(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 073 210 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
28.09.2016 Bulletin 2016/39

(51) Int Cl.:
F25B 5/04 *(2006.01)* ***F25B 41/06*** *(2006.01)*

(21) Application number: **15161544.0**

(22) Date of filing: **27.03.2015**

(84) Designated Contracting States:
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
Designated Extension States:
BA ME
Designated Validation States:
MA

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(54) **REFRIGERATOR WITH ENHANCED EFFICIENCY**

(57) A refrigerator with a refrigerant circuit comprises a compressor (10), a condenser (12), an expansion device (16), a first evaporator (17) downstream the expansion device, a second evaporator (19) downstream the first evaporator and two heat exchangers (18,20) to cause heat exchange between refrigerant flowing from the condenser to the first evaporator, on a first side, and refrigerant flowing downstream the first and second evaporator respectively.

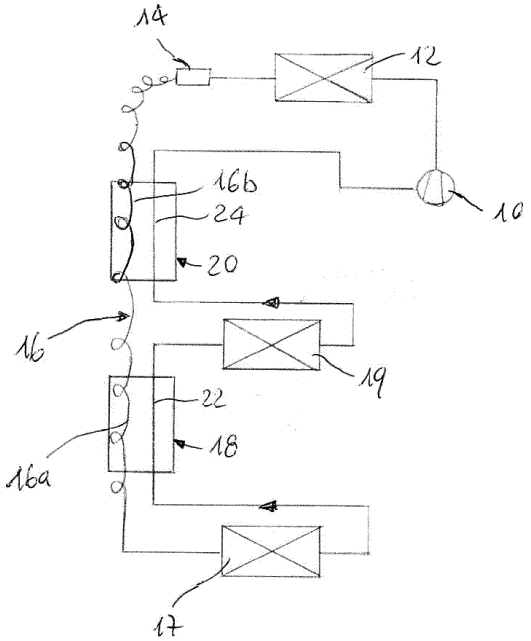


Fig. 2

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Description

[0001] The present invention relates to a refrigerator with a refrigerant circuit comprising a compressor, a condenser, an expansion device, a first evaporator downstream the expansion device, a second evaporator downstream the first evaporator, a heat exchanger to cause heat exchange between refrigerant downstream the condenser and upstream said first evaporator, on one side, and refrigerant downstream the second evaporator and upstream the compressor, on the other side.

[0002] The refrigeration circuit of a refrigerator of the above type is shown in figure 1.

[0003] GB 2143014 suggests using two evaporators in the refrigeration circuit and with heat exchangers between the compressor and one of the evaporators and between the two evaporators respectively. This known solution is quite complex since it uses a diverter valve, two capillary tubes and a suction pipe from the compressor which has a fork, one arm leading to one evaporator and the other arm leading to the other evaporator.

[0004] It is therefore an object of the present invention to provide a refrigerator with a refrigerant circuit of the kind mentioned at the beginning of the description, which has an enhanced energy efficiency and it is simple and easy to be manufactured.

[0005] Such object is reached tanks to the features listed in the appended claims.

[0006] The refrigeration circuit of a refrigerator according to the invention presents an additional heat exchanger to cause heat exchange between refrigerant downstream the condenser and upstream the first evaporator, on a first side, and refrigerant downstream the first evaporator and upstream the second evaporator, on a second side, the expansion device being a single capillary tube that is configured to act as said first side of both heat exchangers.

[0007] By adding a further heat exchanger to the refrigeration circuit of a known refrigerator the title of vapor of refrigerant at the evaporator inlet is reduced. Therefore refrigerant has more liquid that can evaporate in the evaporator, increasing the efficiency of the system. The solution according to the invention gives benefit in term of low energy consumption if compared to known more expensive solutions, for instance use of vacuum insulated panels or variable speed compressors. Of course the solution according to the invention may be used also in combination with these known measures in order to further increase the efficiency of the refrigerator.

[0008] A type of refrigerator similar to the one according to the present invention is known from "dual evaporator" or "sequential evaporator" type refrigerators, but these refrigerators use a non-azeotropic mixture of at least two different refrigerants, for instance propane (R-290) and n-butane (R-600), which has an appropriate gliding temperature difference (GTD) during evaporation and condensation phases. With a refrigeration cycle using the above mixture, known also as Lorenz-Meutzner cycle, it is possible to have identical or at least similar energy saving performances of a dual evaporator refrigeration circuit using a mono-component refrigerant and a by-pass two-circuit cycle, where a 3-way electrovalve is used.

