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Description

Flashgas removal from a receiver in a refrigeration circuit

The invention relates to a refrigeration circuit, having a single or multiple component refrigerant circulating therein, comprising in the flow direction a condenser, a receiver, an expansion device upstream of an evaporator, an evaporator and a single-stage compressing compressor unit.

The invention further relates to a method of operating a refrigeration circuit.

The term "condenser" is understood to mean both a condenser and a gas cooler.

Generic refrigeration circuits are well known. As an example, they are implemented in refrigeration systems, so-called compound refrigeration systems, such as those used in supermarkets. There, compound refrigeration systems generally serve a plurality of refrigeration consumers such as cold stores, refrigerators and freezers. For this purpose, they have a single or multiple component refrigerant or refrigerant mixture circulating therein.

DE 195 22 884 A1 teaches a method of operating a compression refrigeration system having carbon dioxide as the working fluid, and comprising a two-stage throttling and division of the circumferential working fluid flow. Therein, after the first throttle stage, the working fluid mass flow is fed into a medium pressure separator operating in a subcritical mode, the larger fraction of the liquid working fluid mass flow separating in the bottom part of the medium pressure separator is delivered to the evaporator, the smaller vaporous fraction of the working fluid mass flow separating in the top part of the medium pressure separator is expanded over a second throttle stage to closely above vapor pressure. In an internal heat exchanger, the smaller vaporous fraction of the working fluid mass flow is used for subcooling the supercritical high-pressure gas by evaporation and superheating. After the evaporation and superheating, the smaller fraction of the working fluid mass flow is mixed with the outputs of the evaporator lines within a receiver pipe integrated into the evaporator.

FR 2 738 331 A teaches a refrigeration circuit operating in a subcritical mode, having, in the exemplary embodiment of Fig. 1, a compressor, a condenser, a high-pressure float valve, a tank and an evaporator with upstream expansion valves, in which a line connects the upper part of the liquid tank to the input of the compressor, and wherein, in this line, an electronically actuated valve and an additional manual adjustment member are present.

It is known from Girotto S. et. al.: "Commercial Refrigeration System with CO_2 as Refrigerant Experimental Results", International Congress of Refrigeration. Proceedings – Congrès

International du Froid. Comptes Rendus, XX, XX, 17. August 2003 (2003-08-17), pages 1–08, XP000962253, that if flashgas is connected to an intermediate stage, the pressure in the liquid line never exceeds 50 bar.

A refrigeration circuit of the prior art or a refrigeration system in which such a refrigeration circuit is implemented, will be explained in detail with reference to the exemplary embodiment shown in figure 1.

The single or multiple component refrigerant circulating in the refrigeration circuit is condensed within a condenser or gas cooler A – hereinafter only referred to as a condenser –, which is usually disposed outside of the supermarket, e.g., on its roof, via heat exchange, preferably against the outside air.

The liquid refrigerant from condenser A is delivered to a (refrigerant) receiver C via a line B. Within a refrigeration circuit, there must always be enough refrigerant to be able to fill the evaporators of all refrigeration consumers even under maximum refrigeration requirements. However, as with lower refrigeration requirements individual evaporators are only partially filled or even completely empty, the excess refrigerant must be collected in the dedicated receiver C during such periods.

From the receiver C, the refrigerant reaches the refrigeration consumers of the so-called normal refrigeration circuit via liquid line D. Here, consumers F and F’ shown in figure 1 represent any number of consumers of the normal refrigeration circuit. Each of the afore-mentioned refrigeration consumers has an upstream expansion valve E or E’, in which the refrigerant flowing into the refrigeration consumer or the evaporator(s) of the refrigeration consumer is expanded. The refrigerant thus expanded is evaporated in the evaporators of refrigerant consumers F and F’, thus cooling the corresponding refrigerators and cold stores.

The refrigerant evaporated in refrigeration consumers F and F’ of the normal refrigeration circuit is then delivered to compressor unit H via suction line G and compressed therein to the desired pressure of between 10 and 25 bar. Usually, compressor unit H is configured in a single stage only and has several compressors connected in parallel.

The refrigerant compressed in compressor unit H is then, in turn, delivered to condenser A already mentioned via pressure line I.

Via a second liquid line D’, refrigerant from receiver C is delivered to condenser K and evaporated therein by heat exchange against the refrigerant of the freezing circuit yet to be explained, before it is delivered to compressor unit H via line G’.

