



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) **EP 1 260 776 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
27.11.2002 Bulletin 2002/48

(51) Int Cl.7: **F25B 40/00**

(21) Application number: **01112491.4**

(22) Date of filing: **22.05.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**
Designated Extension States:
AL LT LV MK RO SI

(72) Inventor: **Tiedemann, Thomas**
71634 Ludwigsburg (DE)

(74) Representative: **Popp, Eugen, Dr. et al**
MEISSNER, BOLTE & PARTNER
Postfach 86 06 24
81633 München (DE)

(71) Applicant: **Zexel Valeo Climate Control**
Corporation
Saitama 360-0193 (JP)

(54) **A heat exchanger for an air conditioning system**

(57) A heat exchanger (12) for use in a refrigeration system of a vehicle air conditioning system has a first refrigerant pathway (20) through which refrigerant can flow from a gas cooler (11) of the refrigeration system to an expansion valve (13) of the system, and a second refrigerant pathway (21) through which the refrigerant can flow from an evaporator (14) or accumulator 16 of the system to the compressor (10). The two pathways (20, 21) are arranged so that a thermal flow can occur between the refrigerant flowing in them, typically from

the relatively warm refrigerant discharged from the condenser (11) to the colder refrigerant discharged from the evaporator (14) or accumulator 16. In order that the thermal flow can be regulated a bypass (22, 23) is provided through which at least a portion of the refrigerant can flow instead of flowing through the pathway or pathways (20, 21) provided with the bypass and a control valve (V1, V2, V3, V4, V5, V6, Z1, Z2, Z3, Z4) is provided to control the flow of refrigerant through the bypass (22, 23).

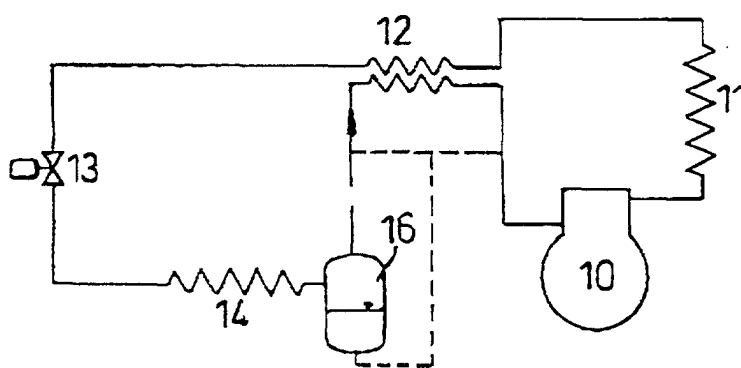


Fig. 2

EP 1 260 776 A1

Description

[0001] The present invention relates to a heat exchanger for an air conditioning system and in particular for a CO₂ air conditioning system for use in an automotive vehicle.

[0002] The use of carbon dioxide (CO₂) as a refrigerant is being investigated widely to replace tetrafluoroethane (R134a) as the refrigerant in the air conditioning systems of automotive vehicles. However, unlike the more conventional refrigerants such as R134a, CO₂ has a low critical temperature so that a trans-critical process must be employed.

[0003] Fig. 1 is a diagram of a conventional cold-vapour refrigeration cycle wherein a refrigerant is circulated in a closed circuit made up of a compressor 1, a first heat exchanger in the form of a condenser 2, an expansion valve 3 and a second heat exchanger in the form of an evaporator 4. The refrigerant, which is under low pressure is evaporated into a gaseous phase in the evaporator 4, which typically comprising a coiled pipe. The evaporation lowers the temperature of the air passing over the evaporator 4, for example for use in a vehicle air conditioning system, such air being that which is blown into the passenger compartment of the vehicle. The compressor 2 draws away the refrigerant from the evaporator 4, compresses it and passes it to the condenser 2, where the refrigerant gives up its heat to the environment, and as a result of its increased pressure and loss of heat condenses back to a liquid phase. It may even become supercooled. Finally, the liquid refrigerant is expanded to a lower vaporizing pressure via the expansion valve 3 and returned to the evaporator 4.

