



(51) International Patent Classification:
F25B 27/00 (2006.01)

(21) International Application Number:
PCT/EP2019/058890

(22) International Filing Date:
09 April 2019 (09.04.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
18166700.7 10 April 2018 (10.04.2018) EP

(71) Applicant: SOCIETE DES PRODUITS NESTLE S.A.
[CH/CH]; Entre-deux-Villes, 1800 Vevey (CH).

(72) Inventor: BISHOP, Peter, William, Dale; Widham House,
New Road Purton, Wiltshire SN5 4HF (GB).

(74) Agent: ELLEBY, Gudrun; Société des Produits Nestlé
S.A., Avenue Nestlé 55, 1800 Vevey (CH).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,

(54) Title: REFRIGERATION CYCLE DEVICE AND METHOD

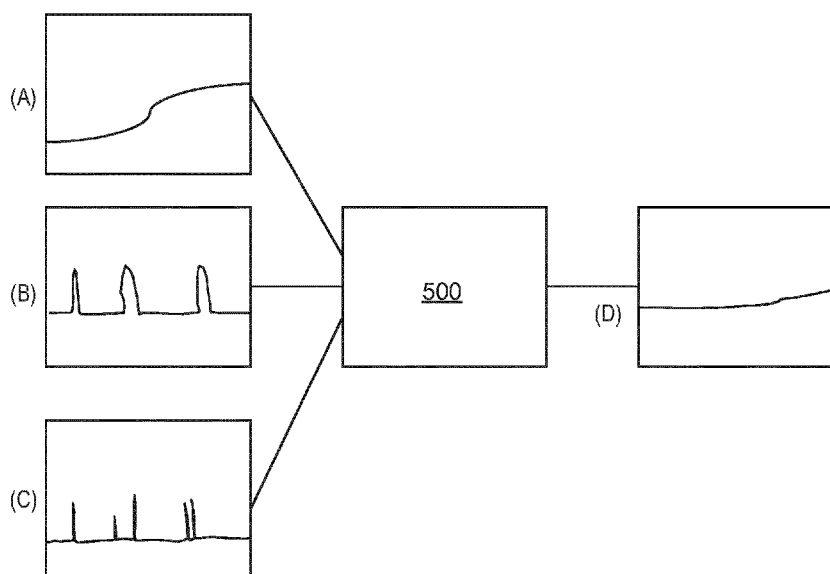


FIG. 4

(57) **Abstract:** Aspects and embodiments provide a refrigeration cycle device configured to cool a cooling chamber located within a housing of the device. Aspects and embodiments also provide a method of controlling operation of a refrigeration cycle device and a computer program product operable, when executed on a computer, to perform that method. One aspect provides a refrigeration cycle device configured to cool a cool chamber located within a housing of the device. The device comprises: a refrigerant fluid arranged to be passed around a refrigeration circuit. The circuit comprises: a variable speed compressor, a condenser, an expansion device and an evaporator. The evaporator is located within the cool chamber and the condenser is located outside the cool chamber. The device further comprises: a chamber sensor configured provide an indication of temperature within the cool chamber and a controller configured to communicate with the cool chamber sensor and one or more components of the refrigeration circuit. The controller comprises trend analysis logic configured to analyse one or more controller input and predict a trend in the one or more controller input based on



TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*

the analysis. The controller is configured to implement closed loop control of the indication of cool chamber temperature by varying speed of operation of said compressor in the refrigeration circuit in dependence upon a combination of: the indication of cool chamber temperature, and the predicted trend in the one or more controller input. The closed loop control adjusts the indication of cool chamber temperature towards a preset value.

REFRIGERATION CYCLE DEVICE AND METHOD

FIELD OF THE INVENTION

Aspects and embodiments of the invention provide a refrigeration cycle device
5 configured to cool a cooling chamber located within a housing of the device. In
particular, aspects and embodiments relate to a refrigeration cycle device in which a
controller comprising trend analysis logic is provided, that logic being configured to
analyse one or more controller input and predict a trend in the controller input based
on that analysis. The controller is configured to control operation of the device based
10 on the predicted trend in the controller input. Aspects and embodiments also provide a
method of controlling operation of a refrigeration cycle device and a computer program
product operable, when executed on a computer, to perform that method.

BACKGROUND

15 Devices which make use of a refrigeration cycle are known. Such devices include, for
example, coolers, refrigerators (fridges) and freezers. All such refrigeration devices
require energy to operate. Operation of such devices can be inefficient.

It will be appreciated that it may be possible to improve power efficiency of a
20 refrigeration cycle device by trying to maintain a substantially steady temperature
within the cooling chamber. One way to try and maintain such a steady temperature is
to configure a controller to monitor temperature in a cool chamber. Typically, a simple
thermostat is provided in the cool chamber, which can tell a controller only whether the
cooling chamber is above or below a desired temperature, but not by how much.
25 Operation of a compressor by the controller may be implemented to try and maintain a
desired temperature within the cool chamber. Some known arrangements may be such
that compressor speed may be varied and a state reported by a thermostat monitored.
However such a system is implemented it is likely that the temperature of the cool
chamber will oscillate between a temperature above a desired temperature and a
30 temperature below a desired temperature. Such operation is inefficient.

A refrigeration cycle device may be required to operate in a range of environments, for
example, domestic, commercial, inside, outside, on grid power, using renewable energy
sources and similar. Efficient operation of a refrigeration cycle device is likely to
35 depend upon the particular environmental factors in each deployment. Typically
control of a refrigeration cycle device is independent of the facts of a given deployment.

It is desired to provide a refrigeration cycle device which may address one or more inefficiency issues identified above.

5 SUMMARY

Accordingly, a first aspect of the invention provides a refrigeration cycle device configured to cool a cool chamber located within a housing of the device, the device comprising: a refrigerant fluid arranged to be passed around a refrigeration circuit, the circuit comprising: a variable speed compressor, a condenser, an expansion device and
10 an evaporator; the evaporator being located within the cool chamber and the condenser being located outside the cool chamber; the device further comprising: a chamber sensor configured to provide an indication of temperature within the cool chamber; a controller configured to communicate with the cool chamber sensor and one or more components of the refrigeration circuit; the controller comprising trend analysis logic
15 configured to analyse one or more controller input and predict a trend in the one or more controller input based on the analysis; the controller being configured to implement closed loop control of the indication of cool chamber temperature by varying speed of operation of the compressor in the refrigeration circuit in dependence upon a combination of the indication of cool chamber temperature, and the predicted
20 trend in the one or more controller input to adjust said indication of cool chamber temperature towards a preset value.

The first aspect recognises that it is possible to control operation of a refrigeration cycle device by seeking to maintain a temperature within a cool chamber at a desired set
25 point. Efficient operation may be achieved by configuring control of components forming the refrigeration circuit such that the temperature within the cool chamber is substantially constant, not being too far below the desired temperature or too far above the desired temperature. It will be appreciated that cooling the cool chamber to a temperature below the desired temperature uses unnecessary energy and similarly,
30 allowing the temperature to increase beyond the desired temperature then requires additional use of the refrigeration circuit. Cycling the cool chamber in that manner may be detrimental to food or drink products stored in the cool chamber. Significant cycling may expose food or drink products stored in the cool chamber to a risk of increased bacterial growth, or significantly alter the texture of the product.
35 Furthermore, overcooling may cause detriment to products stored within the cool chamber.

One efficient way of controlling operation of the refrigeration cycle device is one in which, for a closed cool chamber, cooling of the cool chamber is performed at approximately the same rate as heat seeps into the cool chamber.

5 The first aspect of the invention recognises that many factors may change the consequences, as measured within the cool chamber, of varying operational parameters, for example, the speed of operation of the compressor, of the various components forming the refrigeration circuit. For example, ambient external temperature may have an impact upon how efficiently a refrigeration circuit can
10 operate to extract heat from the cool chamber. The first aspect recognises that one way to account for variability of consequences of a given control action is by looking at historic operation of a device and/or historic consequences of a particular control action, making a prediction about how an action might impact temperature within the cool chamber and using that information when making control decisions. It is that
15 prediction, trend, or historic pattern which can be used to make smart decisions about adjustment to operation of the refrigeration cycle device. It will be appreciated that a trend or pattern in one or more monitored variables, which may, for example, seem unrelated to the indication of cool chamber temperature, may be taken into account when performing closed loop control. For example, time of day may be taken into
20 account - the ambient temperature overnight typically being lower, and the likelihood of the device being opened being lower, even if neither of those specific variables are monitored, the time of day may provide a sufficient pattern or indication of a pattern in the indication of cool chamber temperature on which compressor operation can be based. If the external temperature is not being increased by sun, warm wind, or other
25 external factors and the chamber is not being opened, it will be appreciated that a need to perform significant cooling of the chamber may be less. In particular, the lower ambient temperature and/or lower likelihood of opening results in a decreased need for a compressor to be run at a high speed to effect rapid cooling. As a result, a lower speed of operation of the compressor may be implemented by the controller than may
30 be implemented in an instance when the same cool chamber temperature is reported to the controller and the ambient temperature is likely to increase (for example, over the course of a day) or if a number of repeated chamber opening events is expected.