The refrigerant of the freezing circuit condensed in condenser K is delivered to receiver M of the freezing circuit via line L. From there, the refrigerant is delivered to consumer P – representing any number of consumers –, having an upstream expansion device O, via line N and evaporated therein. Via suction line Q, the evaporated refrigerant is delivered to single- or multi-stage compressor unit R in which it is compressed to a pressure of between 25 and 40 bar, and is then delivered to condenser K already mentioned via pressure line S.

As a refrigerant of the normal refrigeration circuit, R 404A is used as an example, while carbon dioxide is used for the freezing circuit.

Compressor units H and R, receivers C and M and condenser K, as shown in figure 1, are usually disposed in a separate machine room. However, about 80 to 90% of the overall line network is disposed within the sales rooms, the storage rooms or other rooms of a supermarket accessible to personnel and customers. As long as pressures of no more than 35 to 40 bar are used in this line network, this is acceptable for supermarket operators from both a psychological point of view and for cost reasons.

Currently, operation of the normal refrigerant circuit described above is also beginning to be based on the CO_2 refrigerant.

As yet, the sensible use of the natural CO_2 refrigerant in commercial refrigeration has failed due to the insufficient energy efficiency of the simple, single-stage cycle at high (outside) air temperatures, one the one hand. On the other hand, due to the material properties of CO_2, high working pressures – of up to and beyond 100 bar – are required which make the production of corresponding refrigeration circuits or refrigeration systems much more difficult for economic reasons. Therefore, the CO_2 refrigerant has so far only been used commercially for cascade systems in deep freezing – as exemplified in figure 1 – as the working pressures achieved there do not exceed the usual maximum pressure level of 40 bar.

Due to the afore-mentioned higher pressures or pressure level, the pipeline network of the refrigeration circuit must be designed for such pressures or pressure level. However, the materials required to this end are much more expensive than those which may be used for the pressure levels implemented so far. However, in addition, such relatively high pressure levels are also very hard to explain to system operators.

Another problem which arises when using CO_2 as the refrigerant in particular is that, with correspondingly high outside temperatures, a supercritical operation of the refrigeration circuit becomes necessary. High outside air temperatures result in relatively large throttle vapor fractions occurring at the evaporator inlet. This reduces the effective volumetric refrigeration capacity of the circulating refrigerant, however, both the suction and liquid lines and the evaporator must be sized larger accordingly to keep pressure losses as low as possible.

The object of the present invention is to provide a generic refrigeration circuit and a method of operating a refrigeration circuit which overcome the above drawbacks.

This object is achieved by a refrigeration circuit according to claim 1 and a method according to claim 10.

In a refrigeration circuit according to the invention, an intermediate expansion device is disposed between the condenser and the receiver.

In a method according to the invention, an expansion of the refrigerant to an (intermediate) pressure of 5 to 40 bar is performed within the intermediate expansion device disposed between the condenser and the receiver.

The refrigeration circuit according to the invention, the method of operating a refrigeration circuit according to the invention and further designs thereof are explained in greater detail below with reference to exemplary embodiments shown in figures 2 to 5.

Here, figure 2 shows a compound refrigeration system in which a possible design of the refrigeration circuit according to the invention is implemented. The following describes a procedure using HFC(s), PFC(s) or CO_2 as the refrigerant.

The refrigerant compressed to a pressure of between 10 and 120 bar within compressor unit 6 is delivered to condenser or gas cooler 1 via pressure line 7 and condensed or heated therein against outside air. The refrigerant is delivered to refrigerant receiver 3 via lines 2, 2' and 2", wherein, according to the invention, however, it is now expanded in intermediate expansion device a to an intermediate pressure of 5 to 40 bar. This intermediate expansion has the advantage that the downstream line network and receiver 3 only need to be configured for a lower pressure level.

Here, the pressure to which the refrigerant is expanded in mentioned intermediate expansion device a, is preferably selected such that it is below the lowest condensing pressure to be expected.

According to an advantageous design of the refrigeration circuit according to the invention, pressure line 7 is connected or connectable to receiver 3, preferably within its gas space. This connection between pressure line 7 and receiver 3 can be accomplished via a connecting line 17 in which an expansion valve h is disposed.

