlet for a driven flow (116b) and an outlet (116c) for ejection of the mixture of the two flows, at the first inlet (116a) said ejector (116) being fluidically connected to the main circuit in the section downstream of the condenser (110) and upstream of the first expansion device (111) to withdraw a fraction of the flow of refrigerant as driving flow and at the second inlet (116b) being fluidically connected to the first receiver (112) to extract from said receiver as driven flow the vapour phase of the refrigerant, at the outlet (116c) the ejector (116) being fluidically connected to the main circuit in the section between the evaporator and the condenser, to discharge the ejected flow of refrigerant.

2. Plant according to claim 1, wherein said at least one primary compressor is a two-stage compressor (115), having a first low pressure stage (115b) fluidically connected to the evaporator (114) and a second high pressure stage (115a) fluidically connected to the condenser (110), the outlet (116c) of the ejector (116) being fluidically connected to the main circuit at the compressor (115) between the two compression stages.
3. Plant according to claim 1, comprising two separate primary compressors, a low pressure one (115b) fluidically connected to the evaporator (114) and a high pressure one (115a) fluidically connected to the condenser (110), the outlet (116c) of the ejector (116) being fluidically connected to the main circuit between said two primary compressors (115a, 115b).
4. Plant according to claim 2 or 3, comprising a heat exchanger (117) which thermally connects the section of secondary branch downstream of the outlet (116c) of the ejector (116) with the section of main circuit which is comprised between the condenser (110) and the first expansion device (111).
5. Plant according to one or more of the claims from 2 to 4, comprising a secondary receiver of liquid (119) inserted fluidically in the section of secondary branch downstream of the outlet (116c) of the ejector (116), in said second receiver (119) the flow of ejected refrigerant separating into the liquid phase and the vapour phase, said second receiver (119) being fluidically connected to the main circuit by means of a third expansion device (120) in the section comprised between the second expansion device (113) and the evaporator to recirculate the liquid phase in

the main circuit, the vapour phase being aspirated by the second high pressure stage (115a) of the two-stage compressor (115) or by the high pressure compressor (115a).

6. Plant according to claim 1, wherein the secondary branch which the ejector (116) is inserted in is connected to the main circuit downstream of said at least one primary compressor (115) and upstream of the condenser (110).
7. Plant according to claim 6, comprising at least one auxiliary compressor (118) inserted fluidically in the secondary branch downstream of the outlet (116c) of the ejector (116), said auxiliary compressor (118) raising the pressure of the ejected flow to the same pressure level as the refrigerant entering the condenser (110).
8. Plant according to claim 7, comprising a heat exchanger (117) which thermally connects the section of secondary branch downstream of the outlet (116c) of the ejector (116) and upstream of the auxiliary compressor (118) with the section of main circuit which is comprised between the condenser (110) and the first expansion device (111).
9. Plant according to one or more of the claims from 6 to 8, comprising a secondary receiver of liquid (119) inserted fluidically in the section of secondary branch downstream of the outlet (116c) of the ejector (116) and upstream of the auxiliary compressor (118), in said second receiver (119) the flow of ejected refrigerant separating into the liquid phase and the vapour phase, said second receiver (119) being fluidically connected to the main circuit by means of a third expansion device (120) in the section comprised between the second expansion device (113) and the evaporator to recirculate the liquid phase in the main circuit, the vapour phase being aspirated by the auxiliary compressor (118).
10. Plant according to claim 6, comprising at least one pump (121) fluidically inserted in the secondary branch upstream of the first inlet (116a) of the ejector (116), said pump (121) raising the pressure of the driving flow of the ejector so that the pressure of the flow ejected is the equivalent to that of the refrigerant entering the condenser (110).

