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(54) **COOLING CIRCUIT SECTION AND COOLING CIRCUIT**

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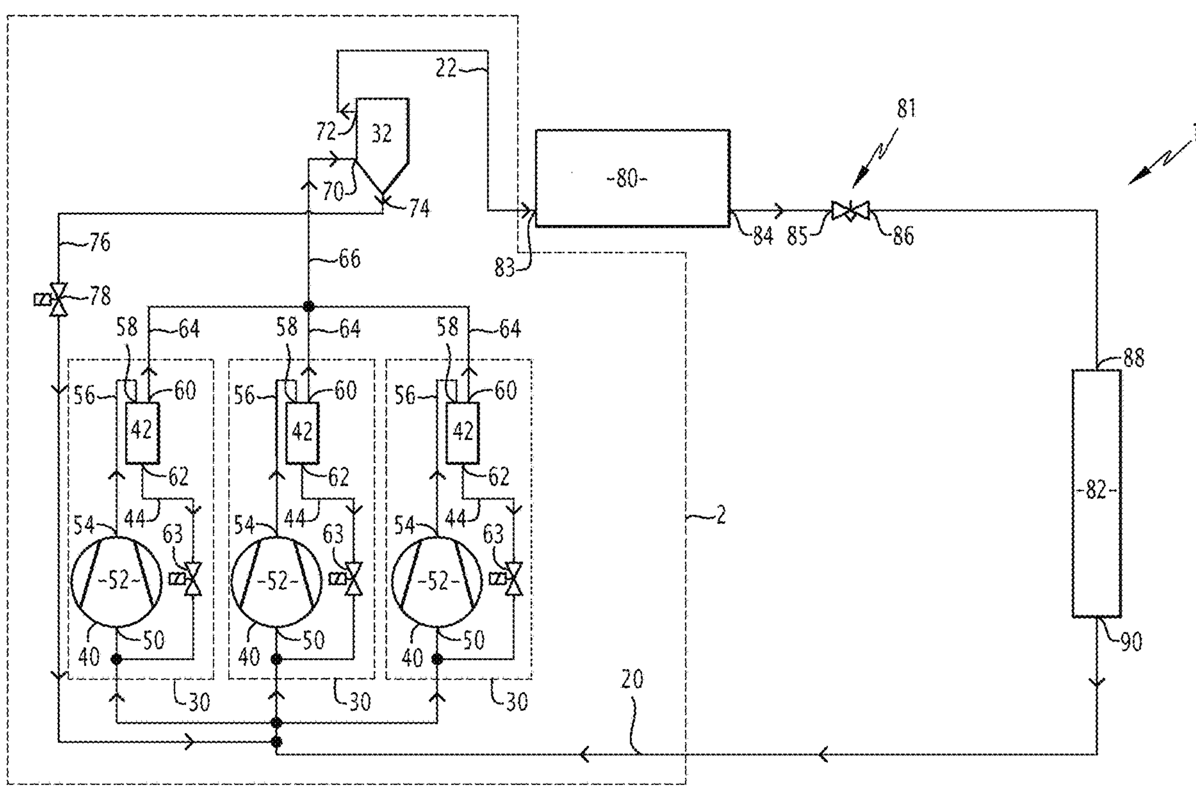
(57) **ABSTRACT**

Cooling circuit section (**2**), intended for the circulation of a refrigerant, said cooling circuit section (**2**) comprising:—at least two compressor assemblies (**30**), fluidically connected in parallel, each compressor assembly (**30**) comprising:—a compressor (**40**) configured to receive a low-pressure refrigerant having a first pressure, and for increasing the pressure of the low-pressure refrigerant so as to produce a compressed refrigerant having a second pressure that is greater than the first pressure, the compressed refrigerant comprising oil,—an individual oil separator (**42**) comprising an inlet (**58**) fluidically connected to the compressor (**40**) so as to receive the compressed refrigerant from the compressor (**40**), each individual oil separator (**42**) being configured to separate a first fraction of oil from the compressed refrigerant, the cooling circuit section (**2**) further comprising a common oil separator (**32**).



