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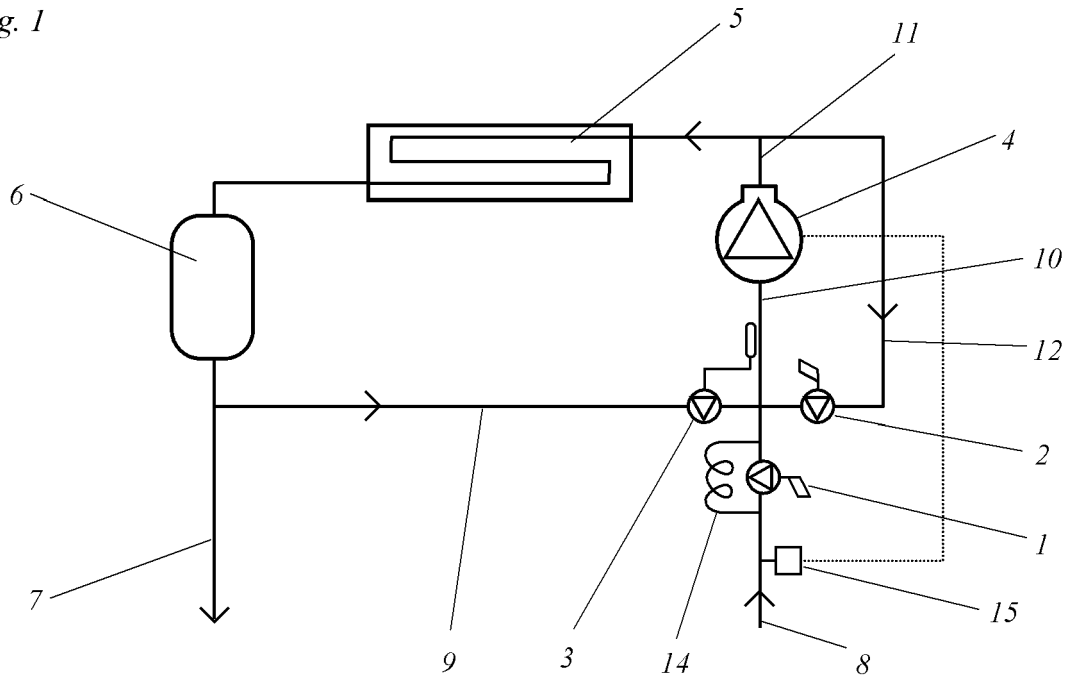
(71) Applicant: **Cano Cavanillas, Javier**
14900 Lucena (ES)

(72) Inventor: **Cano Cavanillas, Javier**
14900 Lucena (ES)

(54) **Variable capacity refrigeration system**

(57) Refrigeration system with variable capacity (fig. 1), said system involving at least: one or more compressors, a condenser, and means to manage the refrigerant flow. Those means consisting of: a restriction control valve in the refrigerant return line from evaporators, a hot gas by-pass valve between the compressor discharge and the compressor suction line, and a thermostatic liquid injection valve into the compressor suction line.

Fig. 1



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Description

Technical Field

[0001] The invention relates to a capacity control system to be applied to the design and construction of self-contained refrigeration units and refrigeration plants in the industrial and commercial refrigeration sector.

Background Art

[0002] In small commercial refrigeration installations, it is often desirable to centralise the cooling production for a group of terminal units, such as refrigerated cabinets and small cold rooms; In addition, some industrial applications need a precise temperature control of the refrigerated medium. Such applications must be supplied with variable cooling capacity, adapted to the instant load. Cooling production plants must then be equipped with a variable capacity control.

[0003] The dominant technology in commercial and industrial refrigeration is that of refrigerant vapour compression, where a refrigerant fluid is compressed by mean of a compressor to a high pressure state, which is then condensed in a condenser at high temperature and driven in liquid phase to the evaporating units. By mean of a restrictor, the liquid refrigerant is expanded to a low pressure state and evaporated in the evaporator at a lower temperature than the refrigerated medium. Finally the refrigerant vapour is driven back to the compressor.

