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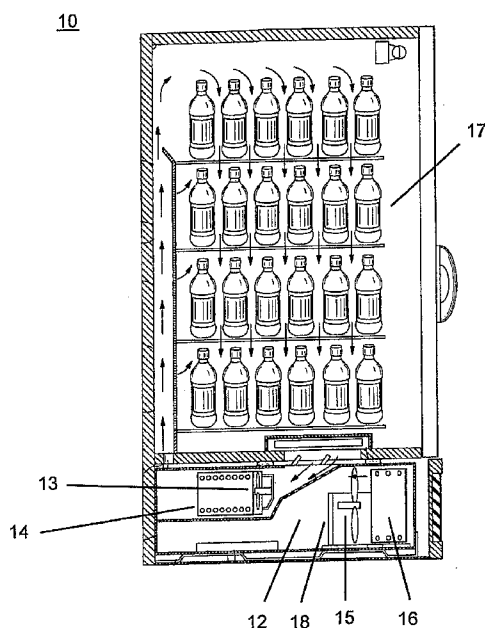
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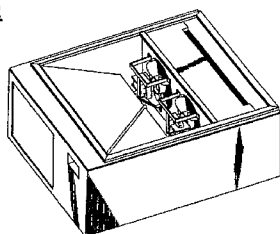
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[Continued on next page]

(54) Title: EVAPORATOR FAN MOTOR CONTROL IN A REFRIGERATED MERCHANDISER



12



A

(57) Abstract: A refrigeration apparatus having an evaporator fan motor control includes an evaporator to remove heat energy from the air in a cooled storage space. The evaporator transfers the heat energy to a refrigerant. At least one evaporator fan moves air from the cooled storage space across the evaporator to improve the transfer of heat energy into the refrigerant. The one or more evaporator fans have an energy consumption and generate a waste heat energy. A refrigeration control unit at least controls the operation of the one or more evaporator fans. During an off mode, the one or more evaporator fans are operated in a reduced energy consumption mode to reduce the energy consumption of the one or more evaporator fans and to reduce the waste heat while still defrosting the evaporator in the off mode.

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Evaporator Fan Motor Control in a Refrigerated Merchandiser

Field of the Invention

[0001] This invention relates generally to a method and apparatus for the operation of evaporator fans and more particularly to the operation of evaporator fans in refrigerated merchandisers.

Background of the Invention

[0002] Merchants of refrigerated beverages, snacks, and perishable foods typically use refrigerated merchandisers to market these products. Refrigerated merchandisers generally comprise a cooled storage space with shelves and a compressor, an evaporator, and a condenser to carry out a refrigeration cycle to cool the storage space. One or more evaporator fans blow storage space air over an evaporator, typically transferring heat energy from the storage space air to a circulating refrigerant in the evaporator coil to facilitate the refrigeration process. Also, one or more condenser fans blow ambient room air to cool the condenser, removing heat energy from the refrigerant.

[0003] When the refrigerator is actively cooling the storage space in an “on mode”, both the condenser and evaporator fans are commanded on. Following a cooling on mode, the evaporator fan is typically left running to defrost the evaporator, but the time required to defrost the evaporator is usually shorter than the compressor off cycle that follows each on mode. Also, the operation of the evaporator fan motor itself adds heat to the refrigerated merchandiser cabinet. The problem is that operation of the evaporator fan beyond what is needed to defrost the evaporator wastes the energy needed to run the fan and needlessly adds heat to the refrigerated merchandiser, much of which ultimately ends up in the cooled storage space.

[0004] Therefore, there is a need for an evaporator motor control that can reduce evaporator fan motor energy consumption during the compressor off cycle.

Summary of the Invention

[0005] A refrigeration apparatus having an evaporator fan motor control includes an evaporator to remove heat energy from the air in a cooled storage space. The evaporator transfers the heat energy to a refrigerant. At least one evaporator fan moves air from the cooled storage space across the evaporator to improve the transfer of heat energy into the refrigerant. The one or more evaporator fans have an energy consumption and generate a waste heat energy. A refrigeration control unit at least controls the operation of the one or more evaporator fans. During an off mode, the one or more evaporator fans are operated in a reduced energy consumption mode to reduce the energy consumption of the one or more evaporator fans and to reduce the waste heat while still defrosting the evaporator in the off mode.

Brief Description of the Drawings

[0006] For a further understanding of these and objects of the invention, reference will be made to the following detailed description of the invention which is to be read in connection with the accompanying drawing, where:

[0007] FIG. 1 shows a refrigerated merchandiser;

[0008] FIG. 1A shows a refrigerated merchandiser cassette;

[0009] FIG. 2 a block diagram including refrigeration electrical controls;

[0010] FIG. 3 shows an embodiment of evaporator fan control using two fan speeds;

[0011] FIG. 4 shows an embodiment of evaporator fan control using control of multiple fans;

[0012] FIG. 5 shows an embodiment of evaporator fan control based on defrosting;

[0013] FIG. 6 shows a graph of power consumption versus time for an evaporator fan control using two fan speeds; and

[0014] FIG. 7 shows a table of energy savings for the evaporator fan control of FIG. 6.