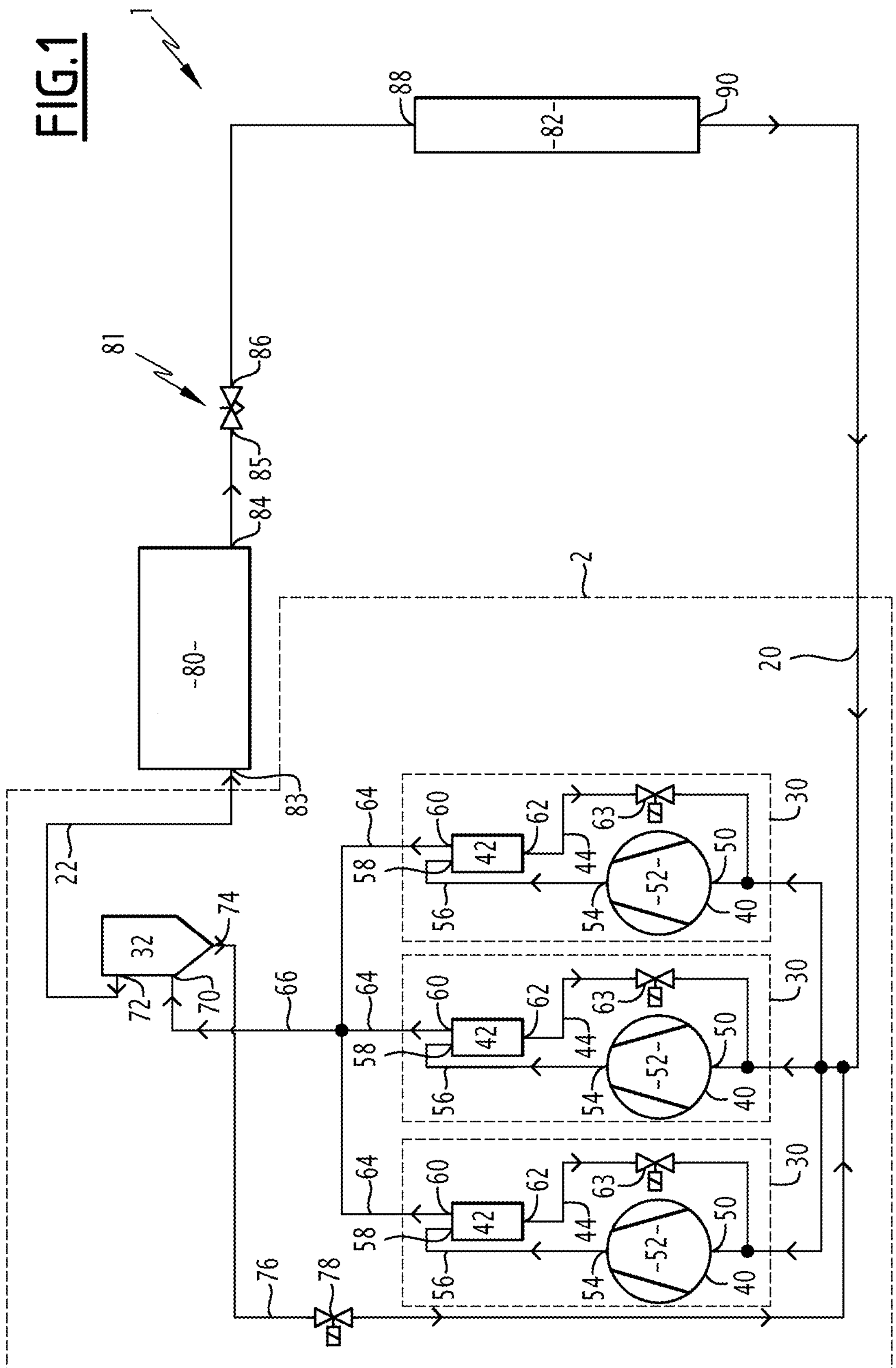

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FIG.1

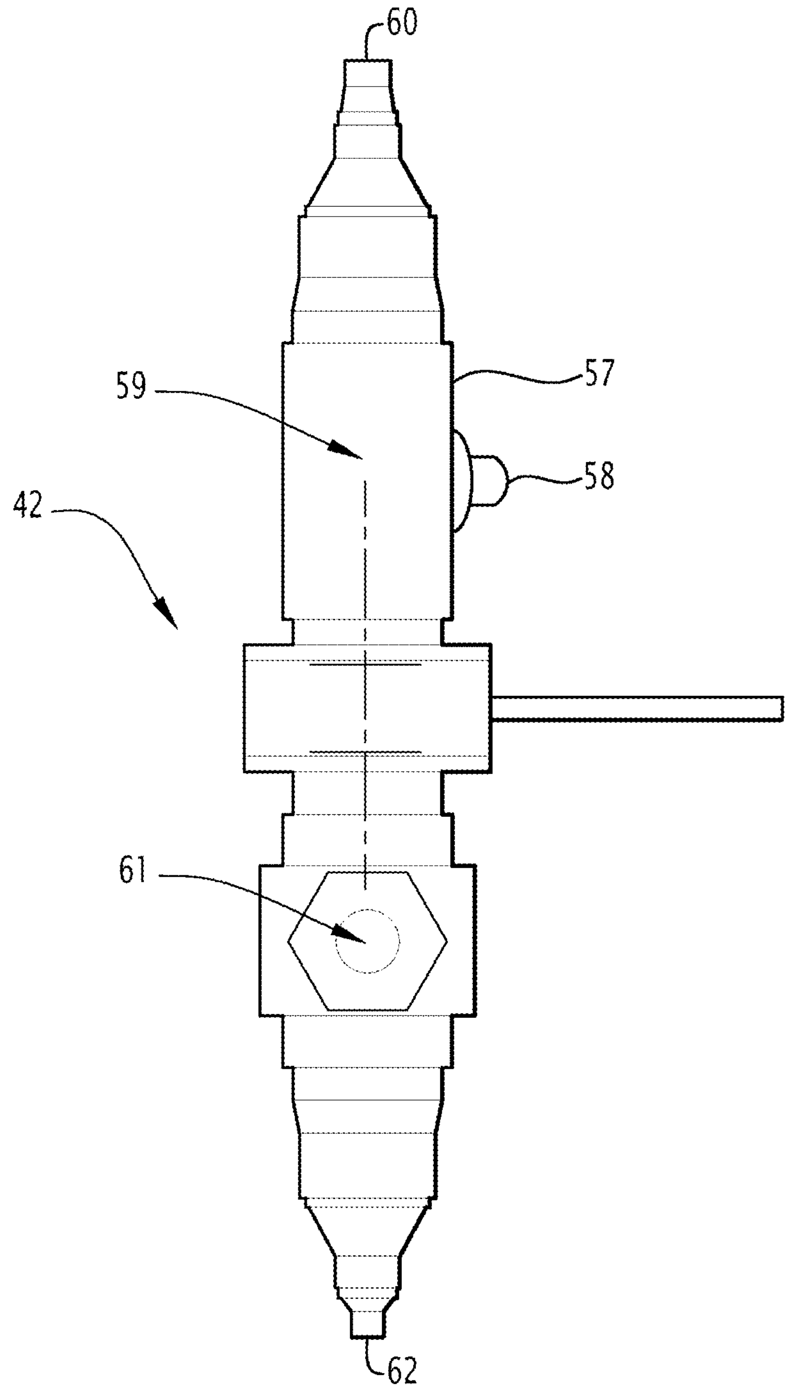

FIG.2

COOLING CIRCUIT SECTION AND COOLING CIRCUIT

[0001] The present invention relates to a cooling circuit section and a cooling circuit.

[0002] The present invention in particular relates to the field of refrigeration units for commercial and residential applications.

[0003] U.S. Pat. No. 4,506,523 discloses a cooling circuit section for a refrigeration system comprising two compressors connected in parallel in a fluid manner. A common discharge header of the compressors is connected to a common oil separation system including an oil separator unit with an oil reservoir. Oil separated from the refrigerant in the separator unit and collected in the oil reservoir is returned directly into the compressors via an oil return line connecting the oil separation system to the compressors.

[0004] However, the cooling circuit section as described above has several drawbacks.

[0005] Indeed, the inventors of the present invention have found that, due to the particular structure of the system with only one common oil separator feeding the oil back into both compressors, the exact amount of oil fed back into each of the compressors is difficult to control. This can be detrimental for the safe operation of the compressors, which requires a sufficient amount of oil. Furthermore, the total amount of oil filtered from the refrigerant in prior art systems is not entirely satisfactory.

[0006] The present invention aims to resolve the aforementioned problems by providing a cooling circuit section with improved operational safety.

