Feb. 24, 1970 A. E. PARKER ET AL 3,496,733

ELECTRONIC ICE BANK CONTROL

Filed May 1, 1968

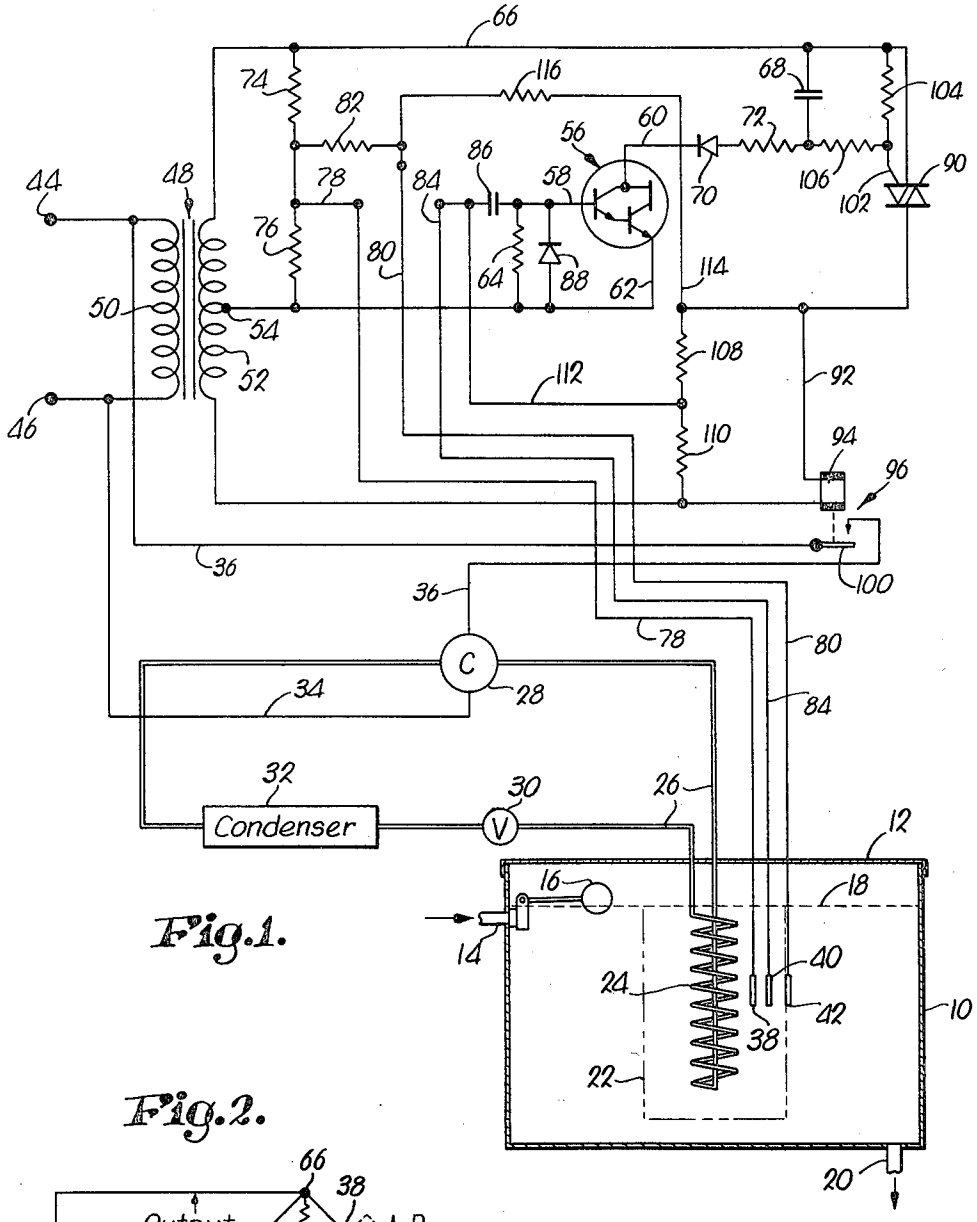
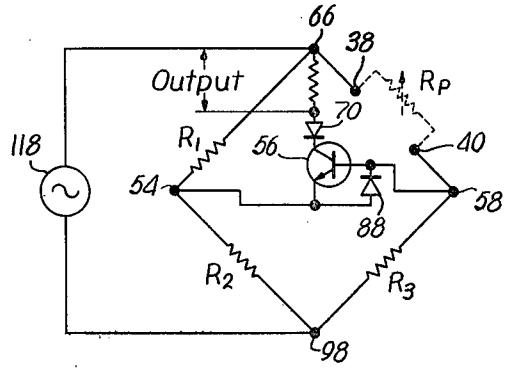


Fig. 1.

