March 7, 1961 J. P. KRIECHBAUM 2,973,630

CONTROL APPARATUS

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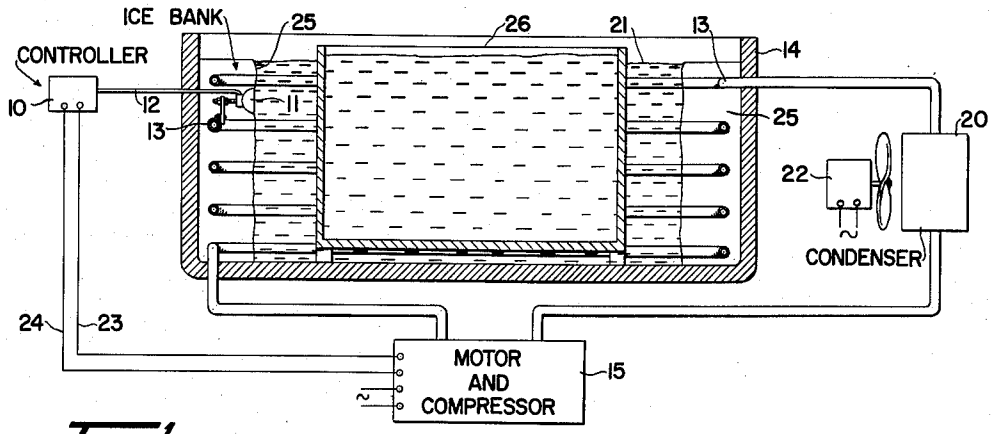


FIG. 1

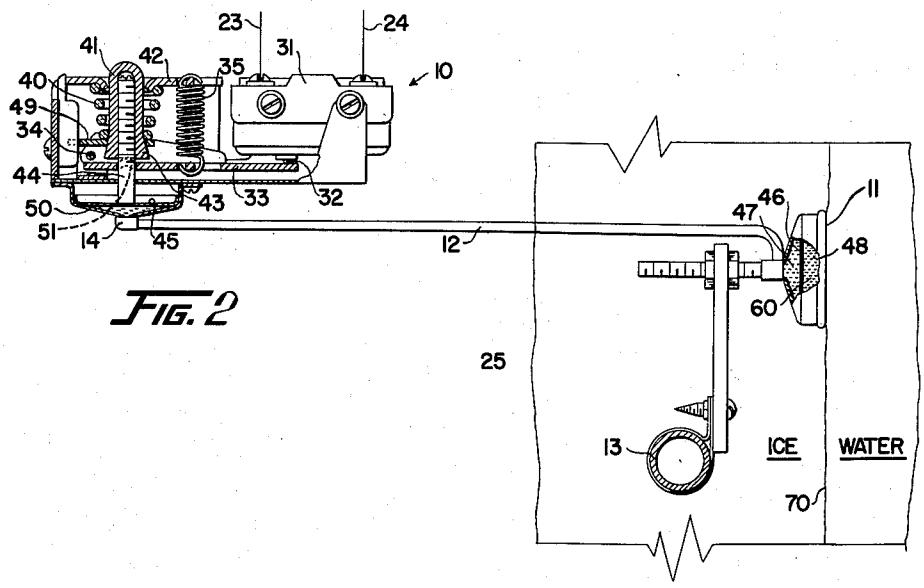


FIG. 2

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CONTROL APPARATUS

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The present invention is directed to temperature sensitive control devices and particularly to such devices in which control is effected by volume changes caused by melting and freezing of a substance contained in a temperature sensing chamber.

Control devices of this type find utility in maintaining a layer of ice of the desired thickness on an evaporator coil submerged in a tank of water. A sensing element filled with water is located approximately at the desired ice level and it is intended that the water within the element be frozen when the element is covered with ice and melted when water surrounds the element. By building up an ice bank during periods of light load, a refrigerating system of moderate size is able to handle intermittent heavy loads.