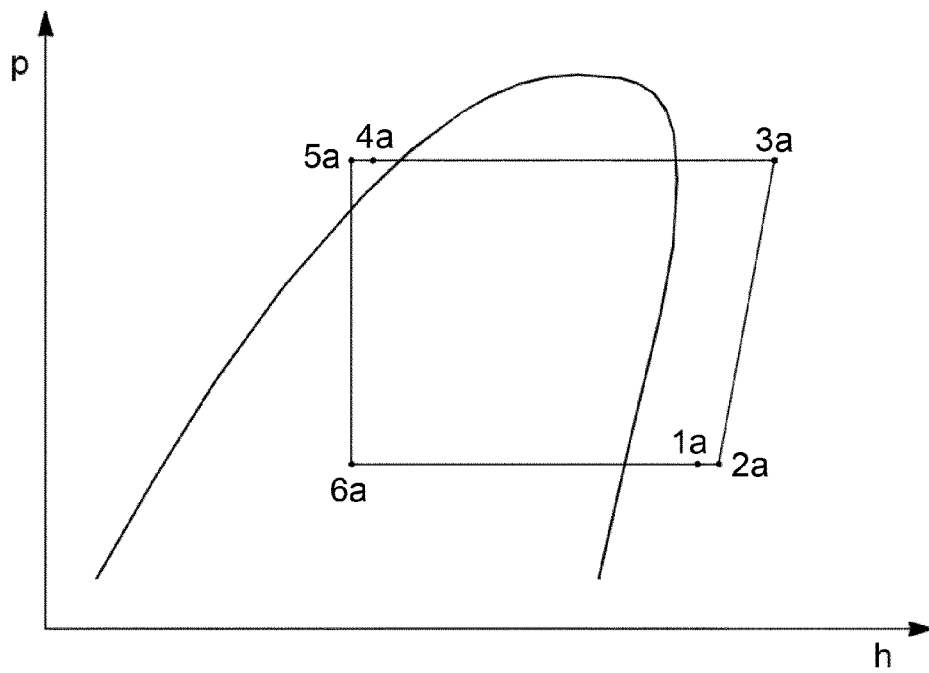
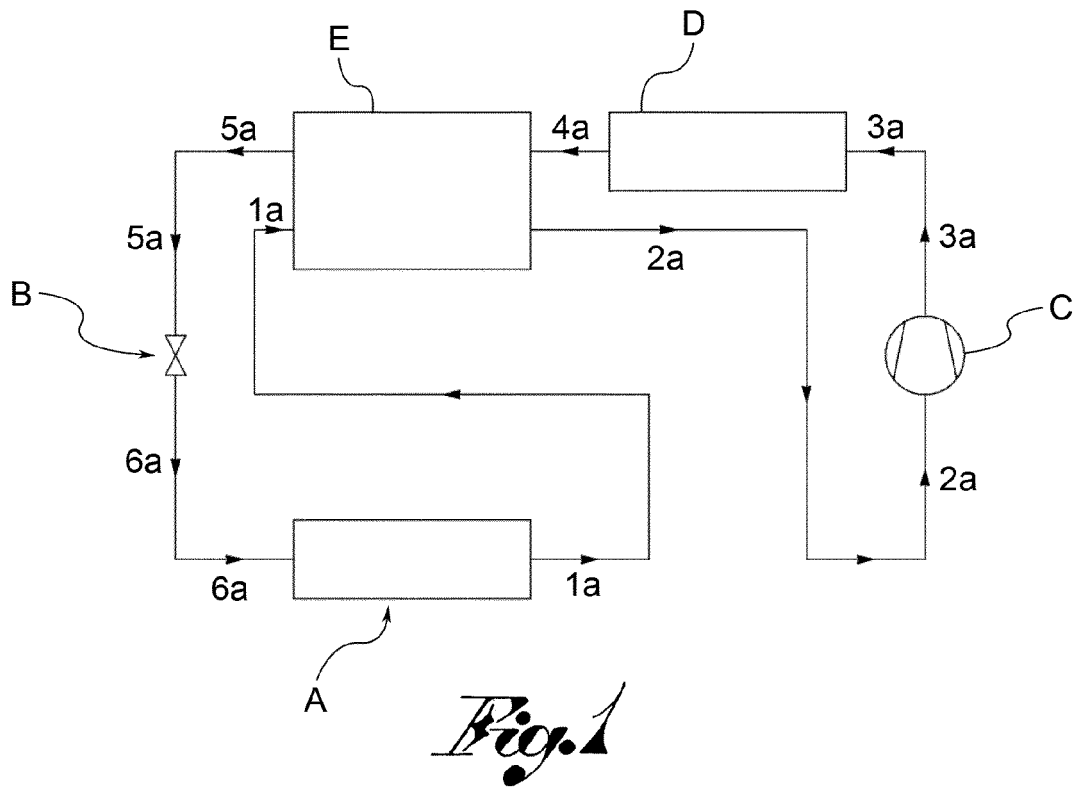
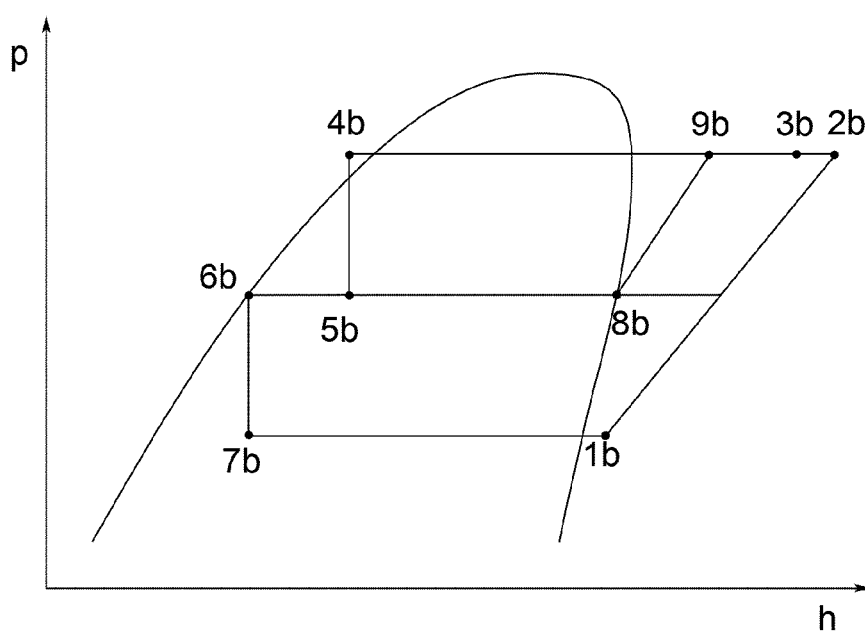
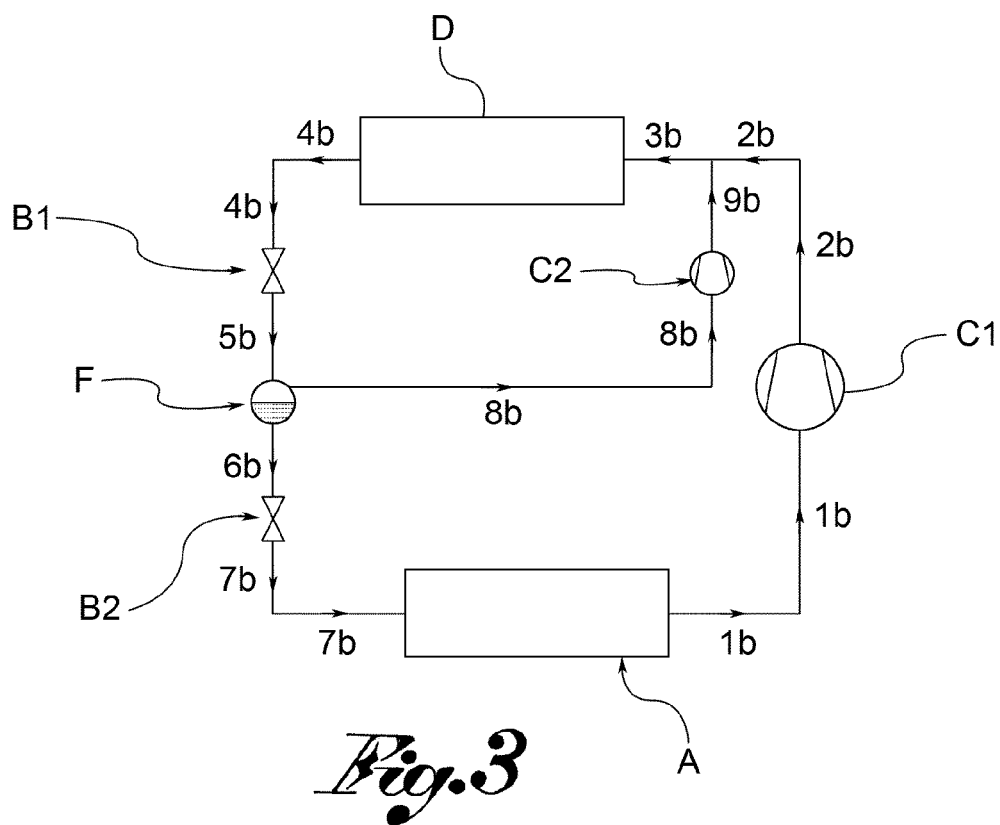


