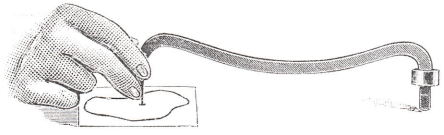
GOODMAN'S

Patent Planimeter

FOR MEASURING AREAS.



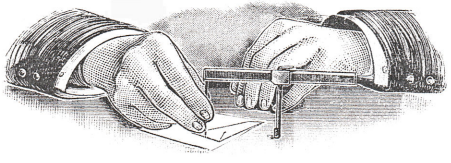
AND

GOODMAN'S

PATENT

Averaging Instrument

FOR INDICATOR CARDS.



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Goodman's Patent Planimeter.

THEORY OF THE INSTRUMENT.

This instrument (Goodman's Patent) is an improvement on the Stang Planimeter made by Knudsen of Copenhagen. In a pamphlet published by him he gives the complete mathematical theory of the instrument and arrives at the following result :—

$$I = \frac{C_1 + C_2}{2} \; p \left[1 - \frac{R^2}{2 p^2}\right]$$

Where I = The area traced out by the pointer in sq. inches,
C_1 = The distance between the dents X and Y in inches,
C_2 = ,, ,, ,, ,, ,, X_1 and Y ,,
p = The length of the instrument in inches,
R^2 = The mean square of the radii of the figure.
(La milien des carrès des distances de T (a) jusqu'à la circonférènce).

The making of such a calculation for every area measured is far too tedious an operation. By using Goodman's Instrument as described above, first in one direction and then in the other, the quantity $\frac{C_1 + C_2}{2}$ is obtained by a direct reading. If the instrument were of very great length as compared with the dimensions of the area, the quantity in the brackets would vanish, then putting $\frac{C_1 + C_2}{2} = c$ the area would simply be equal to the product $p\,c$ and a scale for measuring the distance c in which one square inch was made equal to $\frac{1}{p}$ inches would at once give the area in square inches. But as the areas generally dealt with are of somewhat large dimensions as compared with the length of the instrument the quantity in brackets must not be neglected. Assume for a moment that we are measuring the area of a circle with the instrument—its area is proportional to R^2 hence as $2p^2$ is a constant for any given instrument, the whole quantity $\frac{R^2}{2p^2}$ is proportional to the area traced out by the pointer. Thus by making a scale with gradually increasing divisions this quantity may be entirely eliminated; this is what is accomplished in Goodman's Patent Planimeter, and instead of having to solve the equation as given above in order to find the area, it is read off direct from the scale without any calculation.

If the area dealt with is not a circle the error involved in assuming that its R^2 is equal to the R^2 of a circle of equal area is so small that it is quite inappreciable on a scale which only reads to tenths of a square inch; it would indeed seldom be appreciable on a scale reading to hundredths of a square inch.

INSTRUCTIONS FOR USE.

Let it be required to measure the area of the adjoining figure :—

Fig. 1.

CHOOSE a point A, as near the centre of the figure as can be judged by eye, and from it draw a line A B to the boundary (see Fig. 3). Hold the tracing leg of the instrument in the right hand, placing the point at A, and the hatchet at X, *i.e.* with the instrument roughly square with A B, and press the hatchet in order to make a slight dent in the paper at X; then, the finger having been removed from the hatchet, the tracing point of the instrument is caused to traverse the line A B and the boundary in the direction indicated by the arrows, returning to A via A B, when it will be found that the hatchet has taken up a new position, and it must be again lightly pressed (as illustrated in Fig. 2) in order to make a fresh dent in the paper at Y (Fig. 3). The instrument being held in this position, revolve the paper on which the figure is drawn through about 180° (by eye), using the point of the instrument as a centre (as shown in Fig. 4), and taking care that neither the point nor the hatchet shift while the paper is being turned. The line A B will again be roughly at right angles to the axis of the instrument, but in a reversed position (see dotted figure, Fig. 3). Now cause the tracing point to traverse the boundary as before,

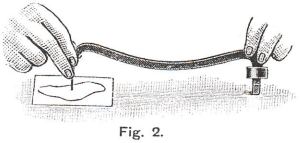


Fig. 2.

but in the opposite direction, as indicated by the dotted arrows. The hatchet will take up the new position X_1 which may or may not coincide with X; then, *the mean of* X Y *and* X_1 Y *measured on the scale engraved on the instrument is the area of the figure;* this can be readily read off by pricking a central point as shown between X and X_1 by eye. When it is inconvenient to turn the paper round, the instrument itself may be turned round to form a dent X_1 on the *opposite* side of the figure, as shown at Fig. 3a. Then by following the boundary in the direction of the arrows Y^1 is obtained. The area is the mean of the lengths X Y and $X_1 Y_1$ The scale as before, or the area = $\frac{X Y + X_1 Y_1}{2}$

Fig. 3.

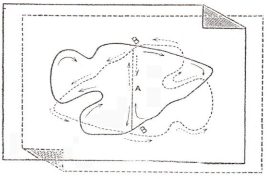
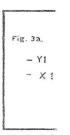


Fig. 3a.



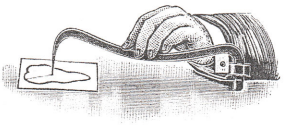


Fig. 4.

When the area is large the instrument will move through a large angle and consequently if approximately square with A B at starting it will be a long way out at the finish. In such a case all that is necessary is to see that the *mean* position of the instrument is square with A B.

In measuring the area off always work from the zero of the curved scale.

CAUTIONS (*see overleaf.*)

If the above instructions are not carried out the Instrument cannot be expected to give accurate results. The user should practise on circles, squares, or figures of known area. (N.B.—When using circles and squares to check the instrument, measure their dimensions ACCURATELY, *i.e.*, to within 1/100 of an inch.)

