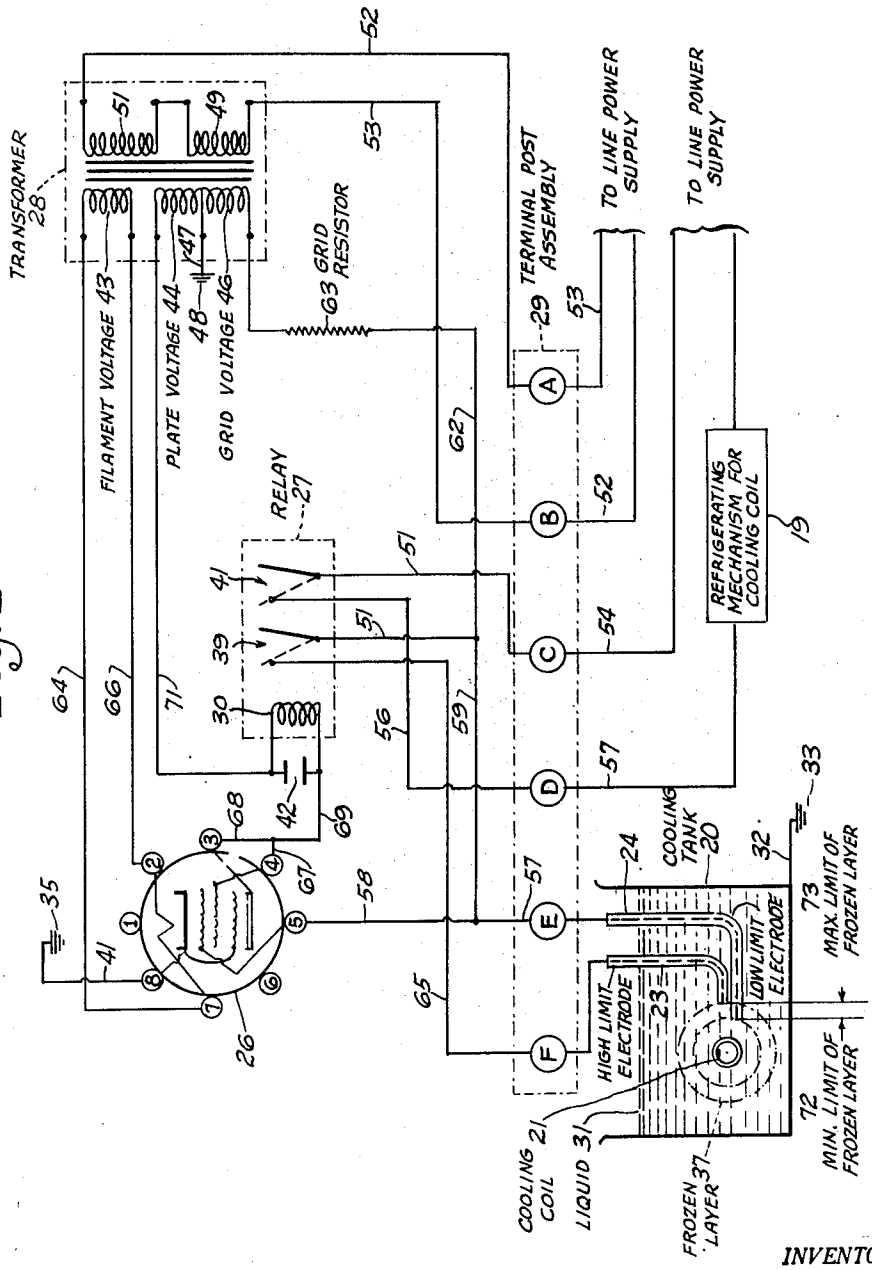
May 9, 1950 G. V. CALABRESE 2,506,775

FREEZING TEMPERATURE CONTROL

Filed April 23, 1947 3 Sheets-Sheet 1

Fig. 1



INVENTOR.
George V. Calabrese
BY
Sheridan, Davis & Cargill