In other words, the first aspect of the invention provides a device in which a controller
35 is configured to make smart control decisions based on an analysis of a trend, pattern, rate of change or prediction of likely variance in one or more monitored device parameters. The monitored device parameter(s) may comprise one or more controller

input. In particular, the smart control of the device takes into account at least one parameter other than the variable speed of operation of the compressor and the indication of temperature of the chamber. The first aspect recognises that many other factors may be significant in relation to the operation of the refrigeration cycle device and implementing control based on, for example, the rate of change of indication of chamber temperature given a selected compressor speed, or the time of day, or the ambient outside temperature or a combination of those factors, can be beneficial. More significantly, taking a likely result, given previous performance of the device or a likely pattern or trend in one or more other parameters, can improve overall operation of the refrigeration device.

The first aspect of the invention may provide a refrigeration cycle device configured to cool a chamber. The refrigeration cycle device may comprise a freezer, fridge or drinks cooler. The cool chamber may be located within a housing or body of the device. The cool chamber may comprise a door or similar to allow a user access to the cool chamber.

The device comprises: a refrigerant fluid arranged to be passed around a refrigeration circuit. The circuit comprises: a variable speed compressor, a condenser, an expansion device and an evaporator. The condenser may comprise a skin condenser integrally formed with the body or housing of the device. The condenser may comprise a grid or fin condenser. The condenser may comprise a combination or two stage condenser formed from a skin condenser and fin/grid condenser. A fan may be provided configured to pass a flow of air or other fluid across an operational surface of the condenser to assist with heat exchange performed by the condenser.

The evaporator is located within the cool chamber and the condenser is located outside the cool chamber.

Whilst the present application has been written with a typical refrigeration cycle device in mind, it will be appreciated that some of the principles described herein may be applicable to a Peltier (thermoelectric) cooling device. In particular, one or more operational variables of that device may be controlled by a controller to perform closed loop control of an indication of temperature in the cool chamber of such a device based on predictions, patterns or trends in one or more other controller inputs.

The device further comprises: a chamber sensor configured provide an indication of temperature within the cool chamber. The chamber sensor may be located within the cool chamber. The chamber sensor may be configured to measure the temperature of the cool chamber at a location within the cool chamber which is not subject to significant micro temperature fluctuations, but instead offers a relatively time stable indication of temperature in the cool chamber. Placing the temperature sensor immediately adjacent to a door or lid, for example, may lead to inappropriate and inefficient action being taken by the controller. The temperature sensor may measure absolute temperature or provide a continuously variable indication of temperature. For example, the sensor may comprise a thermometer, or a sensor configured to offer the controller a resistance, voltage or current reading which can be interpreted as being representative of temperature. It will be appreciated that the sensor may be configured to provide an indication of the air inside the cool chamber, rather than, for example, the temperature of a product stored within the chamber. It will also be appreciated that the change in air temperature within the cool chamber may vary rapidly and significantly, when a device door is opened, for example, whilst a short isolated opening event may cause very little change to the temperature of the product stored in the cool chamber. More than one sensor may be provided to communicate with the controller and provide an indication of temperature in the chamber. Provision of more than one sensor may allow for a degree of mitigation against local temperature fluctuation, since they may be located differently within the chamber and the controller may be configured to calculate an average. Furthermore, in some embodiments, the controller may be configured to disregard the indication of temperature reported in the event that a door opening event has been detected, since that temperature indication may represent a short term fluctuation rather than a trend in temperature increase. The temperature indication may be considered again after a period of time when the door is determined to be closed. Alternatively, if a series or plurality of door opening events is detected over a predetermined time period, an increase in indication of temperature may be predicted, and speed of operation of the fan selected accordingly.

30

The controller may be configured to communicate with the cool chamber sensor and one or more components of the refrigeration circuit. The controller may be configured monitor and/or control one or more components of the refrigeration circuit.

35 The controller may comprise: trend analysis logic configured to analyse one or more controller input. That input may relate to, for example, operation of one or more components of the refrigeration circuit. The trend analysis logic may be configured to

predict a trend in the controller input based on the analysis. The analysis may, for example, comprise a correlation between one or more controller inputs. Using a trend, pattern, derivative or prediction of one or more parameters monitored by the controller allows for intelligent closed loop control to be implemented. The controller trend
5 analysis logic may be, for example, configured to analyse one or more controller input and predict a trend between the controller input and the indication of chamber temperature. The controller trend analysis logic may be, for example, configured to predict a trend or pattern into the future in the controller input and analyse the relationship between the controller input and indication of chamber temperature and
10 control speed of operation of the compressor based on that analysis.

The controller may be configured to implement closed loop control of the indication of cool chamber temperature. The closed loop control may comprise continuous closed loop control, rather than periodic closed loop control. Closed loop control of the
15 indication of cool chamber temperature may be implemented by varying an operational parameter of one or more components of the refrigeration circuit, for example, speed of operation of the compressor, in dependence upon a combination of: the indication of cool chamber temperature, and the predicted trend in the one or more controller input. The closed loop control may operate to adjust the indication of cool chamber
20 temperature towards a preset value. For example, the temperature in the chamber is too high, the controller may take action to increase cooling. The preset value may be selected in dependence upon the food or drink product to be stored in the chamber. The preset temperature may comprise a desired, preferred or target temperature.

25 It will be understood that a closed loop control is a control method according to which an output signal or monitored parameter is fed back as an input to a control system. Such a control method operates to reduce errors and improve system stability. In the case of a device according to the invention, typically the cool chamber temperature is an input to the controller and the change to the cool chamber temperature (as a result
30 of adjusting, for example, compressor speed of operation) is the output of the control process. In contrast, an open loop control method is one in which an output or result of a change made to a system has no effect upon an input to a control process. Open-loop systems are open ended (non-feedback) systems.

35 According to the first aspect of the invention, the operational parameter of one or more components of the refrigeration circuit varied by the controller comprises: speed of

operation of the compressor. Accordingly, if rapid cooling is required, the speed of the compressor may be selected to be high.

Advantageously, the analysed controller inputs comprise: the indication of cool
5 chamber temperature and speed of operation of the variable speed compressor and the
predicted trend comprises a relationship between change in the indication of cool
chamber temperature and speed of operation of the variable speed compressor;
wherein the controller is configured to implement closed loop control of the indication
of cool chamber temperature by varying speed of operation of the variable speed
10 compressor in dependence upon a combination of the indication of cool chamber
temperature and the predicted trend to adjust the indication of temperature towards
the preset value. Accordingly, history of operation of the device, or a typical device, if a
controller is configured to make use of a typical device look up table, can be considered.
If, for example, the indication of temperature shows the controller that the temperature
15 in the chamber is slightly high at the beginning of the day, different action may be
taken compared to if the temperature is too high at the end of the day. At the beginning
of a day, the device may be determined by the controller, based on historic operation of
the device, to be about to be subject to several opening and closing events and a trend
in temperature measured or looked up may indicate that the chamber is likely to heat
20 up relatively rapidly, so a speed of compressor operation may be selected accordingly.
At the end of the day, the device may be about to be closed for several hours and the
trend in temperature in the chamber determined by the controller (based on historical
operation of a device, or an appropriate look-up table) may be such that the
temperature is predicted to creep up only very slowly, and the speed of compressor
25 operation may be selected accordingly. The analysis and trend prediction and
determination by the controller can therefore assist in achieving intelligent and
efficient device control.

It will be appreciated that one or more pattern, prediction or trend may form the basis
30 of one or more look up tables provided to the trend analysis logic. It will be appreciated
that the one or more look up tables provided may be provided or stored in the logic as
part of manufacture or commissioning of the refrigeration cycle device. In some
arrangements, the controller may be configured to use historic data for a particular
device to create one or more such look up tables. Accordingly, the look up tables may
35 be site/device specific. In some embodiments, the controller may be configured to
track a difference between a stored or standard look up table provided as part of
manufacture or commission and a local/site/device specific look up table created form

historic data. In some embodiments, the difference between such tables can be analysed by the controller to identify, for example, a need to service, defrost or otherwise take action in relation to the refrigeration cycle device. Furthermore, the difference between such tables may indicate a desire to change the manner in which the device is installed or operated. For example, if a given speed of operation of a compressor, in a set of other monitored conditions, results in slower change in temperature of an indication of chamber temperature than expected, that may be an indication that the evaporator pipes are covered in an insulator (for example, ice) and the device may require a defrost cycle.

10

Advantageously, the device comprises: an ambient temperature sensor configured to provide an indication of ambient temperature around the device to the controller; and wherein the analysed controller inputs comprise: the indication of ambient temperature around the device; and wherein the controller is configured to implement closed loop control of the indication of cool chamber temperature by varying speed of operation of the compressor in dependence upon a combination of: the indication of cool chamber temperature, and the predicted trend in the indication of ambient temperature to adjust the indication of cool chamber temperature towards the preset value. Accordingly, if the ambient temperature is high and likely to remain high, a compressor speed may be selected accordingly. In some arrangements, the device may include a network connectable device or network connection and the controller may be configured to receive an indication of weather forecast for a geographic location where the device is placed. That information can be used to assist with prediction of ambient temperature. That information may be of particular use if the device is located outside.

