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(54) **Fridge and freezer unit, method for controlling a compressor in a fridge and freezer unit and control circuit for such a compressor**

(57) A fridge and freezer unit (1) is described which comprises a freezing chamber (2) and a refrigeration chamber (3) and a cooling system with a variable-speed compressor (6) which is connected with a cooling circuit which has a cooling surface (11,12) in each storage chamber. In order to have an individual energy economic cooling which is in balance depending on the cooling demand which exists in the refrigeration chamber (3) and the freezing chamber (2), a temperature meter is arranged in the refrigeration chamber which is used to turn on and off the variable-speed compressor (6) and a temperature meter in the freezing chamber (2) which is intended for regulating the number of revolutions for the compressor (6).

With this construction it is possible to regulate the temperature balance of the cooling surfaces (11,12), and accordingly, the cooling effect in each of the chambers (2,3).

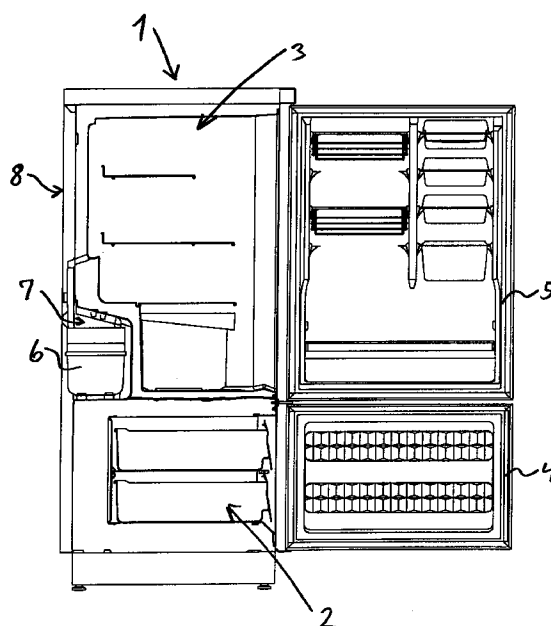


FIG. 1

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Description

The present invention relates to a fridge and freezer unit comprising a refrigeration chamber, a freezing chamber, a refrigeration system having a variable-speed compressor and a cooling circuit having a cooling surface in each of the chambers and temperature measuring means for use in controlling the compressor. Moreover, the invention relates to the method for controlling a compressor in a fridge and freezer unit comprising a refrigeration chamber, a freezing chamber, a refrigeration system having a variable-speed compressor and a cooling circuit having a cooling surface in each of the chambers. Moreover, the invention relates to the control circuit for a compressor in a fridge and freezer unit comprising a refrigeration chamber, a freezing chamber, a refrigeration system having a variable-speed compressor and a cooling circuit having a cooling surface in each of the chambers.

It is desirable to control the temperature in the refrigeration chamber and the freezing chamber in a fridge and freezer unit so that it is possible to obtain a desired temperature independent of the temperature in the other chamber. Thus in the fridge and freezer unit it is desirable to maintain a temperature of approximately 5° C in the refrigeration chamber and a temperature of -18°C in the freezing chamber.

It is known to provide a fridge and freezer unit with two separate refrigeration systems, each comprising a compressor and a cooling circuit and a control device which is typically a thermostat. A thermostat in each of the chambers will provide for start and stop of the refrigeration system based on pre-determined parameters so that a desired temperature is maintained within an interval in the actual storage chamber.

These prior art fridge and freezer unit are disadvantageous due to the use of two refrigeration systems which are bulky and expensive. These refrigeration systems will have a very poor energy economy due to the use of two separate cooling circuits comprising compressor, condensator and evaporator.

Other fridge and freezer units are known in which the control of the refrigeration system is effected by providing a magnetic valve in the refrigeration system. The magnetic valve makes it possible for refrigerating medium only to run to the storage chamber, the refrigeration chamber or the freezing chamber in which refrigeration is necessary within the actual time interval. This construction is disadvantageous as it is vulnerable to failure in the valve system. Moreover, it is difficult to obtain a good and secure function or a good energy economy for the system.

In recent years new compressor types are produced in which the refrigeration output may be controlled. Typically, this is effected by varying the number of revolutions of the compressor. Hereby it is possible to equalise fluctuations in the temperature interval which occurs between start and stop of the compressor. Instead a combined controlling is effected so that the output of the compressor is changed depending on the refrigeration demand and in such a way that the compressor only is stopped if it is not possible to reduce its cooling effect further. An example of such compressor of said type is described in PCT/KR93/00034. The fridge and freezer unit and the control circuit described in said publication would not make it possible to effect a precise and energy-economic individual control of the cooling effect in the refrigeration chamber and the freezing chamber.