Fig. 2.



INVENTORS.
Arthur E. Parker
Robert E. Patterson

BY Schmidt, Johnson, Hovey, Williams & Bradley.
ATTORNEYS.

United States Patent Office

3,496,733
Patented Feb. 24, 1970

3,496,733

ELECTRONIC ICE BANK CONTROL

Arthur E. Parker, Kansas City, and Robert E. Patterson, Raytown, Mo., assignors to The Vendo Company, Kansas City, Mo., a corporation of Missouri

Filed May 1, 1968, Ser. No. 725,644
Int. Cl. F25b 49/00
U.S. Cl. 62—139 9 Claims

ABSTRACT OF THE DISCLOSURE

An ice bank control for a cup beverage dispensing machine employs a bridge network having two levels of sensitivity to provide a differential between turn-on and turn-off of the refrigeration system in order to prevent short cycling. The bridge network responds to changes in the resistivity of the water or ice slush as detected by a pair of spaced electrodes immersed in the water bath. When the refrigeration system is activated by the control, a third electrode is electrically inserted in the water bath by a triac which is also employed to make or break a control circuit for the refrigeration system to effect on and off cycling thereof to maintain the size of the ice bank between desired maximum and minimum limits.

In a cup beverage dispensing machine it is required that the ice bank for cooling the water be controlled within minimum and maximum size limits. Ice bank controls responsive to the change in resistance of the water as it freezes and melts are presently in use. However, it is necessary that practical ice bank controls operate with adequate differential to eliminate any tendency to short cycle the refrigeration system utilized to maintain the size of the bank between the desired limits.

The reduction in the resistance of the water between two spaced electrodes in the cold water supply tank within which the ice bank is maintained commonly provides a signal for starting the refrigeration system, the decrease in resistance being indicative that the ice or slush between the electrodes has changed to water. However, once refreezing commences it is necessary that the sensitivity of the control be changed to prevent short cycling of the refrigeration system. Furthermore, it is also desirable and has been the practice to electrically insert a third electrode with a requirement in the control logic that refreezing occur between both the first two electrodes and one of the latter and the third electrode before cutoff of the refrigeration system. This assures that a sizable new ice bank is formed before the control terminates the operation of the refrigeration system.

Heretofore, controls of the type outlined above have not at all times met desired performance limits consistently under all environmental conditions. Operational limits may be dependent upon line voltage, temperature, or broad parameters of semiconductor devices. Additionally, such controls customarily effect electrical insertion of the third electrode during freezing of the water by means of an additional set of contacts on the control relay of the refrigeration compressor. The current carried by these contacts is oftentimes so small that conductivity tends to be unreliable.

It is, therefore, the primary object of this invention to provide an improved ice bank control having increased reliability and less dependence upon environmental conditions and component parameters.

As a corollary to the foregoing object, it is an important aim of the instant invention to provide an improved control as aforesaid which provides the necessary differential to prevent short cycling of the refrigeration system and also effects electrical insertion of a third resistance-sensing electrode without the use of relay contacts or other mechanical switching means.

Furthermore, it is a specific and important object of the invention to provide such an improved control wherein a bridge network is employed and is operable to provide the required differential, and wherein electronic switching is utilized to insert the third electrode simultaneously with activation of the control circuit for the refrigeration system to commence operation thereof and refreezing of the ice bank once it has reached the minimum permissible size.

In the drawing:

FIGURE 1 is a diagrammatic illustration of a cold water supply tank for a cup beverage dispenser, the control of the instant invention being shown schematically in association with the ice bank refrigeration system; and

FIG. 2 is an electrical schematic diagram of an equivalent circuit illustrating the operation of the bridge network of the control.

