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(54) **Refrigerating circuit**

(57) The refrigerant circuit proposed, designed for refrigeration systems with throttling in two stages (3, 5) and a liquid/vapor separator (4) at intermediate pressure, comprises at least one compressor (1), one heat exchanger (2) of high pressure and at least one evaporator (6) fed through a further throttling valve (5).

The circuit described includes a simple and innovative method for the separation of oil and its distribution to the at least one compressor.

It is described also a type of circuit that provides the use of at least one auxiliary compressor (7) for the suction of flash vapor from the liquid/vapor separator (4) at intermediate pressure, therefore the refrigerant system which employs the circuit arrangement described can operate according to a so-called economizer cycle without any particular device for distributing oil to the suction compressor at different pressures.

It also describes the insertion in the circuit of an ejector (16) for recovering expansion energy in order to increase the overall energy efficiency of a refrigerating system adopting the circuit configuration described.

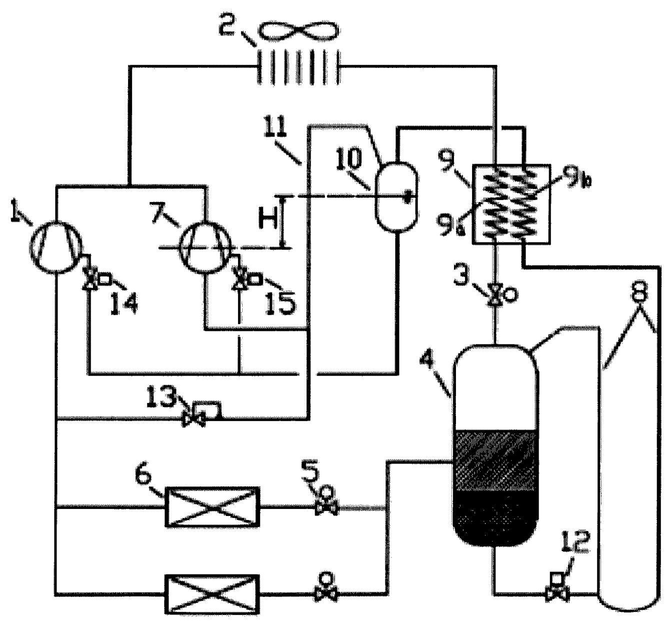

FIG.2

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Description

Introduction and state of the art

[0001] In fig.1 it is shown a simplified diagram of a typical refrigerating circuit that uses R744 - carbon dioxide or CO_2 - as the cooling fluid or working fluid or for simplicity refrigerant. In said circuit at least one compressor 1 sucks the refrigerant in vapor state from at least one evaporator 6 and compresses it to high pressure further entering it in a heat exchanger 2, condenser or gas cooler, in which the refrigerant rejects heat, for example, to outside air. Downstream of said heat exchanger 2 is present a device intended for a first stage of throttling, consisting on a high pressure controlling valve 3, outbound from which the two-phase refrigerant, vapor and liquid, is entered into a liquid / vapor separator tank 4.

[0002] From said separator 4 the refrigerant in liquid state is conveyed through one or more throttling valves 5 for feeding one or more evaporators 6, while the fraction of refrigerant fluid in vapor state, the so-called flash vapor, is subjected to a further expansion down to lower pressure of the cycle, in order to maintain the pressure in said separator 4 below of a desired maximum value. One back pressure regulating valve 13 is included, for this purpose, in the circuit and it is configured for controlling the pressure in the separator 4.

[0003] The inlet port of above mentioned valve 13 is connected to the upper part of the separator 4, that is the zone in which vapor is present, while the output section is connected to the low pressure side of the circuit, for example to the suction port of the at least one compressor 1.

[0004] In order to reduce the energy consumption, instead of controlling the pressure in the separator 4 through the valve 13 and expanding the flash vapor down to low pressure side, it would be preferable to directly compress the above mentioned flash vapor with at least one auxiliary compressor 7 as shown in dotted lines in fig .1. Today this is achieved at the cost of an important complication in the circuit. It emerges the problem of distribution of the oil to the compressors in which the lubricating oil is contained in the bottom of a chamber of the compressor, normally called crankcase, and precisely in the chamber in which the crankshaft and the connecting rod assembly of the pistons are housed, being the above mentioned crankcase maintained at the low pressure or suction pressure of the compressor and thus at the low pressure of the refrigerating circuit. Since the main compressor/s 1 or the auxiliary compressor/s 7 suck from different pressures it is necessary that the oil to be injected in crankcases, where the lubricating oil is stored, in order to restore the level of oil as a result of a certain inevitable oil carryover with the mass flow of compressed fluid, is maintained at a pressure greater or equal to the higher of the two different suction pressures. The state of the art consists on the separation of oil in high pressure. Supposing to use this mode of oil separation there are two alternatives, one of which is the injection of the oil in the compressors directly from the high pressure oil separator, not shown in fig. 1.

