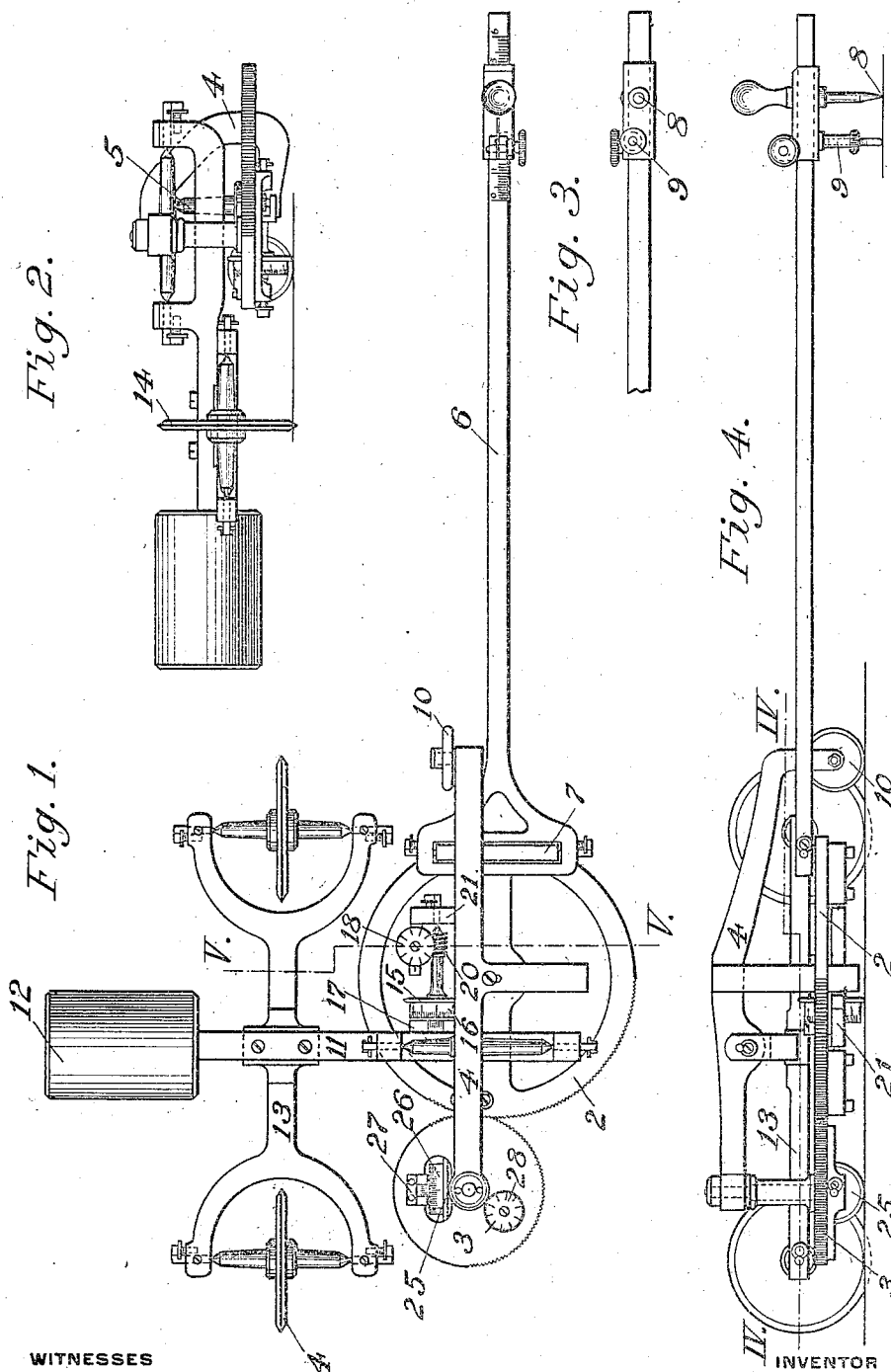


W. S. BUVINGER.
CALCULATING INSTRUMENT.
APPLICATION FILED JULY 8, 1910.

1,058,148.

Patented Apr. 8, 1913.

