EVAPORATION FROM EARTHEN JUGS

By HAZARI LAL GUPTA, ABINASH CHANDRA JAIN

AND

NARENDRA NATH KHANNA*

University of Delhi

(*Received for publication, July 25, 1940*)

ABSTRACT. The thermodynamical theory of the wet-bulb thermometer is extended to evaporation from earthen jugs, and some of the theoretical deductions are verified by experiment. It is found that the time during which a given quantity of air becomes saturated at the temperature of the jug by coming in contact with it is independent of the temperature of the jug.

When water is kept in an earthen pot, due to the cooling produced by evaporation and the poor thermal conductivity of the clay, its temperature reaches to within half a degree of the temperature of the wet-bulb thermometer. The wet-bulb temperature represents the lowest attainable by cooling due to free evaporation in the atmosphere.

The cooling of water in an earthen jug is very similar to the cooling of the wet-bulb thermometer and in fact the thermodynamical theory[1] of the latter can be applied to the former. This is done in the present paper and the experimental results are found to be in accord with the theory.

Let us consider water contained in a porous pot or earthen jug, heated electrically by passing a current I in a coil of resistance R and let T denote the temperature (in degree Kelvin) that is attained in the steady state. T' and T'' denote the absolute temperature of the dry- and wet-bulb thermometers respectively, and x', x'', and x the humidity mixing ratios for the normal air, the air saturated at the wet-bulb temperature T'' and the air saturated at the temperature T of the pot respectively. The normal air contains x' grams of water vapour per gram of dry air, and suppose it takes time τ_0 seconds for $(1+x')$ grams of normal air to come in contact with the jug and become saturated at its temperature, *i.e.*, the amount of water vapour associated per gram of dry air increases from

* Communicated by the Indian Physical Society.

x' to x. The amount of heat given out in the process by $(1+x')$ grams of air is $(c_p+x'c'_p)$ $(T'-T)$, where c_p is the specific heat at constant pressure for air and c'_p, for water vapour, and the heat produced in the coil is $RI^2\tau_0/4{\cdot}2$. If L denote the latent heat of evaporation, the heat required for the evaporation of $(x-x')$ grams of water is L $(x-x')$, and we have

$$L(x-x')=(c_p+x'c'_p)\ (T'-T)+\frac{RI^2\tau_0}{4{\cdot}2} \qquad \dots \quad (1)$$

As c_p/c'_p is about 2 and x' rarely exceeds 0·025, $x'c'_p$ may be neglected compared to c_p in the first factor on the right hand side of eq. (1). Again as a fairly good approximation we may substitute

$$x=\epsilon\frac{e}{p-e}\sim\frac{\epsilon e}{p}\ ; \qquad \dots \quad (2)$$

$$x'=\epsilon\frac{e'}{p-e'}\sim\frac{\epsilon e'}{p} \qquad \dots \quad (2A)$$

where e' is the vapour pressure of normal air, e the saturated vapour pressure for temperature T, p the total pressure and ϵ the ratio of the densities of water vapour and dry air at the same temperature and pressure. We thus obtain

$$\frac{\epsilon L}{p}(e-e')=c_p(T'-T)+\frac{RI^2\tau_0}{4{\cdot}2}$$

or

$$\left(T+\frac{\epsilon Le}{p.c_p}\right)-\left\{\frac{e'L\epsilon}{p.c_p}+T'\right\}=\frac{RI^2\tau_0}{4{\cdot}2\ c_p}$$

$$\left\{T\frac{c_p.p.}{\epsilon L}+e\right\}-\left\{T'\frac{c_p.p.}{\epsilon L}+e'\right\}=\frac{pR\tau_0I^2}{\epsilon L\times 4{\cdot}2}$$

Substituting $\frac{c_p.p.}{\epsilon L}=0{\cdot}501$, we finally have

$$(0{\cdot}501\ T+e)-(0{\cdot}501\ T'+e')=\frac{pR\tau_0I^2}{\epsilon L\times 4{\cdot}2}\ . \qquad \dots \quad (3)^*$$

The time τ_0 that $(1+x')$ grams of normal air takes to be saturated by coming in contact with the jug will depend on the size of the pores and the surface area exposed for the evaporation of water. The surface exposed for evaporation (as explained below) remains constant during the experiment and it is then found that the relation between $\left\{T\frac{c_p.p}{\epsilon L}+e\right\}$ and I^2 is a linear one. This provides

* In the calculations p is taken to be 730 mm.

