

(19) **DANMARK**

(10) **DK/EP 3140023 T3**



Patent- og
Varemærkestyrelsen

(12) Oversættelse af
europæisk patentskrift

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- (51) Int.Cl.: **B 01 D 53/26 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2019-05-20**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2019-04-17**
- (86) Europæisk ansøgning nr.: **15736774.9**
- (86) Europæisk indleveringsdag: **2015-04-27**
- (87) Den europæiske ansøgnings publiceringsdag: **2017-03-15**
- (86) International ansøgning nr.: **BE2015000014**
- (87) Internationalt publikationsnr.: **WO2015168753**
- (30) Prioritet: **2014-05-09 BE 201400347**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
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- (54) Benævnelse: **Fremgangsmåde og indretning til køletørring af gas under anvendelse af varmeveksler med lukket kølekredsløb**
- (56) Fremdragne publikationer:
WO-A1-2006/050132
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DESCRIPTION

[0001] The present invention relates to a method for cool drying a gas.

[0002] More specifically, the invention is intended for cool drying a gas, whereby water vapour in the gas is condensed by guiding the gas through the secondary section of a heat exchanger whose primary section forms the evaporator of a closed cooling circuit in which a coolant can circulate by means of a compressor that is installed in the cooling circuit downstream from the evaporator and which is followed by a condenser and expansion means through which the coolant can circulate.

[0003] An example of a known system can be found in GB 2,183,320 A whereby a device for the compression of gases is disclosed, the device comprising two freeze-dehumidifiers connected to a compressor. Each of the two freeze-dehumidifiers comprising a heat exchanger whereby the gaseous refrigerant is drawn in via the heat exchange and if applicable via a liquid separator by means of a refrigerant compressor.

[0004] Cool drying is, as is known, based on the principle that by lowering the gas temperature the moisture in the gas condenses, after which the condensate is separated in a liquid separator and after which the gas is again heated such that this gas is no longer saturated.

[0005] It is known that in most cases compressed air, supplied by a compressor for example, is saturated with water vapour or, in other words, it has a relative humidity of 100%. This means that in the event of a temperature drop to below the 'dew point' condensation occurs. Because of the condensed water corrosion occurs in the pipes and tools that draw off compressed air from the compressor, and equipment can present premature wear.

[0006] It is consequently necessary to dry this compressed air, which can be done in the aforementioned way by cool drying. Air other than compressed air or other gases can also be dried in this way.

[0007] A method for cool drying is already known whereby the condenser is an air-cooled condenser that is equipped with one or more fans.

[0008] These fans can be switched on and off depending on the cooling required for the condenser and coolant.

[0009] These fans will be switched on at a certain threshold value and switched off again at another threshold value.

[0010] Hereby more cooling is often done than is strictly necessary in order to have a certain reserve, such that the energy consumption of such a fan is often higher than what is really necessary.

[0011] The switching on or off of the fan will vary the condenser pressure.

[0012] This has the disadvantage that when the condenser pressure rises, the compressor will consume more power.

[0013] An example of a system trying to overcome such a disadvantage can be found in US 6,516,622 B disclosing a refrigerant air dryer comprising an evaporator, a compressor, a condenser having a fan and a fan motor, a throttling device and a hot gas bypass valve. The document disclosing a method of control for the fan motor such that if the condensing pressure is greater than a preestablished threshold, the speed of the motor is increased and, if the condensing pressure is less than the preestablished threshold, the motor speed is decreased.

[0014] However, by varying the condenser pressure, the expansion means and other valves in the cooling circuit are affected, and consequently also the evaporator pressure and cooling capacity of the cooling circuit.

[0015] Consequently the expansion means and other valves must be adjusted in order to prevent fluctuations of the evaporator pressure.

[0016] This leads to a very complex control of the system.

[0017] Another known system can be found in WO 2006,050,132 A whereby a controller for a refrigeration system, the controller comprising a first input indicative of an energy consumption of a compressor, a second input indicative of the energy consumption of at least one condenser fan and an output providing a control signal to the condenser fan. The controller storing a condenser set-point and modulating such set-point in order to minimize the energy consumption. Such an example not being the most time efficient solution for an accurate adjustment of the speed of the condenser fan.

[0018] The purpose of the present invention is to provide a solution to at least one of the aforementioned and other disadvantages.

