

## The tilting hygrometer: A new form of absorption hygrometer

This content has been downloaded from IOPscience. Please scroll down to see the full text.

1921 Proc. Phys. Soc. London 34 xvii

(<http://iopscience.iop.org/1478-7814/34/1/316>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

### Download details:

IP Address: 129.96.252.188

This content was downloaded on 01/10/2015 at 22:56

Please note that [terms and conditions apply](#).

## THE TILTING HYGROMETER: A NEW FORM OF ABSORPTION HYGROMETER.

BY

*The late H. G. MAYO, M.A., and PROFESSOR A. M. TYNDALL.*

THE following work arose out of a demand for a hygrometer which would be suitable for use in cold stores. While the instrument herein described fulfils this condition, it is also convenient for use at ordinary room temperature, and may appeal to some as instructive as a piece of laboratory apparatus in a university course. It should be mentioned, however, that the form that it takes was determined by the purpose for which it was designed—namely, for cold store work. For use at room temperatures only the instrument can be modified, so that it is more “foolproof.”

The method employed is that of abstracting the moisture from a given sample of air with phosphorus pentoxide, and measuring the resultant change of pressure on an oil U-tube gauge.

The following advantages may be claimed for the instrument :—

- (1) It is portable.
- (2) It is rapid in action, a reading of the water vapour pressure in a cold store being obtainable in less than three minutes, in terms of the length of a column of oil.
- (3) Tests made at temperatures ranging from  $-10^{\circ}\text{C.}$  to  $20^{\circ}\text{C.}$  show that it is reasonably accurate over this range.
- (4) It can be used on board ship or in any other place where a steady support is not procurable.

Its main objection as an instrument for cold stores is that it must be placed in the store sometime before use, and it is necessary for the operator to enter the store for the purpose of taking the readings.

The present form of the instrument is described below under a special heading. But the following historical summary and account of earlier forms which we have tried will serve to bring out the reasons for this particular design.

### HISTORICAL SUMMARY OF WORK ON ABSORPTION HYGROMETERS.

Edelmann (Wied. Ann., VI., p. 455, 1879) noted the reduction in pressure brought about by exposing a given volume of air to sulphuric acid, which absorbed the water vapour present.

Van Hasselt (Mbl. Nt. Amsterdam, 1879) brought about the required absorption by breaking a bulb of  $\text{P}_2\text{O}_5$  inside the vessel. But in neither case can the instrument be regarded as suitable for repetition work in hygrometry.

Sondern and also Matern (Wied. Ann., IX., p. 147) exposed a sample of air to a water surface and measured the change in pressure (or volume) brought about by saturation.

A. N. Shaw (Trans. Royal Soc. Canada, Vol. X., 1916) on similar lines has devised a constant pressure absorption hygrometer, using sulphuric acid as the drying agent. But the influence of the glass walls of the apparatus and the presence of a number of taps, in our opinion, introduce defects into his apparatus which make it both inaccurate and unsuitable for cold store work.

## PRELIMINARY EXPERIMENTS.

A theoretical calculation from the coefficient of diffusion of water vapour through air shows that in any practical form of apparatus the method of drying a sample of gas by diffusion leads to a slow rate of working. This was confirmed in an experiment in which, by means of a loosely fitting rubber bung, the upper and lower parts of an ordinary desiccator were virtually cut off from one another. The upper part contained the sample of air, and the lower some phosphorus pentoxide. It was arranged that, without opening the desiccator, the bung could be pulled up by a thread, so that there was a wide free passage opened up, through which diffusion of water vapour could take place.

It was found that ultimately the U-tube gauge connected to the desiccator became steady, indicating that the absorption was practically complete, but that at least half an hour elapsed before this occurred.

In practice, therefore, some arrangement must be adopted in which the air is passed over or through the drying agent instead of simply being left in contact with it.

Accordingly a device was tried in which the sample of air was placed in a tube joining the ends of a glass U-tube half-filled with mercury. Without going into the details of the arrangement, it may be said that it was possible to insert in this sample a rod coated with phosphorus pentoxide, and then to drive the air backwards and forwards over it simply by rocking the U-tube in its own plane.

A capillary U-tube oil gauge communicating with the sample and inserted so that its plane was perpendicular to the plane of the apparatus, responded with a rapidity which showed that the absorption of the moisture in the to-and-fro motion was effectively carried out.

But the heat generated in the  $P_2O_5$  produced a temperature effect which, owing to the bad conductivity of the glass walls, died down only slowly, and so greatly decreased the rate of working the instrument.

