Title: REFRIGERATION SYSTEM COMPRISING MULTIPLE REFRIGERATION CONSUMER DEVICES

Abstract: The invention is directed to a refrigeration system, comprising a first and second refrigeration consumer device (11, 51; 21, 61), a first compressor device (32, 72) and a second compressor device (42, 82a). The first refrigeration consumer device (11, 51) is connected to a first suction header (31, 71) for receiving refrigerant and transferring it to the first compressor device (32, 72), the second refrigeration consumer device (21, 61) is connected to a second suction header (41, 81a) for receiving refrigerant and transferring it to the second compressor device (42, 82a). The second suction header (41, 81a) is connected to the first suction header (31, 71) via the second compressor device (42, 82a). The first suction header (31, 71) operates at a first pressure and the second suction header (41, 81a) operates at a second pressure, the first pressure being higher than the second pressure.
REFRIGERATION SYSTEM
COMPRISING MULTIPLE REFRIGERATION CONSUMER DEVICES

The present invention refers to a refrigeration system comprising at least a first refrigeration consumer device and at least a second refrigeration consumer device operating at different cooling temperatures.

Such refrigeration system is typically applied, for example, in a supermarket. A typical supermarket includes cabinet type and/or rack type refrigeration system devices wherein a plurality of individual refrigeration cases are placed throughout the supermarket. The cases display and store the supermarket goods requiring cold temperatures. Typically, a supermarket provides goods which require cooling and provides goods which require freezing at lower temperatures than the temperature required for cooling. Thus, a refrigeration system is required for providing two or more temperature levels for realizing different cooling temperatures, for example required for cooling and freezing, or required e.g. in normal-temperature refrigeration for diary products and meat, respectively.

Each supermarket cold store or cabinet may include a housing that also contains an expansion valve and an evaporator. As the liquid refrigerant passes through the expansion valve, it cools and passes through the evaporator to extract heat therefrom for cooling associated goods. Typically, each evaporator receives a flow of liquid refrigerant from a common refrigeration equipment. The refrigerant output from each evaporator is supplied to the input of a common compressor. A common condenser is connected downstream from the compressor to cool the heated compressed refrigerant from the compressor. The cooled, liquid refrigerant is then supplied back to the evaporators.
For realizing a refrigeration system serving different temperature levels, the following common techniques are applied:

In a first common approach, separate parallel compressor systems having their separate tube circuits and separate central compressor engines are installed for serving a respective temperature level. Each separate parallel system comprises a separate compressor, condenser, and control system. For this reason, such installation is rather expensive as to the required capital expenditure of the equipment.

In a second common approach, a refrigeration system comprises a single compressor and condenser for supplying multiple evaporators functioning independently of one another. Here, the basic principle is that one compressor pumps the low pressure refrigerant in a common suction header from the evaporators into a common condenser. The evaporators are supplied from the common supply of liquid refrigerant from the condenser. With such single compressor system supplying multiple evaporators, one problem is that the compressor suction pressure in the common suction header must be lower than the pressure in the lowest pressure, coldest evaporator connected to the system. One effect is that the refrigerant discharge from the higher pressure, warmer evaporator must be regulated by a suction pressure regulator to accomplish a pressure reduction. The pumping capacity of the system would have to be adapted to the pressure in the common discharge header to serve the lowest pressure, coldest evaporator connected to the system. As a result of the pressure reduction regulators required, the energy consumption of such system is rather high.

In a third common approach, for evaporators serving a higher cooling temperature the respective heat transfer area may be reduced. Again, such installation is rather energy-consuming.

It is therefore an object of the present invention to provide a more efficient refrigeration system which is capable of serving multiple refrigeration consumer devices at two or more operating temperature levels.
This object is solved by a refrigeration system according to the features of present claim 1.

A refrigeration system according to the invention comprises at least a first refrigeration consumer device and at least a second refrigeration consumer device, and comprises a first compressor device and a second compressor device each for compressing refrigerant received from one of the refrigeration consumer devices. The first refrigeration consumer device is connected to a first suction header for receiving refrigerant from the first refrigeration consumer device and transferring it to the first compressor device. The second refrigeration consumer device is connected to a second suction header for receiving refrigerant from the second refrigeration consumer device and transferring it to the second compressor device. The second suction header is connected to the first suction header via the second compressor device. The first suction header operates at a first pressure and the second suction header operates at a second pressure, wherein the first pressure is higher than the second pressure. The first compressor device is adapted to generate the first pressure and the second compressor device is adapted to generate the difference between the first and the second pressure.