According to an advantageous design of the refrigeration circuit according to the invention, pressure line 7 is connected or connectable to line or line portions 2 or 2', 2" connecting condenser 1 and receiver 3. As an example, this connection between pressure line 7 and line 2 or 2', 2" can be accomplished via connecting line 18, shown as a dashed line, in which a valve j is disposed.

The gas space of the receiver is connected or connectable to the input of compressor unit 6.

This connection between receiver 3 and the input of compressor unit 6 is accomplished via a connecting line 12 opening into suction line 11, as shown in figure 2.

Now, the selected intermediate pressure can be kept constant for all operating conditions using expansion valve e provided in line 12 and expansion valve h provided in line 17 or valve j provided in line 18. However, an adjustment such that a constant differential value from the suction pressure is present is also possible. In this way, it is achieved that the throttle vapor fraction at the evaporators is relatively small, resulting in the liquid and suction lines being able to be sized smaller accordingly. This also applies to the condensate line as, now, gaseous components no longer need to flow back therethrough into condenser 1. Thus, it is also achieved with the invention that the required refrigerant filling capacity can be reduced by up to approx. 30%.

Refrigerant is withdrawn from receiver 3 via suction line 4 and delivered to the refrigerant consumers or their heat exchangers E2 and E3. Each of them has an upstream expansion valve b or c in which the refrigerant flowing into the refrigeration consumers is expanded. In turn, the refrigerant evaporated in refrigeration consumers E2 and E3 is then delivered to compressor unit 6 or drawn from evaporators E2 and E3 via suction line 5.

Part of the refrigerant withdrawn from receiver 3 is delivered via line 4 to one or more freezing consumers – represented by heat exchanger E4 – also having an upstream expansion valve d. After the evaporation in heat exchanger or refrigerant consumer E4, this partial refrigerant flow is delivered to compressor unit 10 via suction line 9 and compressed therein to the inlet pressure of compressor unit 6. The thus compressed partial refrigerant flow is then delivered to the input side of compressor unit 6 via line 11.

As a further development of the invention, it is proposed that – as shown in figure 2 – receiver 3 may have an upstream heat exchanger E1.

Here, heat exchanger E1 is preferably connected or connectable with its input side to the output of condenser 1.

As shown in figure 2, a partial flow of the condensed or heated refrigerant can now be withdrawn from condenser or gas cooler 1 or line 2 via line 13, in which an expansion valve f is provided, and evaporated in heat exchanger E1 against the refrigerant to be heated and delivered to heat exchanger E1 via line 2'. The evaporated partial refrigerant flow is then delivered via line 14 to a compressor 6' which is associated with compressor unit 6 described above and preferably operates at a higher pressure level, and compressed therein to the desired final pressure of compressor unit 6.

By means of heat exchanger E1, the refrigerant flow to be expanded in intermediate expansion device a is preferably cooled to such an extent that the throttle vapor fraction of the expanded refrigerant is minimized.

Alternatively or additionally, the throttle vapor fractions accumulating at receiver 3 can also be extracted via line 12 and line 15 shown as a dashed line by means of compressor 6' at a higher pressure level.

Figure 3 shows an embodiment of the refrigeration circuit according to the invention or the method of operating a refrigeration circuit according to the invention, wherein the refrigerant withdrawn from receiver 3 via line 4 is subjected to subcooling in heat exchanger E5.

Here, the subcooling – according to an advantageous design of the invention – is accomplished by heat exchange with the flashgas withdrawn from receiver 3 via line 12.

Liquid lines, such as line 4 shown in figures 2 and 3, at a temperature level underneath the ambient temperature are subject to heat radiation. This results in the refrigerant flowing within the liquid line partially evaporating, thus leading to the formation of unwanted vapor fractions. To prevent this, refrigerants have so far been subcooled either by an expansion of a partial flow of the refrigerant and subsequent evaporation or by an internal heat exchange against a suction flow which is superheated in the process.

In the refrigeration circuit according to the invention or the procedure according to the invention, the temperature difference between the suction and liquid lines or the refrigerant circulating therein may possibly be too low to implement an internal heat exchange for the required subcooling of the refrigerant flowing in the liquid line.