[0004] This cycle could be used with refrigerants such as CO₂ in which heat is given off under supercritical conditions. EP 0,424,474 describes a trans-critical vapour compression cycle device suitable for use with CO₂ as the refrigerant wherein the specific enthalpy of the refrigerant is regulated at the inlet of the evaporator by the deliberate use of the pressure and/or temperature. As shown in Fig. 2, the refrigeration cycle in this device comprises a compressor 10, a gas cooler 11, a counter-current heat exchanger 12, an expansion valve 13, an evaporator 14, a combination liquid separator and accumulator 16, and a return flow through the internal counter-current heat exchanger 12 to the compressor 10. The internal counter-current heat exchanger 12 improves the process efficiency and substantially increases the available refrigerating capacity, particularly at high ambient temperatures. It operates by transferring heat from the relatively warm refrigerant discharged from the condenser 11 to the colder refrigerant discharged from the evaporator 14 or the accumulator 16. The refrigerant temperature is thereby lowered prior to expansion via the valve 13 so that the wet vapour content after expansion is decreased and the available refrigerating capacity is thereby increased. However, the heat transfer causes the refrigerant temperature at the

inlet to the compressor 10 to increase, which results in a proportional increase in the refrigerant temperature leaving the compressor.

[0005] As the heat transfer area of the solid structural components used in the refrigeration system for the heat exchanger 12 cannot be varied, and as the conditions under which air conditioning systems in vehicles are used varies considerably as a result of variation in the ambient temperatures, the driving speed of the compressor and the desired refrigerating capacity, the design of the heat exchanger is a compromise between the following two requirements.

1. The requirement to maximize performance and to achieve a high refrigerating capacity, which necessitates the internal heat exchanger transferring the maximum thermal flow possible from the high-pressure side to the low-pressure side of the circuit. The limitations to this are caused by the fact that the temperatures on either side of the heat exchanger approach one another.

2. The requirement that the optimum operating characteristics of the oil used in the compressor are maintained, which necessitates that the maximum temperature subsequent to compression of the refrigerant and the oil blend used must not exceed an upper permitted temperature. As the temperature of the refrigerant subsequent to compression is determined, *inter alia*, by its temperature at the start of the compression step, heating of the refrigerant upstream of the compressor 10 within the internal heat exchanger 12 must be limited so as to avoid a high final compression temperature which exceeds the upper permitted temperature.

[0006] The object of the present invention is to provide an internal heat exchanger for use in a vehicle air conditioning system in which the thermal flow is substantially maximized under all operating conditions of the air conditioning system whilst the final compression temperature is maintained within permitted limits.

[0007] According to a first aspect of the present invention there is provided a heat exchanger for use in a refrigeration system of a vehicle air conditioning system defining a first refrigerant pathway through which refrigerant can flow from a condenser of the system to an expansion valve of the system; and a second refrigerant pathway through which the refrigerant can flow from an evaporator of the system to a compressor of the system, the two pathways being arranged so that a thermal flow can occur between the refrigerant flowing in the first and second pathways, and characterised in that a bypass is provided through which at least a portion of the refrigerant can flow instead of flowing through at least one of the first pathway and the second pathway, and a control valve is provided to control the flow of refrigerant through the bypass whereby the thermal flow can be

regulated.

[0008] Regulation of the thermal flow in this way enables the following advantages to be realized.

1. An increase in the energetic efficiency of the refrigeration system whilst at the same time increasing its refrigerating capacity. This is particularly useful at high ambient temperatures where a higher performance from the air conditioning system is required.

2. The prevention of a thermal decomposition of the lubricant air conditioning system which would otherwise occur if the temperature of the compressor of the refrigeration system were permitted to rise to too high a level.

[0009] Preferably, the bypass is provided for the first pathway. Alternatively, the bypass is provided for the second pathway. First and second bypasses may also be provided for both the first and the second pathways respectively.

[0010] Preferably also, the control valve is located at a branch-off point in the pathway at either an inlet to the bypass or at an outlet from the bypass whereby refrigerant flow through both the bypass and the pathway provided with the bypass can be controlled. Alternatively, the control valve is located in an intermediate position along the length of the bypass so that only refrigerant flow through the bypass can be controlled.

[0011] Preferably also, a controller is provided to control the opening and closing of the control valves.

[0012] In a modification, a plurality of conduits are preferably provided between the bypass and the pathway at spaced intervals along the length of the pathway and a plurality of control valves are provided to control flow independently through each of the conduits respectively and thereby control overall the flow of refrigerant through the bypass in order that the thermal flow can be regulated.

[0013] Advantageously, in this modification the control valves may comprise thermostatic expansion valves.