A cold water supply tank **10** has a lid **12** and is provided with a water inlet pipe **14** containing a valve which is operated by a float **16**. The level of the water bath within tank **10** is illustrated at **18**; an outlet pipe **20** extends from the bottom of tank **10** and furnishes cold water upon demand.

A refrigeration system is employed to maintain an ice bank **22** in the central portion of tank **10**, the bank **22** being diagrammatically illustrated and shown surrounding an evaporator coil **24** that forms a part of the refrigeration system. A pair of lines **26** for the refrigerant extend from the ends of coil **24** through lid **12** to a compressor **28**, an expansion valve **30**, and a condenser **32** arranged in the conventional manner. The compressor **28** is operated by an internal electric motor, the power leads to such motor being illustrated at **34** and **36**. When the compressor **28** is in operation, it is apparent that water freezes around the coil **24** to form the ice bank **22**. Manifestly, the size of the bank **22**, during periods of light demand, could increase until a substantial portion or all of the water within tank **10** is frozen solid, unless the refrigeration system is cycled to maintain the size of the ice bank **22** within predetermined limits.

The limits are defined by mounting a probe in the water bath in the form of three spaced electrodes **38**, **40** and **42**. The electrode **38** is nearest the coil **24**, the remaining electrodes **40** and **42** being spaced progressively further from coil **24** in a direction radially thereof. The resistivity of water varies substantially in accordance with its physical state. With a spacing between the electrodes **38** and **40** and the electrodes **40** and **42** of approximately ½ inch, the resistance between each of such pairs of electrodes in the presence of water in the liquid state is approximately 20,000 ohms, depending on the temperature of the water and the impurities it contains. As the water is cooled and begins to change to ice, this resistance will increase to approximately 100,000 ohms, again depending upon the impurity content. In the instant invention, this resistance variation of water is utilized to cycle the refrigeration system in a manner to be described hereinafter.

A pair of power terminals **44** and **46** are connected to a suitable source of alternating current such as a 60 cycle, 110 volt supply. A step-down transformer **48** has a primary winding **50** connected across terminals **44** and **46**, and a secondary winding **52** having a center tap **54**. As will become clear, alternating current from secondary **52** is applied to the three electrodes **38**, **40** and **42**, and is selected for the energization of the electrodes to prevent electrolysis of the water. This is of particular significance in order to prevent deterioration of the electrodes by the plating phenomenon, which would occur with most materials if a direct current were applied.

A polarity sensitive device in the form of a monolithic Darlington amplifier **56** has a base input **58**, a collector output connection **60**, and an emitter connection **62**, the latter being directly connected to the center tap **54**. An input resistor **64** is connected across base **58** and emitter **62**. Collector voltage is supplied by a lead **66** extending from the upper end of secondary winding **52** to a capacitor **68**, a series connected diode **70** and resistor **72** connecting capacitor **68** to collector **60** to supply the latter with positive potential during alternate positive half cycles of the alternating current delivered by secondary **52**.

A pair of series resistors **74** and **76** form a voltage divider and are connected across lead **66** and center tap **54**. A lead **78** is connected at the junction of resistors **74** and **76** and extends to the inner electrode **38**. A lead **80** is connected to the same junction by a resistor **82** and extends to the outer electrode **42**. A lead **84** is connected to base **58** by a coupling capacitor **86** and extends to the intermediate electrode **40**. A bypass diode **88** is connected across emitter **62** and base **58** and is poled in the opposite direction to the forward conduction direction of the input of amplifier **56**.

An electronic switching component in the form of a triac **90** has its internal current path connected in series between lead **66** and a lead **92** that extends to the coil **94** of a control relay **96** for the compressor **28**. A control circuit for the compressor **28** is formed by the lead **92** and a lead **98** connecting the other electrical side of the relay coil **94** to the lower end of the secondary winding **52**. The control relay **96** includes a normally open relay switch **100** which is interposed in series with the power lead **36**. The power leads **34** and **36** extend to power terminals **46** and **44** respectively.