[0005] This first solution has the problem of high fraction of refrigerant dissolved in the oil separated in the high pressure, and thus a relevant foaming appears as soon as the mixture of oil and refrigerant fluid is entered in the crankcase of the compressors and is then subjected to a rapid depressurization, a phenomenon which reduces the effectiveness of the lubrication. The alternative solution consists on injection of the mixture of oil and refrigerant, separated in one high pressure oil separator, into an intermediate tank intended to accumulate the oil. In said storage oil tank the degassing, that is the pressure reduction to release part of the refrigerant dissolved in the oil, occurs and from this storage tank, the oil, or the mixture oil/refrigerant with a lower content of the refrigerant fluid, is further sent to the compressors. The pressure must be reduced down to a limit value higher or equal than the highest value between the two suction pressures. This solution reduces the phenomenon of foam formation, but is not completely satisfactory, particularly because the separation of oil in high pressure is never complete and consequently a non-negligible flow of oil flows to the evaporators, so reducing the heat transfer efficiency, but also because with both methods above described a bypass of refrigerant occurs from high pressure side to the suction side at each opening of the valve discharging oil from high pressure oil separator, representing this phenomenon an energy loss. Furthermore the installation of a pressure vessel, such as the oil separator to be installed on the high pressure side of the circuit, is an expensive solution and raises significant safety concerns, as the pressure to which the oil separator is intended to operate can be up to 100 bar in the case of refrigerating systems using CO_2 as a refrigerant.

[0006] The present invention discloses a simple and innovative method intended to solve the problem exposed and realizes a refrigerating circuit that allows operation according to a cycle with economizer.

Description of the drawings

[0007] In Table 1 are shown:

- Fig.1. Diagram of a state of the art refrigeration system
- Fig.2. Diagram of a refrigeration system as described in claims In Table 2 are shown:
- Fig.3. Typical plot of solubility of the pair PAG oil RFL68 / R744
- Fig.4. Diagram of a refrigerating system with ejector

Nomenclature and abbreviations

[0008]

- 1: main compressor

- 2: heat exchanger condenser / gas cooler
- 3: high pressure controlling valve / 1st stage throttling valve
- 4: liquid / vapor separator tank
- 5: throttling valve for evaporator feeding
- 6: evaporator
- 7: auxiliary compressor
- 8: pipe conveying flash vapor
- 9: regenerative heat exchanger with two circuits, 9a and 9b
- 10: Oil storage tank and flash vapor collector
- 11: piping for discharge of flash vapor from tank 10
- 12: discharge valve of oil rich mixture, for example but not exclusively a magnetic valve ON / OFF type
- 13: valve controlling upstream pressure
- 14: Oil supply valve to main compressor/s1, for example but not exclusively a magnetic valve ON / OFF type
- 15: Oil supply valve to auxiliary compressor/s 7, for example but not exclusively a magnetic valve ON / OFF type
- 16: ejector
- 17: suction port of the ejector 16

Description of the invention

[0009] The circuit considered, as in fig.2, includes at least one compressor 1 connected on the suction side to the outlet duct of at least one evaporator 6, being the above mentioned compressor 1 configured to suck the refrigerant in vapor state from the low pressure side of the refrigerating cycle and said compressor 1 is also connected on the discharge side to one high pressure heat exchanger 2.

[0010] Downstream of this heat exchanger 2 there is also a first throttling valve 3 controlling upstream high pressure and configured to control the high pressure of the cycle according to a known technique, for example but not exclusively in such a way to maximize the ratio between the amount of heat transferred from the refrigerating system to the hot sink, for example the outside air, or in an equivalent manner the amount of heat removed from the cold source, and the energy consumption for the compression of the refrigerant fluid. The above mentioned regulating valve 3 can be controlled, according to a known technique, in order to maintain the high pressure of the cycle to an optimum value and dependent on the operating conditions. This regulating valve 3 is also inserted in the circuit between the the heat exchanger 2 and the liquid/vapor separator tank 4, being said valve 3 configured to enter the two-phase refrigerant, vapor and liquid, in the liquid/vapor separator 4 located downstream.

