United States Patent

Coyle et al.

[15] **3,694,925**

[45] **Oct. 3, 1972**

[54] **HUMIDITY CONTROL IN A TEMPERATURE CONTROLLED RAILWAY CAR**

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[21] Appl. No.: **69,852**

[52] **U.S. Cl.** **34/46,** 34/50, 34/77, 62/288, 98/6, 165/21, 105/247

[51] **Int. Cl.** **F26b 21/08**

[58] **Field of Search** 165/21; 62/288; 34/27, 46, 34/50, 77; 98/6; 105/247

[56] **References Cited**

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2,584,727	2/1952	Mellen	34/50 X
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3,486,241	12/1969	Coyle et al.	34/22
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2,195,781	4/1940	Newton	165/21 X

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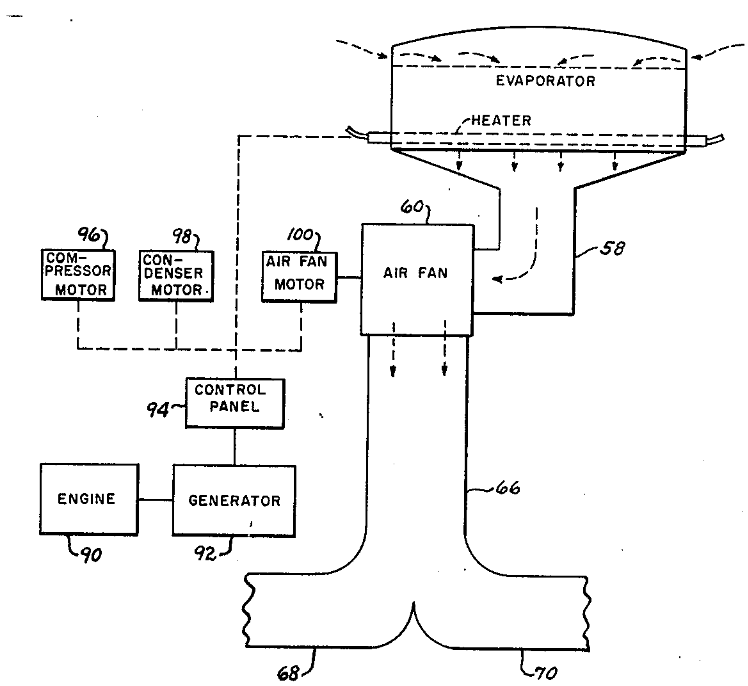
[57] **ABSTRACT**

Thermostatically controlled apparatus for heating or cooling air circulated through a closed railway car is modified so that in a temperature zone near the thermostat setting, where in prior systems the heating or cooling would be stopped, the circulated air is cooled and heated simultaneously to reduce humidity or remove moisture from the air.

The railway car normally transports fresh fruit or vegetables and the moisture content of the fresh produce may be maintained within a specific range as the air being reintroduced within the car has a moisture content.