25

Advantageously, the controller is configured to determine energy consumption of the compressor and the trend analysis logic is configured to analyse the determined energy consumption and predict a trend in the determined energy consumption; and wherein the controller is configured to implement closed loop control of the indication of cool chamber temperature by varying the speed of operation of the compressor in dependence upon a combination of: the indication of cool chamber temperature, and the predicted trend in the determined energy consumption to adjust the indication of cool chamber temperature towards the preset value. Accordingly, the controller may actively monitor power consumption and implement actions to alter the temperature in the chamber in a power efficient, rather than temperature-driven manner, selecting to return the temperature toward the preset level slowly, but power efficiently. This approach may be particularly useful if the device has limited available power, or has

30

35

fluctuating available power, such as may be the case in a device powered by renewable energy or including a battery or similar.

Advantageously, the cool chamber comprises a door and the device comprises a
5 chamber opening sensor configured to detect opening of the door and to report one or
more details of an opening event to the controller; the controller being configured to
implement closed loop control of the operational parameter of one or more
components of the refrigeration circuit in dependence upon a combination of: the
indication of cool chamber temperature, the predicted trend in the one or more
10 controller input and the reported details of the opening event, to adjust the indication
of cool chamber temperature towards the preset value. Details of the opening event
may include, for example: duration, whether another opening event has occurred, time
of day of opening event. Advantageously, the trend analysis logic is configured to
analyse the received details of the opening event and predict a trend in the opening
15 events; and wherein the controller is configured to implement closed loop control of the
indication of cool chamber temperature by varying an operational parameter of one or
more components of the refrigeration circuit in dependence upon a combination of: the
indication of cool chamber temperature, and the predicted trend in the opening events
to adjust the indication of cool chamber temperature towards the preset value. In some
20 embodiments, the trend logic may be configured to analyse the details of opening
events and, for example, ambient temperature and/or time of day to make a prediction
as to the likely change in chamber temperature and appropriate adjustment to one or
more components of the refrigeration circuit.

Advantageously, the cool chamber includes a door and the device comprises a chamber
25 door sensor configured to detect changes in configuration of the door and to report one
or more details of a change in configuration of the door to the controller; the controller
being configured to implement closed loop control of the indication of cool chamber
temperature by varying speed of operation of the compressor in dependence upon a
30 combination of: the indication of cool chamber temperature, the predicted trend in the
one or more controller input and the reported details of the change in configuration of
the door, to adjust said indication of cool chamber temperature towards the preset
value. Advantageously, the sensor may detect opening and closing of the door, and
monitor, for example, how long the door was open, when opening and/or closing took
35 place, time of day of opening/closing and similar.

Advantageously, the controller is configured to determine one or more details of cool chamber content; the controller being configured to implement closed loop control of the operational parameter of one or more components of the refrigeration circuit in dependence upon a combination of: the indication of cool chamber temperature, the
5 predicted trend in the one or more controller input and the determined details of cool chamber content, to adjust the indication of cool chamber temperature towards the preset value. A user may input details of chamber content into the controller. Details of chamber content may be provided to the controller by various other means including, for example, a measure of weight and/or volume within the chamber, image
10 recognition of one or more items in the chamber, for example, via camera, and/or by means of scanning one or more product codes provided on the products. The specific heat capacity of the chamber contents may have an impact on how rapidly the measured indication of temperature in the chamber changes, for example, in response to an opening event, or in a particular ambient temperature. How full the chamber is
15 may also be relevant to device operation. Sensors may be provided within the chamber to provide the controller with that information. Alternatively, the controller may be configured to communicate with a stock check database, in the event the device is used in a commercial or retail, rather than domestic, application. In some arrangements, the target, desired or preset temperature may depend upon the product within the cool
20 chamber. In some arrangements, the controller may be configured to set the target, preferred or preset temperature in dependence upon the type of product determined to be within the chamber. For example, drinks may be stored at a higher temperature than ice cream.

Advantageously, the device comprises: a condenser fan configured to pass air across at least a portion of the condenser in dependence upon a control signal from the controller; and wherein an operational parameter of one or more components of the refrigeration circuit varied by the controller comprises: operation of the condenser fan. Accordingly, the efficiency of heat exchange within the refrigeration cycle device may
30 be altered, albeit with an associated need to use additional energy to run the fan. The condenser may comprise a fin or grid type condenser and the fan may be configured to pass air across the condenser fins or grid. In some embodiments, the condenser may comprise a skin condenser, integrally formed with a wall of the device body or housing, and the fan may be configured to be directed at said wall of the body or housing. In
35 some embodiments, the condenser may comprise two condenser types, arranged in series within the refrigeration circuit. The fan may be configured to pass air across one or both condensers. A sensor may be provided on a surface of a condenser. That

sensor may be configured to communicate with the controller and provide the controller with an indication of temperature of the condenser and/or refrigerant fluid being passed through the condenser. Rather than simply implementing a system which runs a condenser fan when the condenser is running, an indication of
5 temperature of the condenser or refrigeration fluid passing through the condenser may be used to determine whether it is appropriate or necessary to try to increase heat exchange by running the fan. The fan may only be run when it is determined by the controller that there is an overall advantage to the overall system, taking into account, for example, availability of energy and possible energy usage if the fan is used.

10

Advantageously, the operational parameter of one or more components of the refrigeration circuit varied by the controller comprises: speed of operation of the condenser fan. Accordingly, the power load and/or rate of heat exchange achieved by the condenser may be controlled by appropriate control of the speed of operation of the
15 fan.

20

Advantageously, the device may comprise a standalone or portable device. The device may be connectable to grid power. The device may be connectable to one or more renewable power sources, for example: a solar panel or wind turbine. The device may include a rechargeable battery which may be charged by renewable sources or by, for example, grid power, when grid power is available.

25

In some embodiments, the device comprises: a power supply having variable energy availability over time; the controller comprising trend analysis logic configured to
25 communicate with the power supply to receive an indication of available power, to analyse and predict a trend in the indication of available power based on the analysis; and wherein the controller is configured to implement closed loop control of the indication of cool chamber temperature by varying an operational parameter of one or more components of the refrigeration circuit in dependence upon a combination of the
30 indication of cool chamber temperature, and the predicted trend in the indication of available power to adjust the indication of cool chamber temperature towards a preset value. Accordingly, the device may be controlled to take account of available energy and/or likely available energy. Operation of the device is likely to differ in the case where the battery is full and plentiful energy is available, compared to a situation where
35 the battery is full, but no energy is likely to be available for some hours. In some embodiments, the controller may operate, based on trend prediction and energy availability, to change the desired set point of temperature in the chamber, since a

slight alteration of temperature may ensure the chamber stays cool enough, whereas maintaining a previous set point may lead, over a selected time period, to no cooling being available due to a shortage of energy and a consequent potential loss or waste of chamber contents. It will be appreciated that it may be preferable to allow some slow or
5 slight degradation in the product rather than a total loss (for example, in the case of ice cream, if the cool chamber heats up so much that the ice cream melts) due to an energy shortfall.

In some embodiments, the device comprises: a rechargeable battery having variable
10 energy availability over time and an associated energy management controller configured to monitor and control operation of the rechargeable battery; the energy management controller being configured to communicate with the controller; and wherein the controller is configured to vary an operational parameter of one or more components of the refrigeration circuit in dependence upon an indication received from
15 the battery management controller. It will be appreciated that in instances when various sources of power are provided, a separate energy management controller is provided, configured to adapt load on a battery and analyse likely available power to charge said battery. The refrigeration device controller may be configured to defer or alter closed loop control of the chamber temperature in dependence upon a control
20 signal received from the energy management controller.

In some embodiments, the indication from the energy management controller comprises one or more of: a request to vary refrigeration circuit load placed on the battery, a request to change the preset indication of temperature value, a direct request
25 to adjust an operational parameter of one or more components of the refrigeration circuit.

A second aspect of the invention provides a method of controlling a refrigeration cycle device configured to cool a cool chamber located within a housing of the device, the
30 device comprising: a refrigerant fluid arranged to be passed around a refrigeration circuit, the circuit comprising: a variable speed compressor, a condenser, an expansion device and an evaporator; the evaporator being located within the cool chamber and the condenser being located outside the cool chamber; the device further comprising: a cool chamber sensor configured measure an indication of temperature within the cool
35 chamber; the method comprising: determining a cool chamber desired preset indication of temperature; receiving an indication of cool chamber temperature within the cool chamber; analysing one or more monitored device characteristics and

predicting a trend in the one or more device characteristics based on the analysis;
implementing closed loop control of the indication of temperature by varying speed of
operation of the compressor of the refrigeration circuit in dependence upon a
combination of the received indication of cool chamber temperature, and the predicted
5 trend in the one or more monitored device characteristics to adjust said indication of
cool chamber temperature towards said preset value.

In some embodiments, the analysed controller inputs comprise: the indication of cool
chamber temperature and speed of operation of the variable speed compressor and the
10 predicted trend comprises a relationship between change in the indication of cool
chamber temperature and speed of operation of the variable speed compressor; and
implementing closed loop control of the indication of cool chamber temperature
comprises varying speed of operation of the variable speed compressor in dependence
upon a combination of the indication of cool chamber temperature and the predicted
15 trend to adjust the indication of cool chamber temperature towards the preset value.

In some embodiments, the refrigeration cycle device comprises: an ambient
temperature sensor configured to provide an indication of ambient temperature around
the device to the controller; and analysing controller inputs comprises: analysing the
20 indication of ambient temperature around the device; and implementing closed loop
control of the indication of cool chamber temperature comprises varying the speed of
operation of the compressor of the refrigeration circuit in dependence upon a
combination of: the indication of cool chamber temperature, and the predicted trend in
the indication of ambient temperature to adjust the indication of cool chamber
25 temperature towards the preset value.