Therefore, as a further development of the invention – as already mentioned – it is proposed that the refrigerant withdrawn from receiver 3 via line 4 is subcooled in heat exchanger or subcooler E5 against the flashgas expanded from receiver 3 via line 12 and in valve e. Upon passing through the heat exchanger or subcooler E5, the expanded refrigerant superheated in heat exchanger E5 is delivered to the input of compressor unit 6 via line portions 12' and 11. Due to the superheating of the flashgas flow withdrawn from receiver 3 via line 12, sufficient subcooling of the refrigerant flowing therein is achieved in liquid line 4; this subcooling of the refrigerant improves the normal operation of expansion or injection valves b, c and d upstream of evaporators E2, E3 and E4.

Liquid droplets not separated from receiver 3 via line 12 due to a small sizing and/or overfilling of receiver 3 and carried off by the flashgas are evaporated in heat exchanger/subcooler E5 at the latest. Thus, the procedure described also has the advantage that the operational safety of compressor or compressor unit 6 is increased due to a safe superheating of the flashgas flow.

Figure 4 shows a further design of the refrigeration circuit according to the invention or the method of operating a refrigeration circuit according to the invention. For the sake of clarity, figure 4 only shows a portion of the refrigeration circuit according to the invention shown in figures 2 and 3.

As a further development of the method of operating a refrigeration circuit according to the invention, it is proposed that at least a partial flow of the flashgas withdrawn from the receiver is at least temporarily superheated against at least a partial flow of the compressed refrigerant.

Figure 4 shows a possible design of the method according to the invention, wherein a partial flow of the flashgas withdrawn from receiver 3 via line 12 is at least temporarily delivered to heat exchanger E6 via line 16 and superheated therein against the refrigerant compressed in compressor unit 6.

In the procedure shown in figure 4, the flashgas flow to be superheated is superheated in heat exchanger E6 against the entire refrigerant flow compressed in compressor unit 6 which is delivered to the condenser or desuperheater shown in figure 4 via line 7.

Upon passing through the heat exchanger/superheater E6, the flashgas flow is delivered to the input of compressor 6' of compressor unit 6 via line 16'.

The procedure shown in figure 4 makes it possible to ensure that liquid components contained in the flashgas are evaporated without doubt, resulting in higher safety for the compressors or compressor unit 6.

Patentkrav:

1. Kølekredsløb med et enkelt- eller flerkomponent kølemiddel, især CO_2, der cirkulerer deri,
hvor kølekredsløbet muliggør superkritisk drift,
omfattende i strømningsretningen en kondensator/gaskøler (1), en mellemliggende ekspansionsindretning (a) til ekspansion af kølemidlet til et mellemliggende tryk på 5 til 40 bar, en modtager (3), fordampere (E2, E3) med en respektiv opstrøms ekspansionsindretning (b, c) og en kompressorenhed (6), der er forbundet til fordamperne (E2, E3) via en sugeledning (5),
hvor gasrummet i modtageren (3) er forbundet eller kan forbindes til indgangen til kompressorenheden (6),
hvor en ekspansionsventil (e) er tilvejebragt inden i forbindelsesledningen (11, 12) mellem gasrummet i modtageren (3) og indgangen til kompressorenheden (6),
hvor forbindelsesledningen (11, 12) udmunder i sugeledningen (5) opstrøms kompressorenheden (6),
hvor kølemidlet, der trækkes ud af modtageren (3), leveres via en ledning (8) til en eller flere frysekonsumenter (E4) med en opstrøms ekspansionsventil (d),
hvor en kompressorenhed (10) er tilvejebragt, der forsynes via en sugeledning (9) med kølemiddel, der er fordampet inden i frysekonsumenten (E4), og
hvor kølemidlet, der komprimeres i kompressorenheden (10), leveres til kompressorenheden (6) via en sugeledning (11).

2. Kølekredsløb ifølge krav 1, hvor en varmeveksler (E1) er tilvejebragt opstrøms modtageren (3), og/eller hvor varmeveksleren (E1) er forbundet eller kan forbindes (2, 13) på indgangssiden til udgangen af kondensatoren/gaskøleren (1).

3. Kølekredsløb ifølge krav 2, hvor ledningen (2) fra kondensatoren/gaskøleren (1) adskilles i en første ledningsdel (2') og en anden ledningsdel (13), hvor en ekspansionsventil (f) er anbragt inden i den anden ledningsdel (13), og hvor kølemidlet inden i den anden ledningsdel (13) fordampes inden i varmeveksleren (E1) imod kølemidlet i den første ledningsdel (2'), og/eller hvor den anden ledningsdel (13, 14) nedstrøms varmeveksleren (E1) er forbundet eller kan forbindes til indgangen til kompressoren (6') i kompressorenheden (6).

