

KEUFFEL & ESSER CO., NEW YORK

DIRECTIONS
FOR THE
USE, CARE AND ADJUSTMENT
OF
COMPENSATING
POLAR PLANIMETERS



KEUFFEL & ESSER CO.

NEW YORK, 127 Fulton Street, **General Office and Factories, HOBOKEN, N. J.**

CHICAGO

516-20 S. Dearborn St.

SAN FRANCISCO

30-34 Second St.

ST. LOUIS

817 Locust St.

LOS ANGELES

730 S. Flower St.

DETROIT

General Motors Building.

MONTREAL

7-9 Notre Dame St., W.

Drawing Materials, Mathematical and Surveying Instruments, Measuring Tapes.

KEUFFEL & ESSER CO., NEW YORK

DIRECTIONS
FOR THE
USE, CARE AND ADJUSTMENT
OF
COMPENSATING
POLAR PLANIMETERS

KEUFFEL & ESSER CO.

NEW YORK, 127 Fulton Street, General Office and Factories, **HOBOKEN, N. J.**

CHICAGO
516-20 S. Dearborn St.

ST. LOUIS
817 Locust St.

DETROIT
General Motors Building.

SAN FRANCISCO
30-34 Second St.

LOS ANGELES
730 S. Flower St.

MONTREAL
1-9 Notre Dame St., W.

Drawing Materials, Mathematical and Surveying Instruments, Measuring Tapes.



DIRECTIONS FOR USE AND CARE
of the
COMPENSATING POLAR PLANIMETER

CAUTION

Any planimeter is a very delicate instrument, and any injury, even when not apparent to the naked eye, will result in a loss of accuracy. Hence, observe the following precautions at all times.

1. Treat the axle of the measuring roller with the utmost care; protecting it against jar and pressure. If the fine bearing points of the measuring roller are once injured, the instrument will not be accurate. Accuracy can then only be established by repairs.
2. The measuring roller should never be turned by direct action of the hand when resting on a working surface.
3. The measuring roller is made of hardened steel, the polished surface of which should not be touched with the fingers. This will avoid the risk of rust, which affects accuracy.
4. From time to time apply a little fine watch oil to the bearings by means of a toothpick or similar agent.
5. Keep the socket or sockets for the ball joint of the pole arm perfectly clean.
6. Do not press the needle point of the pole into the paper, but set it down lightly on the drawing, since the pole weight is designed to give all the pressure that is required. The pole arm should turn freely about the pole point, as a center.

Observation of these precautions will insure the accuracy of the instrument for an indefinite period.

OPERATION

In operating the planimeter the following precautions should be observed:

1. The sheet containing the plan or other figure to be measured should be smoothed out until it lies perfectly flat upon the drawing-board or table.
2. The drawing-board or table should be approximately level.
3. If any liability exists that the measuring roller may pass over the edge of the plan during the measuring operation, take another sheet of paper of the same thickness and butt its edge against that upon which the plan or other figure is drawn.
4. Do not operate the instrument until it has warmed up to room temperature (65° to 75° F.).
5. Do not use the instrument until it has cooled to room temperature (65° to 75° F.).
6. Always set the instrument so that the tracer-arm *A* and pole-arm *P* form an approximate right angle, when the tracer *T* (see page 4) is, as nearly as possible, in the center of the figure to be measured (see the two diagrammatical illustrations, Fig. 1).

COPYRIGHT, 1938, BY
KEUFFEL & ESSER CO.
PRINTED IN U. S. A.

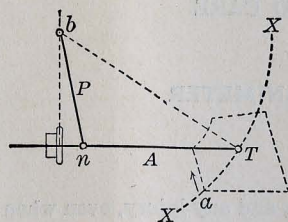
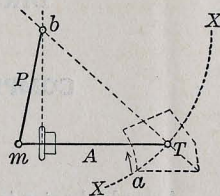


Fig. 1

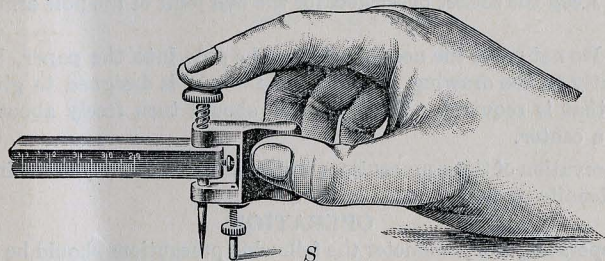


7. While observing (6) be sure that no part of the boundary of the figure is close to and, at the same time, parallel to the base circle (see page 8). If it is, rearrange the instrument or turn the figure so that this condition is avoided.

8. Always guide the tracer point by eye, and endeavor to run it away from the eye rather than toward it. Guiding along a ruler or other stiff surface tends to make the error constant in one direction; whereas, if guided freely, a deviation of the tracer point on one side of the line is usually compensated for by a deviation upon the other side.

9. Always endeavor to have the finger grip directly over the line behind the tracer point; *i. e.*, make the guiding impulse a tangential one. Avoid positions which tend to pull or push in a direction at right angles to the line being traced. It is quite possible to deflect the tracer point, and if this is done at right angles to the line, even so small a deflection as 0.02 millimeters in tracing a circle of 8 cms. ($3\frac{1}{4}$ inch) radius, will cause a difference of 10 units of the vernier.

The proper method of guiding the tracer point is shown in Fig. 2.