Fig. 2



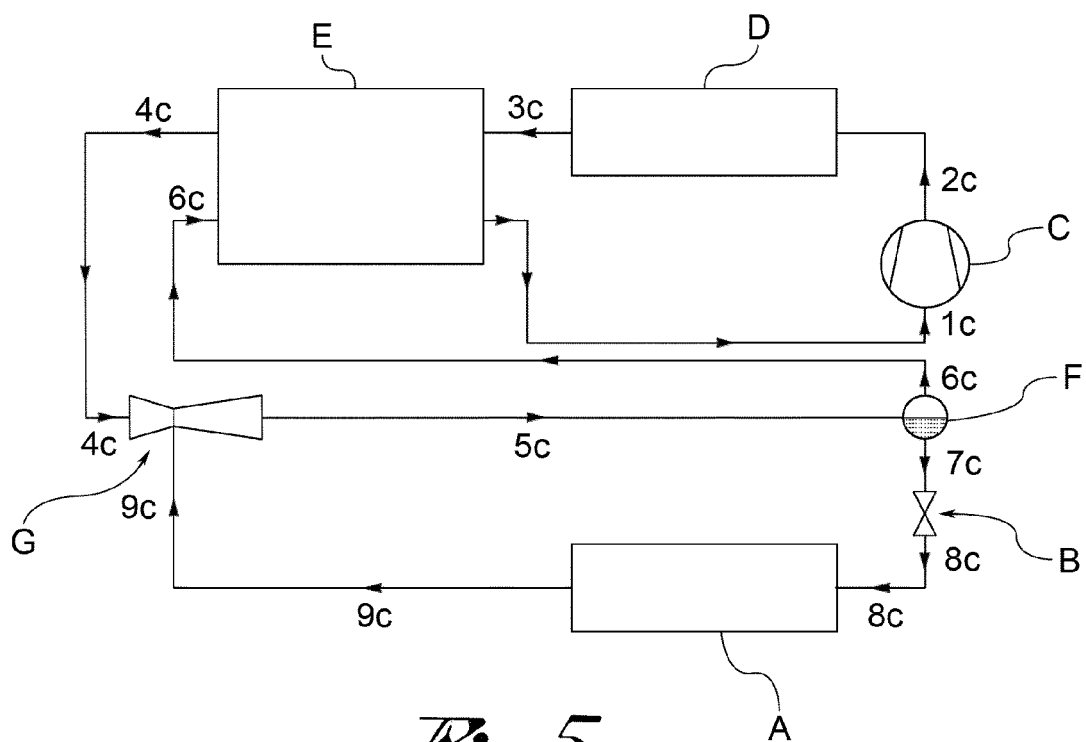


Fig.5

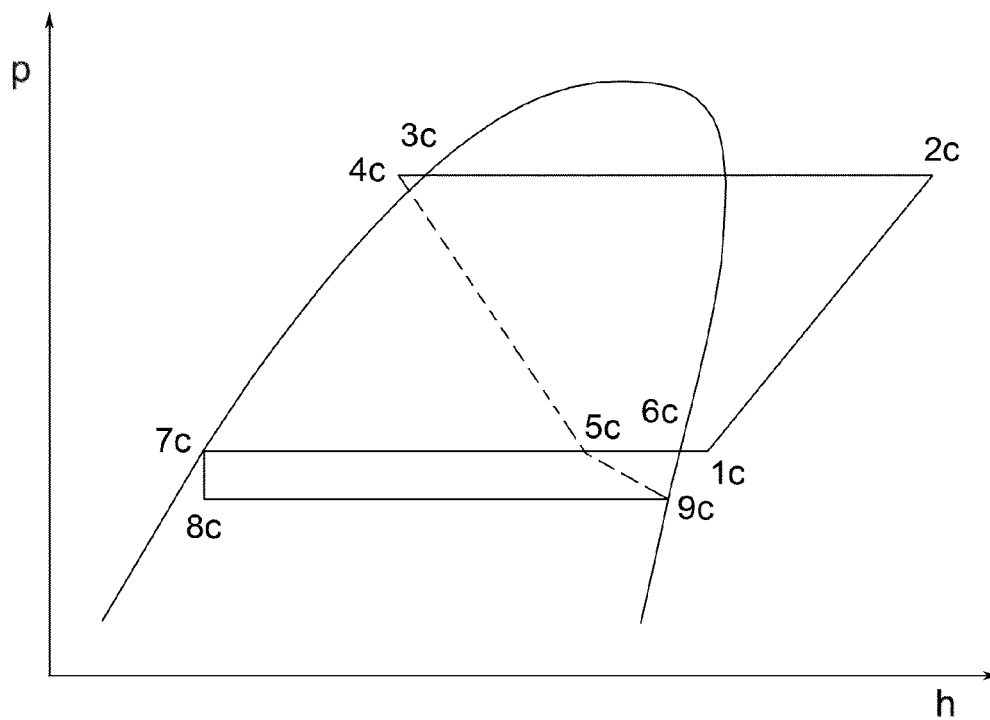


Fig.6

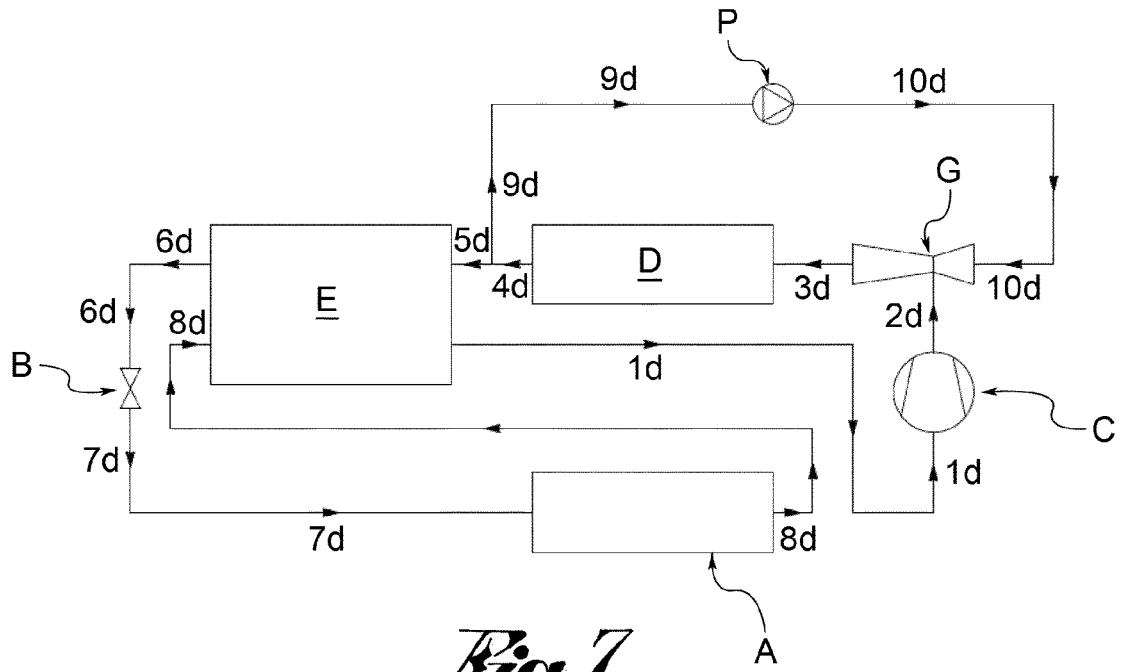


Fig. 7