4 SHEETS-SHEET 1.



WITNESSES

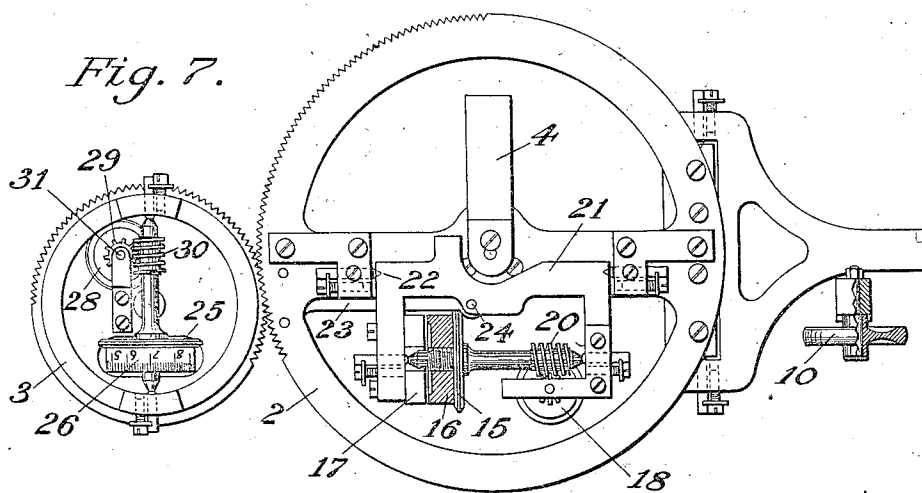
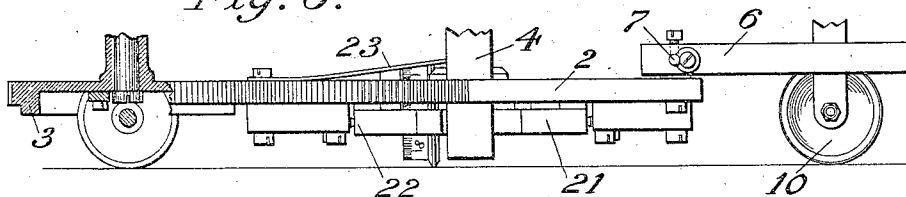
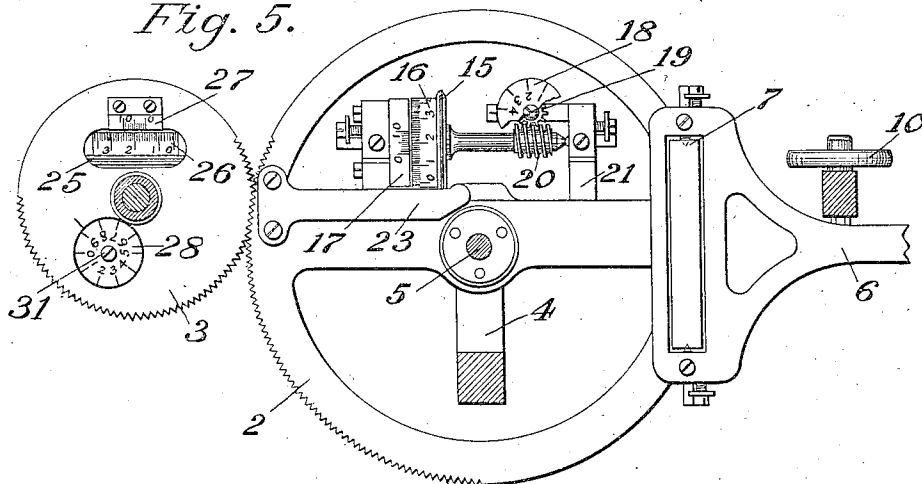
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1,058,148.

4 SHEETS—SHEET 2.



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4 SHEETS—SHEET 3.

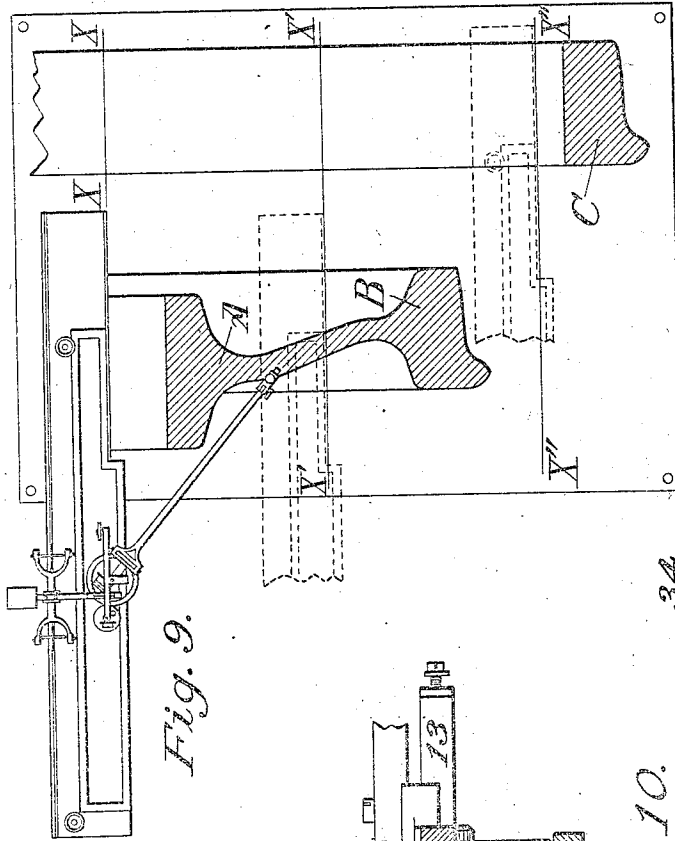


Fig. 9.

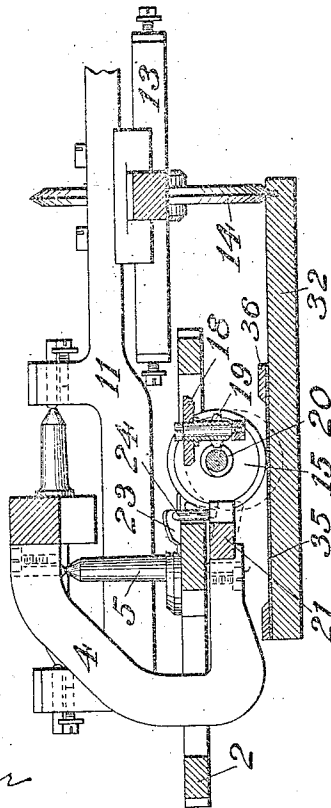


Fig. 8.

Fig. 10.