4. Kølekredsløb ifølge et hvilket som helst af de foregående krav, hvor en trykledning (7) er tilvejebragt til levering af komprimeret kølemiddel fra kompressorenheden (6) til kondensatoren/gaskøleren (1), og hvor trykledningen (7) er forbundet eller kan forbindes til ledningen (2, 2', 2''), der forbinder kondensatoren/gaskøleren (1) med modtageren (3).

5. Kølekredsløb ifølge krav 4, hvor en trykledning (7) er tilvejebragt til levering af komprimeret kølemiddel fra kompressorenheden (6) til kondensatoren/gaskøleren (1), og hvor en ledning (18), i hvilken der er tilvejebragt en ventil (j), forbinder ledningsdelen (2', 2'') mellem varmeveksleren (E1) og den mellemliggende ekspansionsindretning (a) til trykledningen (7) nedstrøms kompressorenheden (6), og/eller hvor en ledning (17), i hvilken der er tilvejebragt en ventil (h), forbinder ledningsdelen mellem den mellemliggende ekspansionsindretning (a) og modtageren (3) til trykledningen (7) nedstrøms kompressorenheden (6).

6. Kølekredsløb ifølge krav 5, hvor det valgte mellemliggende tryk kan justeres via ekspansionsventilen (e) inden i ledningen (12) og via ekspansionsventilen (h) inden i ledningen (17) og/eller via ekspansionsventilen (j) inden i ledningen (18), således at det har en konstant værdi eller en konstant forskel til sugetrykket.

7. Kølekredsløb ifølge et hvilket som helst af de foregående krav, hvor gasrummet i modtageren (3) er forbundet eller kan forbindes til indgangen til en kompressor (6') i kompressorenheden (6).

8. Kølekredsløb ifølge et hvilket som helst af de foregående krav, hvor en trykledning (7) er tilvejebragt til levering af komprimeret kølemiddel fra kompressorenheden (6) til kondensatoren/gaskøleren (1), og hvor en varmeveksler (E6) er tilvejebragt, i hvilken flashgas, der trækkes ud af modtageren (3), overophedes imod komprimeret kølemiddel inden i trykledningen (7).

9. Kølekredsløb ifølge krav 8, hvor flashgassen efter at være passeret gennem varmeveksleren/overophederen (E6) leveres til indgangen til kompressoren (6') i kompressorenheden (6) via en ledning (16').

10. Fremgangsmåde til superkritisk drift af et kølekredsløb ifølge et hvilket som helst af de foregående krav,

i hvilket der cirkulerer et enkelt- eller flerkomponent kølemiddel, især CO_2,

hvor ekspansion af kølemidlet til et mellemliggende tryk på 5 til 40 bar udføres inden i den mellemliggende ekspansionsindretning (a) anbragt mellem kondensatoren/gaskøleren (1) og modtageren (3),

kendetegnet ved, at

det mellemliggende tryk holdes konstant ved hjælp af en ekspansionsventil (e) inden i forbindelsesledningen (11, 12), der forbinder gasrummet i modtageren (3) til indgangen til kompressorenheden (6) og udmunder i sugeledningen (5) opstrøms kompressorenheden (6).

11. Fremgangsmåde ifølge krav 10, hvor kølemidlet (2) afkøles inden mellemliggende ekspansion (a) deraf, hvor afkølingen (E1) af kølemidlet (2) især udføres imod en delvis strømning af kølemidlet (13).

12. Fremgangsmåde ifølge krav 11, hvor kølemidlet (4), der trækkes ud af modtageren (3), er nedkølet.

13. Fremgangsmåde ifølge et hvilket som helst af kravene 10 til 12, hvor mindst en del af flashgassen (12), der trækkes ud af modtageren (3), mindst midlertidigt overophedes imod det komprimerede kølemiddel (7).

14. Fremgangsmåde ifølge et hvilket som helst af kravene 10 til 13, hvor det mellemliggende tryk justeres ved hjælp af mindst én ventil (e, h, j), således at det har en konstant værdi eller en konstant forskel til sugetrykket, hvor denne justering især udføres via ekspansionsventilen (e) inden i ledningen (12) og via ekspansionsventilen (h) inden i ledningen (17) og/eller via ekspansionsventilen (j) inden i ledningen (18).