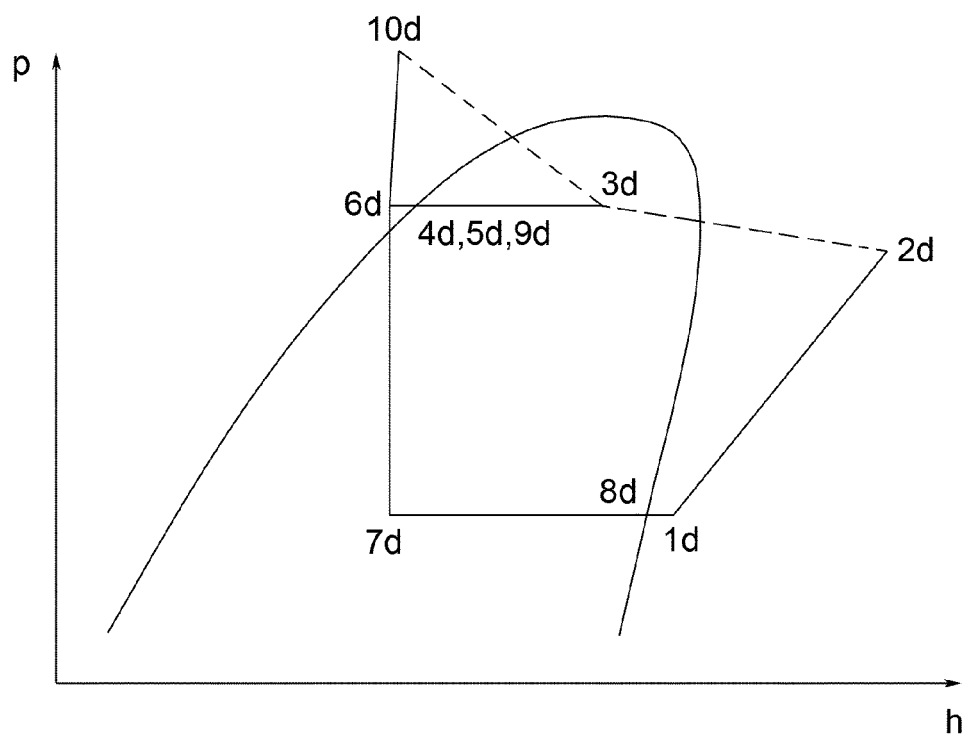


Fig. 8

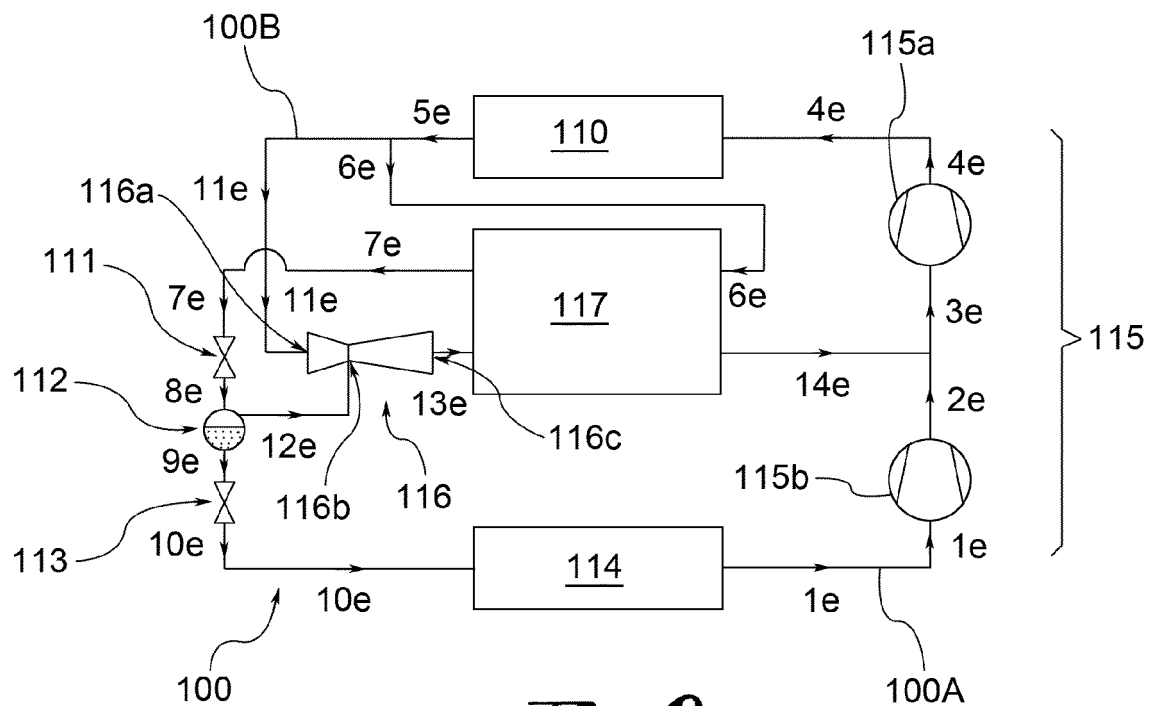


Fig. 9

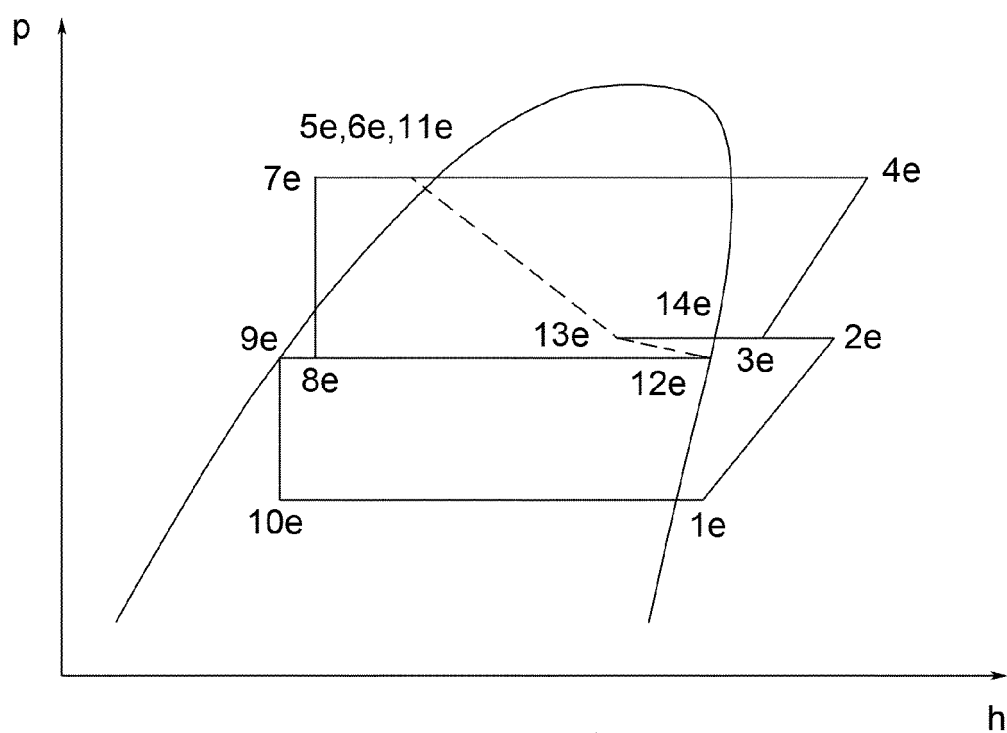


Fig. 10

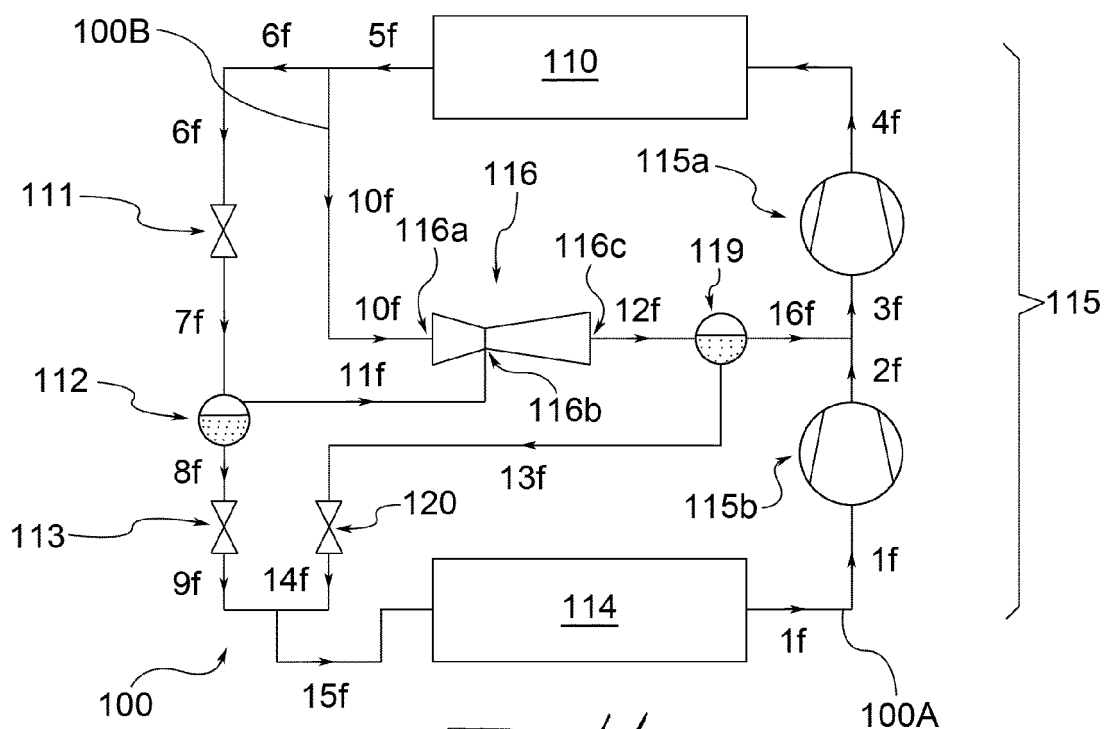