[0004] The vast specialised literature describes diverse capacity control techniques based in regulation valves, such as hot gas by-pass valves and suction restriction valves (ASHRAE. ASHRAE Refrigeration Handbook.ASHRAE, 2002. p.45.15. ; WANG, et al. "Air conditioning and refrigeration" Mechanical Engineering Handbook. FRANK KREITH, 1999. p.9.77. ; WANG. Handbook of Air conditioning and Refrigeration. McGraw-Hill, 2000. p.11.24-26.). Furthermore, the state of art involves many different parts and components for controlling a refrigerant system, and in particular, liquid injection valves and pressure control valves.

[0005] Such pressure control valves have been used in the past to provide refrigeration installations with variable capacity. However, the lower efficiency under partial load operation, and the involved risks over the system reliability have become an impediment for its general use in small modern installations. Instead, some recent compressor technologies implemented by manufacturers provide a continuous variable capacity, such as the compressor known as *inverter,* equipped with a variable speed drive, and some Scroll type compressors with an intermittent discharge device.

[0006] The technological development in the refrigeration sector has traditionally been led by manufacturers of parts and components, since they have been able to consolidate technological improvements by implementing them in their standard products. This has resulted in a great evolution of the separated components: compressors, control valves, heat exchangers, etc. The recent evolution of the value chain in the refrigeration sector has brought about the standard production of subassemblies in a feasible manner, allowing a quick technological progress of self-contained units through the design, test and construction of advanced cooling systems. An example of this tendency is the US patentUS2002021972 , which describes a cooling system combining a hot gas by-pass valve together with a liquid injection valve in a rotary type compressor. Moreover, the European patent EP0981033 A describes a cooling system that uses a suction restriction valve together with a liquid injection valve for capacity control in a Scroll type compressor.

[0007] The present invention has also its origin in the analysis of an advanced cooling system by combining market standard components, such as pressure control valves and liquid injection valves, for the variation of capacity in a hermetic compressor, and in particular in a reciprocating type compressor.

Summary of invention

[0008] The invention refers to a new capacity control system to be applied to the construction of self-contained refrigeration units with variable capacity, said units involving at least one compressor and a condenser, said control system consisting of a new combination of pressure control valves able to adapt the refrigerant flow to the instant load.

[0009] The refrigeration units resulting from this invention are most suitable to be used in small refrigeration installations at both positive and negative temperature, in the commercial and industrial refrigeration sectors, such as centralised installations with multiple evaporators, or industrial applications where it is required an accurate control on the evaporator cooling capacity.

[0010] The key to the invention is the innovative combination of control valves that allows adapting the refrigerant flow to the instant load, while keeping the system within the safety limits, and reasonably reducing the power consumption under partial load.

[0011] The present invention results in better performance in comparison to the existing variable capacity systems based on control valves. It has lower power consumption under partial load than the simple hot gas bypass system, and keeps the operating pressure and temperature within the safety limits even under low load demand. Moreover, the present invention has the advantage of being a much simpler solution than the existing variable capacity compressor technologies, while achieving a similar performance.

Brief description of drawings

[0012] The attached drawings are provided to illustrate the characteristics and the working principle of the invention, and represent a preferential embodiment, given as

a non-restrictive example, wherein:

[0013] Fig. 1 is the schematic representation of the preferential embodiment of a refrigeration subsystem involving a combination of valves subject to the present invention, said valves being of the type of pressure-driven control valves.

[0014] Fig. 2 is the schematic representation of an alternative refrigeration subsystem, analogue to the one in fig. 1, wherein one of those pressure-driven valves is replaced by a motor-driven valve as a function of pressure.

[0015] Fig. 3 is the schematic representation of an alternative refrigeration system, analogue to the one in fig. 2, wherein the electronic control of the motor-driven valve is a function of the temperature of the refrigerated medium.

[0016] Fig. 4 is the schematic representation of an alternative system, analogue to the one in fig. 3. wherein an economizer is also included.

Description of embodiments

[0017] The invention relates to system being able to control the capacity of the compressor or compressors in a refrigeration unit, said system consisting of a new combination of temperature and pressure control valves.