10. Always endeavor to make an even number of determinations of the same area—one with the tracer-arm to the left of the pole arm, and one with the tracer-arm to the right of the pole arm. This will allow the instrument to give full value; *i. e.*, instrumental errors will be eliminated by the average of the results from the two positions. **Do not move the pole when changing the position of the tracer arm.**

11. Adjust the support "s" so that the tracer point just touches lightly upon the paper. A slight pressure upon the head of the tracer point will press it into the paper; the puncture thus made serving to locate the starting point; or mark a resting point in circumscribing a large area.

12. It is advisable to reduce the value of one unit of the vernier by circumscribing the figure several times without stopping. Twice around the figure continuously reduces the unit of the vernier one-half; three times continuously around the figure reduces the value of one unit of the vernier to one-third that given in the Table; n times continuously around the figure reduces the value of one unit of the vernier to

Table value of one unit of the vernier

 n

This method increases accuracy, since, in many cases, the final figure of the reading is, in reality, a fraction of one unit of the vernier. Several repetitions, made continuously, serve to bring out this fact, not only indicating the amount of this fractional unit, but practically giving a fifth figure to the reading.

13. Always set the tracer arm to the shortest length possible, especially with small scales such as $1'' = 100'$, $1'' = 200'$, etc.; since this will reduce the value of one unit of the vernier to the lowest possible terms. The larger the scale ($1'' = 20'$, $1'' = 10'$, etc.) the less the likelihood of error will be through using long settings of the tracer arm.

COMPENSATING PLANIMETER No. 4236.

Setting Up.—Place the planimeter on the plan so that its rests upon three points (the running roller l , measuring roller L , and tracer point T). (See illustration of No. N4238, on page 8). The ball end D of the pole arm P is then placed in the socket (m) (see below), while pole b , which has a point, rests upon the paper in such a way that the pole and tracer arms are approximately at right angles as previously explained.

Now lightly circumscribe the figure to be measured in order to learn whether this operation can be carried out without difficulty. If not, move the pole (*b*) until a suitable position is found; or, should the figure prove too large to be circumscribed in one operation, divide it into sections, circumscribe each section in turn and add the individual results. (See also the section which follows—"Pole Within the Figure").

Units of Measure.—Planimeter No. 4236 measures the area in English units; the unit values of the vernier for various scales being given in the table fixed in the lid of the instrument case, thus:

Scale	Value of unit of vernier		Constant: Pole inside figure
	Given scale	1" = 1"	
1" = 100'	100□'	0.01□"	21598
1" = 50'	25□'	0.01□"	
1" = 66'	0.001 Acre	0.01□"	
1" = 10'	1□'	0.01□"	

To determine the value of one unit of the vernier for any other scale, with the same setting of the divided arm, proceed as follows:

R = Value of one unit of the vernier for the desired scale.

R_1 = Value of one unit of the vernier for the given scale; i. e., that in the lid of the case.

M = The desired scale.

$M_1 =$ The given scale.

Then

$$R : R_1 :: M^2 : M_1^2$$

$$\text{or } R = \frac{R_1 M^2}{M_1^2}$$

Example.—Find the value of one unit of the vernier for scale $1'' = 40'$.

Employing the given scale of $1'' = 10'$, with the given value of one unit of the vernier, or $1\Box'$

$$R = \frac{1 \times 40 \times 40}{10 \times 10} = 16 \square'$$

Making the Measurement. A position having been selected for tracing, with the pole and tracer arms in the correct approximate positions shown in Fig. 1, bring the tracer point *T* to a convenient starting point upon the periphery of the figure. Read the recording dial, measuring roller and vernier, and write down the reading.

Now run the tracing point *T* along the periphery of the drawing, always tracing in a clockwise direction until the starting point is again reached. Read the dial, roller and vernier as before; and set this last reading down above the first. The difference between the two readings, multiplied by the value of one unit of the vernier, taken from the Table, gives the area of the figure circumscribed.

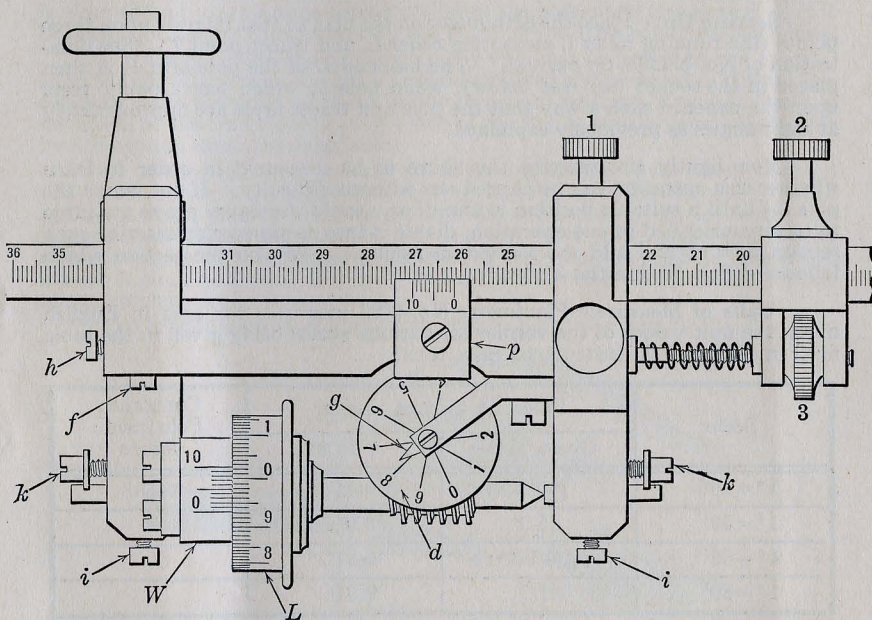


Fig. 3

Reading the Measurement. Fig. 3 shows the registering dial (*d*), the measuring roller (*L*) and the vernier (*W*).