It is the object of the present invention to provide a system of the type mentioned by way of introduction, i.e. a fridge unit, a method and a control circuit which provide for a secure energy-economic controlling of the temperature in a freezing chamber and a refrigeration chamber so that it is possible to maintain the temperature level in said chambers at desired levels.

According to the present invention this is obtained with a fridge and freezer unit which is characterised in that said temperature measuring means comprise a temperature meter in the refrigeration chamber and a temperature meter in the freezing chamber, and that these temperature meters form part of a control circuit made to stop and start the compressor and to control its number of revolutions, respectively. The method according to the invention is characterised in that the compressor is stopped and started following a signal from a temperature meter in one of the chambers, preferably the refrigeration chamber and that the number of revolutions of the compressor is determined following a signal from a temperature meter in the other chamber, preferably the freezing chamber. The control circuit which is used is characterised in that it comprises a temperature meter to be arranged in one of the chambers, preferably the refrigeration chamber and which is made to start and stop the motor of compressor and a temperature meter to be arranged in the other chamber, preferably the freezing chamber and which is made for controlling the revolutions of the motor.

As the temperature meter, preferably a thermostat, in the refrigeration starts and stops the compressor according to demand while another temperature meter, preferably a thermostat in the freezing chamber, controls the refrigeration output from the compressor through control of the number of revolutions, it becomes possible to control the temperature balance in the two storage chambers of the fridge and freezer unit by controlling the temperature balance of the cooling surfaces. By controlling the temperature balance of the cooling surfaces it is possible to maintain the temperature in the refrigeration chamber and the freezing chamber at the desired level independent of the ambient temperature.

Thus there are two regulation mechanisms which together provide the signals for the control of the compressor which is needed in order for the compressor to be set at a suitable number of revolutions and thereby a suitable output dependent of the actual load situation.

As the cooling surfaces for the refrigeration chamber and the freezing chamber are connected with each other then

both cooling surfaces will be active simultaneously. Accordingly, a difference in the cooling effect in the refrigeration chamber and the freezing chamber may only be obtained if the temperature difference between a cooling surface and goods in the refrigeration- and/or the freezing chamber is amended.

If it is assumed that a situation exists where the number of revolutions for the compressor exactly gives a cooling effect which corresponds to the effect which is supplied due to the temperature difference between the cooling surface and goods in the refrigeration chamber which is 5°C. Moreover, it is supposed that the temperature of the cooling surface is exactly -18°C. In this situation the temperature difference in the refrigeration chamber will be: 5°C - (-18°C) = 23°C and the temperature difference in the freezing chamber will be: -18°C - (-18°C) = 0°C.

As the effect transfer may be decided from equation: effect = surface of cooling surface x surface coefficient x temperature difference then this situation means that there will be no effect for cooling in the freezing chamber. If the number of revolutions for the compressor is slightly increased then this would provide a more cold cooling surface and a cooling in the freezing chamber will also occur. It is the relative difference between goods and cooling surface in the two chambers which gives the desired balance, thereby it is possible to obtain the desired temperatures of e.g. +5°C and -18°C in the refrigeration chamber and the freezing chamber, respectively.

In the situation where the number of revolutions of the compressor just provided the cooling effect corresponding to the supplied effect, the temperature difference of 23°C caused a great effect in the refrigeration chamber whereas the temperature difference in the freezing chamber of 0°C would not cause any effect. In the changed situation with increased number of revolutions the temperature of the cooling surfaces is lowered e.g. -20°C. Now there will exist a temperature difference of 25°C in the refrigeration chamber which causes a slightly greater effect than the effect in the former situation. In the freezing chamber there will now exist a temperature difference of 2°C which means that there will also be supplied an effect to the freezing chamber.

In the new situation with an increased number of revolutions the compressor will run in shorter intervals (decided by the ratio 23°C/25°C) in order still to maintain 5°C in the refrigeration chamber in which there will be no amendments in the cooling demand of the goods. However, now the effect will be obtained that a simultaneous cooling in the freezing chamber occurs, seeing that a temperature difference is obtained between the cooling surface and the goods in the freezing chamber. The situation with the shorter intervals where the compressor is running should be considered from an ordinary operation situation in which the compressor will be designed to run a certain part of the time, e.g. 50%.

The net result which occurs in the new situation will be a more cold freezing chamber and a refrigeration chamber having an unchanged temperature. In other words a higher number of revolutions for the compressor will change the balance so that relatively more cooling effect is added to the freezing chamber than the cooling effect added to the refrigeration chamber. Vice-versa a lower number of revolutions will change the balance in such a way that relatively less cooling effect is added to the freezing chamber than the cooling effect added to the refrigeration chamber.