Attys

May 9, 1950 G. V. CALABRESE 2,506,775

FREEZING TEMPERATURE CONTROL

Filed April 23, 1947 3 Sheets-Sheet 2

Fig. 3

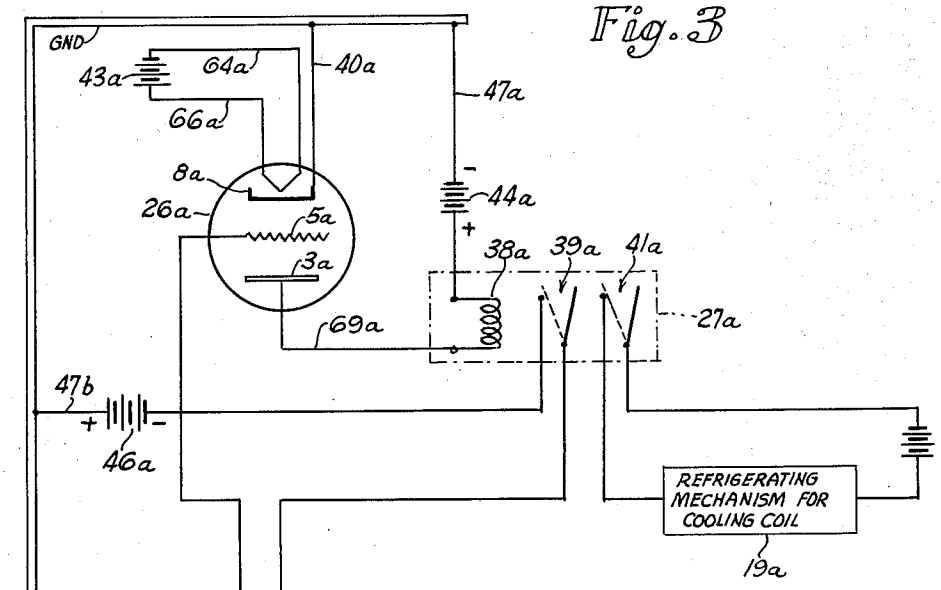
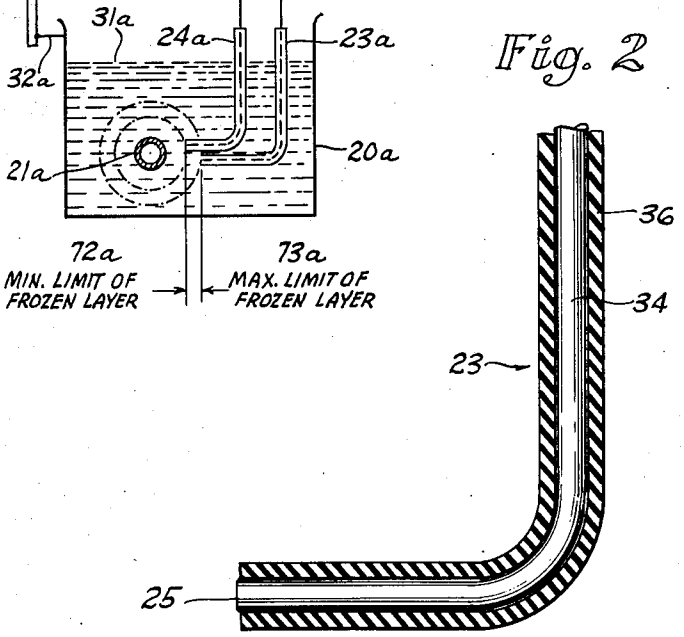