[0014] The heat exchanger of the present invention can thus be used in a refrigeration system for a vehicle air conditioning system and connected in series with a compressor, a condenser, an expansion valve, and an evaporator to form an integral closed circuit. The refrigerant used is preferably carbon dioxide.

[0015] According to a second aspect of the present invention there is provided a method of regulating thermal flow in a refrigeration system for a vehicle air conditioning system, comprising the steps of evaporating a refrigerant into a gaseous phase in an evaporator and passing it to a compressor; compressing a gaseous refrigerant in the compressor; passing the refrigerant to a gas cooler where the refrigerant is permitted to up its heat to the environment expanding the refrigerant to a

lower vaporizing pressure via an expansion valve; returning the refrigerant to the evaporator; and inserting an internal heat exchanger into the refrigeration cycle in order that a thermal flow can occur between the refrigerant flowing in a first pathway located intermediate the condenser and the expansion valve and the refrigerant flowing in a second pathway located intermediate the evaporator and the compressor; and characterised in that a bypass is provided through which refrigerant can flow instead of flowing through at least one of the first pathway and the second pathway, and a control valve is provided to control the flow of refrigerant through the bypass whereby the thermal flow can be regulated.

[0016] The present invention will now be described by way of example with reference to the accompanying drawings, in which:-

Fig. 1 is a diagram of a conventional cold-vapour refrigeration cycle;

Fig. 2 is a diagram of a conventional trans-critical vapour compression refrigerating cycle;

Fig. 3 is a schematic diagram of a heat exchanger in accordance with the present invention for use in a refrigerating cycle as shown in Fig. 2;

Fig. 4 is a view similar to Fig. 3 showing various locations for the positions of one or more control valves forming part of the heat exchanger; and

Fig. 5 is a schematic diagram of a modified heat exchanger in accordance with the present invention;

[0017] As shown in Fig. 3, a heat exchanger 12 according to the present invention for use in a refrigeration cycle of a vehicle air conditioning system as described above with reference to Fig. 2 comprises a first refrigerant pathway 20 through which high-pressure refrigerant can flow from the condenser 11 of the refrigeration system to the expansion valve 13 and a second refrigerant pathway 21 through which low-pressure refrigerant can flow from the evaporator 14 or the accumulator 16 to the compressor 10. The two pathways 20, 21 are arranged in a conventional manner so that a thermal flow can occur between the refrigerant flowing in them. Preferably, the pathways 20, 21 are arranged in a manner which would maximize the thermal flow.

[0018] However, in order that the thermal flow between the pathways 20, 21 can be regulated, a bypass 22 is provided through which refrigerant can flow instead of flowing through at least one of the pathways 20, 21. In Fig. 3 the first pathway 20 is provided with the bypass but a similar bypass 23 could be provided for the second pathway, as shown in Fig. 4, in addition to or in place of the bypass 22. In order to control the flow of refrigerant through the bypass 22 or the bypass 23, a control valve V1 is provided. As shown in Fig. 3, when the control

valve V1 closes the bypass 22, all of the refrigerant flows through the pathway 2 and in this case the thermal flow between the pathways 20 and 21 is maximized. When the thermal flow is to be reduced, the control valve V1 is operated to reduce the high-pressure side flow of refrigerant through the pathway 20 by permitting flow through the bypass 22. In extreme cases the flow through the pathway 20 can be completely stopped so that the refrigerant flows solely through the bypass 22. In this case the refrigeration cycle operates in a manner as described with reference to Fig. 1 where no internal heat exchanger is present.

[0019] It will be appreciated that control of the flow of refrigerant on the low-pressure side of the heat exchanger by the use of the bypass 23 and associated control valve would have the same effect.

[0020] The control valve V1 can be installed in a variety of positions as shown in Fig. 4. If the control valve is located at a position V1 or V2 on the high-pressure side of the exchanger in the first pathway 20 at the branch-off points for the bypass 22, or similarly at a position V3 or V4 on the low-pressure side of the exchanger in the second pathway 21 at the branch-off points for the bypass 23, then flow of refrigerant through the pathways 20 and 21 as well as through the bypasses 22 and 23 can be directly controlled. However, the control valve could be located at positions V5 and V6 at intermediate positions within in the bypasses 22 and 23 respectively. In this case only the flow through the bypasses 22 and 23 can be directly controlled and, owing to the lower pressures losses of the bypasses 22, 23 as compared to the pathways 20 and 21, nearly the full flow through the heat exchanger may be diverted to the bypasses 22, 23. The advantage of positioning the control valve at positions V5 and V6 is that it permits a less complex valve to be used than would be the case for the other positions.