[0007] To that end, the invention relates to a cooling circuit section, intended for the circulation of a refrigerant, said cooling circuit section comprising:

- **[0008]** at least two compressor assemblies, fluidically connected in parallel, each compressor assembly comprising:
  - **[0009]** a compressor configured to receive a low-pressure refrigerant having a first pressure, and for increasing the pressure of the low-pressure refrigerant so as to produce a compressed refrigerant having a second pressure that is greater than the first pressure, the compressed refrigerant comprising oil,
  - **[0010]** an individual oil separator comprising an inlet fluidically connected to the compressor so as to receive the compressed refrigerant from the compressor, each individual oil separator being configured to separate a first fraction of oil from the compressed refrigerant,
  - **[0011]** the individual oil separator further comprising:
    - **[0012]** a refrigerant outlet, through which the compressed refrigerant is intended to be discharged from the individual oil separator after separation of the first fraction of oil and
    - **[0013]** an oil outlet, through which the first fraction of oil is intended to be discharged from the individual oil separator, the individual oil separator being further configured to return the first fraction of oil to the compressor,
- **[0014]** the cooling circuit section further comprising a common oil separator fluidically connected to the refrigerant outlet of each individual oil separator so as to receive the compressed refrigerant from each of the compressor assemblies, the common oil separator being configured to separate a second fraction of oil from the compressed refrigerant.