[0019] The object of the present invention is a method for cool drying a gas, whereby water vapour in the gas is condensed by guiding the gas through the secondary section of a heat exchanger whose primary section forms the evaporator of a closed cooling circuit in which a coolant can circulate by means of a compressor that is installed in the cooling circuit downstream from the evaporator, and which is followed by a condenser and expansion means through which the coolant can circulate, whereby use is made of an air-cooled condenser with a frequency controlled fan, and the method comprises the step of controlling the speed of the aforementioned fan so that the condenser pressure is kept equal to a calculated or set target value, in that the calculated or set target value for the condenser pressure is chosen such that the combined power absorbed by the compressor and the fan is a minimum, and in that use is made of a predetermined matrix that shows the combined power absorbed by the compressor

and the fan as a function of the evaporator pressure and the condenser pressure, whereby the method comprises the steps of:

- the determination of the evaporator pressure;
- on the basis of the aforementioned matrix, the determination of the target value for the condenser pressure, which ensures a minimum combined power at the evaporator pressure determined in this way.

[0020] An advantage is that such a method that makes use of a frequency controlled fan enables the condenser pressure to be kept constant by suitably adjusting the speed of the fan.

[0021] This has the advantage that the evaporator pressure will not vary and that the valves in the cooling circuit do not or almost do not have to be adjusted as a result of changes in the condenser pressure.

[0022] This means that the control and adjustment of such a device is much simpler.

[0023] Another advantage is that a frequency controlled fan will last longer than a fan that can only be switched on and off.

[0024] The valves in the cooling circuit will also last longer as they do not have to be constantly adjusted.

[0025] It is known that the power consumed by the fan can be determined from the speed of the fan. The fan speed will determine the condenser pressure. The compressor power can be determined on the basis of the condenser pressure and the evaporator pressure.

[0026] Consequently by suitably choosing the condenser pressure the combined power can be kept to a minimum such that the device will consume very little energy.

[0027] The invention also concerns a device for cool drying a gas, whereby water vapour in the gas is condensed by cooling the gas, whereby this device is provided with a heat exchanger with a secondary section through which the gas to be dried is guided in order to cool the gas, and with a primary section that forms the evaporator of a closed cooling circuit in which a coolant can circulate by means of a compressor downstream from the evaporator, whereby downstream between the compressor and the evaporator the cooling circuit successively comprises a condenser and expansion means through which the coolant can circulate, whereby the condenser comprises a frequency controlled fan, whereby the device comprises a control unit and whereby the control unit controls the speed of the aforementioned fan such that the condenser pressure is kept equal to a calculated or set target value, whereby the control unit is provided with a control algorithm that enables, by varying the fan speed, an accompanying variation of the combined power absorbed by the compressor and the fan to be determined and the fan speed to be adjusted to the speed at which the aforementioned

combined power is a minimum, and whereby the control unit is provided with a predetermined matrix that shows the combined power absorbed by the compressor and the fan as a function of the evaporator pressure and the condenser pressure and that the control unit is also connected to means to determine the evaporator pressure, whereby the control unit determines the target value for the condenser pressure using the aforementioned matrix on the basis of the signal from the aforementioned means so that the combined power is a minimum and adjusts the fan speed so that the condenser pressure is equal to this aforementioned target value.

[0028] The advantages of a device according to the invention are analogous to the above-mentioned advantages.

[0029] With the intention of better showing the characteristics of the invention, a few preferred variants of a method and device according to the invention are described hereinafter by way of an example, without any limiting nature, with reference to the accompanying drawings, wherein:

figure 1 schematically shown a device according to the invention;

figure 2 schematically shows a matrix that shows the combined power absorbed by the compressor and fan as a function of the evaporator pressure and condenser pressure.

[0030] The device 1 shown in figure 1 for cool drying essentially consists of a heat exchanger 2 whose primary section forms the evaporator 3 of a closed cooling circuit 4, in which a compressor 5, a condenser 6 and expansion means 7 are also placed in succession.

[0031] In this case the compressor 5 is driven by a motor 8 and is used to make a coolant circulate through the cooling circuit 4 according to arrow A. The compressor 5 can be a volumetric compressor for example, while the motor 8 is an electric motor for example.

[0032] The coolant can be R404a for example, but the invention is of course not limited as such.

[0033] In this case and preferably the expansion means 7 are formed by an expansion valve 7.

[0034] The secondary section 9 of the heat exchanger 2 forms part of a pipe 10 for drying moist air whose direction of flow is indicated by arrow B. The entrance of this pipe 10 can be connected to an outlet of a compressor, for example, for the supply of the compressed air to be dried.

