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A HUMIDITY REGULATOR.[1]

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The necessity for accurate control of temperature in the study of chemical reactions has been the mother of numerous inventions for the automatic maintenance of constant temperature. But the maintenance of constant humidity has been left largely to the ingenuity

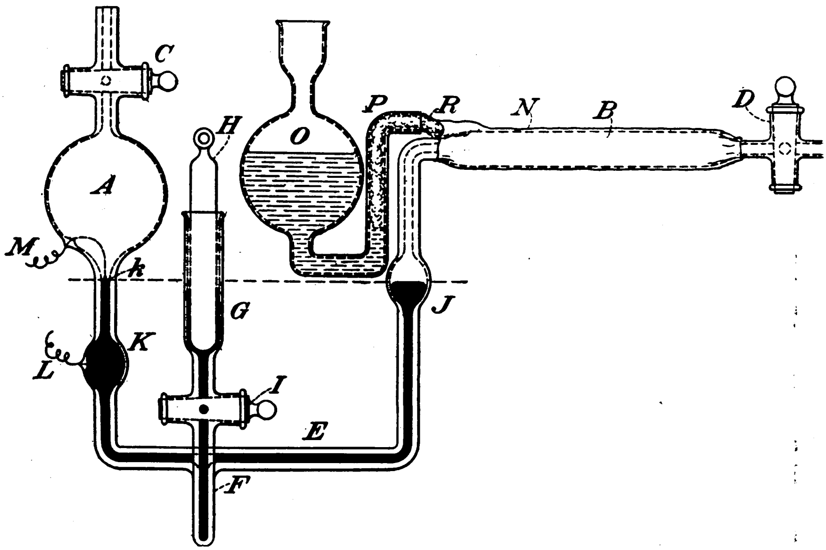

FIG. 1.—Humidity regulator, general view.

of those who are interested in the textile industries and in cold storage, and the scientific investigator is without an instrument which he can make for himself and depend upon in his studies of the development of plant life or of any phenomena influenced by the humidity of the surrounding air.

[1] In accordance with the requirements of the Department of Agriculture the apparatus herein described has been patented and the patent dedicated to the public. The patent is No. 1,042,893, issued Oct. 29, 1912.

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In the ripening of cheese humidity plays a very important rôle, and it was in connection with this that the regulator herein described was devised. A description of the apparatus is given in the hope that its accuracy and simplicity as well as the ease with which it can be made will commend it to those who need such an instrument.

A general view of the apparatus is shown in figure 1. Figure 2 is a sectional view of the capillary connections.

DESCRIPTION OF THE APPARATUS.

The regulator operates on the principle of the wet and dry bulb hygrometer. It consists of a dry bulb *A* and a bulb *B* kept moist by a thin covering of wicking or muslin. This is fed with water from the reservoir *O*. For convenience in adjusting as well as for cleaning and filling both bulbs are provided with cocks, *C* and *D*. In order to present a convenient as well as a large surface, *B* is made cylindrical. The bulbs *A* and *B* are connected by the capillary tube *E*, partially filled with mercury. This tube is connected by a T-joint, *F*, to a leveling bulb, or preferably to a cup and plunger, *G* and *H*, by which the height of the mercury in the capillary may be adjusted. The cock *I* serves to open or break communication between the capillary and the leveling device. The bulbs *J* and *K* serve as mercury reservoirs and prevent accidental emptying of the capillary and consequent interchange of the gases in *A* and *B*.

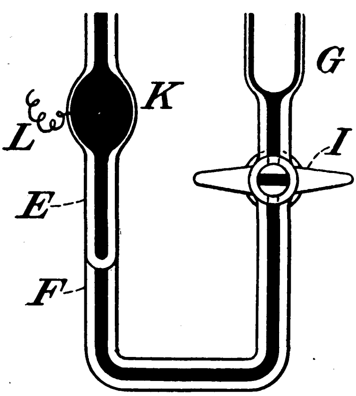

FIG. 2.—Humidity regulator, sectional view of capillary connections.