2 Claims, 6 Drawing Figures



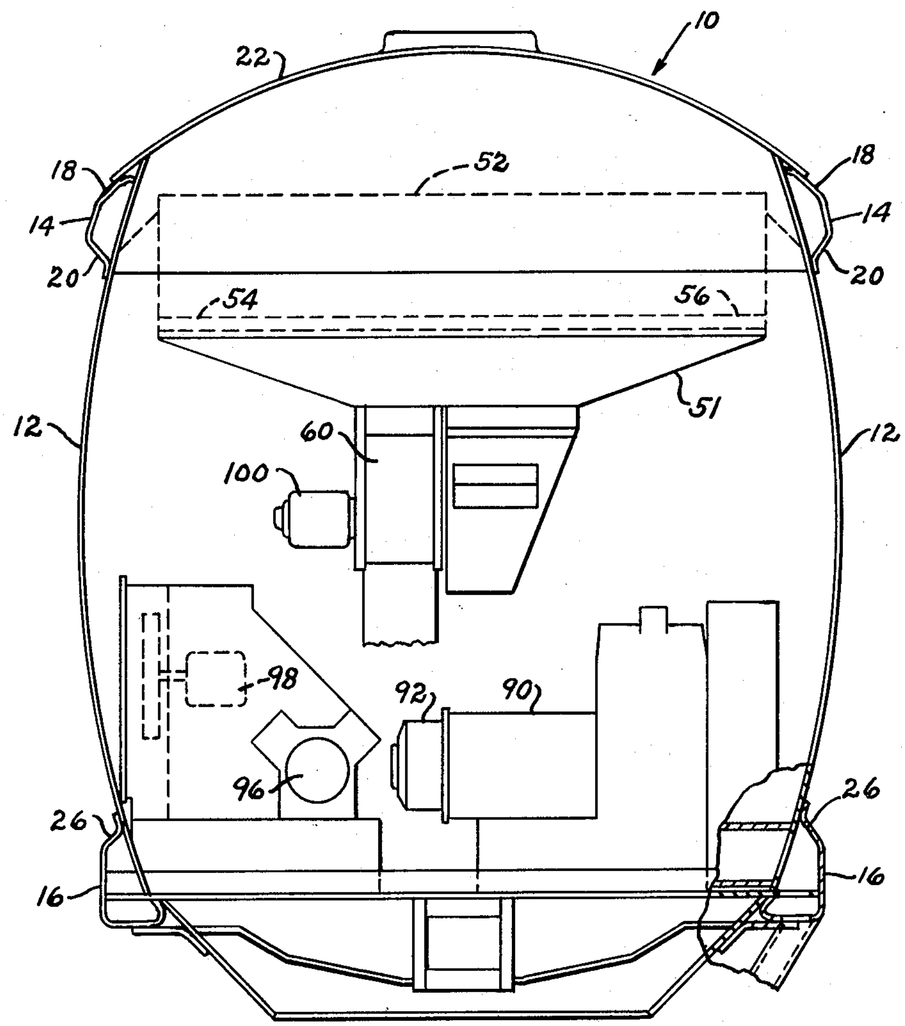


FIG. 1.

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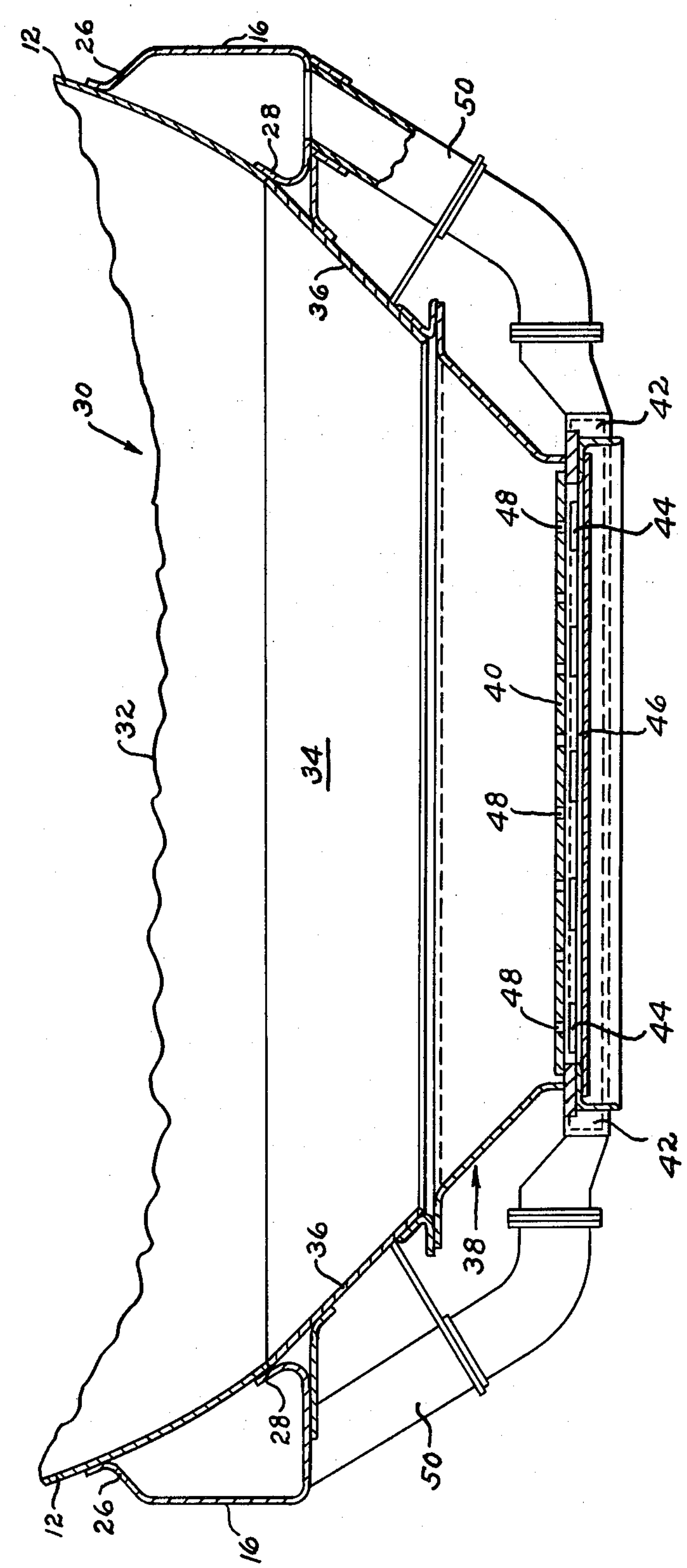

FIG. 2.