Detailed Description of the Invention

[0015] FIG 1 shows a refrigerated merchandiser 10 suitable for the system and method of inventive evaporator fan operation. Refrigerated merchandiser 10 can cool storage space 17 using the well known refrigeration cycle. Three of the major components used to carry out the refrigeration cycle are evaporator 14 (typically including an evaporator coil), condenser 16, and compressor 18. In operation (the “on mode”) one or more evaporator fans 13 draw air from interior storage space 17 over evaporator 14 removing heat from the air and returning cooler air to interior storage space 17. A refrigerant circulated through evaporator 14 (not shown) is thus heated. The heated refrigerant is later cooled by condenser 16 working in conjunction with one or more condenser fans 15 to remove heat from the refrigerant and dissipate it into a flow of cooler ambient room air. The majority of the refrigeration components of refrigerated merchandiser 10 can be assembled into a refrigeration cassette 12 as shown in FIG 1A. Refrigeration cassette 12 can be made conveniently removable from refrigerated merchandiser 10 for ease of servicing. Such an exemplary refrigerated merchandiser is explained in more detail in PCT/US05/33078, “*Evaporator fan/motor assembly support bracket*”, filed September 16, 2005 and incorporated herein by reference in its entirety.

[0016] FIG. 2 shows refrigeration controls (refrigeration control unit) 21 used to at least control the operation of one or more evaporator fan(s) 13 and typically to also control the one or more condenser fans 15 and the operation of compressor 18. During a refrigeration cooling cycle (“on mode”), compressor 18 is powered and both evaporator fans 13 and condenser fans 15 are in operation. In conventional operation, at the end of a refrigeration cycle (“off mode”), the compressor and condenser fans are turned off, but the evaporator fans continue to operate. During the off mode, evaporator fan operation is used to defrost evaporator coil 14. However, in most instances, the time required to defrost evaporator 14 is shorter than the compressor off cycle. Therefore the evaporator fan is running much longer than required.

[0017] The heat added to refrigerated merchandiser by evaporator fan 13 is approximately 30% to 50% of the total cooling load of the merchandiser. According to the invention, power to evaporator fan(s) 13 can be reduced when full operation

of the fan(s) 13 is not required during the off cycle to defrost evaporator coil 14. The energy savings is two fold. First there are direct savings by the reduction in electrical power consumption by fan(s) 13 and secondly, fan(s) 13 create less waste heat that ultimately ends up in cooled storage space 17 because refrigeration cassette 12 is located in the merchandiser below cooled storage space 17.

[0018] According to a preferred embodiment of the invention, as shown in FIG. 3, during a cooling on cycle, the compressor is on and one or more evaporator fans 13 are operating at high speed. At the completion of the on cycle, active cooling of storage space 17 ends when compressor 18 is shut off. During the off cycle, the one or more evaporator fan(s) 13 are set by refrigeration controls 21 to a low speed. The low speed operation of evaporator fans 13 reduces the direct electrical energy needed to run the fan(s) 13 as well reduces the waste fan heat that is introduced into storage space 17 as a result of the heat energy generated by the operation of fan(s) 13. It should be noted that while the electrical energy to fan(s) 13 is significantly lower during an off cycle, there is still sufficient air flow through evaporator 14 to defrost it.

[0019] An additional improvement in efficiency (not shown in FIG. 3) can be gained by adding a third fan speed, such that the one or more evaporator fan(s) 13 are set by refrigeration controls 21 to a third higher fan speed, during an initial cool down period ("pull down") of storage space 17. The third higher fan speed can be especially useful during high refrigeration loading situations, such as when new products are added to refrigerated merchandiser 10. One method to detect the addition of newly added products is to detect a temperature rise in storage space 17.

[0020] In another embodiment of the invention, shown in FIG. 4, during a cooling on cycle, the compressor is on and N evaporator fans 13 are operating at an operating speed. At the completion of the on cycle, active cooling of storage space 17 ends when compressor 18 is shut off. During the off cycle, the one or more (M) evaporator fans 13 are turned off leaving (N-M) fans still running at the operating speed. The reduced number of operating evaporator fan(s) 13 reduces the direct electrical energy needed to run the remaining (N-M) fan(s) 13 as well reducing the amount of waste fan heat introduced into storage space 17 as compared to the heat energy generated by the operation of N fan(s) 13. It should be noted that while the

electrical energy to fan(s) 13 is significantly lower during an off cycle, there is still sufficient air flow through evaporator 14 to defrost it.

[0021] An additional improvement in efficiency (not shown in FIG. 4) can be gained by adding additional fans P, such that (N+P) fan(s) evaporator fan(s) 13 are turned on by refrigeration controls 21, during an initial cool down period ("pull down") of storage space 17. The additional airflow caused by the operation of (N+P) fan(s) evaporator fan(s) 13 can be especially useful during high refrigeration loading situations, such as when new products are added to refrigerated merchandiser 10.

[0022] In yet another embodiment of the invention, shown in FIG. 5, during a cooling on cycle, the compressor is on and N evaporator fan(s) 13 are operating at an operating speed. At the completion of the on cycle, active cooling of storage space 17 ends when compressor 18 is shut off. During the off cycle, the one or more evaporator fan(s) 13 are still running at the operating speed until the temperature of evaporator 14 rises to a level indicating that evaporator 14 is defrosted, or some other method of defrost detection as known in the art indicates that evaporator 14 defrosted. One way to detect a defrost condition at evaporator 14 is by temperature sensing to determine when the temperature of evaporator 14 has risen a predetermined amount above the freezing point of water as can be accomplished using temperature sensors, including bimetal switch, bimetallic sensor, thermistors, resistance temperature devices (RTDs), thermocouples, and infrared (IR) sensors. When it is detected that evaporator 14 is defrosted, evaporator fan(s) 13 can be turned off by refrigeration controls 21.