[0015] According to advantageous but not mandatory aspects of the invention, such a cooling circuit section may comprise one or several of the following features, taken in any technically possible combination:

- **[0016]** the common oil separator comprises an inlet, fluidically connected to the compressor assemblies so as to receive the compressed refrigerant from the compressor assemblies, a refrigerant outlet, through which the compressed refrigerant is intended to be discharged from the common oil separator after separation of the second fraction of oil, and an oil outlet, through which the second fraction of oil is intended to be discharged from the common oil separator;
- **[0017]** the cooling circuit section further comprises a common feedback tube fluidically connecting the common oil separator to each of the compressors so as to feed the second fraction of oil back into the compressors;
- **[0018]** the common feedback tube comprises an expansion valve configured to decrease the pressure of the second fraction of oil from the second pressure to the first pressure;
- **[0019]** each compressor assembly comprises an individual feedback tube fluidically connecting the oil outlet of the individual oil separator to the compressor so as to feed the first fraction of oil back into the compressor of the compressor assembly;
- **[0020]** the individual feedback tube comprises an expansion device configured to decrease the pressure of the first fraction of oil from the second pressure to the first pressure;
- **[0021]** the common oil separator is a coalescence oil separator or a centrifugal oil separator;
- **[0022]** each of the individual oil separators is configured to separate the oil from the refrigerant based on differences in the densities of the refrigerant and the oil;
- **[0023]** the individual oil separators are chosen among a fluid speed decrease oil separator, configured to decrease the speed of the fluid fed into the oil separator and a fluid direction modification oil separator, configured to change the direction of the fluid fed into the oil separator;
- **[0024]** the compressor of each compressor assembly is a hermetic compressor;
- **[0025]** the refrigerant is carbon dioxide, preferably carbon dioxide R744.

[0026] The invention further relates to a cooling circuit comprising a cooling circuit section as described above, the cooling circuit further comprising a heat exchanger device configured to cool the refrigerant, an expansion valve and an evaporator device.

[0027] According to advantageous but not mandatory aspects of the invention, such a cooling circuit may comprise one or several of the following features, taken in any technically possible combination:

- **[0028]** the heat exchanger device, the expansion valve and the evaporator device are connected in series, the heat exchanger device being connected to an outlet of the common oil separator and the evaporator device being connected to an inlet of the compressor assemblies;

[0029] the heat exchanger device is a condenser configured to cool the refrigerant such that the refrigerant condenses into a liquid state;

[0030] the heat exchanger device is a gas cooler configured to cool the refrigerant such that the refrigerant remains in the gaseous state.

[0031] The invention and other advantages thereof will become more clearly apparent in the light of the description which follows of an embodiment of a cooling circuit section according to the invention, only given as an example and made with reference to the appended drawings wherein:

[0032] FIG. **1** is a schematic diagram of a cooling circuit comprising a cooling circuit section according to the invention, and

[0033] FIG. **2** is a schematic diagram of an individual oil separator of the cooling circuit of FIG. **1**.

[0034] FIG. **1** shows a cooling circuit **1** intended for the circulation of a refrigerant. In this figure, the intended circulation direction of the refrigerant in the cooling circuit is indicated by arrows.

[0035] The refrigerant is a fluid adapted for transporting heat from a volume that is to be cooled to an environment.

[0036] The refrigerant is of a type as known as such in the art. For example, the fluid is a hydrochlorofluorocarbon fluid. In another example, the refrigerant is carbon dioxide (for example R744). However, any other adapted type of refrigerant may be used.

[0037] As shown in FIG. **1**, the cooling circuit **1** comprises a cooling circuit section **2**.

[0038] The cooling circuit section **2** comprises an inlet tube **20**, an outlet tube **22**, and at least two compressor assemblies **30** and a common oil separator **32** disposed there-between.