[0018] Said combination of valves involves: a restriction valve (1) regulating the refrigerant flow returning to the compressor; a bypass valve (2) between the compressor discharge and the compressor suction line, said valve being adjusted to keep a minimum suction pressure level; and a liquid injection valve (3) between the liquid refrigerant supply line and the compressor suction line, said valve being adjusted to keep a fixed temperature gap between the temperature of the compressor suction line and the dew-point temperature.

[0019] Figure 1 represents a refrigeration subsystem, corresponding to a single-compressor condensing unit or refrigeration plant, based on the principle of the invention. This subsystem consists of: a compressor (4), a condenser (5), a liquid receiver (6), a high-pressure refrigerant supply line, (6) and a low pressure refrigerant return line (8). This subsystem incorporates the combination of valves as described above.

[0020] The restriction valve (1) regulating the refrigerant flow is installed on the refrigerant return line, said valve keeps the pressure in the return line to a constant value, said valve may consist of a pressure-driven valve, the so-called constant-pressure valve. When restricting the refrigerant return flow, said valve produces a pressure drop in the compressor suction line (10).

[0021] By reducing the pressure in the compressor suction line (10), a considerable reduction of the compressor pumping capacity is achieved, as the absorbed power is also reduced. However, hermetic compressors need at least a certain refrigerant flow rate to be able to cool its motor windings. Thus, a certain minimum suction pressure must be maintained.

[0022] To said purpose, a refrigerant bypass valve (2) is installed on a bypass line (12) between the compressor discharge (11) and the compressor suction line (10). Said valve may consist of a pressure-driven control valve, the so-called hot gas bypass valve. When the suction pressure drops below a given value, said control valve opens to introduce hot gas into the compressor suction line (10) to maintain the suction pressure. As a result suction gas temperature is also increased.

[0023] To prevent the compressor from working under high discharge temperature, that may deteriorate lubricating oils, suction gas temperature must also be limited to a given value. Such a value is ideally the lowest temperature as possible that ensures the lack of refrigerant in liquid phase. Thus, suction gas temperature should be slightly superheated with respect to its dew-point temperature.

[0024] To cool down suction gas temperature to a given superheat value, a liquid injection valve (3) is installed on the compressor suction line (10). Said valve may consist of a thermostatic expansion valve, driven by the fluid inside a bulb at the same pressure than the suction line.

[0025] Such system as described so far, would be able to work permanently even under no load. Such a situation is to be avoided, so a control device should be added to stop the compressor under null return flow-rate.

[0026] A capillary tube (14) bypassing the pressure control valve (1), said capillary tube being calibrated to admit a small refrigerant flow rate, will produce, under a low load situation, a reduction of pressure in the return line (8), even beyond the pressure set point of the restriction valve (1), said restriction valve being closed under said situation. The refrigerant return line (8) is also equipped with a low pressure switch (15), said pressure switch being calibrated to an activation pressure greater than the pressure set point of the bypass valve (2), and said pressure switch turning off the compressor when the pressure in the return line (8) drops below said given value.

[0027] When any evaporating unit restarts the demand of refrigeration, the refrigerant is allowed into the corresponding evaporator with the consequent increase of the pressure in the return line (8), and when said pressure in the return line (8) increases over said given value, said pressure switch (15) reactivates and restarts the compressor (4).

[0028] Figure 2 represents an alternative construction of the refrigeration system introduced in figure 1, wherein the pressure-driven control valve (1), the pressure switch (15) and the capillary tube (14), are replaced by a motor-driven control valve (16), said valve being controlled by an electronic controller as a function of the pressure read by a pressure transducer (17).

[0029] In such alternative construction, the electronic controller (18) regulates the opening of the motor-driven restriction valve (16) to maintain a constant pressure in the refrigerant return line (8), said pressure being read by the pressure transducer (17). When the controller or-

ders the complete closing of the motor-driven valve (16), it also turns off the compressor (4).

[0030] Figure 3 represents an alternative construction of a complete refrigeration system, wherein the motor-driven restriction valve (1) is now controlled by an electronic controller (18) as a function of the temperature value read by a temperature probe (20), said probe being placed on the refrigerated medium.

