A THERMOSTAT FOR LOW TEMPERATURES

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In order to carry out a series of experiments on the velocity of crystallization of water, it was necessary to construct a thermostat that could be held constant at temperatures from 0° to about -20° . The apparatus that was finally devised for this purpose is described below and a cross section shown in Fig. 1.

Fig. 1

The general plan consists of a primary bath A and a secondary bath B. The primary bath is filled with a mixture of ice, salt and water, which is pumped through a coil in the secondary bath. When the temperature of the solution in B becomes too low, a regulator closes a cock by means of the wheel E and shuts off the flow of the cold brine. Similarly, when B becomes too warm, the cock is opened and the flow of brine lowers the temperature.

The essential details of the apparatus are as follows: The primary bath A is eighteen inches square and fourteen inches deep. It is constructed of heavy galvanized iron and is placed in a box and insulated with a 4 inch layer of sawdust. The dimensions of the secondary bath are $25'' \times 5\frac{1}{2}''$ and $6\frac{1}{2}''$ in depth. It is also constructed of galvanized iron and is placed in a wooden box, M. Between the bath and M is a one inch layer of felt. M is provided with a tightly fitting

cover and is covered on the outside with a layer of felt about half an inch thick.

The brine from the primary bath is pumped by means of the turbine C, through D, back into A again through a return pipe that is not shown in the figure. The brine coming in at the intake of the pump passes through fine copper gauze which removes bits of straw, etc., that would clog the pump. The axle of the pump extends through a packing box to the outside of the bath. It is driven by means of the wheel I, which is connected with a one-tenth H. P. motor.

The secondary bath is agitated by a screw-shaped stirrer, F, which is driven from the outside of the bath. For a long narrow bath of this kind, this has proven the most efficient type of stirrer. A double window, J, makes it possible to observe the growth of the crystals in the tubes that are immersed in the bath. The panes of glass in this double window are about three-fourths of an inch apart. This double window has the advantage that it furnishes an air space which is an insulator and eliminates, to a considerable extent, the heating of the bath. Moreover, water vapor does not condense to ice on the outside of the glass and thus interfere with the view of the inside of the bath as is the case when a single window is used. The inside of the bath is illuminated by two 4 c. p. 6 volt incandescent bulbs, H, H, similar to those used for automobile side lamps. Considerable difficulty was experienced in finding a suitable regulator. The ordinary form of glass regulator filled with toluene is not satisfactory. The liquid in the regulator conducts the heat so slowly that there is a great lag in its operation with a consequent diminishing of the constancy of the bath. This was in part avoided by using a regulator, G, consisting of a steel tube filled with mercury. To further reduce the lag, the mechanism shown in the figure was used.¹ This consists of a slowly rotating wheel, K, to which a platinum wire is attached to an excentric

¹ Gouy: Jour. Phys., 6, 479 (1897); see also Barnes: Phil. Trans., 199, 149 (1902).

so that it moves up and down in the stem of the regulator. When the mercury expands it makes contact with the platinum wire, an electrical connection is made that rotates the wheel E, thus opening the cock in a manner to be described shortly. This sends cold brine through the pipe D. The platinum wire, however, is slowly withdrawn from the mercury and the contact broken before the mercury is through expanding, thus compensating for the lag in the regulator. If the bath has been cooled to the desired temperature by the opening of the cock, the mercury will usually have commenced to contract by the time the platinum wire begins to descend again. This device must be regulated to suit the individual bath, the length of throw of the wire and the speed with which it moves being the factors that must be controlled.

The success of the thermostat depends upon the method of automatically opening and closing the cock that admits the cold brine. The details of the arrangement are shown in Fig. 2. The pipe D is provided with a cock, Q, which is an

Fig. 2

ordinary water cock used on faucets. To the end of the rod Y, operating this cock, a wooden wheel, E, about six inches in diameter, is secured by a nut, Z. Two rubber stoppers, S, S, are secured to E. When the wheel is turned these stop-

pers come in contact with the "bumpers" T, T and so make it impossible for E to make a complete revolution. A nine point rocking switch, L, is connected to E by means of a string X. To bring the bath to the right temperature the nut Z, fastening E to the cock, is loosened and the cock opened enough to allow the bath to come to a temperature a few tenths of a degree above that desired. E is then turned as far as possible to the right and the nut tightened. Turning the wheel to the left will now open the cock and permit a larger stream of the cold brine to flow through the secondary bath. When the temperature of the bath becomes too high the regulator, by means of the relay R, throws the motor P, into a 110 v. A. C. circuit. This starts the motor (shown in Figs. 1 and 2) and rotates E to the left, opening the cock. The rotation of E pulls the rocker of the switch to the left and breaks the 110 v. circuit. The connections through the switch are made in such a way that as soon as the points of the rocker leave the mercury cups on the right the 110 volt circuit is broken. As soon as contact is made with the mercury cups on the left of the switch the fields of the motor are reversed.¹ The cold brine now runs through the secondary bath until the mercury in the regulator begins to contract. The current through the relay is then broken. This starts the motor P, once more, but the direction in which it turns has been reversed consequently E is rotated to the right, the cock is closed once more and the 110 volt current again shut off. For as soon as the points of the rocker leave the mercury cups at the left the 110 volt current is broken, and the fields of the motor are reversed when contact is made with the cups at the right. The making and breaking of the current by means of the regulator thus intermittently opens and closes the cock. The motor that does this is in motion only while the cock is being opened or closed and at no other time.

The binding posts or wires in Fig. 2 that are numbered

¹ The motor used for opening and closing the cock was made by the General Electric Co. It is described as follows: Induction motor. 60 cycles. 110 volt. Type Dss. $\frac{1}{16}$ H. P. Speed 1800. Cat. 66931.

the same are connected directly. Thus 6 on the relay has a direct connection with 6 on the rocker switch.

The solution used in the secondary bath was made by mixing two parts of water with one part of glycerine and one part of ethyl alcohol.

In a test carried out to ascertain the constancy of this thermostat it was found that at a temperature of -12° during a run of six hours the temperature varied $\pm 0.03^{\circ}$. By using a mixture of calcium chloride and ice in the primary bath it is possible to keep the secondary bath at a temperature of -25° to -30° .

The automatic cock described above may be used at temperatures above zero. For example, ice water could be substituted for the brine solution, and at higher temperatures the primary bath could be entirely replaced by a boiler generating superheated steam.

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