The pointer (*g*) lies between 7 and 8 on the registering dial, indicating that the first figure of the reading is 7000.

The zero of the vernier (*W*) is between 9 and 0 on the measuring roller (*L*), indicating that the second figure of the reading is 900. Hence, combining the first and second figures, the reading, so far, is 7900.

The zero of the measuring roller vernier (*W*) lies between the third and fourth of the ten small divisions, which lie between 9 and 0, indicating that the third figure of the reading is 30. Hence, combining the first, second and third figures, the reading so far is 7930.

Now look along the vernier (*W*) and see which of its divisions is exactly opposite a division on the roller (*L*). In this case, the second division of the vernier from the vernier zero coincides with a division of the measuring roller. This indicates that the final, or fourth figure, of the reading is 2. Hence, our first reading becomes 7932—which means 7932 units of the vernier.

Example. Suppose that you are to circumscribe a plan drawn to the

scale of one inch equals 10 feet. Having set the tracer point *T* at the starting point, the first reading is as given above—7932 units of the vernier.

After circumscribing the plan, you find the pointer (*g*) between 8 and 9 on the dial (*d*); the zero of the vernier (*W*) between 7 and 8 of the numbered divisions on the roller (*L*), and between 4 and 5 of the small divisions which divide the space between 7 and 8 on the roller; and the first division of the vernier (*W*) from its zero is directly opposite a line on the measuring roller. Your second reading is, therefore, 8741.

2nd reading = 8741

1st reading = 7932

Difference = 809.

On the scale one inch equals 10 feet, the value of one unit of the vernier is one square foot. Hence, 809 units of the vernier multiplied by one square foot, gives 809 square feet, the area of the figure circumscribed.

Had the scale been 1:1; that is, full size, it would have been necessary for you to multiply 809 units of the vernier by 0.01 square inch (the value of one unit of the vernier for the full size scale). The answer would then have been 8.09 square inches.

Conversely, 8.09 square inches, to a scale of one inch equals 10 feet, is equal to 8.09 times 100 square feet, or 809 square feet. This shows the relation between the 1:10 scale and the 1:1 scale, and removes some of the planimeter's mystery.

Possibly, if the periphery had been traced continuously four times about, the second reading would have been 11,167 (one complete revolution of the dial plus 1167), in which case the difference would have been 11,167—7932, leaving 3235. The value of one unit of the vernier would have been reduced to one-quarter square foot. $3235 \times \frac{1}{4} \square' = 808.75 \square'$. On the full size scale this would become 8.0875 square inches.

Large Figures. A figure too large to be circumscribed in one operation of the planimeter with the pole outside the figure, may have its area determined in two ways.

1. It may be split into two or more smaller areas, each of which is separately circumscribed by the planimeter, and the results added. This may be the only method possible with large areas.

2. Where the area does not exceed the utmost capacity of the planimeter for a single operation, the pole may be placed within the figure.

Pole Within the Figure. By referring to Fig. 1, it will be seen that when the tracer point is maintained in such a position that the plane of the measuring roller always passes exactly through the pole *P* (the position in Fig. 1), a complete circle may be circumscribed whose area will not be registered. In other words, the measuring roller slides in a direction at right angles to its own plane, instead of rolling. This circle is known as the "base" circle, and it should always be the endeavor in all operations of the planimeter to keep the measuring roller as far from this base circle as it is possible to get it.

The area of the base circle is separately determined for each instrument; and is translated into terms of units of the vernier by the manufacturer. This value in these units, is given in the last column labelled "constant: Pole inside figure" of the table in the lid of the case.

Use of Constant. If the area to be circumscribed is greater than that of the base circle, the measuring mechanism will register as many units of the vernier as the area circumscribed is greater than the base circle. Hence, the vernier units recorded must be added to the constant before the measurement is reduced to terms of area.

If the area circumscribed is less than the base circle, the measuring mechanism turns backward; *i. e.*, it registers the number of vernier units which must be deducted from the constant before the measurement is reduced to terms of area.

Since the position of the pole within the figure arises from the necessity of circumscribing a large area, the probabilities of the registering dial (*d*)

exceeding one complete revolution is great. Hence, for this reason and others, which will demonstrate themselves, it is best to have the entire recording mechanism register zero before circumscribing the figure. This may be done by raising the roller clear of the plan, and turning it gently with the hand until the registering dial reads zero.

Example. The area of a circle 14 inches in diameter is to be determined. Set the registering dial to zero, as described above.

Observations of the measuring roller during the operation of circumscribing will indicate that it is revolving backward; *i. e.*, from 0 to 9 to 8 to 7, etc. Observation of the registering dial will show that it again passes zero. The reading is found to be 8597. One complete revolution of the registering dial is equivalent to 10,000 units of the vernier; but the operation proceeded until the dial had circumscribed another part of a revolution. Since it was revolving backwards, this part of a revolution is equivalent to 10,000 minus 8597, or 1,403 units of the vernier. These 1403, added to the 10,000 of the complete revolution, make 11,403 units of the vernier recorded in the reverse direction—that is, subtracted from the total number of units in the base circle.