[0023] It should be noted that refrigeration controls 21 can comprise electromechanical switches, relays, or contactors to control fan(s) 14, fan(s) 15, and compressor 18. Fan speeds can also be set by using multi-speed fans with dedicated power leads for each fan speed, or by a passive or active electronic fan speed control. Power semiconductor switches including SCRs, TRIACs, transistors, FETs, MOSFETs, and insulated gate bipolar transistors (IGBTs) can also be used for both on-off power controls as well as being used in electronic fan speed controls. Refrigeration controls 21 can also comprise a microcontroller, microcomputer, logic board using standard function digital logic chips or programmable logic elements,

including gate arrays, programmable gate arrays, field programmable gate arrays (FPGA), ASICs, or other suitable electronic controls including a programmable logic controller (PLC). Typically refrigeration controls 21 will comprise a mix of both digital electronic control elements and power electrical switching elements as described above.

[0024] It should also be noted that any type of fan suitable to move air across evaporator 14 can be used to practice off cycle energy savings afforded by the various embodiments of the invention. Suitable fan types include propeller blade fans, blowers, and squirrel cage fans.

[0025] It should be noted that the inventive method and apparatus for controlling evaporator fan operation in refrigerated merchandisers is not limited to refrigerated merchandisers and can more generally be applied to other types of refrigeration equipment.

[0026] **example:**

[0027] A simulation of the preferred embodiment where evaporator fan speed is reduced during the cooling off mode was carried out. The graph of FIG. 6 shows a comparison of standard operation of refrigerated merchandiser according to the prior art compared to operation of the evaporator fans at a reduced speed during the off mode according to the invention. The graph is a plot of electrical power consumption (in Watts) plotted versus relative units of time, such as numbered sample points (on a scale of 0 to 1200). The solid curve shows the power consumption of an exemplary refrigerated merchandiser operated with the evaporator fans always on at a single fixed motor speed. The dotted curve, overlapping the solid curve during common operation over the on cycle, shows the dramatic power savings with a two speed evaporator motor dropped to a low speed during the off mode. FIG. 7 is a table that shows the cost savings achieved by the reduced need for electrical power by a refrigerated merchandiser operated according to the invention. In this simulation example, it can be seen that with an overall 2.8% reduction in energy consumption, a cost savings of approximately \$6 per year or at least \$73 can be achieved over a 12 year product life cycle.

[0028] The power and cost figures of the example are merely an illustration of one simulated case and do not reflect any limits on the potential energy saving possible using any of the aforementioned embodiments of the invention.

[0029] While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawing, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the invention as defined by the claims.

We Claim:

1. A refrigeration apparatus having an evaporator fan motor control comprising:
 - an evaporator to remove heat energy from the air in a cooled storage space, the evaporator to transfer the heat energy to a refrigerant;
 - at least one evaporator fan to move air from the cooled storage space across the evaporator to improve the transfer of heat energy into the refrigerant, the one or more evaporator fans having an energy consumption and generating a waste heat energy; and
 - a refrigeration control unit to at least control the operation of the one or more evaporator fans; wherein during an off mode, the one or more evaporator fans are operated in a reduced energy consumption mode to reduce the energy consumption of the one or more evaporator fans and to reduce the waste heat while still defrosting the evaporator in the off mode.
2. The refrigeration apparatus of claim 1 wherein the reduced energy consumption mode comprises operating the evaporator fan at a reduced speed in the off mode as compared to the on mode.
3. The refrigeration apparatus of claim 2 wherein the evaporator fan is run at an increased speed in a pull down mode as compared to the on mode.
4. The refrigeration apparatus of claim 1 wherein the reduced energy consumption mode in the off mode comprises turning off at least one of a plurality of two or more evaporator fans that operate in the on mode.
5. The refrigeration apparatus of claim 4 wherein a pull down mode comprises turning on at least one more evaporator fan than the number of evaporator fans that run during the on mode.

6. The refrigeration apparatus of claim 1 wherein the reduced energy consumption mode comprises operating the evaporator fan in the off mode until an evaporator defrost condition is detected, and then turning off the evaporator fan until the next on cycle.

7. The refrigeration apparatus of claim 6 wherein a defrost condition is detected by sensing the temperature of the evaporator using a sensor selected from the group of sensors consisting of a bimetal switch, a bimetallic sensor, a thermistor, a thermocouple, a RTD, and an IR sensor.

8. The refrigeration apparatus of claim 1 wherein the refrigeration apparatus is a refrigerated merchandiser.

9. The refrigeration apparatus of claim 1 further comprising:

a condenser to remove at least some of the heat deposited in the refrigerant and to transfer the removed heat to ambient air in the vicinity of the refrigeration apparatus;

at least one condenser fan to move ambient air across the condenser to improve the transfer of heat energy from the refrigerant to the ambient air; and

a compressor to increase the pressure of the refrigerant causing it to flow through the evaporator and the condenser.

10. A method to reduce energy consumption in a refrigerator comprising the steps of:

a. blowing air to be cooled from the refrigerated space of the refrigerator across an evaporator to transfer heat from a space to be cooled to a refrigerant with one or more evaporator fans during a refrigeration compressor on mode;

b. reducing the energy consumption of the one or more evaporator fans during a compressor off mode while still defrosting the evaporator during the compressor off mode.

11. The method of claim 10 wherein reducing the energy consumption of the one or more evaporator fans during a compressor off mode comprises reducing the speed of the one or more evaporator fans while still defrosting the evaporator during the compressor off mode.