[0035] After the secondary section 9 of the heat exchanger 2, more specifically at its output, a first liquid separator 11 is installed in the pipe 10.

[0036] In this case a section 12 of this pipe 10, before it reaches the secondary section 9 of the heat exchanger 2, extends through a precooler or recovery heat exchanger 13. After the secondary section 9 a section 14 of this pipe 10 also extends through this recovery heat exchanger 13, with the opposite flow to the aforementioned section 12.

[0037] The heat exchanger 2 is a liquid coolant-air heat exchanger and constructionally can form one unit with any recovery heat exchanger 13 that is an air-air heat exchanger.

[0038] The output of the aforementioned pipe 10 can be connected to a compressed air network (not shown in the drawings), for example, to which compressed air consumers are connected such as tools that are driven by compressed air.

[0039] In this case the compressor 5 is bypassed by one bypass pipe 15 that connects the outlet of the compressor 5 to the injection point P that is located upstream from the compressor, but downstream from the outlet 16 of the evaporator.

[0040] The bypass pipe 15 is constructed with a hot gas bypass valve 17 for tapping off coolant from the cooling circuit 4.

[0041] Downstream from the injection point P and upstream from the compressor, a second liquid separator 18 is incorporated in the closed cooling circuit 4.

[0042] According to the invention the condenser 6 is an air-cooled condenser that is equipped with a frequency controlled fan 19, whose speed is infinitely adjustable in this case.

[0043] The device 1 is further provided with a control unit 20. The control unit 20 is connected to the motor 8 and the fan 19 in order to control them.

[0044] The control unit 20 is also connected to means 21 to determine the condenser pressure and to means 22 to determine the evaporator pressure.

[0045] It is clear that it is not excluded that means are provided to determine the lowest gas temperature (LAT) of the gas to be dried.

[0046] It is clear that the means 22 determine the evaporator temperature instead of the evaporator pressure in view of the unequivocal link between the two.

[0047] The method for cool drying by means of a device 1 according to figure 1 is very simple and as follows.

[0048] The air to be dried is carried through the pipe 10 and thus through the secondary section 9 of the heat exchanger 2 according to arrow B.

[0049] In this heat exchanger 2 the moist air is cooled under the influence of the coolant that

flows through the primary section of the heat exchanger and thus the evaporator 3 of the cooling circuit 4, 2.

[0050] As a result condensate is formed that is separated in the first liquid separator 11.

[0051] The cold air that contains less moisture in absolute terms after this first liquid separator 11, but still has a relative humidity of 100%, is heated in the recovery heat exchanger 13 under the influence of the newly supplied air to be dried, such that the relative humidity falls to preferably below 50%, while the new air to be dried is already partially cooled in the recovery heat exchanger 13 before being carried to the heat exchanger 2.

[0052] The air at the output of the recovery heat exchanger 13 is thus drier than at the input of the heat exchanger 2.

[0053] To enable cooling of the moist air to be cooled in the secondary section 9 of the heat exchanger, the coolant is guided through the cooling circuit in the direction of arrow A through the evaporator 3 or the primary section of the heat exchanger 2.

[0054] The warm coolant that comes out of the evaporator 3 is in the gas phase and will be raised to a higher pressure by the compressor 5, then cooled in the condenser 6 by the fan 19 and condensed.

[0055] Any liquid coolant still present after the evaporator 3 will be held back by the second liquid separator 18.

[0056] The liquid cold coolant will then be expanded by the expansion valve 7 and will cool further, before being driven to the evaporator 3 to cool the air to be dried there.

[0057] Under the influence of heat transfer the coolant will warm up in the evaporator 3, evaporate and again be guided to the compressor 5.

[0058] The hot gas bypass valve 17 in the bypass pipe 15 will ensure that when the air in the heat exchanger 2 cools down too greatly, for example in the event of a variable load of the cool dryer, a certain quantity of coolant in the form of a hot gas will be driven over the compressor via the aforementioned bypass pipe 15 in the direction of the arrow A'. In this way the cooling capacity of the device 1 can decrease and prevent the condensate in the heat exchanger from freezing or the temperature of the coolant falling too greatly.

[0059] In order to keep the control of the cooling circuit 4 as simple as possible, the fan 19 will be controlled by the control unit 20 such that the condenser pressure p_c is kept constant at a calculated or set target value.

[0060] In order to determine this target value, in this case use is made of a matrix that is stored in the control unit 20, for example.

[0061] An example of such matrix is shown in figure 2.