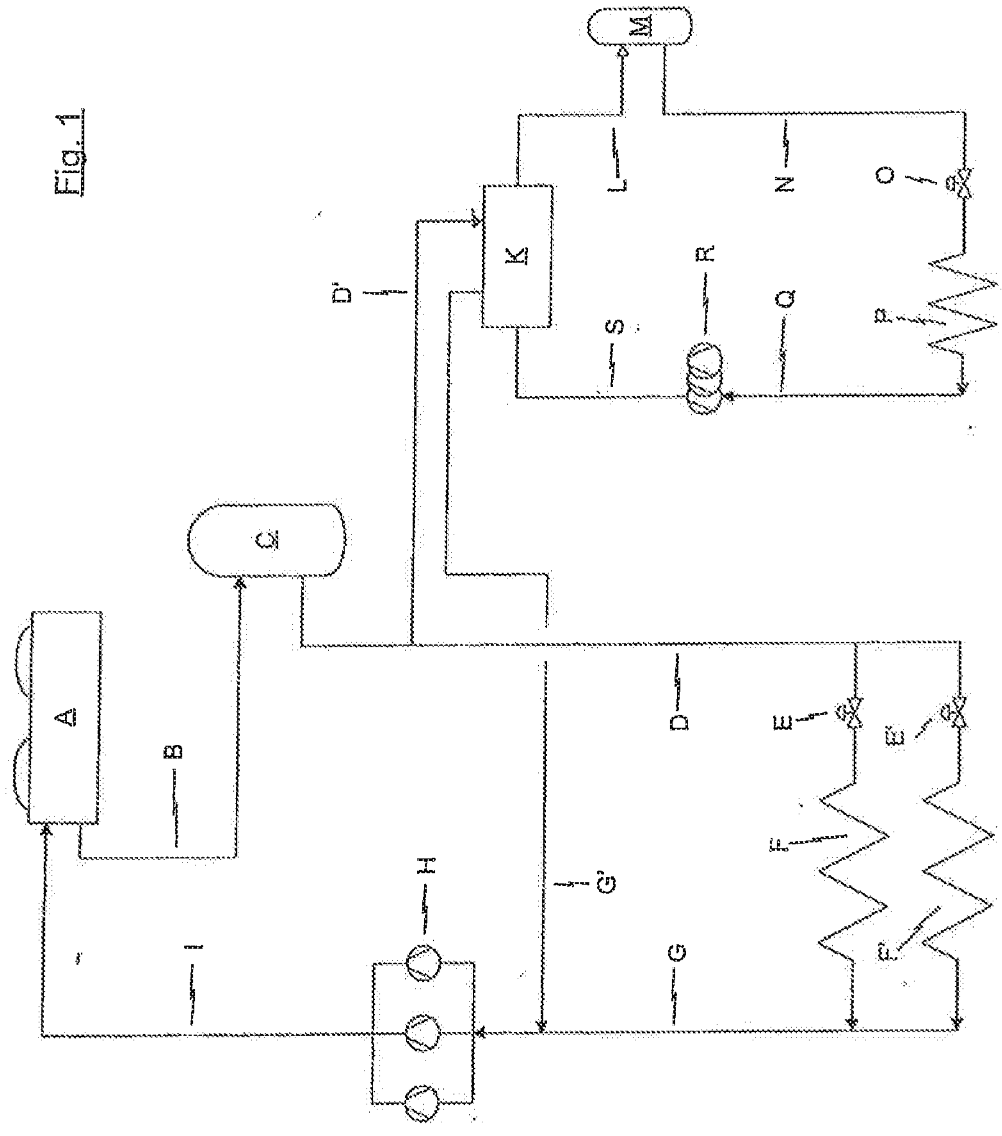

Fig. 1

