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(54) **MICROPROCESSOR CONTROLLED DEFROST TERMINATION**

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(57) **ABSTRACT**

An apparatus and method are disclosed for terminating a refrigeration unit's defrost function. The refrigeration unit comprises an evaporator, a temperature sensor to measure the temperature of the evaporator during a defrost function, and a controller configured to calculate the rate of temperature change and terminate the defrost function when the rate meets a specified criteria, such as a predetermined rate or a sharp increase in the rate after the evaporator temperature has increased above the freezing point of water.

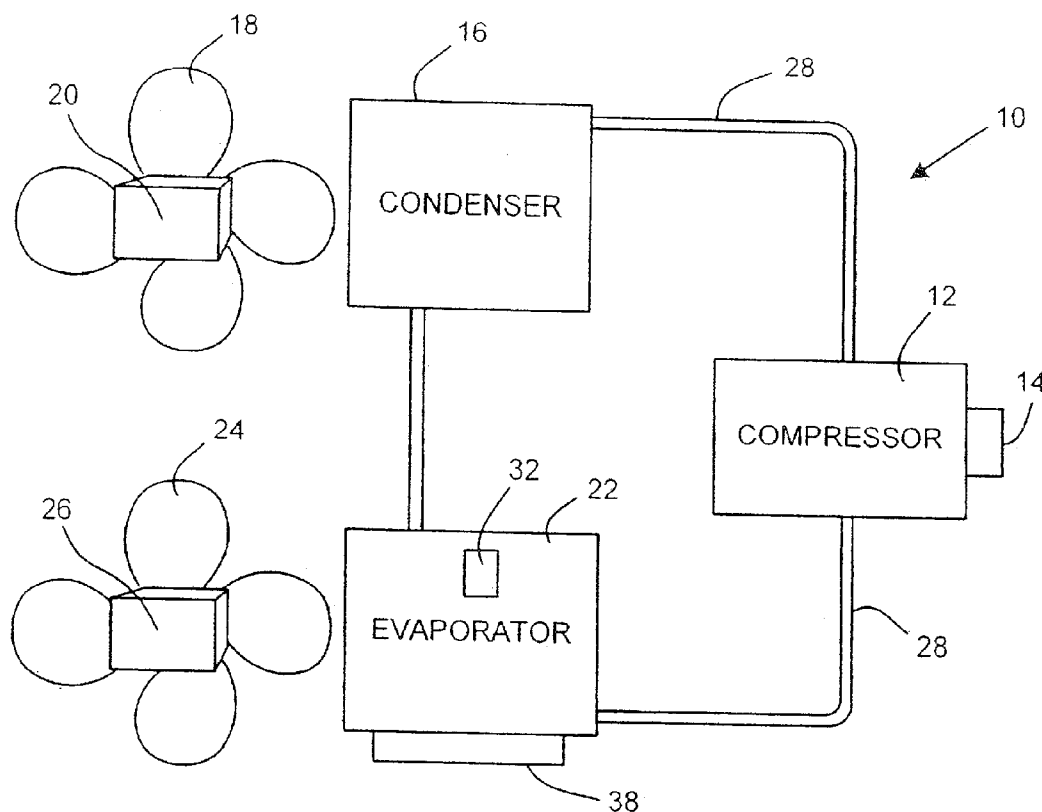
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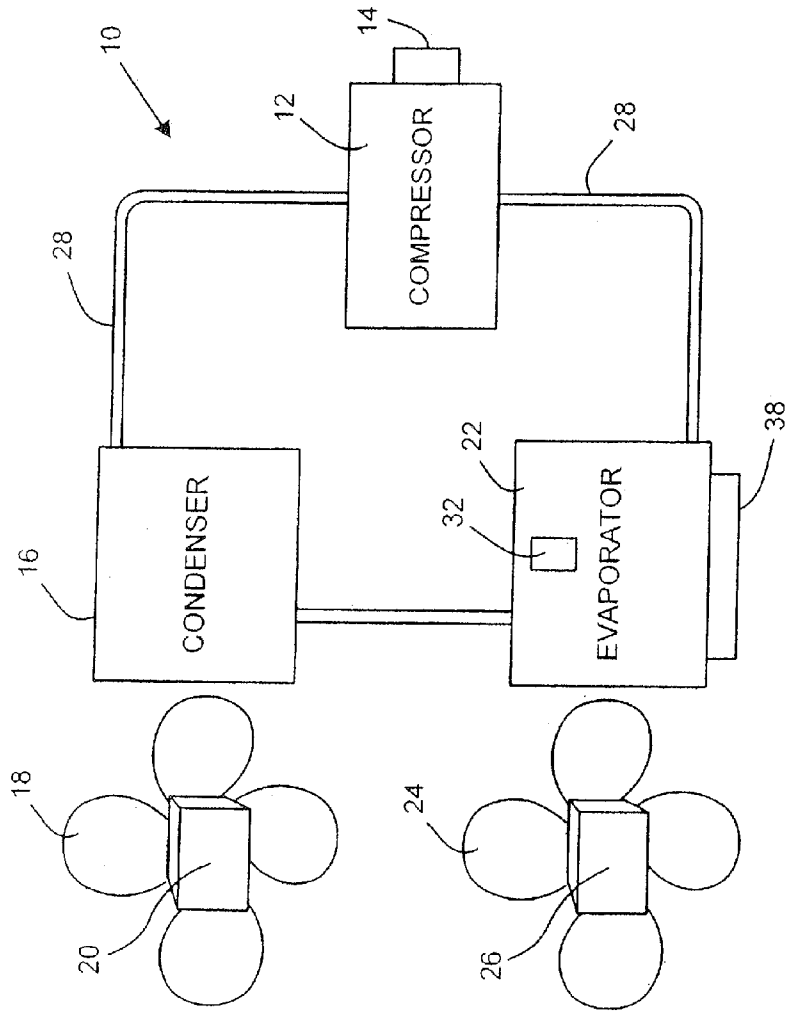