Erratic operation and undesirable short cycling has been experienced with controls of this type in the past. This has been due to inability of the sensing element to differentiate between water and ice at the melting temperature, and is also due to the melting point of the ice within the sensing chamber being slightly less than the ice of the ice bank. This latter effect is due primarily to pressure maintained on the sensing element by the switch mechanism actuated thereby, and secondarily to any impurities that may be contained in the element fill.

According to the present invention the refrigerating system is controlled by a sensing element having a fill that melts and contracts to close an associated switch at a temperature slightly above the melting point of the ice bank. The fill can be controlled to freeze and expand to open the switch at a temperature slightly below the normal freezing temperature of the ice of the ice bank. In order to attain this low temperature the sensing element must be embedded in the ice bank to a depth at which the temperature gradient between the ice surface and the evaporation coil equals the freezing temperature of the fill. When the refrigeration system is stopped, the temperature of the ice bank will equalize at the melting temperature, but the element fill will remain frozen until the element is clear or substantially clear of the ice because the fill melts at a temperature slightly above the ice melting temperature. When the water surrounding the element is definitely above the freezing point the fill will melt to start the compressor. Since the element fill melts above the melting point of ice and freezes below the freezing point of water, the thickness of the ice bank is controlled with sufficient accuracy and without needless short cycling of the refrigeration system.

In prior systems of this type the fill in the sensing element melted at or below the melting temperature of the ice bank and consequently the switch controlled by the element was reclosed at some undetermined time after being opened, the time depending largely on how long it took the ice bank to equalize in temperature. Hence the operation of the refrigeration system was only indirectly related to the position of the sensing element relative to the position of the outer ice surface.

Also, according to the invention, it is proposed that an additive be mixed with water in a ratio to provide an element fill having a melting point slightly above the melting point of pure water. It has been found that a very small amount of deuterium oxide (commonly known as heavy water) added to water provides a mixture that melts slightly above 32° F. This mixture provides a fill whose melting and freezing points are closely related to the melting and freezing points of pure water but higher. All other known materials when mixed with pure water result in lower melting and freezing points.

The water in the open tank will freeze at 32° F. since an ice surface exists at which the freezing takes place. This is not true of the water in the sensing element, however, and considerable super-cooling takes place before freezing occurs. Thus, if no ice is present in the sensing element it must be cooled to some temperature below 32° F. before freezing will start. The amount of super-cooling is controlled by various means including insertion of silver iodide crystals in the element as has been known heretofore.

It is therefore an object of the present invention to provide an improved temperature control system.

It is another object of the present invention to provide an improved temperature control device.

It is another object of the present invention to provide an improved liquid fill for temperature control device.

It is still another object of the present invention to provide an improved liquid fill for temperature control devices used to control the amount of ice forming on the sensing element wherein the fill melts at a temperature slightly above the freezing point of water forming the ice.

These and other objects will become apparent upon a study of the specification and drawings of which:

Figure 1 is a schematic view of a temperature controller when used to maintain an ice bank in a milk storage installation.

Figure 2 is a cutaway view of the ice bank controller shown in Figure 1.

Referring to Figure 1, a temperature control device **10**, having a remotely located sensing element **11** connected thereto by a capillary **12**, is shown as used in an ice bank control installation for maintaining a predetermined amount of ice around the coils of a refrigeration apparatus. The particular installation shown is for illustrative purposes only and has an evaporator coil **13** spaced from the inner side walls of a tank **14**. This coil is connected in series to a motor and compressor unit **15** and a condensing coil or condenser **20**. The refrigeration apparatus, upon operation of the motor and compressor unit, takes heat from the water **21** in the tank and the heat is expelled from condenser **20** as air is passed therethrough by a fan **22**. Controller **10** is connected by wires **23** and **24** to control the motor. The sensing element **11**, through controller **10**, controls the compressor to maintain an ice bank **25** of a predetermined thickness on the coils. This ice bank is a means of storing cooling capacity for cooling a second inner tank.