In some embodiments, the method comprises: determining energy consumption of the
compressor; analysing the determined energy consumption to predict a trend in the
determined energy consumption; implementing closed loop control of the indication of
30 cool chamber temperature by varying the speed of operation of the compressor in
dependence upon a combination of: the indication of cool chamber temperature, and
the predicted trend in the determined energy consumption to adjust the indication of
cool chamber temperature towards the preset value.

35 In some embodiments, the cool chamber comprises a door and the refrigeration cycle
device comprises a chamber opening sensor configured to detect opening of the door
and to report one or more details of an opening event; the method comprising:

receiving the report of one or more details of an opening event and implementing closed loop control of the indication of cool chamber temperature by the speed of operation of the compressor in dependence upon a combination of: the predicted trend in the one or more controller input and the reported details of the opening event, to
5 adjust the indication of cool chamber temperature towards the preset value.

In some embodiments, the method comprises analysing the received details of the opening event; predicting a trend in the opening events; and implementing closed loop control of the indication of cool chamber temperature by varying speed of operation of
10 the compressor in dependence upon a combination of: the indication of cool chamber temperature, and the predicted trend in the opening events to adjust the indication of cool chamber temperature towards the preset value.

In some embodiments, the method comprises: determining one or more details of cool
15 chamber content; and implementing closed loop control of speed of operation of the compressor in dependence upon a combination of: the indication of cool chamber temperature, the predicted trend in the one or more controller input and the determined details of cool chamber content, to adjust the indication of cool chamber temperature towards the preset value.

20

In some embodiments, the refrigeration cycle device comprises: a condenser fan configured to pass air across at least a portion of the condenser; and the method comprises: varying operation of the condenser fan.

25 In some embodiments, the operational parameter of one or more components of the refrigeration circuit varied comprises: speed of operation of the condenser fan.

In some embodiments, the refrigeration cycle device comprises: an energy supply having variable energy availability over time; and the method comprises: receiving an
30 indication of available energy; analysing and predicting a trend in the indication of available energy based on the analysis; and implementing closed loop control of the indication of cool chamber temperature by varying speed of operation of the compressor in dependence upon a combination of: the indication of cool chamber temperature, and the predicted trend in the indication of available energy to adjust the
35 indication of cool chamber temperature towards a preset value.

In some embodiments, the refrigeration cycle device comprises: a rechargeable battery having variable energy availability over time and an associated energy management controller configured to monitor and control operation of the rechargeable battery; the method comprising: receiving an indication from the energy management controller
5 and varying an operational parameter of one or more components of the refrigeration circuit in dependence upon the indication received from the energy management controller.

In some embodiments, the indication from the energy management controller
10 comprises one or more of: a request to vary refrigeration circuit load placed on the battery, a request to change the preset value, a direct request to adjust an operational parameter of one or more components of the refrigeration circuit.

A third aspect of the invention provides a computer program product operable, when
15 performed on a computer, to perform the method of the second aspect.

Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than
20 those explicitly set out in the claims.

Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.
25

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 illustrates schematically main functional components used in a typical
30 refrigeration system;

Figure 2 is a perspective representation of a mobile standalone retail kiosk for dispensing or selling food and/or drink;

Figure 3 illustrates schematically main functional components of a refrigeration cycle device forming part of mobile standalone kiosk for dispensing or selling food and/or
35 drink such as that shown in Figure 2;

Figure 4 illustrates schematically one possible functional arrangement of a refrigeration device controller for use in a system such as that shown in Figure 2

DESCRIPTION OF THE EMBODIMENTS

A refrigeration cycle device according to described arrangements may comprise, for example, a cooler, fridge, freezer, or similar.

5

Figure 1 illustrates schematically main functional components used in a typical refrigeration system. A refrigeration cycle device or apparatus 10 typically includes a circuit around which refrigerant fluid is passed. The main operational components of the circuit typically comprise: a compressor 20, a condenser 30, an expansion
10 mechanism (usually a capillary tube) 40 and an evaporator 50. In the case of a cooler, fridge or freezer, the device or apparatus is usually arranged such that there is a cool chamber within a housing. The device or apparatus operates to cool that chamber to a temperature lower than that outside the housing. The evaporator 50 is typically located within the cool chamber and the cool chamber is located inside the housing. The
15 condenser 30 is located outside the cool chamber. In some arrangements, the condenser is located outside the housing. The condenser 30 in some arrangements may form part of the housing, or may be integrally formed with the housing.

The compressor 20 is configured to compress the refrigerant fluid. Compressing the
20 refrigerant causes an increase in refrigerant fluid temperature. The condenser 30 located outside the cooling chamber operates to radiate heat away from the refrigerant fluid compressed by the compressor 20. The expansion valve 40 is configured to expand the refrigerant fluid that has dissipated heat by passing through the condenser 30. The expansion causes the refrigerant to cool. That cooled refrigerant fluid is
25 passed to the evaporator 50 within the cooling chamber which is configured to perform heat exchange between the chamber air and the refrigerant expanded by the expansion mechanism 40. The evaporator 50 acts to heat the refrigerant fluid and therefore extract heat from the cooling chamber.

30 Before describing particular arrangements in detail, a general overview is provided.

A refrigeration cycle device or apparatus such as that described in relation to Figure 1 may further comprise a controller.

35 A controller may itself comprise trend analysis logic configured to analyse one or more controller input and predict a trend in the one or more controller input based on the analysis. The controller is configured to implement closed loop control of the

indication of cool chamber temperature by varying speed of operation of said compressor in the refrigeration circuit in dependence upon a combination of: the indication of cool chamber temperature, and the predicted trend in the one or more controller input. The closed loop control adjusts the indication of cool chamber
5 temperature towards a preset value.

In general it will be appreciated that operation of a refrigeration cycle device may be optimised by taking into account a trend, pattern or prediction relating to one or more additional operational characteristics (other than the cool chamber temperature, or speed of operation of the compressor itself, though a trend/pattern or prediction
10 mapping a correlation between an additional characteristic and cool chamber temperature may be used) relating to the device. For example, the speed of the compressor may be controlled based upon a combination of: desired temperature within the cooling chamber, measured temperature of the cooling chamber and an indication of temperature outside the device housing. It will, for example, be
15 appreciated the ambient temperature outside the device will have an impact upon condenser operation and consequently the temperature of the refrigerant fluid as it passes around the circuit. A similar result may be achieved by, for example, controlling the speed of the compressor based upon a combination of: desired temperature within the cooling chamber, measured temperature of the cooling chamber and/or an
20 indication of temperature of the refrigerant fluid at one or more points in the fluid circuit.

The controller may comprise an appropriately configured computer. The controller may be configured to control operation of the compressor. In particular, the controller
25 may be configured to instruct the compressor to switch on and off. The compressor may be able to operate at varying speeds. The speed of compressor operation may be continuously variable. The controller may be configured to control speed of operation of the compressor.

30 The controller may monitor and/or control power consumption of the compressor. The compressor may be able to operate at varying power consumption levels. The power consumption of the compressor may be continuously variable. The controller may be configured to control power consumption of the compressor by, for example, varying speed of operation of the compressor.

35 The controller may be configured to communicate with one or more information sources to obtain information about the environment in which the refrigeration cycle

device or apparatus is operating. The one or more information sources may, for example, comprise one or more sensors. For example, the device may comprise a temperature sensor located outside the cooling chamber. The temperature sensor may be located outside the housing. The temperature sensor may be located on the housing.

5 The information sources may comprise a humidity sensor. The humidity sensor may be located inside and/or outside the cool chamber. The information may be provided relating to the humidity inside and/or outside the chamber. The information sources may comprise one or more temperature sensors provided on the condenser. The information sources may comprise one or more temperature sensors provided on the

10 evaporator. The information sources may include a location sensor, and/or mechanism to obtain an indication of a geographical area in which the device is located. The information sources may, for example, include an indication of a weather forecast for the geographical area in which the device is located. The controller may be configured to obtain trend indications in relation to any one of the information sources.

15 The controller may be configured to communicate with one or more information sources to obtain information about the environment within the cooling chamber forming part of the device itself. The information sources may comprise, for example, a temperature sensor located inside the cooling chamber. The information sources may, for example, include sensors which monitor opening and/or closing events related to

20 the cooling chamber. The information sources may, for example, comprise information relating to the content of the cooling chamber. That information may, for example, comprise an indication of how full or empty the cooling chamber is. The controller may be configured to obtain trend indications in relation to any one of the information

25 sources.

The controller may be configured to monitor and control the state of various components forming part of the refrigeration device. The controller may, for example, include appropriate sensors to allow for monitoring of an indication of temperature of

30 the refrigeration fluid at one or more locations within the refrigeration circuit. The controller may, for example, monitor and/or control speed of operation of the compressor, and/or may monitor power availability and similar.

Furthermore, the device may, for example, comprise additional functional components.

35 For example, the device may comprise a stand-alone device which is not connected to grid power. In such a case, the device may, for example, comprise one or more sources of power, for example, a battery, a diesel, petrol or hydrogen fuelled generator or fuel

cell, and/or one or more alternative energy sources, such as a solar panel, wind turbine or similar. The device may comprise a back-up power supply. The device may, for example, include a battery. The battery may comprise a rechargeable battery. The controller may be configured to monitor and/or control one or more operational
5 characteristic of such components forming part of the refrigeration device.