The triac **90** has a control input or gate **102** connected to lead **66** by a resistor **104**, and connected to the junction of capacitor **68** and resistor **72** by a resistor **106**. The capacitor **68** is employed to store trigger current for the gate **102**, and the resistor **106** lengthens the time constant.

A pair of resistors **108** and **110** are in parallel (via lead **92** and relay coil **94**) between lead **98** and a lead **112** which is connected to the lead **84** extending to electrode **40**. A lead **114** joins the interconnection of lead **92** and resistor **108** to a resistor **116** connected to the lead **80** that extends to electrode **42**.

As mentioned hereinabove, operation of the compressor **28** must be cycled in order to control the size of the ice bank **22**. The water bath and ice bank arrangement illustrated herein is particularly suitable for cup beverage dispensers where the demand for cold water is subject to extreme variations. For example, there may be long periods such as overnight in which the dispensing machine is not in use. Therefore, the ice bank **22** must be maintained under conditions where only occasional operation of the refrigeration system is required, and under other conditions such as heavy cold water demand where perhaps relatively constant operation of the system will be necessary to maintain the ice bank **22**.

The equivalent circuit of FIG. 2 is instructive in the understanding of the operation of the instant invention to satisfy the above requirements. A bridge network is formed by various elements of the circuitry of FIG. 1, as will be appreciated with reference to the equivalent circuit. The bridge shown in FIG. 2 has four resistance arms designated R_1, R_2, R_3 and R_p. An AC source **118** is connected to the two input terminals of the bridge presented by the junctions of arms R_1 and R_p, and R_2 and R_3. These two input terminals are designated **66** and **98** respectively and correspond to the upper end of the transformer secondary **52** (lead **66**) and the lower end of the transformer secondary **52** (lead **98**) illustrated in FIG. 1. The output terminals of the bridge are designated **54** and **56** and, therefore, correspond to the center tap of the transformer secondary **52** and the base input of amplifier **56** respectively. Thus, resistance arms R_1 and R_2 are equivalent to the transformer secondary **52** and the resistance arm R_3 is equivalent to the parallel resistors **108** and **110**.

The resistance arm R_p comprises the control arm of the bridge and is variable in resistance in accordance with the resistivity of the water between the electrodes **38** and **40** of the ice bank probe. For purposes of illustration, the bridge will be considered to be at a balanced condition when the resistance of R_p is approximately 100,000 ohms. The Darlington amplifier **56** is illustrated in FIG. 2 as a NPN transistor amplifier, its equivalent for purposes of explanation of the operation of the network. The collector of amplifier **56** in the equivalent circuit is connected through an output resistor to the bridge input terminal **66**; therefore, the amplifier **56** is in condition for conduction only during alternate half cycles of the alternating current when terminal **66** is positive. The condition of the bridge at times when the collector of amplifier **56** is negative may thus be disregarded.

Assuming that the compressor **28** is not in operation and that the ice slush between electrodes **38** and **40** is thawing due to the effect of ambient temperature or demand or both, the resistance of R_p is decreasing and ultimately reaches a value where the bridge is out of balance to an extent to turn on the Darlington amplifier **56** or its single transistor equivalent in FIG. 2. It is assumed that the turn-on point corresponds to a resistance of R_p of approximately 30,000 ohms, which is 70,000 ohms less than the resistance in arm R_p needed for a balance condition. Thus, when input terminal **66** is positive, current flows from output terminal **58** to output terminal **54** across the base-emitter junction of the amplifier **56**. When amplifier **56** assumes its conductive state, an output appears across the collector output resistor (FIG. 2) and is utilized, as will be subsequently explained, to gate the triac **90**. The diode **88** permits current flow between output terminals **54** and **58** when the bridge unbalances in the opposite direction at times when input terminal **66** is negative and input terminal **98** is positive.

Referring to FIG. 1, it may be seen that the Darlington amplifier **56** in its excited, conductive state provides a current path through the capacitor **68** to the center tap **54**. Voltage is now applied to the gate **102** of the triac **90** to render the latter conductive, the capacitor **68** serving to store trigger current for gate **102** during the alternate half cycles of the alternating current from transformer secondary **52** in which lead **66** is negative with respect to center tap **54** and amplifier **56** is nonconductive; therefore, the triac **90** remains on during both positive and negative half cycles of the alternating current. Turn-on of the triac **90** effects energization of relay coil **92** to close switch **100** and place the compressor **28** in operation.