[0011] The lubricating oil used for the compressor/s 1 is of type non-miscible or partially miscible with the liquid refrigerant. Reference is made, for example but not exclusively, to the pair refrigerant / lubricant R744 / PAG (polyalkylene glycol). The above mentioned pair refrigerant / lubricant has a solubility curve similar to the one shown in fig.3 and the oil is then defined partially miscible with the refrigerant CO_2 or R744. In fig.3, that reports in abscissa the percentage mass of liquid refrigerant CO_2 dissolved into the mixture refrigerant/PAG oil and in ordinate the temperature, in degrees Kelvin, of the mixture itself, the hatched area represents the immiscibility region. For a pair refrigerant/lubricant defined of type immiscible or partially miscible there is separation of two phases, one of which is rich of refrigerant and the other one is rich of oil. It is possible, for example, to see from the diagram of fig.3 that at a temperature of 0°C (273K) the maximum percentage of CO_2 dissolved in the oil-rich phase is about 32%, and consequently at this condition the percentage of oil corresponds to 68%.

[0012] The fraction of CO_2 in excess is separated in a phase rich of refrigerant or consisting on pure refrigerant. The PAG oil used in the example has a density of about 1020 kg/m^3 at a temperature of 0°C and density is increasing with decreasing of temperature. For example at -10°C the density is about 1050 kg/m^3, while the liquid refrigerant R744 has a density, also increasing with the decrease of temperature, of about 925 kg/m^3 at 0°C and about 980 kg/m^3 at - 10°C. The gradient of density as a function of the temperature is therefore approximately -3 kg/(m^3*K) for the oil and -5.5 kg/(m^3*K) for the refrigerant fluid CO_2 in saturated liquid state. The temperature at which the density of the CO_2 refrigerant liquid exceeds that of the oil is about -30°C.

[0013] Due to the above there will be in the liquid/vapor separator tank 4 a separation between the refrigerant/oil phase rich of oil and the refrigerant/oil phase rich of refrigerant, at the limit practically pure refrigerant as in the example, due to different densities in a certain range of pressure/temperature.

[0014] In the case of the example the range of temperature, between -30°C and +30°C, widely includes operational envelope of the refrigerating system characterized by the circuit object of the present invention, as, for example, saturation temperature in the liquid/vapor separator tank 4 may vary, in practical applications between -5 and +10°C. The oil-rich phase will settle at the bottom of the liquid/vapor separator tank 4 and the separation of the two phases may be enhanced by an appropriate configuration of said tank 4, for example but not exclusively by the positioning of the inlet and outlet of refrigerant and oil to appropriate levels, and therefore for example but not exclusively discharging the oil from the bottom of the separator 4 and distributing the refrigerant to liquid line from a port at a higher level.

[0015] Again with reference to fig.2 the liquid/vapor separator tank 4 is configured for feeding of the evaporators with liquid refrigerant, taken from the liquid/vapor separator tank 4 to a sufficiently high level so as to avoid carrying the oil-rich phase to the evaporators, while a pipe 8 connects the upper part of the tank 4 with an oil storage tank 10 configured for separation of the oil from the refrigerant vapor, while a pipe 11 connects the upper part of the oil storage tank 10 with the low pressure line of the refrigerating circuit via a valve 13 controlling upstream pressure. The above mentioned pipe 8 connects the upper part of the liquid/vapor separator tank 4, therefore the vapor contained in this volume, with the oil tank 10. One regenerative heat exchanger 9 is interposed between the separator liquid/vapor 4 and the oil accumulation tank 10.

