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(54) Refrigeration system using "free energy" for circulation of liquid refrigerant by pressure

(57) The invention concerns a cascade refrigerating system (4) comprising a first high temperature refrigeration system operating with a first refrigerant, where the first high temperature system comprises heat exchanging means (2), where heat is exchanged from a second low temperature refrigeration system, which second low temperature refrigeration system comprises pumping means arranged to supply refrigerant to evaporating means (40,42,44). The purpose of the invention is to provide an energy efficient refrigerating system that is suitable for refrigerant circulation with reduced energy consumption for circulation of refrigerant in refrigeration systems. This can be achieved with a system as described in the opening paragraph if the cascade refrigeration is modified so that the second low temperature refrigeration system comprises at least two pumping vessels (20,22) connected through respective check valves (13,14,28,30), which pumping vessels are connected to heating means (64,66), in which refrigerant is evaporated for generating a higher pressure, which high pressure is led to the top of the pumping vessels for pressing refrigerant with high pressure towards the evaporation means. It is hereby achieved that when the liquid refrigerant is exposed to the heating means, it evaporates and generates pressure in the related vessel. In this way, the circulation system can operate with refrigerant completely without oil since the system does not include any compressors or pumps. This leads to a better performance and a better heat transfer.

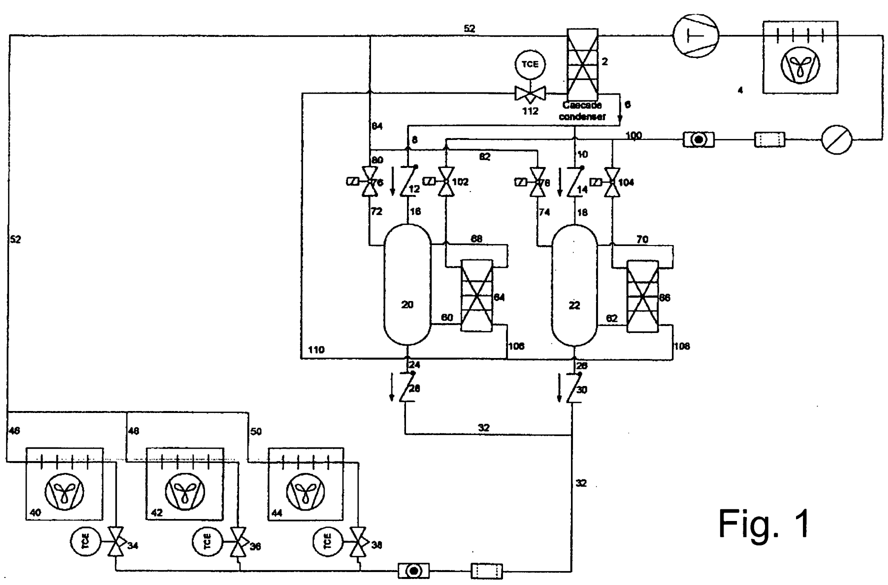

Fig. 1

EP 1 536 190 A1

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Description

[0001] The invention relates to a cascade refrigerating system comprising a first high temperature refrigeration system operating with a first refrigerant, which high temperature refrigeration system comprises compressor means, connected to condensing means, where the first high temperature system further comprises heat exchanging means, where heat is exchanged from a second low temperature refrigeration system, which second low temperature refrigeration system comprises pumping means arranged to supply refrigerant to evaporating means.

Background of the Invention

[0002] GB 1,146,428 describes improvements in a flooded coil refrigerant system where tanks are designed for collecting a recirculating excess refrigerant from the evaporators to eliminate slugging of the compressor. The driving force of the prior art system is the pressure difference between the compressor discharge or condenser pressure and the suction pressure of the compressor, similar to most other refrigerant systems. In operation one of the receivers are connected to the condenser, and liquid refrigerant is filling the first receiver, which at the same time is connected through restriction means to flooded evaporators, from which refrigerant is led to the second receiver, where liquid is remaining and gas is led to the suction side of the compressor. When the first receiver is empty, or the second receiver is full, valves are opened and closed in order to change the operation of the receivers.