Fig. 11

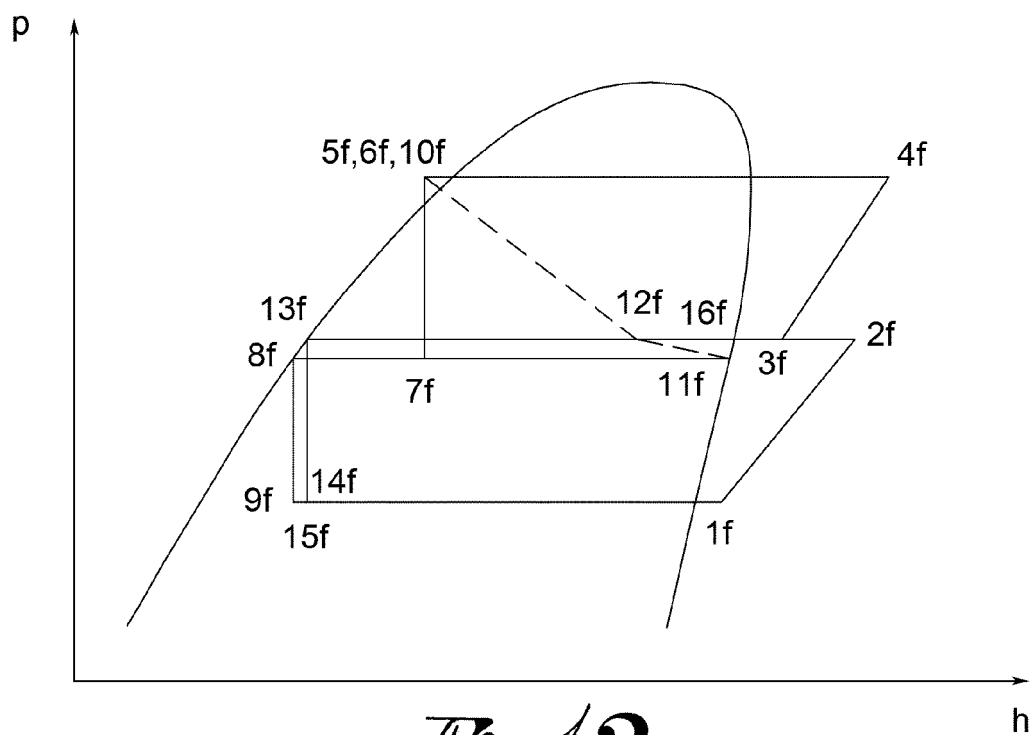


Fig. 12

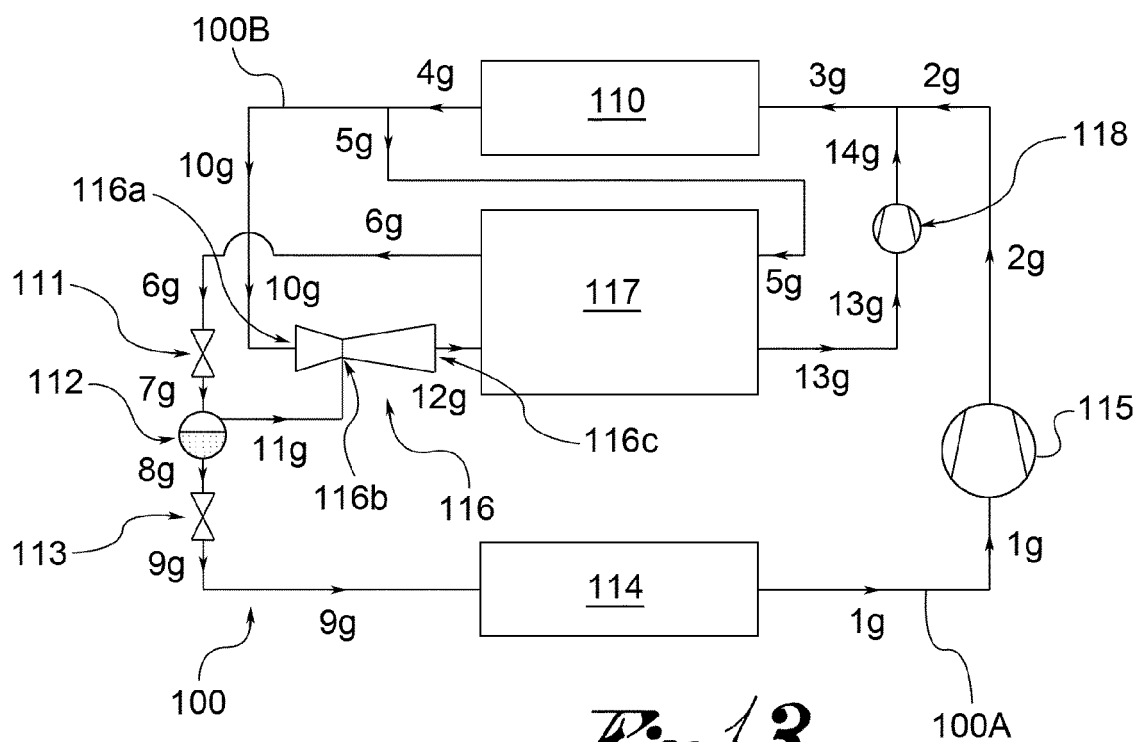


Fig. 13

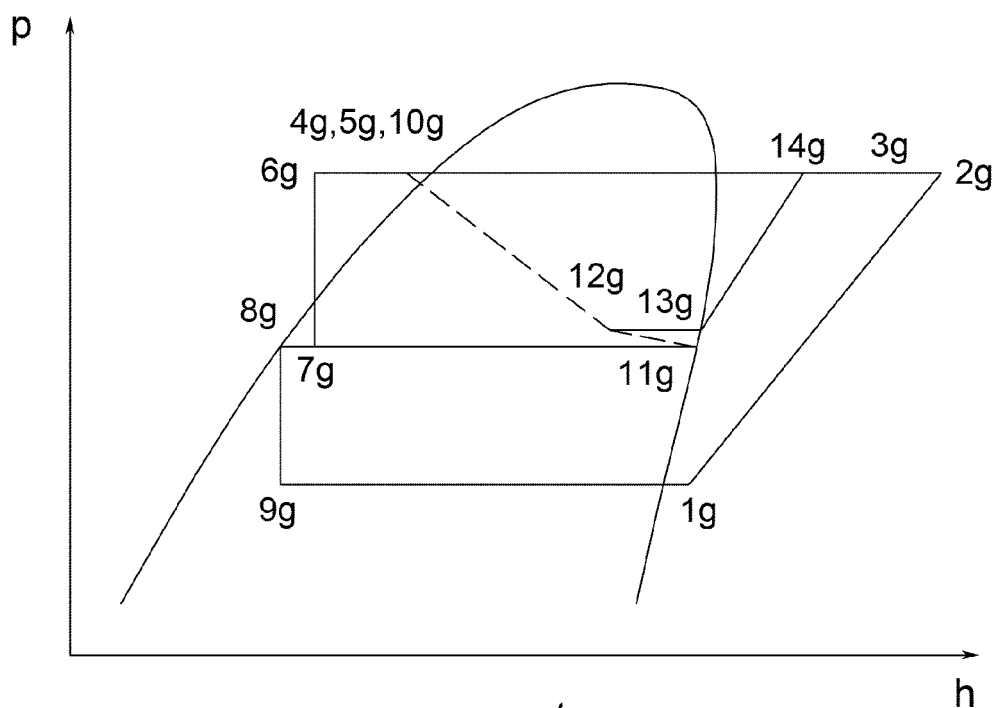