It will be appreciated that the temperature of the cooling chamber may be related to the number of times the cooling chamber is opened, and/or how closely spaced such
10 opening events are and/or how long each opening of the cooling chamber lasts. Efficient operation of the device may be implemented, for example, by controlling the speed of the compressor based upon a combination of: desired temperature within the cooling chamber, measured temperature of the cooling chamber and one or more indications relating to cooling chamber opening events.

15 It will be appreciated that the temperature of the cooling chamber may be related to one or more trends in one or more controller inputs. Efficient operation of the device may be implemented, for example, by appropriate analysis of historic trends relating to operation of the device. For example, across a 24 hour period, a typical temperature
20 cycle outside the cooling chamber may be observed. The temperature may, for example, drop overnight and increase during the day. Operation of the compressor may take account of such typical fluctuation. The controller may be configured to controlling the speed of the compressor based upon a combination of: desired temperature within the cooling chamber, measured temperature of the cooling
25 chamber, an indication of temperature outside the cooling chamber and an indication of trend in temperature outside the cooling chamber. In some arrangements where, for example, the device is located outside, it may be advantageous to take into account one or more of: time of day, weather forecast, and/or one or more locally observed trends in time of day or weather, and/or historic correlation between one or more monitored or
30 calculated characteristics of device operation and historic operation of, for example the speed of the compressor and resulting temperature within the cooling chamber.

All such smart control of the refrigeration cycle device or apparatus may improve energy efficiency. Such efficiency improvements may be helpful to minimise
35 operational cost of a device connected to a standard grid power supply. Such smart control may be of particular use if the device is not connected to a reliable energy supply, or is battery powered, where that battery has finite available energy.

Arrangements may provide a standalone renewable and/or battery powered refrigeration cycle device or apparatus. Arrangements may provide a mobile refrigeration cycle device or apparatus. Arrangements may provide an outdoor
5 refrigeration cycle device or apparatus.

A refrigeration cycle device or apparatus may comprise a battery and an associated battery management control unit. The refrigeration cycle device controller may be configured to communicate with the battery management control unit. The battery
10 management control unit may be configured to manage available energy to charge a rechargeable battery with a load upon the battery. The load on the battery may comprise compressor operation. The battery management control unit may be configured to communicate with the refrigeration cycle device controller. The battery management controller may take precedence over desired operation of the refrigeration
15 cycle controller. That is to say, ensuring energy availability so that the device can operate may take precedence over energy efficiency or maintenance of a stable temperature within the cooling chamber. The battery management control unit may, for example, be configured request a change to a cooling chamber “set point” temperature, for battery management purposes. Similarly, the battery management
20 control unit may, for example, be configured request a change to compressor energy consumption or operating speed for battery management purposes.

A refrigeration cycle device or apparatus may comprise: a compressor and controller as described above, according to which the controller is operable to control operation of
25 the compressor in dependence upon one or more indication of available energy. The indication of available energy may be requested or provided by the battery management control unit.

A refrigeration cycle device or apparatus may comprise a refrigeration circuit in which a
30 mechanism to alter operation of the condenser forming part of the refrigeration circuit is provided. The controller may be configured to alter condenser operation in dependence upon an indication of temperature of refrigerant fluid temperature after passing through the condenser. The condenser may comprise a fin or grid heat exchanger. The refrigeration cycle device or apparatus may comprise a fan configured
35 to direct a flow of air over such a heat exchanger. The controller may be configured to implement use of the fan to increase heat dissipation if the temperature of the refrigerant fluid after passing through the condenser is too high. In some

arrangements the fan may comprise a variable speed fan and the controller may be configured to switch a fan on and/or control the speed of operation of the fan in dependence upon the measured temperature of the refrigerant fluid after passing through the condenser. Alternatively, control of the fan may be implemented in
5 dependence upon one or more of: temperature outside the housing, ambient temperature outside the device or apparatus, predicted temperature outside the housing, a weather forecast, a temperature difference between measured temperature within the cooling chamber and any one of: temperature outside the housing, ambient temperature outside the device or apparatus, predicted temperature outside the
10 housing, a weather forecast.

A refrigeration cycle device or apparatus may comprise a refrigeration circuit in which more than one condenser is provided. In particular, more than one type of condenser may be provided in series. One of those condensers may comprise a fin or grid heat
15 exchanger with a fan configured to pass a flow of air over the grid or fins of the heat exchanger. As described in general terms above, the controller may be configured to control operation of the fan in dependence upon the refrigerant fluid after passing through one or more condensers.

It will be appreciated that intelligent or smart control of a fan configured to alter operation of the condenser may help to improve stability of temperature within the cooling chamber of the device. It will also be appreciated that preventing continuous operation of a fan associated with a condenser may offer energy savings. In some
20 arrangements, for example, running a fan may coincide with a period in which energy from renewable sources may be freely available: full sun may cause a high temperature outside the device housing, but also may mean plentiful energy is available from a solar source to accommodate running a fan to improve operation of the condenser.
25

A refrigeration cycle device or apparatus may comprise controller logic. The controller
30 logic may be configured to store, calculate and/or determine one or more indication related to one or more monitored parameters associated with device operation. The controller logic may be configured, for example, to calculate or determine trends referred to above. The controller logic may be configured to access one or more look up tables associated with parameters mentioned above. For example, the controller logic
35 may be able to access a look up table which relates compressor speed or power consumption to one or more of: measured temperature inside the cooling chamber, measured temperature outside the housing, predicted temperature outside the housing,

and/or a difference between measured cooling chamber temperature and external temperature.

The controller logic may comprise communication logic. The communication logic
5 may, for example, comprise a machine type communication device, a network connection, and/or a wireless network communication device. Accordingly, the controller may be configured to provide one or more monitored parameters to a remote control centre. The controller may be configured to communicate with that remote control centre. The remote control centre may be configured to communicate with a
10 local controller to control operation of the device.

The local controller and/or remote control centre may be configured to analyse one or more monitored parameters to calculate device efficiency and/or a coefficient of performance associated with a refrigeration cycle device. The local controller and/or
15 remote control centre may be configured to analyse one or more monitored parameters or determined trends in monitored parameters to recognise an indication of device fault or failure.

One particular implementation is now described in detail:
20

Figure 2 is a perspective representation of a mobile standalone kiosk for dispensing or selling food and/or drink.

The kiosk 200 may be movable between locations and may, for example comprise a
25 mobile or portable kiosk. That kiosk includes a freezer 210 in which ice cream is stored until purchased. The kiosk is used to vend ice-cream to customers.

Figure 3 illustrates schematically main functional components of a refrigeration cycle device forming part of mobile standalone kiosk for dispensing or selling food and/or
30 drink such as that shown in Figure 2. The freezer or cooler 300 forming part of the illustrated kiosk comprises: a cool chamber 310 in which the food and/or drink can be placed. The main operational components of the refrigeration cycle device operating to cool the cooling chamber are: a compressor 320, a condenser 330 located outside the cool chamber 310, an expansion mechanism 340 (usually a capillary tube and an
35 evaporator 350 located within the cool chamber 310.

- The refrigeration cycle device operates to cool the cool chamber 310 to a temperature lower than that experienced around the kiosk. In the illustrated arrangement, the condenser comprises a two stage condenser. The two stages are arranged in immediate series within a refrigeration circuit. A first stage condenser comprises a skin condenser
5 formed integrally with an outer wall of the cool chamber housing. A second stage condenser comprises a grid or fin condenser. A fan 360 is provided and configured to pass air across one or more of the outer wall of the cooling chamber housing and/or the fins or grid forming part of the second stage condenser.
- 10 The kiosk includes a computer. The computer is configured to provide a fridge/freezer/cooler controller 370. The controller is configured to control operation of various components of device 300 including the compressor 320. In particular, the controller is configured to instruct the compressor to switch on and off and to control speed of operation of the compressor. The speed of operation of the compressor is
15 continuously variable. In the example shown in Figure 3, a temperature sensor 380 is provided within the cooling chamber 310. A further temperature sensor is provided on the outside of the kiosk 390. The controller 370 is configured to communicate with both temperature sensors 410, 420.
- 20 The controller 370 provided operates to try to improve power efficiency of a refrigeration cycle device by trying to maintain a substantially steady temperature within the cooling chamber. The controller 370 monitors the temperature in the cooling chamber 310 and operation of the compressor 320 is adjusted based upon direction and magnitude of difference between the measured temperature and a
25 desired (set-point) temperature to be maintained within the cool chamber 310. The controller is configured such that compressor 320 speed is varied in dependence upon measured temperature within the cooling chamber 310 and the difference between the measured temperature and desired temperature. In particular, if the temperature is determined to be much greater than a desired temperature within the cooling chamber
30 310, (for example, when a device is first switched on, or after it has been switched off for maintenance or defrosting) the speed of operation of the compressor 320 may be set to be high or maximum available speed. If the temperature is determined to be only slightly greater than a desired temperature, the speed of operation of the compressor may be relatively low, in order to try and maintain a steady state of operation where the
35 rate of cooling is approximately equal to the rate of heating being experienced within the cooling chamber. In such a way, the temperature of the cooling chamber can be maintained at a near constant level, rather than fluctuating in a cycle between a

temperature above the desired temperature and a temperature below the desired temperature linked to hysteresis of a thermostat and lag in a refrigeration system.