Referring to Figure 2 the controller **10** is shown in more detail. It has a snap switch **31** having an operating plunger **32** which is engaged by a lever **33**. The lever is pivoted at one extremity on a shaft **34**. A spring **35** is attached to lever **33** to bias it upward in a counterclockwise direction about pivot **34** to engage the plunger **32** of the switch. A second spring **40** is coiled about an adjustment nut **41**. Spring **40** is lodged between the upper portion of the casing **42** and a collar **49** carried on bell-shaped portion **43** of nut **41** at the lower end

thereof. Collar 49 provides a friction load on nut 41 to prevent its movement after calibration. A shaft 44 which passes through a hole in lever 33 has one extremity screwed into nut 41 and its other extremity attached to a diaphragm 45 in the operating head 50 of the device. The diaphragm is biased downward by a force applied to shaft 44 through nut 41 by spring 40. The lower end 43 of nut 41 contacts a raised portion 51 of lever 33. When the diaphragm 45 is moved upward the nut 41 compresses spring 40 to allow lever 33 to move upward under the force of spring 35 pushing the plunger 32 of the switch upward. By the adjustment of nut 41, the device is calibrated and the switch will operate for a predetermined movement of diaphragm 45.

Sensor 11 contains a diaphragm 46 to separate the unit into two chambers. Chamber 47 is connected to tube 12. The liquid fill used in chamber 47, tube 12, and below the diaphragm of operating head 50 has a relatively low freezing point. It is used only to transmit the force of the sensing element 11 to controller 10. Chamber 48 is filled with a liquid fill 60. When the liquid 60 in chamber 48 freezes, a pressure is developed which is reflected through the capillary tube to diaphragm 45 to operate the switch.

Liquid fill 60 comprises a liquid such as water with a predetermined percentage of deuterium-oxide (D_2O) which is commonly known as heavy water. Deuterium-oxide when added to a liquid such as water has the characteristic of increasing its freezing point above the normal freezing point of water alone. For example, a solution of water might be made with deuterium-oxide to have a freezing point of 32.3° F. After this solution is added to the device it will generally pick up impurities as a result of the normal handling during the manufacturing process which, for example, might reduce the freezing point to 32.2° F. Further, it has been found in a pressure developing control device of this sort the pressure in the sensing element as a result of the freezing of the liquid is sufficient to further reduce the freezing point of this specified mixture to 32.1° F. This is an improvement over the prior art as heretofore with water fills the impurities and pressure tends to reduce the freezing point below the freezing point of pure water at 32° F.

Operation

Referring to Figure 2 it is assumed that the control has operated the switch 31 to energize the associated motor compressor unit and the evaporator coil 13 is cold, for example, around 20° F. There will be a temperature differential between the evaporator coil and the water bounding the edge of the ice bank at 70 as the water will be 32° F. or above. As long as the controller sensing element 11 is in contact with water, as shown, its temperature will remain around 32° F., thus, there will be a temperature gradient between the under side of the element 11 and the evaporator coil from 20° F. to 32° F. As soon as the ice bank starts to form on the right side of the element, the element temperature will drop and it will be between the extreme temperatures of 20° F. and 32° F. As the ice bank continues to form, the temperature of the element will drop until the solution therein begins to freeze to develop a pressure on diaphragm 45 to operate the switch and turn the compressor off. The freezing temperature depends upon the amount of super-cooling and as mentioned it can be controlled and even reduced to zero so that the freezing and melting point of the fill is the same.