[0021] A modification of a heat exchanger 12 according to the present invention for use in a refrigeration cycle of a vehicle air conditioning system as described above with reference to Fig. 2 is shown in Fig. 5. Here the heat exchanger comprises a bypass 22 for the first pathway 20 and a plurality of conduits 24 are provided between the bypass 22 and the pathway 20 at spaced intervals along the length of the pathway 20. In the illustrated embodiment three such conduits 24a, 24b, 24c are provided, each of which is provided with a control valve Z1, Z2, Z3 respectively to control independently the refrigerant flow therethrough. A further control valve Z4 is provided in the inlet to the bypass 22.

[0022] When the thermal flow between the pathways 20 and 21 is to be reduced, a first control valve Z1 can be opened to permit refrigerant flow through the conduit 24a so that a major portion of the refrigerant is diverted from the pathway 20 into the bypass 22 through the conduit 24a due to the lower pressure losses, the minor portion of the refrigerant continuing to flow through the pathway 20. If it is desired to reduce the thermal flow still

further, the valves Z2 and Z3 may be opened in succession to permit flow through the conduits 24b and 24c thus diverting refrigerant from the pathway 20 at successively earlier stages of the refrigerants travel through the heat exchanger 12. By opening the valve Z4, the refrigerant will flow wholly through the bypass 22 and the pathway 20 is then completely bypassed.

[0023] It will be appreciated that an equivalent arrangement could be provided which controls an inflow of refrigerant to the pathway 20 from the bypass 22 rather than an outflow of refrigerant from the pathway 20 as described above.

[0024] The variable which is used to control operation of the control valves V1-V6 and Z1-Z4 is the temperature of the refrigerant subsequent to its compression in the compressor 10. If this temperature exceeds a predetermined level, then the control valves V1-V6 and Z1-Z4 are set to operate to increase the flow of refrigerant through the bypass 22, 23 so that the thermal flow between the pathways 20 and 21 is reduced. The final compression temperature is thereby also reduced. However, owing to the interrelationship between the temperature of the refrigerant both before and after compression, it is also possible to use the temperature of the refrigerant prior to compression as the control variable.

[0025] In a vehicle air conditioning system, the configuration of the valves V1 to V4 in Fig. 4 may be arranged to correspond with the controller of the cooling water circuit of the vehicle as in both cases a mass flow of fluid is distributed to two circuits dependent on the operating temperature. However, the design of valves V5 and V6 and of the valves Z1 to Z4 is simpler because only one mass flow of fluid is controlled dependent on the operating temperature. Conventional thermostatic expansion valves as used in air-conditioning and refrigerating engineering, or valves of this type, can be used for these valves.

Claims

1. A heat exchanger (12) for use in a refrigeration system of a vehicle air conditioning system defining a first refrigerant pathway (20) through which refrigerant can flow from a gas cooler (11) of the system to an expansion valve (13) of the system; and a second refrigerant pathway (21) through which the refrigerant can flow from an evaporator (14) or accumulator 16 of the system to a compressor (10) of the system, the two pathways (20, 21) being arranged so that a thermal flow can occur between the refrigerant flowing in the first and second pathways (20, 21), and

characterised in that

a bypass (22, 23) is provided through which at least a portion of the refrigerant can flow instead of flowing through at least one of the first pathway (20) and

the second pathway (21), and a control valve (V1, V2, V3, V4, V5, V6, Z1, Z2, Z3, Z4) is provided to control the flow of refrigerant through the bypass (22, 23) whereby the thermal flow can be regulated.

