SCIENTIFIC APPARATUS AND LABORATORY METHODS

A SIMPLE SENSITIVE THERMOSTAT REGULATOR

Two excellent precision thermostats for liquid baths have recently been described.[1,2] Both of these thermostats, unfortunately, are rather expensive and difficult to make. The instrument here described is simple, inexpensive, sensitive, easily adjustable, and can be made by any one with even a limited knowledge of glass blowing. The sensitivity of the thermostat is at least ± 0.001° C. in the 0° to 35° C. range for relatively long periods of time. For this range petroleum ether (benzine, B. P. 40° to 60° C.) is the activating medium. There is also available another benzine with a boiling-point of 68° to 70° C. which would considerably extend the working range, but since the author has not needed to use temperatures above 30° C. he has not tried the higher boiling-point benzine and has no information as to its relative activity. With the benzine used there is an exceedingly rapid response to very slight temperature changes and there is an expansion of about 2 inches in a 1-mm capillary tube for each Centigrade degree. Temperature regulation is therefore possible with ease and precision and high sensitivity is obtained. Changes in atmospheric pressure, as noted by Ferguson *et al.*,[2] affect the temperature readings, but they can be easily controlled by the method suggested by those authors. A slight improvement in their method is here suggested.

The details of construction are readily seen in the accompanying sketch (Fig. 1). Expansion bulb A is made of 18 inches of 12-mm thin-walled glass tubing and is fused to about 15 inches of 4-mm medium-walled tubing, bent as indicated in the sketch. The top of the **U**-bend should be, at all times, below the surface of the liquid of the bath in which the thermostat is used. To this tube is fused a bulb, B, for mercury, made of about 1 inch of 12-mm tubing, or large enough to accommodate all the mercury that is shifted by changes in temperature for the complete range of the thermostat. To the lower end of this bulb is fused another piece of 4-mm tubing, C, bent to form a **U**-tube to which can be fused the thermostat head, H. This **U**-tube is an essential part of the thermostat, as it compensates for the weight of

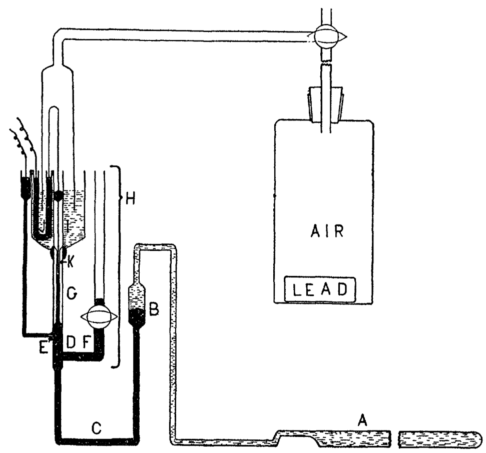

FIG. 1. Thermostat regulator.

the mercury and prevents the mercury from passing into and mixing with the petroleum ether. The thermostat head, H, consists of a 2-inch piece of 7-mm tubing, D, through which is fused a piece of platinum wire, E; a stopcock side arm, F, which has been bent upward; and a 2-inch length of 6-mm, 1-mm bore[3] capillary tubing, G. To the upper end of the capillary tube is fused 2¼ inches of 7-mm tubing, I. The junction of G and I should be on the same level as the top of the **U**-bend above B, so that the entire sensitive portion of the regulator is submerged in the bath. Around the junction of G and I there is fastened, either by fusing or with red sealing wax, an inverted bell of 30-mm tubing to act as a water seal for the atmospheric-pressure stabilizer. A 2-inch **U**-tube, J, filled with mercury, is fastened to the bell and to the top of tube I to aid in making an electrical contact. Fastened over the platinum wire E and to the outside of the bell is a capillary tube drawn from a piece of 7-mm tubing, with the unconstricted portion at the top. This tube is also filled with mercury and makes the second electrical contact.

Before use the thermostat regulator is completely filled with petroleum ether. Then mercury is introduced through the ether and tapped around the **U**-bend so as partially to fill the mercury bulb, B. After all the ether above the mercury has been dried out, a piece of copper wire to one end of which has been fused a piece of platinum wire, K, is introduced into tube I. This wire is provided with a collar 2¼ inches above the platinum tip of such size as to produce friction in tube I. The other end of the copper wire is bent into a 2-inch **U**-bend so that the wire will extend down inside of tube J to complete

[1] James A. Beattie, "A Precision Thermostat for Temperatures from −25° to 500° C." *Rev. Sci. Instruments* 2 (8): 458–465, 5 figs.; also in Publ. Mass. Inst. Tech., 67 (42) 1931.