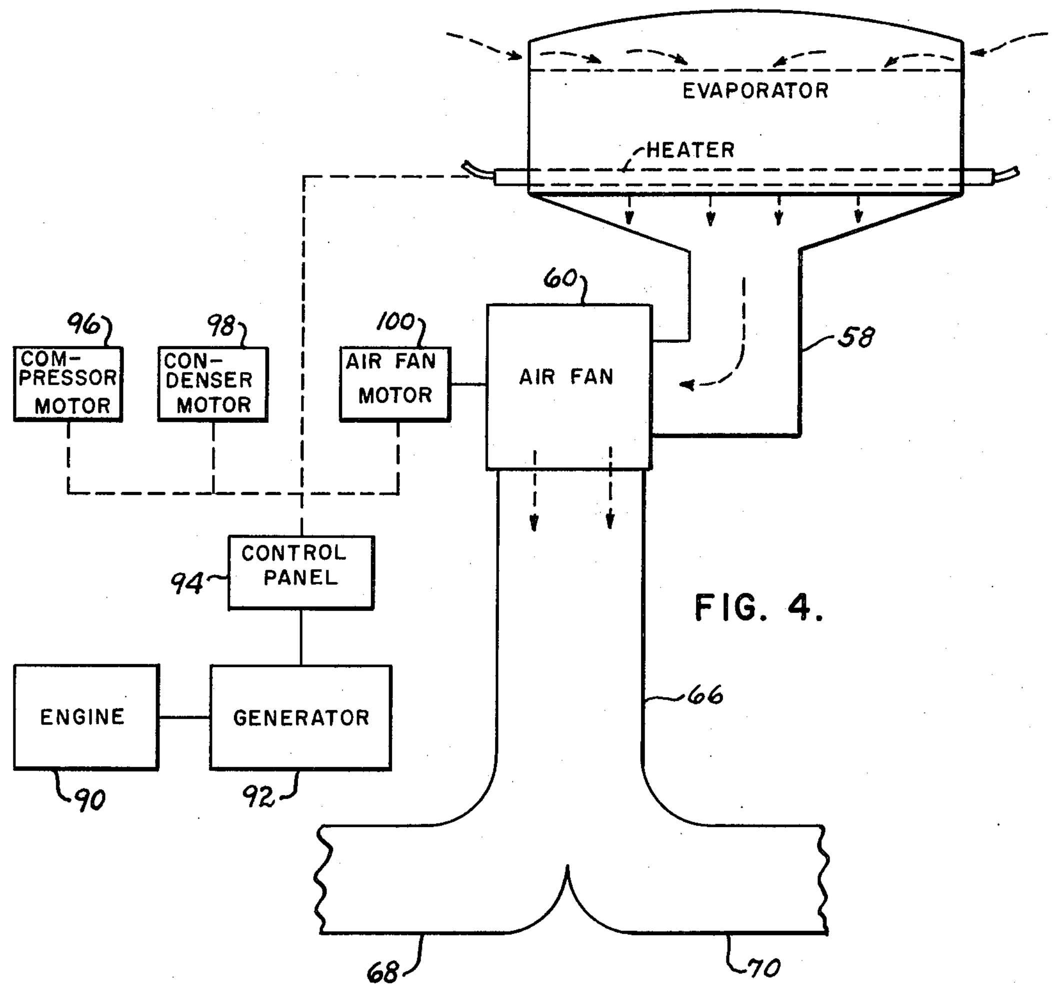
EVAPORATOR
HEATER
60
58
96
COM-PRESSOR MOTOR
98
CON-DENSER MOTOR
100
AIR FAN MOTOR
AIR FAN
CONTROL PANEL
94
ENGINE
GENERATOR
90
92
66
68
70

FIG. 4.

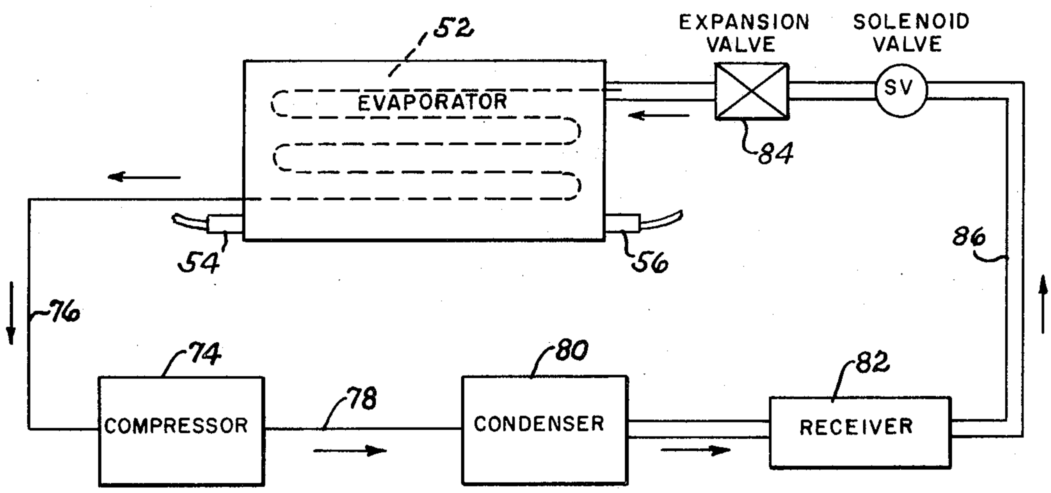
52
EVAPORATOR
EXPANSION VALVE
SOLENOID VALVE
SV
84
86
54
56
76
74
COMPRESSOR
78
80
CONDENSER
82
RECEIVER

FIG. 3.

