The Balance as a Sensitive Barometer

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III. Rider German silver wire, 189.05 mgm.

7 determinations alternately left and right.

Mean travel of rider 0.1764 mm.

Mean deflexion 38.70 divisions.

Mean value for 40 divisions... 0.1691 mgm.

The separate determinations range between

40 divisions = 0.1709

and 40 „ = 0.1654.

IV. The same rider.

7 determinations alternately left and right

Mean travel of rider 0.3004 mm.

Mean deflexion 64.84 divisions.

Mean value for 60 divisions... 0.2578 mgm.

The separate determinations range between

60 divisions = 0.2612

and 60 „ = 0.2518.

LXVI. *The Balance as a Sensitive Barometer.**By G. W. TODD, M.Sc.**

It occurred to the author while testing with Professor Poynting the accuracy of a new method of determining the sensibility of a balance, described on p. 926, in which a thin rod or fibre is used instead of the usual rider, that a balance might with proper precautions be converted into a very delicate barometer.

A difference in volume on the opposite sides of a balance will give rise to motions of the pointer when the density of the surrounding air changes. Small oscillations of the pointer, due chiefly to convection currents, become negligible if this difference in volume is sufficiently large. Alterations in the density of the air are produced by changes in pressure, in temperature, and in the percentage of aqueous vapour in it. By eliminating the effects of any two of these the variations in the other may be obtained. Thus the balance might be used either as a barometer, thermometer, or hygrometer.

* Read June 25, 1909.

Experiments were carried out with the balance mentioned in the previous paper. A sealed copper sphere, about 760 c.c., was suspended from one arm and counterpoised with brass weights placed in the opposite scale-pan. The movements of the pointer were observed by means of a small "doubly suspended" mirror which reflected a distant scale into a telescope. One division in this telescope corresponded to a rise or fall in the atmospheric pressure of the order of .002 mm. of mercury.

If W, V are the weight and volume of the sphere and W', v similar quantities for the counterpoise, we have, assuming that the difference in volumes of the opposite sides of the balance itself is nil and that the air is dry,

$$W - VDp \frac{273}{760} \frac{1}{A} = W' - vDp \frac{273}{760} \frac{1}{A},$$

where p = atm. press. in mm., D = density of air at 0° C. and 760 mm., A = abs. temp.

$$\therefore W - W' = (V - v)Dp \frac{273}{760} \frac{1}{A}.$$

If the air is moist and the pressure of aqueous vapour is f mm.,

$$W - W' = (V - v) \frac{273}{760} \frac{1}{A} \{(p - f)D + fd\},$$

where d = dens. of wat. vap. at 0° C. and 760 mm.

Suppose there is a change ∂W when there are changes $\partial p, \partial f, \partial A$, then

$$\partial W = (V - v) \frac{273}{760} \left[\partial p \frac{D}{A} + \partial A \frac{(D - d)f - Dp}{A^2} + \partial f \frac{(d - D)}{A} \right].$$

With the balance-case dry,

$$\partial W = (V - v) \frac{273}{760} \left[\partial p \frac{D}{A} - \partial A \frac{Dp}{A^2} \right]$$

or

$$\partial p = \frac{760A}{(V - v)273D} \partial W + \frac{p}{A} \partial A.$$

In the micro-barograph, which is given later (fig. 1),

$$\partial W = 4.6 \times 10^{-6} \partial S,$$

where S is the scale-reading in the telescope. This ratio was the mean of several obtained by moving the rider a known distance and noting the deflexion in the telescope, taking into account the rate at which S was altering at the time. The quantity $(V-v)$ differed by less than 1 c.c. from 760 c.c., so that

$$\partial p = \frac{4.6 \times 10^{-6} A}{273D} \partial S + \frac{p}{A} \partial A.$$

With the temperature and pressure variations acting together the whole scale would often pass across the field of the telescope in less than half an hour, and it had to be brought into view again by moving the rider in the required direction by means of the micrometer-screws. Observations of S and A were taken alternately every thirty seconds, and the barograph was obtained by plotting the terms on the right of the above equation and adding.

The barographs showed many oscillations in pressure of the order of .02 mm., the period of oscillation being from ten to fifteen minutes, a period quite different from that of the balance. The question arose whether these oscillations were real oscillations of pressure, or whether they were caused by oscillations in temperature not shown on the mercury thermometer suspended in the balance in consequence of the capacity for heat of its bulb.