PRICE of Planimeter, in Case - - 15/-.

Goodman's Patent Averaging Instrument.

THEORY OF THE INSTRUMENT.

This Averaging Instrument is a modification of Goodman's Patent Planimeter.

By using the Averager as described above for the Planimeter, first in one direction and then in another, the quantity $\frac{C_1 + C_2}{2}$ is reduced to a single reading.

Let $\frac{C_1 + C_2}{2} = c$ then $I = c\, p \left[1 - \frac{R^2}{2\, p^2}\right]$

Assuming for the moment that the quantity in the brackets may be neglected, we have $I = c\, p$; but $I = h\, l$ where h = the mean height, and l = the length of the figure, therefore $h\, l = c\, p$; but in the Averager we make the length of the instrument p = the length of the diagram l, hence $h = c$, or the mean height of the figure is equal to the mean of the distances between the dents X and Y and the dents X_1 and Y_1. The quantity in the brackets however, although not great, must not be neglected. The ratio $\frac{R}{p}$ is very nearly constant, but not quite—we shall return to this point later on. Assuming it to be constant for the instant then the whole quantity in the brackets will also be constant; let it $= k$, then $h\, l = c\, p\, k$ and $h = c\, k$, hence, if we construct a scale $\frac{1}{k}$ times its true size, the value of c as measured on it, will be the true mean height of the figure. Some instruments are made on this principle with such a scale engraved on the beam—the reading then has simply to be multiplied by the scale of the spring used in the indicator; in other instruments this scale is dispensed with, and the ordinary boxwood scales usually supplied with indicators may be employed. In the latter class of instrument we have $\frac{h\, l}{p\, k} = c$, then in order that c may $= h$ we must have $l = p\, k$, that is to say, the length of the instrument between the legs is $p\, k$ and the length from the centre of the hatchet to the point is p; this of course can only be true for one particular value of p, if k is a constant, but we mentioned above that k was not quite constant—it varies slightly with the length of the diagram in such a way as to render the quantity $k\, p$ constant, or so nearly so that even with very careful observation no error is revealed. The distance c measured on an ordinary scale and multiplied by the scale of the indicator spring gives the mean effective pressure on the piston, or this may be read off direct by using the special scales supplied with indicators.

INSTRUCTIONS FOR USE.

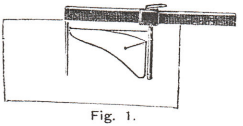
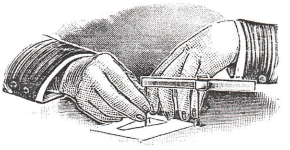


Fig. 1.

SET the Instrument (Fig. 1) so that the distance between the inside of the legs is equal to the length of the indicator diagram. Choose a point A (Fig. 2), as near the centre of the diagram as can be judged by eye, and from it draw a line A B to the boundary. Pin the card down to the table. Hold the tracing leg of the instrument in the right hand, placing the point at A and the hatchet at X (*i.e.*, with the instrument roughly square with A B), and press the hatchet so as to make a slight dent in the paper at X; then, the finger having been removed from the hatchet, the tracing point of the instrument is caused to traverse the line A B and the boundary in the direction shown by the arrows, returning to A via A B, when it will be found that the hatchet has taken up a new position, and it must be again lightly pressed in order to make a fresh dent in the paper at Y. The instrument being held in this position, revolve the indicator card through about 180° (by eye) using the point of the instrument as a centre, and taking care that neither the point nor the hatchet shift while the card is being turned. The line A B will again be roughly at right angles to the axis of the instrument, but in a reversed position as shown in dotted lines. Now cause the tracing point to traverse the boundary as before (Fig. 2), but in the opposite direction, as shown by the dotted arrows. The hatchet will take up the new position X_1 which may or may not coincide with X; then, *the mean of* X Y *and* X_1 Y *is the mean height of the diagram*, and this can be readily read off by picking a central point, as shown, between X and X_1 by eye. The mean height thus obtained multiplied by the scale of the indicator spring gives the mean effective pressure on the piston; this, of course, may be measured off direct with the proper scale corresponding to the indicator spring



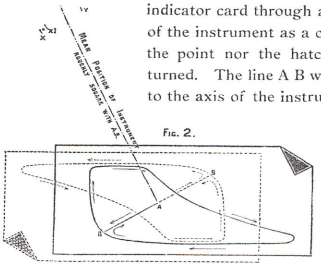


Fig. 3.

When dealing with "looped" diagrams, such, for example, as are obtained with non-condensing Engines when cutting off too early in the stroke, the pointer must be caused to follow right round the loop (Fig. 3); the instrument thus automatically subtracts the negative area, and gives the mean effective pressure on the piston just as with "non-looped" diagrams.

CAUTIONS.

Do not allow the hatchet to work on a rough surface—smooth writing or drawing papers are suitable; do not work on wood, as the hatchet tends to travel along the grain.

Do not allow the hatchet to go off the edge of the paper or over ridges; in some cases it will be necessary to put a piece of paper over the corner of the card for the hatchet to work upon. Hold the instrument freely—not so tightly that the motion of the hatchet is interfered with; the use of the loose weight will prevent side slip.

Use the instrument on a flat table, not on a sloping desk. See that the instrument is held with its legs fairly vertical.

On no account attempt to sharpen hatchet, either with an oilstone or otherwise. Do not make deep dents—all that is required are slight dents sufficient to indicate the initial and final positions of the hatchet.

The Instrument cannot be expected to give accurate results if the above instructions are not carried out. The beginner should practise on a rectangle of say 4in. × 1½in; set the instrument to the length of the figure, then the mean distance between the dents will be 1½in., or the mean height of the rectangle.

PRICE of Averaging Instrument, in Case - - 15/-.