—	Rise of Thermometer due to			Tons per Inch.
	Heat and Pressure.	Heat.	Pressure.	
9645	0·1	0·1	—	$1\frac{3}{4}$
11678	0·6	0·1	0·5	$1\frac{3}{4}$
11679	0·3	0·1	0·2	$1\frac{3}{4}$
9645	0·1	0·1	—	$2\frac{1}{2}$
11679	0·7	—	0·6	$2\frac{1}{2}$
9645	− 0·7	− 0·7	—	$2\frac{1}{2}$
11678	0·9	"	1·6	$2\frac{1}{2}$

It will be noticed that the change of reading of the standard thermometer was not constant, as in some of the experiments a rise of 0°·1 was observed, while in one a fall of 0°·7 was recorded. This latter result is probably due to the fact that the hydraulic press was not in very good order, so that a large quantity of water at a lower temperature than the surrounding air had to be drawn through the apparatus before the pressure began to act on the gauge.

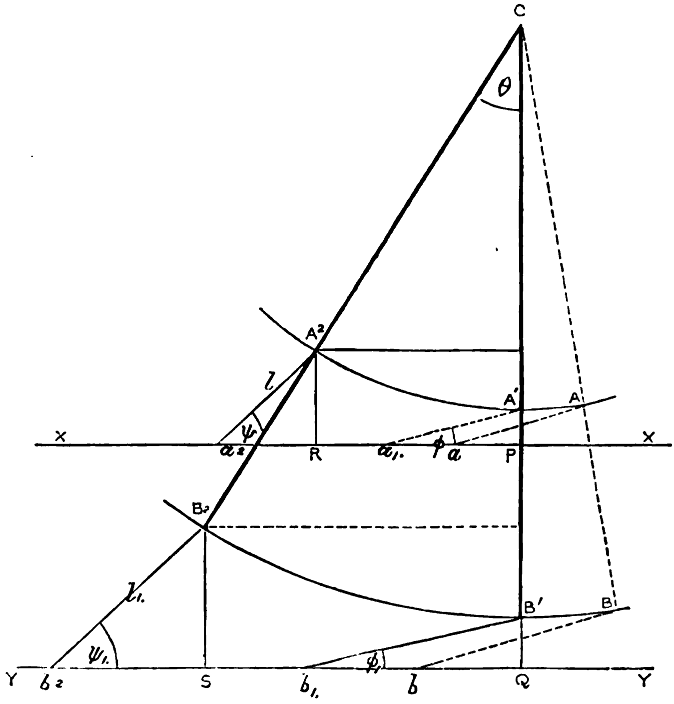
The foregoing experiments are sufficient to show that the new instruments perform satisfactorily, and also that the original thermometers described by Admiral FitzRoy were good and trustworthy instruments in so far as regards their capability of resisting pressure.

No. II.

On the Principle of the Pantagraph designed by F. Galton.

In the pantagraph I have designed to reduce the tracings of the various self-recording meteorological instruments, the reduction is effected by two separate but similar actions, in length and in breadth. One hand of the operator controls the movements from side to side of the original tracing and of the plate that receives the reduced figure; the other hand controls the movements up and down of the style that passes over the original figure, and of the point that scratches the reduced copy. In both cases the reduction is effected by means of an arm connected through links with carriages compelled to run along parallel lines.

The following analysis shows the conditions of length and position that have to be observed in making and adjusting the instrument, and I shall now restrict my explanation to this, because although the existing instrument works very satisfactorily, yet the new one (which is not yet sufficiently finished to make a drawing from) will be its superior in range of adjustment and in many other points of detail. It is therefore advisable to delay the description until the new instrument shall have been some time at work, and its appurtenances brought into perfect order.



C A B is an arm which can be moved round C to any desired position as C A_1 B_1 or C A_2 B_2.

a is a point on a carriage that moves along a tramway, or is otherwise guided, so that it may be pushed to any desired position in the line X X, but nowhere else. It is connected with C A B by a link A*a*, and therefore assumes the positions a_1 a_2, corresponding to the positions of the arm C A_1 B_1, C A_2 B_2.

Similar arrangements are made in respect to B, and the two tramways are made parallel to one another.

Required to find the conditions, if any, that will cause the movements of *a* and *b* to bear a uniform proportion to one another.

Take C A_1 B_1 perpendicular to the tramways, and let C A_2 B_2 be any other position of the arm. Let fall the perpendiculars A_2 R and B_2 S.

Call the vertical angle θ; call the angle $A_2 a_2$ P, ψ; the angle $A_1 a_1$ P, φ; and the link A*a*, *l*.

Let the corresponding values in the arrangement connected with B, be ψ_1, φ_1, and l_1.