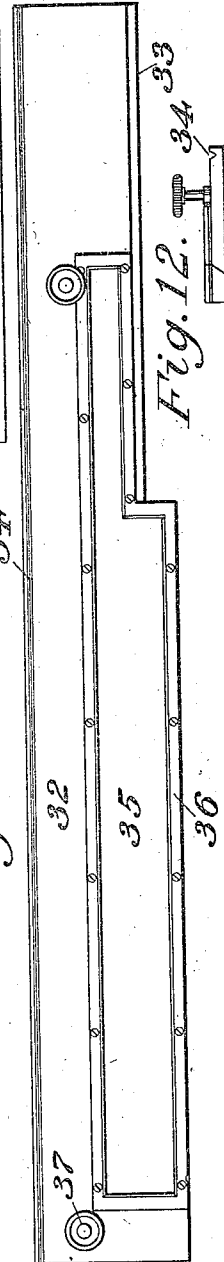


Fig. 12.

Fig. 11.

Fig. 11.

WITNESSES

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4 SHEETS—SHEET 4.

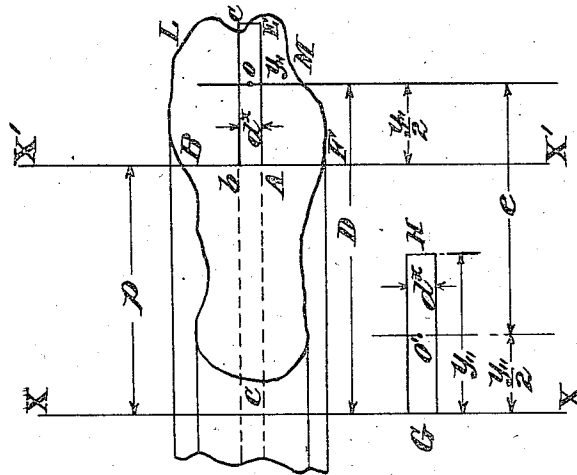


Fig. 14.

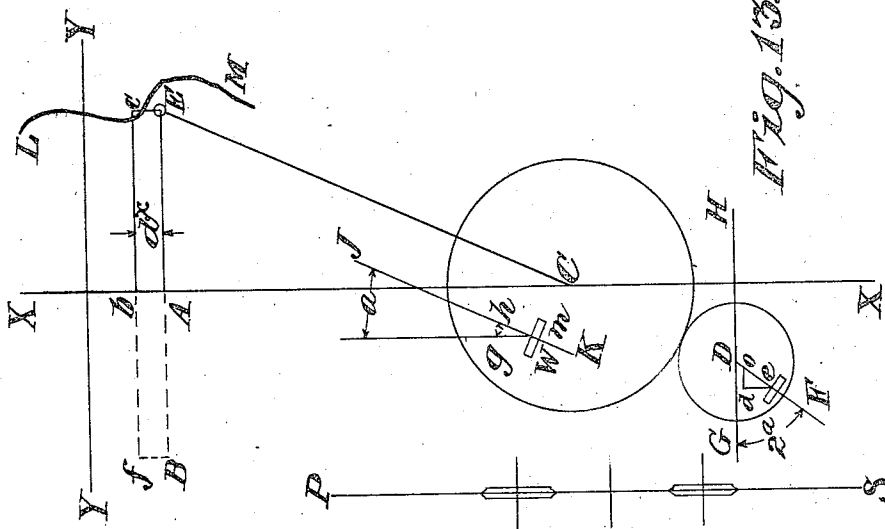


Fig. 13.

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UNITED STATES PATENT OFFICE.

WILLIAM S. BUVINGER, OF PITTSBURGH, PENNSYLVANIA.

CALCULATING INSTRUMENT.

1,058,148.

Specification of Letters Patent,

Patented Apr. 8, 1913.

Application filed July 8, 1910. Serial No. 571,078.

To all whom it may concern:

Be it known that I, WILLIAM S. BUVINGER, of Pittsburgh, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Calculating Instrument, of which the following is a full, clear, and exact description, reference being had to the accompanying drawings, forming part of this specification.

My invention relates to apparatus used to determine the weight of solids of revolution, such as wheels, tires and similar cylindrical or annular articles, from the contour of a diametrical cross section of the article.

Heretofore, it has been proposed to determine the weight of such articles from a sectional drawing by means of planimeters which indicate values relating to surfaces only, having no provision for indicating volume or weight. Such planimeters usually indicate some fixed multiple of the area or of the product of the area and the distance of its center of gravity from the axis to which the instrument is adjusted. The range of action of such instruments is limited by the length of the tracing point arm and no provision is made to take care of figures whose contour exceeds the range of the tracing point arm. Consequently, such instruments are not adapted for use upon sections of wheels and tires of great diameter. Likewise, these instruments have been constructed formerly of a design which does not permit rapid and convenient adjustment to position relative to the central axis of the sectional contour of wheels and similar bodies, and require for the purpose mechanism in addition to that forming the instrument proper. The measuring wheels of such planimeters roll and slide upon the drawing illustrating the cross section being measured, and in using these instruments, creases, buckles or other inequalities in the surface of the drawing will introduce serious errors in the readings of the measuring wheels, while frequently the surface of the drawing itself is so small, relative to the range of travel of the measuring wheels, as to prevent the use of the instrument upon it.

One object of this invention is to provide apparatus of novel construction having means by which the weight of solids of revolution is directly indicated, with a minimum amount of computation which is easily made

by those having little skill in computation and is made without reference to certain complex mathematical values necessarily used heretofore with planimeters and similar instruments.