When a control of this type is used in a bulk milk tank apparatus as shown in Figure 1, the ice bank is normally not expected to be maintained over a 12 hour period due to the frequency of the milking period. Assuming no ice is formed on the coil, the refrigeration apparatus is placed in operation. As the ice formed around the sensing element as shown in Figure 2, the temperature of the sensing element drops. Since there is no ice in the chamber 48, the freezing point of the fluid is much lower than 32° due to the super-cooling phenomenon. In some cases, the ice bank may build two inches beyond the element before the refrigeration apparatus is shut off. Since a temperature gradient exists between cooling coil 13 and the edge of the ice bank 70, the element may be several degrees below 32° F. before the fluid in chamber 48 freezes to turn off the refrigeration apparatus. As the evaporator coil ceases to take heat from the ice, the temperature of the ice bank will increase and it has been found to approach a uniform temperature of around 32° F. At this time the sensing element which is embedded in the ice bank would be at 32° F. It is obvious that if the melting point of the liquid therein was below 32° F., as in controls of the prior art, the ice formed in element 11 would melt to again turn on the compressor. As soon as the compressor was turned on, the evaporator coil would again start cooling the ice bank and re-establish the gradient across the bank until the ice in the element again forms to shut off the compressor. Such a phenomena results in short cycling of the compressor which is not desired.

When the warm milk is poured into the tank 26, the ice bank is normally melted completely away from the sensing element; in fact, the equipment manufacturer generally designs the capacity of the equipment so the ice bank is completely used each time the tank is filled with warm milk. Under such conditions, the ice would be completely melted in chamber 48, and upon the ice bank being again formed on the cooling coil, the super-cooling phenomenon takes place again and the ice builds up the element.

Normally the control device is not used where the ice bank is only partially melted back to uncover the element 11; however, if such a condition should take place, the ice in chamber 48 may not completely melt. Upon a subsequent operation of the refrigeration apparatus, the ice bank forms on the cooling coil until the element is substantially covered as shown in Figure 2. Since the super-cooling phenomenon did not take place as ice already exists in chamber 48, a differential is maintained by the difference in freezing point of the fluid in chamber 48 as brought about by the difference in pressure needed to operate the control device 10. When the refrigeration apparatus is operating and the ice bank is being formed, a freezing point slightly below 32° exists in chamber 48 so the element 11 must be substantially covered with ice before the fluid in chamber 48 freezes. Once the refrigeration apparatus is turned off, a different pressure in chamber 48 is needed to re-energize the refrigeration apparatus by controller 10. In other words, a slightly higher melting point of the fluid in chamber 48 exists when the fluid in chamber 48 is melting to energize the refrigeration apparatus. The slightly higher melting point is probably above 32° if the deuterium oxide is used. Without the deuterium oxide, the melting temperature would be below 32°, and the refrigeration apparatus would be turned on as soon as the ice bank reached the uniform temperature around 32°. The short cycling condition is eliminated by the use of deuterium oxide.

With the improved fill used in the sensing element, the freezing point is slightly above 32° F. and the ice in the element does not melt until the ice bank reduces in size sufficiently to expose the element to the water so that the element temperature can increase above 32° F.

As stated before, in the manufacturing of such a device the amount of impurity has a great effect upon the freezing temperature of the liquid fill. By the use of this deuterium-oxide it is possible to anticipate the possible percentage of impurities and to compensate for the possible reduction in the fill temperature due to the impurities by the addition of more deuterium-oxide.

Another advantage of this improved fill is that it has possibly less tendency to super-cool than the normal fills heretofore used. In the initial operation of the device as the ice bank is forming around the element **11** it has been found, with conventional fills, that the element temperature often drops much lower than the freezing point of the liquid therein and yet the liquid does not freeze. As super-cooling depends on so many factors the freezing temperature can vary which causes variations in the thickness of the ice bank. To lessen this, crystals are often added to control and stabilize the amount of super cooling as it greatly affects the control results of such a temperature control device.