12. The method of claim 10 wherein reducing the energy consumption of the one or more evaporator fans during a compressor off mode comprises turning off one or more of the evaporator fans while still defrosting the evaporator during the compressor off mode.

13. The method of claim 10 wherein reducing the energy consumption of the one or more evaporator fans during a compressor off mode comprises turning off the evaporator fans after an evaporator defrost condition had been detected during the compressor off mode.

14. The method of claim 13 wherein reducing the energy consumption of the one or more evaporator fans during a compressor off mode by turning off the evaporator fans after an evaporator defrost condition had been detected comprises reducing the energy consumption of the one or more evaporator fans during a compressor off mode by turning off the evaporator fans after an evaporator defrost condition had been detected by a temperature sensor during the compressor off mode.

15. A refrigeration apparatus having an evaporator fan motor control comprising:

an evaporator means for removing heat energy from the air in a cooled storage space, the evaporator means to transfer the heat energy to a refrigerant;

an evaporator fan means for moving air from the cooled storage space across the evaporator to improve the transfer of heat energy into the refrigerant, the

evaporator fan means having an energy consumption and generating a waste heat energy; and

a refrigeration control means for controlling at least the operation of the evaporator fan means; wherein during an off mode, the evaporator fan means is operated in a reduced energy consumption mode reducing the energy consumption of the evaporator fan means and reducing the waste heat while still defrosting the evaporator in the off mode.

16. The refrigeration apparatus of claim 15 wherein the reduced energy consumption mode comprises the refrigeration control means operating the evaporator fan means at a reduced speed in the off mode as compared to the on mode.

17. The refrigeration apparatus of claim 15 wherein the reduced energy consumption mode in the off mode comprises the refrigeration control means turning off at least one fan of the evaporator fan means that operate in the on mode.

18. The refrigeration apparatus of claim 15 wherein the reduced energy consumption mode comprises the refrigeration control means operating the evaporator fan means in the off mode until an evaporator defrost condition is detected by a defrost detection means, and then turning off the evaporator fan until the next on cycle.

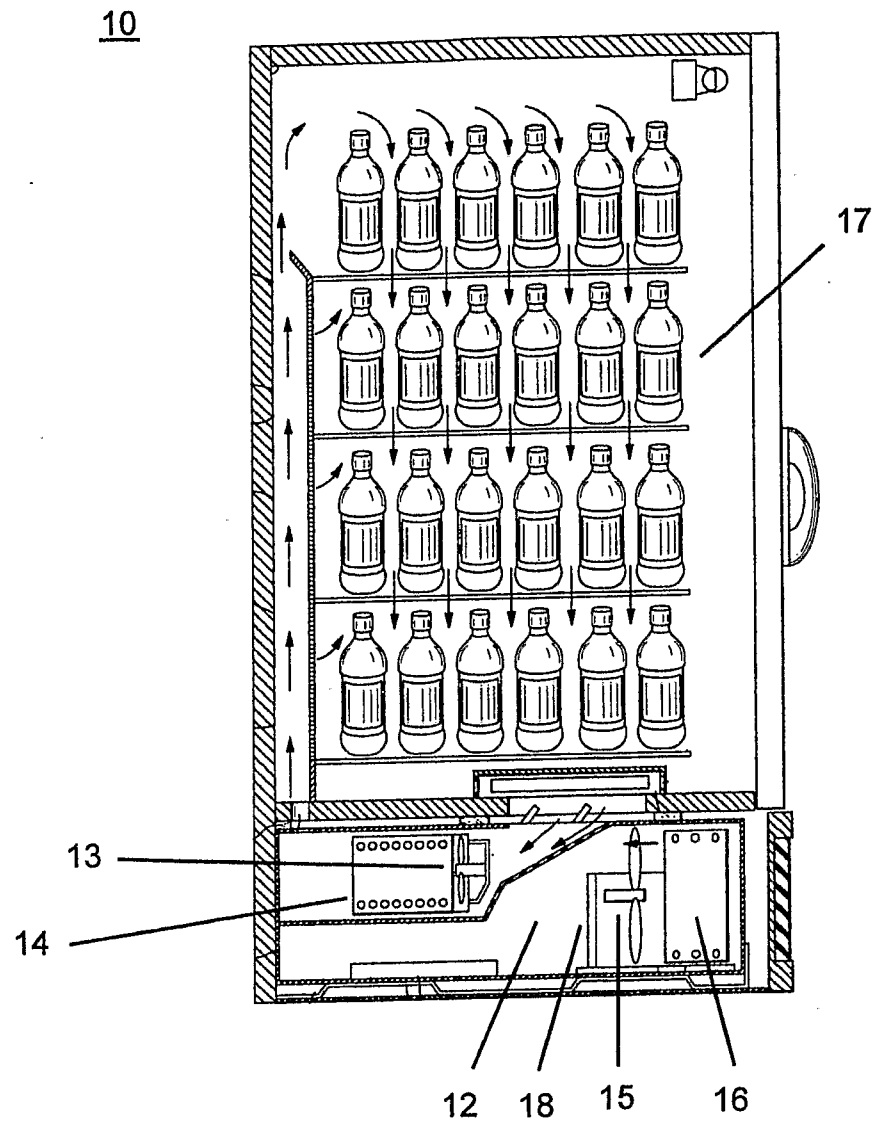
19. The refrigeration apparatus of claim 15 further comprising:

a condenser means for removing at least some of the heat deposited in the refrigerant and to transfer the removed heat to ambient air in the vicinity of the refrigeration apparatus;

a condenser fan means for moving move ambient air across the condenser to improve the transfer of heat energy from the refrigerant to the ambient air; and

a compressor means for increasing the pressure of the refrigerant causing it to flow through the evaporator and the condenser.