[0031] Such construction in addition involves an evaporator (21) and an expansion valve (22). The electronic controller (18) controls the opening of the motor-valve (19) to maintain a constant temperature of the refrigerated medium. When the controller orders the complete closing of the motor valve (16), it also turns off the compressor (4).

[0032] Figure 4 represents an analogue construction of figure 3, wherein an economizer (23) is also involved, said economizer being placed between the liquid supply line (7) and the liquid injection line (9). In one side of said economizer the liquid refrigerant in the supply line (7) is subcooled to provide a greater refrigeration effect. On the other side of the economizer a part of the liquid refrigerant flow, once expanded through the injection valve (3), is evaporated.

Claims

1. Variable capacity refrigeration system consisting of: at least one compressor (4), a condenser (5), and a combination of control valves, **characterised in that** at least one control valve (1) restrains the refrigerant flow to maintain the pressure in the return line from evaporators to a given constant value, said valve being installed on the return line (8); and another control valve (2) bypasses hot refrigerant gas to maintain the compressor suction pressure over a given threshold value, said valve being installed in a bypass line between the compressor discharge and the compressor suction line.

2. Machine as per claim 1, **characterised in that** the compressors, the condenser, said control valves and other components are integrated in a self-contained unit.

3. Machine as per claim 1, **characterised in that** said restriction control valve (1) and said refrigerant bypass valve (2), are pressure-driven control valves.

4. Machine as per claims 1 and 2, where in addition it involves a liquid injection valve (3) into the compressor suction line, **characterised in that** said valve is a thermostatic valve driven by the fluid in a bulb, said bulb being placed on the compressor suction line (10).

5. Device to be applied to a machine built according to claims 1 and 2, said device being designed for the on/off control of the compressors by mean of a pressure switch placed on the refrigerant return line (8), **characterised in that** the use of said pressure switch is combined with a capillary tube (14) bypassing the restriction control valve (1), said capillary tube being dimensioned to let through a small fraction of the total refrigerant flow rate.

6. Machine as per claim 1, **characterised in that** at least the restriction control valve (1) is a motor-driven control valve being managed by an electronic controller (18) as a function of the read value of a pressure transducer (17), said transducer being placed on the refrigerant return line (8).

7. Machine as per claim 1, **characterised in that** at least the restriction control valve (1) is a motor-driven control valve being managed by an electronic controller (18) as a function of the read value of a temperature probe (20), said probe being placed on the refrigerated medium.

8. Machine as per claim 1, **characterised in that** it also involves an economizer heat exchanger (23), said economizer being placed between the liquid refrigerant supply line and the liquid injection line.