2. A heat exchanger as claimed in Claim 1,
characterised in that
the bypass (22) is provided for the first pathway (20). 5
3. A heat exchanger as claimed in Claim 1 or Claim 2,
characterised in that
the bypass (23) is provided for the second pathway (21). 10
4. A heat exchanger as claimed in any one of Claims 1 to 3,
characterised in that
first and second bypasses (22, 23) are provided for both the first and the second pathways (20, 21) respectively. 15
5. A heat exchanger as claimed in any one of Claims 1 to 4,
characterised in that
the control valve (V1, V3) is located at a branch-off point in the pathway (20, 21) at an inlet to the bypass (22, 23) whereby refrigerant flow through both the bypass (22, 23) and the pathway (20, 21) provided with the bypass (22, 23) can be controlled. 20
6. A heat exchanger as claimed in any one of Claims 1 to 4,
characterised in that
the control valve (V2, V4) is located at a branch-off point in the pathway (20, 21) at an outlet from the bypass (22, 23) whereby refrigerant flow through both the bypass (22, 23) and the pathway (20, 21) provided with the bypass (22, 23) can be controlled. 25
7. A heat exchanger as claimed in any one of Claims 1 to 4,
characterised in that
the control valve (V5, V6, Z4) is located in an intermediate position along the length of the bypass (22, 23) so that refrigerant flow through the bypass (22, 23) can be controlled. 30
8. A heat exchanger as claimed in any one of Claims 1 to 7,
characterised in that
a controller is provided which controls the opening and closing of the control valve (V1, V2, V3, V4, V5, V6). 35
9. A heat exchanger as claimed in any one of Claims 1 to 8,
characterised in that 40

a plurality of conduits (24a, 24b, 24c) are provided between the bypass (22) and the pathway (20) at spaced intervals along the length of the pathway (20), a plurality of control valves (Z1, Z2, Z3) being provided to control flow independently through each of the conduits (24a, 24b, 24c) respectively and thereby control overall the flow of refrigerant through the bypass (22) in order that the thermal flow can be regulated.

10. A heat exchanger as claimed in Claim 9,
characterised in that
the control valves (Z1, Z2, Z3, Z4) comprise thermostatic expansion valves. 15
11. A refrigeration system for a vehicle air conditioning system comprising a compressor (10), a gas cooler (11), an expansion valve (13), an evaporator (14), and an internal heat exchanger (12) connected in series to form an integral closed circuit, the internal heat exchanger (12) defining a first refrigerant pathway (20) through which refrigerant can flow from the condenser (11) to the expansion valve (13) and a second refrigerant (21) pathway through which the refrigerant can flow from the evaporator (14) to the compressor (10), the two pathways (20, 21) being arranged so that a thermal flow can occur between the refrigerant flowing in the pathways (20, 21), and
characterised in that
a bypass (22, 23) is provided through which refrigerant can flow instead of flowing through at least one of the first pathway (20) and the second pathway (21), and a control valve (V1, V2, V3, V4, V5, V6, Z1, Z2, Z3, Z4) is provided to control the flow of refrigerant through the bypass (22, 23) whereby the thermal flow can be regulated. 25
12. A system as claimed in Claim 11,
characterised in that
the refrigerant is carbon dioxide. 30
13. A method of regulating thermal flow in a refrigeration system for a vehicle air conditioning system, comprising the steps of 35
 - evaporating a refrigerant into a gaseous phase in an evaporator (14) and passing it to a compressor (10); compressing a gaseous refrigerant in the compressor (10);
 - passing the gaseous refrigerant to a gas cooler (11) where the refrigerant is permitted to give up its heat to the environment expanding the refrigerant to a lower vaporizing pressure via an expansion valve (13); returning the refrigerant to the evaporator (14); and inserting an internal heat exchanger (12) into the refrigeration cycle in order that a thermal flow can occur between the refrigerant flowing in a first pathway 40

(20) located intermediate the gas cooler (11) and the expansion valve (13) and the refrigerant flowing in a second pathway (21) located intermediate the evaporator (14) and the compressor (10); and

5

characterised in that

a bypass (22, 23) is provided through which refrigerant can flow instead of flowing through at least one of the first pathway (20) and the second pathway (21), and a control valve (V1, V2, V3, V4, V5, V6, Z1, Z2, Z3, Z4) is provided to control the flow of refrigerant through the bypass (22, 23) whereby the thermal flow can be regulated.

10

15

14. A method as claimed in Claim 13,

characterised in that

the control valve (V1, V2, V3, V4) is located at a branch-off point in the pathway provided with the bypass whereby refrigerant flow through both the bypass and the pathway provided with the bypass can be controlled.

20

15. A method as claimed in Claim 13,

characterised in that

the control valve (V5, V6, Z4) is located in an intermediate position along the length of the bypass so that refrigerant flow through the bypass can be controlled.