$c_p=\cdot23$
$\epsilon=\cdot62$
L = 540 calories.

us with a verification of the theory of evaporation, and also shows the constancy of τ_0 for a constant surface exposed for evaporation.

The experimental arrangement is illustrated in figure 1. p is a porous pot (of the type used for Leclanche cells of diamater 5·3 cms.) which in some of the experiments had about one halt of its surface coated with sealing wax leaving only the portion SS of its surface free for the evaporation of water.

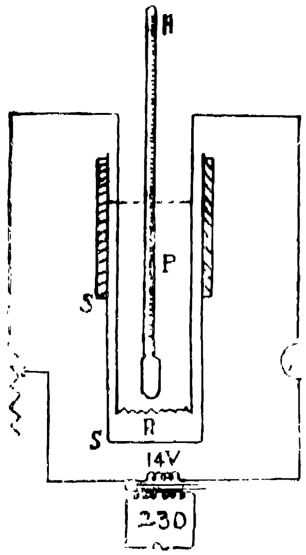

FIGURE 1

At the beginning of the experiment the pot is nearly full of water, but even at the end of the experiment the water level is above the exposed surface SS thus offering a constant surface for evaporation during the experiment. The resistance coil R is of 2·25 ohms. When a current I is passed through the coil,

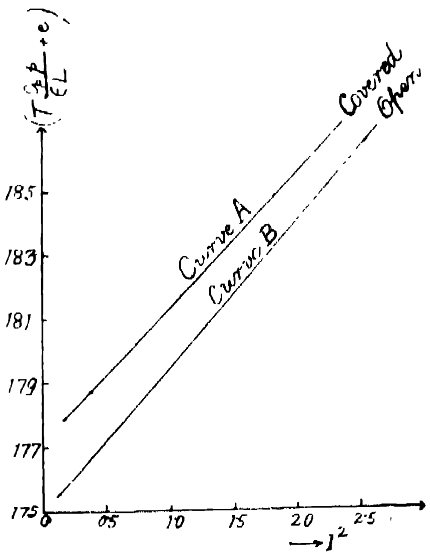

FIGURE 2

after a few minutes the temperature T of the water as indicated by the thermometer H becomes practically steady. Readings are taken for increasing values of I till the temperature T rises above the dry-bulb temperature.

A typical curve for $\left(T - \frac{c_p . p}{e I_r} + e\right)$ plotted against I^2 is shown in figure 2 (curve A) which shows that the relation between them is linear, thus verifying the thermodynamical theory of evaporation and also the assumption regarding the constancy of τ_0. Experiments were also performed with the pot without the coating of sealing wax, and even here it is interesting to note that the relation observed between $\left(T - \frac{c_p . p}{e I_r} + e\right)$ and I^2 is a linear one (curve B, fig. 2). At the start of the experiment, the pot is almost full. At the end of the experiment it is still about two-thirds full. At first sight it would appear that for the uncoated pot the area exposed for evaporation will decrease as the water level sinks in the pot, but, due to capillary action, water creeps along the walls of the pot above the water level inside it, and thus the evaporation-area remains almost constant. However, at the end of the experiment, when the water level has fallen below the top of the pot by about one-third of its length, the points tend to fall below the straight line B. The value of τ_0 can be obtained from the slope of the straight line and we find in the case of figure 2 (curve B) $\tau_0 = 3{\cdot}4$ seconds. The value of τ_0 for a pot, or perhaps better still the value τ_0 for unit area of a porous pot, may be taken as a measure of the "evaporation efficiency" for a pot. It is hoped to undertake such a comparative study for different types of pots at a later date.

Thanks are due to Dr. D. S. Kothari for suggesting the problems and his interest in the work.

REFERENCE

1 Brunt, Dynamical Meteorology. Hazari Lal and Abinash Chandra, *Ind. Jour. Phys.*, **13**, 305 (1939).