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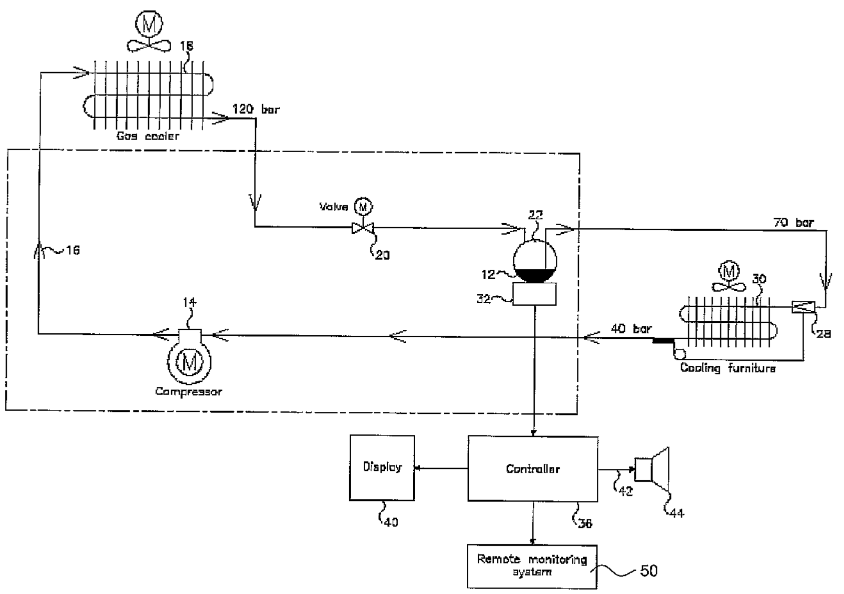
(54) Title: REFRIGERANT LEAKAGE DETECTION



(57) Abstract: The present invention relates to a refrigeration system with a detector for detection of refrigerant leakage, the system comprising a flow circuit for recirculation of a refrigerant and including a compressor for generation of a refrigerant flow from a low-pressure side to a high-pressure side of the compressor and, in the order defined by the flow direction, connected in series with a condenser for cooling of the refrigerant towards the ambient temperature, a receiver for accommodation of refrigerant, a pressure reducing device separating the low-pressure side and the high pressure side of the compressor, and a first evaporator for evaporation of the refrigerant, and a weight transducer mounted in operational contact with the receiver for generation of an output signal corresponding to the weight of the receiver.

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REFRIGERANT LEAKAGE DETECTION

The present invention relates to a refrigeration system capable of detecting leakage of the refrigerant, and in particular the present invention relates to a refrigeration system intended for a supermarket with many cooling sites.

Typically, refrigeration systems with several cooling sites, such as refrigeration systems for a supermarket, have a receiver for accommodation of the refrigerant. In such a cooling system, the amount of refrigerant in the receiver varies as a function of the load at the sites. The variation increases with the number of cooling sites. Typically, the receiver is capable of accommodating the total amount of refrigerant in the system.

Maintenance of the refrigeration system requires monitoring of the amount of refrigerant in the system since the system requires a minimum amount of refrigerant for proper operation. Possible leakages should be detected since refilling of refrigerant ads to the cost of system operation, and leakage of refrigerant may contaminate the environment.

Typically, a conventional refrigeration system has a sight glass in the receiver allowing manual inspection of the liquid level in the receiver.

In a transcritical refrigeration system, the pressure of the refrigerant is too high to allow a transparent sight glass in the flow system at a reasonable cost.

It is an object of the present invention to provide a refrigeration system with automatic detection of loss of refrigerant.

It is a further object of the present invention to provide a transcritical refrigeration system with automatic detection of loss of refrigerant.

According to the present invention the above-mentioned and other objects are fulfilled by provision of a refrigeration system comprising a flow circuit for recirculation of a refrigerant, the flow circuit comprising a compressor for generation of a refrigerant flow from a low-pressure side to a high-pressure side of the compressor and, in the order defined by the flow direction, connected in series with a condenser for cooling of the refrigerant towards the ambient temperature, a receiver for accommodation of refrigerant, a pressure reducing device separating the low-pressure side and the high pressure side of the compressor, and a first evaporator for evaporation of the refrigerant.

A weight transducer is mounted in operational contact with the receiver for generation of an output signal corresponding to the weight of the receiver. The weight transducer may for example be mounted underneath the receiver supporting and simultaneously weighing the receiver. However, in a preferred embodiment the receiver is suspended by one or more wires with a weight transducer in each of the wires. In a retrofit installation, i.e. when the one or more weight transducers are installed in an existing refrigeration system, the one or more weight transducers may be installed substantially without changing the position of the receiver by suspension of the receiver. Hereby, modification of the tubing connected to the receiver is not required.