FIG. 1

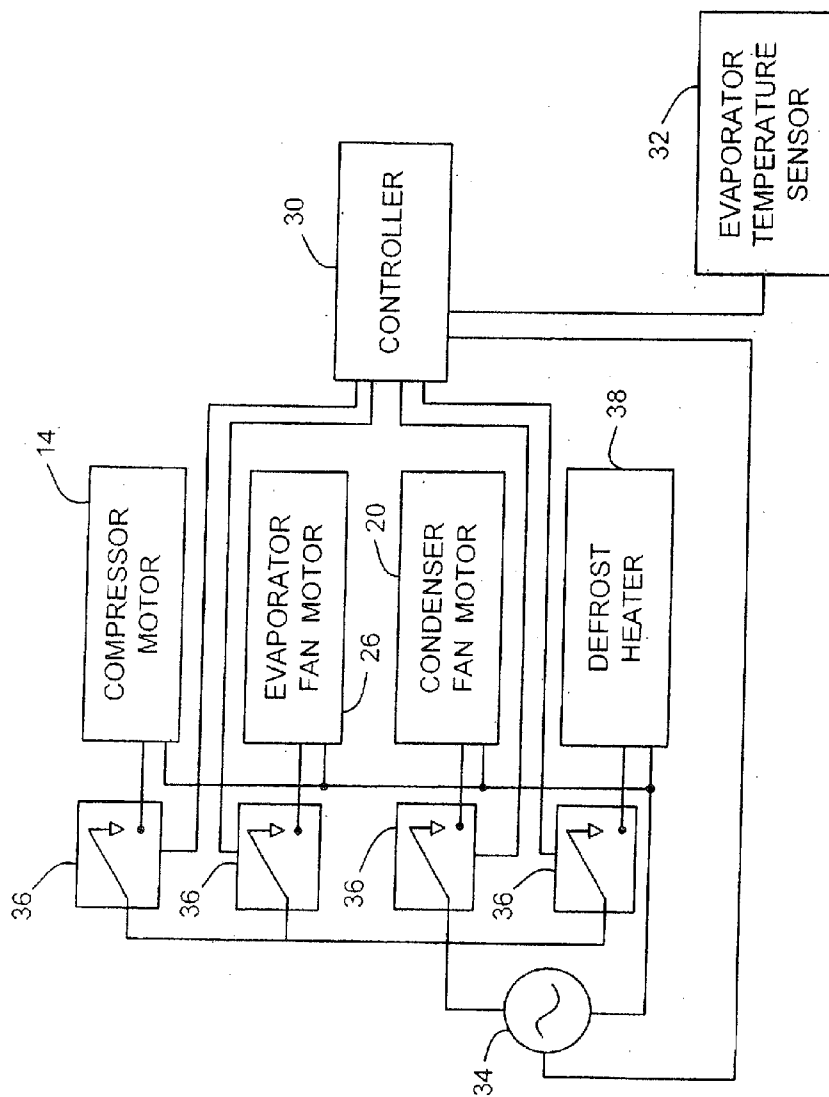


FIG. 2

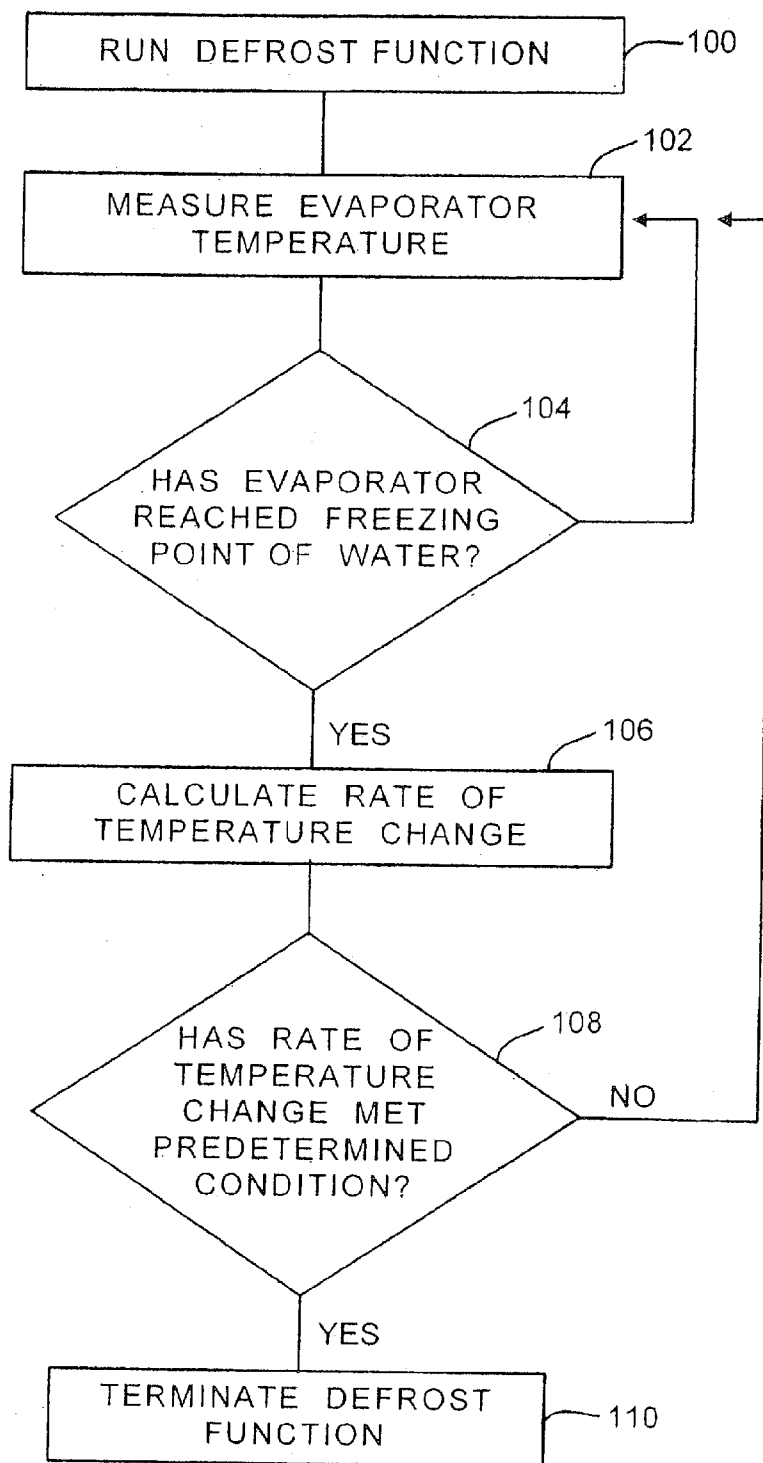


FIG. 3

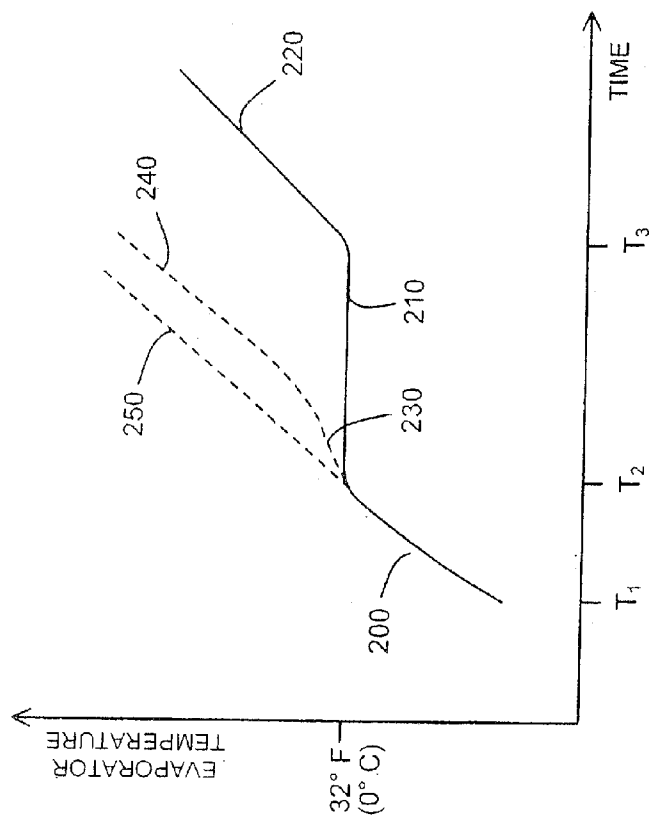


FIG. 4

MICROPROCESSOR CONTROLLED DEFROST TERMINATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] Reference is made to, and this application claims priority from and the benefit of U.S. Provisional Application Ser. No. 61/161,269, filed Mar. 18, 2009, and entitled MICROPROCESSOR CONTROLLED DEFROST TERMINATION.

BACKGROUND OF THE INVENTION

[0002] This invention relates generally to refrigerated devices having cooled enclosures, and more specifically to detecting when an accumulation of ice on an evaporator associated with the refrigerated device has been removed during a defrost operation.

[0003] Refrigeration containers include refrigeration units for cooling. As is well known in the art, a refrigeration unit has a compressor driven by a compressor motor, a condenser, a condenser fan driven by a condenser fan motor, an evaporator, and an evaporator fan driven by an evaporator fan motor. Refrigerant is circulated through the compressor, condenser, and evaporator, which are connected by refrigerant tubes. The operation of a refrigerator is controlled by a microprocessor or programmable controller. The controller is responsible for maintaining the temperature within the enclosure by controlling the refrigeration unit. More specifically, the controller regulates run times of the compressor motor, condenser fan motor, and evaporator fan motor. The controller has a time measurement device, or internal clock, to measure elapsed time for a variety of conditions.