[0039] The inlet tube **20** is intended for the circulation of a refrigerant having a first pressure and the outlet tube **22** is intended for the circulation of a refrigerant having a second pressure, the second pressure being greater than the first pressure. The compressor assemblies **30** are configured to increase the pressure of the refrigerant from the first pressure to the second pressure.

[0040] Preferably, the second pressure is strictly greater than the first pressure.

[0041] In the example of FIG. **1**, the cooling circuit section **2** comprises three compressor assemblies **30**. However, a different number of compressor assemblies **30** may be used depending on the needs.

[0042] The compressor assemblies **30** are fluidically connected in parallel. More particularly, each compressor assembly **30** is fluidically connected to the inlet tube **20** of the cooling circuit section **2** such that it receives at least a portion of the refrigerant circulating in the inlet tube **20**.

[0043] Each compressor assembly **30** comprises a compressor **40**, an individual oil separator **42** and an individual feedback tube **44**.

[0044] The compressor **40** is for example hermetic compressor.

[0045] A hermetic compressor is a compressor in which the motor and the mechanical compression parts are arranged in a hermetically closed casing. The casing is more particularly a steel casing.

[0046] The only openings in the casing are the inlet **50** and the outlet **54** which are configured to receive or discharging the refrigerant. In particular, there is no additional opening for feeding additional fluids, such as oil, into the compressor.

[0047] The casing of the hermetic compressor is not configured to be opened.

[0048] The compressor **40** comprises an inlet **50** for the refrigerant, a compression unit **52** for compressing the refrigerant from the first pressure to the second pressure and an outlet **54** for the refrigerant.

[0049] Each inlet **50** is fludically connected to the inlet tube **20**.

[0050] The first pressure depends on the application requirements. The first pressure is for example comprised between 12 and 60 bar, and typically equal to 28 bar.

[0051] The second pressure depends typically on the ambient air condition. The second pressure is for example comprised between 45 and 130 bar.

[0052] In the following, the refrigerant having the first pressure is referred to as "low-pressure refrigerant" and the refrigerant having the second pressure is referred to as "compressed refrigerant".

[0053] The compression unit **52** of the compressor **40** comprises mechanical moveable parts (not shown) which are lubricated by oil. The oil is of any type adapted for the use in refrigerant compressors. It may be, for example, a mineral or a vegetable oil.

[0054] During the operation of the compression unit **52**, a fraction of the oil used for the lubrication of the compressor **40** mixes with the refrigerant. Therefore, the compressed refrigerant exiting the compressor **40** at the outlet **54** comprises some oil.

[0055] The amount of oil introduced into the refrigerant is, for example, a function of the rotation frequency of the compressor **40** and/or of a working point of the compressor **40**.

[0056] The individual oil separator **42** is configured to separate a first fraction of the oil contained in the compressed refrigerant and for returning this first fraction of oil into the compressor **40** through the individual feedback tube **44**.

[0057] The individual oil separator **42** is fluidically connected to the compressor **40** so as to receive the compressed refrigerant from the compressor **40**. In particular, an inlet **58** of the individual oil separator is fluidically connected, for example via a connection tube **56**, to the outlet **54** of the compressor **40**.

[0058] The individual oil separator **42** comprises, in the example of FIG. **2**, a separation unit **59**, a refrigerant outlet **60** and an oil outlet **62**.

[0059] The individual oil separator **42** is configured to separate, in the separation unit **59**, a first fraction of oil from the compressed refrigerant such that the first fraction of oil exits the individual oil separator **42** through the oil outlet **62** and the remaining compressed refrigerant exits the individual oil separator **42** through the refrigerant outlet **60**.

[0060] The compressed refrigerant exiting the individual oil separator still comprises oil. More particularly, the amount of oil remaining in the compressed refrigerant corresponds to the amount of oil in the compressed refrigerant entering the individual oil separator **42** reduced by the first fraction of oil removed by the individual oil separator **42**.

[0061] The individual oil separator **42** is of any type adapted to separating oil from a refrigerant.

[0062] According to one embodiment, the individual oil separator **42** is configured to separate the oil from the refrigerant based on the differences in the densities of the refrigerant and the oil.

[0063] According to one example, the oil separator **42** is a fluid direction modification oil separator, which is configured to modify the trajectory of the refrigerant so as to separate the lighter molecules from the heavier ones. In fact, when the trajectory of the fluid is modified, the heavier molecules in the fluid tend to continue, due to their inertia, on their initial trajectory, whereas lighter molecules tend to change their trajectory. The light molecules are thus separated from the heavy molecules. Such fluid direction modification oil separators are known in the art.