9. Machine as per claim 1, where the compressor is a reciprocating compressor.

10. Machine as per claim 1, where the compressor is a scroll compressor.

11. Machine as per claim 1, where the condenser is a tube-fin type coil with forced ventilation.

Fig. 1

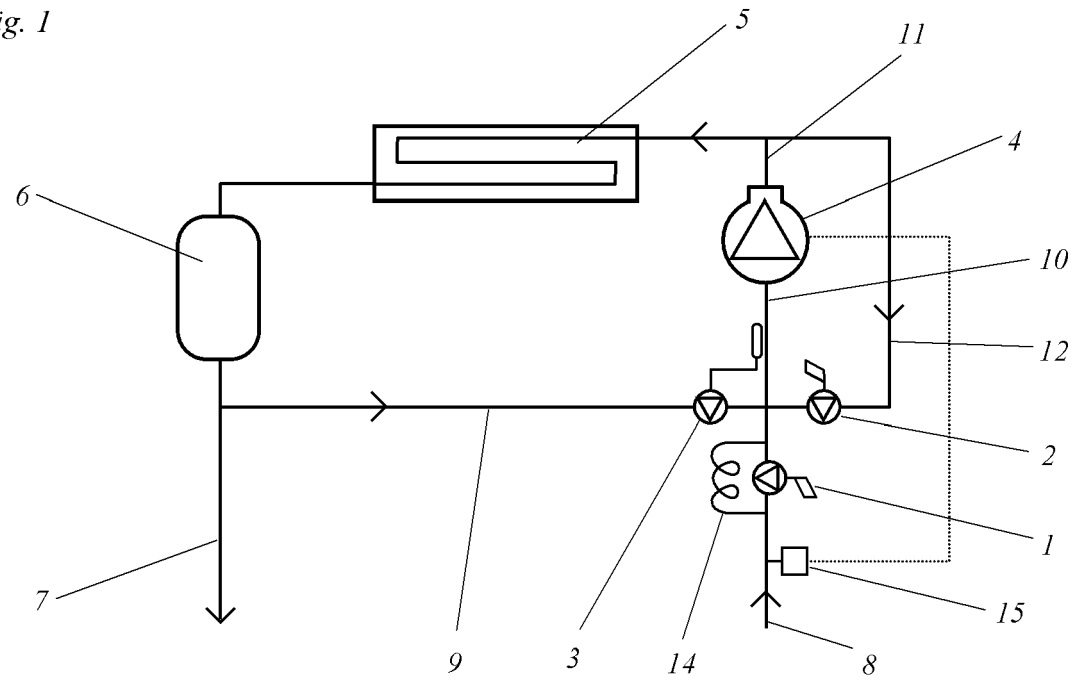