The system may further comprise a controller that is connected with the weight transducer for reception of the weight transducer signal and being further adapted for monitoring the transducer signal as a function of time and for detecting loss of refrigerant based on the signal.

The controller may further be adapted for detecting loss of refrigerant by comparison of actual weight transducer signal values with previous weight transducer signal values. For example, the controller may further be adapted for detecting loss of refrigerant by monitoring, e.g. the minimum, maximum, average, etc., weight transducer signal value as a function of time, e.g. as recorded at appropriate time intervals, such as daily, weekly, monthly, etc..

Utilization of a weight transducer for monitoring the amount of refrigerant may be particularly advantageous in a refrigeration system that is adapted for transcritical operation. The high pressures of such a system, e.g. 120 bar at the high-pressure side and 40 bar at the low-pressure side of the compressor, makes manual inspection of the amount of refrigerant tedious and costly.

It is an important advantage of the present invention that the automatic detection of loss of refrigerant provides an early detection of a leakage so that the leakage may be found and repaired at an early stage before excessive loss of refrigerant. This saves the cost of running a less effective refrigerant system, saves the cost of refilling refrigerant, and protects the environment.

The weight transducer signal values may be recorded as a function of time, and the signal values of a day and night may be averaged over several days, e.g. a week. Significant negative deviations of the weight transducer signal value from the corresponding averaged values may trigger indication of loss of refrigerant to an operator of the system.

The minimum weight transducer signal value of a day may be recorded and compared with previous minimum values, and a minimum weight transducer signal value that is significantly smaller than previous values may trigger indication of loss of refrigerant to an operator of the system, or, a trend of minimum weight transducer signal values that shows a steadily decrease of the minimum values with time may trigger indication of loss of refrigerant to the operator.

Alternatively, or additionally, the maximum weight transducer signal value of a day may be recorded and compared with previous maximum values, and a maximum weight transducer signal value that is significantly smaller than previous values may trigger indication of loss of refrigerant to an operator of the system, or, a trend of maximum weight transducer signal values that shows a steadily decrease of the maximum values with time may trigger indication of loss of refrigerant to the operator.

Further, a sudden decrease in receiver content may be detected and trigger indication of loss of refrigerant to the operator. This may be used to detect e.g. a pipe breakdown, theft of refrigerant, etc. Preferably, the date and time of the sudden decrease is also recorded.

The controller may indicate loss of refrigerant by generation of an alarm signal, such as a visual display or an audible signal or a combination of a visual and an audible signal.

The refrigeration system according to the present invention may further comprise a remote monitoring system allowing an operator of the system to monitor various system parameters including one or more of the above-mentioned weight transducer signal values and a possible alarm signal from a remote location. The refrigeration system and the remote monitoring system may for example be interconnected through a LAN network, a WAN network, such as the Internet, etc, etc. Further, an alarm signal may be communicated through a telephone network, such as a PSTN network, a mobile telephone network, e.g. utilizing SMS messaging, etc, to predetermined subscriber(s).

Below the invention will be described in more detail with reference to the exemplary embodiments illustrated in the drawing, wherein

Fig. 1 is a blocked schematic of a first embodiment of a transcritical cooling system according to the present invention,

Fig. 2 shows a suspended receiver,

Fig. 3 is a plot of a subcritical cooling cycle,

Fig. 4 is a plot of a transcritical cooling cycle, and

Fig. 5 is a plot illustrating control of gas cooler pressure.

Fig. 1 is a blocked schematic of a first embodiment 10 of a transcritical cooling system according to the present invention. The system 10 comprises a refrigerant flow circuit for recirculation of CO_2 refrigerant 12, the flow circuit comprising a compressor 14 for generation of a refrigerant flow in the direction of the arrow 16 from a low-pressure side to a high-pressure side of the compressor 14 and, in the order defined by the flow direction, connected in series with a gas cooler 18 for cooling of the refrigerant 12 towards the ambient temperature, a valve 20 for pressure reduction as will be further explained below, a receiver 22 for accommodation of CO_2 refrigerant 12. The receiver 22 is connected to an expansion valve 28 that cooperates with the compressor 14 for generation of the low-pressure side and the high-pressure side of the compressor 14, and a first evaporator 30 for evaporation of the CO_2 refrigerant.

A weight transducer 32 is mounted underneath and in operational contact with the receiver 22 for generation of an output signal 34 corresponding to the weight of the receiver 22.

The system 10 further comprises a controller 36 that is connected with the weight transducer 32 for reception of the weight transducer signal 34 and being further adapted for monitoring the transducer signal 34 as a function of time and for detecting loss of refrigerant based on the signal 34.