The refrigeration system according to the invention provides for the advantage that no separate plural refrigeration systems are required in order to serve multiple refrigeration consumer devices at two or more temperature levels. Rather, the refrigeration system according to the invention requires a first and a second compressor device, wherein the first compressor device may be a single large compressor system or a multi-compressor pack having smaller compressors connected in parallel, which are used in lieu of one large compressor. The second compressor device may be a smaller single compressor system, e.g. of the type of an oil-free linear compressor. According to the respective practical requirements, only small differences between the first and the second pressure may occur so that oil—lubricated compressors cannot be used as a matter of insufficient discharge and oil temperatures, if the difference between the temperature and pressure levels was too small. Thus, potential
damages will be caused if oil-lubricated compressors were used as a second compressor device.

A great benefit of the invention is that the pumping capacity of the first compressor device may be reduced to serve the higher first pressure in the first suction header, whereas the second compressor device generates the difference between the first and the second pressure in order to serve the lower temperature level of the second refrigeration consumer device. Here, no pressure reduction according to a pressure regulator valve occurs for reducing the refrigerant discharge from the higher pressure, warmer evaporator to enter the common suction header before it is again pumped into the high pressure side of the refrigeration system. Thus, according to the invention, the efficiency of the refrigeration system is increased.

According to an embodiment of the invention, multiple second refrigeration consumer devices are connected to the second suction header which is a common suction header for the second refrigeration consumer devices. According to this embodiment, the multiple second refrigeration consumer devices operate at a common second temperature level which may be different from the first temperature level of the first refrigeration consumer device.

According to another embodiment of the invention, the refrigeration system comprises a third refrigeration consumer device and a third compressor device for compressing refrigerant received from the third refrigeration consumer device. The third refrigeration consumer device is connected to a third suction header for receiving refrigerant from the third refrigeration consumer device and transferring it to the third compressor device. The third suction header is connected to the first suction header via the third compressor device and operates at a third pressure, wherein the first pressure of the first suction header is higher than the third pressure of the third suction header. In this embodiment, the third compressor device is adapted to generate the difference between the first and the third pressure. As a result, a refrigeration system is provided which is capable of serving three different temperature levels for each respective one of the three different refrigeration consumer devices. Due to the interconnec-
tion of the respective first to third compressor devices more than two temperature levels can be realized, wherein each consumer device of the low level (second and third consumer devices) can be controlled individually. Here, the third pressure in the third suction header may be different from the second pressure in the second suction header for providing different temperature levels.

According to an embodiment of the invention, the second compressor device or at least one of the second and third compressor devices comprises a non-oil-lubricated compressor. For example the second compressor device or at least one of the second and third compressor devices comprises a linear compressor. Such linear compressor is constructed to have a frictionless bearing so that oil for lubricating the bearing is not required. A linear compressor provides for the benefit of a continuous power control capability, which may be realized by an electronic stroke control of the piston. According to these benefits the linear compressor is capable of generating also rather low pressure differences between the first and the second or third suction headers.

According to a further embodiment of the invention, the linear compressor is a linear compressor of a modified design which is, in a secondary function, capable of enabling a flow through the compressor with low pressure drop. Such compressor design provides advantages in a defrost operation of the refrigeration system. For example, in a defrost operation the linear compressor is operated in a secondary operation mode in which a fluid flow through the compressor is enabled with low pressure drop, in particular when the piston is at its end position (open position).

In another embodiment of the invention the linear compressor comprises a by-pass line which is capable of enabling a flow with low pressure drop. Such by-pass line may be used in connection with a linear compressor of a standard design for enabling a defrost operation of the refrigeration system. In such defrost mode the linear compressor is switched in off-condition and the refrigerant required for defrosting the evaporator of the corresponding refrigeration
consumer device reaches the respective evaporator through the respective by-pass line.

According to another embodiment of the present invention, the second compressor device or at least one of the second and third compressor devices comprises a cross-head compressor. Such cross-head compressor is a further type of a non-oil-lubricated compressor (oil-free compressor) which is, however, more costly than a linear compressor as described above.

As concerns the first compressor device, according to an embodiment of the invention, the first compressor device may be constructed as a typical piston or reciprocating compressor, which is oil-lubricated, for adapting the first compressor device to high capacity demands. According to an embodiment the first compressor device may comprise a multi-compressor design having multiple compressors connected in parallel, wherein such multi-compressor is preferably speed-controlled. Such compressor design is preferred with respect to the continuously controlled linear compressor of the second compressor device interacting with the first compressor device.

Further advantageous features, aspects, and details of the invention are evident from the dependent claims.