Fig. 2

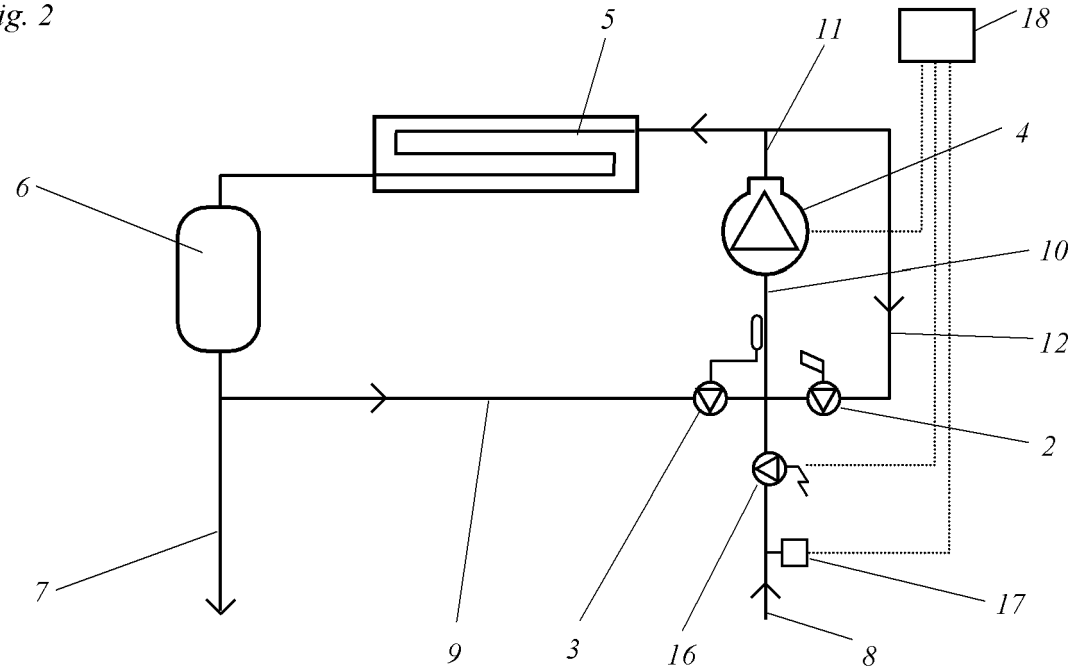

Fig. 3

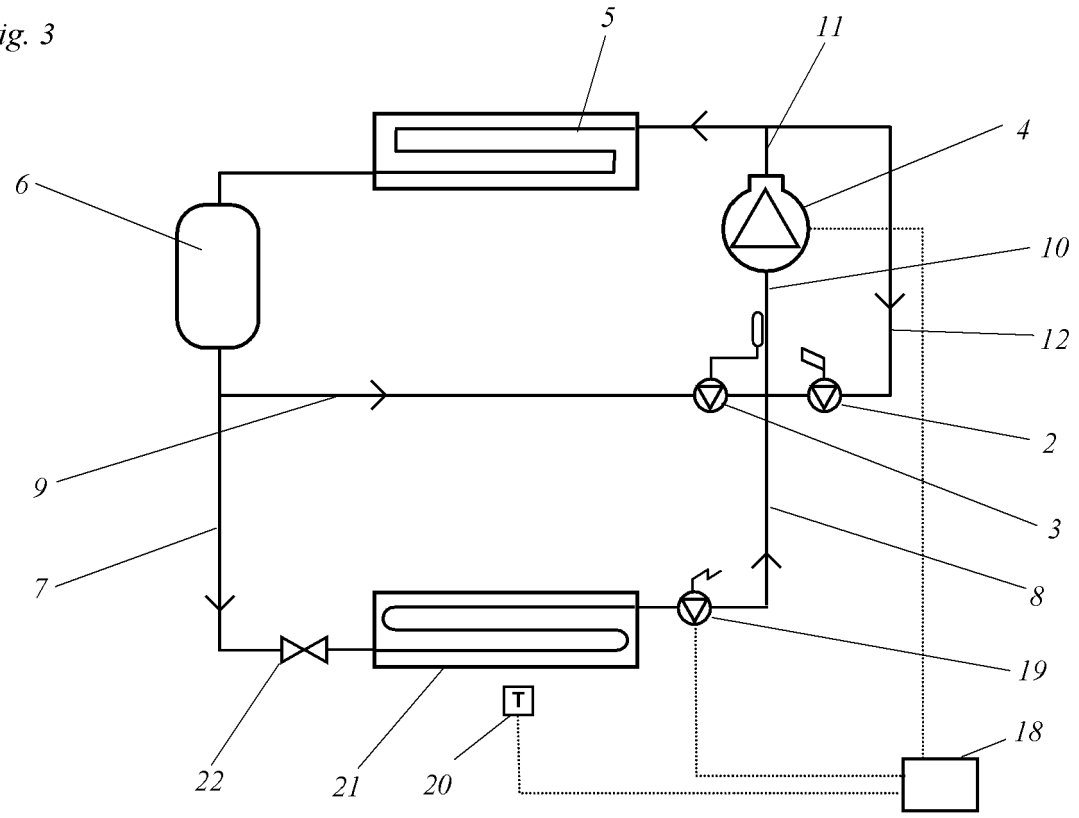
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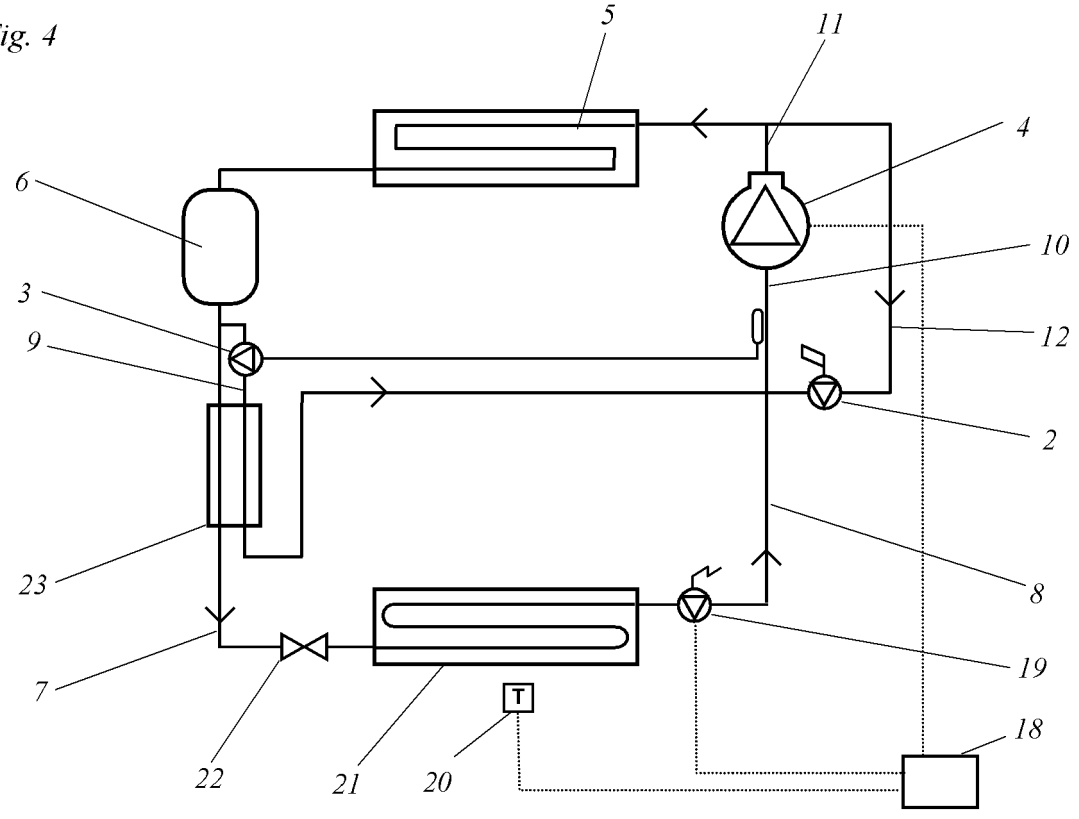
Fig. 4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EUROPEAN SEARCH REPORT