[0004] As the refrigeration unit operates, water vapor condenses on the evaporator. When the evaporator operates at temperatures below freezing, this water freezes on the evaporator, resulting in frost and ice buildup. The frost and ice buildup restricts air flowing through the evaporator, and the ability for heat transfer to occur between the air and the evaporator, which detracts from the refrigeration unit's cooling efficiency. To enhance the efficiency of refrigerators, defrost functions are instituted, whereby the ice or frost buildup is thawed and removed.

[0005] These defrost functions typically occur periodically, often automatically when ice or frost buildup on the evaporator is detected. When the defrost function starts, the cooling process stops and the evaporator is heated rather than cooled, thereby melting the frost and ice. This heating can be accomplished by reversing the refrigeration cycle (referred to as reverse cycle defrost). Additionally, a resistive heating element can be used to assist heating the evaporator (referred to as electric defrost). In any case, the refrigeration function ceases. Running the defrost function is necessary to improve the efficiency of refrigeration. However, the defrost function consumes a lot of energy since the unit is heated during this time rather than cooled. Currently, typical defrost functions run until the evaporator reaches a specified temperature often well above the point at which all the frost or ice has been removed. Alternative defrost functions use a pressure sensor or pressure switch. Some run for a predetermined amount of time. All these functions heat the refrigerator, and hence, any items in the refrigerator for a period of time longer than necessary to fully defrost the evaporator. This effective reduc-

tion in cooling time wastes energy and increases the instability of the refrigeration container's temperature.

[0006] It would be advantageous to save energy and produce more stable, constant refrigeration temperatures by terminating the defrost function dynamically, dependent on and closer to the point in time at which ice is fully removed from the evaporator.

SUMMARY OF THE INVENTION

[0007] In one embodiment of the invention, a microprocessor controlled refrigeration unit is provided that terminates a defrost function based on the point in time at which ice or frost buildup is removed from an evaporator component of the refrigeration unit. A temperature sensor is provided to measure the temperature of the evaporator. A microprocessor is provided capable of calculating rates of temperature change in the evaporator during the defrost function, and terminating the defrost function when the rate of temperature change meets a predetermined condition or criteria.

[0008] In another embodiment of the invention, a method is provided to terminate the defrost function in a refrigeration unit based on the point in time at which ice or frost buildup is removed from an evaporator component of the refrigeration unit. During the defrost function, the rate of temperature increase is measured or calculated. When the rate of temperature change meets a predetermined condition, the defrost function is terminated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a mechanical block diagram according to one embodiment of the invention.

[0010] FIG. 2 is an electrical block diagram of a refrigeration container according to one embodiment of the invention.

[0011] FIG. 3 is a flow chart depicting operation of a defrost function termination scheme according to one embodiment of the invention.

[0012] FIG. 4 is a graphical representation showing a basis for the defrost function termination according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] In the detailed description that follows, identical components have been given the same reference numerals, and in order to clearly and concisely illustrate the present invention, certain features may be shown in somewhat schematic form.

[0014] FIGS. 1 and 2 illustrate a refrigeration unit 10 for cooling a container or device. Because refrigeration systems are well known, and the invention can be adapted to work with many, if not all conventional refrigeration units, FIGS. 1 and 2 are highly schematic. One skilled in the art will appreciate that the invention can be adapted for use in many refrigerated devices, such as, but not limited to, commercial refrigerator/freezer combinations, commercial stand-alone freezers, residential refrigerator/freezers, and transportable refrigeration containers.