Additionally, when the triac **90** is rendered conductive, lead **114** is placed at substantially the same potential as lead **66** to increase the potential at electrode **42** with respect to the center tap **54**. Furthermore, the potential at lead **112** (base input **58** decreases with respect to the center tap **54**. Referring to FIG. 2, this change in the potential at lead **112** is equivalent to disconnecting arm R_3 from bridge input terminal **98** and reconnecting R_3 to a tap on R_2. Thus, the voltage reference of the bridge output terminal **58** relative to the bridge output terminal **54** is now between terminals **54** and **98**. This throws the bridge further out of balance and increases the current flowing between the output terminals **58** and **54** and, therefore, through the input circuit of the amplifier **56**. It will be appreciated that the amplifier **56** is driven harder and thus the sensitivity of the network is changed, requiring that the resistance R_p change to a substantially higher value in order to decrease the drive to the amplifier sufficiently to return the same to its nonconductive state.

As the compressor **28** operates and the water or ice slush between electrodes **38** and **40** refreezes, the resistance between these two electrodes increases. It is as-

sumed that a resistance of R_p of 70,000 ohms is required to return amplifier **56** to its nonconductive state. Thus, as the ice bank **22** grows the resistance of R_p ultimately reaches 70,000 ohms normally prior to the time that the resistance between electrodes **40** and **42** reaches 70,000 ohms, since the latter two electrodes are spaced the same distance apart as electrodes **38** and **40** but electrode **42** is further from the evaporator coil **24**. However, it is to be remembered that the potential difference across electrodes **40** and **42** was substantially increased at the time the triac **90** was turned on. Therefore, a second, independent path for flow of excitation to the amplifier base input **58** now exists between electrodes **40** and **42**. The values of resistors **74**, **76**, **82** and **116** are selected to set the increased potential difference across electrodes **40** and **42** at a level to require the resistance therebetween to also increase to 70,000 ohms before drive current for amplifier **56** is reduced to cut-off. The combined effect, therefore, of the change in the sensitivity of the bridge network and the increasing of the voltage on electrode **42** is to require that the resistance between both of the pairs of electrodes **38–40** and **40–42** reach 70,000 ohms before amplifier **56** will return to its nonconductive state. Thus, it is assured that a sizable new ice bank **22** is formed.

When the amplifier **56** returns to its nonconductive state, the triac **90** is rendered nonconductive and relay coil **94** is de-energized. This deactivates the compressor **28** but the evaporator coil **24** will continue to refrigerate the ice bank **22** for a time after the compressor **28** is deactivated, resulting in a further increase in the resistance of the ice slush between the electrodes **38** and **40**. The bridge network is now returned to normal and thus will balance at a resistance of R_p of approximately 100,000 ohms. Should this occur and the bridge become unbalanced in the opposite direction by a resistance of R_p of greater than 100,000 ohms, the amplifier **56** will not respond since negative potential will be applied to the diode **70** during the time that current flows from the base input **58** to the emitter connection **62**. Thus, the amplifier **56** is phase sensitive to preclude spurious operation of the refrigeration system.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. Apparatus for controlling the size of an ice bank maintained in a water-containing region by a refrigeration system, said apparatus comprising:

a pair of spaced electrodes adapted to be disposed in said region for sensing the resistance of water between the electrodes;

means for supplying electrical energy;

a bridge network having an input coupled with said supply means, a pair of output terminals, and a control arm including said electrodes as a resistive element thereof and thereby being variable in resistance in accordance with changes in the resistivity of the water between the electrodes during freezing and melting;

electrically responsive switching means for controlling operation of said system, and including a device coupled with said output terminals and having a normal state and an excited state for cycling said system on and off,

said control arm effecting unbalancing of the network to an extent to excite the device and cause the latter to assume its excited state in response to a change in one direction of the resistance between said electrodes to a first predetermined value; and

circuit means coupled with said switching means and said network for further unbalancing the network, when the device assumes its excited state, to preclude return of the device to its normal state until the resistance between said electrodes changes in the opposite direction to a second predetermined value different than said first value, whereby to establish a resistance differential in said control arm between turn-on and turn-off of said system.