[0009] A refrigerator of this type is disclosed by US 5 207 077 and EP 2 592 366. In both the above documents the expansion device is placed immediately upstream the first evaporator, i.e. the low-temperature evaporator. In US 5207077 the expansion device is identified in the drawing as an expansion valve, while in EP 2592366 the expansion device is a capillary tube arranged at the side of the first evaporator. In said first solution the presence of the valve does increase the overall cost of the appliance, and it may create problem of condensation on suction tube. In the second solution, as it is also disclosed in "Performance optimization of a Lorenz-Meutzner cycle charged with hydrocarbon mixtures for a domestic refrigerator-freezer", IJR, N. 35, Issue 1, Jan 2112, pages 36-46, the optimum capillary tube length is of the order of 10 - 15 m if similar energy consumption performances of a bypass two-circuit cycle are to be obtained.

[0010] In the above documents the sub-cooling from second evaporator and compressor and the additional one required by using these mixtures (tube connection between first and second evaporator) is obtained through use of heat exchangers made with two tubes. In EP 2 592 366 it is explained that these tubes work better in case one is inside the other and in counter-flow.

[0011] On the above mentioned publication and patents indications are given also on modifications required by a refrigerator/freezer product using a non-azeotropic mixture. In the above mentioned article "Performance optimization of a Lorenz-Meutzner cycle charged with hydrocarbon mixtures for a domestic refrigerator-freezer" are given also information on modification in length of capillary (required at least 10m) in order to have benefits in energy and correct behavior of product.

[0012] The applicant has also made experimental work on a refrigeration circuit designed for a modified Lorenz-Meutzner cycle which does not present the above problems and has a low cost. According to such modification the expansion device is a capillary tube that is configured to act as said first side of both heat exchangers.

[0013] According to such solution developed by the applicant for a non-azeotropic mixture, the capillary tube is used externally to the other tubes of the refrigerant circuit, and the refrigerant flow in the capillary tube is in counter flow with reference to the refrigerant flow in the tube of the refrigerant circuit. Of course the capillary tube may be used internally to the other tube.

[0014] Even if the above results are promising, the solution tested by the applicant has still the problem of requiring a loading of the refrigerant circuit with a mixture of refrigerants having a certain composition and distribution. This implies an higher cost and an increased complexity in the manufacturing process of the refrigerator.

[0015] According to the invention, the applicant has

surprisingly discovered that the same circuit designed for a non-azeotropic mixture of refrigerants presents thermodynamic advantages even if used with a single refrigerant, i.e. a refrigerant whose composition is made mainly by a single chemical compound. This result could not be expected and therefore the choice of using a circuit specifically designed for a non-azeotropic mixture of refrigerants for a single mono-compound refrigerant could not be predicted by a person skilled in the art.

[0016] According to a preferred feature of the invention, for a first heat exchanger (the one obtained with capillary tube and suction tube connecting the freezer evaporator to the fridge evaporator) the single capillary tube is parallel and in contact with the tube from the freezer evaporator, and has a length of at least 700 mm.

[0017] According to a second embodiment of the invention, for the first heat exchanger the capillary tube is wrapped around the tube from the freezer evaporator, and has a length of at least 1000 mm, with a contact length on such tube of at least 400 mm.

[0018] The second heat exchanger between the capillary tube and the suction tube upstream the compressor is dimensioned as in traditional refrigerators.

[0019] Further advantages and features of a refrigerator according to the present invention will be clear from the following detailed description, provided by way of non limiting example, with reference to the attached drawings in which:

- Figure 1 is a schematic view of a refrigerant circuit of a refrigerator according to the prior art;
- Figure 2 is a schematic view of a refrigerant circuit of a refrigerator according to the present invention;
- Figure 3 is a detail of one of the two heat-exchangers of figure 1 according to a first embodiment, and
- Figure 4 is a detail similar to figure 3 and referring to a second embodiment of the invention.

[0020] With reference to the drawings, and particularly to figures 2-4, the refrigerant circuit according to the invention comprises a compressor 10, a condenser 12, usually placed on back wall of the refrigerator, cooled by natural convection or with forced air, a drier 14 as normally used on a domestic refrigerator / freezer appliance.

[0021] Downstream the drier, the circuit comprises a single capillary tube 16 with an internal diameter comprised between 0.60 and 0.80mm. In figure 1 the capillary tube 16 is schematically represented as a tube with a plurality of loops, only for distinguishing it from the suction tube (in the technical field of domestic refrigerators it is usual to represent a capillary in this way).