While the invention has been described in connection with a temperature control device for controlling the ice bank in a storage container, it is obvious that the invention may be used in other applications and therefore it is intended that the present invention only be limited by the scope of the appended claims—in which I claim:

1. In a control system for controlling the size of an ice bank maintained on the evaporator coil of a refrigeration apparatus which are submerged in water, a switch for controlling the operation of the refrigeration apparatus, a pressure sensitive switch operator for operating said switch, a sensing element having a first and a second chamber separated by a flexible wall, said sensing element being attached to the evaporator coil, conduit means connecting said first chamber and said pressure operator in a closed liquid filled system so that upon the compression of said liquid a predetermined amount in said first chamber said operator causes said switch to stop the operation of the refrigeration apparatus, a fluid expanding upon freezing and having a freezing point and a melting point above 32° F., said fluid being used to fill said second chamber so that upon said sensing element being covered with ice and being exposed to a temperature below 32° F. said fluid will freeze to expand and apply a compressing force through said wall to said fill and thus operate said switch shutting down the refrigeration apparatus, said refrigeration apparatus being reenergized when said element is substantially uncovered.

2. In a control system for controlling the size of an ice bank maintained on a cooling coil submerged in water of a cooling apparatus, a switch for controlling the operation of the cooling apapratus, a pressure sensitive switch operator for operating said switch, a sensing element having a chamber filled with fluid having a freezing temperature slightly above the freezing temperature of water, said element being adapted to be mounted adjacent the cooling coil in the water, means connecting said element to said operator whereby, upon said fluid expanding as it freezes as the ice bank surrounds said sensing element to produce a pressure in said chamber, said switch is operated to deenergize the cooling apparatus, said fluid having a freezing and melting temperature slightly above the freezing temperature of water, whereby said operator operates the switch to reenergize the cooling apparatus when the ice bank recedes from its surrounding condition of said element.

3. In a control system for controlling the size of an ice bank maintained on a cooling coil submerged in water of a cooling apparatus, a switch for controlling the operation of the cooling apparatus, a pressure sensitive switch operator for operating said switch, a sensing element having a chamber filled with fluid, said element being adapted to be mounted adjacent the cooling coil in the water, means connecting said element to said operator whereby upon said fluid expanding as it freezes as the ice bank surrounds said sensing element to produce a pressure in said chamber, said switch is operated to deenergize the cooling aparatus, said fluid having a freezing and melting temperature slightly above the freezing temperature of water, said fluid freezing as the ice bank surrounds said sensing element at a predetermined temperature above the freezing temperature of the water even though the fluid is under a pressure upon increasing in volume as the temperature gradually decreases, said fluid having a melting point above the freezing point of water even though the pressure created by said fluid when frozen would normally reduce the freezing point whereby said cooling apparatus is not reenergized until the ice surrounding said element is removed to raise the temperature of the element above said predetermined freezing temperature of water.

4. A sensing element adapted to be mounted adjacent a cooling coil of an ice bank controlling apparatus wherein an ice bank is maintained on a cooling coil submerged in a water tank, comprising, a chamber filled with a fluid which upon expanding produces a pressure in the chamber, means adapted to control the temperature of the cooling coil in response to the pressure developed in said chamber, said fluid comprising deuterium oxide and water, said fluid having a freezing temperature above the freezing temperature of water so that the effect of the pressure developed in said chamber when said fluid freezes to increase in volume does not lower the freezing or melting temperature below the freezing temperature of the water.

5. A thermal sensing unit for controlling the size of an ice bank on a heat exchanger comprising, a chamber filled with a fluid so that upon said fluid freezing to increase in volume a condition indicative of the temperature is obtained, means responsive to said increase in volume and the resultant pressure developed in said chamber adapted to control the capacity of the heat exchanger, said fluid comprising water and deuterium oxide whereby said fluid freezes and melts at a temperature above the freezing point of water alone and the effect of said pressure on said fluid to lower the freezing point is overcome.

6. A thermal sensing unit comprising, a chamber filled with a fluid so that upon said fluid freezing to increase in volume a pressure indicative of the temperature is obtained, said fluid comprising water and deuterium oxide whereby said fluid freezes at a temperature above the freezing point of water alone and the effect of pressure on said fluid which results in the lowering of the freezing point of the fluid is reduced.

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