Fig. 2



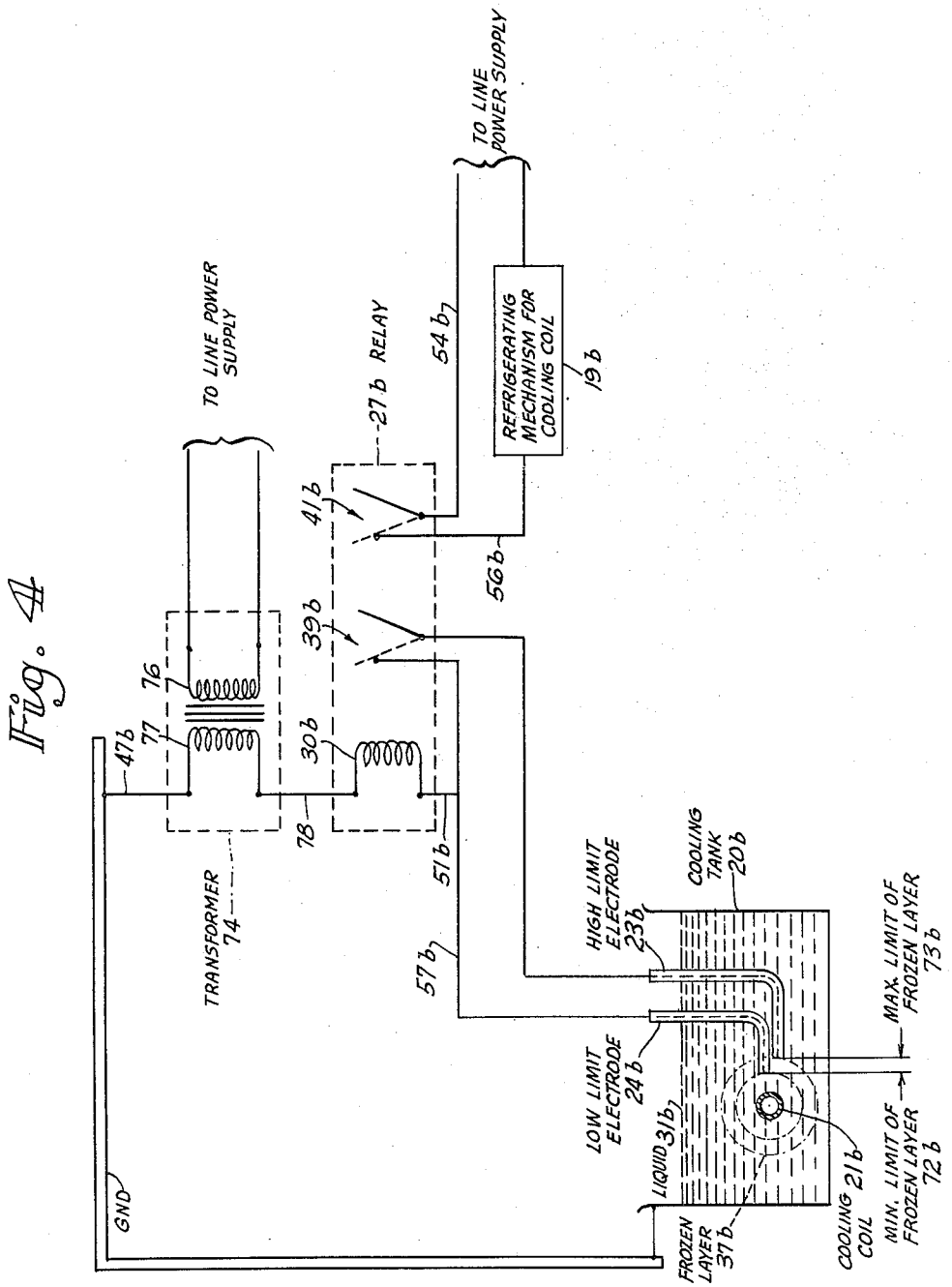
INVENTOR.
George V. Calabrese
BY
Sheridan, Davis & Cargill
Attys

May 9, 1950 G. V. CALABRESE 2,506,775

FREEZING TEMPERATURE CONTROL

Filed April 23, 1947 3 Sheets-Sheet 3

Fig. 4



INVENTOR.
Geo. V. Calabrese
BY
Sheridan, Davis & Cargill
Attys

Patented May 9, 1950 2,506,775

UNITED STATES PATENT OFFICE

2,506,775

FREEZING TEMPERATURE CONTROL

George V. Calabrese, Chicago, Ill., assignor to Lumenite Electronic Company, Chicago, Ill., a corporation of Illinois

Application April 23, 1947, Serial No. 743,281

11 Claims. (Cl. 62—141)

1

This invention relates to a liquid cooling system of the type having a freezing coil or the like immersed in the liquid and which operates normally with a layer of the frozen liquid on the coil. It relates primarily to a control for maintaining the thickness of the frozen layer between predetermined maximum and minimum limits.

One example of a service where my invention is particularly applicable is in maintaining a liquid or a portion thereof at substantially its freezing temperature. In the dairy industry, for instance, large quantities of water slightly above the freezing point are used. Water for this purpose is commonly cooled in a tank having a cooling coil immersed therein. This coil is associated with refrigerating mechanism which maintains it well below the freezing point of the water so that a layer of ice accumulates on the outside of the coil. To keep the main body of the water as cold as possible without actually freezing it, it is desirable that a certain minimum layer of ice remain on the coil at all times; conversely, to provide for the most efficient heat transfer from the water to the coil, it is desirable that the layer of ice not be permitted to build up beyond a certain maximum thickness. Therefore, in operating such a cooling system, it has been the practice to adjust the freezing mechanism so the layer of ice builds up only slowly, during normal conditions of use, and to shut the unit down for defrosting when the frozen layer has built up to an inefficient thickness. Obvious disadvantages of such a manual control system include: undesirably wide fluctuations in temperature of the liquid controlled, especially during abnormally high or low withdrawals of liquid; and the ever-present possibility that the operator may forget to defrost, causing the whole tank to freeze solid during a period of low demand, or not adjusting the freezing mechanism low enough causing the temperature of the liquid to creep up to a point that may endanger the operation of the main processing equipment.

Accordingly, an object of the present invention is the provision of a completely automatic control system for regulating the thickness of a layer of ice or other frozen material directly in response to the thickness of the layer so that when a maximum thickness accumulates the operation of the refrigerating mechanism will be stopped or cut back sufficiently to permit the melting of the frozen layer and when the layer is melted to a minimum thickness, the operation of the refrigerating mechanism will be restarted or increased sufficiently to cause the layer to accumulate again.