This principle of regulation means that the conditions in one of the chambers, preferably the refrigeration chamber, determines when the compressor shall run in order to maintain the temperature in this chamber whereas the conditions in the other chamber, preferably the freezing chamber, determines the magnitude of the effect which the compressor shall supply in order to maintain the desired temperature conditions in the other chamber.

In principle it is possible to freely choose whether the refrigeration chamber or the freezing chamber shall determine the on/off situation or the number of revolutions of the compressor. However, due to the longer time intervals which exist in a freezing chamber it will be normal to have the temperature conditions in the refrigeration chamber to determine the off/off-condition for the compressor.

In order to support the understanding of the advantages an example will follow in order to illustrate the effect of the control according to the invention.

In an imaginary example it is supposed that the system has been designed so that the desired temperatures are maintained at an ambient temperature of 25°C and with the temperature of the cooling surfaces being -22°C in the interval in which the refrigeration system is active. A running percentage is defined as the ratio between the interval in which the refrigeration compressor is active and the total time. This running percentage is supposed to constitute 33% in this example. Seeing that a fridge and freezer is used in which a temperature of 5°C is desired in the refrigeration chamber and a temperature of -18°C in the freezing chamber then temperature differences are obtained as stated in table 1 below. The relative cooling effect in the refrigeration chamber and the freezing chamber is obtained by multiplying with the running percentage which will give the values stated in table 1 below.

Table 1

	Temperature difference	running percentage
Refrigeration chamber	5 - (-22)°C = 27°C	27 x 33% = 8.9
Freezing chamber	(-18) - (-22)°C = 4°C	4 x 33% = 1.32

Table 1 (continued)

	Temperature difference	running percentage
Ratio refrigeration chamber/freezing chamber		$8.9/1.32 = 6.75$

The relative cooling effect which occurs in the two chambers shall be in balance with the cooling demand in the two chambers. In the imaginary example it is supposed that this is the case.

If a change now occurs in the cooling demand which e.g. may happen if the ambient temperature is changed, then the balance will no longer be maintained and the temperatures in the refrigeration chamber and the freezing chamber will differ from the desired temperatures. In the prior art system one would normally control with regard to the temperature in the refrigeration chamber and then the temperature in the freezing chamber will be adjusted accordingly, then only one cooling circuit is used having cooling surfaces in each of the chambers. The balance which occurs to the surroundings will then be as stated in table 2 below.

Table 2

	T (surroundings 25°C)	T (surroundings 15°C)
Refrigeration chamber	$25-5^{\circ}\text{C} = 20^{\circ}\text{C}$	$15-5^{\circ} = 10^{\circ}\text{C}$
Freezing chamber	$25-(-18)^{\circ}\text{C} = 43^{\circ}\text{C}$	$15-(-18)^{\circ}\text{C} = 33^{\circ}\text{C}$
Ratio refrigeration chamber/freezing chamber	$43/20 = 2.15$	$33/10 = 3.33$

The increasing ratio between the temperature differences for the freezing chamber and the refrigeration chamber means that the freezing chamber will have too small cooling to maintain the desired temperature of -18°C . In a particularly extreme situation where the ambient temperature will drop to 5°C there will be no need for cooling in the refrigeration chamber whereas a large cooling demand will still exist in the freezing chamber. Thus a cooling demand will exist in the freezing chamber which is expressed by the temperature difference: $5-(-18)^{\circ}\text{C} = 23^{\circ}\text{C}$. If one solely controls according to the temperature in the refrigeration chamber then one will see that the compressor is stopped and the goods which are stored in the freezing chamber will be spoiled.

Earlier it has been suggested to use a so-called "cottage safety" in the form of an energy creator, preferably an electrical bulb which is arranged in the refrigeration chamber. Hereby an artificial influence is established on the temperature meter in the refrigeration chamber so that the compressor will always be running. However, such a known solution is disadvantageous according to an energy economic point of view.

In a fridge and freezing unit according to the invention it will, according to the method and with the control circuit, be possible to control the relative cooling effect in the two chambers. Thus it will be possible that the earlier ratio of 6.75 between the refrigeration chamber and the freezing chamber may be influenced if the temperature of the cooling surfaces is changed. It is possible to change the temperature of the cooling surfaces in order to increase or decrease the number of revolutions for the motor of the compressor and thereby increase or decrease the output of the compressor.

Following the above example it is presumed that the temperature of the cooling surfaces is lowered to -26°C . This means that the cooling effect is increased and then temperature differences and running percentages will occur as stated in table 3 below.