[0015] Referring to FIGS. 1 and 2, the refrigeration unit 10 has a compressor 12 driven by a compressor motor 14, a condenser 16, a condenser fan 18 driven by a condenser fan motor 20, an evaporator 22 and an evaporator fan 24 driven by an evaporator fan motor 26. The motors 14, 20, and 26 can be powered by a power source 34. An optional defrost heater 38 can also be powered by the power source 34. Refrigerant is

circulated through the compressor 12, condenser 16, and evaporator 22, which are connected by tubes 28. The operation of the refrigerator 10 is controlled by a processor or programmable controller 30. By controlling power through relays 36, the controller 30 regulates when the compressor motor 12, condenser fan motor 20, evaporator fan motor 26, and optional defrost heater 38 operate.

[0016] During refrigeration, water vapor condenses on the evaporator 22 at any time the evaporator temperature is below the dew point of the air passing through. When the evaporator temperature is below the freezing point of water, the condensation on it can freeze, resulting in frost or ice buildup on the evaporator 22. This frost or ice buildup obscures the evaporator 22 and blocks its surrounding air space, causing a less efficient refrigeration process. The controller 30, through various mechanisms known in the art, periodically or as necessary, initiates a defrost function to remove any frost or ice buildup on the evaporator 22. The defrost function entails stopping the cooling operation of the refrigeration unit 10. Typically, during defrost, the refrigeration unit runs in reverse in order to heat the evaporator 22 and melt any frost or ice. Sometimes, a resistive heater 38 is used alone or in combination with the above-described method to defrost the evaporator 22. The term “defrost means” will be used to mean any combination of the above described apparatus and methods of defrosting, as well as any other apparatus and methods of defrosting.

[0017] The controller 30 has a time measurement device, or internal clock, to measure elapsed time. In one embodiment of the invention, a temperature sensor 32 is able to record the surface temperature of the evaporator 22 over continuous intervals. The temperature readings can be converted to electrical signals and electrically communicated to the controller 30. The controller 30, or another processor, is configured to calculate the rate of temperature change in the evaporator 22 using the temperature measured over time. Although FIG. 1 schematically depicts one temperature sensor 32, multiple temperature sensors 32 can be used.

[0018] Depending on the particular refrigerator, these sensors 32 can be placed on the structural support or the refrigerant tubes of the evaporator 22, as ice can collect in both places. For example, in one embodiment using a reverse cycle defrost, it can be preferable to attach sensor(s) 32 to the structural support of the evaporator 22 where ice will melt last because heating occurs from the fluid in the refrigerant tubes. In another embodiment, such as one with an electric defrost, it can be preferable to attach sensor(s) 32 to the refrigerant tubing or the structural support, or both. Lastly, it is also conceived to mount the sensors variously, so that the refrigerant inside the evaporator 22 can be measured, or the air passing through the evaporator can be measured. One skilled in the art will appreciate various locations or methods by which the temperature sensor(s) 32 can be mounted to measure the temperature inside the evaporator 22.

[0019] Referring additionally to FIG. 3, the operation of the refrigeration unit, with respect to the termination of the defrost function, is described. During the defrost function, the controller 30 monitors the temperature of the evaporator 22. The temperature sensor 32, measures the temperature of the evaporator 22, according to box 102, and provides the temperature to the controller 30. Temperature measurement does not necessarily need to be direct. Another physical characteristic of the evaporator 22 can be directly measured that can be related to temperature and used to indicate when the evaporator

22 has reached approximately the freezing point of water. For instance, the pressure inside the evaporator 22 can also be measured and used to indicate the temperature of the evaporator 22. Measuring another physical characteristic of the evaporator 22 as a proxy for temperature is considered to be “measuring the temperature” as stated herein.

[0020] When the temperature reaches approximately the freezing point of water, according to decision box 104, the controller 30 begins calculating the rate of temperature change, according to step 106. This rate can be calculated prior to this point, but proceeding to step 110 requires the temperature of the evaporator 22 to have reached approximately the freezing point of water. Furthermore, the measured temperature need not necessarily be directly compared to determine if the evaporator 22 has reached approximately the freezing point of water. This determination can be made in other ways. For instance, the decrease in positive temperature change rate that occurs in the evaporator 22 at approximately the freezing point of water can be used to determine when the evaporator 22 has reached approximately the freezing point of water. This concept is explained below with regard to FIG. 4. In accordance with decision box 108, the controller 30 continues to receive temperature readings and calculate the rate of temperature change until the rate meets a predetermined condition or criteria. The condition can be programmed into the controller 30. Once the condition has been met, the controller terminates the defrost function, box 110 of FIG. 3, by restoring normal operation of the refrigeration unit 10. By this manner of terminating the defrost function, the termination temperature floats. Rather than terminating based on a predetermined temperature of the coil, or a predetermine length of time, termination is dependent on the actual point in time ice is melted.