Application Number
EP 10 38 2016

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2009/056561 A1 (OLIVA TORRAS S A L [ES]; CASTELLTORT NADAL VICENTE [ES]; FERNANDEZ MUN) 7 May 2009 (2009-05-07) * page 6, line 10 - page 11, line 20; figure 2 *	1	INV. F25B41/04
X	WO 2005/088212 A1 (ARCELIK ANONIM SIRKETI [TR]; GULDALI YALCIN [TR]; KOCATURK SERDAR [TR]) 22 September 2005 (2005-09-22) * paragraph [0023] - paragraph [0028]; figure 3 *	1,2	
X	WO 2008/079122 A1 (CARRIER CORP [US]; LIFSON ALEXANDER [US]; TARAS MICHAEL F [US]) 3 July 2008 (2008-07-03) * page 3, line 11 - page 6, line 26; figure 1 *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B

1 ~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
Munich	14 June 2010	Szilagyi, Barnabas

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 (P04C01)

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Application Number
EP 10 38 2016

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

see additional sheet(s)

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 10 38 2016

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1, 2

   Variable capacity refrigeration system integrated in a self-contained unit

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2. claims: 1, 3

   Variable capacity refrigeration system with pressure-driven control valves

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3. claims: 1, 4, 8

   Variable capacity refrigeration system with a liquid injection valve

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4. claim: 5

   Device designed for the on/off control of compressors

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5. claims: 1, 6

   Variable capacity refrigeration system with a motor-driven control valve controlled as a function of the read value of a pressure transducer

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6. claims: 1, 7

   Variable capacity refrigeration system with a motor-driven control valve controlled as a function of the read value of a temperature probe

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7. claims: 1, 9

   Variable capacity refrigeration system with a reciprocating compressor

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8. claims: 1, 10

   Variable capacity refrigeration system with a scroll compressor

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9. claims: 1, 11

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 10 38 2016

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

Variable capacity refrigeration system wherein the condenser is a tube-fin type coil with forced ventilation

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 10 38 2016

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
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14-06-2010

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		US 2010043468 A1	25-02-2010

EPO FORM P0459

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

REFERENCES CITED IN THE DESCRIPTION

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- EP 0981033 A **[0006]**

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- ASHRAE Refrigeration Handbook. ASHRAE, 2002, 45.15 **[0004]**
- Air conditioning and refrigeration. **WANG et al.** Mechanical Engineering Handbook. FRANK KREITH, 1999, 9.77 **[0004]**
- **WANG.** Handbook of Air conditioning and Refrigeration. McGraw-Hill, 2000, 11.24-26 **[0004]**