Table 3

	Temperature differences	Running percentage
Refrigeration chamber	$5-(-26)^{\circ}\text{C} = 31^{\circ}\text{C}$	$31 \times 33\% = 10.23$
Freezing chamber	$(-18)-(-26)^{\circ}\text{C} = 8^{\circ}\text{C}$	$8 \times 33\% = 2.64$
Ratio refrigeration chamber/freezing chamber		$10.23/2.64 = 3.88$

As it occurs it has been possible to shift the relative balance between the cooling effect of the refrigeration and freezing chamber. In the illustrated example the relative balance is changed with a ratio of: $6.75/3.88 = 1.74$. This may also be expressed as the effect which is obtained in the percentage increase of the cooling effect in the freezing chamber in relation to the refrigeration chamber. In the imaginary example the cooling effect in the freezing chamber is

increased by 74% in relation to the cooling effect in the refrigeration chamber.

It is preferred that the ratio between the relative cooling effects in the two chambers is regulated in order to be between 2 and 8 and preferably between 3 and 5.

In a similar way as illustrated in the above examples it is possible to shift the temperature balance in the opposite direction if this is desirable. Thus it will be possible to control the temperature in the two storage chambers independent of each other and simultaneously obviate the disadvantages which were connected with the prior art embodiments. Thus with the system according to the present invention it is possible to have an energy economic cooling.

Specific calculation examples will not be given for the temperature interval for ambient temperature and cooling surfaces which may be used in connection with the system according to the present invention. However, the system may work satisfactorily at ambient temperature being minus degrees and at very high ambient temperatures. Thus it will be possible for the system to work with ambient temperatures within an interval from -18°C to any high temperature which may be handled with a given capacity of the chosen compressor. The temperature of the cooling surfaces of the cooling circuit may be chosen arbitrarily low dependent of the capacity of the compressor. Thus it is possible to make use of any temperature interval from -18°C or below.

A description will not be given of the actual electronic control which is used, seeing that a person skilled in the art may be able to embody such control electronics in the light of the above description of the invention.

The compressor which is used in the fridge and freezing unit may be any type in which the cooling effect may be controlled. However, from an energy economic point of view it is preferred to make use of a variable-speed compressor of the type having a permanent magnetic motor. The fridge and freezing unit will conveniently be provided with the refrigeration chamber arranged above the freezing chamber and with a compressor arranged in a recess in the back of the unit between the two chambers. Alternatively, the compressor may be arranged in the bottom of the fridge and freezing unit below the two chambers. Moreover, it is possible to arrange the refrigeration chamber below the freezing chamber.

The invention will now be explained in more detail with reference to the accompanying drawing, in which

- Fig. 1 illustrates a fridge and freezing unit according to the invention, partly in section and having open doors,
- Fig. 2 illustrates the unit according to Fig. 1 as seen from the backside,
- Fig. 3 shows a tube diaphragm illustrating the cooling circuit in the fridge and freezing unit illustrated in Figs. 1 and 2, and
- Fig. 4 shows a schematic view illustrating the construction of the control circuit.

Fig. 1 shows a fridge and freezing unit 1 comprising a freezing chamber 2 and a refrigeration chamber 3. The unit itself is illustrated partly in section as seen from the side. A door 4 is intended for closing the freezing chamber 2 and a door 5 is intended for closing the refrigeration chamber 3. The unit comprises a variable-speed compressor 6 which is arranged in a recess 7 at the back of the unit in a position between the freezing chamber 2 and the refrigeration chamber 3. The fridge and freezing unit comprises a cooling circuit which is illustrated in Fig. 3. The cooling circuit is connected with the variable-speed compressor 6 through conduit means 9 and comprises a condensator 10, a cooling surface 11 for the refrigeration chamber 3 in the form of an evaporator plate and a cooling surface 12 for the freezing chamber 2 in the form of an evaporator casing. Moreover, the cooling circuit comprises a drying filter 13.

The compressor 6 is connected with an electronic motor control 14 which through conduit means is connected with the temperature measuring means in the refrigeration chamber 3 and in the freezing chamber 2. The temperature meters are not illustrated, however, they will be known for a person skilled in the art. The temperature meter in refrigeration chamber 3 is intended for stopping and starting the motor of the compressor 6 and the temperature meter in the freezing chamber 2 is intended for regulating the number of revolutions for the motor of the compressor 6. The compressor motor is a permanent magnetic motor.

The unit illustrated functions in that the compressor 6 is stopped and started following the signal from the temperature meter in the refrigeration chamber 3 whereas the number of revolution for the motor of the compressor 6 is determined following a signal from the temperature meter in the freezing chamber 2.

By amending the number of revolutions it is possible to change the temperature of the cooling surfaces 11, 12 and hereby it is possible to bring the relative cooling effect in each of the chambers 2, 3 in balance with the actual cooling demand. In the freezing chamber 2 the ideal temperature desired is -18°C and in the refrigeration chamber 3 the ideal temperature desired is 5°C.