Now ψ is known in terms of the rest, because

(1) $l \sin \psi = \text{C A versin } \theta + l \sin \varphi$, and so for ψ_1,

therefore our problem is to find the relations (if they exist) between φ and φ_1; l and l_1; C A and C B; that shall ensure the space of $a_1 d_2$ to bear a constant relation to $b_1 b_2$, = say $\frac{1}{c}$, for all values of θ.

$$a_1 a_2 = \mathrm{P}a_2 - \mathrm{P}a_1 = \mathrm{R}a_2 + \mathrm{R\,P} - \mathrm{P}a_1$$
$$b_1 b_2 = \mathrm{Q}b_2 - \mathrm{Q}b_1 = \mathrm{S}b_2 + \mathrm{S\,Q} - \mathrm{Q}b_1$$

$$\frac{a_1 a_2}{b_1 b_2} = \frac{l \cos \psi + \mathrm{C\,A} \sin \theta - l \cos \varphi}{l_1 \cos \psi_1 + \mathrm{C\,B} \sin \theta - l_1 \cos \varphi_1} = \frac{1}{c}$$

but from (1) $l \cos \psi = l \sqrt{1 - \sin^2 \psi} = \sqrt{l^2 - (l \sin \varphi + \mathrm{C\,A\ vers.}\ \theta)^2}$
and similarly for $l_1 \cos \psi_1$

therefore $\dfrac{\sqrt{l^2 - (l \sin \varphi + \mathrm{C\,A\ versin}\ \theta)^2} + \mathrm{C\,A} \sin \theta - l \cos \varphi}{\sqrt{l_1^2 - (l_1 \sin \varphi_1 + \mathrm{C\,B\ versin}\ \theta)^2} + \mathrm{C\,B} \sin \theta - l_1 \cos \varphi_1} = \dfrac{1}{c}.$

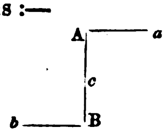
First, we see that these values can be real only so long as $l \sin \varphi + \mathrm{C\,A\ versin}\ \theta$ (or $\mathrm{A_2\,R}$) is less than l; or the distance between A and the tramway is less than the length of the link, a fact which is evident enough on inspection of the figure.

Secondly, the equation holds for the combined values

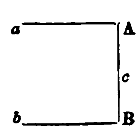
$$\varphi = \varphi_1, \frac{l}{l_1} = \frac{1}{c}, \frac{\mathrm{C\,A}}{\mathrm{C\,B}} = \frac{1}{c}, \text{ and for no other ones.}$$

We may simplify the conditions yet further, by making $\varphi = \varphi_1 = o$; that is to say, by so arranging the instrument that the link shall be parallel to the tramway when C A B is perpendicular to it; in this case the adjustment of $\frac{\mathrm{C\,A}}{\mathrm{C\,B}} = {}^1$ must be made by varying the position of C, while those of A and of B remain intact. This is the arrangement adopted in the pantagraphs already made.

If it be desired that $\frac{1}{c}$ should be negative, or $\frac{l}{l_1} = -\frac{1}{c}$, and $\frac{\mathrm{C\,A}}{\mathrm{C\,B}} = -\frac{1}{c}$, *i.e.*, that the movements of the arms should be in contrary directions, or that the reduction should be reversed, then $l = \frac{-l_1}{c}$ and $\mathrm{C\,A} = \frac{-\mathrm{C\,B}}{c}$ consequently both l_1 and C B having opposite signs to l and C A, the arms will lie thus :—



and not thus



First adjustment :—To find the position of C so that $\frac{\mathrm{C\,A}}{\mathrm{C\,B}}$ shall $= \frac{1}{c}$.

(1) When A lies between C and B

$$\frac{\mathrm{C\,A}}{\mathrm{C\,B}} = \frac{\mathrm{C\,A}}{\mathrm{C\,A + A\,B}} = \frac{1}{c}, \text{ or } \mathrm{C\,A}\,(c-1) = \mathrm{A\,B},\ \mathrm{C\,A} = \frac{\mathrm{A\,B}}{c-1}$$

(2) When C lies between A and B (reverse action)

$$\frac{\mathrm{C\,A}}{\mathrm{C\,B}} = \frac{\mathrm{C\,A}}{\mathrm{A\,B - A\,C}} = \frac{1}{c}, \text{ or } \mathrm{C\,A} = \frac{\mathrm{A\,B}}{c+1}.$$

Hence A B ought to be divided into some convenient number of graduations, and one that is divisible in many ways, such as 60 ; and the graduations should be numbered from A towards B. The same scale of divisions should be continued on the other side of A, and those graduations should be separately numbered, beginning also from A. It is then easy to find the position of c. For example, if it be required to reduce to $\frac{1}{4}$, $c = \frac{1}{4}$.

(1) Direct reduction : Set C among the upper graduations at $\frac{60}{4-1}$ or at 20; then C A = 20, C B = C A + A B = 80, and $\frac{\mathrm{C\,A}}{\mathrm{C\,B}} = \frac{20}{4 \times 20}$.

(2) Reverse reduction : Set C among the lower graduations at $\frac{60}{4+1}$ or at 15; then C A = 15, C B = 60, and $\frac{\mathrm{C\,A}}{\mathrm{C\,B}} = \frac{15}{4 \times 15}$.

Second adjustment:—To find the position of a so that $\frac{\mathrm{A}\,a}{\mathrm{B}\,b}$ shall $= \frac{1}{c}$, it being, at the same time, required that C B and B b shall remain intact.

Since, in the two triangles C A a, C B b, the sides C A, A a are proportional to C B, B b, and since C A a, C B b are right angles, as also the vertical angles at C are identical in case (1) and equal in case (2), it follows that the triangles are similar, and that C a b is a straight line. Consequently, after making the adjustment described in the last paragraph, of $\frac{\mathrm{C\,A}}{\mathrm{C\,B}} = \frac{1}{c}$, we have simply to shift a into the line C b, and the adjustment is complete.

These adjustments of C and of a are mechanically effected on the same principle that is employed in shifting the centre of the well-known instrument, the proportional compasses.

FRANCIS GALTON.