2

Another object of the present invention is the provision of an ice or other frozen layer thickness control system of the character described in which the thickness of the ice is automatically regulated in response to change in electrical conductivity of the liquid as it solidifies on the freezing coil, and vice versa.

Other objects and advantages will become apparent in the following description taken in connection with the drawings in which:

Figure 1 is a diagrammatic view of a freezing control system illustrating one embodiment of the present invention;

Fig. 2 is a fragmentary view of one of the electrodes shown in Fig. 1;

Fig. 3 is another, simplified embodiment of the present invention; and

Fig. 4 is still another embodiment illustrating the principles of this invention.

Like parts are designated by like reference characters throughout the drawing.

A liquid cooling system, employing one embodiment of the present invention to regulate the thickness, for example, of ice collecting on a cooling coil immersed in a tank of water, is shown in Fig. 1. It should be understood, however, that this example is given only by way of illustration and not by way of limitation inasmuch as the control system of the present invention is applicable generally to regulating the thickness of any layer of material freezing or precipitating out of a solution where that solution has a different electrical conductivity than said layer, as will be seen in the following description.

In the example of Fig. 1 the system includes: a tank 20 having a cooling or freezing coil 21 immersed in a liquid 22 which for the purpose of this example may be assumed to be ordinary tap water which normally has an appreciable electrical conductivity; electrode means, including electrodes 23 and 24; a vacum tube 26; a relay 27; a transformer 28; a terminal post assembly 29; and refrigerating mechanism 19 operative to cool the coil 21 below the freezing point of the liquid 31.

The tank 20 will be constructed in such a way as to place the liquid 31, which in this case is water, in electrically conductive relationship with the conductor 32 which is grounded at 33. A simple way of effecting this is to employ a grounded metal tank.

The cooling coil 21 may take the form of any cold wall or member whose temperature may be reduced below the liquid freezing point by the refrigerating mechanism 19. In this case it is shown in the form of an ordinary annular cross-

section tube through which low temperature gases are directed to extract heat from the tank 20.

The electrodes 23 and 24 in this case comprise an inner, L-shaped, conductive metal rod 34 (see Fig. 2) having a tubular sheathing 36 of liquid-repellent, electrical insulating material such as polyvinylidene chloride available from Dow Chemical Company under the trade name "Saran." Only the tip or end face 25 of each rod 34 is exposed to the liquid, the insulating sheathing 36 extending above the surface of the water. The tip is the effective portion of each electrode and its spacing from the surface of the cooling coil is determinative of one limit of the thickness of the ice layer 37 on the cooling coil. The electrodes are mounted in any suitable manner such that they are fixed with respect to the cooling coil 21 and such that the electrode 23 is spaced at a greater distance than 24 from the coil. The spacing of electrode 23 determines the maximum thickness of the ice layer and the spacing of electrode 24 determines its minimum thickness, as will be seen.

A wide variety of vacuum tubes may be employed in the embodiment shown in Fig. 1. In general, any grid-controlled tube may be used. In the embodiment of Fig. 1, I have shown, for purposes of illustration, a pentode tube of the type 25L6–GT having the following connections: plate, #3; cathode with suppressor grid, #8; control grid, #5; screen grid, #4; and cathode heater or filament, #2 and #7. The cathode #8 is grounded at 35 through the conductor 40. As will be described in conjunction with the Fig. 3 modification, a simple triode tube may be used.

The relay 27 comprises an activating coil 38 and a pair of normally open switches 39 and 41 which are closed when a sufficiently high current flows through the coil 38. To prevent chattering of the relay on the pulsating direct current passing through the plate circuit of the tube, a condenser 42 of suitable capacity may be connected in parallel across the relay coil 38.

The transformer 28 may be any suitable power source or sources for actuating the control circuit. It is a convenient means for supplying the different power requirements for the grid, plate and filament circuits from a single A. C. source. Where desired, as shown in Fig. 3, the transformer may be dispensed with and other power sources such as batteries used instead. In this instance the transformer is provided with secondary coils 43, 44 and 46 to supply the requisite filament, plate and grid voltages. Coils 44 and 46 have a common conductor 47 grounded at 48.

Electrically operated refrigerating mechanism is generally designated by the numeral 19. These mechanisms are well-known, for example the electric-motor-driven compressor type, and it is therefore believed unnecessary to show any specific type in the drawing. It will of course be understood that the refrigerating mechanism is operably associated with the cooling coil 21 in such a way as to cool the latter either intermittently or continuously in varying degrees of coldness in accordance with the particular control system superimposed on it.