[0003] Pumping liquid refrigerant with gas pressure systems is prior disclosed in W.F.Stoecker, Industrial refrigeration, chapter 8-8 to 8-10, page 241 to 251 and chapter 8-9, page 246-247, where energy analysis of gas pumping is described:

> *"Gas pumping systems are lower at first costs, require lower maintenance expense... and are not subject to cavitations. Gas pumping systems require more power for the pumping process than mechanical pumps...* "
>
> *"It is generally accepted that energy cost of the gas pumping system is greater than that of the mechanical pump...* "
>
> *"There is another loss associated with gas pumping ...by the warm vapour heating the cold liquid and the walls of the pumping vessel " "All the foregoing may be summarized by estimating that the cost of gas pumping may be 50% to 100% higher than liquid pumping.*

[0004] DE 3511421 A1 describes a refrigeration circuit, which comprises adjustable means for increasing the pressure in the refrigeration circuit with a low condensation temperature. In this way, it is possible to fulfil condensation by using very low refrigerant temperatures with a very low condensation pressure without circulation problems occurring.

[0005] This system relates to energy savings using low condensing temperatures and thus maintaining sufficient refrigerant pressure for the expansion valve.

[0006] EP 1 046 868 A2 describes a refrigeration system having a refrigeration cycle, which provides optimised energy consumption.

[0007] This system also relates to energy savings using low condensing temperatures and thus maintaining sufficient refrigerant pressure for the expansion valve.

[0008] GB 1,146,428 describes a liquid refrigerant recirculating system and relates to refrigerating systems and more particularly to improvements in systems in which the evaporator coils are supplied with an excess of liquid refrigerant, which excess is collected and recirculated back through the evaporator.

[0009] This invention relates to improvements in a flooded coil refrigerant system where tanks are designed for collecting a re-circulating excess refrigerant from the evaporators to eliminate slugging of the compressor.

[0010] The invention relates to a refrigerating system where a liquid refrigerant is circulated in piping by means of pressure. The pressure is produced by using free or "low value" energy only without using any energy consuming pumps, compressor etc.

[0011] The system includes an expansion device (i.e. expansion valve, orifice, capillary tube or similar) and an evaporator where the pressurized gas is produced by evaporating refrigerant. The pressurized gas is supplied into at least two receivers through each the pipe branch is provided with respective check valves and solenoid valves.

[0012] The receivers are arranged to supply refrigerant to at least one evaporator through a check valve associated with each receiver.

[0013] All of the above-mentioned prior art systems are using compressors or pumps to generate the driving force of the pumping systems.

[0014] The disadvantage of systems using discharge gas generated by a compressor is:

- Energy consumption of the compressor.
- Energy loss by the warm vapour heating the cold liquid and the walls of the pumping vessel.
- Energy loss by bypassing discharge gas to suction side.
- The compressor is running continuously to generate pressure.
- Capacity control of the might be required compressor.
- Service and maintenance of the compressor.
- Running noise of compressors.
- Compressor oil in refrigeration system, requiring

separating and return system.
- Poor heat transfer of coils, due to oil in refrigeration system.

[0015] The disadvantage of systems using pumps is:

- Energy consumption of the pump.
- Energy loss by flooded evaporators and excess refrigerant circulated.
- Capacity control of the might be required pump.
- Service and maintenance of the pump.
- Running noise of pump.
- Subject to cavitations
- Leaking shaft seal = loss of refrigerant.
- Limited life time.

[0016] None of the prior art systems relates to the purpose of this invention, using free or "low value" energy for circulation of liquid refrigerant with pressure.

[0017] It is known from the state of the art to use gravity force for generating flow of the refrigerant. Gravity force systems can be difficult to install on site due to physical restrictions of the installation components and piping in the buildings.

[0018] The purpose of the invention is to provide an energy efficient refrigerating system that is suitable for refrigerant circulation with reduced energy consumption for circulation of refrigerant in refrigeration systems.