FIG. 1



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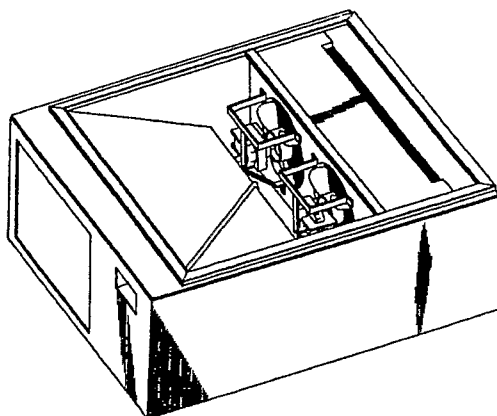


FIG. 1A

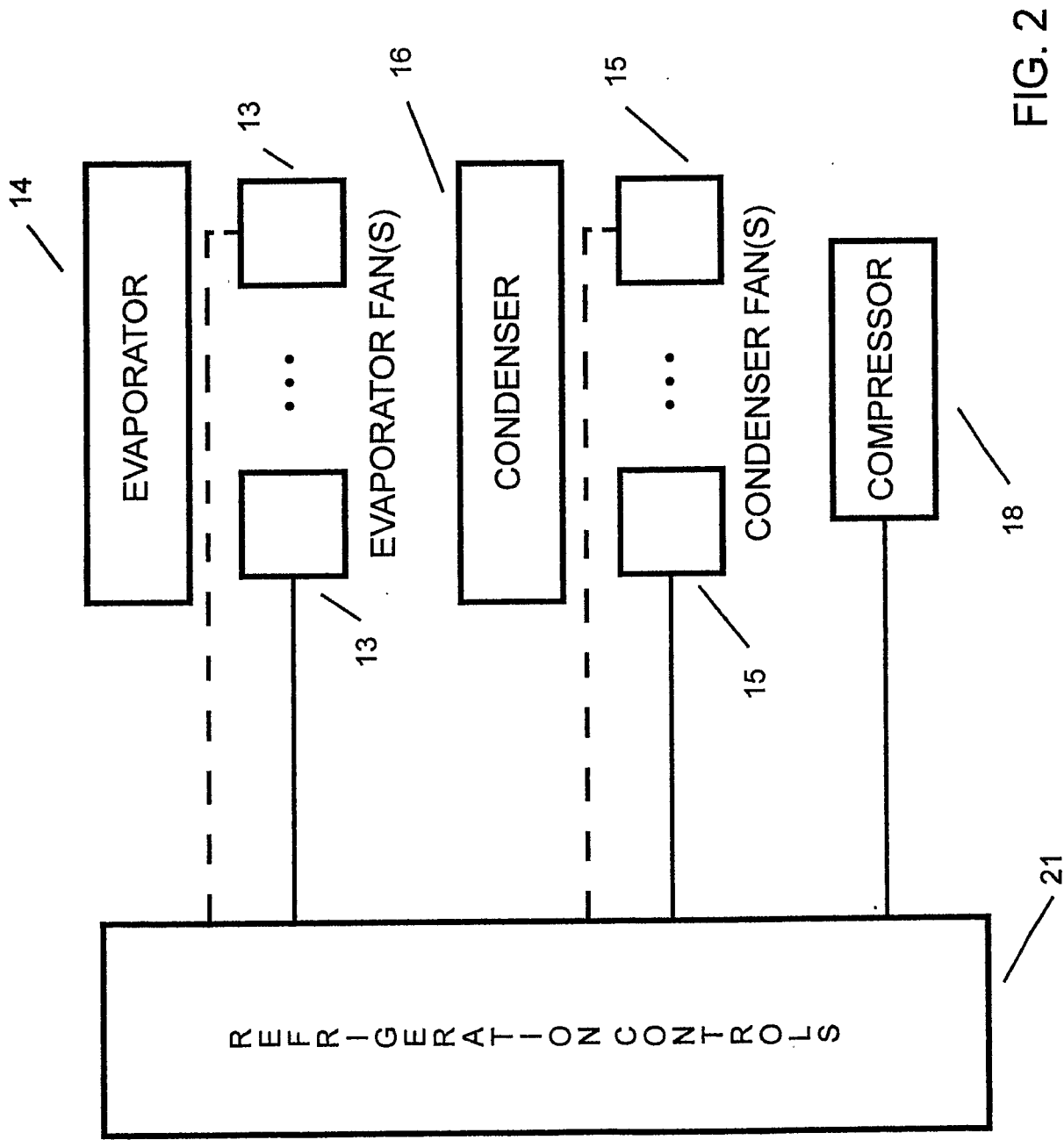


FIG. 2

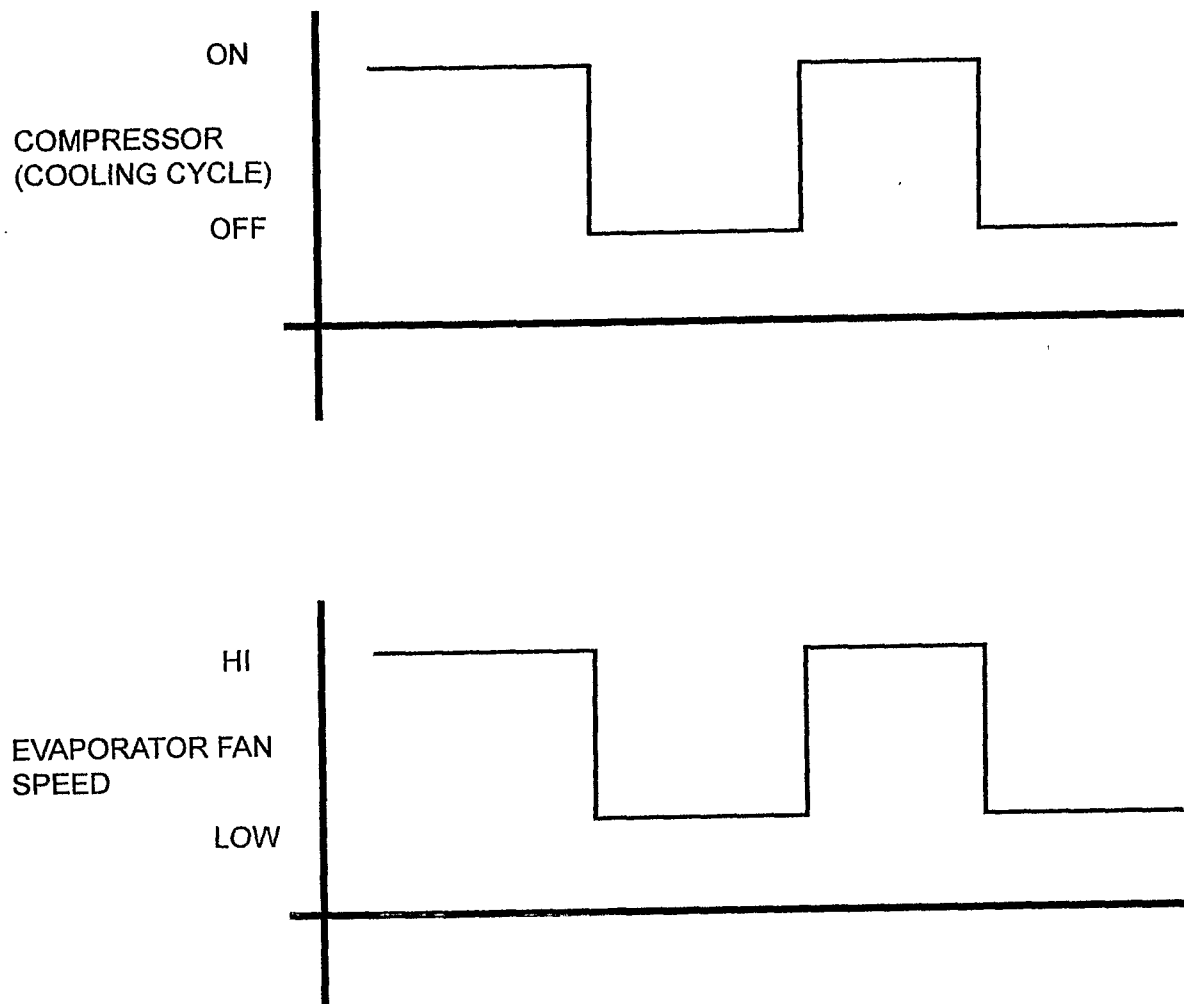


FIG. 3

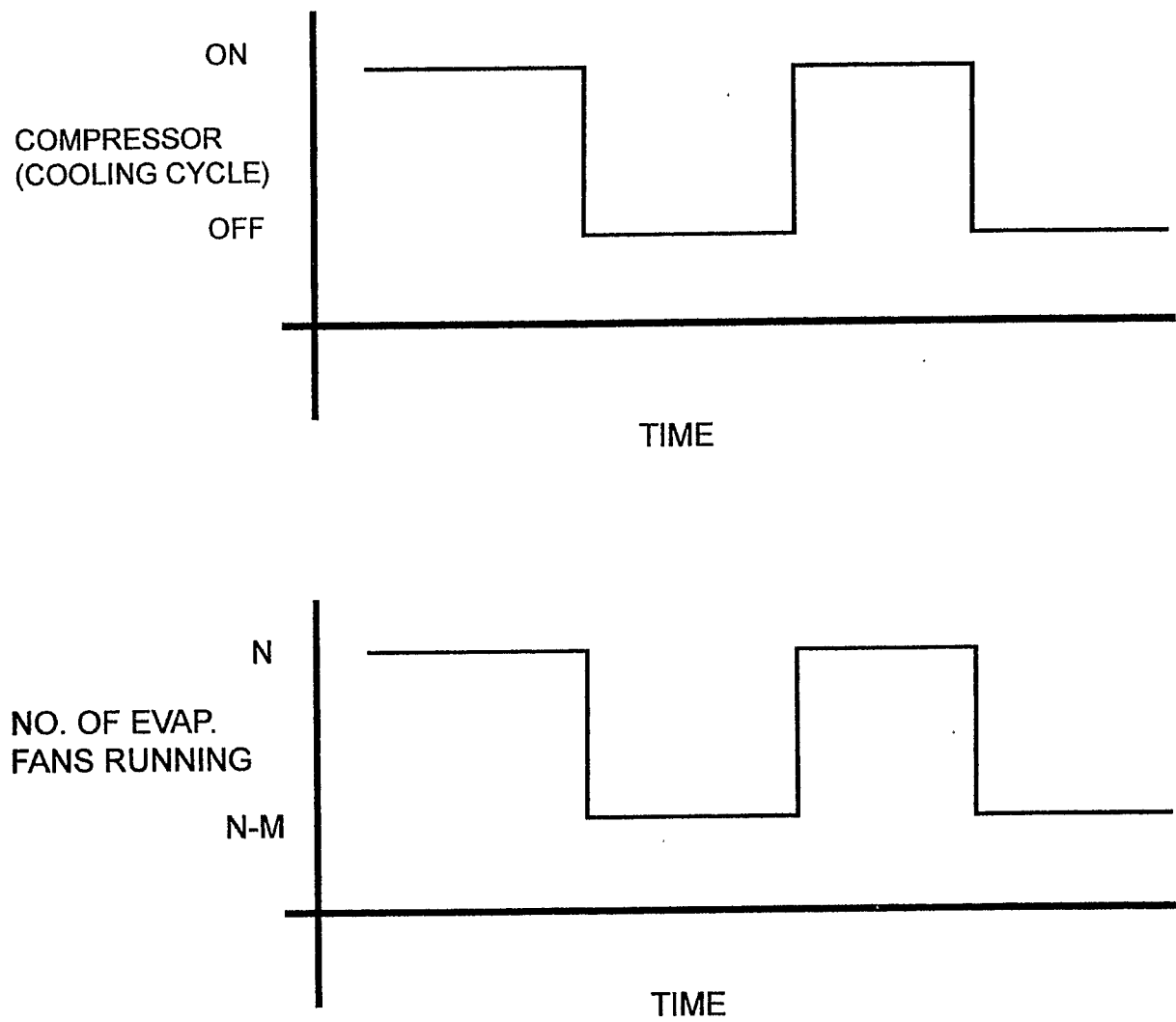


FIG. 4

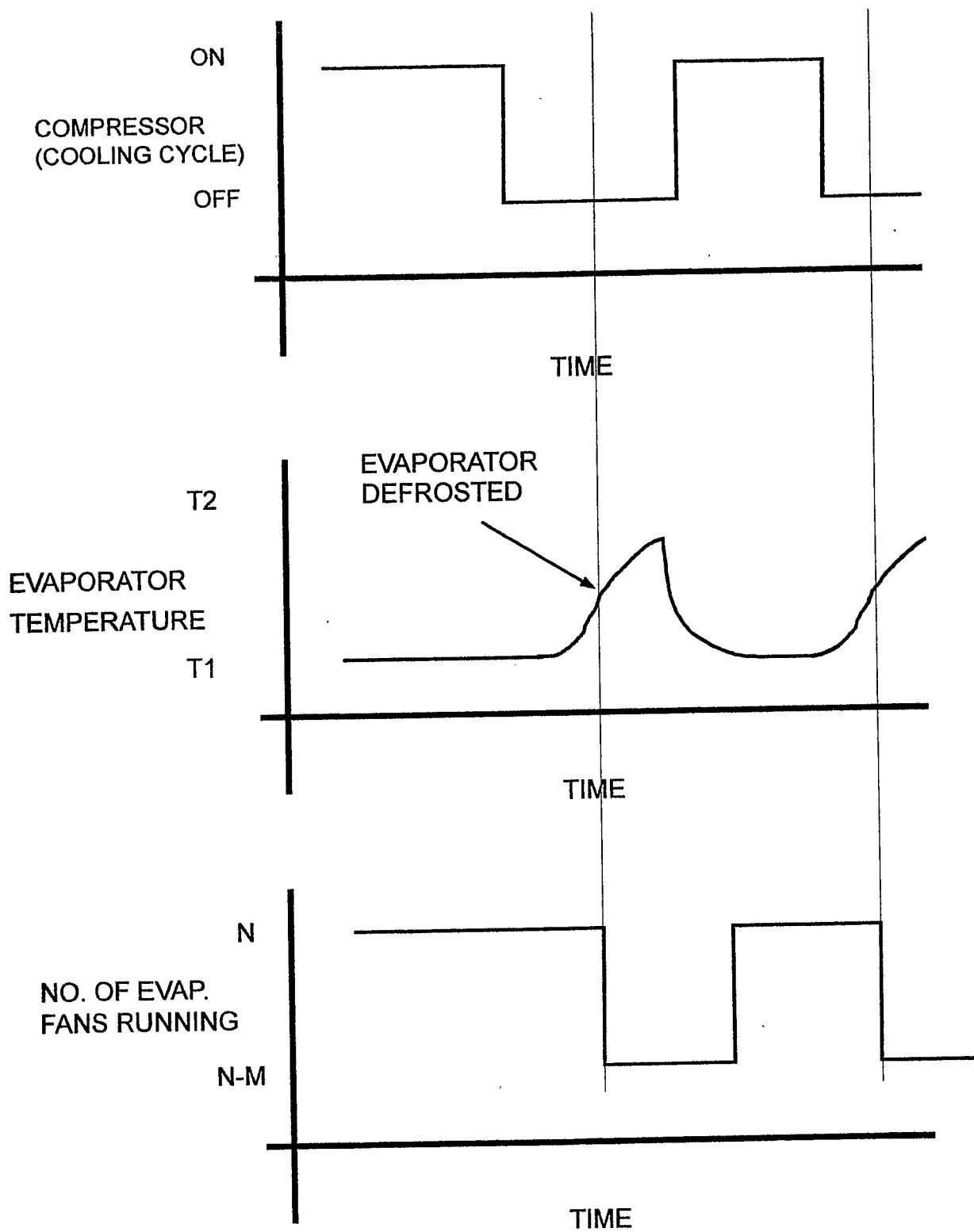


FIG. 5

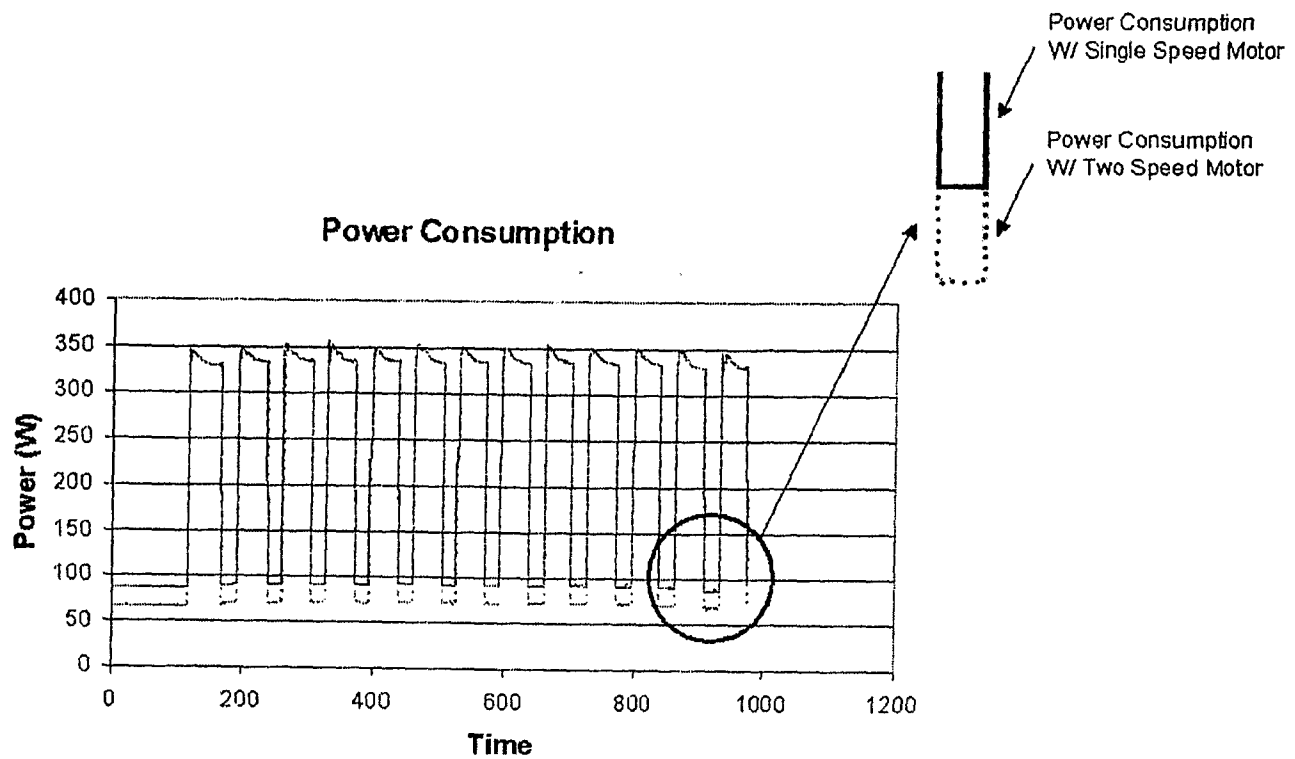


FIG. 6

	1 spd	2 spd
average Power	252	245
kwh/day	6.04	5.87
kwh/year	2204	2143
Cost @\$0.1/kwh	220.40	214.29

2.8% Energy Consumption Reduction

\$ 6.11 Savings per year