The controller is further adapted for detecting loss of refrigerant by comparison of actual weight transducer signal values with previous weight transducer signal values. In the illustrated embodiment, the controller is adapted for detecting loss of refrigerant by monitoring the daily minimum weight transducer signal value as a function of time.

The minimum weight transducer signal value of a day is recorded and compared with previous minimum values, and a minimum weight transducer signal value that is significantly smaller than previous values triggers indication of loss of refrigerant to an operator of the system.

The controller indicates loss of refrigerant by displaying an alarm signal 38 on a visual display 40 and forwarding an audio alarm signal 42 to a loud speaker 44 for emission of an audible alarm signal.

The refrigeration system 10 may further comprise a remote monitoring system 50 allowing an operator of the system 10 to monitor various system parameters including one or more of the above-mentioned weight transducer signal values and a possible alarm signal from a remote location. The controller 36 and the remote monitoring system may for example be interconnected through a LAN network, a WAN network, such as the Internet, etc, etc. Further, the controller 36 may be adapted to communicate an alarm signal through a telephone network, such as a PSTN network, a mobile telephone network, e.g. utilizing SMS messaging, etc, to predetermined subscriber(s).

Fig. 2 shows the receiver 22 equipped with two S-shaped weight transducers 32, 33 inserted in two suspension wires 52, 54 suspending the receiver 22. Refrigerant 12 enters the receiver 22 through tube 21 connected to the valve 20 shown in Fig. 1, and refrigerant 12 leaves the receiver 22 through tube 27 connected to the expansion valve 28 shown in Fig. 1. Suspension of the receiver 22 simplifies retrofitting of existing refrigeration systems in that minimum change of the mounting position of the receiver 22 is required in order to install the one or more weight transducers 32, 33 in the existing system.

Fig. 3 illustrates subcritical operation of the system 10 in a conventional Log (p), h (enthalpy) diagram. The enthalpy H is defined by the equation: $H = U + pV$, where U is the internal energy, p is the pressure, and V is the volume of the system. Between point 1 and 2, the compressor 14 compresses the CO_2 refrigerant, and subsequently heat is released from the refrigerant from point 2 to 3 below the critical point 46 by condensation of the refrigerant in the gas cooler 18 at a constant pressure. The expansion from point 3 to 4 takes place at constant specific enthalpy at passage of the expansion valve 28. The heat absorption takes place in the evaporator 30 in the cooling furniture of the system 10 from point 4 to 1 at constant pressure. The control valve 20 is fully open when the system 10 operates subcritically.

Fig. 4 illustrates transcritical operation of the system 10. The most important difference between the plot of Fig. 4 and the plot of Fig. 3 is that the CO_2 refrigerant is above the critical point 46 at the high-pressure side of the compressor 14 and thus, heat is released from the refrigerant by CO_2 gas cooling in the gas cooler 18. The coefficient of performance (COP) of the system 10 is less for transcritical cycles than for subcritical cycles due to the lacking phase transition, i.e. no condensation, during heat release.

The expansion from point 3 to 4 takes place in two steps, namely from point 3 to 5, and subsequently from point 5 to 4. The valve 20 reduces the pressure from point 3 to point 5 so that CO_2 in the liquid phase enters the heat exchanger 22 and is collected in the receiver 22. Further, the valve 20 is controlled in such a way that the pressure in the gas cooler 18 attains a value that gives a high COP. This is further illustrated in Fig. 5. In addition to the transcritical cooling cycle, Fig. 5 shows two isotherms 34, 36. It should be noted that a decrease of the gas cooler pressure at the point 3 moves the point 4 to the right by a large amount because of the low and almost horizontal slope of the isotherm 34 so that the available specific enthalpy for release in the evaporator decrease by a large amount. Since the specific enthalpy added by the compressor 14 decreases by a small amount, the resulting COP decreases by a large amount. Conversely, an increase of the gas cooler pressure at the point 3 moves the point 3 to the left by a small amount because of the steep slope of the isotherm 34 so that the available specific enthalpy for release in the evaporator increases by a small amount. Since the specific enthalpy added by the compressor 14 also increases by a small amount, the resulting COP hardly changes.

It should be noted that if the slope of the isotherm 34 is larger than the slope of the line between points 1 and 2, the COP decreases for increased gas cooler pressure. This illustrates that there is an optimum value for the gas cooler pressure that maximizes the COP, and preferably the valve 20 is adjusted in such a way that the gas cooler pressure attains, at least approximately, this optimum pressure value. Typically, the gas cooler pressure is app. 120 bar while the pressure at the low-pressure side of the compressor 14 is app. 40 bar.