[0062] The matrix gives the combined power that is absorbed by the compressor and the fan as a function of the evaporator pressure p_v and the condenser pressure p_c .

[0063] The control unit 20 receives the value P_{vn} for the evaporator pressure p_v from the means 22. On the basis of this value P_{vn} the control unit 20 determines a target value for the condenser pressure p_c at which the joint combined power is a minimum.

[0064] In the example of figure 2, the minimum combined power is equal to x_{nn} and the accompanying target value for the condenser pressure is equal to p_{cn} .

[0065] The control unit 20 will adjust the speed of the fan such that the condenser pressure p_c reaches and maintains the determined target value p_{cn} .

[0066] In this way the condenser pressure p_c is kept constant and at such a target value that the combined power absorbed by the compressor 5 and the fan 19 is a minimum, which has the advantage that the device 1 will operate under optimum energy-efficient conditions, as the compressor 5 and the fan 19 are the main consumers of energy in the cooling circuit 4.

[0067] It is possible that the control unit 20 is such that the target value of the condenser pressure p_c is determined periodically, in other words the control unit 20 periodically determines a target value for the condenser pressure p_c from the matrix on the basis of the signal from the means 22. The interval with which the target value is determined can be chosen as a function of the variation of the load of the device 1 for example.

[0068] Instead of using a matrix, the target value for the condenser pressure p_c can also be determined by means of a preprogrammed control algorithm in the control unit 20.

[0069] Hereby the control unit 20 will determine the power absorbed by the compressor 5 on the basis of the signal from the means 21 and 22, and determine the power absorbed by the fan 19 on the basis of the current speed of the fan 19 so that the combined power can be determined.

[0070] Then the control unit 20 will increase or decrease the speed of the fan 19 by a certain step and again determine the combined power.

[0071] The control unit 20 will determine for what fan 19 speed the combined power was a minimum and will adjust the fan 19 to this speed.

[0072] If need be the previous steps are repeated iteratively until a minimum combined power

is reached.

[0073] This control algorithm ensures that the control unit 20 is self-learning as it were and independent of the device 1 and the cooling circuit and consequently can be applied in different devices 1 and cooling circuits 4.

[0074] In another preferred embodiment the fan 19 speed is adjusted to the minimum speed whereby the calculated or set target value for the condenser pressure p_c is reached or whereby the condenser pressure p_c is as good as equal to the target value.

[0075] This target value may be determined on the basis of the methods described above, or otherwise.

[0076] This has the advantage that the fan speed is no higher than is strictly necessary.

[0077] When at a certain speed the target value for the condenser pressure p_c is reached within a certain allowed tolerance, it is not necessary to further increase the speed in order to actually reach the target value. Indeed, it is possible that, in order to actually reach the target value, the speed will still have to increase very substantially. This will be coupled with a strong increase in the consumed power of the fan 19, while the variation of the condenser pressure p_c will only be limited.

[0078] It is clear that the calculated or set target value can be determined in many different ways so that the combined power absorbed by the compressor 5 and the fan 19 is a minimum.

[0079] It is also clear that the fan 19 speed can be controlled or adjusted in many different ways by the control unit 20 so that the condenser pressure p_c is kept equal to the target value.

[0080] Although in the example shown the device 1 is provided with only one heat exchanger 2, it is clear that a number of heat exchangers 2 can also be provided.

[0081] The present invention is by no means limited to the embodiment described as an example and shown in the drawings, but such a method and device can be realised in different variants without departing from the scope of the invention.

REFERENCES CITED IN THE DESCRIPTION

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- GB2183320A [0003]
- US6516622B [0013]
- WO2006050132A [0017]

P a t e n t k r a v

1. Fremgangsmåde til koldtørring af gas, hvor vanddamp i gassen kondense-
res ved at føre gassen gennem det sekundære afsnit (9) af en varmeveksler
5 (2), hvis primære afsnit danner fordamperen (3) af et lukket kølekredsløb (4),
i hvilket et kølemiddel kan cirkulere ved hjælp af en kompressor (5), der er
installeret i kølekredsløbet (4) nedstrøms fra fordamperen (3), og som efterføl-
ges af en kondensator (6) og ekspansionsmidler (7), hvorigennem kølemidlet
kan cirkulere, **kendetegnet ved, at** der anvendes en luftafkølet kondensator
10 (6) med en frekvensstyret ventilator (19), **ved, at** fremgangsmåden omfatter
trinnet med at styre hastigheden af ventilatoren (19), således at kondensator-
trykket (p_c) holdes lig med en beregnet eller indstillet målværdi, **ved, at** den
beregnete eller indstillede målværdi af kondensatortrykket (p_c) er udvalgt på
en sådan måde, at den kombinerede effekt, som absorberes af kompressoren