\$ 73.36 Savings per 12 year life of product

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US06/19756

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - (2006.01) - F25D 17/00

USPC - 62/180

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)

IPC(8) (2006.01) - F25D 17/00

USPC - 62/180

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)

USPTO EAST System (US, USPG-PUB, EPO, DERWENT), MicroPatent, IP.com, DialogPro Search terms: "additional fan", "evaporator fan", "evaporator fans", "extra fan", "increased speed", "pull down", "reduced energy consumption", "reduced energy", "temperature sensor", bimetallic, Daddis, defrost, fan, and refriger*.

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 2004/0050075 A1 (KING et al.) 18 March 2004 (18.03.2004) see paragraphs [0028], [0049], [0051].	1, 4, 8, 9, 10, 12, 15, 17 and 19 ----- 5, 6, 7, 13, 14 and 18
X --- Y	US 3,877,243 A (KRAMER) 15 April 1975 (15.04.1975) see the entire document.	1, 2, 10, 11, 15 and 16 ----- 3
Y	US 4,021,213 A (NEIDHARDT et al.) 03 May 1977 (03.05.1977) see the abstract and claim 1.	5
Y	GB 21 45 208 A (KING et al.) 20 March 1985 (20.03.1985) see page 4, lines 12-19.	6, 7, 13, 14 and 18
Y	US 5,187,941 A (TERSHAK et al.) 23 February 1992 (23.01.1992) see column 8, lines 32-36.	6, 7, 13, 14 and 18
Y	JP 64-63773 A (SHOZO) 09 March 1989 (09.03.1989) see the abstract.	3

☐ Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search

28 October 2006

Date of mailing of the international search report

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