CLAIMS

1. A refrigeration system comprising a flow circuit for recirculation of a refrigerant, the flow circuit comprising

a compressor for generation of a refrigerant flow from a low-pressure side to a high-pressure side of the compressor and, in the order defined by the flow direction, connected in series with

a condenser for cooling of the refrigerant towards the ambient temperature,

a receiver for accommodation of refrigerant,

a pressure reducing device separating the low-pressure side and the high pressure side of the compressor, and

a first evaporator for evaporation of the refrigerant, and

a weight transducer mounted in operational contact with the receiver for generation of an output signal corresponding to the weight of the receiver.

2. A refrigeration system according to claim 1, further comprising a controller that is connected with the weight transducer for reception of the weight transducer signal and that is further adapted for monitoring the transducer signal as a function of time and for detecting loss of refrigerant based on the signal.

3. A refrigeration system according to claim 2, wherein the controller is further adapted for detecting loss of refrigerant by comparison of actual weight transducer signal values with previous weight transducer signal values.

4. A refrigeration system according to claim 3, wherein the controller is further adapted for detecting loss of refrigerant by monitoring the daily minimum weight transducer signal value as a function of time.

5. A refrigeration system according to any of the previous claims, the system being adapted for transcritical operation during high ambient temperatures and wherein the condenser functions as a gas cooler during transcritical operation.

6. A refrigeration system according to any of the previous claims, further comprising a remote monitoring system allowing an operator to monitor an alarm signal indicating loss of refrigerant.

7. A refrigeration system according to claim 6, wherein the remote monitoring system provides monitoring of various system parameters.

8. A method of detecting loss of refrigerant in a refrigeration system comprising

a compressor for generation of a refrigerant flow from a low-pressure side to a high-pressure side of the compressor and, in the order defined by the flow direction, connected in series with

a condenser for cooling of the refrigerant towards the ambient temperature,

a receiver for accommodation of refrigerant,

a pressure reducing device separating the low-pressure side and the high pressure side of the compressor, and

a first evaporator for evaporation of the refrigerant, and

a weight transducer mounted underneath and in operational contact with the receiver for generation of an output signal corresponding to the weight of the receiver,

the method comprising the step of monitoring weight transducer signal values as a function of time for detecting loss of refrigerant based on the values.

9. A method according to claim 8, further comprising the step of detecting loss of refrigerant by comparison of actual weight transducer signal values with previous weight transducer signal values.

10. A method according to claim 9, further comprising the step of detecting loss of refrigerant by monitoring the daily minimum weight transducer signal value as a function of time.

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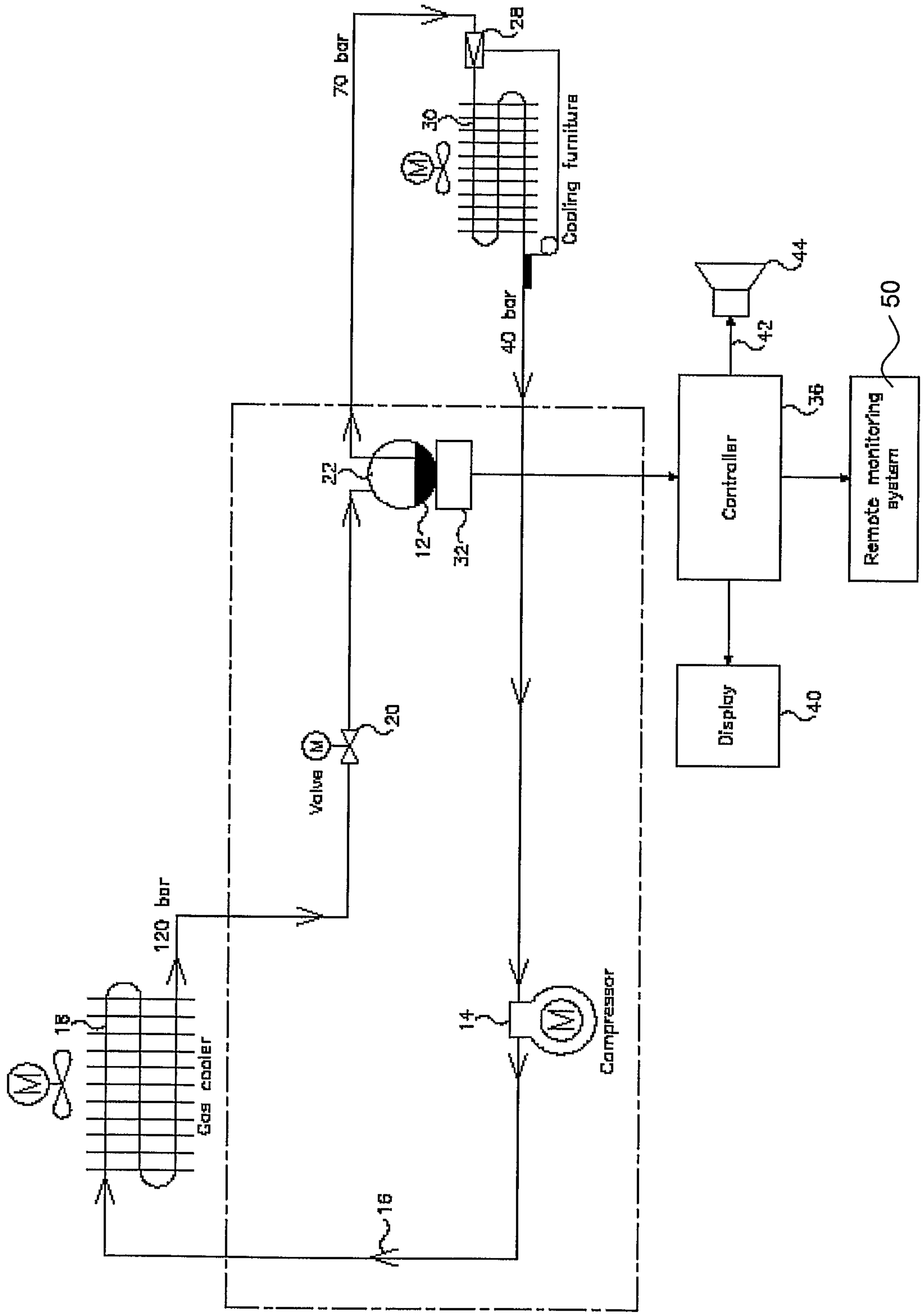