To decide this question twelve thermojunctions were made with fine wires of copper and constantan, each wire being about six centimetres long. Six of these junctions were embedded in wax and placed in a box of brass filings, while the other six were left exposed to the air. The covered junctions having their capacity for heat made very large by the surrounding brass filings, would "lag" behind the exposed junctions and would not be affected by small oscillations in temperature. The ends of this thermopile were connected to a low resistance galvanometer. One division on the scale was approximately equal to a difference of .009° C. between the exposed and covered junctions. When the thermopile was exposed in the room the scale-reading oscillated aimlessly to and fro, but when placed inside the balance no oscillations could be detected. The spot of light travelled slowly and uniformly in one direction, showing

that the temperature in the balance was slowly rising and that the covered junctions were "lagging."

After this the temperature of the air inside the balance was measured by thermojunctions to avoid errors due to lagging. One set of junctions was kept at a fairly constant temperature in a Dewar tube containing water, the temperature being indicated on a Beckmann thermometer.

An idea of the sensitiveness of such a balance-barometer may be obtained from the table given below and the corresponding micro-barograph. The observations given extended over half an hour. The Beckmann thermometer in the Dewar vessel indicated the same temperature throughout.

TABLE.

1° C. difference between the junctions in the balance and those in the Dewar vessel corresponded to 28·8 divisions on the galvanometer-scale.

Galv. zero = 272·2. Room temp. = 13°·8 C. Rider at 13·152.

Time.	Telescope.	Galv.	Time.	Telescope.	Galv.
P.M. 4—0	243·7	239·1	P.M. 4—16	229·2	237·3
1	243·3		17	226·3	
2	242·6	238·9	18	225·6	
3	243·6		19	223·1	237·0
4	243·7	238·6	20	224·7	
5	243·9		21	227·0	
6	242·8		22	227·0	236·7
7	242·2	238·3	23	226·1	
8	244·9		24	225·8	
9	246·7	238·0	25	226·1	236·3
10	245·0		26	227·7	
11	246·2		27	228·5	236·0
12	246·3	237·7	28	230·9	
13	244·0		29	232·0	
14	240·1	234·6	30	232·6	232·1
15	234·6		31	232·1	

The second column in the table gives the telescope-readings of the balance-pointer, and the third gives the

galvanometer readings from which the temperature inside the balance is obtained. In the barograph the nearly straight curve represents the temperature, the lower irregular

Fig. 1.

curve the actual observations of the position of the balance-beam, and the upper curve the positions reduced to a constant temperature.

DISCUSSION.

Mr. M. E. J. GHEURY expressed his interest in Mr. Todd's successful attempt to apply the well-known influence of barometric pressure upon the indications of a sensitive balance to detect small variations in the

atmospheric pressure. Prof. Marvin has just described (*Monthly Weather Review*, 1908) a delicate recording barometer, which shows plainly variations of .05 mm.; another type of recording barometer, the *statoscope*, records variations of the order of .02 mm. Both instruments give traces which show, even in calm weather, a succession of irregular ripples of variable amplitude and period. The question presents itself: can such an elaborate method as the one described by the Author be of practical value, when such minute changes can be actually recorded by instruments which require practically no attention besides the adjustment of the zero, and now and again a time check, and need no temperature correction?

Another point of greater importance is that when such small changes as these can be detected, there is no means of discriminating between the meteorological variations and the purely artificial ones, due to the fact that the instrument is in a building in which for various reasons there may be eddies and ascending or descending currents having nothing to do with the dynamics of the atmosphere, but leaving traces upon the record sheet. It is probable that a large number of the variations observed are due to entirely artificial changes of pressure, and such sensitive instruments, to give records of any use, should be placed in an isolated and quiet position, far from a building, in a shelter designed for the purpose.

It is in the study of the degree to which such sensitive barometers are affected by artificial perturbations that Mr. Todd's apparatus becomes useful. Such perturbations could be produced purposely and at regular intervals, and the magnitude of their effect on the instrument ascertained. To decide, therefore, if the records obtained so far by similar sensitive apparatus are the correct interpretation of genuine meteorological phenomena seems to be the only practical use to which Mr. Todd's ingenious apparatus can be put, but it is a very useful and necessary investigation to which much interest remains attached.

The AUTHOR in reply to Mr. Gheury recognized the practical value of a self-recording instrument. In the telescope of his balance-barometer one-tenth of a division could be estimated, so that the sensitiveness was from fifty to a hundred times greater than that of the *statoscope*. It therefore might be worth the little extra trouble involved in compounding two records—the temperature variation and the balance pointer variation—each of which could be made automatically.

The balance was little affected by sudden jars, such as the slamming of doors in other parts of the building. The opening or shutting of a door in the same room only occasionally caused a small motion, of the order of half a division, in the telescope. During observations this door was of course kept shut. A wave in the barograph of the same period as that of the balance might be due to a momentary impulse transmitted through the building, but other waves would not be open to the same suspicion.