In fig. 4 a schematic diaphragm is illustrated which shows the construction of the control circuit for the compressor 6. The compressor 6 is via a shaft 15 connected with the motor 16. The motor 16 is connected with the motor control 14. The motor control 14 is connected with a temperature regulator 17. The compressor and the temperature regulators are connected with the fridge and freezing unit 1 itself. The fridge and freezing unit 1 receives an ambient influence 18 consisting of the ambient temperature, new goods being placed in or withdrawn from the refrigeration chamber and/or the freezing chamber, and opening of the doors 4, 5 to the refrigeration chamber and the freezing chamber, respectively.

The refrigeration system gives an influence 19 to the compressor in form of suction pressure, suction temperature and condensator pressure. The compressor gives an influence 20 to the refrigeration system in form of a mass flow of cooling medium and temperature of the cooling medium. The shaft 15 induces a number of revolutions 21. This number of revolution gives an influence 22,23 to the compressor 6 and to the motor 16. The motor 16 gives an influence 24 on the motor control through a metering of voltage and power consumption. The motor control gives an influence 25 on the motor 16 in form of a voltage determining the number of revolutions for the motor and/or the on-off condition of the motor. The motor control receives an influence 26 from the temperature regulator 17 in form of a desired number of revolution. The desired number of revolutions 26 is produced in the temperature regulator as a result of an input 27 for the desired temperature in a refrigeration department and an input 28 for a desired temperature in a freezing department. Moreover, the temperature regulator receives a signal 29 for the measured temperature in the freezing chamber and a signal 30 indicating the measured temperature in the refrigeration chamber.

Thus, the control circuit 14 will establish a control of the compressor, and accordingly, a control of the temperature of the cooling surfaces 11,12 in order to establish a balance between the temperature thereof and the actual cooling demand in refrigeration chamber 3 and freezing chamber 2.

Claims

1. Fridge and freezer unit (1) comprising a refrigeration chamber (3), a freezing chamber (2), a refrigeration system having a variable-speed compressor (6) and a cooling circuit having a cooling surface (11,12) in each of the chambers and temperature measuring means for use in controlling the compressor, **characterised** in that said temperature measuring means comprise a temperature meter in the refrigeration chamber (3) and a temperature meter in the freezing chamber (2), and that these temperature meters form part of a control circuit (4) made to stop and start the compressor (6) and to control its number of revolutions, respectively.
2. Fridge and freezer unit according to claim 1, **characterised** in that the temperature meter in the freezing chamber is a thermostat connected in series with the motor (16) of the compressor in order to stop and start it, and that the temperature meter in the freezing chamber is a thermostat connected with a control electronic (14) controlling the revolutions of the motor.
3. Fridge and freezer unit according to claim 2, **characterised** in that the compressor comprises a permanent magnet motor.
4. Fridge and freezer unit according to any of the preceding claims, **characterised** in that it is arranged with the refrigeration chamber (3) above the freezing chamber (2) and that the compressor (6) is situated in a recess (7) in the back of the unit between the two chambers.
5. Method for controlling a compressor in a fridge and freezer unit comprising a refrigeration chamber (3), a freezing chamber (2), a refrigeration system having a variable-speed compressor (6) and a cooling circuit having a cooling surface in each of the chambers, **characterised** in that the compressor (6) is stopped and started following a signal (27) from a temperature meter in one of the chambers, preferably the refrigeration chamber (3), and that the number of revolutions of the compressor is determined following a signal (28) from a temperature meter in the other chamber, preferably the freezing chamber (2).
6. Method according to claim 5, **characterised** in that the relative cooling effect in each of the chambers is brought into balance with the actual refrigeration demand in the two chambers by changing the temperatures of the cooling surfaces by changing the output of the compressor.
7. Method according to claims 5 or 6, **characterised** in that the ratio between the relative cooling effect in the two chambers is controlled in order to be between 2 and 8, preferably between 3 and 5.
8. Control circuit for a compressor in a fridge and freezer unit (1) comprising a refrigeration chamber (3), a freezing chamber (2), a refrigeration system having a variable-speed compressor (6) and a cooling circuit having a cooling surface in each of the chambers, **characterised** in that it comprises a temperature meter to be arranged in one of the chambers, preferably the refrigeration chamber (3), and which is made to start and stop the motor (16) of compressor and a temperature meter to be arranged in the other chamber, preferably the freezing chamber (2), and which is made for controlling the revolutions of the motor.