The invention, its advantageous features, and benefits will be better understood by reference to the following description of embodiments of the invention, taken in conjunction with the accompanying drawings, in which:

Fig. 1 schematically shows a first embodiment of a refrigeration system according to the invention;

Fig. 2 schematically shows a second embodiment of a refrigeration system according to the invention;

Fig. 3 schematically shows multiple refrigeration consumer devices according to Fig. 1 in greater detail.
The present invention will now be described with reference to the accompanying drawings in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein.

According to Fig. 1, a first embodiment of a refrigeration system according to the invention is shown, which may be applied, for example, as a supermarket refrigeration system including a plurality of refrigeration consumer devices such as refrigeration cases or cabinets. The refrigeration system 1 illustratively includes multiple refrigeration consumer devices 11-14, commonly referred to as 10, and multiple refrigeration consumer devices 21-24, commonly referred to as 20. However, according to another embodiment of the invention, the refrigeration system 1 may include only a first refrigeration consumer device such as 11, and a second refrigeration consumer device such as 21. In the present embodiment of Fig. 1, the consumer devices 10 and 20 shall operate at different temperatures for cooling different goods, e.g. diary products in 10 and meat in 20, wherein meat requires a lower cooling temperature than diary products. Thus, the cooling temperature in consumer devices 10 (e.g. -6°C) is higher than the cooling temperature (e.g. -13°C) in consumer devices 20.

The refrigeration consumer devices 10 are connected to a first suction header 31 for receiving refrigerant 34 from the refrigeration consumer devices 10 and transferring it to the first compressor device 32 for compressing the received refrigerant. The refrigeration consumer devices 20 are connected to a second suction header 41 for receiving refrigerant 44 from the refrigeration consumer devices 20 and transferring it to a second compressor device 42 for compressing the received refrigerant. The second suction header 41 is connected to the first suction header 31 via the second compressor device 42.

The saturation temperature of the refrigerant is a direct function of pressure within the evaporator. In effect, the pressure at which suction headers 31 and 41 operate determines the temperature at which the respective evaporators of the consumer devices 10 and 20 will operate. In Fig. 1, refrigeration consumer
devices 20 operate at the lower temperature, hence the pressure of suction header 41 is set lower than the pressure in suction header 31. Thus, the first suction header 31 operates at a first pressure $p_1$ and the second suction header 41 operates at a second pressure $p_2$, the first pressure $p_1$ being higher than the second pressure $p_2$. In other words, the refrigerant 34 in suction header 31 comprises a first pressure $p_1$ which is higher than pressure $p_2$ of refrigerant 44 in suction header 41.

A common condenser device (not shown), generally referred to as 35, is connected downstream from the first compressor device 32. This common condenser is for cooling the heated compressed refrigerant from the compressor 32. A common high pressure receiver (not shown) is connected downstream from the condenser to collect liquid refrigerant, which is then supplied back to the respective refrigeration consumer devices 10 and 20.

In Fig. 3 multiple refrigeration consumer devices according to Fig. 1 are shown in greater detail. According to Fig. 3, refrigeration consumer devices 11, 12, and 13 are shown, which are connected to the first suction header 31 in a parallel manner. Each of the refrigeration consumer devices 11-13 comprises a respective expansion valve 112, 122, 132 connected to a respective input line 113, 123, 133. Respective evaporators 111, 121, and 131 of refrigeration consumer devices 11-13 are connected to respective output lines 114, 124, and 134 and expansion valves 112, 122, 132. These output lines are connected to common suction header 31 for transferring refrigerant to the common compressor device 32. As the liquid refrigerant passes through the respective expansion valve 112, 122, and 132, it cools and passes through the respective evaporator 111, 121, 131 to extract heat therefrom. For example, fans blow air through the evaporators to extract heat from the air so that a flow of cool air is generated and directed toward the goods to be kept cool. The circuit shown in Fig. 3 is analogously applied to refrigeration consumer devices 20 of Fig. 1, and to refrigeration consumer devices 50 and 60 as shown in Fig. 2.