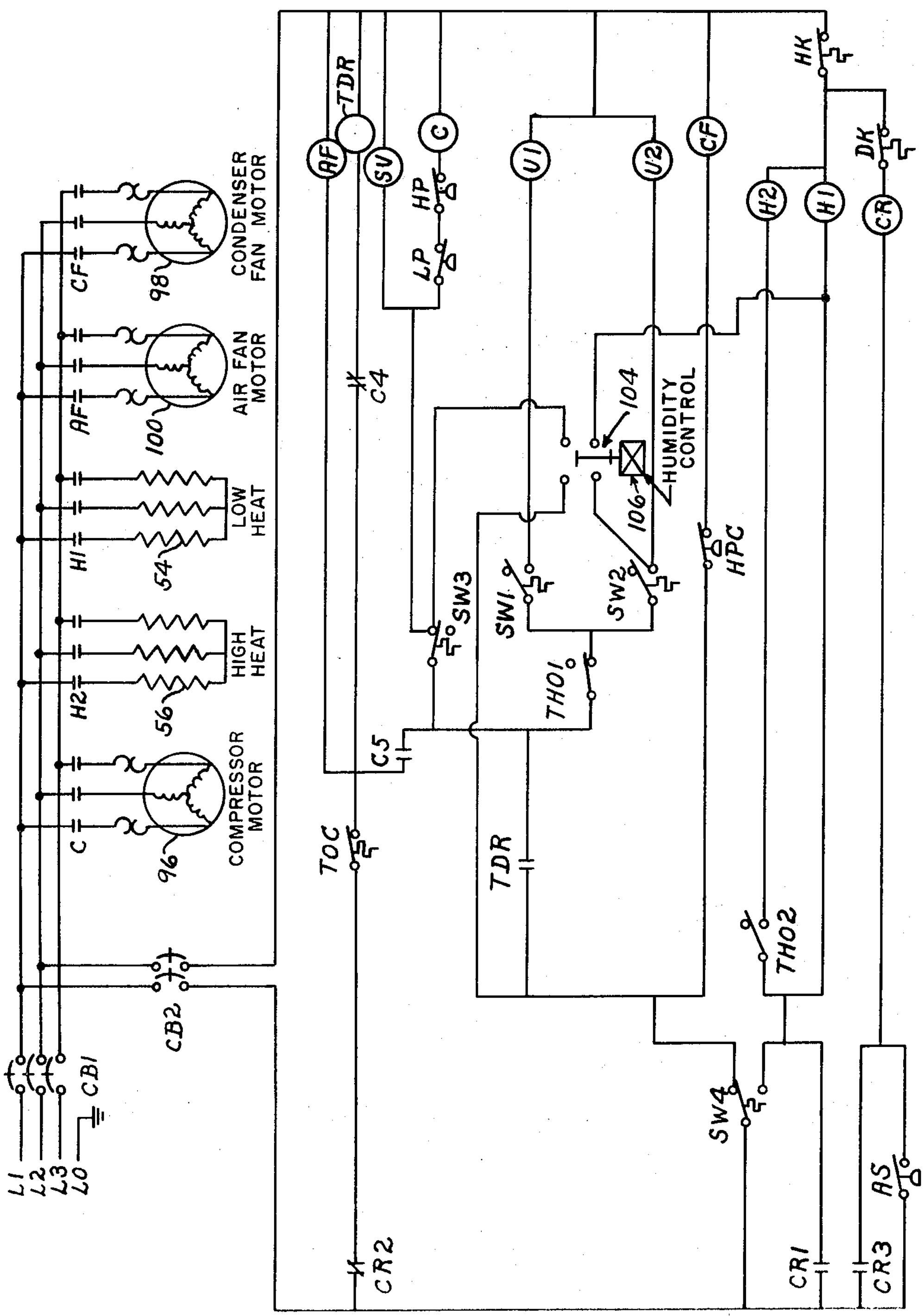
CONDENSER FAN MOTOR
98
CF
AIR FAN MOTOR
100
AF
LOW HEAT
54
H1
HIGH HEAT
56
H2
COMPRESSOR MOTOR
96
C
CB2
CB1
L1
L2
L3
L0
TDR
AF
SV
C
HP
LP
C4
U1
U2
CF
HK
DK
H2
H1
CR
104
106
HUMIDITY CONTROL
SW3
SW1
SW2
HPC
THO1
C5
TOC
TDR
THO2
SW4
AS
CR2
CR1
CR3

FIG. 5.