Explanation of the invention

[0019] This can be achieved with a system as described in the opening paragraph if the cascade refrigeration is modified so that the second low temperature refrigeration system comprises at least two pumping vessels connected through respective check valves, which pumping vessels are connected to heating means, in which refrigerant is evaporated for generating a higher pressure, which high pressure is lead to the top of the pumping vessels for pressing refrigerant with high pressure towards the evaporation means.

[0020] It is hereby achieved that when the liquid refrigerant is exposed to the heating means, it evaporates and generates pressure in the related vessel. In this way, the circulation system can operate with refrigerant completely without oil since the system does not include any compressors or pumps. This leads to better performance and better heat transfer. The heating means can be heated by any low temperature waste energy. Low value energy sources as air, water, and waste heat can be used for heating the heating means. The supplied energy must be removed by the first high temperature refrigeration system so these systems are not energy neutral.

[0021] The heating means might be formed as at least one heat exchanger, which heat exchanger can be heated by the first refrigerant, which heat exchanger has an inlet connected to the outlet of the condensing means through control valves, and where the outlet from the heat exchanger is connected to the inlet of the heat exchanging means through pressure reduction means. It is hereby achieved the first refrigerant is used for the heating. The temperature of the refrigerant is reduced in the condensing means and has been mostly liquefied in the condensing means. By passing the heat exchanger, the mostly liquefied refrigerant is sub cooled, and the content of cooling energy is increased. The energy for evaporating the liquid is removed from the high stage of the cascade system making this application energy neutral.

[0022] The heat exchanger has an inlet for the second refrigerant connected to the lower part of the pumping vessels, where the heat exchanger has an outlet connected to the upper part of the pumping vessels. It is hereby achieved that refrigerant liquid is supplied by gravity from one of two pumping vessels to a related heat exchanger located in the same level as the lower part of the pumping vessels.

[0023] The second refrigerant is supplied by gravity in mostly liquid form from at least one of the pumping vessels through an outlet to a related heat exchanger, which heat exchanger is located at the same level as the lower part of the pumping vessel. It is hereby achieved that the refrigerant is injected into one or more heat exchangers where the pressurized gas is produced by evaporating the second refrigerant. In this way, a pressure difference is provided with enough force to press refrigerant through the refrigeration system.

[0024] The pressurized gas produced by the evaporating refrigerant is supplied through solenoid valves into the vessel acting as high pressure. This makes the contained liquid refrigerant flow through non-return valves into the liquid line. In the meantime, a solenoid valve equalizes the pressure between the condenser and the other vessel, which makes the refrigerant fill the vessel by gravity.

[0025] When the high pressure vessel is empty, a control circuit makes the sequence alter so the second vessel is supplying liquid, and the first vessel is filling.

- No energy costs for circulation of refrigerant.
- No rotating parts (pumps or compressors) requiring regular maintenance.

The drawings

[0026] In the following, the refrigerating system is described according to the figure, where

fig. 1 shows an embodiment of the invention comprising one compressor, where

fig. 2 shows an alternative embodiment for the invention.

[0027] Fig. 1 shows a cascade refrigerating system, where the cascade heat exchanger 2 is cooled by a high temperature (HT) refrigeration system 4. The HT refrigeration system 4 can be any suitable system using any suitable refrigerant. The heat exchanger 2 functions as the cascade condenser of the low temperature (LT) refrigeration system. Liquid flows through the pipe 6 and alternating further through the pipe 8 or 10, which leads to no-return valves 12 or 14 and through the pipe 16 or 18 into the pumping vessels 20 or 22. The outlet of the pumping vessels 20 or 22 are connected through pipe 24 or 26, through no-return valves 28 or 30 into the liquid line 32 which leads to flow restriction means 34,36,38 which restriction means might be electronically controlled expansion valves. From the restriction means, the refrigerant is led further to evaporators 40,42,44. The outlet pipes 46,48,50 from the evaporators 40,42,44 are led through the common return line 52 to the cascade condenser 2.