[0022] The circuit comprises a first heat exchanger 18 and a second heat exchanger 20. The first heat exchanger 18 presents a first side made by a capillary tube portion 16a in contact with a portion 22 of the circuit tube between first or low temperature evaporator 17 (placed in the freezer compartment - not shown) and second or higher temperature evaporator 19 (placed in the fridge compartment - not shown). A detail of such heat exchanger is shown in figure 3, and applicant has determined through experimental tests that the length of this tube/tube heat exchanger (with two parallel straight tubes taped together by means of an adhesive aluminum tape - not shown in the drawings for sake of clarity) is preferably at least 0,7 m, more preferably more than 1 m. The total length of the capillary tube is preferably higher than 3,5 m. internal diameter of the suction tube 22 is preferably comprised between 5 and 8 mm.

[0023] According to a further embodiment shown in figure 4, the capillary tube 16a is wrapped around the tube 22 of the refrigerant circuit with use of an aluminum tape (not shown). The length of the suction tube on which the capillary is spirally wound is preferably higher that 0,4 m, with a length of the wrapped capillary higher than 1 m.

[0024] The second heat exchanger 20 is similarly composed of a capillary tube portion 16b and a portion 24 of suction tube upstream the compressor 10. The length of such double-pipe heat exchanger 20 is substantially similar to the one known from usual refrigerators, and therefore it will not be further described here.

[0025] The solution according to the invention can be applied to direct cooled evaporator products (static evaporators in freezer and fridge compartments) and hybrid products (no frost freezer and static fridge).

[0026] Testing activity carried out by the applicant in a refrigerator (with freezer and fridge compartments) having a total internal volume around 300 liters, shows the main benefits obtained applying the cycle according to the invention on a bottom mount freezer built-in product and by using a single refrigerant. Such advantages are still significant if a comparison is made between the technical solution according to the invention and a sample previously tested with a non azeotropic mixture of hydrocarbons refrigerants, for instance propane/normal butane (R290/R600).

[0027] A refrigerator/freezer direct cooled with evaporators in series has been tested (according to Standard IEC 62552) and results are as follows:

- With mixture R290/R600a (20/80): energy consumption 424 Wh/24h
- With single refrigerant R600a: energy consumption 447 Wh/24h (+4,9%)

[0028] Energy consumption of same product without the additional heat exchanger according to the invention has an energy consumption of approximately 470 Wh/24h, therefore about 5% higher if compared to a refrigerator according to the invention.

[0029] Additional heat exchanger cools down more refrigerant in the capillary: that allows that refrigerant comes to evaporator with less vapor, increasing the evaporator efficiency.

[0030] In the tests carried out by the applicant a capillary mass flow rate of 4,1 l/min (measured with nitrogen at 10 bar) has been used. Anyway, solution can be ap-

plied also with different flow rates (indicatively from 3,8 l/min to 5 l/min).

Claims

1. Refrigerator with a refrigerant circuit comprising a compressor (10), a condenser (12), an expansion device, a first evaporator (17) downstream the expansion device, a second evaporator (19) downstream the first evaporator (17), and a heat exchanger (20) to cause heat exchange between refrigerant downstream the condenser (12) and upstream the first evaporator (17), on a first side (16b), and refrigerant downstream the second evaporator (19) and upstream the compressor (10), on a second side (24), **characterized in that** it comprises an additional heat exchanger (18) to cause heat exchange between refrigerant downstream the condenser (12) and upstream the first evaporator (17), on a first side (16a), and refrigerant downstream the first evaporator (17) and upstream the second evaporator (19), on a second side (22), the expansion device being a single capillary tube (16, 16a, 16b) that is configured to act as said first side (16a, 16b) of both heat exchangers (18, 20).

2. Refrigerator according to claim 1, wherein the refrigerant comprises a single compound.

3. Refrigerator according to claim 1 or 2, wherein both the heat exchangers (18, 20) are shaped as double-pipe exchangers formed by said capillary tube (16, 16a, 16b) in a heat exchange relationship with corresponding portions (22, 24) of tube of the refrigerant circuit.

4. Refrigerator according to claim 3, wherein said capillary tube (16a, 16b) is externally in contact with said portions of tube (22, 24).

5. Refrigerator according to claim 3 or 4, wherein the capillary tube has a total length higher than 3,5 m.

6. Refrigerator according to claim 4 or 5, wherein the length of the additional heat exchanger (18) is higher than 0,7 m.