15 (5) og ventilatoren (19) udgør et minimum, og **ved, at** der anvendes en forud-
bestemt matrix, som viser den kombinerede effekt, der absorberes af kom-
pressoren (5) og ventilatoren (19) som en funktion af fordampertrykket (p_v) og
kondensatortrykket (p_c), hvor fremgangsmåden omfatter følgende trin:

- bestemmelse af fordampertrykket (p_v);
- 20 - på basis af den førnævnte matrix, bestemmelse af målværdien for konden-
satortrykket (p_c), som sikrer en kombineret minimumseffekt ved det fordam-
pertryk (p_v), der bestemmes på denne måde.

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** fremgangsmåden om-
25 fatter de følgende iterative trin:

- bestemmelse af den aktuelle kombinerede effekt, der absorberes af kom-
pressoren (5) og ventilatoren (19);
- øgning og sænkning af hastigheden af ventilatoren (19) med et særligt trin;
- bestemmelse af den nye aktuelle kombinerede effekt, der absorberes af kom-
30 pressoren (5) og ventilatoren (19);
- indstilling af hastigheden af ventilatoren (19) til den hastighed, hvor den be-
stemte kombinerede effekt er lavest;

- hvis nødvendigt, iterativ gentagelse af de tidligere trin.

- 5 **3.** Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** under trinnet med indstilling af ventilatorhastigheden, indstilles hastigheden til minimumshastigheden, hvor den beregnede eller indstillede målværdi for kondensatortrykket (p_c) er nået, eller hvor kondensatortrykket (p_c) er tilnærmelsesvis lig med målværdien.
- 10 **4.** Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** den beregnede og indstillede målværdi for kondensatortrykket (p_c) bestemmes periodisk.
- 15 **5.** Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** fremgangsmåden anvendes til tørring af gas, der stammer fra en kompressor.
- 20 **6.** Indretning til koldtørring af gas, hvor vanddamp i gassen kondenseres ved at afkøle gassen, hvor denne indretning (1) er forsynet med en varmeveksler (2) med et sekundært afsnit (9), hvorigennem den gas, som skal tørres, føres for at afkøle gassen, og med et primært afsnit, som danner fordamperen (3) af et lukket kølekredsløb (4), i hvilket et kølemiddel kan cirkulere ved hjælp af en kompressor (5) nedstrøms fra fordamperen (3), hvor kølekredsløbet (4) nedstrøms mellem kompressoren (5) og fordamperen (3) efterfølgende omfatter en kondensator (6) og ekspansionsmidler (7), hvorigennem kølemidlet kan cirkulere, **kendetegnet ved, at** kondensatoren (6) omfatter en frekvensstyret ventilator (19), og at indretningen (1) omfatter en styreenhed (20), hvor styreenheden (20) styrer hastigheden af ventilatoren (19) således, at kondensatortrykket (p_c) holdes lig med en beregnet eller indstillet målværdi, hvor styreenheden (20) er forsynet med en styrealgoritme, som ved at variere hastigheden af ventilatoren (19), tillader en ledsagende variation af den kombinerede effekt, som absorberes af kompressoren (5) og ventilatoren, der skal bestemmes, og
- 25
- 30