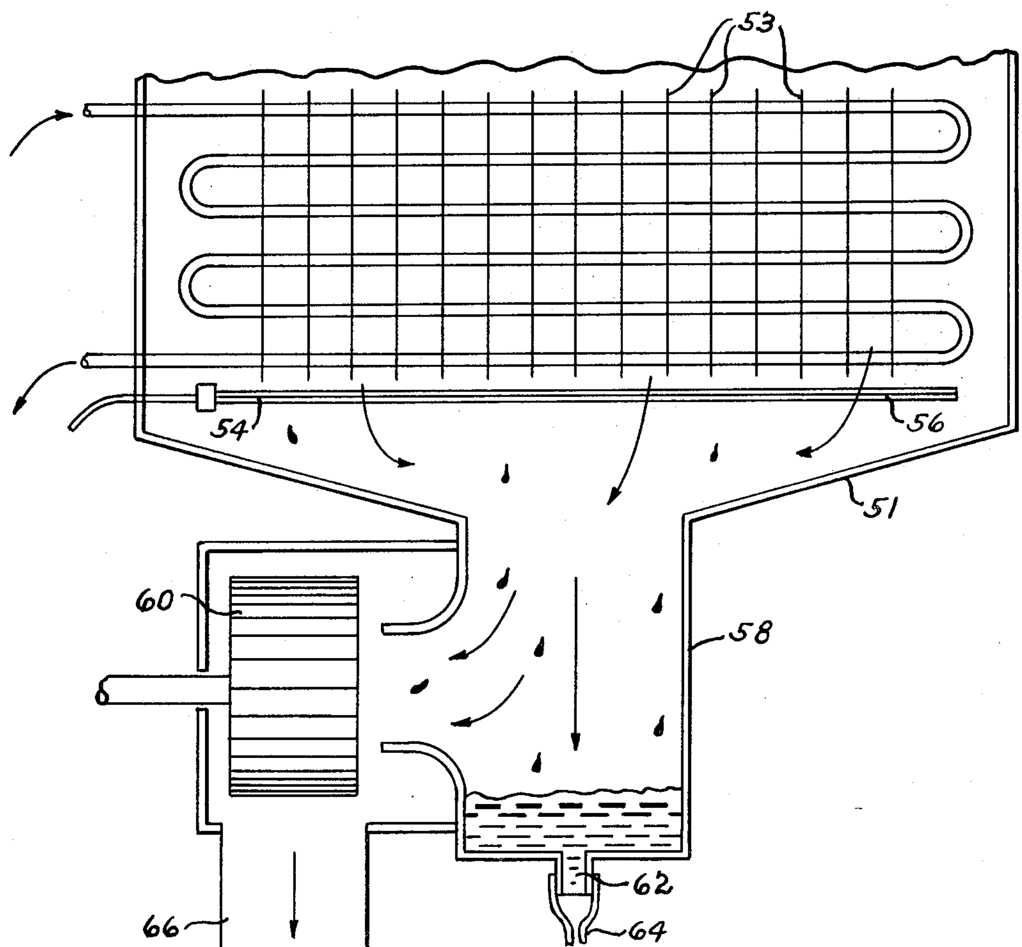

FIG. 6.

HUMIDITY CONTROL IN A TEMPERATURE CONTROLLED RAILWAY CAR

BACKGROUND OF THE INVENTION

This invention pertains to controlling the aeration of a railway car in transit and heating or cooling the air. A system for thus aerating a railway car is disclosed in U.S. Pat. No. 3,486,241. In such prior systems a thermostat is set to a desired temperature and a control circuit causes either heating or cooling of the air circulated through the car to bring it to about the desired temperature, and then the heating or cooling is stopped as long as the temperature remains within a given range, called the holding zone or dead zone.

Fruits and vegetables are living organs even though separated from the plant. Because fruits and vegetables are alive "they breathe" or take in oxygen and give off carbon dioxide which is known as respiration. During the respiratory process, moisture is sometimes emitted which needs to be removed from the car to eliminate any excess moisture content from the fruits and vegetables. The moisture content varies with the type of fruit or vegetable and with the temperature of the commodity.

Excessive moisture content may be in certain commodities, such as fresh fruits or vegetables, due to storage conditions or to a partially deteriorated condition. For example, potatoes in a partially deteriorated condition may emit an excess amount of moisture when placed within the car. Further, depending on ambient temperatures, excessive condensation may occur within the car such as the roof areas of the car during cold weather and this condensation may be partially absorbed by the commodity.

The quality of fruits and vegetables is affected by the amount of moisture in the air surrounding them in transit. A high relative humidity of around 90 percent is desirable in most commodities to minimize any deterioration and to have the commodity in top quality upon unloading. An excess of moisture in the commodity might require an excessive drying time after the commodity is unloaded and before it is processed. Thus, in addition to a specific temperature range for the commodity during transit, the moisture content of the commodity should be maintained within a specific range for maintaining the top quality of the commodity.