[0021] The schematic graphical depiction of FIG. 4 illustrates the principle behind predetermining the condition. The condition is based on qualities regarding the rate at which the temperature of the evaporator 22 rises while and after ice and frost melts off the evaporator 22. During refrigeration, the evaporator 22 operates well below the freezing point of water. During defrosting, when ice exists on an evaporator 22, the evaporator 22 is heated toward the freezing point of water. When the evaporator 22 reaches the freezing point of water, if ice is still present, the positive rate at which the evaporator temperature rises then reduces. When ice is present on the evaporator 22, the rate change can be abrupt. This significant event can be used to mark a point in time where the evaporator reaches approximately the freezing point of water. The rate remains reduced until most or all of the ice and frost melts. Because of this rate change, then, in addition to marking the actual temperature of the evaporator 22, marking the rate decrease or the difference between the rates at slope segments 200 and 210 can be used to determine the point in time when the temperature reaches the freezing point of water.

[0022] The rate change is significant, for instance, if it can be identified and distinguished. The characteristics of the rate change can vary depending on the configuration of the system, particularly as the configuration relates to the thermal transfer qualities of the system. For instance, using a higher powered resistive heater 38 can speed the melting rate and affect the noticeable change in rate as the evaporator 22 reaches the freezing point of water. Or in another instance, the steadiness in rate of temperature increase before and after it pauses at the temperature of the ice can vary according to the system configuration. Therefore, the rate change is significant

if it can be identified, and in particular, if it can be distinguished from any normal fluctuation in the steady rate. One skilled in the art will recognize ways to identify and distinguish the rate change.

[0023] After the evaporator temperature approaches the temperature of ice on the evaporator, the rate remains low until most or all of the ice melts. FIG. 4 reflects this significant pause in temperature change by the flatness of the curve over a period of time. Again, the pause can vary, this time depending further on how much ice is on the evaporator. The pause is significant in that it is detectable and distinguishable. At the end of the pause, when the ice and frost has mostly or fully melted, the temperature increase resumes. There occurs a sharp increase in the rate of temperature change. This is the point in time at which the defrost function will be terminated. Similar to the decline when the evaporator temperature approaches the freezing point of water, the increase will be significant.

[0024] This principle can be used to predetermine the condition upon which the controller relies to terminate the defrost function. With regard to predetermining the termination condition, in one embodiment, the value to which the rate increases after the ice fully melts is predetermined and programmed into the controller 30. When the measured rate reaches or exceeds the predetermined rate, the defrost function is terminated. In another embodiment, a minimum acceleration in temperature change rate is programmed into the controller. When that minimum acceleration is met, the controller terminates the defrost function. In yet another embodiment, the pause in temperature rise is detected and used to terminate the defrost function. For instance, the predetermined condition can be the detection of a pause or disruption in the rate for a length of time. In another embodiment, the difference between the rates represented by the slope segments 210 and 220 is used to determine when to terminate the defrost function. Other alternatives relying on the rate at which temperature changes, as depicted in FIG. 4, are conceived that one skilled in the art would recognize to be equivalent and within the scope of the invention.