2. Apparatus as claimed in claim **1**,

said change in one direction of the resistance between the electrodes being a decrease in the resistance therebetween,

said change in the opposite direction of the resistance between the electrodes being an increase in the resistance therebetween,

said second value being greater than said first value.

3. Apparatus as claimed in claim **2**,

and a third electrode spaced from said pair of electrodes and adapted to be disposed in said region for sensing the resistance of water between the third electrode and one electrode of said pair of electrodes,

said circuit means being coupled with said third electrode for establishing a sufficient potential difference across the third electrode and said one electrode, when said device assumes its excited state, to provide a path between said third electrode and said one electrode for flow of electrical excitation to said device to preclude return of the latter to its normal state until the resistance between said third electrode and said one electrode increases to said second value together with the resistance between said pair of electrodes, whereby to assure that the ice bank has sufficient size before freezing is terminated.

4. Apparatus as claimed in claim **1**,

said device having input means for sensing current flow between said output terminals to effect a change of state of the device from the normal to the excited state when the network is unbalanced to said extent,

said circuit means effecting an increase in the current flow between said output terminals to apply greater drive to the input means of said device in response to said change of state thereof from the normal to the excited state.

5. Apparatus as claimed in claim **1**,

said electrical energy comprising alternating current,

said device having polarity sensitive input means for sensing a unidirectional current flowing between said output terminals, and a polarity sensitive output connection coupled with said supply means and conditioned for operation of said device in its excited state only during alternate half cycles of said alternating current of a particular polarity, whereby the device undergoes a change of state from the normal to the excited state thereof only when said alternating current is of said particular polarity and said unidirectional current simultaneously flows between said output terminals, thus the device will not assume its excited state if the network should become unbalanced by a change in said opposite direction of the resistance between said electrodes.

6. Apparatus for controlling the size of an ice bank maintained in a water-containing region by a refrigeration system, said apparatus comprising:

first, second, and third spaced electrodes adapted to be disposed in said region for sensing the resistance of water between the first and second electrodes and the second and third electrodes, said resistance being variable in accordance with changes in resistivity of the water during freezing and melting;

means for supplying electrical energy;

a control circuit for said system coupled with said supply means;

electrically responsive switching means operably coupled with said circuit and including a device having a normal state and an excited state for controlling current flow in said circuit;

said device being provided with an operating input coupled with said second electrode;

said first electrode being coupled with said supply

means to cause electrical excitation to be delivered to the operating input of said device to effect a change of state of the latter from the normal to the excited state thereof when the resistance between said first and second electrodes decreases to a predetermined value; and

circuit means interconnecting said control circuit and said third electrode and, when said device assumes said excited state thereof, establishing a sufficient potential difference across the third electrode and said second electrode to provide a path therebetween for flow of additional electrical excitation to said device to preclude return of the latter to its normal state until the resistance increases between both the first and second electrodes and the third and second electrodes, whereby to assure that the ice bank has sufficient size before freezing is terminated.

7. Apparatus as claimed in claim 6,

said switching means further including an electrically controllable switching component in series with said control circuit and said circuit means and responsive to said device for making and breaking the control circuit to cycle the system on and off and simultaneously effect the establishment of said potential

difference across the second and third electrodes when the device is in its excited state.

8. Apparatus as claimed in claim 6,

said switching means further including an electrically controllable electronic switching component in series with said control circuit and said circuit means and having a control input connected with the output of said device,

said component being responsive to changes of state of said device for making and breaking said control circuit to cycle the system on and off and simultaneously effect the establishment of said potential difference across the second and third electrodes when the device is in its excited state.

9. Apparatus as claimed in claim 8,

said electrical energy comprising alternating current,

said switching component comprising a triac having a gate presenting said control input.

References Cited

UNITED STATES PATENTS

2,506,775	5/1950	Calabrese	62—139
3,298,191	1/1967	Burke	62—140

MEYER PERLIN, Primary Examiner