Another object of the invention is to provide an instrument by which the correct weight of large and small wheels and tires, wheel and tire blanks, and similar bodies, and the intermediate forms produced in the various steps of the forming operations may be quickly obtained by persons with limited mathematical ability.

A further object of my invention is to provide apparatus having means by which the one instrument will quickly and easily indicate the weight of solids of revolution having cross sections of a diameter and thickness much greater in extent than the range of the tracing point arm forming part of the apparatus.

A still further object of my invention is to provide a surface or track of novel construction and forming part of this apparatus, of a size sufficient to include the maximum range of movement of the rolling and sliding wheels.

Referring to the drawings, Figure 1 is a plan showing one form of computing instrument constructed and arranged in accordance with my invention. Fig. 2 is an end elevation of the same. Fig. 3 is an inverted plan showing a bottom view of the adjustable tracing point and supporting standard. Fig. 4 is a side-elevation of the apparatus shown in Figs. 1 and 2. Fig. 5 is a sectional plan on the line IV—IV of Fig. 4 showing the measuring wheels forming part of the apparatus. Fig. 6 is a side elevation and partial section of the portion shown in Fig. 5. Fig. 7 is a bottom view of the portion shown in Fig. 5. Fig. 8 is a vertical section on the line V—V of Fig. 1 showing the large gear wheel and its measuring roller. Fig. 9 is a plan showing the illustration of a drawing of a half section of a car wheel and of a tire of large diameter or size greater than the range of the tracing arm with the apparatus adjusted to an operating position upon it. Fig. 10 is a plan of the supporting plate upon which the guide carriage wheels and measuring rollers forming part of the instrument travel when the apparatus is in use. Fig. 11 is a side

elevation of the supporting plate shown in Fig. 10. Fig. 12 is an end elevation of the plate shown in Figs. 10 and 11. Fig. 13 is a diagrammatic plan representing the mathematical axis of the calculating instrument shown in the preceding figures. Fig. 14 is a diagram showing a portion of the contour of a figure of larger diameter than may be compassed by the tracing arm of the instrument when the instrument is adjusted to the central axis of the figure.

In the drawings, referring to Fig. 1, 2 designates a large spur gear wheel meshing with a smaller spur gear wheel 3, the teeth of the wheels being held in position relative to each other by a wheel support formed by the cross bar 4. The vertically extending arbor 5 of the large gear 2 is pivotally mounted on the support 4 so as to permit of a limited angular movement of both large and small gear wheels, in the instrument shown, the relative angular movement of the smaller gear wheel being twice that of the larger. A tracing arm 6 is connected to the larger gear wheel 2 by a hinged joint 7, so as to permit of a limited vertical movement of the outer end of this arm, the longitudinal axis of the arm passing through the vertical axis of the wheel 2 and arbor 5. A longitudinally adjustable tracing point 8 and a vertically adjustable standard 9 are mounted upon the outer end of the tracing arm 6. The tracing point 8 is adjusted longitudinally upon the tracing arm 6 to a determined position indicated for the material composing the solid whose weight is being computed, the distance from the center of the arbor 5 varying in relation to the weight per unit of volume of various materials. By means of the standard 9, the tracing point is raised or lowered to a position which will permit it to follow the contour of the figure easily without touching the paper.

A pilot wheel 10 is secured to one end of the support 4 and a pivoted horizontally extending cross arm or support 11 connects the cross arm or support 4 with the counterweight 12. A guide carriage frame 13 is rigidly connected with the arm 11, this frame having on its forked ends the pivotally mounted wheels 14 which are provided with a V-shaped periphery for a purpose later described.

A roller or measuring wheel 15 having a decimal scale 16, a vernier 17 and a dial 18 which is connected by a worm wheel 19 on its arbor with the worm 20 on the arbor for the roller 15, is rotatably mounted in the vertically movable frame 21 which is held connected to the large gear wheel 2 by the pivots 22. A flat spring 23 and a pin 24 are provided to hold the roller 15 on the frame 21 in frictional contact with the underlying tablet surface or track for the roller 15. It

will be noted that the horizontal axis of the roller 15 is made to be constantly parallel to or co-incident with a vertical plane passing through the tracing point and the vertical axis of the arbor 5. A second roller or measuring wheel 25 having a decimal scale 26, a vernier 27 and a dial 28 which is connected by a worm wheel 29 with the worm 30 on the arbor for the roller 25, is mounted so as to rotate within the small gear wheel 3. The horizontal axis of the roller 25 is located so as to be perpendicular to a vertical plane which includes the tracing point 8 and the vertical axis of the arbor 5 of the gear wheel 2 when in the position shown in Fig. 1.

The supporting plate 32 is provided with a beveled straight edge 33 as is clearly shown in Fig. 10 which extends in a line passing through the extension of the vertical axis 5 of the large wheel 2. A straight groove 34, which is V-shaped in cross section, extends along the rear edge of the supporting plate and is parallel to the straight edge 33, this V-shaped groove engaging with the V-shaped peripheries of the wheels 14 and forming a guide or track for these wheels. The tablet or running surface 35 which preferably is formed of bristol-board or like material, is secured to and held in position on the plate 32 by an edging strip 36, this table providing a suitable surface for the rolling and sliding action of the measuring rollers or wheels 15 and 25. Knobs 37 are provided on its opposite ends to facilitate handling of the plate, these knobs also serving as stops in limiting the travel of the carriage frame 13.