According to Fig. 1, the first compressor device 32 is adapted to generate the pressure $p_1$ in the first suction header 31, whereas the second compressor de—
vice 42 is adapted to generate the difference between pressures \( p_1 \) and \( p_2 \). Thus, the first compressor 32 is sized to meet the pumping pressure in suction header 31, whereas the second compressor 42 is sized to meet the pressure difference \( p_1 - p_2 \) between the first suction header 31 and the second suction header 41. Therefore, a refrigeration system 1 is provided, which is more efficient as compared to common refrigeration systems, since the respective compressor devices may be designed to meet the individual demands within the refrigeration system. In particular, the first compressor device 32, which may be a multi-compressor pack, is designed to meet the requirements of the high-level temperature consumers, whereas any further low-temperature consumer is provided with a compressor of its own so that no pressure regulation valves are needed for coupling the different systems. If the low-temperature consumers, like consumers 20 in Fig. 1, were not in operation, the corresponding compressor device, such as 42 in Fig. 1, is switched in off-condition to save energy.

According to Fig. 2, a second embodiment of a refrigeration system 2 according to the invention is illustrated. Similar to Fig. 1, first refrigeration consumer devices 51-54, commonly referred to as 50, are connected to a first suction header 71 for receiving refrigerant and transferring it to a first compressor device 72. Like consumer devices 10 the refrigeration consumer devices 50 require a higher cooling temperature than refrigeration consumer devices 61-64, commonly referred to as 60. Each of the refrigeration consumer devices 61-64 is connected to a respective compressor device 82a-82d via respective suction headers 81a-81d. The suction headers 81a-81d are for receiving a refrigerant from the respective refrigeration consumer device and for transferring it to the respective compressor device. The suction headers 81a-81d are connected to the first suction header 71 via the respective compressor device 82a-82d. For example, suction header 81a contains refrigerant 84a at pressure \( p_2 \), suction header 81b contains refrigerant 84b at pressure \( p_3 \), suction header 81c contains refrigerant 84c at pressure \( p_4 \), and suction header 81d contains refrigerant 84d at pressure \( p_5 \). The pressures \( p_2-p_5 \) are different from pressure \( p_1 \) of refrigerant 74 in the first suction header 71. Also the pressures \( p_2-p_5 \) may be different.
from each other so as to serve different temperature levels of the consumer
devices 61-64.

A common condenser (not shown), generally referred to as 75, is connected
downstream from the compressor 72, which is connected to suction header 71
for cooling the heated compressed refrigerant from the compressor.

According to the embodiment of Fig. 2, the consumer devices 61-64 of the
low—temperature level are separated from each other so that individual cooling
may be provided to the respective consumer devices. Each consumer device
61-64 is provided with a separate compressor device 82a-82d, which may be
a linear compressor type similar to compressor device 42 according to Fig. 1.
As a result, each consumer device 61—64 can be controlled individually. Here,
the respective compressor devices 82a-82d are adapted to generate the dif-
ference between the respective lower pressure p2-p5 and the higher pressure
p1 in suction header 71.

Due to the above—mentioned advantages of a linear compressor design the
compressor device 42 of Fig. 1 and the compressor devices 82a-82d, or at
least one of them, comprise a non-oil-lubricated compressor such as a linear
compressor. Here, a linear compressor of a standard design may be used, or a
linear compressor of modified design, which is in a secondary function capable
of enabling a flow through the compressor with low pressure drop. Such com-
pressor design is advantageous with respect to defrost operation of the refrig-
eroation system. In such operation the modified compressor or its respective
piston is brought at its end position (open position) in which a fluid flow
through the compressor with low pressure drop is enabled. The warm flow of
refrigerant flows through the opened linear compressor to the evaporator of the
respective consumer device for defrosting the same. According to another
embodiment, as exemplary shown in Fig. 1, the compressor device 42 is a lin-
ear compressor of standard design comprising a bypass line 43 which is capa-
ble of enabling a fluid flow with low pressure drop, in particular for defrost op-
eration.
A further benefit of the invention is that the linear compressor, e.g. compressor device 42 of Fig. 1, is capable of functioning as a circulation pump in a circulation pump operation in which the suction headers serve as return flow lines. In a circulation pump operation the suction headers as shown in Figures 1 and 2 may also serve as return flow lines, on condition that the circulation pump factor does not exceed 1.0 so as to avoid liquid slugging within the compressor.

The circulation pump factor is defined as

mass flow (real) / mass flow with complete evaporation.

In such circulation pump operation the refrigerant is operated in fluid condition near its vapor saturation temperature with reduced cooling power.