The table shows that the constant, or total number of units in the base circle for this particular planimeter is 26,797.

$$26,797 - 11,403 = 15,394 \text{ units.}$$

The value of one of these units is 0.01 square inch. (See Table).

$$15,394 \times 0.01 \text{ square inch} = 153.94 \text{ square inches.}$$

Example. The area of a circle 22 inches in diameter is desired.

Set the registering dial to zero as described above.

Observation indicates that the movement of the measuring roller is positive, and that the registering dial made between one and two revolutions.

The final reading is 1,216 units.

Add 10,000 units for one complete revolution of the dial.

The entire reading is 11,216 units, by which the area circumscribed exceeds the total number of units in the base circle.

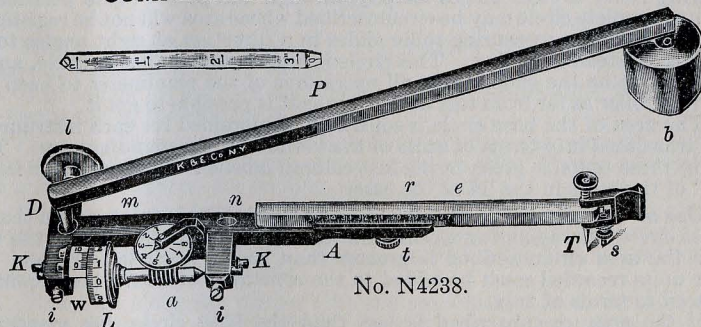
Reading—11,216

Constant—26,797

Total . . . 38013 units.

$$38,013 \text{ units} \times 0.01 \text{ sq. in.} = 380.13 \text{ sq. inches.}$$

COMPENSATING PLANIMETER No. N4238.



The general principles governing the construction and operation of No. N4238 are the same as those applying to No. 4236.

The chief differences between the two lie in the greater capacity and limited adjustment of the tracer arm of No. N4238.

Units of Measure.—Planimeter No. N4238 measures the area in either metric or English units; the necessary settings of the tracer arm (A) being given in the table fixed in the lid of the instrument case. This table has the following form (the values given not necessarily being the same as those in the table furnished with your instrument):—

ENGLISH SYSTEM					
Position of ball-joint of pole-arm	Scale	Setting on tracer arm	Value of unit of vernier		Constant: Pole inside figure
			Given Scale	1" = 1"	
In socket nearest tracer-point	1" = 10'	10□"	1□'	0.01□"	
In socket furthest from tracer-point	1" = 10'	16□"	1.6□'	0.016□"	18169
METRIC SYSTEM					
In socket furthest from tracer-point	Proportion 1 : 1000	1□D.	10□m	10□mm	18268

The unit values of the vernier for other scales in the English system can be calculated by the method described on page 5. The same method applies also to the metric system, as follows:

Example.—Find the value of one unit of the vernier in metric measure for the proportion 1 : 2500.

$$R = \frac{10 \times 2500 \times 2500}{1000 \times 1000} = 62.5 \text{ } \square m.$$

It should also be understood that if the proportion is set at one inch to 10 units in any system, the value of one unit of the vernier will bear the same ratio to the scale used as in the case of one inch is equal to 10 feet. For instance, with the arm set for a scale of 1" = 10' (10□" in this case), one inch may equal 10 chains; in which case one unit of the vernier will equal one square chain. Or if one inch equals 10 meters, then one unit of the vernier will equal one square meter. Or, if one inch equals 10 varas, then one unit of the vernier will equal one square vara.

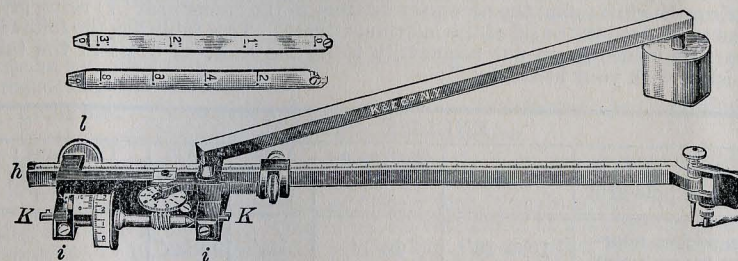
By tracing continuously about the periphery n times, the value of one unit of the vernier may be reduced to Tabular value

Adjusting Tracer Arm.—In order to bring the tracer arm to the setting given on the card, it is necessary to manipulate screw (t). It will be found, upon examination, that the tracer arm (r) has, in its lower face, two holes. When screw (t) is in the hole nearest the tracer point, the tracer arm may be set to the mark 10□". Hence, the screw (t) must be in this hole when the arm (r) is brought to the setting "In socket nearest tracer point". When screw (t) is in the hole farthest from the tracer point, the tracer arm may be set to the marks 16□" and 1□D. Hence, the screw (t) must be in this hole, when the arm (r) is set at the adjustment "In socket furthest from tracer point". The given adjustment must always be set to the index mark on the bevel of bar (v).

Which Socket To Use. It is further necessary to take care that, in an instrument with two sockets, with the settings given in the table, the ball joint (D) is in socket (n) for the position, "In socket nearest tracer-point" and in socket (m) for the position, "In socket furthest from tracer-point".