Electrical connection is made with the mercury by the sealed-in platinum wire *L*. Another platinum wire, *M*, is sealed in in such a way that its fused and smooth tip extends into the capillary at *k*. These wires are connected with a battery and relay, and are spanned with a condenser and a by-pass in order to eliminate sparking at the contact *k*.

METHOD OF OPERATION.

The operation of the regulator is as follows: The whole instrument is placed in a current of air whose humidity it is desired to regulate. Evaporation takes place on the moist bulb *B*, producing a cooling of the inclosed gas. The consequent reduction in pressure permits the excess pressure in *A* to drive the mercury away from the platinum contact at *k*. By this break in the circuit the relay is released in such a way that there is actuated a steam or water spray or a heating unit for raising the vapor tension of a body of water over which the air flows. As the humidity of the air is thus increased the evaporation from *B* diminishes, and consequently the cooling. The pressure in *B* therefore regains its former value and contact is again made at *k*, the relay is actuated, and the source of moisture is shut off. For laboratories having electric current it will probably be found convenient to raise the vapor pressure by having the relay control an electric immersion heater plunged in a small vessel of water, and to have this vessel kept at constant water level, as is the Victor Meyer water bath.

If the space whose humidity it is desired to control is not to be kept at constant temperature, and constant relative humidity is still demanded, it should be remembered that for a given relative humidity the temperature of the wet bulb will increase less rapidly than that of the dry bulb, with a rising temperature. Compensation for this can not be made by varying the relative sizes of the two bulbs, but it can be done by adjusting the pressures within the two bulbs.

To find the conditions to be established if it is desired to maintain a constant relative humidity we apply the following considerations: Since the circuit controlling the humidifier is made and broken at the point *k*, the volumes of the gas in the two bulbs must be kept constant, and in order that the mercury column may not be displaced any increment of pressure in the one bulb must be compensated for by an equal increment of pressure in the other.

Let T = the absolute temperature of the dry bulb.

T' = the absolute temperature of the wet bulb for a given relative humidity at temperature T.

Let T increase by ΔT and T' by $\Delta T'$, when the same relative humidity is maintained.

Let P = the initial pressure of the dry bulb at T.

P' = the initial pressure of the wet bulb at T'.

When T increases by ΔT, P increases by ΔP.

When T' increases by $\Delta T'$, P' increases by $\Delta P'$.

As mentioned above, the condition desired is that $\Delta P = \Delta P'$.

From the equation for a gas at constant volume,

$$\frac{P}{P_2}=\frac{T}{T_2} \text{ and } \frac{P'}{P'_2}=\frac{T'}{T'_2},$$

where the subscripts represent the temperature and pressure under a second set of conditions, we may deduce the equation

$$\frac{P}{P'}=\frac{\Delta T'T}{\Delta TT'}$$

From this last equation we may calculate the pressure which must be imposed upon the gas in the wet bulb, provided we start with a known pressure of gas in the dry bulb and postulate the relative humidity and the range of temperature. For example, suppose it is desired to maintain a constant relative humidity of 82 within the range of temperature 21° C. to 26° C. From the psychrometric tables,[1] when the relative humidity is 82 and the dry bulb is at 21.11° C. the wet bulb is at 18.88° C., and when the dry bulb is at 26.11° C. the wet bulb is at 23.61° C. Transposing these temperatures to the absolute scale—

$$T = 294.11$$
$$T_2 = 299.11$$
$$T' = 291.88$$
$$T'_2 = 296.61$$

If, now, we give P the value 777 mm. of mercury, P′, from our equation, becomes 815.1 mm. Whence $P' - P = 38.1$ mm.