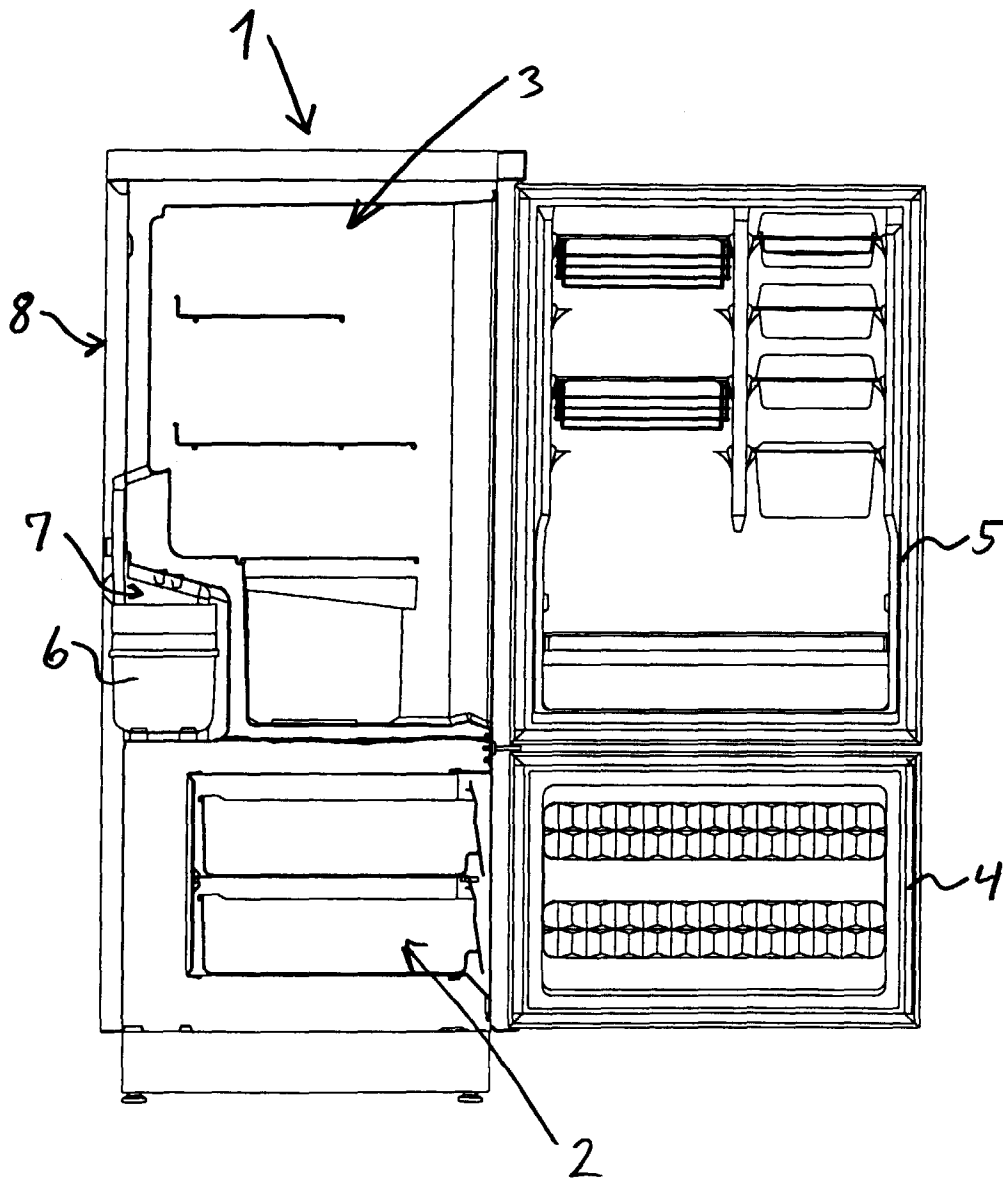


FIG. 1