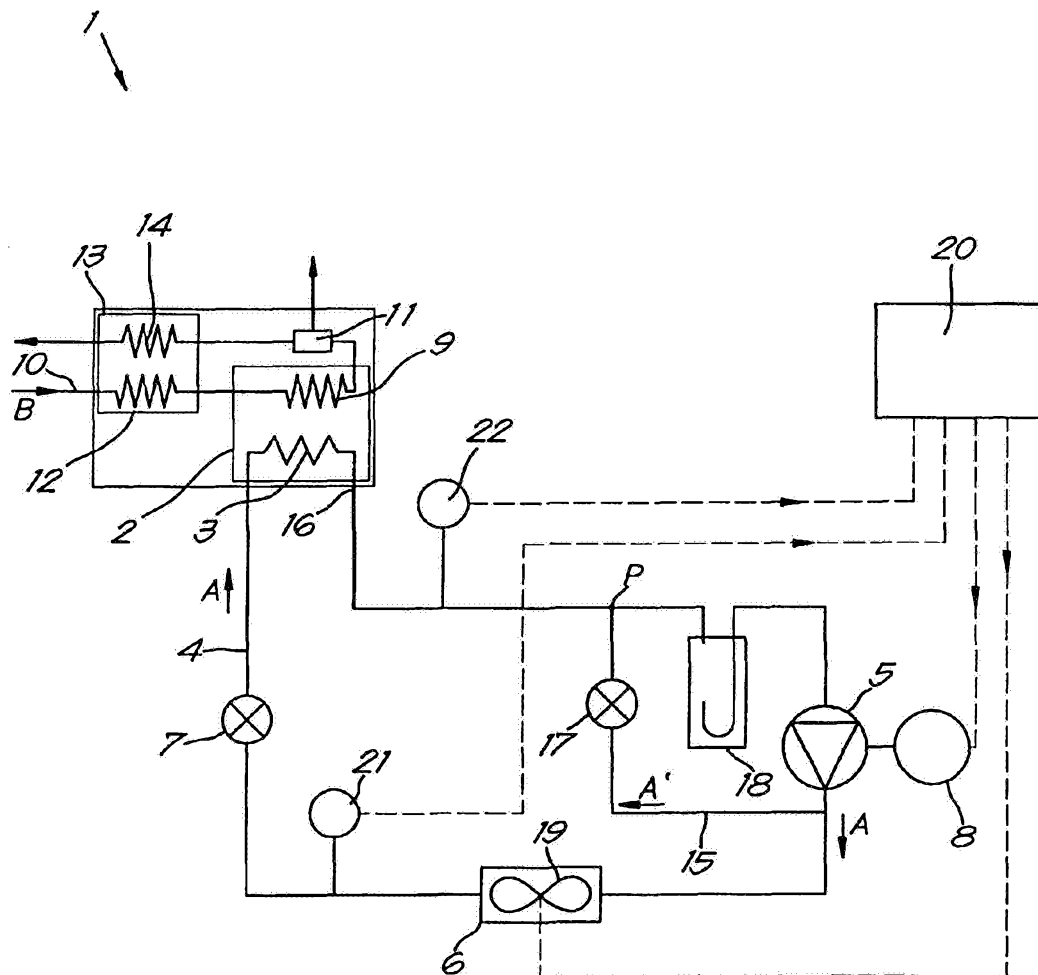
ventilatorhastigheden at indstilles til den hastighed, ved hvilken den kombinerede effekt er et minimum, og hvor styreenheden (20) er forsynet med en forudbestemt matrix, som viser den kombinerede effekt, der absorberes af kompressoren (5) og ventilatoren (19) som en funktion af fordampetrykket (p_v) og kondensatortrykket (p_c), og at styreenheden (20) også er forbundet med midler (22) til at bestemme fordampetrykket (p_v), hvor styreenheden (20) bestemmer målværdien for kondensatortrykket (p_c) under anvendelse af den førnævnte matrix på basis af signalet fra de nævnte midler (22), således at den kombinerede effekt er et minimum og indstiller hastigheden af ventilatoren (19), således at kondensatortrykket (p_c) er lig med målværdien.

7. Indretning ifølge krav 6, **kendetegnet ved, at** styreenheden (20) indstiller hastigheden af ventilatoren (19) til minimumshastigheden, hvor den beregnede eller indstillede målværdi for kondensatortrykket (p_c) er nået, eller hvor kondensatortrykket (p_c) er tilnærmelsesvis lig med målværdien.

8. Fremgangsmåde ifølge krav 6 eller 7, **kendetegnet ved, at** styreenheden (20) periodisk bestemmer den beregnede eller indstillede målværdi for kondensatortrykket (p_c).

9. Indretning ifølge et hvilket som helst af de foregående krav 6 til 8, **kendetegnet ved, at** den gas, der skal tørres, stammer fra en kompressor.

DRAWINGS

*Fig. 1*

p_v p_c	p_{v1}	p_{v2}	p_{v3}	...	p_{vn}	...
p_{c1}	x_{11}	x_{21}	x_{31}	...	x_{n1}	...
p_{c2}	x_{12}	x_{22}	x_{32}	...	x_{n2}	...
p_{c3}	x_{13}	x_{23}	x_{33}	...	x_{n3}	...
...	...	...	...	...	...	...
p_{cn}	x_{1n}	x_{2n}	x_{3n}	...	x_{nn}	...
...	...	...	...	...	...	...

Fig. 2