COMPENSATING PLANIMETERS Nos. 4240 AND 4240½.



No. 4240

The general principles governing the construction and operation of Nos. 4240 and 4240½ are the same as those applying to No. N4238.

The chief differences between the two lie in the greater capacity and adjustable tracer arms of Nos. 4240 and N4240½.

Graduated Tracer Arm. The tracer arm of this instrument is graduated in half millimeters, and numbered in half centimeters from 5 to 36. This graduation is usually referred to in terms of half millimeters, in which case the arm is said to be graduated from 50 to 360.

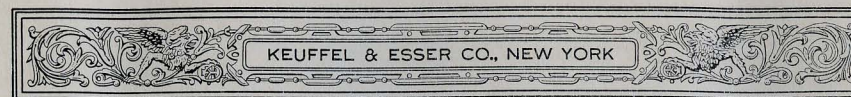
This full graduation permits the tracer arm to be set at any length which will give an easily handled value of one unit of the vernier. The various settings are given in the tables found in the case of the instrument, and reproduced below. The figures given are not necessarily the same as those in the table furnished with your instrument.

METRIC SYSTEM				
Proportion	Setting on divided arm	Value of unit of vernier		Constant: Pole inside figure
		Given Proportion	1:1	
1 : 1000	327.0	10□m	10□mm	23270
1 : 500	262.2	2□m	8□mm	
1 : 2500	201.5	40□m	6.4□mm	
1 : 4000	205.7	100□m	6.25□mm	
1 : 2000	165.3	20□m	5□mm	
1 : 5000	132.9	100□m	4□mm	

Constant for Indicator Diagrams: Multiply by 0.0635

ENGLISH SYSTEM				
Scale	Setting on divided arm	Value of unit of vernier		Constant: Pole Inside figure
		Given Scale	1" = 1"	
1" = 5'	337.1	0.4□'	0.016 □"	23176
1" = 10'	211.9	1□'	0.01 □"	
1" = 25'	337.1	10□'	0.016 □"	
1" = 40'	264.1	20□'	0.0125□"	
1" = 50'	211.9	25□'	0.01 □"	
1" = 100'	211.9	100□'	0.01 □"	

Constant for Indicator Diagrams: Divide by 0.04 or multiply by 0.0025



It is possible, of course, to find values of one unit of the vernier for all scales for one setting of the measuring arm, using the rule given on page 5. Hence, with a setting of 337.1, using a scale of 1" = 10', the value of one unit of the vernier would be 1.6 square feet. With the same setting of the tracer arm (337.1), using a scale of 1" = 100', the value of one unit of the vernier would be 160 square feet. This, however, is not so convenient a unit as that given in the table for a scale of 1" = 100', since through reducing the length of the tracer arm to 211.9, a value of 100 square feet may be assigned to one unit of the vernier. Hence, since the value of one unit of the vernier is smaller, the result will be more accurate.

Setting the Tracer Arm. In order that the measuring or tracer arm may be accurately set, the frame of the carriage carries the vernier (*p*) (see Fig. 3), by means of which the arm may be set to the nearest 0.05 of a millimeter.

To set the arm proceed as follows; assuming that 337.1 is to be the setting:

Loosen screws (1) and (2) and slide the graduated arm until the 7th division beyond 33 (between 33 and 34) is near the zero of the vernier. Tighten screw (2). Revolve the milled nut (3) until the first division of the vernier beyond zero is on a line with the 8th division beyond 33 on the tracer arm. Then tighten (1).

To set the arm at 211.9, loosen (1) and (2) as before; slide the arm until the first division past 21 is near the zero of the vernier; tighten (2); revolve (3) until the 9th division of the vernier is on a line with the 9th division past 21 on the tracer arm, and tighten (1).

Operation. The operation of the instrument is precisely the same as that of No. N4238.

Example. Scale 1" = 100'.

Suppose that the figure is circumscribed four times continuously, and the second reading is 9143

First Reading 6288

Difference 2855

Tabular value of one unit of the vernier (see table in case) = 100□'.

For four continuous repetitions, the value of one unit of the vernier is

$$\frac{100}{4} = 25□'. \quad 2855 \times 25 = 71375 \text{ square feet.}$$

The probabilities are that with one circumscribing the difference would have been 714 units.

$$714 \times 100□' = 71400 \text{ square feet.}$$

To obtain the setting of the tracer arm for any scale and value of one unit of the vernier. It may be desirable at some time to adopt a scale or proportion not given in the table, and also to have the value of one unit of the vernier for this scale come out in some even number. This is done as follows:

l = Value of 1 unit of the vernier for a scale of 1:1 corresponding to the value of 1 unit of the vernier which it is desired to adopt for the desired scale.

S = The longest setting of the tracer arm given in the table.

S_1 = The shortest setting of the tracer arm given in the table.

U = The value of one unit of the vernier on the scale 1:1 for the longest setting S .

U_1 = The value of one unit of the vernier on the scale 1:1 for the shortest setting S_1 .

X = Unknown setting of the tracer arm.

Then:—

$$X = S - \frac{(S - S_1)(U - l)}{(U - U_1)}$$

Example. Find the setting of the tracer arm for the scale $1'' = 40'$ which will give a value of one unit of the vernier of $20\Box'$.