[0064] For example, the separation unit **59** of the individual oil separator **42** comprises a T-shaped tube comprising a main tube and two deviation tubes fluidically connected to the deviation tube. Each deviation tube extends substantially perpendicular to the main tube. A first deviation tube of the separation unit **59** is connected to the refrigerant outlet **60**, while the second deviation tube of the separation unit **59** is connected to the oil outlet **62**.

[0065] According to an alternative embodiment, the individual oil separator **42** is a fluid speed decrease oil separator configured to decrease the speed of the fluid received therein so as to separate the oil from the refrigerant. As known, the speed decrease of a considered fluid within the oil separator **42** depends on its density. Fluid speed decrease oil separators are known in the art.

[0066] In the example shown in FIG. **2**, the individual oil separator **42** further comprises a casing **57** and an inspection glass **61**. The inspection glass **61** comprises a glass inserted into an opening of the casing **57**. The inspection glass **61** is configured to visualize the oil flow out of the individual oil separator **42**.

[0067] As mentioned above, the individual oil separator **42** is configured to feed the first fraction of oil back to the compressor **40**. In particular, the oil outlet **62** of the individual oil separator **42** is fluidically connected, via the individual feedback tube **44**, to a tube communicating with the inlet **50** of the compressor **40**.

[0068] In the example shown in the figures, the individual feedback tube **44** comprises an expansion device **63** configured to decrease the pressure of the first fraction of oil from the second pressure to the first pressure. In the example shown in the figures, the expansion device is an expansion valve. However, any other adapted expansion device may be used, for example a capillary tube.

[0069] The refrigerant outlet **60** of the individual oil separator **42** of each compressor assembly is fluidically connected to the common oil separator **32**.

[0070] More particularly, each compressor assembly **30** comprises an individual connection tube **64** having an inlet connected to the refrigerant outlet **60** of the individual oil separator **42**. The cooling circuit section **2** further comprises a common connection tube **66** having an inlet connected to an outlet of each of the individual connection tubes **64**, and an outlet connected to the common oil separator **32**.

[0071] As shown in FIG. **1**, the common oil separator **32** comprises an inlet **70**, fluidically connected to the compressor assemblies **30** so as to receive the compressed refrigerant from the compressor assemblies **30**, a separation unit (not shown), configured to separate a second fraction of oil from the compressed refrigerant, a refrigerant outlet **72**, through which the compressed refrigerant is intended to be discharged from the common oil separator **32** after separation of the second fraction of oil, and an oil outlet **74**, through which the second fraction of oil is intended to be discharged from the common oil separator **32**. More particularly, the refrigerant outlet **72** is fluidically connected with the outlet tube **22** of the cooling circuit section.

[0072] The common oil separator **32** may be of any other type adapted for separating oil from the refrigerant. More particularly, the common oil separator **32** is configured to separate the second fraction of oil from the refrigerant.

[0073] Preferably, for example in order to save cost, the individual oil separators **42** are of a different type than the common oil separator **32**. In particular, the individual oil separators **42** are configured to separate a significantly smaller amount of oil from the refrigerant than the common oil separator **32**.

[0074] The common oil separator **32** is, for example, a coalescence oil separator.

[0075] The coalescence oil separator is an oil separator configured to operate according to the coalescence principle. The coalescence principle is the accumulation of droplets of two identical substances which are dispersed in a fluid by reunification of the identical substances.

[0076] In an alternative embodiment, the common oil separator **32** is a centrifugal oil separator.

[0077] The centrifugal oil separator is an oil separator configured to separate oil from the refrigerant by centrifugation. In particular, due to the density difference between the oil and the refrigerant, the oil is separated by means of a rotating cylinder inside the centrifugal oil separator. Such centrifugal oil separators are known in the art.

[0078] The cooling circuit section **2** further comprises a common feedback tube **76** fluidically connecting the common oil separator **32** to each of the compressors **40** so as to feed the second fraction of oil back to the compressors **40**.

[0079] In particular, the oil outlet **62** of the common oil separator **32** is fluidically connected, via the common feedback tube **76**, to the inlet tube **20** of the cooling circuit section **2**.

[0080] In the example shown in the figures, the common feedback tube **76** comprises an expansion device **78** configured to decrease the pressure of the second fraction of oil from the second pressure to the first pressure. In the example shown in the figures, the expansion device **78** is an expansion valve. However, any other adapted expansion device may be used, for example a capillary tube.

[0081] In the example shown in FIG. **1**, the cooling circuit section **2** forms part of a cooling circuit **1**, further comprising a heat exchanger device **80**, an expansion valve **81** and an evaporator device **82**.