[0028] A part stream of the refrigerant is led from the pumping vessels 20 or 22 through the pipe 60 or 62 into the heat exchangers 64 or 66 where liquid refrigerant is evaporated when exposed to a heat source. The gas is led back to the related vessels 20,22 through the pipes 68,70, generating pressure for the operation of the system.

[0029] The vessel 20,22 will in loading mode equalize pressure through pipe 72,74, onto the solenoid valves 76,78, through the pipes 80,82,84 into the common return line 52.

The HT refrigeration system 4 is used as the heat source, where the liquid refrigerant is led through the liquid line 100, through the solenoid valves 102,104, into the heat exchangers 64,66 in operation. The sub-cooled HT liquid refrigerant is led through the pipes 106, 108, 110 into the HT expansion device 112.

[0030] Operation mode A: The vessel 20 is empty and loading, and the vessel 22 is full and supplying.

[0031] The solenoid valve 102 is closed and the solenoid valve 76 is open equalizing the pressure between the vessel 20 and cascade condenser 2. Liquid refrigerant is led from the cascade condenser 2, through the pipe 6,8, non-return valve 12, and pipe 16, loading the vessel 20.

[0032] The pressure is higher in the pipe 32 than in the pipe 24, so the non-return valve 28 is closed.

[0033] In the meantime, the solenoid valve 104 is open, and the solenoid valve 78 is closed.

[0034] Liquid refrigerant liquid is supplied by gravity from the vessel 22 to the heat exchanger 66 located at the same level as the lower part of the vessel 22.

[0035] When the liquid refrigerant is exposed to the heat source in the heat exchanger 66, the liquid evaporates and generates higher pressure in the vessel 22.

[0036] When the pressure in the vessel 22 is higher than in the pipe 10, the non-return valve 14 is closed.

[0037] When the pressure in the vessel 22 is higher than in the pipe 32, the non-return valve 30 opens supplying liquid refrigerant into the liquid line 32.

[0038] This situation continues until the vessel 22 is empty which could be detected by detection means or by using a timer (not shown). The detection or the timer means might communicate to an electronic system (also not shown), and when the vessel 22 is empty, the vessel 20 is probably more or less full of a liquid. In this situation, the system alternates into operation mode B.

[0039] Operation mode B: The vessel 22 is empty and loading, and the vessel 20 is full and supplying.

[0040] The solenoid valve 104 is closed, and the solenoid valve 78 is open equalizing the pressure between the vessel 22 and the cascade condenser 2. Liquid refrigerant is led from the cascade condenser 2 through the pipe 6, 10, the non-return valve 14, and the pipe 18 loading the vessel 22.

[0041] The pressure is higher in the pipe 32 is higher than in the pipe 26 so the non-return valve 30 is closed.

[0042] In the meantime, the solenoid valve 102 is open, and the solenoid valve 76 is closed.

[0043] Liquid refrigerant liquid is supplied by gravity from the vessel 20 to the heat exchanger 64 located at the same level as the lower part of the vessel 20.

[0044] When the liquid refrigerant is exposed to the heat source, it evaporates and generates higher pressure in vessel 20.

[0045] When the pressure in the vessel 20 is higher than in the pipe 8, the non-return valve 12 is closed.

[0046] When the pressure in the vessel 20 is higher than in the pipe 32, the non-return valve 28 opens supplying liquid refrigerant into the liquid line 32.

[0047] This situation continues until the vessel 20 is empty which could be detected by detection means or by using a timer (not shown). The detection or the timer means might communicate with an electronic system (also not shown), and when the vessel 20 is empty, the vessel 22 is probably more or less full of a liquid. In this situation, the system alternates back into operation mode A.

[0048] In this way, the system can operate by changing between an active (supplying) and an inactive (loading) vessel during the whole operation.

[0049] In this way, a highly effective refrigeration system is built where a liquid refrigerant is circulated in the piping by means of pressure using free or "low value" energy only without using any energy consuming pumps, compressor etc.