Furthermore, the controller 370 comprises trend analysis logic configured to analyse one or more controller input and predict a trend in said one or more controller input

5 based on said analysis. The controller 370 is configured to implement closed loop control of the indication of cool chamber temperature by varying compressor speed in dependence upon a combination of said indication of cool chamber 310 temperature, and said predicted trend in cool chamber temperature to adjust the indication of cool chamber temperature towards the preset value.

10

The controller is also configured, in the illustrated example, to control the speed of the compressor 320 based upon a combination of: desired temperature within the cooling chamber, measured temperature of the cooling chamber and an indication of

15 temperature measured by sensor 390 outside the device housing. It will, for example, be appreciated the ambient temperature outside the kiosk may have an impact upon condenser 330 operation and consequently the temperature of the refrigerant fluid as it passes around the circuit. If the kiosk is placed in a hot environment, operation of the controller will differ to an arrangement in which the kiosk is placed in a cold environment, since monitoring the ambient temperature around the kiosk can assist
20 the control of the compressor to try and maintain a steady state in which cooling of the cooling chamber is approximately equal to heating of the cooling chamber through, for example, the chamber walls and ingress of air when the chamber is opened to allow food and/or drink to be removed from the chamber.

25 The kiosk illustrated comprises a two-stage condenser. The controller is configured to change condenser operation in dependence upon ambient temperature outside the kiosk. The controller is configured to implement use of the fan 360 to increase heat dissipation in dependence upon the ambient temperature outside the kiosk. The fan comprises a variable speed fan and the controller is configured to switch a fan on and
30 control the speed of operation of the fan in dependence upon the measured ambient temperature. It will be appreciated that when the ambient temperature outside the kiosk is high, heat dissipated by the condenser may be increased by appropriate use of the fan. It will also be appreciated that not using the fan unless necessary may result in power saving.

35

The kiosk illustrated in Figures 2 and 3 is a standalone kiosk. It is not connected to grid power. The kiosk includes a PV panel and a rechargeable battery. The computer

provided is configured to monitor parameters relating to the battery and available solar energy and communicate with an appropriate battery management system 430. The battery management system in the arrangement shown is configured to manage load (demand) on the available power. The load includes operation of the refrigeration cycle device. The load also includes, for example, lighting, a payment system and display and communication system 440. The kiosk comprises a rechargeable battery and the computer comprises an associated battery management control unit 430. The refrigeration cycle device controller 370 is configured to communicate 450 with the battery management control unit. The battery management control unit is configured to manage available power to both charge a rechargeable battery and supply a load calling upon available power and/or the battery. The battery management control unit is configured to communicate with the refrigeration cycle device controller. The battery management controller decisions take precedence over decisions of the refrigeration cycle controller. Thus ensuring power availability so that the kiosk can operate at all times takes precedence over power efficiency or maintenance of a stable temperature within the cooling chamber. The battery management control unit is configured request a change to a cooling chamber "set point" temperature, for battery management purposes. Similarly, the battery management control unit can request a change to compressor power consumption or operating speed for battery management purposes.

20

Figure 4 illustrates schematically one possible functional arrangement of a refrigeration device controller for use in a system such as that shown in Figure 2. The arrangement shown recognises that many factors may change the consequences, as measured within the cool chamber, of varying operational parameters, for example, the speed of operation of the compressor, of the various components forming the refrigeration circuit. In the example shown, ambient external temperature (A) (graph shows temperature against time), an indication of freezer temperature (B) (graph shows temperature against time) and door opening events (C) (graph shows opening event trigger against time) are inputs to a device controller 500.

25

In general, the controller 500 is configured to recognise that ambient temperature and door opening events may have an impact upon how efficiently a refrigeration circuit can operate to extract heat from the cool chamber. The controller is configured to recognise that one way to account for variability of consequences of a given control action is by looking at historic operation of a device and/or historic consequences of a particular control action, and make a prediction about how an action might impact temperature within the cool chamber and using that information when making control

30

35

decisions. It is that prediction, trend, or historic pattern which can be used to make smart decisions about adjustment to operation of the refrigeration cycle device. It will be appreciated that a trend or pattern in one or more monitored variables (A), (B) and (C), which may, for example, seem unrelated to the indication of cool chamber temperature or directly related to speed of operation of the compressor (D) (graph shows speed of operation in RPM against time) implemented by the controller 500, are taken into account when the controller 500 is performing closed loop control of the indication of cool chamber temperature (B) by adjusting compressor speed (D).

10 In a general implementation such as that shown in the example of Figure 4, the controller 500 is configured to know/predict that the ambient temperature overnight is typically lower, and from historical operation of the device, the controller 500 may have learned that the likelihood of the device being opened (C) overnight is low. If the external temperature is not being increased by sun, and the chamber is not being

15 opened, it will be appreciated that a need to perform significant cooling of the chamber may be less. In particular, the lower ambient temperature and/or lower likelihood of opening results in a decreased need for a compressor to be run at a high speed to effect rapid cooling. As a result, a lower speed of operation of the compressor is implemented by the controller 500 than may be implemented in an instance when the same cool

20 chamber temperature is reported to the controller and the ambient temperature is likely to increase (for example, over the course of a day) and if a number of repeated chamber opening events is expected.

In one particular possible implementation, shown in detail in Figure 4, the information communicated to the controller 500 over the same time period is illustrated graphically in the graphs charting factors (A), (B), (C) and (D). It can be seen that the ambient temperature (A) goes up sharply and then levels off. Over the same time period, the indication of cool chamber temperature (B) is largely level, with brief peaks in temperature. Those peaks in reported temperature correspond to door opening events shown in (C). Controller 500 is configured such that the spikes in indication of temperature of the cool chamber (B) are largely ignored, since they are determined to correlate/respond to door opening events shown in (C). The controller is configured to predict/learn that short and/or infrequent door opening events do not cause a significant change in the temperature of product in the cool chamber. That is to say,

30 although a rush of hot air into the cool chamber can cause a spike in reported indication of cool chamber temperature, once the door is closed, that small volume of hot air which entered the chamber and caused the reading spike is itself cooled, without

a need to run the compressor. As a result, it can be seen that the controller 500 does not react to the level of door opening events and spikes in cool chamber temperature reported, and the speed of operation of the compressor (D) exhibits no spikes, just a slow increase as the ambient external temperature increases. That slow increase keeps
5 the chamber temperature substantially stable, as shown in (B), despite the ambient temperature increase shown in (A).

It will, of course, be appreciated that the controller 500 may, in other instances, see a general increase in chamber temperature (B) if the door opening events (C) are long
10 and/or frequent and that a different action might be taken to change the compressor speed (D) in relation to such a trend.

Although illustrative embodiments of the invention have been disclosed in detail herein, with reference to the accompanying drawings, it is understood that the
15 invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art without departing from the scope of the invention as defined by the appended claims and their equivalents.

CLAIMS

1. A refrigeration cycle device configured to cool a cool chamber located within a housing of said device, said device comprising:
- 5 a refrigerant fluid arranged to be passed around a refrigeration circuit, said circuit comprising: a variable speed compressor, a condenser, an expansion device and an evaporator;
- said evaporator being located within said cool chamber and said condenser being located outside said cool chamber; said device further comprising:
- 10 a chamber sensor configured provide an indication of cool chamber temperature within said cool chamber;
- a controller configured to communicate with said cool chamber sensor and one or more components of said refrigeration circuit;
- said controller comprising trend analysis logic configured to analyse one or more
- 15 controller input and predict a trend in said one or more controller input based on said analysis;
- said controller being configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in said refrigeration circuit in dependence upon a combination of said indication of cool
- 20 chamber temperature, and said predicted trend in said one or more controller input to adjust said indication of cool chamber temperature towards a preset value.
2. A refrigeration cycle device according to claim 1, wherein said analysed controller inputs comprise: said indication of cool chamber temperature and speed of
- 25 operation of said variable speed compressor and said predicted trend comprises a relationship between change in said indication of cool chamber temperature and speed of operation of said variable speed compressor;
- wherein said controller is configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said variable
- 30 speed compressor in dependence upon a combination of said indication of cool chamber temperature and said predicted trend to adjust said indication of temperature towards said preset value.
3. A refrigeration cycle device according to any preceding claim, wherein said
- 35 device comprises: an ambient temperature sensor configured provide an indication of ambient temperature around said device to said controller;

and wherein said analysed controller inputs comprise: said indication of ambient temperature around said device;

and wherein said controller is configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in dependence upon a combination of: said indication of cool chamber temperature, and said predicted trend in said indication of ambient temperature to adjust said indication of cool chamber temperature towards said preset value.

4. A refrigeration cycle device according to any preceding claim, wherein said cool chamber comprises a door and said device comprises: a chamber door sensor configured to detect changes in configuration of said door and to report one or more details of a change in configuration of said door to said controller; said controller being configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in dependence upon a combination of: said indication of cool chamber temperature, said predicted trend in said one or more controller input and said reported details of said change in configuration of said door, to adjust said indication of cool chamber temperature towards said preset value.