25

30

16. A method as claimed in any one of Claims 13 to 15,

characterised in that

a plurality of conduits (24a, 24b, 24c) are provided between the bypass (22) and the pathway (20) at spaced intervals along the length of the pathway (20), a plurality of control valves (Z1, Z2, Z3) being provided to control flow independently through each of the conduits (24a, 24b, 24c) respectively and thereby control overall the flow of refrigerant through the bypass (22) in order that the thermal flow can be regulated.

35

40

45

50

55

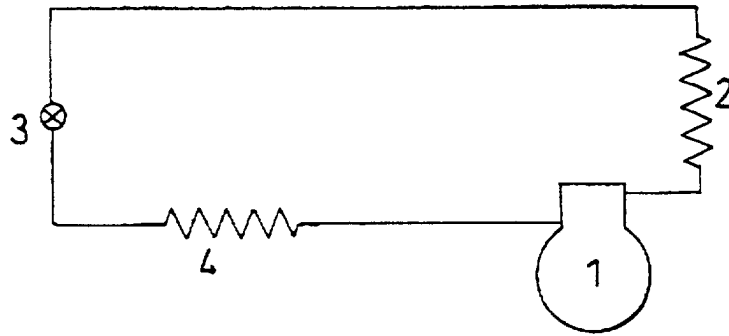


Fig. 1

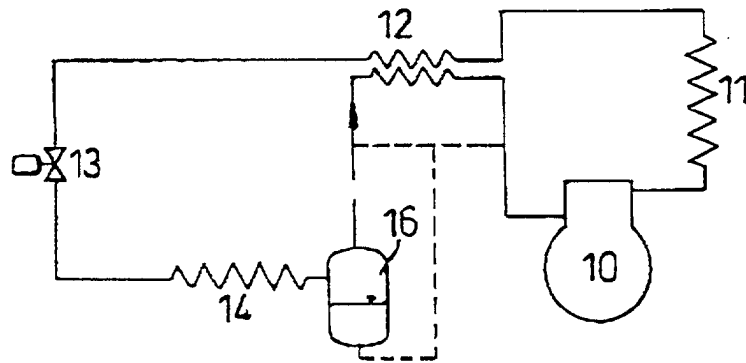


Fig. 2

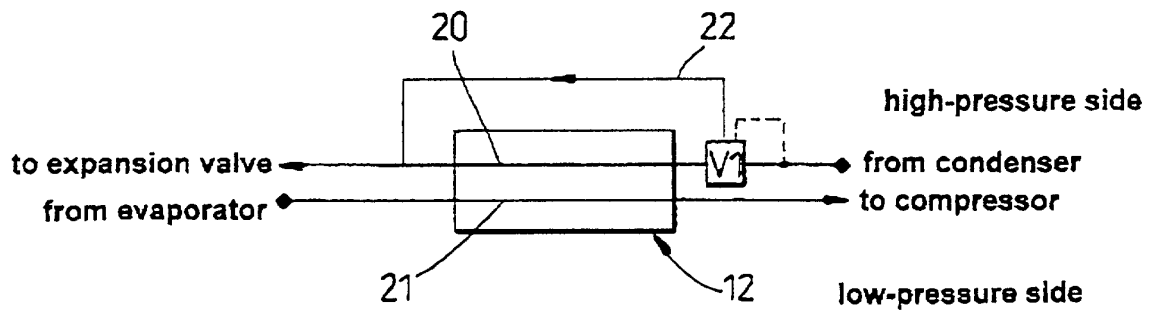


Fig. 3

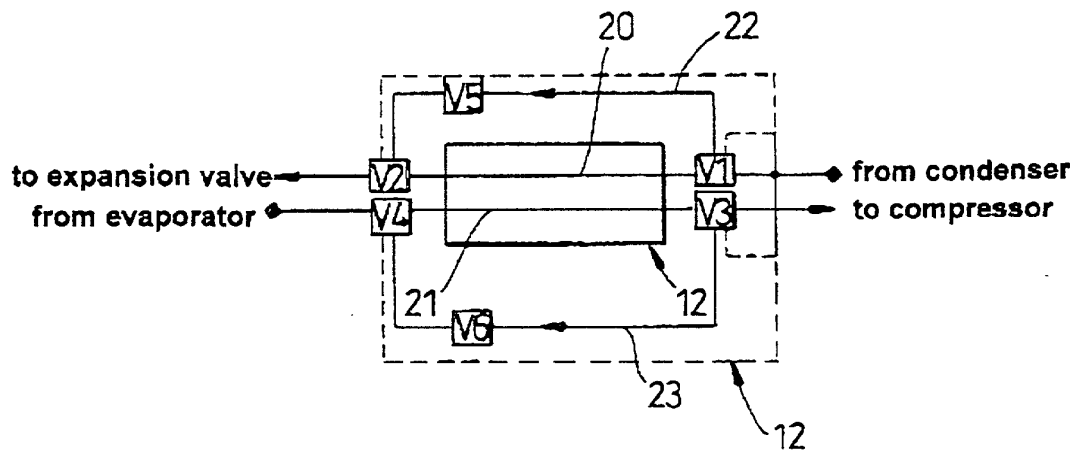


Fig. 4

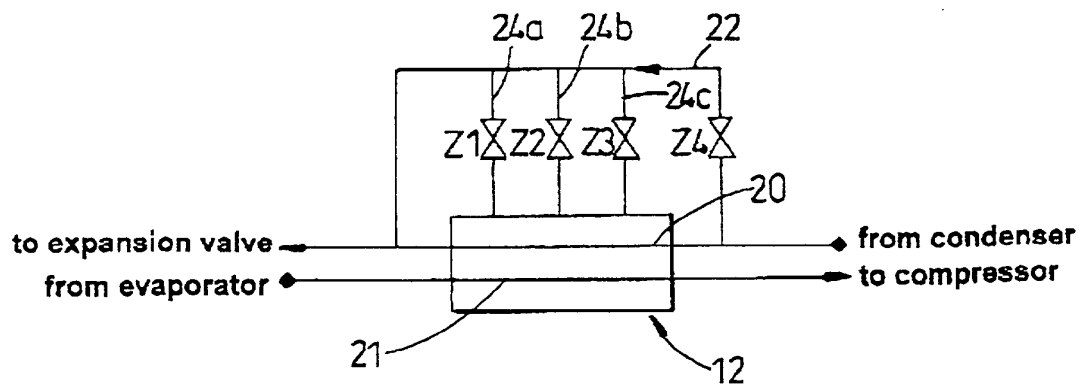


Fig. 5



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 11 2491

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	EP 1 043 550 A (ZEXEL CORP) 11 October 2000 (2000-10-11)	1,3,7-9	F25B40/00
Y	* column 7, line 32 - column 9, line 5; figures 3,4 *	2,5,6, 11-16	
Y	EP 0 779 481 A (SHOWA ALUMINUM CORP) 18 June 1997 (1997-06-18) * column 12, line 14 - column 14, line 20; figure 12 *	2,5, 11-16	
Y	US 5 479 789 A (BORTEN WILLIAM H ET AL) 2 January 1996 (1996-01-02) * column 2, line 62 - column 3, line 67; figure 1 *	6	