[0050] Fig. 2 shows an alternative embodiment of the invention where only the heat exchangers 64,66 are changed in the fig. 2. Because of these very few changes, the description is the same for both fig. 1 and fig. 2. The only difference between the two figures is that the heat exchangers on fig. 2 are placed as separate components outside the pumping vessels 20,22 where the heat exchangers in fig. 2 are integrated into the pumping vessels 20,22.

[0051] The way of operation is nearly the same, but the heat exchangers on fig. 2 are probably submerged, and by heating the submerged evaporated, bubbles are formed which will form a high-pressure bubble in the top of the vessel 20,22. As soon as the pressure in the pumping vessel exceeds the pressure in the line 32, the valve 28 or 30 will open, and liquid will be supplied into the liquid line.

Claims

1. A cascade refrigerating system (4) comprising a first high temperature refrigeration system operating with a first refrigerant, which high temperature refrigeration system comprises compressor means, connected to condensing means, where the first high temperature system further comprises heat exchanging means (2), where heat is exchanged from a second low temperature refrigeration system, which second low temperature refrigeration system comprises pumping means arranged to supply refrigerant to evaporating means (40,42,44), **characterised in that** the second low temperature refrigeration system comprises at least two pumping vessels (20,22) connected through respective check valves (12,14,28,30), which pumping vessels (20,22) are connected to heating means (64,66), in which refrigerant is evaporated for generating a higher pressure, which high pressure is led to the top of the pumping vessels (20,22) for pressing refrigerant with high pressure towards the evaporation means (40,42,44).

2. A cascade refrigerating system (4) according to claim 1, **characterised in, that** the heating means are formed as at least one heat exchanger (64,66), which heat exchanger (64,66) is heated by the first refrigerant, which heat exchanger (64,66) has an inlet connected to the outlet of the condensing means (4) through control valves (102, 104), and where the outlet from the heat exchanger (64,66) is connected to the inlet of the heat exchanging means (2) through pressure reduction means (112).

3. A cascade refrigerating system according to claim 1 or 2, **characterised in, that** the heat exchanger (64,66) has an inlet (60,62) for the second refrigerant connected to the lower part of the pumping vessels (20,22), where the heat exchanger has an outlet (68,70) connected to the upper part of the pumping vessels (20,22).

4. A cascade refrigerating system according to one of the claims 1-3, **characterised in that** the second refrigerant is supplied by gravity in a mostly liquid form from at least one of the pumping vessels (20,22) through an outlet to a related heat exchanger (64,66), which heat exchanger (64,66) is located at the same level as the lower part of the pumping vessel (20,22).

5. A cascade refrigerating system according to one of the claims 1-4, **characterised in that** the pumping vessels (20,22) comprises integrated heat means (64,66), which heating means are connected through valves (102,104) to the first high temperature refrigeration system.