5. A refrigeration cycle device according to claim 4, wherein said trend analysis logic is configured to analyse said received details of a change in configuration of said door and predict a trend in said changes of configuration of said door; and wherein said controller is configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in said refrigeration circuit in dependence upon a combination of: said indication of cool chamber temperature, and said predicted trend in said changes of configuration of said door to adjust said indication of cool chamber temperature towards said preset value.

6. A refrigeration cycle device according to any preceding claim, wherein said controller is configured to determine one or more details of cool chamber content; said controller being configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in dependence upon a combination of: said indication of cool chamber temperature, said predicted trend in said one or more controller input and said determined details of cool chamber content, to adjust said indication of cool chamber temperature towards said preset value.

7. A refrigeration cycle device according to any preceding claim, wherein said controller is configured to determine energy consumption of said compressor and energy available to said device; said controller being configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in dependence upon a combination of: said indication of cool chamber temperature, said predicted trend in said one or more controller input and said indication of energy consumption of said compressor and said indication of energy available to said device, to adjust said indication of cool chamber temperature towards said preset value .
8. A refrigeration cycle device according to any preceding claim, wherein said controller is configured to communicate with a humidity sensor configured to provide an indication of chamber humidity; said controller being configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in dependence upon a combination of: said indication of cool chamber temperature, said predicted trend in said one or more controller input and said indication of chamber humidity, to adjust said indication of cool chamber temperature towards said preset value.
9. A refrigeration cycle device according to any preceding claim, wherein said device comprises:
a condenser fan configured to pass air across at least a portion of said condenser in dependence upon a control signal from said controller; and wherein said controller is configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor and operation of said condenser fan.
10. A refrigeration cycle device according to claim 9, wherein said controller is configured to adjust speed of operation of said condenser fan.
11. A refrigeration cycle device according to any preceding claim, wherein said device comprises: a power supply having variable power availability over time; said controller comprising trend analysis logic configured to communicate with an energy management controller to receive an indication of available power, and to analyse and predict a trend in said indication of available power based on information received from said energy management controller;

and wherein said controller is configured to implement closed loop control of said indication of cool chamber temperature by varying speed of operation of said compressor in dependence upon a combination of said indication of cool chamber temperature, and said predicted trend in said indication of available power to adjust
5 said indication of cool chamber temperature towards a preset value.

12. A refrigeration cycle device according to any preceding claim, wherein said device comprises: a rechargeable battery having variable energy availability over time and an associated energy management controller configured to monitor and control
10 operation of said rechargeable battery; said energy management controller being configured to communicate with said controller;
and wherein said controller is configured to vary speed of operation of said compressor circuit in dependence upon an indication received from said energy management controller.

13. A refrigeration cycle device according to claim 12, wherein said indication from said energy management controller comprises one or more of: a request to vary refrigeration circuit load placed on said battery, a request to change said preset value, a direct request to adjust an operational parameter of one or more components of said
15 refrigeration circuit.

14. A method of controlling a refrigeration cycle device configured to cool a cool chamber located within a housing of the device, said device comprising: a refrigerant fluid arranged to be passed around a refrigeration circuit, the circuit comprising: a
20 variable speed compressor, a condenser, an expansion device and an evaporator; said evaporator being located within said cool chamber and said condenser being located outside said cool chamber; the device further comprising: a cool chamber sensor configured to measure an indication of temperature within said cool chamber;
said method comprising:
30 determining a cool chamber desired preset indication of temperature;
receiving an indication of cool chamber temperature within said cool chamber;
analysing one or more monitored device characteristics and predicting a trend in said one or more device characteristics based on the analysis;
implementing closed loop control of said indication of temperature by varying speed of
35 operation of said compressor of said refrigeration circuit in dependence upon a combination of said received indication of cool chamber temperature, and said

predicted trend in said one or more monitored device characteristics to adjust said indication of cool chamber temperature towards said preset value.