SUMMARY OF THE INVENTION

The present invention relates to a covered hopper railway car for the transport of fresh fruits and vegetables and has a recirculating air system employing both heating and cooling apparatus controlled by a circuit regulated by a thermostat. The thermostat may be manually set at a predetermined temperature, such as 60°, and means are provided to operate the heating apparatus and the cooling apparatus simultaneously in a holding zone of a few degrees around 60° F. For example, the holding zone may be between 56° F. and 61° F. when the thermostat is set at 60° F. and the heating apparatus and cooling apparatus will be operated simultaneously in this band or zone. Below 56° only the heating apparatus will be activated and above 61° only the cooling apparatus will be activated. Within the holding zone, water vapor is condensed when the air passes over evaporator coils of the cooling apparatus and removed from the circulated air. Some of the moisture may be re-evaporated when the air passes the heating apparatus for recirculation. A humidity sensitive control may be employed to permit simultaneous activation of the heating apparatus and cooling apparatus only when the relative humidity is above a predetermined amount, such as 70 percent, for example. Thus, upon the relative humidity dropping below 70 percent, neither the heating apparatus nor the cooling apparatus would be activated in the holding or dead zone.

BRIEF DESCRIPTION OF THE DRAWING point,

FIG. 1 is an end elevation of a covered hopper railway car showing heating and cooling equipment mounted thereon and certain parts broken away to show the air conduits.

FIG. 2 is a transverse section of a bottom hopper structure.

FIG. 3 is a schematic of the air conditioning cycle for cooling the returned air from the car.

FIG. 4 is a schematic showing the means for supplying power to the aerating system.

FIG. 5 is a diagrammatic view illustrating the control circuit.

FIG. 6 is a diagrammatic view illustrating the moisture removal from the air.

Referring to the drawings, a covered hopper railway car is generally indicated **10** and comprises a pair of arcuate side sheets **12**, a hollow reinforcing side plate **14** extending longitudinally along the upper marginal portion of each side sheet **12** for the length of car **10**, and a hollow side sill **16** extending longitudinally along the lower marginal portion of each side sheet **12** for the length of car **10**.

Side plate **14** is generally channel-shaped and has respective upper and lower legs **18**, **20** to form a hollow air-tight box-shaped structure. An arcuate roof **22** is secured to side plates **14**. Side sills **16**, which extend along the lower marginal portion of each side sheet **12**, have an upper leg **26** and lower leg **28** secured to the outer surface of adjacent side sheet **12** to form hollow air-tight box-shaped structures therewith.

Car **10** has a plurality of hoppers **30** separated by partitions **32**, as more fully shown in aforementioned U.S. Pat. No. 3,486,241. End slope sheets **34** and side slope sheets **36** lead to bottom discharge structures generally indicated **38**. Bottom discharge structures **38** are adapted to permit a flow of air upwardly into the lading for aerating the interior of the car in addition to permitting the discharge of lading from the car. A gravity gate **40** carried by bottom outlet structure **38** is mounted thereon for sliding movement between open and closed positions. Fixed to the bottom of each outlet structure **38** is a pneumatic conduit **42** communicating with the interior of hopper **30** through, for example, slots **44**, chamber **46** and perforations **48** in gate **40**. Conduits **42** are connected by pipes **50** to side sills **16**. The air, which is thus conveyed from side sills **16** to hoppers **30**, passes through the body of the car and into the channels formed by side plates **14**, and then into a closed chamber **51** at the top of one end of the car. Chamber **51** contains the evaporator **52** of the refrigeration apparatus and heaters **54**, **56**. Chamber **51** has a duct **58** leading to air fan or blower **60**. Duct **58** has a drain **62** which may be provided with a rubber valve or other self-opening valve **64**. The output of air fan **60** passes through conduit **66**, which divides into laterally extending conduits **68, 70** communicating with side sills **16**. Thus the air circulates through the car.

Referring particularly to FIG. **3**, in the event the exhaust air from side plates **14** is above a predetermined temperature, such as sixty degrees F, evaporator **52** will cool the air. Evaporator **52** includes a plurality of generally horizontally extending coils having vertical fins or plates **53** connected thereto with the air flowing between the plates. A conventional refrigeration cycle is employed with a refrigerant liquid in the coils absorbing latent heat from the moving air until the liquid is completely evaporated and forms a gas. A compressor **74** draws the gas through suction line **76** from evaporator **52** due to suction exerted from the pumping action of the compressor.

Compressor **74** compresses the refrigerant gas drawn from evaporator **52** and discharges the gas through line **78** to condenser **80**. Condenser **80** cools the gas and the refrigerant changes from gas to liquid. The liquid refrigerant is then collected in receiver **82** and is forced by pressure through solenoid valve SV to an expansion valve **84** in line **86** leading to evaporator **52**. The expansion valve **84** controls the flow of liquid refrigerant to evaporator **52** and is responsive to the outlet temperature of evaporator **52**. Expansion valve **84** releases the pressure of the liquid and reduces it from the condenser pressure to that of the evaporator. The reduction of pressure allows the refrigerant to boil at a low temperature since heat from the air flows through the evaporator surface into the liquid which is at a lower temperature. This refrigeration cycle is, of course, well-known and is represented in FIG. **3** without details and refinements.

