III. "Report on Hygrometric Methods. First Part, including the Saturation Method and the Chemical Method, and Dew-point Instruments." By W. N. SHAW, M.A. Communicated by R. H. SCOTT, F.R.S., Secretary to the Meteorological Council. Received January 17, 1888.

(Abstract.)

With the exception of certain "absolute hygrometers," the behaviour of which has not yet been sufficiently tested, the determination of the pressure of water-vapour in the air is indirect and requires a formula of reduction. The formulæ in use are based upon assumptions which are at present not so completely verified by experiment that any hygrometric method can be relied upon to give measures of the pressure of aqueous vapour trustworthy to within 0·1 mm. of mercury. The authority for these statements is given in detail in an account of the hygrometric work done since 1830. This account is appended to the report as Note A.

In the report, the chemical hygrometric method is provisionally regarded as a standard. The formula of reduction applicable in this case is

$$e = \frac{760(1+\alpha t)}{\Delta d} f,$$

where e is the pressure of aqueous vapour in millimetres; f, the number of grammes of moisture per cubic metre in the air at temperature $t°$ C.; α the coefficient of expansion of air per degree C.; Δ the density of dry air at 0° and 760 mm., *i.e.*, 1293 grammes per cubic metre; and d is the specific gravity of the moisture referred to air at the same temperature and pressure.

The assumptions upon which the formula is based are—(1) That it is possible to absorb the whole of the moisture from air by passing it over desiccating substances; and (2) that a numerical value can be assigned to d. The first assumption has been discussed by Regnault and others, and is sufficiently nearly accurate for all hygrometric calculations. With regard to the second, Regnault's direct observations upon steam (free from air) and other evidences point to the value 0·622. The assumption can, moreover, be tested, by applying the chemical method to air saturated at a known temperature, assuming the value 0·622 for d, and comparing the results with the table of saturation pressures *in vacuo*. This, however, *assumes Dalton's law to be strictly accurate*, an open question, upon which opinion is reserved until further experimental investigation is concluded. Regnault made the comparison in sixty-eight experiments, in fifty-nine of which the air was practically saturated when it entered the drying tubes. For these he found that

the value 0·622 gave results which were less than the tabulated pressures, the errors being always of the same sign, but so small in amount that he neglected them in his subsequent work.

The ultimate object of the experiments described in the report was to examine the behaviour of dew-point instruments in air of known state, and for this purpose air was saturated at a known temperature and drawn by an aspirator through vessels in which the dew-point instrument could be placed when required, and subsequently through drying tubes of special pattern. The vapour-pressure was thus obtained at the two extremities of the train of apparatus and the results compared.

The following questions are raised and discussed :—

i. Were the drying tubes used as efficient as Regnault's ?

ii. Does the pressure of vapour in the air become changed by passing through the apparatus designed to contain the dew-point instruments, or by the mere presence of those instruments themselves ?

iii. Do the results of the chemical method agree with the tabulated vapour-pressures *in vacuo* when the air is more or less heated after being saturated ?

iv. Can the observed differences between the results be obviated by assuming a value for d (other than 0·622), which is compatible with values obtained by other methods ?

v. Can any reason be assigned for the differences observed by Regnault in the case of saturated air ?

(i.) The answer to the first question is given in an account of a series of twelve experiments practically repeating Regnault's observations with saturated air. The tabulated results show divergences in the same direction and of the same order of magnitude as those in Regnault's paper. Some incidental points are also discussed namely, the comparative efficiency of phosphoric anhydride, sulphuric acid, and calcium chloride, and the effect of india-rubber and glass connexions between drying tubes. It is shown that the sulphuric acid and phosphoric anhydride tubes are efficient, that as a rule one tube is all that is strictly necessary, but that two should be used to provide for the case of exhaustion of the first tube or too rapid flow of air, and further, that the glass and mercury connexions between the tubes employed in the second series of experiments cannot be regarded as producing any effect.

(ii and iii.) The answers to the second and third questions are furnished by the results of eighty-two experiments with the chemical method upon air saturated at known temperatures by a specially designed "saturater" in a water bath. The temperatures of saturation lay between 1° C. and 21° C., and, with one exception, were below the tem-

perature of the surrounding air. Each experiment involved upwards of thirty readings of weight, pressure, and temperature. The temperature readings were corrected by means of a special comparison at Kew. Of the eighty-two observations thirty-two are retained as being free from any known disturbing causes, and from them it appears that, with d equal to 0·622, the pressure deduced by the chemical method is on the average greater by 0·03 mm. than that given in Regnault's table of vacuum pressures, as recalculated in Landolt and Börnstein's tables. This difference is very small compared with the discrepancies from Dalton's Law observed by Regnault in the case of water vapour.

(iv.) With regard to the fourth question; if the observations be employed to determine the value which must be substituted for d, the specific gravity of saturated steam referred to air at the same temperature and pressure, the mean value of d so obtained is 0·6245, which agrees very closely with 0·6240, the mean value for the same range of temperature deduced from Clausius's calculations based on thermodynamical reasoning. The value 0·622 is probably correct if the air is not nearly saturated; in that case the measure of the pressure of vapour in the air is 2/622 greater than it would be if the same air were reduced in temperature (at constant pressure), until it was saturated.

(v.) The one observation of the second series with saturated air gives a result 0·18 mm. smaller than the tabulated pressure, and thus with the twelve experiments of the first series confirms the results of Regnault's observations. To account for this, it is suggested that air which is very nearly or quite saturated, would deposit some of its moisture on the glass tubes used to conduct it from one vessel to another. This behaviour of nearly saturated air has been already noticed, and it is confirmed by the observations on dew-point instruments, and moreover, by experiments directly intended for the purpose, quoted in a note.

Details are given of observations with Regnault's hygrometer and Dines's hygrometer when exposed in glass vessels between the saturater and the drying tube. The two instruments are separately discussed. With Regnault's instrument, after some practice, two different observers obtained practically identical results. In ordinary observations, the observed temperatures of the dew-point were below the temperature of saturation, but seldom by more than 0·1° C. A considerable amount of uncertainty was shown to be attached to the readings, and by very close inspection readings of the dew-point were obtained above the temperature of saturation, in one case by as much as 0·7° C.

From the experiments with Dines's hygrometer, it appears that the instrument is likely to give very easy determinations of the dew-point that are within small limits of error; but that if the instrument be

observed with the closest attention, the result will be considerably too high in consequence of the formation of a dew deposit at a temperature above the true dew-point, and it may possibly be erroneous in consequence of variations in temperature of the different parts of the box containing the thermometer.

An account is given of Alluard's modification of Regnault's hygrometer, and of Bogen's hygrometer.

A second note, B, is appended to the report, showing the tables used in various countries for the reduction of wet and dry bulb observations.

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