The mathematical theory upon which the calculating instrument is based is as follows:—The mathematical axes of the calculating instrument are represented by Fig. 13. Let XX be the straight edge of the metal tablet extended, which passes through the center C of the large toothed wheel. GH is drawn perpendicular to XX and passes through the center D of the small toothed wheel, which is located at any distance from XX. The diameter of the small wheel is made one half that of the large wheel with which it engages, and in consequence its relative angular motion is twice that of the large wheel. JK and DF are the horizontal axes of the measuring rollers W and W' of the large and small wheels respectively. By suitable mechanism, JK is held parallel at all times to the tracing arm EC and FD will coincide with GH, due to the action of the gear wheels, when EC is made to coincide with XX. PS represents the track upon which the carriage travels and is parallel to XX. Therefore, the line XX will pass through the center C of the large wheel in all positions of the instrument. $gm=dx$ is the path of translation

of the wheel W and is parallel to XX. gh is drawn perpendicular to JK. $de=dx$ is the path of translation of the wheel W' and is parallel to XX. do is drawn perpendicular to XX and parallel to GH. LEM represents a portion of the contour of the diametral cross section of any wheel or circular article having its central axis coincident with XX and whose weight is to be determined. If the cross section of the article is referred to XX and YY as coordinate axes, AEcb may be considered as representing any elemental strip of the area lying between LEM and XX, having a length y_1 and an infinitely small width dx . If such strip be revolved about XX as an axis, it will generate a circular solid or disk having a diameter $EB=2y_1$ and a thickness dx . The weight of this disk will be indicated by the expression $\pi w y_1^2 dx$ in which w is the weight per unit of volume of the material composing the wheel. The tracing arm EC ($=R$) forms an angle a with the axis XX when its tracing point is at E and the axis DF of the roller W' forms an angle $2a$ with the line GH at the same time, due to the action of the gear wheels. Suppose the point E to move the width dx at the length y_1 and with it the rollers W and W' which are in contact with the tablet surface. The rollers will partly roll and partly slip during this movement due to their angular position with the direction of motion, and according to the principle of action of measuring wheels, we may write

$$\frac{\text{Turning of } W'}{\text{Motion of translation of } W'} = \frac{2\pi r n}{dx} = \frac{do}{eo}$$

where r is the radius of the roller W' and n the reading of the roller scale for the movement dx . Now

$$\frac{do}{eo} = \cos. 2a = 1 - 2 \sin.^2 a$$

$$\frac{\text{Turning of } W}{\text{Motion of translation of } W} = \frac{2\pi r' n'}{dx} = \frac{gh}{gm} = \sin. a'$$

in which r' is the radius of the roller W and n' is the reading of the roller scale for the movement dx . But

$$\frac{AE}{EC} = \frac{y_1}{R} = \sin. a'$$

and

$$\frac{2\pi r' n'}{dx} = \frac{y_1}{R}$$

whence

$$n' = \frac{1}{2\pi r' R} y_1 dx$$

By making

$$\frac{1}{2\pi r' R} = 2\pi w p$$

in which w is the weight per unit of volume

and

$$\frac{AE}{EC} = \frac{y_1}{R} = \sin. a$$

whence

$$\frac{2\pi r n}{dx} = 1 - 2 \sin.^2 a = 1 - \frac{2y_1^2}{R^2}$$

or

$$n = \frac{1}{2\pi r} dx = \frac{2}{2\pi r R^2} y_1^2 dx.$$

As the contour of the section of a wheel is always a closed figure, when the entire outline has been traced by the point E, the sum of a series of quantities similar to the

$$\frac{1}{2\pi r} dx$$

becomes zero, so that by making

$$\frac{1}{\pi r R^2} = \pi w$$

the reading of the roller gives the value of $\pi w \int y^2 dx$ or the weight of a wheel having the given cross section. The small gear wheel roller will of itself indicate the weight of any wheel whose cross section can be traced by the point, but in order to adapt the instrument for sections of large diameter, an additional measuring roller is necessary.

Let XX, Fig. 13, be any line parallel to the axis of the cross section of the wheel. Let LEM be considered as a portion of the contour of a figure of larger diameter than may be reached by the tracing arm R when the instrument is adjusted to the axis of the wheel (see Fig. 14). AEcb will represent any elemental strip of the portion of the figure inclosed between the contour and the parallel XX. Let y_{11} be the length of this strip and dx its width. The tracing arm EC forms an angle a' with the axis AC. The movement of the tracing point for a width dx will be

of the material and p the distance which the axis of the instrument AC (Fig. 13) has been moved from the axis of the wheel, we have

$$n' = 2\pi w p y_{11} dx.$$

As the part of the section under consideration is a closed figure having AC as a portion of its contour, when the point has traced the outline, the reading of the roller will give the value of

$$2\pi w p \int y dx.$$

Let LEMFCB, Fig. 14, represent one half of the cross section of a ring of greater diameter than the tracing arm is long, and whose weight is to be determined. XX is the central axis of this ring. Its section is

divided into two parts by the line X'X' drawn at a distance p from the axis XX which permits the contour of the part FCB to be traced by the point when the instrument is adjusted on the axis XX. From what has been explained above, the weight of this portion of the ring may be obtained from the reading of the small gear wheel roller, and the weight of the portion LEMFB remains to be determined. Let AECb be an elemental strip of the total area LEMFB, having a length y_{11} and an infinitely small width dx . Let o be the center of gravity of the area $y_{11}dx$ and D its distance from the axis XX of the wheel. The distance of the center of gravity from X'X' will be $\frac{y_{11}}{2}$. Draw a similar strip GH in the