To supply power for the operation of the aerating system, a diesel engine **90** drives a generator **92**. Controls for the phasing of the various operations are arranged in control panel **94**. Electric energy from generator **92** drives compressor motor **96**, condenser fan motor **98**, and air fan motor **100**.

FIG. **5** is a schematic diagram of a circuit for the apparatus. Circuit breaker CB **1** connects three phase power line L0-L3 through contactors C, H2, H1, AF, and CF and suitable overload switches to compressor motor **96**, heaters **54, 56**, air fan motor **100**, and condenser fan motor **98**. Various other control elements are connected across lines L1, L2 through circuit breaker CB2. Thermostat switches SW1 to SW4 are shown in the cooling position with the power off in FIG. **5**. When circuit breakers CB1 and CB2 are closed, current flows through the solenoids of contactors AF and CF closing them to energize air fan motor **100** and condenser motor **98**. Time delay relay TDR also receives current, and after a **60** second delay closes its contacts and permits current to flow through thermostat switches SW4 and SW3 to solenoid valve SV in the cooling apparatus. At the same time current flows through low and high pressure switches LP and HP to the coil of contactor C, closing contactor C and contacts C5 and placing compressor motor **96** in operation. The cooling system is then in operation. Contacts C4 also open causing time delay relay contacts TDR to open. When the temperature of the returned air is cooled sufficiently, switch SW3 opens, cutting off contactor C and compressor motor **96**, as well as closing valve SV. Thermal switch TOC senses the temperature of the compressor and opens if the compressor overheats, thereby opening contactor C and cutting off current to compressor motor **96**, as well as air fan motor **100**.

Compressor **74** operates fully loaded until the temperature drops near the set point of the thermostat, which senses the return air at evaporator **52**. For example, at 4° F. above the set point, switch SW1 closes, and unloader solenoid U1 is energized to unload two compressor cylinders. At about 1° F. above the set point switch SW2 closes and solenoid U2 unloads two more compressor cylinders. At the set point SW3 opens. Contactor C then opens to stop compressor operation and thus stop cooling, and places the apparatus in a holding mode, with the evaporator fan operating. Condenser fan motor **98** is kept in operation because contactor CF is energized through switch SW4 and head pressure control switch HPC. Fan motor **98** continues to operate until the refrigerant pressure drops below the setting of the head pressure control switch HPC. Also, in this mode, time delay relay TDR is energized and liquid line solenoid valve SV is not energized. If switch **104** were not present, the apparatus would remain in this condition until the temperature of return air at the evaporator rose to about one degree above the set point of the thermostat, and then thermostat switch SW3 would close and the cooling cycle resume. The effect of switch **104** will be described below.

If the temperature of returned air drops 4° F. or more below the setting of the thermostat, switch SW4 throws to its other position to start a heating cycle. Heat contactor H1 is then energized through overheat switch HK, which is adjusted to open at some excessive temperature. For rapid heat up of a cold car in preparation for loading, additional heaters **56** are required, and these are energized by designing switch THO2 to close when the thermostat is turned up to "preheat" which is above 85° F. on the dial. Closing switch TH02 causes contactor H2 to connect heaters **56** to the power circuit. During normal or "preheat" heating, contactor AF closes to operate air fan motor **100**, and time delay relay TDR is energized and closed. The heaters are energized until the temperature at the thermostat rises to within 3° of its set point. Then, switch SW4 returns to its original position and disconnects from contactors H1 and H2.

When the temperature is within the zone from, for example, 3° below set point up to the set point, neither the heaters or the cooling system are operating unless switch **104** is manually activated. The evaporator fan **100** is in operation in this holding zone to circulate air through the car. Switch **104** when manually activated causes both the heaters **54** and the compressor **74** to operate in this holding zone to remove moisture from the air.

When the switch is manually activated and the temperature at the thermostat rises to within 3° of its set point as described above, contactor C is then energized through SW4 and the upper contacts of switch **104**. Compressor motor **96** is started and liquid line solenoid SV is opened. Contacts C5 close, providing a holding circuit for contactor C after contacts TDR open as a result of opening of contacts C4. Contactor CF is energized via SW4 to start condenser fan motor **98**. Thus the cooling apparatus is placed in operating condition. Further, heater **54** is reconnected to power line L1-L3, since contactor H1 is energized through contacts C5, THO1, SW2, and the lower contacts of switch **104**. The cooling apparatus and heater **54** are operative in the holding zone between about 3° F. below and 1° F. above the thermostat set point. After being in the dead zone for some time following a heating cycle, generally the temperature of the air at the evaporator begins to drop again. Switches SW1-SW4 require about a 1° F. differential to actuate, and at about 4° F. below the thermostat set point, switch SW4 reverses and contactor C opens. Thus, while the holding zone is between about 3° F. below and 1° F. above the thermostat set point, the simultaneous heating and cooling is between about 4°F. below and 2° F. above the thermostat set point since switches SW1-SW4 require a 1° differential to actuate. Switch **104** as described above is manually activated by the shipper if it is desired to remove excess moisture from the lading. In some instances, excess moisture may not be present and switch **104** will not be activated. Thus, neither the cooling apparatus nor the heating apparatus will be activated in the holding or dead zone.