Fig. 14

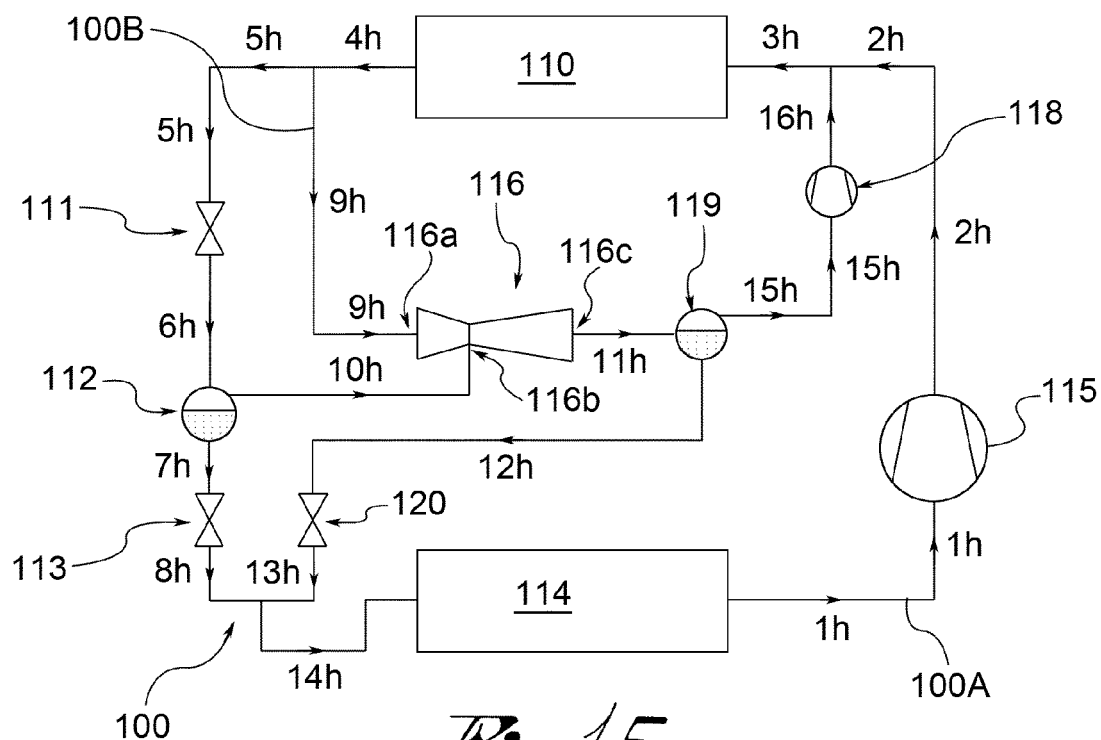


Fig. 15

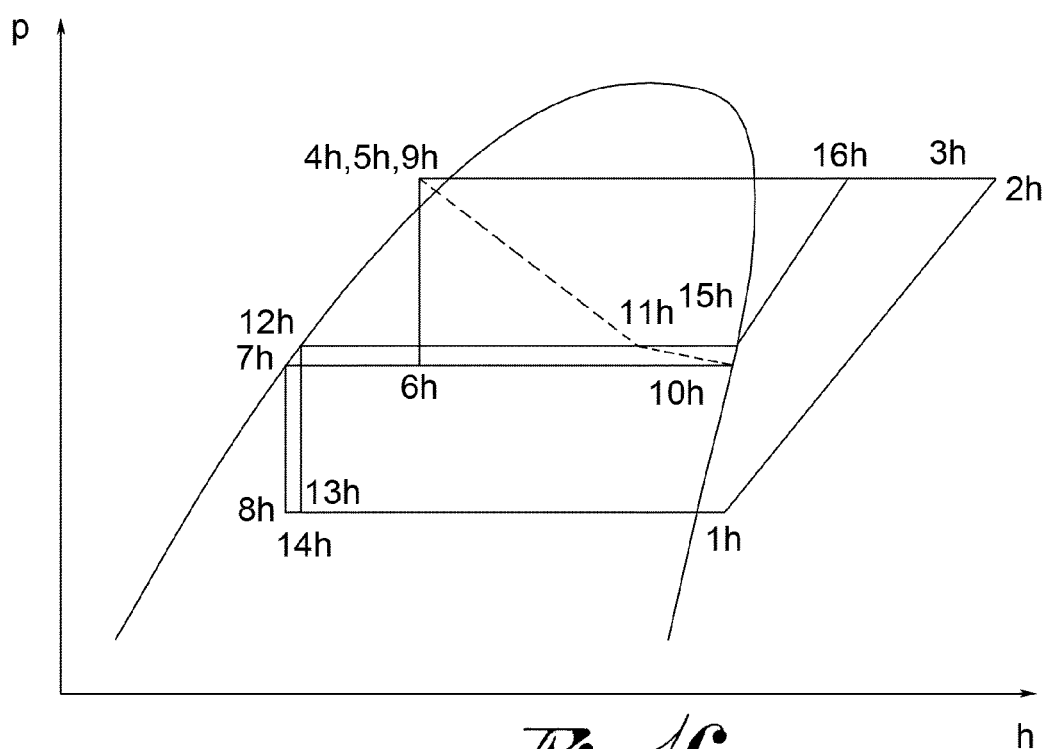


Fig. 16

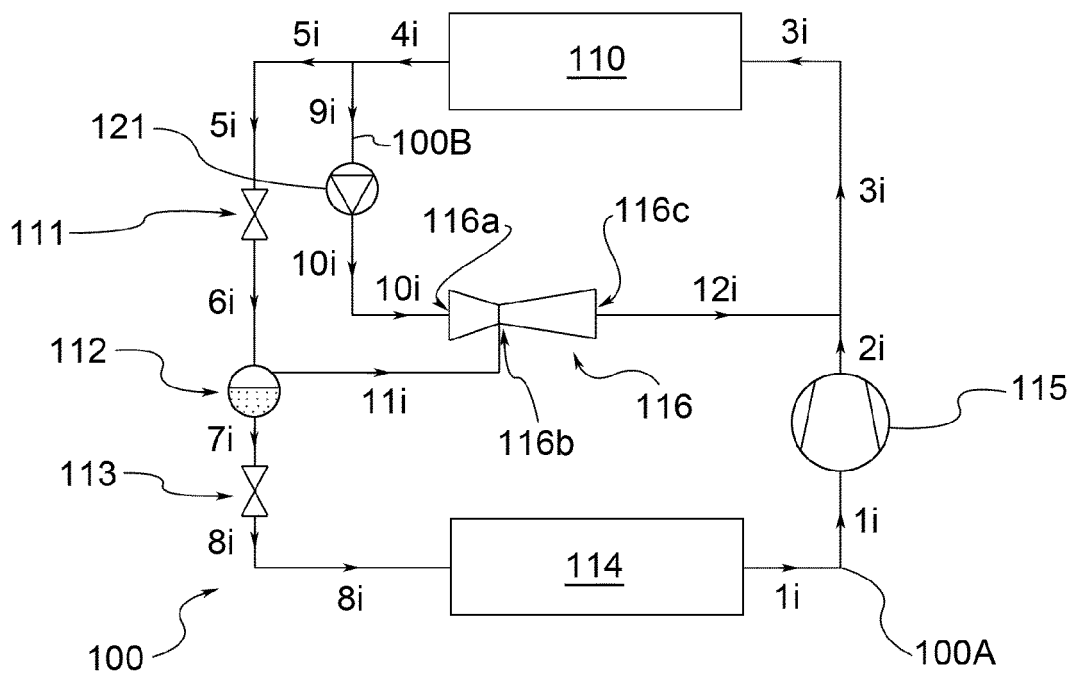


Fig. 17