same relative position to XX as AECb is to X'X' with its center of gravity o' at a distance e from the center of gravity of AECb. The weight of the flat ring formed by the revolution of the area AECb about XX as an axis will be

$$2\pi w D y_{11} dx,$$

w being the weight of a unit of volume of the material. As

$$D = \frac{y_{11}}{2} + e; \quad 2\pi w D y_{11} dx = \pi w y_{11}^2 dx + 2\pi w e y_{11} dx$$

and as $e = p$

$$2\pi w D y_{11} dx = \pi w y_{11}^2 dx.$$

The weight of the whole ring LEMFB will be indicated by the expression

$$\pi w f y^2 dx + 2\pi w p f y dx.$$

But

$$\pi w f y^2 dx \text{ and } 2\pi w p f y dx$$

are the values given by the small and large wheel rollers, respectively, when the instrument is adjusted to X'X' (Fig. 14) as an operating axis. Therefore the weight of the ring LEMFB will be the sum of the readings of the two rollers after tracing the section. The weight of the entire ring LEMFCB will be the sum of the weights of its two parts FCB and LEMFB.

It should be noted that the motion of the tracing point at any instant may be resolved into two components in the direction of XX

and YY (Fig. 13) respectively, but the component in the direction of XX only, controls the final reading of the rollers. The turning of the rollers due to the departure of the tracing point from the place of starting, in the direction of YY is, for any closed figure, exactly neutralized by its return, hence this movement leaves no final record on the scales and need not be considered.

By drawing the parallels upon which the instrument is adjusted at intervals of $2p$, $3p$, $4p$, &c., from the axis XX of the section, the expression

$$2\pi w p f y dx$$

becomes

$$2\pi w (2p) f y dx, 2\pi w (3p) f y dx, 2\pi w (4p) f y dx, \&c.$$

hence the large gear wheel roller will give values for all of them if its reading be multiplied by the factor 2, 3 or 4, according to the parallel upon which the instrument is adjusted.

From what has been explained above, it should be apparent that the diametral range of this instrument is practically unlimited and that the weights of locomotive tires and other larger circular articles can be easily computed.

From the equations

$$\frac{1}{\pi r R^2} = \pi w \text{ and } \frac{1}{2\pi r' R} = 2\pi w p$$

and by bearing in mind that the formulas assume one revolution of the roller to indicate 1 on the scale, suitable values of r , r' and R may be obtained which will permit the construction of an instrument. By rearrangement, the equation

$$\frac{1}{\pi r R^2} = \pi w$$

becomes

$$R = \sqrt{\frac{1}{\pi^2 w r}}$$

or as expressed in the claims

$$r R^2 = \frac{1}{\pi^2 w}$$

That is in general, for all instruments of this kind

$$\text{Length of tracing arm} = \sqrt{\frac{\text{Number of units of weight indicated by one revolution of the measuring wheel}}{\pi^2 \times \frac{\text{Number of units of weight per unit of volume of the material}}{\text{Radius of the measuring wheel}}}}$$

In like manner for the large wheel, the theory requires that the relation

$$\frac{1}{2\pi r' R} = 2\pi w p$$

be maintained in the construction of the

instrument, in order that the measuring roller may give a final reading

$$2\pi w p f y dx$$

which is the increase of the weight of any given section as a result of shifting the axis. The axis of the measuring wheel and

the tracing arm are assumed, of course, to remain parallel. By rearrangement, the equation

$$\frac{1}{2\pi r' R} = 2\pi w p$$

$$r' = \frac{1}{4\pi^2 R w p}$$

That is in general for all instruments,

10

$$\text{Radius of the measuring wheel} = \frac{\text{Number of units of weight indicated by one revolution of the measuring wheel}}{4\pi^2 \times \text{Radius of the tracing arm} \times \text{of weight per unit of volume of the material} \times \text{Distance shifted by the axis of the instrument.}}$$

For practical reasons, it is desirable to make the radii r and r' of the measuring wheels approximately four tenths of an inch and the scales to read 1000 for one revolution of the wheel, with the use of the vernier. The value for p is made 10 inches so that the parallels for the adjustment of the instrument on any cross section are drawn at intervals of 10, 20, 30, 40, &c., inches from its central axis. In order that the tracing arm R for these wheels may be of short and convenient length, it is nearly always necessary to multiply the final readings of the scales by a decimal factor, such as 0.5, 0.10 or 0.15. In the case of the large gear wheel roller this factor is combined with its transfer factor for the various parallels and in the practical use of the instrument, the scale readings for any setting are multiplied by but one simple decimal number.