70 bar
28
30
Cooling furniture
44
50
40 bar
42
36
Controller
Remote monitoring system
22
12
32
20
Valve
Display
40
120 bar
18
Gas cooler
14
Compressor
16

Fig. 1

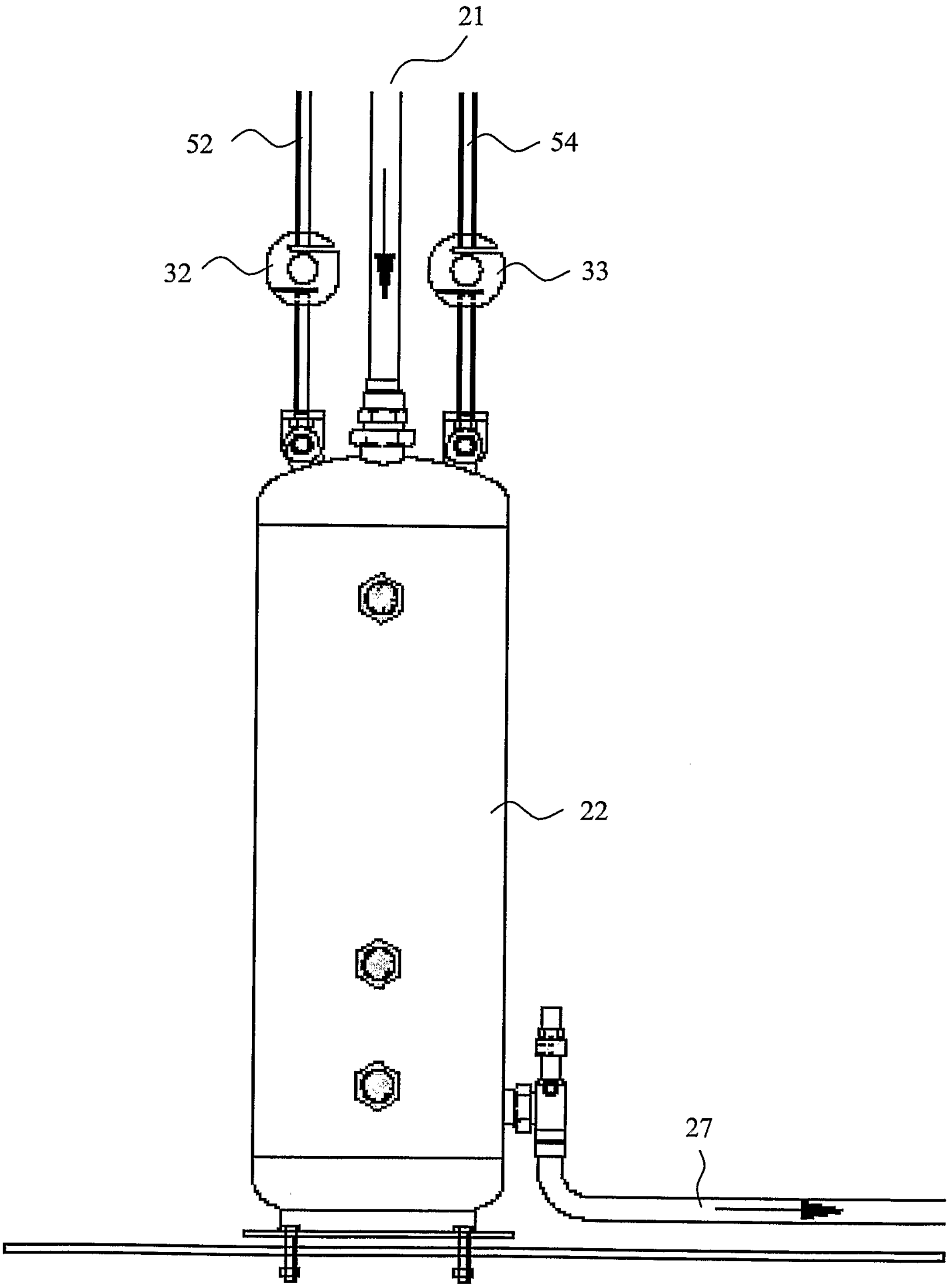