7. Refrigerator according to any of the preceding claims, wherein each heat exchanger (18, 20) is made by the capillary tube (16, 16a, 16b) and by a tube (22, 24) defining the second side of the heat exchangers placed in parallel one against the other.

8. Refrigerator according to any of the preceding claims 1-6, wherein each heat exchanger (18, 20) is made by a tube (22, 24) defining the second side of the heart exchangers and by a the capillary tube (16, 16a, 16b) wrapped around it.

9. Refrigerator according to claim 7 or 8, wherein both heat exchangers (18, 20) are covered by an aluminum layer.

10. Refrigerator according to any of the preceding claims, wherein both evaporators (17, 19) are static evaporators placed in a freezer compartment and in a fridge compartment respectively.

11. Refrigerator according to any of claims 1-10, wherein the second evaporator (19) is a static evaporator placed in a fridge compartment, and the first evaporator (17) is a no-frost evaporator placed in a freezer compartment.

12. Refrigerator according to any of the preceding claims, wherein the refrigerant is n-butane.

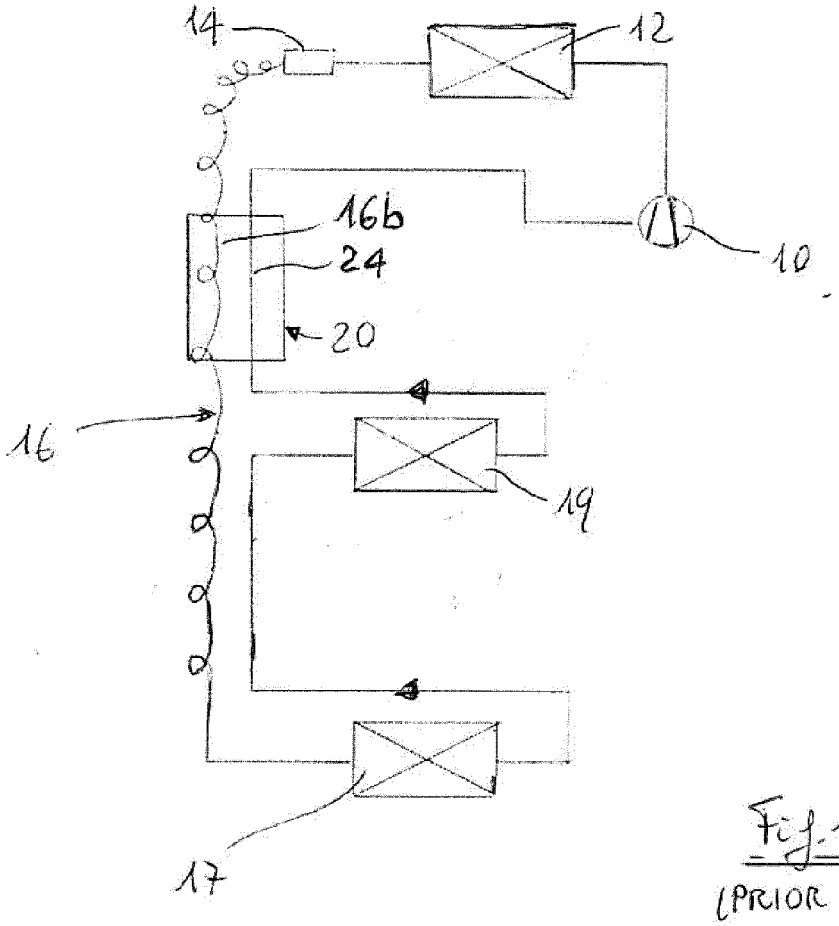


Fig. 1
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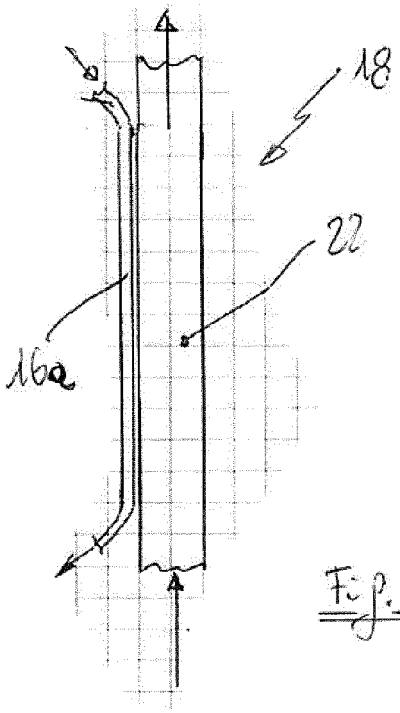