[0016] The heat exchanger is characterized by two circuits in thermal contact, here defined 9a - primary - and 9b - secondary - in which two fluids at different pressure can flow through for exchanging heat. The pipe 8 will be also equipped with a connection, at the geodetic level of the bottom of the liquid / vapor separator tank 4, in which the oil-rich mixture will be injected, and the outflow will take place by gravity and will be controlled, for example but not exclusively with a timer, via a valve 12, for example but not exclusively of type ON/OFF electrically operated, connected to the portion of volume, at the bottom of the tank 4, where the rich mixture of oil will be settled. The flash vapor coming from the top of the liquid/vapor separator tank 4 and mixed with a certain flow of oil and refrigerant from the bottom of the above mentioned separator tank 4 will be entered through the pipe 8 in the secondary circuit, 9b, of the regenerative heat exchanger 9. The primary circuit 9a of the heat exchanger 9 will be configured for the circulation of the mass flow coming from the condenser/gas cooler heat exchanger 2. In the heat exchanger 9 the solution rich in oil will be warmed up by the heat exchanged with the high pressure warm fluid exiting the condenser/gas cooler 2, there will be a distillation of the refrigerant fluid and finally the oil will separate by gravity from the vapor in the oil accumulation tank 10. The top of the oil tank 10 will be connected through the pipe 11 with the inlet section of a valve 13 controlling upstream pressure, configured to maintain at a desired value the pressure in the liquid/vapor separator 4, and also in the oil storage tank 10, being the outlet section of the valve 13 connected to the suction side of the at least one compressor 1.

[0017] To improve the efficiency of the system the pipe 11 will be connected with the suction port of at least one auxiliary compressor 7, configured to recompress the flash vapor avoiding its expansion down to low pressure. The tank 10 will be placed at the geodetic level H higher than that of the at least one compressor 7, and the oil will easily flow by gravity towards the at least one compressor 7 through the opening of one valve 15 for each compressor, based, for example, on the level of oil present in the crankcase of said compressor 7.

[0018] Similarly from the storage tank 10 the oil will also feed the main compressor/s 1 through the opening of one valve 14 based, for example, on the level of oil present in the crankcase of the at least one compressor 1, being the oil storage tank 10 at a pressure higher than that existing in the crankcase of the at least one compressor 1. In this circuit configuration an upstream pressure controlling valve 13, as previously described, although not strictly necessary could contribute to a precise adjustment of the pressure in the liquid/refrigerant separator tank 4 and in the oil storage tank 10. The circuit may also include, when it is present at least one auxiliary compressor 7 and in order to further improve the energy efficiency of the system, at least one ejector 16 connected in parallel or in alternative to the high pressure control valve 3. An example of such a configuration is shown in fig. 4. In this case, the suction side of the at least one compressor 1, or in general the low pressure side of the refrigerating circuit, will also be connected to the secondary suction port 17 of ejector 16, which will be configured to suck part of the vapor coming from the evaporator 6 and subject it to a first compression, without the need to provide additional external energy to the system, up to the intermediate pressure existing in the liquid/vapor separator 4 from which the refrigerant vapor can be sucked by the at least one auxiliary compressor 7 together with the flash vapor, as above described.

Claims

1. **Refrigerating circuit** as from fig. 2, including at least one main compressor (1) configured for the suction of vapor from at least one evaporator (6), a high-pressure heat exchanger (2) configured for heat rejection to an external fluid, a first throttling valve (3) and a liquid/vapor separator (4) arranged to feed the at least one evaporator (6) with liquid refrigerant through a second throttling device (5), being the lubricating oil used by the compressor (1) of a type not miscible or partially miscible with the refrigerant - for example, but not exclusively, of PAG type when the refrigerant is carbon dioxide - and having said oil a density greater than that of the refrigerant in the conditions existing in the liquid/vapor separator (4), being the refrigerating circuit **characterized by** a two-circuit regenerative heat exchanger (9) configured for the circulation, in the primary circuit (9a), of the refrigerant leaving the high-pressure heat exchanger (2) and for the circulation, in the secondary circuit (9b), of the flash vapor produced during the first throttling process through valve (3), the circuit further including a pipe (8) connecting the top of the separator (4) with the inlet of the secondary circuit (9b) of the heat exchanger (9), being said pipe (8) configured to convey the flash vapor and for injection, at an intermediate point, of a flow of oil or oil-rich mixture, for example but not exclusively through a valve (12), from the bottom of the liquid/vapor separator (4), and being the exit of the secondary circuit (9b) of the heat exchanger (9) connected to the top of an oil storage tank (10) configured for separation by gravity of the oil from vapor and for conveying the refrigerant vapor to the inlet of a valve (13) adapted for controlling the pressure of the oil tank (10) and of the separator (4) by means of the controlled discharge of refrigerant

vapor from the oil storage tank (10) into the suction of the at least one compressor (1), in which the oil level is restored with oil from the oil tank (10) through a valve (14).