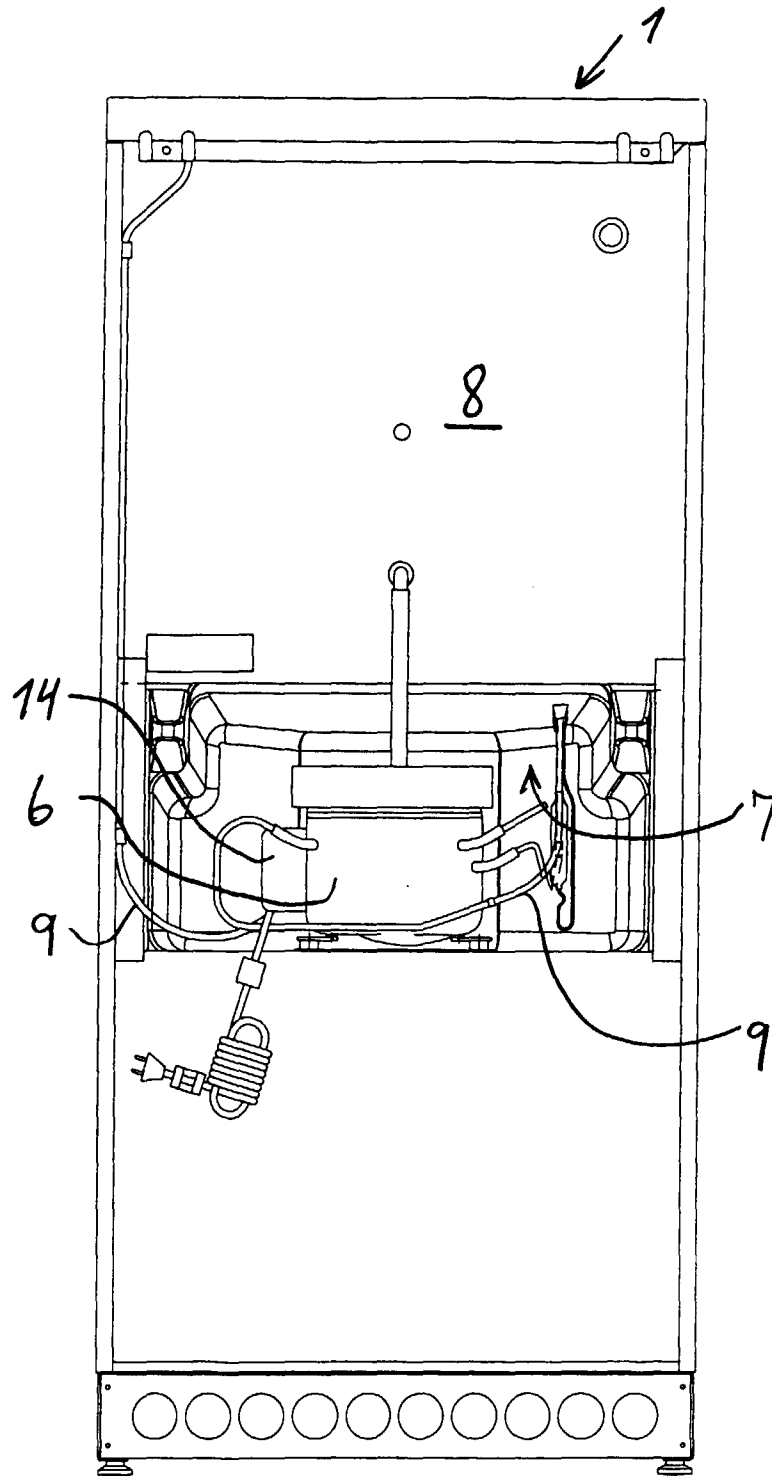
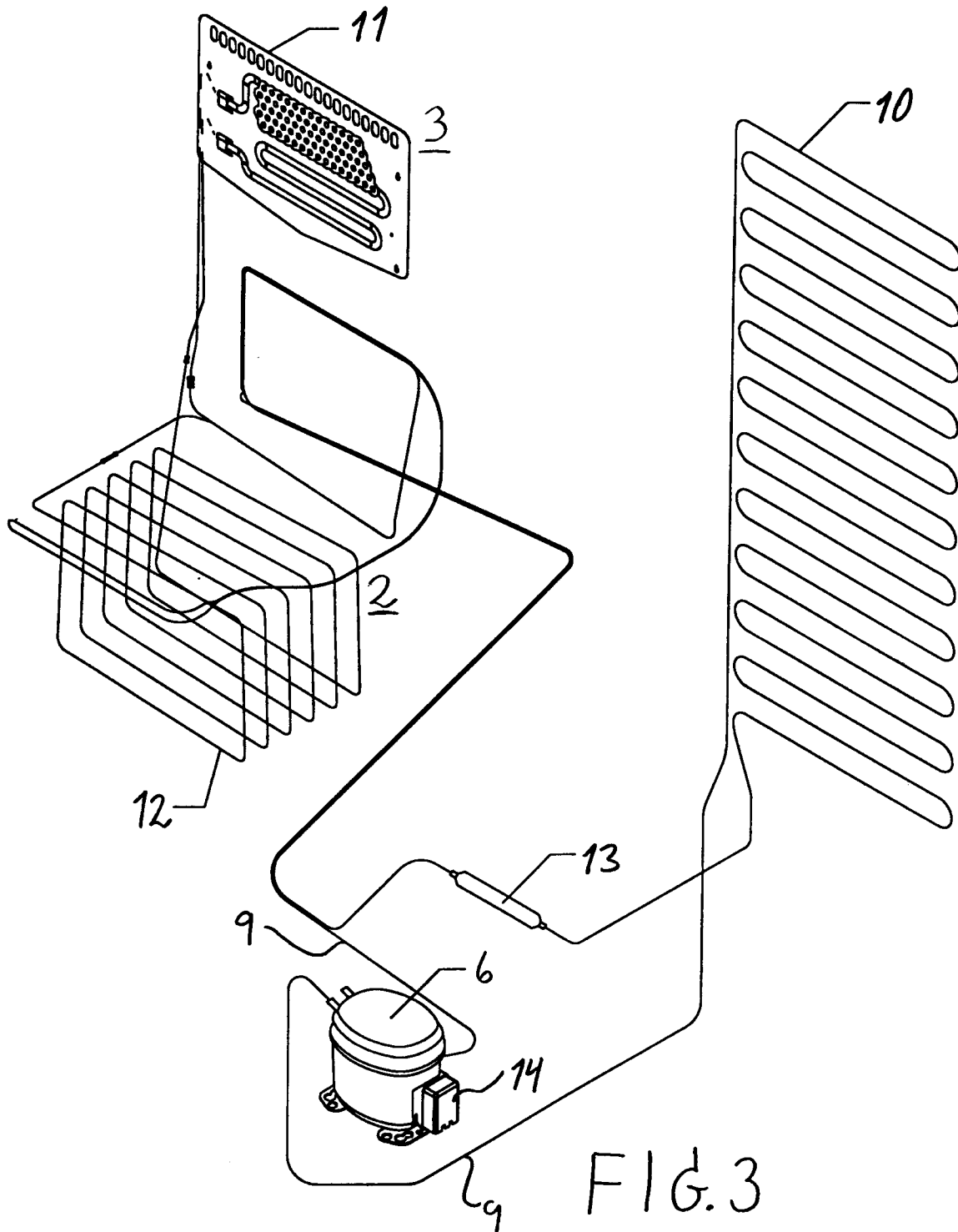