[0082] The cooling circuit section **2** and the heat exchanger device **80** may, for example, form a condenser unit. The condenser unit is configured to compress and to condense the refrigerant.

[0083] The condenser unit is, for example, configured to be installed distant from the evaporator device. For example, in the case of a cooling circuit **1** implemented in a supermarket, the condenser unit may be installed in an equipment room and the evaporator device **82** in a customer area.

[0084] The heat exchanger device **80** comprises an inlet **83**, fluidically connected to the outlet tube **22** of the cooling circuit section **2**, an outlet **84** and a heat exchanging unit (not represented) arranged there-between.

[0085] For example, the heat exchanging unit comprises tubes which are fluidically connected to the inlet **83** and the outlet **84** and at least one fan configured to provide an air circulation across the tubes.

[0086] According to one example, the refrigerant is intended to enter the heat exchanger device **80** in a gaseous state.

[0087] The heat exchanger device **80** is configured to cool the refrigerant. In particular, the heat exchanger device **80** is configured to reject heat from the refrigerant into the environment of the heat exchanger device **80**. The refrigerant at the outlet **84** has a temperature strictly smaller than a temperature of the refrigerant at the inlet **83**.

[0088] According to one embodiment, the heat exchanger device **80** is a condenser. In this case, the heat exchanging unit is a condensation unit. The condenser is configured to cool the refrigerant in such a manner that the refrigerant condenses from a gaseous state into a liquid state. The condenser is, in this example, configured to cool a refrigerant at a pressure inferior to a critical pressure point. In this embodiment, the refrigerant is intended to exit the heat exchanger device **80** in a liquid state.

[0089] In another example, the heat exchanger device **80** is a gas cooler. The gas cooler is configured to cool the refrigerant in such a manner that it remains in the gaseous state. In this case, the refrigerant is intended to exit the heat exchanger device **80** in a gaseous state.

[0090] According to one example, the refrigerant is carbon dioxide and the heat exchanger device **80** operates with the refrigerant in a supercritical state. In particular, the refrigerant has for example a pressure greater than 73 bar. In this example, the heat exchanger device **80** is configured to provide the refrigerant in a supercritical gaseous state at the outlet **84**.

[0091] The outlet **84** of the heat exchanger device **80** is fluidically connected to an inlet **85** of the expansion valve **81**. The expansion valve **81** is configured to expand the refrigerant. It is configured to decrease the pressure of the refrigerant from the second pressure to the first pressure.

[0092] An outlet **86** of the expansion valve **81** is fluidically connected to the evaporator device **82**.

[0093] The evaporator device **82** comprises an inlet **88**, an outlet **90** and an evaporator unit (not represented) arranged there-between. For example, the evaporator device **82** comprises heat exchange tubes (not represented).

[0094] The evaporator device **82** is configured to evaporate the refrigerant by heat exchange between the refrigerant circulating through the evaporator device **82**, and more particularly in the heat exchange tubes, and a cooling volume (not represented). The cooling volume is for example an inside of a refrigerator, a freezer, a cooling cabinet such as multideck cabinet, for example in a supermarket, or self-service counter, for example in a supermarket, a cold room or a refrigerated warehouse.

[0095] The outlet **90** of the evaporator device **82** is connected to the inlet tube **20** of the cooling circuit section **2**.

[0096] The cooling circuit section according to the invention is particularly advantageous. In particular, the combination of individual oil separators **42** and a common oil separator **32** allows for a safe operation of the system, and more particularly of the compressors, thanks to a simple and reliable management of the oil management in the cooling circuit section.

[0097] In particular, within the cooling circuit **1** of the invention, the oil level in each compressor **40** is automatically maintained at a safe operational level, as each compressor **40** receives, via the individual feedback tube **44**, a fraction of oil released into the refrigerant during compression of the refrigerant by the compressor **40**.

[0098] For example, if one of the compressors **40** operates at a high frequency, a high amount of oil is released into the compressed refrigerant in this compressor **40**. The corresponding individual oil separator **42** is then configured to feed back this large amount of oil directly into the corresponding compressor **40**, in order to ensure that the compressor **40** disposes of enough oil for lubrication.

[0099] This is particularly important in the case of a hermetic compressor, in which, due to the hermetic closure of the casing, it is not possible to feed new oil into the compressor via its casing from outside of the cooling circuit.