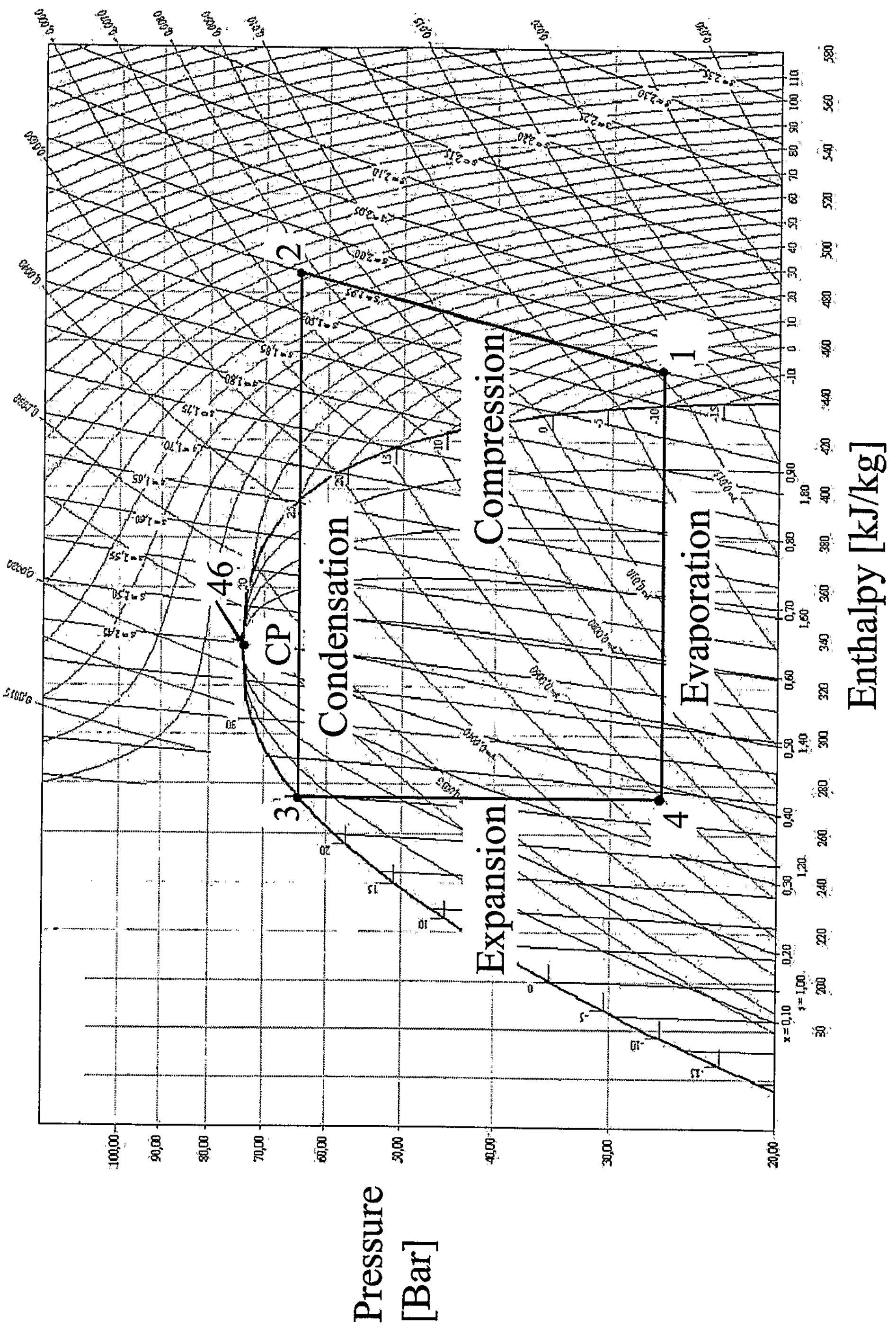
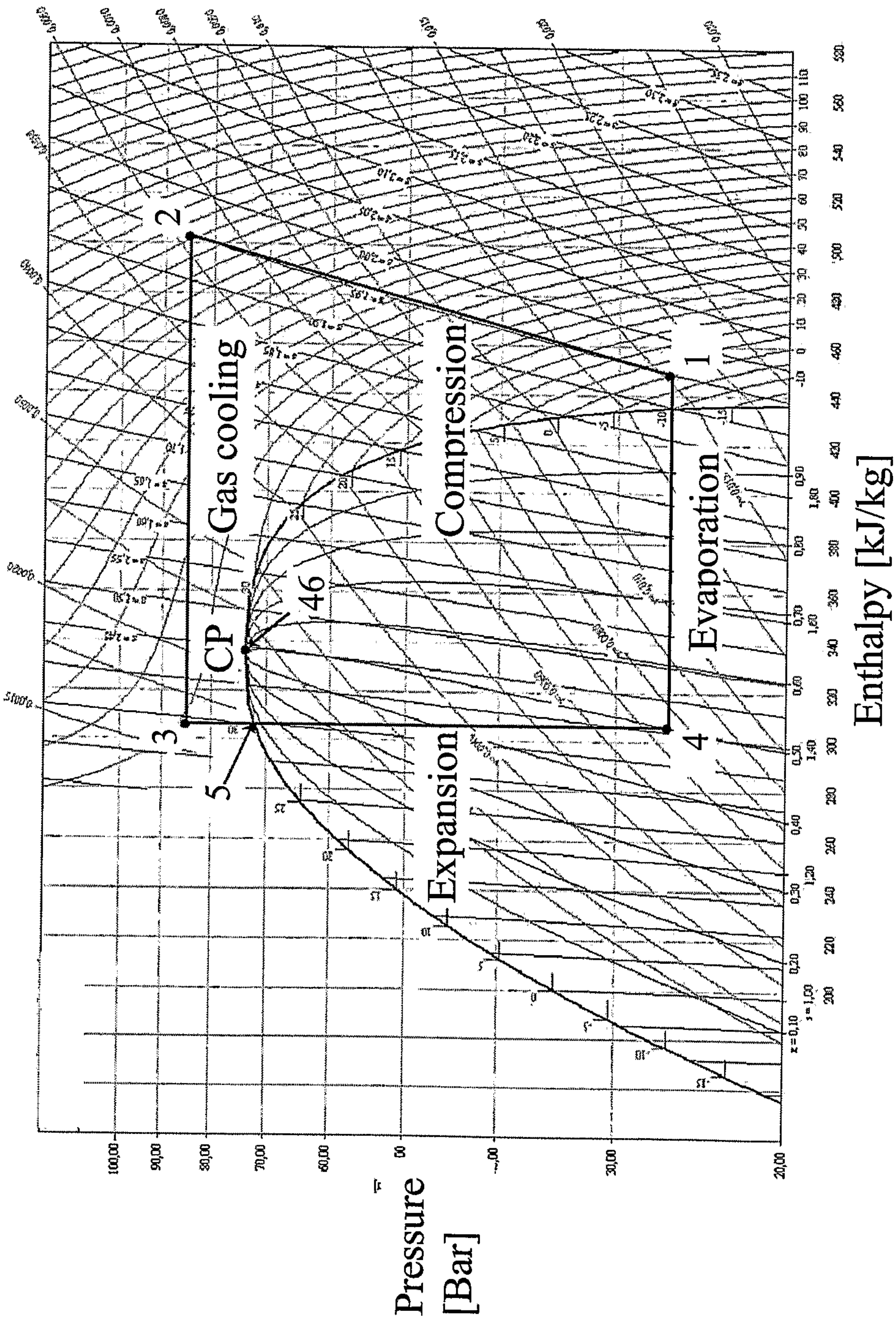