[2] Alfred L. Ferguson, Kenneth Van Lente and Richard Hitchens, "High-precision Constant-temperature Bath." *Ind. Eng. Chem.*, Anal. Ed., 4: 218–219, 4 figs. 1932.

[3] There has been no difficulty with sticking when tube of this bore has been used.

the electrical circuit. By opening and closing the stopcock in tube F the mercury in tube G can be brought to the desired height for any temperature. A tube, 1 inch in diameter, of 4-mesh hardware cloth provides a satisfactory shield for the expansion bulb.

In selecting the relay care should be taken that the thermostat circuit has a current small enough to prevent arcing and fouling of the mercury. The types proposed by the authors cited ([1, 2]) are satisfactory, but several commercial makes are also good and are considerably less expensive. Any "super-sensitive," positive-action relay that does not use more than 3 volts at 4 milliamperes should be entirely satisfactory.

The atmospheric-pressure stabilizer suggested by Ferguson and coworkers can be improved by inserting a stop-cock between the upper bell and the air bottle. This enables one to set the apparatus for a given temperature at any atmospheric pressure, to place the upper bell in the water seal without changing the pressure, and then by closing the stop-cock to maintain this pressure except for variations due to temperature on the portions of the glass above the bath. Another suggestion is to place some lead in the air bottle and submerge it in the water bath so as to reduce these temperature effects to a minimum.

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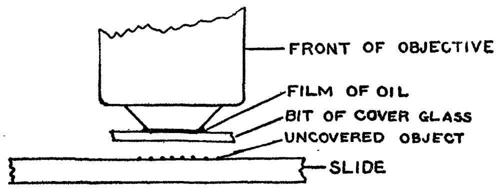
USING A "DRY" MICROSCOPE OBJECTIVE ON UNCOVERED OBJECTS

THE usual type of high power "dry" microscope objective is not satisfactory for use on uncovered objects, as its optical combination is calculated on the assumption that a cover-glass of definite thickness intervenes between the front lens and the object. Such objectives would often be convenient for use on uncovered objects, such as blood smears, small parts of insects, etc., and can be adapted to such use by a simple expedient.

All that is required for the proper working of the objective is the presence of the cover-glass between



the front lens and the object; either on the object, on the front lens or at any point between. Hence, if a bit of cover-glass is fastened over the front lens, the objective will give good images of uncovered objects. The piece of cover-glass may be made to adhere temporarily with a drop of cedar oil, mineral oil or water.

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SPECIAL ARTICLES

THE INTERNAL EXPOSED SURFACE OF FOLIAGE LEAVES

THERE has been increasing realization of the importance of the internally exposed surface of foliage leaves. Much of the water lost and most of the carbon dioxide absorbed by leaves must pass through the cellulose walls bordering on connected intercellular spaces. The rates of leaf functions have often been expressed in terms of external surface but a knowledge of the extent of the internally exposed areas bordering on the intercellular spaces is important and without such information comparisons based on superficial area may not be significant.

Irregularity in the form of mesophyll cells has been probably the greatest barrier to such measurements. The writer has developed a method based on careful camera lucida drawings of the several cell layers in both vertical and horizontal sections; measurements of these drawings were then made with chartometer and planimeter. Formulae were derived to facilitate computation of the ratio between the internally exposed cell wall and the externally exposed surface of selected samples which were free from veins.

Ratios for a few species appear in the following table.

Leaf	Type	Exposure	Thickness	Ratio
Syringa vulgaris	Mesomorphic	Sun	228 μ	13.2
Vitis vulpina	Mesomorphic	Sun	163 μ	11.6
Citrus limonia	Xeromorphic	Sun	238 μ	22.2
Berberis nervosa	Xeromorphic	Shade	254 μ	9.8
Bryophyllum Calicynum	Succulent	Greenhouse	610 μ	7.8

The method, which is too elaborate for description here, involves many measurements of a number of items, averages being used in the formulae. Though many measurements enter into the computation for a given species, differences in the internal organization of leaves even on the same tree indicate that the ratio in a given case should be considered as a mean about which variation must be expected.

Preliminary results, which include other species in addition to those noted above, indicate: (1) that succulents may have a relatively small internal surface ($R = 7.86$); (2) mesomorphic sun leaves though thin