Moreover an important point was emphasised by this design. If moist air is admitted to a perfectly dry vessel, the humidity of the sample rapidly falls due to adsorption of water vapour by the walls. When the mercury is raised this water film is covered over by or shared with the mercury surface, and not removed by the  $P_2O_5$ . In this way the mercury gradually gets wet in a sequence of experiments, and it is then impossible to fill the vessel with a true sample of the external air, because the humidity will change by contact with the walls and mercury before connection between the sample and the outside atmosphere can be cut off. This was shown by the fact that the apparatus gave good results when first set up, but gradually failed.

We believe that this effect vitiates nearly all the early experiments referred to in the historical summary above.

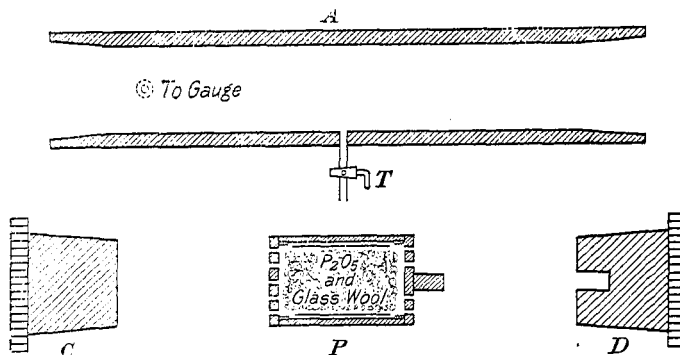
To eliminate these troubles an arrangement is necessary in which the surface area in contact with the sample is practically unchanged throughout and is made moreover of metal instead of glass to reduce both the surface effect and the temperature effect due to heating of the drying agent.

In the first instrument of this type, the air in a brass cylinder was made to surge backwards and forwards through  $P_2O_5$  in a side tube by working a rod and piston in the cylinder. The rod passed through a stuffing box at each end, so that the volume of the vessel did not change with the motion of the piston. Taps were provided so that the cylinder could first be filled with the sample by carrying out a number of strokes without exposing the  $P_2O_5$ .

Trials in cold stores revealed troubles due to the hardening of the packing of the stuffing boxes and leakage of the various taps. Moreover, the process of ensuring before starting that the adsorbed film on the inner walls of the cylinder was really in equilibrium with the sample admitted involved a tedious number of strokes of the piston and loss of time. We believe that those difficulties are all met in the final form of apparatus—in so far as it may be said to be final.

#### FINAL FORM OF APPARATUS.

The rod and piston is replaced by a brass plunger fitting a brass cylinder well but sufficiently loosely to slide from one end to the other without lubrication when the cylinder is tilted through about  $30^\circ$ . The figure shows the details of the arrangement. In the ordinary way the cylinder *A* is left freely open at both ends so that the film on its walls is in equilibrium with the air of the room. When a measurement of humidity is required it is closed at both ends by the insertion of the plunger *P* and two ground-in solid plugs *C* and *D*, the tap *T* being kept open during this operation. A hole in *D* receives at the end of a stroke a pin projecting from the plunger *P*. In this way the plunger may readily be inserted into and removed from



the tube before and after an experiment without touching it with the fingers. The plunger *P* is hollow and its ends perforated. It is loosely packed with glass wool dipped previously into  $P_2O_5$  powder. No  $P_2O_5$  is placed on the wool touching the ends of the plunger, and a glass sleeve similarly protects its sides.

Communication with the outside air is cut off by closing the tap *T* and the cylinder is then tilted so that the plunger falls towards the plug *C*; air passes through the  $P_2O_5$  and dries in the process. Reversing the direction of the tilt reverses the direction of motion of air. Spring clips are fixed to the end of the cylinder to hold the plugs in position and prevent them being loosened by impacts from the plunger.

A few oscillations are sufficient to dry a sample, as may be seen by the motion of the oil gauge which is connected to the cylinder by a side tube. In general, however, about twenty oscillations have been made first and these have been followed by a brief halt and a few more oscillations. In this way the greater part of the effect of evolution of vapour from the walls and of heat from the  $P_2O_5$  is eliminated.

Very consistent results have been obtained with this apparatus both at room temperature and in cold store. Moreover, the possibility of leakage is greatly decreased owing to there being only one tap to look after and no stuffing boxes.