It is first necessary to find (l), the actual value of one unit of the vernier corresponding to the scale $1'' = 40'$, where one unit of the vernier = $20\Box'$.

One square inch on the scale $1'' = 40' = 40 \times 40 = 1,600$ square feet.

1,600 square feet, divided by $20\Box'$, the value of one unit of the vernier for the scale $1'' = 40' = 80$.

Hence, to cover one square inch requires 80 units of the vernier.

Hence, one unit of the vernier = $\frac{1}{80}$ of a square inch, or 0.0125 square inch.

$$X = 337.1 - \frac{(337.1 - 211.9)(.016 - .0125)}{.016 - .01}$$

$$= 337.1 - \frac{125.2 \times .0035}{.006}$$

$$X = 337.1 - \frac{.43820}{.006}$$

$$= 337.1 - 73.03$$

$$= 264.07, \text{ or } 264.1$$

This is the required setting.

Indicator Diagrams. The tracer arm of Nos. 4240 and 4242 can be immediately set to show the mean height of indicator diagrams.

This is readily understood from the theory of the planimeter, by which all figures are automatically reduced to rectangles, with the tracer arm as the base, and the actual distance covered by the circumference of the measuring roller as the height. Hence, if the tracer arm is made equal to the base line of the indicator diagram, and the outline of the diagram is then traced in the usual manner, the circumference of the measuring roller will actually roll over a distance equal to the mean height of the diagram. Since one unit of the vernier

measures $\frac{1}{1000}$ of the actual circumference of the roller, it is only necessary to

multiply the total number of vernier units resulting from the tracing by $\frac{1}{1000}$ of

the length of the circumference in order to obtain the actual total distance covered by the circumference of the measuring roller. In these planimeters the actual distance in millimeters covered by the circumference in a movement equivalent to one unit of the vernier is .0635; and the actual distance in inches covered by the circumference in a movement equivalent to one unit of the vernier is 0.0025.

The method of obtaining the length of the base is simple.

Remove the pole arm. Set the tracer point T to the right end of the base

of the diagram; loosen screws (1) and (2); and slide the carriage (keeping the roller clear of the paper) until the left end of the base is seen in the middle of the small hole at the bottom of the socket for the pole arm. (See Fig. 4).

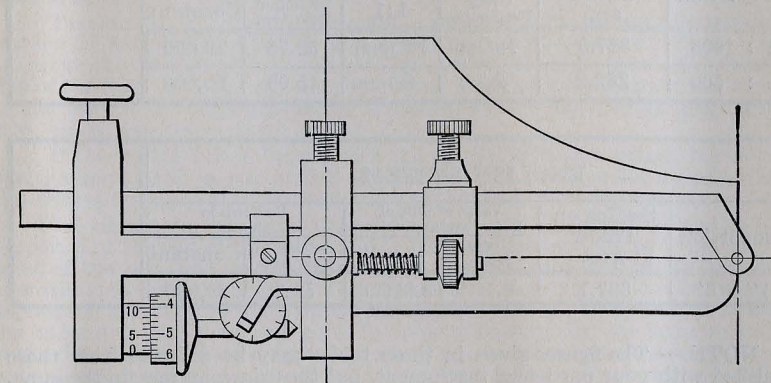
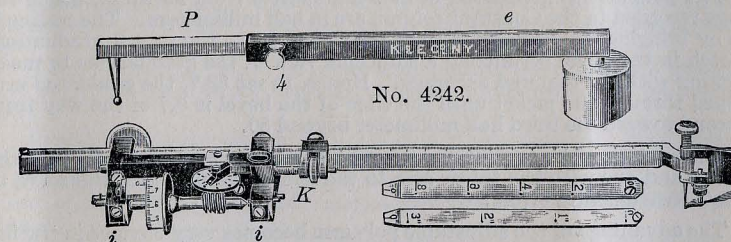


Fig. 4.

Clamp the tracer arm in this position. Replace the pole arm and trace the periphery of the diagram in exactly the same manner as any other figure would be circumscribed.

COMPENSATING PLANIMETERS Nos. 4242 AND 4242½.



Nos. 4242 and 4242½ are similar to Nos. 4240 and 4240½; the difference between the two lying in the adjustable pole arm. This not only increases the capacity of Nos. 4242 and 4242½, but makes more convenient the measurement of areas with the pole within the figure.

Increase in Capacity. When a measurement is made with the pole outside the figure, the length of the pole arm has no influence upon the result. Hence, the capacity of any instrument may be greatly increased by increasing the length of the pole arm.

In No. 4242, by loosening screw (4), the pole arm (P) may be slipped through the jacket (e) so as to give any length of pole arm between about 5½ and 13 inches. Hence, for large areas, the extension of the pole arm to its greatest length, and the setting of the tracer arm to its greatest tabular length, gives a much greater reach than can be obtained with No. 4240. On the other hand, through reducing the pole arm to its shortest length, and the tracer arm to its smallest tabular setting, great convenience and accuracy in the measurement of small areas is attained.

Pole Inside the Figure. The tables of settings for Nos. 4242 and 4242½ generally are the same as that for Nos. 4240 and 4240½, except for the column marked "Constant." This is shown below.