15. A computer program product operable, when executed on a computer, to
5 perform the method of claim 14.

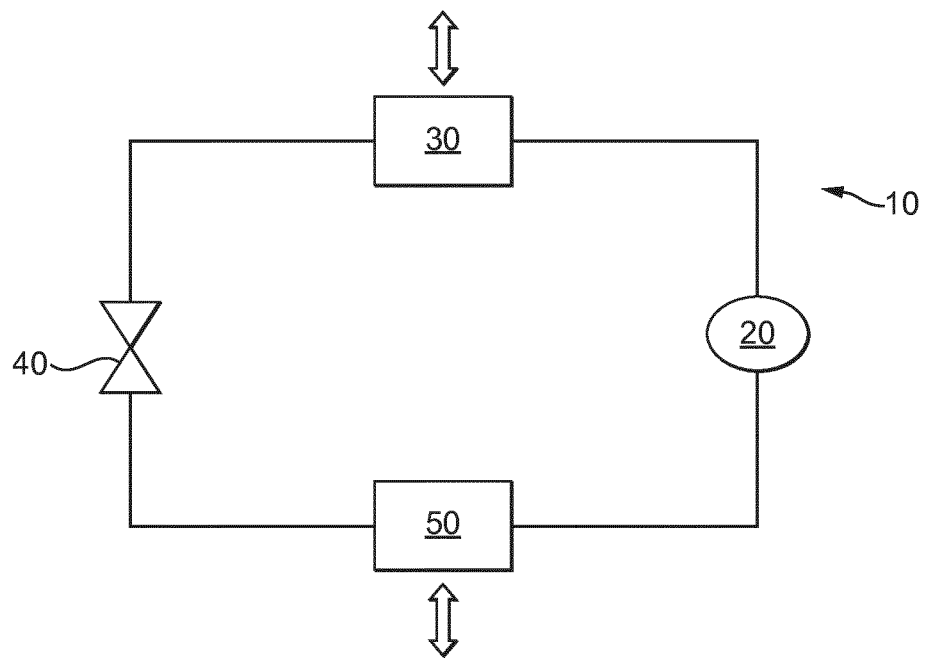


FIG. 1

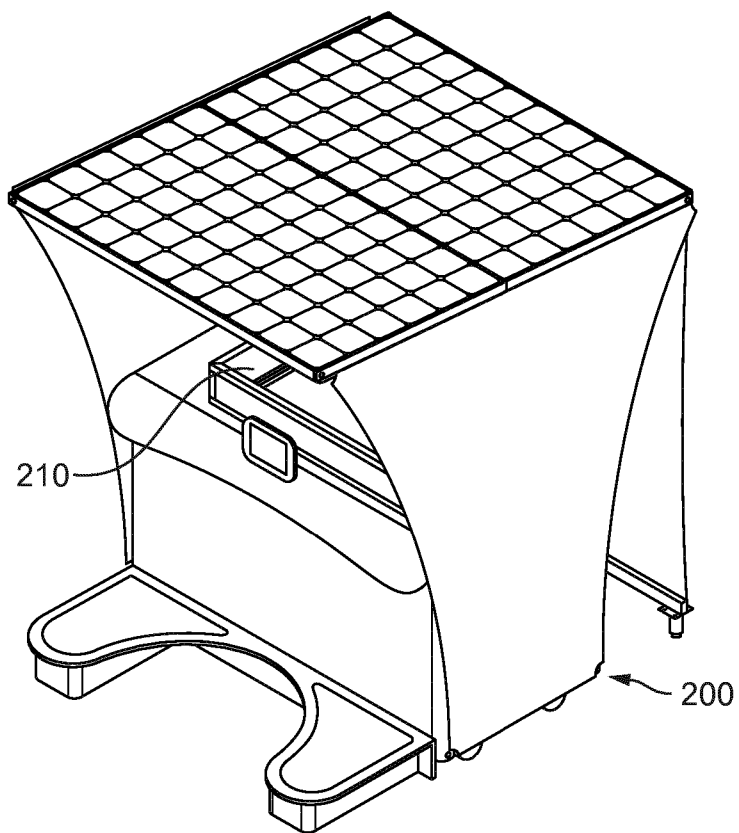


FIG. 2

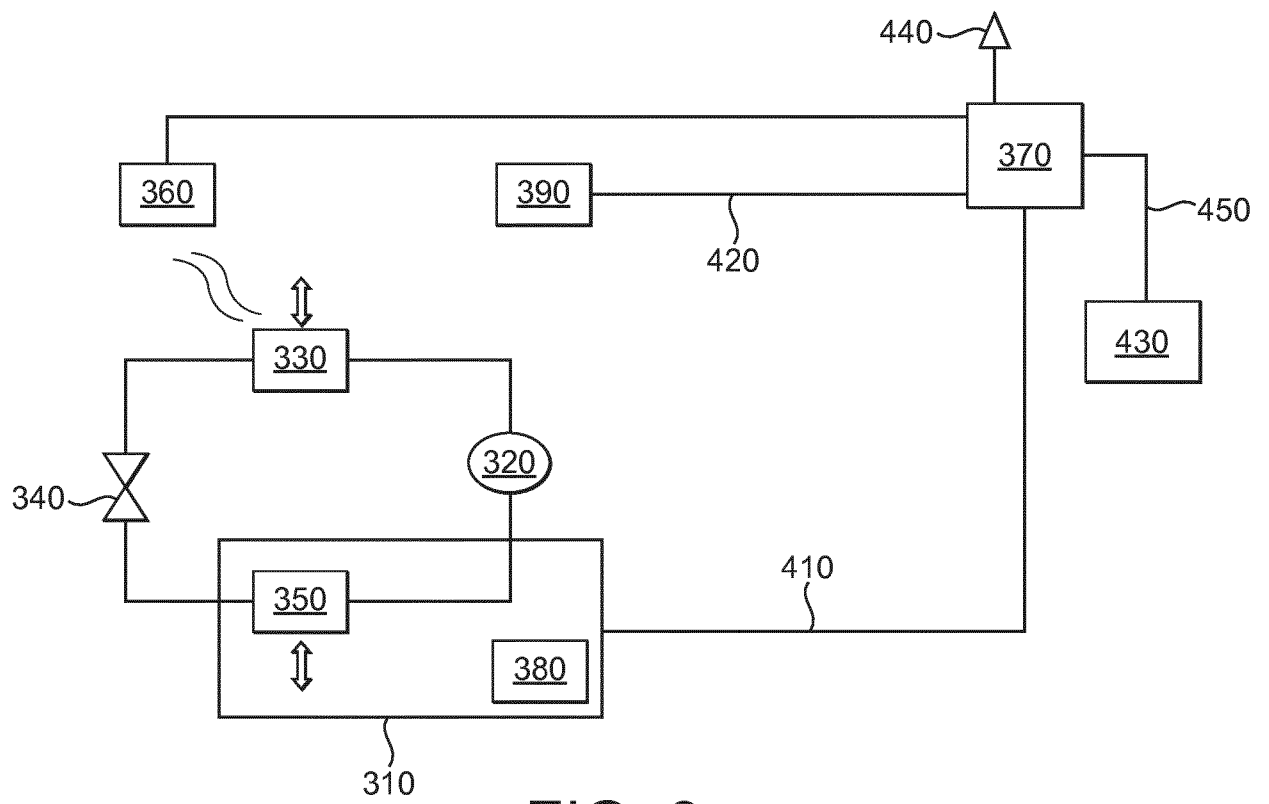


FIG. 3

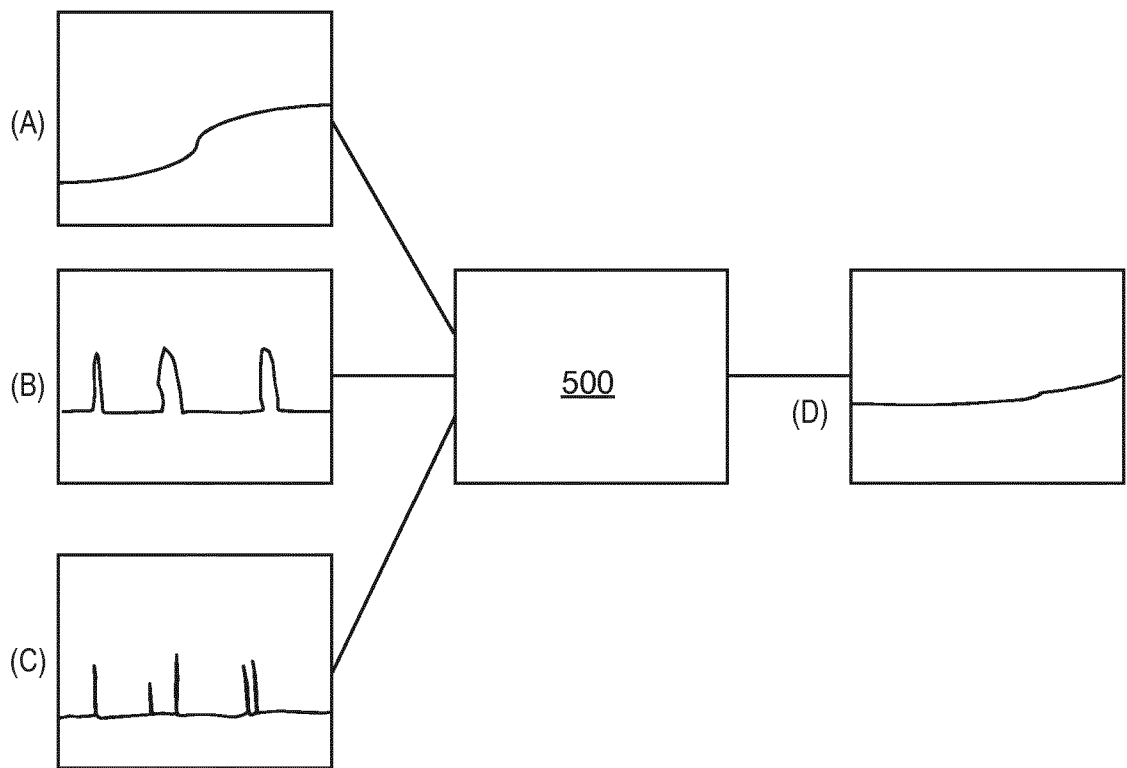


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2019/058890

A. CLASSIFICATION OF SUBJECT MATTER
INV. F25B27/00
ADD.

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

B. FIELDS 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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2015/000636 A1 (STOCKBRIDGE MICHAEL [US] ET AL) 1 January 2015 (2015-01-01) abstract paragraphs [0001] - [0006], [0016], [0021] - [0031]; figures 2,4,5 -----	1-3,6, 14,15 4,5,7, 11-13
X Y	DE 10 2006 044999 A1 (DANFOSS COMPRESSORS GMBH [DE]) 19 April 2007 (2007-04-19) paragraphs [0001] - [0017], [0022] - [0024]; figures 1,2 -----	1-3,6 4,5,7, 11-13
X Y	DE 10 2014 211095 A1 (BSH HAUSGERÄTE GMBH [DE]) 17 December 2015 (2015-12-17) paragraphs [0001] - [0022]; figure 2 ----- -/-	1,2,4 5,7, 11-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 July 2019

Date of mailing of the international search report

23/07/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Weisser, Meinrad

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/058890

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2004/050075 A1 (KING EDDIE W [US] ET AL) 18 March 2004 (2004-03-18) paragraphs [0004] - [0011], [0022] - [0030]; figures 1-4 -----	4,5
Y	US 2015/226475 A1 (CHOI BYOUNGSUK [KR] ET AL) 13 August 2015 (2015-08-13) paragraphs [0008] - [0030], [0059] - [0085]; figures 2, 3, 4 -----	4,5
Y	US 5 548 969 A (LEE KUN B [KR]) 27 August 1996 (1996-08-27)	4
A	abstract column 1, line 7 - column 2, line 59; figures 1, 2, 4A, 4B, 4C column 6, lines 11-59 -----	5
Y	CN 106 642 902 A (GUANGDONG FIVESTAR SOLAR ENERGY CO LTD) 10 May 2017 (2017-05-10) paragraphs [0002] - [0007], [0037] - [0041], [0048]; figures 1,2 -----	7,11
Y	US 4 367 633 A (STRATHMAN RONALD L [US]) 11 January 1983 (1983-01-11) abstract column 1, lines 19-38; figure 5 column 5, line 53 - column 9, line 68 -----	7,11-13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2019/058890

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
1-7, 11-15
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3, 6, 14, 15

Refrigeration cycle having a variable speed compressor, wherein the compressor speed is controlled based on the load temperature or ambient temperature.

2. claims: 4, 5

Refrigerant cycle having a variable speed compressor and a door with door sensors, wherein the compressor speed is based on the number of opening and closing events.

3. claim: 7

Refrigerant cycle having a variable speed compressor and a determination of energy consumption, wherein the compressor speed is controlled based on the energy consumption.

4. claim: 8

Refrigerant cycle having a variable speed compressor and a humidity sensor, wherein the compressor speed is controlled based on the humidity inside the cool chamber.

5. claims: 9, 10

Refrigerant cycle having a variable speed compressor and a condenser fan.

6. claims: 11-13

Refrigeration cycle having a variable speed compressor and a variable power supply and/or a battery, wherein the compressor speed is controlled based on the available amount of energy.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/058890

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015000636 A1	01-01-2015	EP 2822791 A1 US 2015000636 A1 WO 2013134453 A1	14-01-2015 01-01-2015 12-09-2013
DE 102006044999 A1	19-04-2007	NONE	
DE 102014211095 A1	17-12-2015	DE 102014211095 A1 WO 2015189009 A1	17-12-2015 17-12-2015
US 2004050075 A1	18-03-2004	AU 2003272482 A1 BR 0313440 A BR PI0313440 B1 CN 1682170 A CN 101504551 A EP 1540438 A1 ES 2315529 T3 HK 1137522 A1 JP 2005539313 A MX PA05001045 A US 2004050075 A1 WO 2004025388 A1	30-04-2004 12-07-2005 21-11-2017 12-10-2005 12-08-2009 15-06-2005 01-04-2009 28-10-2011 22-12-2005 08-04-2005 18-03-2004 25-03-2004
US 2015226475 A1	13-08-2015	EP 2905566 A1 KR 20150093357 A US 2015226475 A1	12-08-2015 18-08-2015 13-08-2015
US 5548969 A	27-08-1996	IT RM950192 A1 JP 2703734 B2 JP H07280412 A KR 950027329 A US 5548969 A	02-10-1995 26-01-1998 27-10-1995 16-10-1995 27-08-1996
CN 106642902 A	10-05-2017	NONE	
US 4367633 A	11-01-1983	NONE	