[0100] Furthermore, the cooling circuit section **2** presents a very high efficiency for separating the oil from the refrigerant, since the cooling circuit **1** is configured to separate the oil from the refrigerant in two stages, namely in the individual oil separator **42** and the common oil separator **32**. As a consequence, with the cooling circuit **1** of the invention, at the fluid outlet **72** of the common oil separator **32**, no or almost no oil is left in the refrigerant after it leaves the common oil separator **32**. The fact that the refrigerant circulating through the heat exchanger device **80** and the evaporator device **82** only contains very small amounts of oil is further advantageous, since it improves the thermodynamic performance of the refrigerant in the cooling circuit **1**.

1. Cooling circuit section, intended for the circulation of a refrigerant, said cooling circuit section comprising:
- at least two compressor assemblies, fluidically connected in parallel, each compressor assembly comprising:
  - a compressor configured to receive a low-pressure refrigerant having a first pressure, and for increasing the pressure of the low-pressure refrigerant so as to produce a compressed refrigerant having a second pressure that is greater than the first pressure, the compressed refrigerant comprising oil,
  - an individual oil separator comprising an inlet fluidically connected to the compressor so as to receive the compressed refrigerant from the compressor, each individual oil separator being configured to separate a first fraction of oil from the compressed refrigerant,
  - the individual oil separator further comprising:
    - a refrigerant outlet, through which the compressed refrigerant is intended to be discharged from the individual oil separator after separation of the first fraction of oil and
    - an oil outlet, through which the first fraction of oil is intended to be discharged from the individual oil separator, the individual oil separator being further configured to return the first fraction of oil to the compressor,
- the cooling circuit section further comprising a common oil separator fluidically connected to the refrigerant outlet of each individual oil separator so as to receive the compressed refrigerant from each of the compressor assemblies, the common oil separator being configured to separate a second fraction of oil from the compressed refrigerant.

2. Cooling circuit section according to claim **1**, wherein the common oil separator comprises an inlet, fluidically connected to the compressor assemblies so as to receive the compressed refrigerant from the compressor assemblies, a refrigerant outlet, through which the compressed refrigerant is intended to be discharged from the common oil separator after separation of the second fraction of oil, and an oil outlet, through which the second fraction of oil is intended to be discharged from the common oil separator.

3. Cooling circuit section according to claim **1**, wherein the cooling circuit section further comprises a common feedback tube fluidically connecting the common oil separator to each of the compressors so as to feed the second fraction of oil back into the compressors.

4. Cooling circuit section according to claim **3**, wherein the common feedback tube comprises an expansion valve configured to decrease the pressure of the second fraction of oil from the second pressure to the first pressure.

5. Cooling circuit section according to claim **1**, wherein each compressor assembly comprises an individual feedback tube fluidically connecting the oil outlet of the individual oil separator to the compressor so as to feed the first fraction of oil back into the compressor of the compressor assembly.

6. Cooling circuit section according to claim **1**, wherein the individual feedback tube comprises an expansion device configured to decrease the pressure of the first fraction of oil from the second pressure to the first pressure.

7. Cooling circuit section according to claim **1**, wherein the common oil separator is a coalescence oil separator or a centrifugal oil separator.

8. Cooling circuit section according to claim **1**, wherein each of the individual oil separators is configured to separate the oil from the refrigerant based on differences in the densities of the refrigerant and the oil.

9. Cooling circuit section according to claim **8**, wherein the individual oil separators are chosen among a fluid speed decrease oil separator, configured to decrease the speed of the fluid fed into the oil separator and a fluid direction modification oil separator, configured to change the direction of the fluid fed into the oil separator.

10. Cooling circuit section according to claim **1**, wherein the compressor of each compressor assembly is a hermetic compressor.

11. Cooling circuit section according to claim **1**, wherein the refrigerant is carbon dioxide.

12. Cooling circuit comprising a cooling circuit section according to claim **1**, the cooling circuit further comprising a heat exchanger device configured to cool the refrigerant, an expansion valve and an evaporator device.

13. Cooling circuit according to claim **12**, wherein the heat exchanger device, the expansion valve and the evaporator device are connected in series, the heat exchanger device being connected to an outlet of the common oil separator and the evaporator device being connected to an inlet of the compressor assemblies.

14. Cooling circuit according to claim **12**, wherein the heat exchanger device is a condenser configured to cool the refrigerant such that the refrigerant condenses into a liquid state.

15. Cooling circuit according to claim **12**, wherein the heat exchanger device is a gas cooler configured to cool the refrigerant such that the refrigerant remains in the gaseous state.

16. Cooling circuit section according to claim **11**, wherein the refrigerant is carbon dioxide R744.

* * * * *