METRIC SYSTEM

Proportion	Setting on Tracer arm	Value of unit of vernier		Pole inside figure	
		Given Proportion	1:1	Setting of Pole Arm	Constant
1 : 1000	327.0	10□m	10□mm	52.75	20,000
1 : 500	262.2	2□m	8□mm	45.00	20,000

ENGLISH SYSTEM

Proportion	Setting on Tracer Arm	Value of unit of vernier		Pole inside figure	
		Given Scale	1" = 1"	Setting of Pole Arm	Constant
1" = 5'	337.1	0.4□'	0.016□"	52.7	20,000

NOTE.— The figures given in these tables may be different from those furnished with your particular instrument, but the principles remain the same.

This means that with the tracer arm set at 327.0 for metric measure, and the adjustable pole arm set at 52.75, the Constant for the pole within the figure will be 20,000; or, with the tracer arm set at 262.2 for metric measure, and the pole arm set at 45.00, the Constant for the pole within the figure will be 20,000. For English measure the Constant will be 20,000, when the tracer arm is set at 337.1 and the pole arm at 52.7.

The pole arm is graduated in half millimeters from 20 to 70, hence the settings recorded in the Constant column are in half millimeters. The setting is made by bringing the beveled edge of the sleeve (*e*) to the proper graduation, the notch in the bevel permitting a sufficient view of the graduations to make the setting with the required accuracy. Hence, to set 52.7, the graduated arm is slipped through the jacket until the edge of the bevel is 0.7 of the way from the second toward the third half millimeter beyond 50.

The average of two readings—one with the tracer arm to the right of the pole arm, and one with the tracer arm to the left of the pole arm will serve to eliminate instrumental errors.

The advantage of the adjustable pole arm becomes very obvious in tracing areas with the pole inside the figure, where these areas are less than that of the base circle. The result is given directly, instead of requiring a subtraction as in the case of the fixed pole arm.

Example. The area of a circle 16 inches in diameter is required.

Set the tracer arm at 337.1, and the pole arm at 52.7.

Upon tracing the periphery of this circle, beginning with the measuring mechanism registering zero, the second reading will be 2566. The size of the figure itself indicates clearly that, could it be traced in a direct manner, with the pole outside, the registering dial would have passed through an entire revolution before reaching 2566. Hence, the reading becomes 12566 units of the vernier.

$$12566 \times .016 \square'' = 201.056 \square''.$$

Had the area been circumscribed twice continuously, a second reading of 25133 would probably have been obtained; which multiplied by $\frac{0.016}{2}$ would give 201.064 as the area. This is closer to 201.0624, the actual area, than 201.056 obtained with only one tracing of the periphery.

TESTING THE PLANIMETER

While it is a good plan to make frequent tests of the accuracy of the planimeter, it is a bad plan to attempt any adjustments unless the need for these is absolutely certain.

Testing Rule. Each instrument is supplied with testing rule which is marked □" for English measure, and □ cm. for metric measure. These rules are accurately graduated from the zero formed by the needle point on the under side of the rule near one end (the point being held in by the head of the screw on the top face). Each graduation is marked by a small conical depression into which the tracer point fits.

If the testing rule is turned with the needle point as a center, the tracer point, when placed in one of the depressions, will circumscribe a circle of an area corresponding to the number marked at that particular depression.

To operate the rule, press the needle point into the paper. Screw up the support *S* at the end of the tracer arm. Place the tracer point over the needle point of the rule, and set the pole so that the pole arm and tracer arm are approximately at right angles. Then insert the tracer point into the selected depression, and turn the rule, not the planimeter by hand. If necessary, weight the tracer arm near the tracer point in order to be sure that the latter remains in the depression. Rotate the rule through one or more complete revolutions, beginning and ending at a mark made opposite the line at the bevel end of the rule. With these planimeters the fairest tests are usually obtained with a setting of the tracer arm which will give a value of 0.016□" or 10□ mm to one unit of the vernier.

The second reading minus the first reading, multiplied by the value of one unit of the vernier should be equal to the area of a circle of a magnitude equal to the quantity marked at the depression in which the tracer point was inserted.

Measuring Roller. The measuring roller should turn freely under a slight impulse of the finger. Do not touch the polished steel parts of the roller.

If the measuring roller, at room temperature, does not turn freely, or seems to be too loose in its bearings, a slight adjustment may be made as follows:

Slightly loosen set screws (*i i*) (see cuts of instruments). The bearings may then be either loosened or tightened by turning the screws (*KK*). After the adjustment is made, the set screws (*i i*) should again be tightened. Do not make this adjustment unless you are absolutely certain of its necessity.

Tracer Arm. If the tracer arm and the axis of the measuring roller are not parallel, the result obtained by having the tracer arm to the right of the pole arm will be different from that with the tracer arm to the left of the pole arm. The correct result is the average of the two results obtained with the two different relations of the pole and tracer arms, provided that the pole remains in the same position for both conditions.

For those who desire to keep the tracer arm exactly parallel to the axis of the measuring roller, the following adjustment may be made:

Use the testing rule and make several determinations with the tracer arm to the right and the left of the pole arm. The difference may be corrected by slightly loosening set screw (*h*) (Fig. 3, page 6), and then turning the screw (*f*). Several trials may be necessary before this adjustment is correctly made. Be sure to tighten set screw (*h*) after each manipulation of screw (*f*).