In calculating the humidity from the gauge reading two constants are necessary, the density of the oil and the relative volumes of the wet air in the cylinder and the dry air in the plunger. These factors, once measured, are constants for the instrument if it is made to pattern. The gauge tube is capillary so that the motion of the oil produces no appreciable change of volume in the sample.

The relative internal volumes of cylinder and plunger were measured and it was calculated from these that the observed reduction in pressure must be multiplied by 1.30\* to give the true vapour pressure of the wet air before it was passed through the drying chamber. A chemical hygrometer was set up by which the mean humidity of the air over a period of half-an-hour was determined. This reading was compared with the average of a set of readings with the absorption hygrometer, taken at the beginning and end of the same period.

Two typical sets of results are given in Table I., the first obtained at room temperature in the laboratory and the second in cold store. In general six readings were taken with the absorption hygrometer, three just after the chemical hygrometer was started and three just before it was completed. It was assumed that the humidity was changing if at all at a uniform rate during this time, so that the mean reading might be compared with that of the chemical hygrometer. It will be seen that the mean absorption hygrometer reading is in excellent agreement with that of the chemical hygrometer. In fact the results practically always were in good agreement as may be seen from the summarised readings given in Table II.

The hygrometer was tested at room temperature and in several cold store chambers in the Bristol district.

Column 1 of the table gives the temperature of the air in Centigrade degrees, column 2 the difference in level in cms. ( $h$ ) of the oil gauge column.

Column 3 gives the vapour pressure in mms. of mercury obtained from ( $h$ ) by multiplying it by 1.30\* and by the ratio of the densities of oil and mercury. Column 4 gives the corresponding numbers obtained with the chemical hygrometer.

Column 5 giving relative humidities is included mainly to show that the values are reasonable in amount. The high humidity (97 per cent.) taken at  $-9.5^{\circ}\text{C}$ . was obtained by placing the instrument in the duct leading directly from the chamber containing the brine pipes to the store. That of 92 per cent. at  $-10^{\circ}\text{C}$ . was obtained in a store recently filled with frozen meat.

The hygrometer therefore when compared with the chemical hygrometer stands the test and is naturally more convenient and rapid for general use.

It should, however, be pointed out that with the instrument in this form the readings are useless in an atmosphere which is rapidly changing in temperature or when the instrument has been brought into a room the temperature of which is different from that of the instrument. For such cases it would be necessary to have a dummy cylinder on the other end of the gauge—as indeed we used in some preliminary earlier experiments—in order that the temperature changes may affect both sides equally. But the simplicity and convenience of the hygrometer is thereby somewhat sacrificed and provided care is taken not to touch the cylinder with bare hands or to breathe upon it, this elaboration is unnecessary in most cases.

\* The four observations marked with an asterisk in Table II. were taken with an instrument for which the constant was 1.19 instead of 1.30.

TABLE I.

Temperature.	Observations.	Calculated vapour pressure in mms. of mercury.
16.3°C.	Absorption Hygrometer—readings in cms....	12.7
		12.7
		12.6
		12.3
		12.4
		12.5
		—
	Mean ...	12.5
	Chemical Hygrometer—	
	Volume of air ... ..	5 litres
Change in weight of drying tube ...	0.0454 gm.	
		8.9
		8.9
-4.0°C.	Absorption Hygrometer—readings in cms....	3.9
		3.7
		3.7
		3.7
		3.6
		3.5
		—
	Mean ...	3.7
	Chemical Hygrometer—	
	Volume of air ... ..	5 litres
Change in weight... ..	0.0147 gm.	
		2.9
		2.8

TABLE II.

Temperature in degrees Centigrade.	Mean gauge reading in cms. of oil.	Vapour Pressure in mms. of Hg.		Relative Humidity.
		Absorption Hygrometer.	Chemical Hygrometer.	
*16.8	14.3	10.2	10.1	72
*16.0	12.93	9.2	9.2	68
*15.4	12.5	8.9	8.9	68.5
13.1	10.2	7.93	8.00	71
12.9	10.6	8.23	8.35	74
12.7	9.8	7.6	7.64	69
12.5	8.9	6.9	7.00	64
-2.5	4.0	3.1	3.20	83
-3.5	3.5	2.7	2.68	79
-4	3.7	2.9	2.80	88
-9.5	2.6 (mean of two readings only)	2.0	2.03	97
*-10	2.1	1.8	—	92

Lastly it may be seen that in special cases by suitable choice of reagent in the plunger the instrument might be adapted for rapid measurement of an impurity in air or another gas within certain limits of percentage of impurity.