32. *A New Form of Condensation-hygrometer.*

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1. Since the year 1845 in which Regnault invented his celebrated hygrometer various forms of dew-point hygrometer were devised. Almost all of them however was based on Regnault's principle, that is, on the observation of the temperature of the condensing surface at the moment when dew begins to deposit on it.

Generally the dew-point instrument is not suited for use in open air except in calm weather, since in a moving air the constant renewal of the air prevents its attaining the dew-point unless the condensing surface is cooled to a considerably lower temperature. The dew-point hygrometer invented by Crova avoids this defect. Also in the modern form of Regnault's apparatus improved in the National Physical Laboratory, the silver thimble on the surface of which dew deposits is mounted in a wooden box, the air inside the box being taken from open air.

Even in these ingenious devices there still remains the difficulty of observing the exact moment at which dew begins to deposit. In a new form of condensation hygrometer which will be described below is avoided almost all of the difficulties inherent to dew-point apparatus. Firstly the principle underlying in the construction of the new form of hygrometer will be given, and secondly an outline of construction of the instrument will be described.

2. Let the volume of a sample of air taken from open air be v . Suppose the total pressure of the air, the tension of vapour, the mass of dry air and that of water vapour are p , f , λ and μ respectively, then we have

$$(p-f)v = \lambda RT \quad \text{and} \quad fv = \mu R_1 T,$$

where R and R_1 are the individual gas constants for dry air and aqueous vapour. From the equations given above we get

$$pv = (\lambda R + \mu R_1) T. \tag{1}$$

By cooling the sample of air a part of water vapour in it becomes condensed. Let the mass of vapour condensed be μ' . Let the temperature and pressure of the sample of air be T' and p' respectively at the moment when the aqueous vapour in it begins to condense. The decrease of the total pressure is a combined effect of the cooling of air and the condensation of aqueous vapour in it.

Since in our case the volume is constant, we have

$$p'v = [\lambda R + (\mu - \mu') R_1] T'. \tag{2}$$

Here the aqueous vapour in the same vessel is saturated at temperature

T' , therefore the tension of it is equal to the maximum tension of aqueous vapour at the same temperature. Let this tension be F' , then we get

$$F'v = (\mu - \mu') R_1 T'. \quad (3)$$

From (2) and (3) we have

$$p'v = \lambda RT' + F'v. \quad (4)$$

From (1) and (4) we have

$$(p - p')v = \lambda R(T - T') + \mu R_1 T - F'v.$$

Writing $\Delta p = (p - p')$ and $\Delta T = (T - T')$, we get

$$(F' + \Delta p)v - \lambda R(T - T') = \mu R_1 T$$

$$\therefore \mu = (F' + \Delta p) \frac{v}{R_1 T} - \lambda \frac{R}{R_1} \frac{(T - T')}{T}.$$

Since

$$f = \mu \left(\frac{R_1 T}{v} \right), \text{ we have}$$

$$f = (F' + \Delta p) - \lambda \frac{R}{v} \Delta T.$$

In closely examining the relative importance of the terms of the right hand side of the above equation we know that the effect of term containing the difference of temperature is by far greater than that of the pressure term. Hence in translating the idea expressed in the above equation into a mechanism, it is very important to suppress altogether the change of temperature when cooling the masses of air, or at least to make the change of temperature as small as possible.

3. Basing upon the principle described above we may construct a hygrometer in the following way. First we fill a spherical or cylindrical vessel of copper or of any other metal having good thermal conductivity with dry air, and fill another exactly similar vessel of the same material and of the same volume with a sample of air, the humidity of which we intend to observe. A *U*-tube manometer connecting both vessels serves us to measure the difference of the pressures inside both vessels.

Then we put both vessels in a large basin filled with cool water. The thermometers inserted in the vessels allows us to measure the temperature of air inside them. As the matter of principle the temperature of air in both vessels is to be equal. After an elapse of a few minutes the manometer will show a sudden fall of the pressure in the vessel with the sample of air in it. The decrease of pressure is nothing but Δp . We may assume that the air in the vessel becomes saturated with aqueous vapour. Hence we may obtain the humidity of the air by adding Δp to F' , the saturation vapour pressure at the temperature T' of the air in the vessel.

In the construction of such an instrument firstly we must make

special effort to make the temperature of the air inside both vessels approach to that of the cool water. Since the thermal capacity of air is very small compared with that of the copper or other metal constituting the wall of the vessels, the metal wall and air inside will be in thermal equilibrium in a few minutes.

Secondly we must make the volume of the tubing connecting the vessels to the manometer as small as possible. Generally the air inside the tubing is not in the same temperature with that of air inside the vessels, and therefore will gradually creep into the vessels after the condensation occurs in the air inside the vessels. Of course this will not effect the final result of our observation of humidity.

Thirdly care must be taken not to cause too much supersaturation of aqueous vapour in the air inside the vessel before the condensation occurs.

4. In a specimen of the newly designed hygrometer made in the work shop of the Central Meteorological Observatory, Tokyo, the outline of the instrument can be best explained by Fig. 1. In the figure *A* and *B* are hemispherical vessels of copper, having the identical construction. The thickness of the wall is 0.3 mm. Both vessels are tightly screwed into a cylindrical frame *C*. The temperature of air in *A* and *B* is measured by thermometers inserted in the vessels. They are not shown in the figure. The oil manometer *M* allows us the difference of the pressure in *A* and *B*. In our instrument the clock oil, the specific gravity of which is 0.9 is used. The three way cock *N* is connected to the ends of the *U*-tube manometer, and to the vessels *A* and *B*.

Fig. 1.

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In conclusion we wish to express our sincere feeling of gratitude to the authorities of the Imperial Academy for the grant, from which the cost of making a specimen of the newly designed hygrometer was defrayed.