The operation of my improved apparatus, in obtaining the weight of a wheel or other article, is as follows:—The supporting plate 32 shown in Fig. 10 is placed so that the beveled straight edge 33 co-incides approximately with the axial center line X, X , on a drawing of the wheel section A in a position which will permit the tracing point 8 to follow the axial center line X, X , of the figure to be traced, as is illustrated in Fig. 9. The instrument is then placed upon the tablet or plate 32 with the guide wheels 14 in the V-shaped groove 34 on the tablet, the rollers 15 and 25 being supported upon the surface of the tablet or running surface 35. The tracing point 8 of the instrument having been adjusted on the arm 6 to the position required by the material of the wheel is then placed at any point selected on the lines outlining the contour of that partial section A of the wheel included between the parallel lines X, X , and X', X' . The tracing point is then moved around the section in a clock-wise direction until the point of starting is again reached. The difference in the readings of the decimal scales of the measuring wheel 25 connected with the small gear wheel 3 taken at the beginning and end of the tracing operation will then indicate the weight of that portion of the wheel formed by a solid of revolution of the section which has just been traced by the point

8. The more closely the tracing point is caused to follow the lines on the outline of the section A the more accurately the resulting weight will be indicated. Preferably the measuring wheels are turned to register zero before starting to move the tracing point to indicate weight. The supporting plate or tablet 32 is then moved so as to make its straight edge 33 co-incide approximately with the line X', X' , (which is drawn parallel to the axis X, X) and to a position upon it which will permit the point 8 to follow the line X', X' , as shown by a broken line on Fig. 9. The contour of the partial section B is then traced by the point 8. Readings of the decimal scales on the measuring wheels connected with the large and small gear wheels 15 and 25, respectively, will be taken both before and after the operation of tracing the contour of the section B and the difference in the readings of the measuring wheel scales at the beginning and end of this tracing operation will indicate the weight of the portion of the solid of revolution about X, X , formed by the section B of the wheel just traced. The sum of the values obtained from the readings of the scales of the two measuring wheels will indicate the weight of the portion B of the wheel formed by the revolution of its section about the axis X, X , and the weight of the entire wheel section will be equal to the sum of the weights of these partial sections, A and B. In a similar manner the tablet is transferred to bring the straight edge 33 parallel to and substantially coincident with the line X'', X'' , as indicated by broken lines on Fig. 9, and the half section C of the tire is traced by the point 8 in a similar manner to that before described for the sections A and B of the wheel. In this position of the instrument, the weight of a tire or other body of annular cross section formed by the revolution of such half section about the central axis X, X , will be equal to the value obtained from the scales of the small gear wheel measuring wheel, plus that obtained from the scales on the measuring wheel operatively connected to the larger gear wheel.

The instrument may be transferred to any one of a series of lines equi-distant from

each other and parallel to the central axis X, X, provided the value obtained from the scales on the large gear wheel measuring roller is multiplied by the number of the transfer line upon which the instrument is placed. For example, if placed on the second line, multiply by 2; if on the third line, multiply by three, and so on. The weight of the partial sections included between the parallels will in each case be the sum of the value obtained from the scale readings upon the small gear wheel measuring roller, plus that obtained from the scales of the larger gear wheel measuring roller when multiplied by its transfer factor 2, 3, or 4, &c. By this means the weight of locomotive tires of irregular contour and of the largest diameter, and similar annular bodies, may be easily and quickly computed from a drawing of their half cross section upon a small sheet of paper. The distance between the transfer lines is fixed for each instrument, usually being made some whole number of units distance which is slightly less than the extreme angular range of the tracing point.

In order to compute the weight of solids composed of different materials, the tracing point is adjusted horizontally to different distances from the center of the large gear wheel which distances will be marked upon the tracing arm for the different materials. Experience has shown that rolling and sliding measuring wheels of a certain diameter give readings more nearly equal to the mathematical values which they are designed to indicate than wheels of smaller or of larger diameter, and in order to limit this diameter and at the same time preserve the mathematical relation of the movement of their circumferences, it is always expedient to multiply the readings of the scales by a simple decimal number such as 0.5, or 0.10 or 0.15. This in no wise affects the purpose or arrangement of the apparatus forming this invention. The scales are usually divided into 100 parts circumferentially and are supplied with a vernier reading to tenths of these parts. A dial divided into 10 or 20 parts enables readings to be made ranging from 1 to 10,000, or 1 to 20,000. Any other suitable division may be made if required.

The adaptation of the fundamental principle of operation of measuring or integrating wheels for obtaining the weight of circular articles from the contour of their cross section is new. The combination of two measuring wheels to obtain by the sum of their readings directly the weight of fractional parts of the section, has never before been applied or suggested in any other measuring device. Simplifying the operation of computing the weight of large sections by dividing them into parts by means of a system of equi-distant adjustment lines mutually parallel to the central axis of a

wheel, is original with the applicant, and supplies a demand for an instrument of small size with large diametral range. The use of the supporting plate to include the track for the guide carriage, the tablet surface of the extreme range of movement for the measuring wheels, and the straight edge for rapid and easy adjustment to the axis of operation, make the instrument practical and capable of performing the results intended.

Modifications in the construction and arrangement of the parts may be made without departing from my invention as defined in the claims.

I claim:—

1. A calculating instrument for determining the weight of solids of revolution comprising a measuring wheel, a tracing arm connected to and arranged to govern the movement of said measuring wheel and having a tracing point thereon, said measuring wheel having twice the angular movement of the tracing arm, and said tracing point being positioned on the arm to have a radius of angular movement relative to the diameter of the measuring wheel whereby the square of the radius of movement of the tracing point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-squared multiplied by the weight per unit of volume.

2. A calculating instrument for determining the weight of solids of revolution comprising a measuring wheel, a tracing arm connected to and arranged to govern the movement of said measuring wheel and having a tracing point thereon, said measuring wheel having twice the angular movement of the tracing arm, and said tracing point being positioned on the arm to have a radius of angular movement relative to the diameter of the measuring wheel whereby the square of the radius of movement of the tracing point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-squared multiplied by the weight per unit of volume, said tracing point being adjustable on the arm to vary the radius of movement of the tracing point.