Fig. 2



1
2
3
4
46
CP
Condensation
Compression
Evaporation
Expansion
Enthalpy [kJ/kg]
Pressure [Bar]

Fig. 3



2
1
3
4
5
46
CP
Gas cooling
Compression
Evaporation
Expansion
Enthalpy [kJ/kg]
Pressure [Bar]

Fig. 4

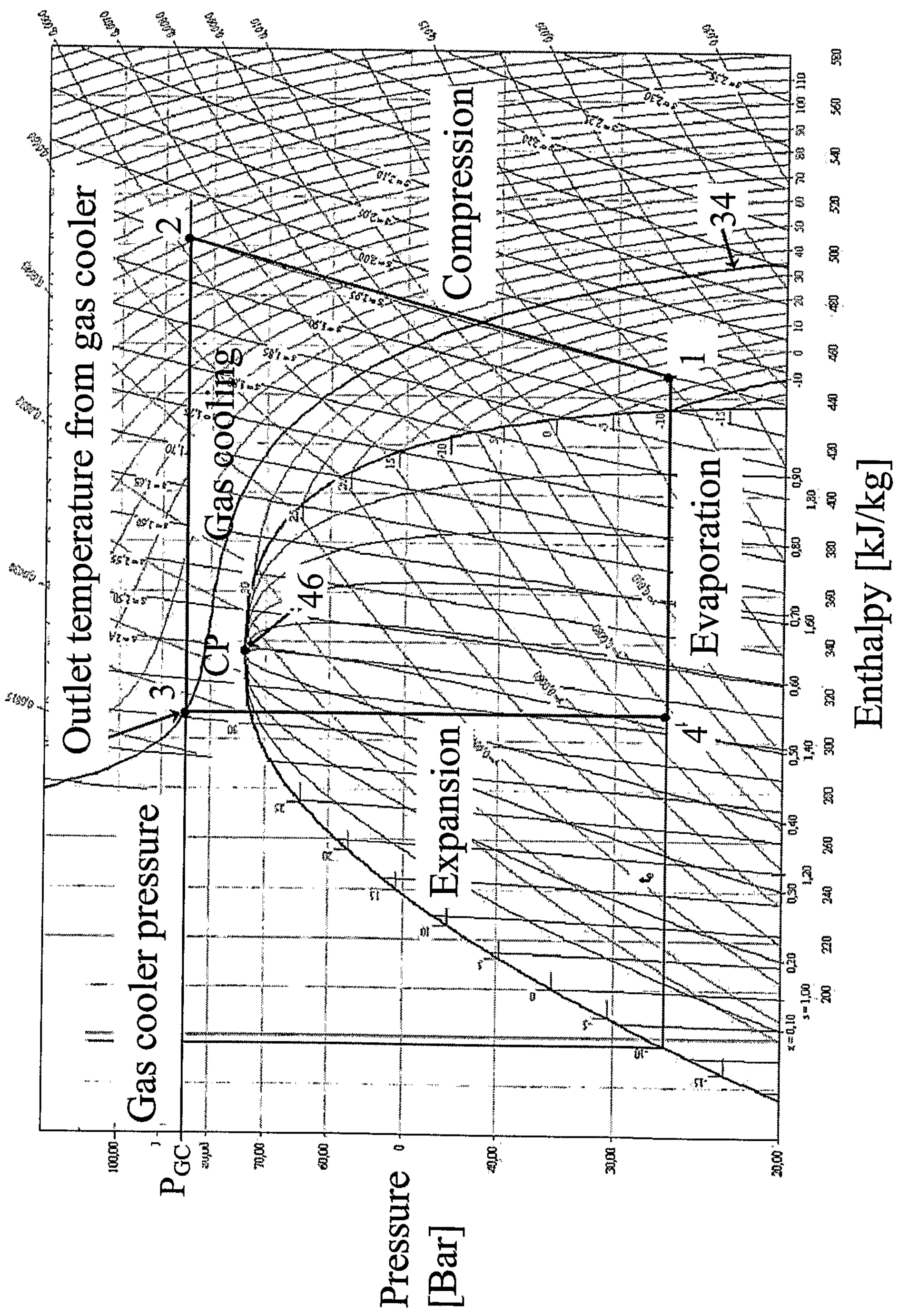

Outlet temperature from gas cooler
Gas cooler pressure
Gas cooling
Compression
Expansion
Evaporation
CP
1
2
3
4
34
46
P_{GC}
Pressure [Bar]
Enthalpy [kJ/kg]

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2006/000460

A. CLASSIFICATION OF SUBJECT MATTER
INV. F25B49/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 253 482 A (MURWAY EDI [US]) 19 October 1993 (1993-10-19) column 3, line 13 - line 35 column 4, line 29 - line 37; claim 3; figure 1	1-10
X	US 5 214 918 A (OGUNI KENSAKU [JP] ET AL) 1 June 1993 (1993-06-01) column 4, line 27 - column 5, line 7; figures 1,2	1-10
A	US 5 046 322 A (BULLA DON A [US] ET AL) 10 September 1991 (1991-09-10) the whole document	1-10
A	DE 38 00 055 A1 (CONSUL SA [BR]) 14 July 1988 (1988-07-14) the whole document	1-10

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 October 2006	20/11/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Ritter, Christoph

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2006/000460

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 967 567 A (PROCTOR ROBERT H [US] ET AL) 6 November 1990 (1990-11-06) the whole document -----	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/DK2006/000460

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DE 3800055	A1	14-07-1988	BR	8700018 A	02-08-1988
			IT	1223601 B	29-09-1990
US 4967567	A	06-11-1990	NONE		