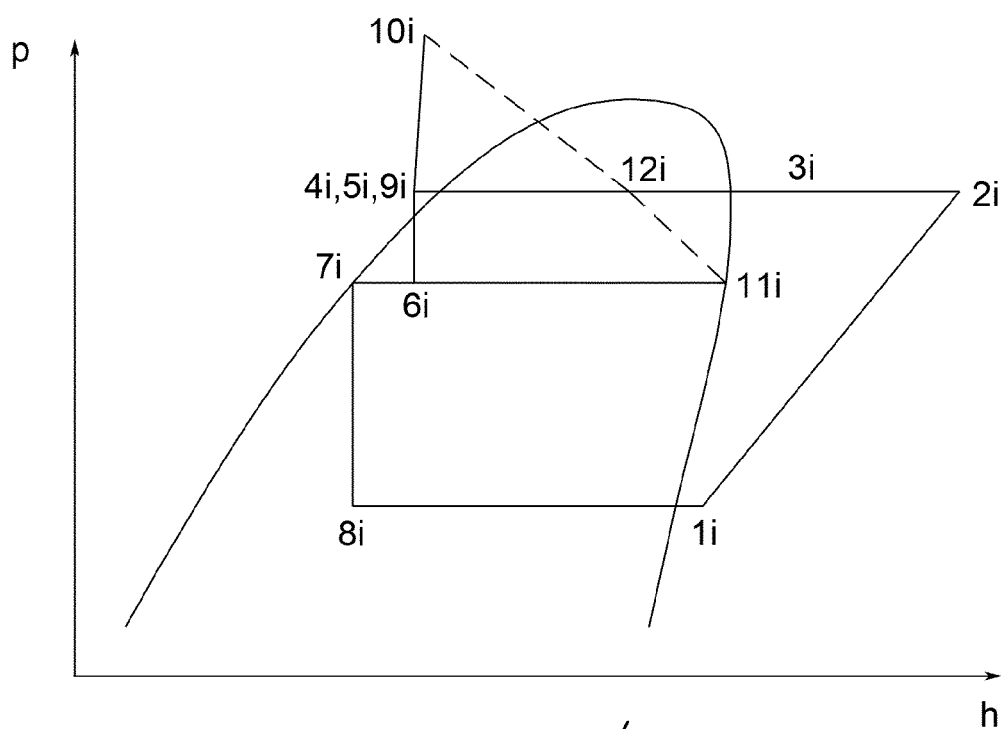


Fig. 18



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 Application Number
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Place of search The Hague		Date of completion of the search 16 April 2014	Examiner Bidet, Sébastien
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