[0025] In an alternate situation, if the evaporator 22 reaches the freezing point of water when heated during the defrost function, and little or no ice is present (i.e. it has been entirely or almost entirely melted already) then there may be no change, little change, an insignificant change, or a very brief change in the rate at which the temperature of the evaporator rises. The transition from slope segment 200 through 230 to 240 depicts an instance in which very little ice is present when the evaporator temperature approaches and exceeds the freezing point of water. The slope adjusts for a short period of time. The transition from slope segment 200 to 250 depicts an instance in which no ice is present. There is no change or almost no change in the rate of temperature increase. In the case where the rate change is insignificant, undetectable, or not meaningful, then the measured temperature of the evaporator 22 can still be used to determine the evaporator 22 has reached the freezing point of water. Then, the predetermined condition that the rate of temperature rise would have to meet to signal the controller 30 to terminate the defrost function would be the absence of any significant or detectable change after the evaporator reached approximately the freezing point of water.

[0026] Alternative embodiments of the refrigeration unit exist, as well, consistent with the scope of the invention that would be recognized by those skilled in the art. For instance,

one such embodiment would be the incorporation of the above-disclosed defrost function termination based on rate of temperature change with a time-sensitive termination feature. That is, as a safety mechanism to prevent the chance of a prolonged heating of the refrigeration unit, the controller can be programmed to terminate the defrost function if it exceeds a certain time limit, or if the evaporator 22 exceeds a certain temperature or pressure. Other examples include the addition of fail safes, known in the art, to ensure operation of the refrigeration unit and defrost function if one or more components or features, such as the temperature sensor(s), fail to work.

[0027] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A refrigeration unit comprising:
 - an evaporator;
 - defrost means for defrosting said evaporator;
 - at least one temperature sensor in measurable connection with said evaporator; and
 - at least one controller communicatively connected to said at least one temperature sensor, wherein said at least one controller is configured to calculate a rate of temperature rise and to terminate operation of said defrost means when said rate exhibits a predetermined criteria.
2. The refrigeration unit of claim 1, wherein said predetermined criteria is a predetermined rate.
3. The refrigeration unit of claim 1, wherein said predetermined criteria is a significant increase.
4. The refrigeration unit of claim 1, wherein said at least one controller is further configured to determine a point in time at which said temperature has risen to a freezing point of water.
5. The refrigeration unit of claim 4, wherein said predetermined criteria is a predetermined rate after said point in time.
6. The refrigeration unit of claim 4, wherein said predetermined criteria is a significant increase after said point in time.
7. The refrigeration unit of claim 4, wherein said predetermined criteria is a lack of significant increase after a specified length of time starting at said point in time.
8. The refrigeration unit of claim 1, wherein said predetermined criteria is a significant increase after a significant decrease.
9. A method for terminating a refrigerator defrost function, the method comprising:
 - initiating a function to defrost an evaporator in a refrigeration unit;
 - measuring the temperature of said evaporator during said function to defrost said evaporator;
 - calculating a rate of temperature change of said evaporator, said calculation based on said measured temperature; and
 - terminating said function to defrost when said rate of temperature change exhibits a specified criteria.

10. The method of claim **9**, further comprising the step of determining a first point in time at which said temperature of said evaporator reaches approximately the freezing temperature of water.

11. The method of claim **10**, wherein said point in time is determined by a significant decline in said rate of temperature change

12. The method of claim **9**, wherein said specified criteria is a predetermined value.

13. The method of claim **9**, wherein said specified criteria is a significant increase.

14. The method of claim **10**, wherein said specified criteria is a lack of significant increase after a specified duration of time starting at said point in time.

15. The method of claim **9**, wherein said step of measuring occurs at continuous intervals over a length of time.

16. The method of claim **9**, wherein said step of calculating occurs at continuous intervals over a length of time.

17. A method for terminating a refrigerator defrost function, the method comprising:

operating a defrost function in a refrigeration unit;
measuring the rate of temperature increase of an evaporator during said defrost function; and
terminating said defrost function based on said rate of temperature change.

18. The method of claim **17**, the terminating step occurring when a significant increase is detected in said rate of temperature change.

19. The method of claim **17**, said terminating step occurring when a said rate of temperature change exceeds a predetermined rate value.

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