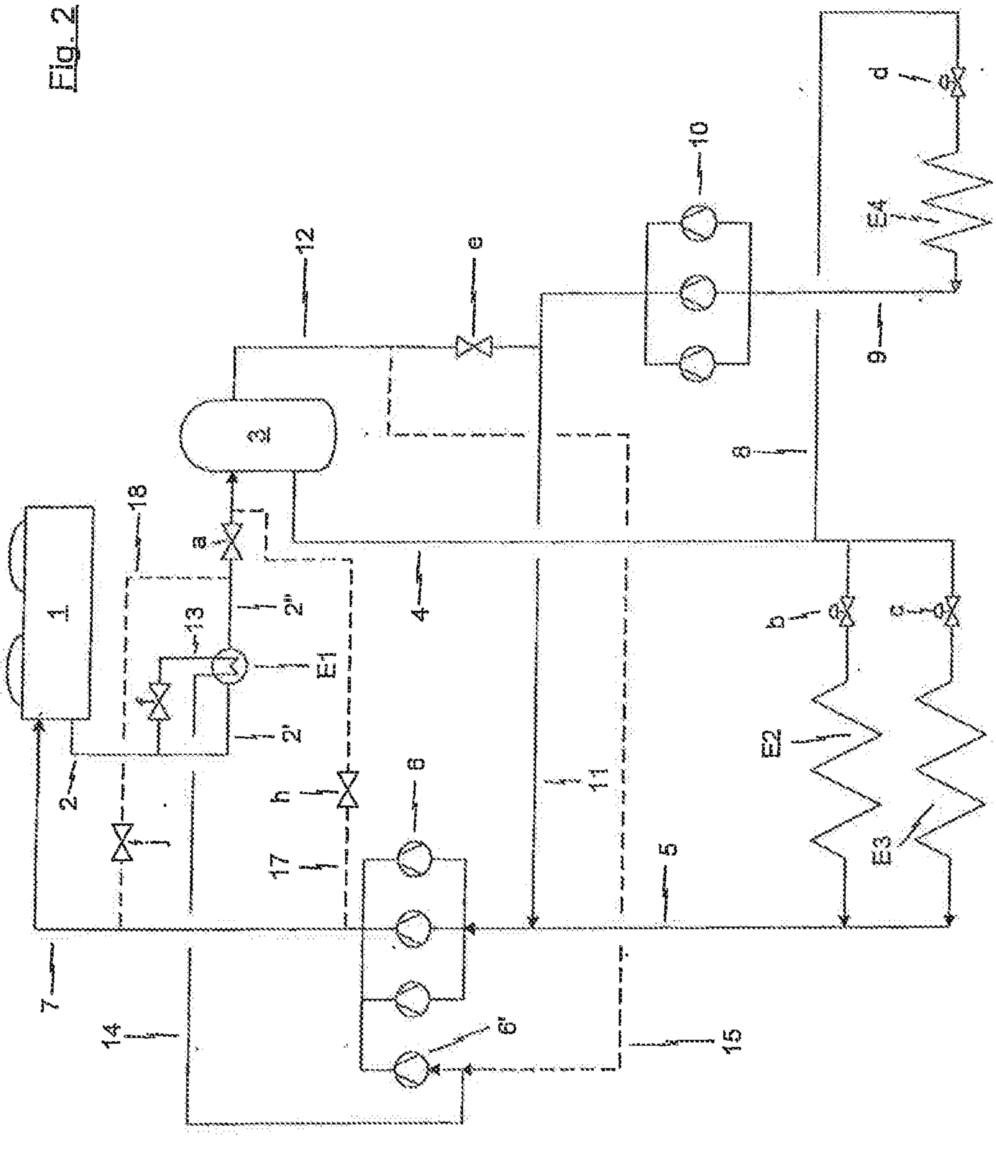

Fig. 2

Fig. 3

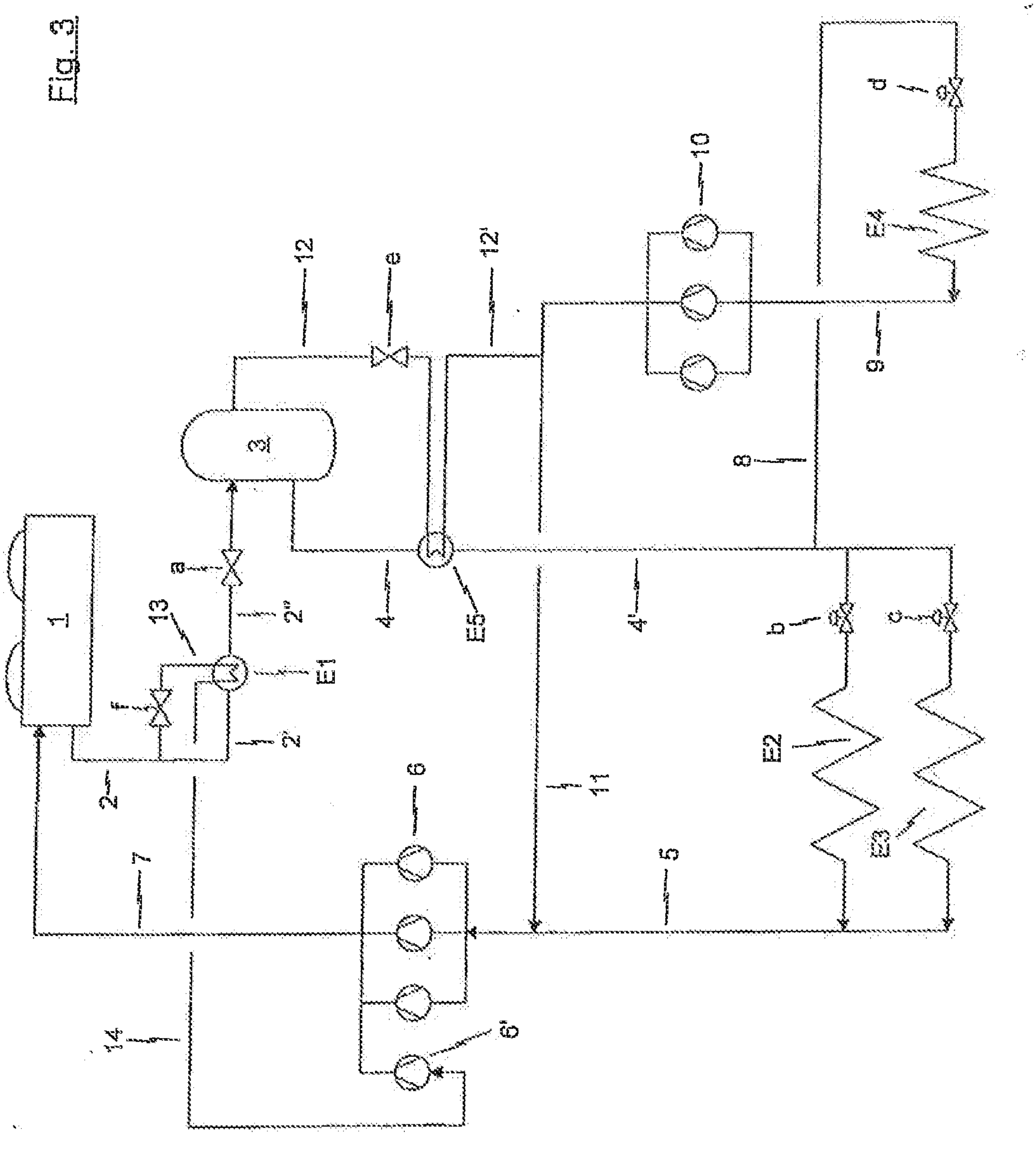