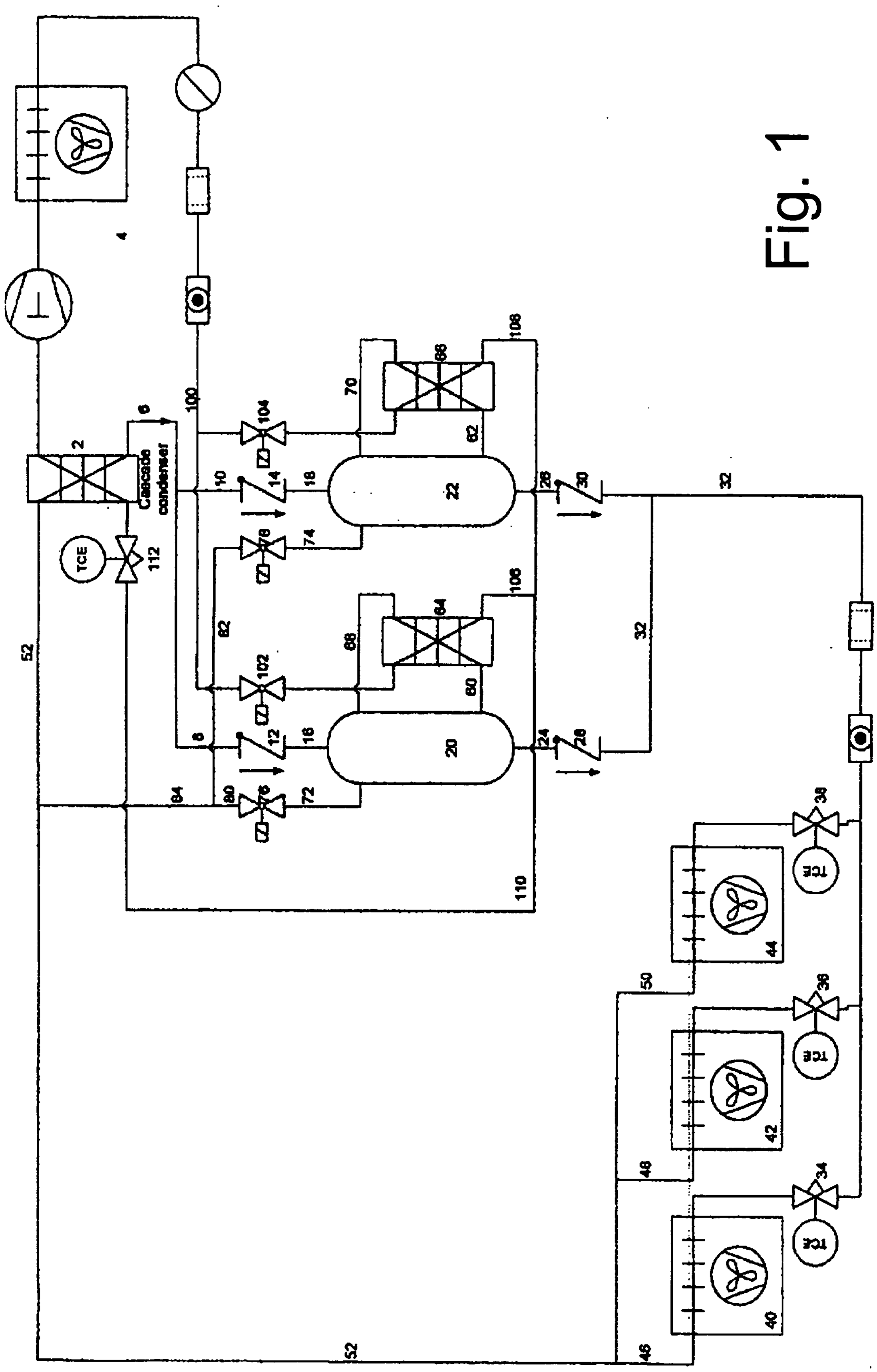

Fig. 1

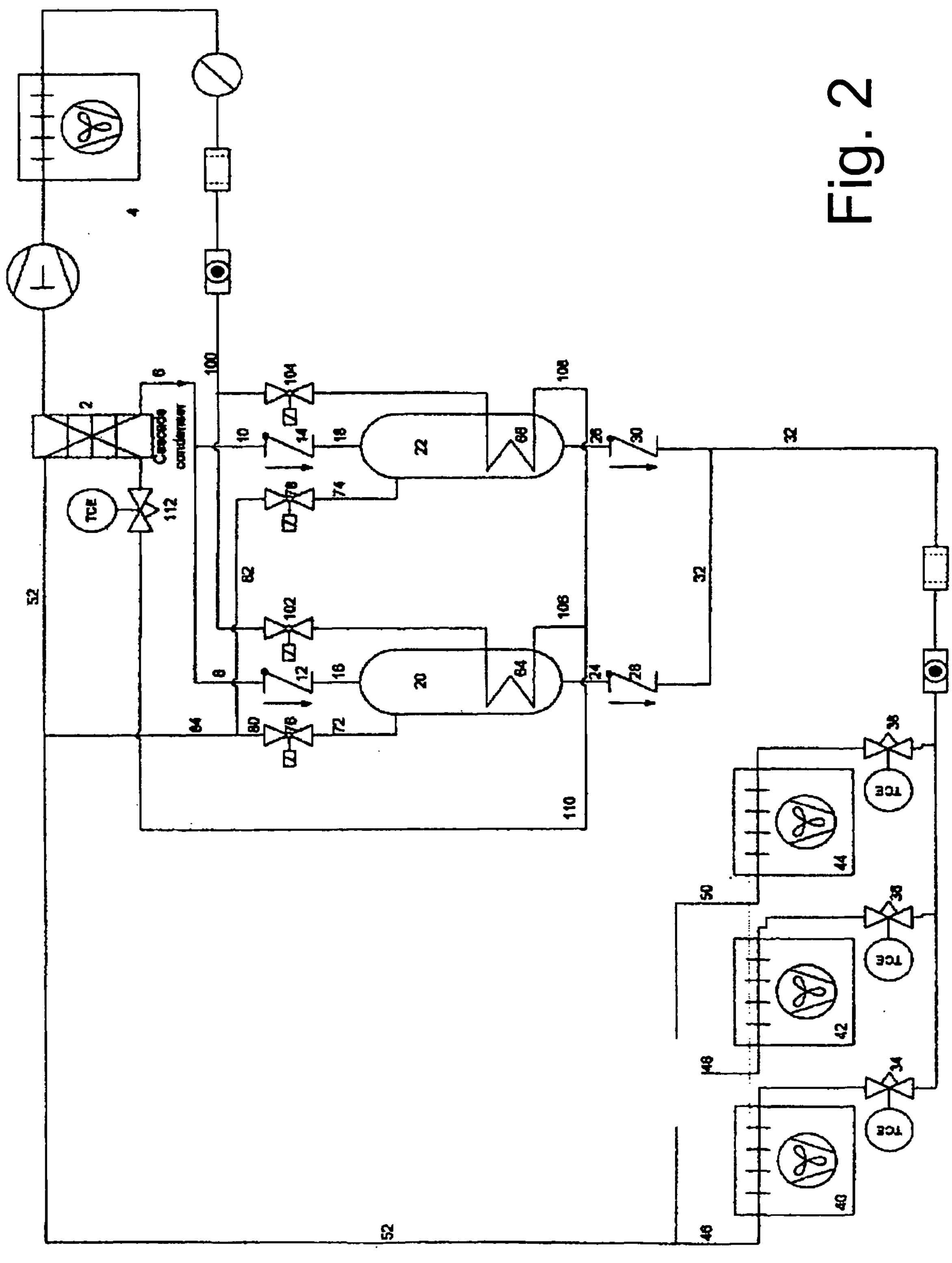

Fig. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 02 5510

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 2002, no. 06, 4 June 2002 (2002-06-04) -& JP 2002 048422 A (KYORITSU REINETSU KK), 15 February 2002 (2002-02-15) * abstract; figures 1,4 * -----	1-3,5	F25B25/00
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 10, 31 August 1999 (1999-08-31) -& JP 11 132507 A (DAIKIN IND LTD), 21 May 1999 (1999-05-21) * abstract; figures 1,5,9-11 * -----	1-4	
X	EP 0 857 936 A (DAIKIN INDUSTRIES, LIMITED) 12 August 1998 (1998-08-12)	1,2	
A	* abstract; figures 5,7,10,12,15,20,21 * * column 1, line 7 - line 11 * * column 9, line 43 - column 10, line 12 * * column 24, line 50 - column 25, line 9 * * column 27, line 51 - column 28, line 41 * * column 34, line 9 - line 55 * -----	3	TECHNICAL FIELDS SEARCHED (Int.Cl.7) F25B
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	15 March 2005	Yousufi, S

CATEGORY OF CITED DOCUMENTS

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