Alternately, a humidity sensitive control **106** may be provided to activate switch **104** when the relative humidity rises above a preset level. For example, humidity control **106** may be set for activating switch **104** when the relative humidity within the railway car reaches 80 percent and for deactivating switch **104** when the relative humidity drops below 80 percent.

If frost blocks the evaporator coil **52** so that a preset differential pressure across the coil is exceeded, switch AS is closed to initiate automatic defrosting. Relay CR then operates, closing contacts CR1 and CR3. The air or evaporator fan **60** and the compressor **74** are deactivated during this operation by contacts CR2. Heater **54** is turned on by contactor H1. Relay CR is opened to terminate the defrost cycle when thermostat DK, adjacent the evaporator coil, opens at about **55** degrees F. Thermostat HK, which is designed to open at 150° F., acts as a backup for thermostat DK, in the event DK should fail to function. Contacts CR3 hold relay CR closed, even though air switch AS opens due to differential pressure change when air fan motor **100** stops, upon the opening of contacts CR2. The defrosting is not part of the invention, but is described for the sake of completeness.

It is evident from the foregoing that the system will circulate air through the car and heat or cool the air to maintain a temperature near the thermostat setting. When the temperature of the air is within a predetermined range of the thermostat set point, both the heating and refrigerating apparatus are operated to remove moisture or dehumidify the air. Some of the moisture condensed when the air passes over evaporator coils **52** may be re-evaporated by heater coil **54**, and some will be carried into the air fan **60** and serve to cool it, and the rest will be dispensed. In an exemplary case, the air approaching evaporator **52** may have a temperature of 60° F. and a relative humidity of 100 percent, and after cooling and heating it may leave air fan **60** at 60° F. and a relative humidity of 90 percent.

As a specific example of a covered hopper railway car embodying the present invention with potatoes being carried in the winter months, potatoes in a partially deteriorated condition with an excess moisture content are loaded out of storage with storage temperature of the potatoes around 50° F. and the ambient temperature around 0° F. The potatoes are loaded into the hopper car with the thermostat set at 60° F. and the potatoes are heated from 50° to 60° F. over a period of around three days. With switch **104** activated, evaporator **52** is actuated at 56° F. The heating coil **54** is deactivated at 61° F. Thus simultaneous heating and cooling is effected between 56° F. and 61° F. to provide a holding zone of 5° with the thermostat set point of 60° F.

As a specific example of use during the summer months with onions being loaded from the field at an ambient temperature of 80° F., the thermostat is set at 50° F. With switch **104** activated simultaneous heating and cooling occurs between 46° and 51° F. The thermostat may be manually set at any desired temperature. For example, if thermostat is manually set at 65° then the holding zone would be between 61° and 66°. Humidity sensitive control **106** for onions is set at a relative humidity of over 70 percent thereby to permit activation of switch **104** and simultaneous heating and cooling only when the relative humidity is over 70 percent. If the relative humidity is less than 70 percent, then the heating and cooling units would not be actuated thereby providing a dead zone between 46° and 51° F. in which neither heating nor cooling is provided.

When onions are transported during the winter months with an ambient temperature of around 30° F. the thermostat set point may be 35° F. which is the optimum temperature for the storage of onions. However, when onions are transported during the summer months at an ambient temperature of around 70° the thermostat is set at 50° F. so that condensation does not form on the surface of the onions when they are unloaded. For different commodities, the set point of humidity sensitive control **106** might vary. For example, with potatoes, the humidity control might be manually set at 90 percent. For carrots, the humidity control might be manually set at 95 percent.

What is claimed is:

1. A railway covered hopper car comprising a substantially closed body for containing lading, a fan for recirculating air through said body, heating means for the air, cooling means for the air, a control circuit including an adjustable thermostat for operating the heating means at air temperatures generally below the setting of the thermostat and operating the cooling means at temperatures generally above the setting of the thermostat, said heating means and said cooling means having high and low rates of operation, said control circuit including manually closeable switching means for selectively operating the heating means and cooling means simultaneously at their low rates in the holding range of the thermostat, for condensing and removing moisture from the air and humidity responsive means for opening said switch when the humidity of the recirculated air is below a predetermined level.

2. A railway car according to claim **1**, including means for conveying a portion of the condensed water to the intake of said fan and draining off the remainder of the condensed water.

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