Power supply for the transformer primary coils 49 and 51 is carried by conductors 52 and 53 through terminal posts A and B. Power supply for the refrigerating mechanism is carried by conductors 54 and 56 through terminal posts C and D and is controlled for intermittent or on and off operation in this case by the closing and opening of relay switch 41. Where desired the power source for the transformer primary and the refrigerating mechanism may be the same and not separate as shown in the Fig. 1 embodiment.

This invention is based to a large extent on my discovery that in a cooling system of this type, the ice or other frozen material formed from the water or other liquid and collected on the cooling coil has an electrical conductivity sufficiently lower than that of liquid that this difference in conductivity can be used to control the charge on the grid 5 which in turn is effective to permit or prevent flow through the grid circuit to the relay which is effective to start or stop the refrigerating mechanism. The system is thus directly responsive to the thickness of the ice layer 37 to control the operation of the refrigerating mechanism. And, since the accumulation of the relatively non-conductive ice about the electrode tips 25 is effective to change the grid bias, it may also be said that the operation of the refrigerating mechanism is controlled in response to the change in electrical conductivity as the water freezes to ice, or vice versa, at the electrode tips 25.

The low limit electrode 24 is connected through terminal post E directly to the control grid #5 through conductors 57 and 58; to one side of relay switch 39 through conductors 59 and 61; and to the secondary 46 through conductor 62. The latter will preferably be provided with a grid resistor 63, where needed to reduce the grid voltage to a desired amount depending on the requirements for the particular tube used. The resistance of the grid resistor 63 will preferably be selected at a value above that of the liquid between the tank 20 and the electrodes, this latter resistance varying somewhat between installations depending on the dissolved salts and temperature.

The high limit electrode 23 is connected by conductor 65 through terminal post F to the relay switch 39.

The filament connections #2 and #7 are supplied by the secondary coil 43 through conductors 64 and 66.

The screen grid and plate connections #3 and #4, respectively, are exteriorly connected by conductors 67 and 68 which in turn are joined to conductor 69 leading to one end of the relay coil 38. The other end of the coil is connected with the secondary 44 through conductor 71.

In considering now the operation of the embodiment shown in Fig. 1, assume that the relay switches 39 and 41 are open, as shown in solid lines. This of course means that the refrigerating mechanism 19 is not being supplied with power through conductors 54—56 and therefore is not operating. Assume also that there is no ice collected on the coil 21. Since both ends of the electrodes are covered with conductive water (or other liquid), a circuit will be completed through the water and the grid voltage secondary 46. This circuit may be traced as follows: grid voltage secondary 46—grid resistor 63—conductors 62, 59, 57—low limit electrode 24—tank liquid 31—tank 20—conductor 32—grounds 33 and 48—and conductor 47. No flow will occur through the high limit electrode 23 at this time because the relay switch 39 is open. Current flow through the circuit traced above will be effective to lower the negative charge on the control grid #5 sufficiently to permit plate current to flow and energize the relay 27.

Plate current will be a pulsating D. C. current due to the rectifying action of the tube which allows only the negative half of the A. C. cycle to

pass. This plate current may be traced as follows: secondary 44—conductor 47—grounds 48 and 35—conductor 40—cathode #8—plate #3—conductors 68, 69—relay coil 38—and conductor 71. The relay will be energized by this plate current sufficiently to close both switches 39 and 41 (See broken line positions, Fig. 1).

The closing of switch 41 will energize the refrigerating mechanism 19, causing it to cool the coil 21 and to begin collecting ice thereon.

The closing of switch 39 will place the high limit electrode 23 in communication with the control grid #5 so that, even after ice collects about the low limit electrode, current will still flow through the high limit electrode to maintain the bias on the control grid to keep the refrigerating mechanism running until both electrodes are covered with ice.

As previously stated, ice is an appreciably poorer conductor than the water commonly used in processes of this kind. Thus, when the ice layer builds up on the cooling coil to the point 72 to cover the tip 25 of low limit electrode 24, current flow through that electrode will be stopped or substantially reduced so that the major part of the current flow will be carried by the other electrode which is still exposed to water.

As the refrigerating mechanism continues to run, the ice layer will be built up until it covers the high limit electrode, at point 73. Current flow through the water in the tank will then be stopped. This will cause the grid bias to change, that is to become sufficiently more negative as to stop the plate current through the tube, causing the relay switches to open. This will stop the refrigerating mechanism whereupon the ice layer will begin to melt. The opening of switch 39 at this time places the high limit electrode out of communication with the control grid #5 so that melting of ice from that electrode will be ineffective to restart the refrigerating mechanism.

When the ice melts back to the point 72, the water circuit will once more be completed through the low limit electrode 24, making the control grid less negative so as to permit the plate current to energize the relay and restart the refrigerating mechanism as described above, whence the above-described cycle will be repeated.