2. **Refrigerating circuit** as in claim 1) including, additionally, at least one auxiliary compressor (7) configured for the compression of flash vapor produced during the first throttling process through valve (3), being the suction port of said at least one compressor (7) connected through a pipe (11) to the upper part of the oil storage tank (10), located at a geodetic level H higher than that of the at least one compressor (7), the circuit further including a pipe adapted for supplying lubricating oil to the at least one compressor (7) from the bottom of the oil storage tank (10) via a valve (15).

3. **Refrigerating circuit** as in claims 1), 2) and as from fig. 4, including at least one ejector (16), mounted in parallel or alternatively to the first throttling valve (3), being the secondary port (17) of said at least one ejector (16) connected directly or indirectly to the suction side of the at least one main compressor (1) and being the at least one compressor (7) configured for suction, from top of oil tank (10), of both flash vapor and mass flow compressed by the at least one ejector (16) into the liquid/vapor separator (4).

4. **Refrigerating system** using the circuit arrangements described in claims 1), 2) and 3).

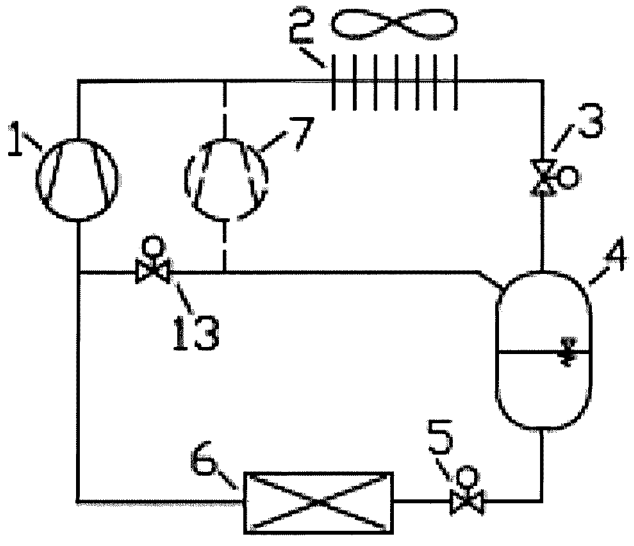


FIG.1

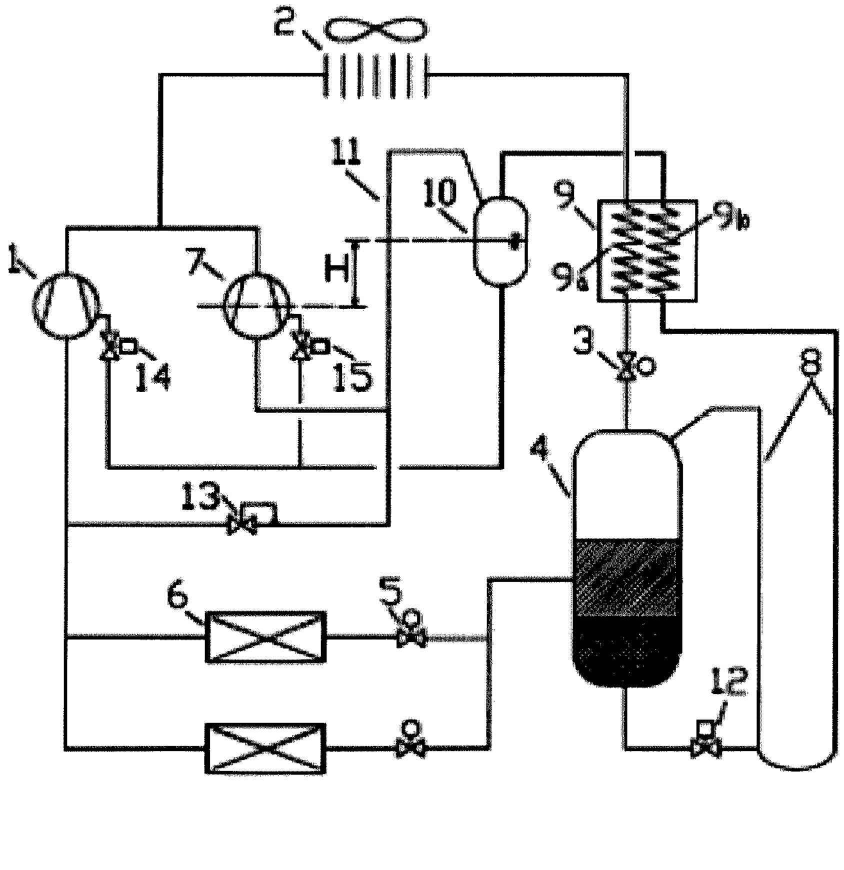


FIG.2

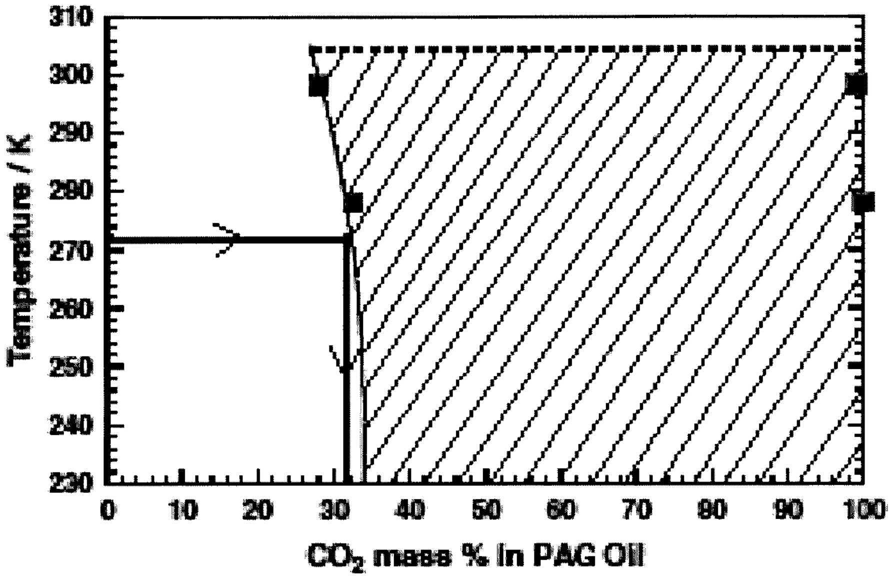
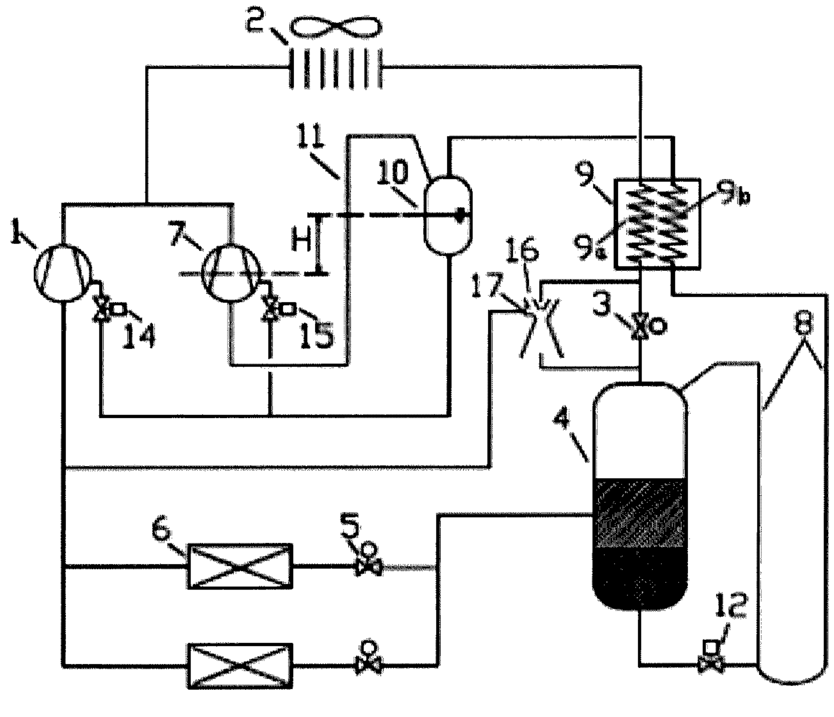

310
300
290
280
270
260
250
240
230
Temperature / K
0
10
20
30
40
50
60
70
80
90
100
CO_2 mass % in PAG Oil

FIG.3


2
11
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9b
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FIG.4

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EUROPEAN SEARCH REPORT

Application Number
EP 13 42 5114

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TECHNICAL FIELDS SEARCHED (IPC)
F25B

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	3 June 2014	Léandre, Arnaud

CATEGORY OF CITED DOCUMENTS

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