FIG. 2



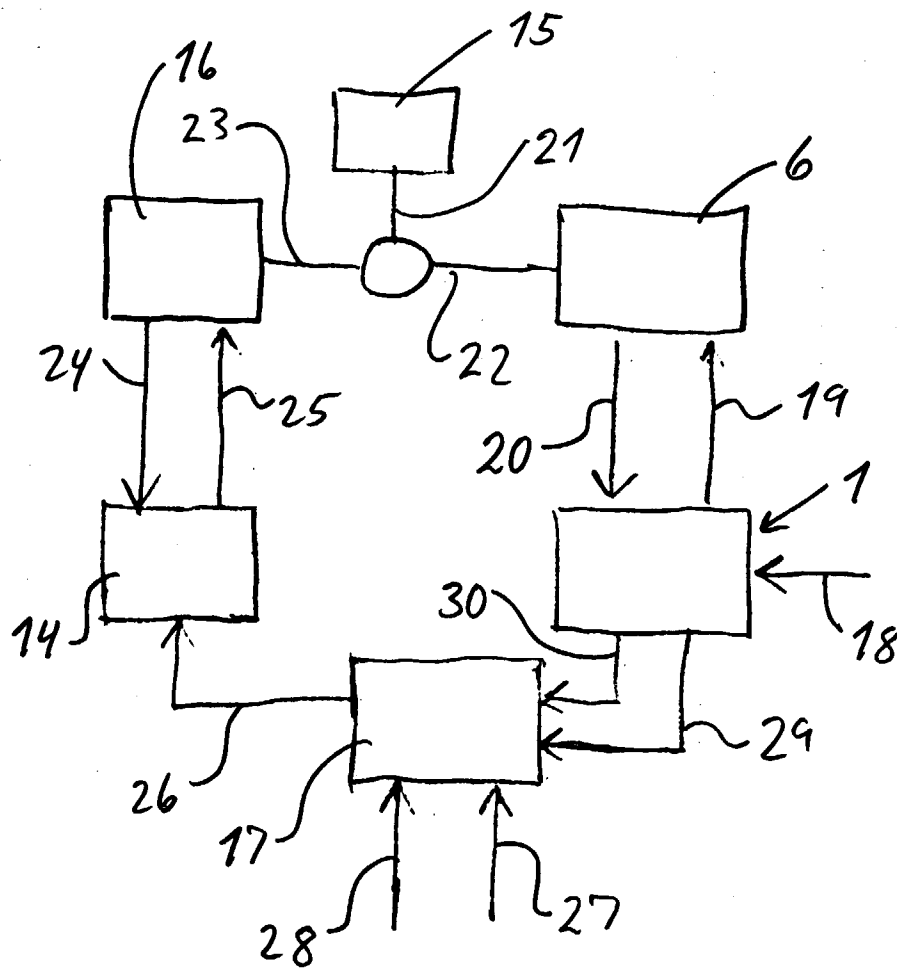


FIG. 4