Fig. 3 shows a more simplified, direct-current variation of the embodiment shown in Fig. 1 to illustrate a simple vacuum tube circuit and to more clearly present the basic principles of the invention. It will be seen that the Fig. 3 embodiment is the same in principle as the Fig. 1 embodiment except that the transformer 28 and certain of the wiring has been eliminated by substituting D. C. electrical source symbols, designated by the numerals 43*a*, 44*a* and 46*a*, for the A. C. secondaries 43, 44 and 46 respectively. Further simplifications have been achieved by eliminating the condenser 42 which is not required for D. C. operation and by eliminating the grid resistor 63 which will not be used where the grid voltage source 46*a* is low enough not to require such resistance in the circuit. As will be seen, elements of the Fig. 3 embodiment, which are similar to those of the Fig. 1 embodiment, are indicated by the same reference character, followed by *a*. In view of the preceding description of the operation of the Fig. 1 embodiment, it is believed that operation of the similar, Fig. 3 embodiment will be obvious.

The embodiments shown in Figs. 1 and 3 illustrate circuits in which a small current

through the liquid is employed to control a larger plate current through the vacuum tube, this larger current being effective to actuate the relay controlling the starting and stopping of the refrigerating mechanism. Thus, in those two embodiments, the current passing through the liquid is not the same as that passing through the relay coil 39 (or 39*a*).

Fig. 4 illustrates another embodiment which is a still further simplification of my invention in that a current high enough to pass through the liquid and actuate a sensitive relay coil 30*b* is produced by transformer means 74. Thus, by passing a current through the liquid circuit high enough to actuate the relay, the vacuum tube means employed in the previously described embodiments may be dispensed with.

Describing the Fig. 4 embodiment now in more detail, it comprises: a cooling tank 20*b* having high and low limit electrodes 23*b* and 24*b* suitably spaced from cooling coil 21*b* immersed beneath the liquid in the tank; a relay 27*b* having normally open switches 39*b* and 41*b* actuated by current passing through coil 30*b*; a transformer 74 having primary and secondary coils 76 and 77 respectively; and refrigerating mechanism 19*b* operative to cool the coil 21*b* below the freezing point of the liquid 31*b*.

The relay 27*b*, refrigerating mechanism 19*b*, cooling tank 20*b*, and parts associated with the latter, are for purposes of illustration, assumed to be the same as similar parts shown in Figs. 1 and 3, the only new element being the transformer 74 which is substituted for the vacuum tube. Furthermore, while an alternating current circuit is illustrated in Fig. 4, it will be obvious that the circuit may be adapted to D. C. operation by substituting, for the transformer, a D. C. source of proper potential.

In considering now the operation of the embodiment shown in Fig. 4, assume that the relay switches 39*b* and 41*b* are open as shown in solid lines. This, of course, means that the refrigerating mechanism 19*b* is not being supplied with power through conductors 54*b*—56*b* and therefore is not operating. Assume also that there is no ice collected on the coil 21*b* as would be the case when the apparatus is first placed in operation. It will be recognized that the liquid 31*b* can be any electrically conductive liquid; however, for purposes of illustration, it will be assumed for the case being described that the liquid is ordinary tap water which contains sufficient dissolved salts to make it conductive. Since the ends of both electrodes 23*b* and 24*b* are covered with this conductive water, a circuit will be completed through the water, the relay coil 30*b* and the transformer secondary 77. This circuit may be traced as follows: Conductor 47*b*—ground—conductor 32*b*—tank 20*b*—liquid 31*b*—low limit electrode 24*b*—conductors 57*b* and 51*b*—relay coil 30*b*—conductor 78—and secondary coil 77. No current will pass through the high limit electrode 23*b* at this time because the relay switch 39*b* is open.

Current flow through the circuit traced above will energize the relay to close both switches 39*b* and 41*b*. Considerable leeway is possible when selecting the sizes of transformer and relay which may be used in the circuit and the transformer may be either of the step-down or step-up type, depending on the secondary voltage required and depending on the primary voltage available. In one specific example employing ordinary tap water in the cooling tank it was found that a

secondary E. M. F. of 80 volts was sufficient to cause a current of 20–30 milliamperes to flow in the circuit traced above and, to make the circuit effective in the manner above described, it was necessary only to select the relay 27b with the coil 30b suitably wound to close switches with a coil current of this magnitude.

The closing of switch 41b will energize the refrigerating mechanism 19b causing it to cool the coil 21b and to begin freezing ice thereon.

The closing of switch 39b, coincidentally with 41b, will place the high limit electrode 23b in parallel with the low limit electrode so that even as ice builds up on the coil and collects about the low limit electrode, current will still flow through the high limit electrode to keep the refrigerating mechanism running until the high limit electrode is covered with ice.