X	EP 0 915 306 A (DENSO CORP) 12 May 1999 (1999-05-12)	1,3,7,8	
A	* column 5, line 49 - column 6, line 27; figure 1 *	11-13	
A	EP 1 059 495 A (MITSUBISHI HEAVY IND LTD) 13 December 2000 (2000-12-13) * column 1, line 16 - line 44; figure 6 *	1,11,13	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	DE 199 44 951 A (BEHR GMBH & CO) 22 March 2001 (2001-03-22)		F25B
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 1 October 2001	Examiner Jessen, F
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03 82 (P/4001)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 01 11 2491

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

01-10-2001

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
EP 1043550	A	11-10-2000	JP	11193967 A	21-07-1999
			EP	1043550 A1	11-10-2000
			US	6260367 B1	17-07-2001
			WO	9934156 A1	08-07-1999
EP 0779481	A	18-06-1997	JP	9166363 A	24-06-1997
			EP	0779481 A2	18-06-1997
US 5479789	A	02-01-1996	NONE		
EP 0915306	A	12-05-1999	EP	0915306 A2	12-05-1999
			JP	11201568 A	30-07-1999
			US	6105386 A	22-08-2000
EP 1059495	A	13-12-2000	JP	2000346472 A	15-12-2000
			CN	1278052 A	27-12-2000
			EP	1059495 A2	13-12-2000
			NO	20002839 A	11-12-2000
DE 19944951	A	22-03-2001	DE	19944951 A1	22-03-2001
			FR	2798726 A1	23-03-2001
			JP	2001091103 A	06-04-2001

EPO FORM P0450

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82