Fig. 4

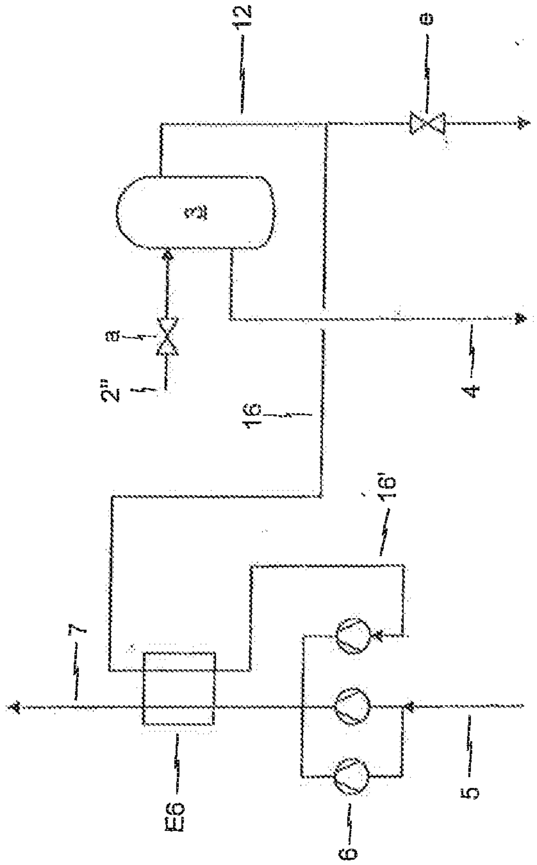

Fig. 5