Moreover, a linear compressor of a modified design or a linear compressor of standard design with the bypass line provide the advantage that they can operate (when in an open position) from a low first temperature level to a lower second temperature level before being connected to the remainder of the refrigeration system. This operation is especially required for the defrost operation where the compressors contain liquid fluid rather than gaseous refrigerant. In this condition, the first compressor, such as 32 of Fig. 1, when being operated after such defrost operation, operates from the current temperature level to reach the first temperature level at pressure p1, whereas the linear compressor, such as 42 in Fig. 1, operates from the first temperature level to reach the second temperature level associated with pressure p2 before being connected to suction header 31. This reduces the motor size required for compressor 42.
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Claims

1. A refrigeration system, comprising
   - at least a first refrigeration consumer device (11, 51) and at least a second
     refrigeration consumer device (21, 61),
   - a first compressor device (32, 72) and a second compressor device (42, 82a)
     each for compressing refrigerant received from one of the refrigeration con-
     sumer devices,
   - the first refrigeration consumer device (11, 51) connected to a first suction
     header (31, 71) for receiving refrigerant from the first refrigeration consumer
     device and transferring it to the first compressor device (32, 72),
   - the second refrigeration consumer device (21, 61) connected to a second
     suction header (41, 81a) for receiving refrigerant from the second refrigeration
     consumer device and transferring it to the second compressor device (42, 82a),
   - wherein the second suction header (41, 81a) is connected to the first suction
     header (31, 71) via the second compressor device (42, 82a),
   - wherein the first suction header (31, 71) operating at a first pressure (p1) and
     the second suction header (41, 81a) operating at a second pressure (p2), the
     first pressure being higher than the second pressure,
   - wherein the first compressor device (32, 72) is adapted to generate the first
     pressure (p1) and the second compressor device (42, 82a) is adapted to gener¬
     ate the difference between the first and the second pressure (p1, p2).

2. The refrigeration system according to claim 1, further comprising
   multiple second refrigeration consumer devices (21 — 24) connected to the
   second suction header (41) which is a common suction header for the second
   refrigeration consumer devices.

3. The refrigeration system according to claim 1, further comprising
   - a third refrigeration consumer device (62),
   - a third compressor device (82b) for compressing refrigerant received from
     the third refrigeration consumer device (62),
- the third refrigeration consumer device (62) connected to a third suction header (81b) for receiving refrigerant from the third refrigeration consumer device and transferring it to the third compressor device (82b),
- wherein the third suction header (81b) is connected to the first suction header (71) via the third compressor device (82b),
- wherein the third suction header (81b) operating at a third pressure (p3), the first pressure (p1) being higher than the third pressure (p3),
- wherein the third compressor device (82b) is adapted to generate the difference between the first and the third pressure (p1, p3).

4. The refrigeration system according to claim 3, wherein the third pressure (p3) is different from the second pressure (p2).

5. The refrigeration system according to any one of claims 1 to 4, wherein the second compressor device (42) or at least one of the second and third compressor devices (82a, 82b) comprises a non-oil— lubricated compressor.

6. The refrigeration system according to any one of claims 1 to 5, wherein the second compressor device (42) or at least one of the second and third compressor devices (82a, 82b) comprises a linear compressor.

7. The refrigeration system according to claim 6, wherein the linear compressor (42, 82a, 82b) is a linear compressor of modified design which is, in a secondary function, capable to enable a flow through the compressor with low pressure drop.

8. The refrigeration system according to claim 6 or 7, wherein the linear compressor (42) comprises a bypass line (43) which is capable to enable a flow with low pressure drop.

9. The refrigeration system according to any one of claims 1 to 8, wherein the second compressor device (42) or at least one of the second and third compressor devices (82a, 82b) comprises a cross—head compressor.
10. The refrigeration system according to any one of claims 1 to 9, wherein the first compressor device (32, 72) comprises a multi-compressor design, in particular a speed-controlled multi-compressor design.

11. The refrigeration system according to any one of claims 1 to 10, wherein the first compressor device (32, 72) comprises an oil-lubricated piston compressor.

12. The refrigeration system according to any one of claims 1 to 11, wherein the second compressor device (42, 82a) is adapted to function as circulation pump in a circulation pump operation in which the suction headers (31, 71, 41, 81a) serve as return flow lines.

13. The refrigeration system according to any one of claims 1 to 12, further comprising multiple first refrigeration consumer devices (11 - 14, 51 - 54) connected to the first suction header (31, 71) which is a common suction header for the first refrigeration consumer devices.

14. The refrigeration system according to any one of claims 1 to 13, comprising a common condenser device (35, 75) connected downstream from the first compressor device (32, 72).
Fig. 3
**A. CLASSIFICATION OF SUBJECT MATTER**

INV. F25B1/10 F25B1/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. RELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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**Date of the actual completion of the international search**

21 April 2006

**Date of mailing of the international search report**

02/05/2006

Name and mailing address of the ISA/Authorized officer

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De Graaf, J. D.
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