Uniformity of Readings. Repeated tracings of the figure should not result in any great difference in the results. The accuracy of the planimeter in this respect may be determined as follows:

With a setting of the tracer arm giving a value of one unit of the vernier of 0.016□", test the instrument by means of the testing rule. The difference between the greatest and least result of several tracings should not exceed 2 to

KEUFFEL & ESSER CO., NEW YORK

2.5 units of the vernier. This will correspond to an accuracy of about 1 in 125 for a circle of 2 cms. ($\frac{1}{8}$ in.) radius; and 1 in 2000 for a circle of 10 cms. (4 inches) radius. *If the difference exceeds this, the instrument should be sent to the manufacturer for repairs.*

Reverse Tracing. The difference between the greatest and least readings as described under "Uniformity of Readings," should not be exceeded when the tracing is done in both the clockwise and counter-clockwise directions. An excessive difference indicates the need for repairs.

Settings of Tracer Arm. The settings of the tracer arm given in the Table should be correct.

For this test it is best to use a figure (square, triangle, etc.) whose area is accurately known, and which may be traced free-hand. The correct setting is determined as follows:

$$C = \text{Number of vernier units corresponding to the calculated area of the figure traced}$$

$$= \frac{\text{calculated area}}{\text{value of unit of vernier for scale 1:1}}$$

C_1 = Number of vernier units resulting from actually circumscribing the periphery of the figure.

D = The setting of the tracer arm given in the table.

B = The correction to setting of the tracer arm as given in the table.

Then:

$$B = \frac{C - C_1}{C} D \text{ or } \frac{C_1 - C}{C} D$$

If C_1 is larger than C , then B is added to D .

If C is larger than C_1 , then B is subtracted from D .

Constant for Pole Within the Figure. This is tested as follows:

Take a large square of known area and trace it in a clockwise direction.

A = The known area.

U = Value of one unit of the vernier on the scale 1:1 for the setting of the tracer arm used.

R_1 = The first reading of the instrument.

R_2 = The second reading of the instrument.

C = The Constant.

Then:—

$$C = \frac{A}{U} + R_1 - R_2.$$

The Pole Point. If the point of the pole (b) becomes blunt, loosen the screw on the back of the pole, and turn the pin end for end. Both points may be reground or renewed.

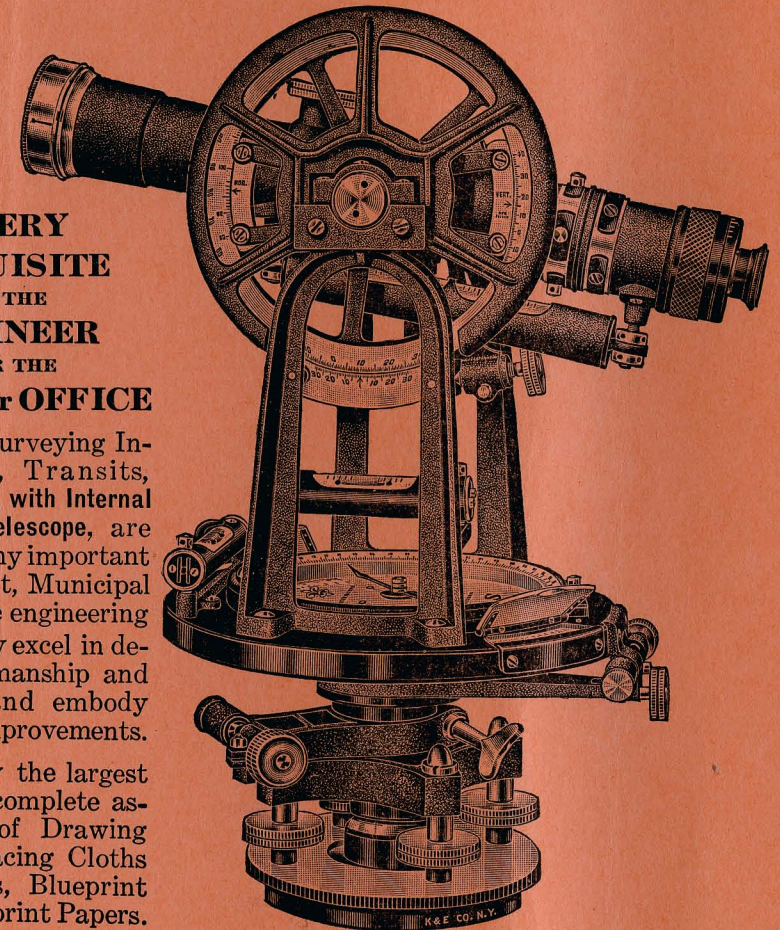
KEUFFEL & ESSER CO., NEW YORK

EVERY REQUISITE OF THE ENGINEER FOR THE FIELD or OFFICE

K & E Surveying Instruments, Transits, Levels, etc., with Internal Focusing Telescope, are used on many important Government, Municipal and Private engineering works. They excel in design, workmanship and accuracy and embody the latest improvements.

We carry the largest and most complete assortment of Drawing Papers, Tracing Cloths and Papers, Blueprint and Brownprint Papers.

Write for
General Catalogue



K & E Engineer's Transit No. N5060FS,
with Internal Focusing Telescope
and K & E Stadia Circle.

We manufacture the celebrated K & E Measuring Tapes, Flat Wire Tapes, Bandchains, etc. Accurate. Excellent quality. Large assortment.

The K & E **WYTEFACE** Steel Tapes represent the latest improvements in the method of graduating tapes, resulting in a saving of time and reducing the possibility of errors in reading.