When the ice layer builds up to the point 73b which is the maximum limit for the frozen layer, current flow through the high limit electrode will be stopped or at least sufficiently reduced that the relay switches will open. This will stop the refrigerating mechanism whereupon the ice layer will begin to melt. Since the opening of switch 39b will have taken the high limit electrode 39b out of the circuit, melting of the ice layer past that electrode will be ineffective to restart the refrigerating mechanism.

When the ice melts back to the point 72b, the water circuit will once more be completed through the low limit electrode 24b whence the refrigerating mechanism will be restarted and the above described cycle will be repeated.

While particular embodiments of the present invention have been shown for illustrative purposes only, it will be understood that the invention is not limited to the specific details disclosed, since many modifications may be made. It is therefore contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of the invention.

I claim:

1. In a cooling system for an electrically conductive liquid, said system having a cooling member associated with intermittently operable means for cooling by said cooling member below the freezing point of said liquid to cause a layer of frozen liquid to accumulate on said member, means for regulating the thickness of said layer between predetermined limits comprising: an electrical control circuit including two electrodes mounted within the liquid and spaced at different distances from said member, and including the normally-unfrozen bulk portion of said liquid; and means in said circuit responsive to changes in electrical conductivity of said circuit when freezing and thawing takes place at the respective electrodes to control the starting and stopping of said cooling means to regulate the thickness of said layer between minimum and maximum limits corresponding respectively to the distances of said electrodes from said member.

2. In a cooling system for an electrically conductive fluid having a member immersed in said fluid and having means for lowering the temperature of said member below the freezing point of said fluid to solidify a layer of the latter on said member, control means for limiting the minimum and maximum thicknesses of said layer comprising; a control circuit including minimum and maximum limit electrodes mounted within the liquid and spaced at different distances from said member, including the normally-liquid bulk portion of said fluid, and including means for impressing an E. M. F. across said electrodes and said liquid bulk portion whereby current can flow in said circuit when one or both of the electrodes is covered by liquid, and whereby further substantial current cannot flow therein when the electrodes are covered with non-liquid; electrical means in said circuit responsive to flow of current therein to cause the cooling of said member by said temperature-lowering means, and responsive to lessened flow of current therein to reduce the cooling of said member by said temperature-lowering means; relay means effective to energize that part of said circuit through the upper electrode when said member is being cooled by the temperature-lowering means, and effective to deenergize that part of the circuit through the upper electrode when the cooling of said member by said temperature-lowering means is being reduced; whereby when the frozen layer builds up to cover the maximum limit electrode, the cooling of the member will be reduced until the layer melts to uncover the minimum limit electrode whence the cooling of the member will again be increased, thereby maintaining the thickness of the layer between limits determined by the distances of the respective electrodes from the member.

3. In a cooling system for an electrically conductive liquid having a cold wall positioned in heat exchanging relation with said liquid and having mechanism operative to reduce the temperature of said cold wall below the freezing temperature of said liquid to cause a frozen layer of said liquid to accumulate thereon, electrode means including a pair of electrodes connected in parallel and mounted within the liquid in spaced relation with respect to said cold wall, said electrodes being spaced at different distances from said wall an electric circuit including the normally unfrozen bulk portion of said liquid and said electrode means, and means for regulating the operation of said temperature reducing mechanism in response to fluctuations of current in said circuit to maintain the thickness of said layer between limits determined by the spacing of said electrode means from said cold wall.

4. In a cooling system for an electrically conductive liquid having a cold wall positioned in heat exchanging relation with said liquid and having mechanism operative to lower the temperature of said cold wall below the freezing temperature of said liquid to cause a frozen layer of said liquid to accumulate thereon, said layer having a substantially different electrical conductivity than when in liquid form, means for regulating the thickness of said layer comprising a pair of parallel-connected electrodes mounted within the liquid and spaced at different distances from said cold wall, an electrical circuit comprising said electrode pair and the normally-unfrozen bulk of said liquid in series relation and E. M. F. means therefor, said circuit being responsive to the change in electrical conductivity of the liquid at the respective electrodes when changing between liquid and frozen states to regulate the operation of said temperature lowering mechanism to maintain the thickness of said layer between limits determined by the respective distances of the electrodes from the cold wall.

5. In a cooling system for an electrically conductive liquid which freezes into a solid having a relatively lower electrical conductivity, said system including a cooling member immersed in said liquid and having freezing means associated

therewith operative to cool said member below the freezing point of said liquid to cause a layer of said solid to collect thereon, means for controlling the thickness of said layer including a pair of electrodes mounted within the liquid at different distances from said cooling member, said distances corresponding to predetermined maximum and minimum thicknesses of said layer, and electrical circuit means for controlling the starting and stopping of said freezing means in response to variations in current conducted through said liquid to said electrodes.