This difference may be established by having the dry-bulb arm of the apparatus sufficiently long so that a column of mercury 3.8 cm. long may stand above the level of the mercury at *J*. By proper burette connections at *D* and *C*, and by manipulation in a circulating atmosphere of 82 relative humidity, the proper adjustments in the pressures within the two bulbs may be made.

For many purposes, however, a constant relative humidity is not so desirable with varying temperature as is a rising relative humidity with rising temperature and falling relative humidity with falling temperature. In the curing of cheese, for instance, loss of water will doubtless be more rapid at a temperature of 20° C. and a relative humidity of 80 than at 15° C. and the same humidity. What is perhaps desirable in this case is the maintenance of such a degree of vapor pressure in the atmosphere that the rate of evaporation from the cheese will remain uniform throughout a variation in temperature. Until we know more of the vapor pressure of cheese the desired regulation will, for small variations in temperature, be closely approximated by placing the gas in the two bulbs under approximately equal pressures. This condition is shown in figure 1, where the mercury is at the same height in the two arms.

Since at higher temperatures the evaporation from the wet bulb will be more rapid than at lower temperatures for any given relative humidity, the temperature of the wet bulb will increase less than that of the dry bulb with a rising temperature. To maintain the equilibrium determined by $P = P'$ the relative humidity must be increased so that $\Delta T = \Delta T'$. This means that the same amount of evaporation will take place at T as at $T + \Delta T$. In other words, the rate of evaporation from the muslin remains constant, and consequently for small variations in temperature the rate of evaporation

[1] C. F. Marvin. Psychrometric Tables. U. S. Department of Agriculture, Weather Bureau Bulletin 235, p. 68.

from the cheese may, with but little error, be assumed to remain approximately constant.

In the calculations given above it has been assumed that barometric pressure has no influence upon the evaporation from the muslin covering of the wet bulb; that the expansion of the glass and mercury may be neglected; that the gas in both bulbs is free from water vapor; and that the difference in temperature between the dry and wet bulbs is a linear function of the relative humidity. By filling the bulbs with dry gas we may safely neglect the other sources of error, except that due to a very wide variation in barometric pressure.

POINTS TO BE OBSERVED.

For the satisfactory working of the apparatus the following points should be observed:

(1) The bore of the capillary E must be large enough to allow a free movement of the mercury.

(2) To insure against possible sticking of the mercury the apparatus should be placed where it will receive a slight vibration.

(3) This vibration, as well as the active circulation of the air which it is necessary to have about both bulbs, may be obtained by placing the apparatus in front of a fan and upon the same standard that supports the driving mechanism.

(4) Electric contact at k is best made with a wire tipped with nickel or "nicrome," since mercury will adhere to platinum if the latter is either too clean or too dirty.

(5) Sparking at the contact k must be prevented. A tin-foil condenser spanned across the terminals and reenforced with a by-pass of high resistance will effectually prevent sparking, provided the lowest possible current that will give the relay a positive action is used, and provided the circuit is kept as free as possible from all coils except those of the relay.

(6) To guard further against the ill effects of sparking at k the bulbs should be filled only with a dry gas, preferably pure nitrogen or hydrogen.

(7) Since the wet bulb will respond to changes in temperature only slowly, the box or room which serves as humidostat must be so insulated that rapid fluctuations in temperature are avoided; and more important still, its capacity for moisture must be such that rapid fluctuations in the humidity are avoided.

(8) Only distilled water should be used to keep the muslin covering of B moist. The muslin should be renewed or cleansed weekly, and in preference to the reservoir O, one of constant water level should be so adjusted that the supply of water to N will keep the wet bulb moist, not soaked.

The apparatus is by no means "foolproof," and no claims are made that it will be useful in careless hands. For the purpose for which it was designed it has proved satisfactory, in spite of the fact that the room in which it was used had paraffined walls with practically no moisture capacity, a condition extremely unfavorable for the maintenance of constant vapor pressure.

Approved.

James Wilson,

Secretary of Agriculture.

Washington, D. C., *January 22, 1913.*

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