Fig. 3

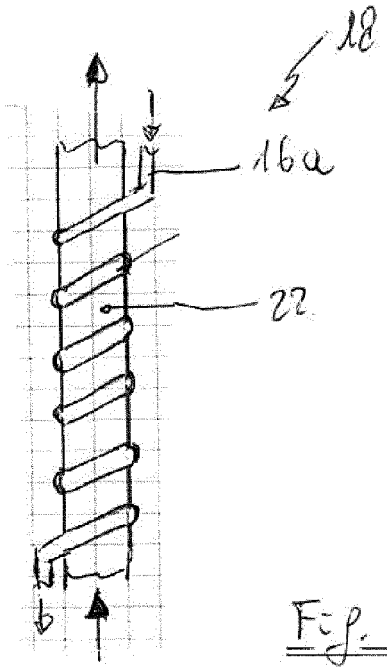


Fig. 4

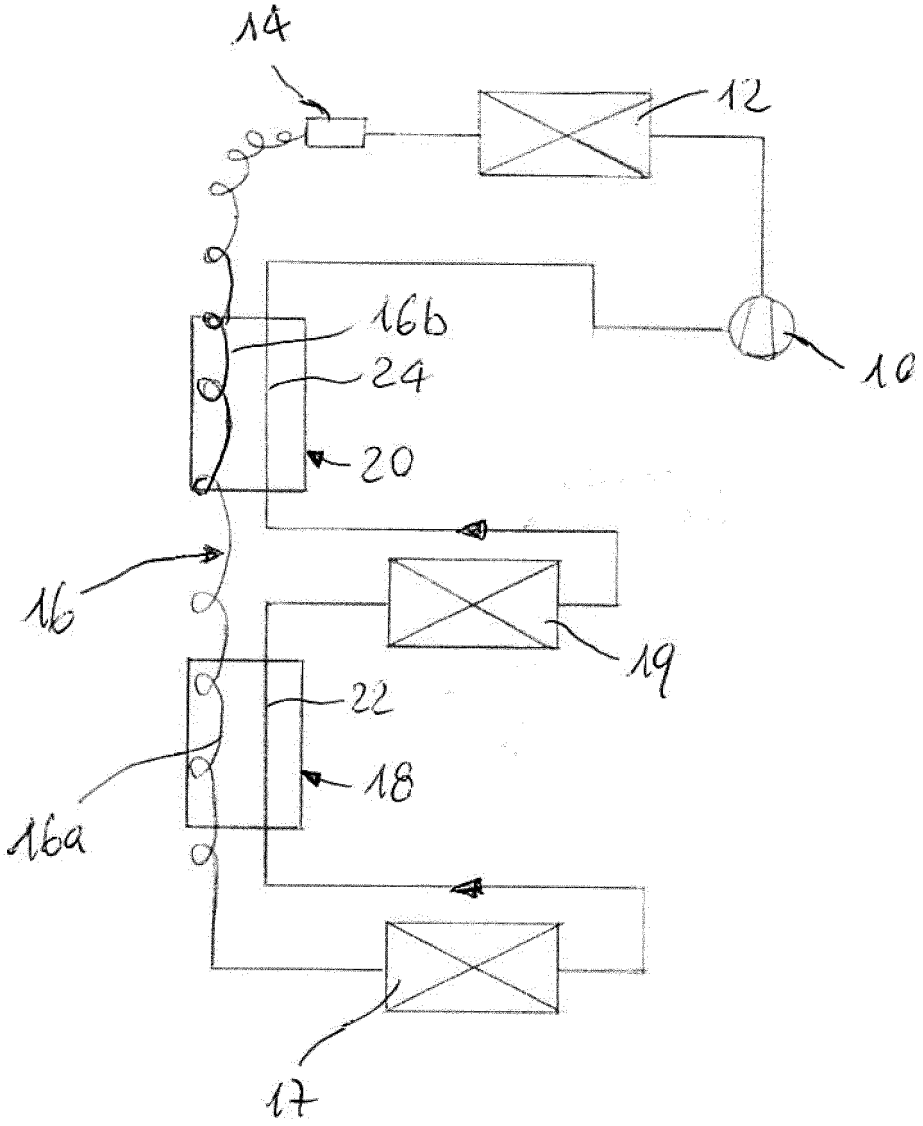


Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 15 16 1544

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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
Munich	4 September 2015	Szilagyi, Barnabas

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

Application Number
EP 15 16 1544

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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