6. In a cooling system for an electrically conductive liquid having a cold wall positioned in heat exchanging relation with said liquid and having mechanism operative to reduce the temperature of said cold wall below the freezing temperature of said liquid to cause a frozen layer of said liquid to accumulate thereon, electrode means including at least two electrodes mounted within the liquid in a predetermined spaced relation with respect to said cold wall, vacuum tube means having a plate circuit associated with control means for said temperature reducing mechanism effective to regulate the temperature reducing action thereof on said cold wall, control grid means in said vacuum tube associated with said electrode means responsive to the respective electrical conductivities of said layer and said liquid to control the current in said plate circuit to maintain the thickness of said frozen layer between predetermined limits corresponding to the respective spacings of two of said electrodes from said cold wall.

7. In a cooling system for electrically conductive water and the like having a cooling coil immersed therein and having intermittently operable cooling means for cooling said coil below the freezing point of said water to cause a layer of ice to collect upon said coil, means for controlling the thickness of said layer including a pair of electrodes mounted within the water and spaced at different distances from said coil, a vacuum tube having a plate circuit effective to control the starting and stopping of said cooling means and having a control grid circuit associated with said electrodes to control said plate circuit in response to the flow of current through said water to one or the other of said electrodes.

8. In a cooling system for an electrically conductive liquid having a cold wall positioned in heat exchanging relation with said liquid and having mechanism operative to reduce the temperature of said cold wall below the freezing temperature of said liquid to cause a frozen layer of said liquid to accumulate thereon, electrode means comprising a pair of electrodes mounted within the liquid adjacent said cold wall and at different distances therefrom corresponding to predetermined minimum and maximum thicknesses of said layer thereon, vacuum tube means including a plate, a cathode and a control grid, electrical means associated with the plate circuit of the vacuum tube for controlling the operation of said temperature reducing mechanism, and electrical means associated with said electrodes and said grid for regulating current in the plate circuit in response to increase and decrease of current through the liquid and the electrode means.

9. In a cooling system for an electrically conductive liquid having a cold wall positioned in heat exchanging relation with said liquid and having mechanism operative to lower the temperature of said cold wall below the freezing temperature of said liquid to cause a frozen layer of said liquid to accumulate thereon, said layer having substantially different electrical conductivity than when in liquid form, means for regulating the thickness of said layer comprising: electrode means including a pair of electrodes mounted within the liquid and spaced at predetermined different distances from said cold wall; means including a source of E. M. F. for completing an electric circuit through said electrode means and said liquid; and relay means responsive to change in flow of current in said circuit to change the cooling effect of said temperature lowering means on said cold wall when the thickness of the frozen layer corresponds to either of said predetermined electrode distances from the cold wall.

10. In a cooling system for an electrically conductive liquid having a cold wall positioned in heat exchanging relation with said liquid and having mechanism operative to lower the temperature of said cold wall below the freezing temperature of said liquid to cause a frozen layer of said liquid to accumulate thereon, said layer having substantially different electrical conductivity than when in liquid form, means for regulating the thickness of said layer comprising: electrode means including a pair of electrodes mounted within the liquid and spaced at predetermined distances from said cold wall, relay means effective to connect said electrodes in parallel and to connect said temperature cooling mechanism to a source of E. M. F.; a circuit through said liquid, said electrode means and a source of E. M. F.; said circuit being associated with said relay means to control the actuation of the latter in response to the condition of current flowing in said circuit.

11. In a cooling system for an electrically conductive liquid having a cold wall positioned in heat exchanging relation with said liquid and having mechanism operative to lower the temperature of said cold wall below the freezing temperature of said liquid to cause a frozen layer of said liquid to accumulate thereon, said layer having substantially different electrical conductivity than when in liquid form, means for regulating the thickness of said layer comprising: electrode means including a high limit and a low limit electrode mounted within the liquid and spaced at different distances from said cold wall corresponding respectively to desired maximum and minimum thicknesses of said layer; relay means having an actuating coil and a pair of switches movable between the open and closed positions in response to current flowing through said coil; and an E. M. F. source connected in series with said coil, said liquid, and said low limit electrode; said high limit electrode being connected in parallel with said low limit electrode through one of said switches; said other switch being operative to control the cooling effect of said temperature cooling mechanism on said cold wall.

GEORGE V. CALABRESE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,999,930	Hirschl	Apr. 30, 1935
2,117,104	Rorison	May 10, 1938
2,143,687	Crago	Jan. 10, 1939
2,421,819	Vandenberg	June 10, 1947