3. A calculating instrument for determining the weight of solids of revolution comprising a measuring wheel, a tracing arm connected to and arranged to govern the movement of said measuring wheel and having a tracing point thereon, said measuring wheel having twice the angular movement of the tracing arm, said tracing point being positioned on the arm to have a radius of angular movement relative to the diameter of the measuring wheel whereby the square of the radius of movement of the tracing point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-squared multiplied by the

weight per unit of volume, and a second measuring wheel governed by the movement of said tracing arm, said second wheel having one-half the angular movement of the first measuring wheel.

4. A calculating instrument for determining the weight of solids of revolution comprising a measuring wheel, a tracing arm connected to and arranged to govern the movement of said measuring wheel and having a tracing point thereon, said measuring wheel having twice the angular movement of the tracing arm, said tracing point being positioned on the arm to have a radius of angular movement relative to the diameter of the measuring wheel whereby the square of the radius of movement of the tracing point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-squared multiplied by the weight per unit of volume, and a second measuring wheel governed by the movement of said tracing arm, said second wheel having one-half the angular movement of the first measuring wheel, said tracing point being adjustable on the arm to vary the radius of movement of the tracing point.

5. A calculating instrument for determining the weight of solids of revolution comprising a measuring wheel, a tracing arm having a tracing point, and means actuated by movement of the tracing arm to govern the movement of the measuring wheel, the tracing point being positioned on the arm to have a radius of angular movement relative to the diameter of the measuring wheel whereby the square of the radius of movement of the tracing point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-squared multiplied by the weight per unit of volume.

6. A calculating instrument for determining the weight of solids of revolution comprising a rotary measuring wheel, a tracing arm having a tracing point, and means actuated by movement of the tracing arm to govern the movement of the measuring wheel, the tracing point being positioned on said arm to have a radius of angular movement relative to the diameter of the measuring wheel whereby the square of the radius of movement of the tracing point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-squared multiplied by the weight per unit of volume, said tracing point being adjustable on the arm to vary the radius of movement of the point.

7. A calculating instrument for determining the weight of solids of revolution comprising a measuring wheel, a tracing arm having a tracing point, and means actuated by movement of the tracing arm to govern the movement of the measuring wheel, the tracing point being positioned on

the arm to have a radius of angular movement relative to the diameter of the measuring wheel whereby the square of the radius of movement of the tracing point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-squared multiplied by the weight per unit of volume, and a second measuring wheel operatively connected to and having one-half the angular movement of said first wheel.

8. A calculating instrument for determining the weight of solids of revolution comprising a measuring wheel, a tracing arm having a tracing point, and means actuated by movement of the tracing arm to govern the movement of the measuring wheel, said arm having the tracing point positioned thereon to give a radius of angular movement of the tracing point relative to the diameter of the measuring wheel whereby the square of the radius of movement of the measuring point multiplied by the radius of the measuring wheel equals the reciprocal of the product of pi-square times the weight per unit of volume, said tracing point being adjustable on the tracing arm to vary the radius of movement of the point for different materials, and a second measuring wheel operatively connected to and having one-half the angular movement of said first wheel.

9. A calculating instrument for indicating the weight of a solid of revolution from a diagram showing the diametral cross sectional contour of the solid of revolution, comprising a pair of measuring wheels graduated to indicate weight, one wheel having twice the angular movement of the other, a tracing point to encircle the diagram and means actuated by the movement of the tracing point and actuating the measuring wheels to govern the movement of the wheels in indicating the weight of the solid of revolution encircled by the tracing point.

10. A calculating instrument having a tracing point thereon, adapted to compass the contour of the diametral cross section of circular bodies of uniform cross section, a swinging arm to which said tracing point is secured, a rolling and sliding measuring wheel having a horizontal axis pivotally connected to the tracing arm, means for giving the axis of the measuring wheel twice the horizontal angular motion of the tracing point, said measuring wheel being adapted to indicate the weight of circular articles of uniform cross section whose diametral cross section is compassed by the tracing point.

11. Apparatus for computing from a drawing of the articles, the weight of circular articles having a uniform cross section, comprising a rolling and sliding measuring wheel having a horizontal axis, a gear

wheel in which said measuring wheel is mounted having an angular motion and a tracing arm operatively geared to said measuring wheel having an adjustable tracing point thereon adapted to follow the contour of the diametral cross section of said articles, the tracing point having one-half the horizontal angular motion of the axis of the measuring wheel.

- 10 12. In an instrument for computing the weight of circular articles having a uniform cross section from a drawing of the article, a carriage having wheels thereon, a track on which the carriage wheels are mounted, a radially movable tracing arm on the carriage having a longitudinally adjustable tracing point, a gear wheel operatively connected to said carriage having an angular motion relative thereto, a rolling and sliding measuring wheel mounted on said gear wheel having its horizontal axis parallel to a vertical plane passing through the longitudinal center of the radial arm and tracing point, a second gear wheel mounted on said carriage and meshing with said first gear wheel, a rolling and sliding measuring wheel mounted in the second gear wheel, said second gear wheel having twice the angular motion of the first gear wheel, the measuring wheels being adapted to indicate the weight of a circular article whose diametral cross section is encircled by the tracing point.

13. Apparatus for determining from a drawing the weight of circular bodies having a uniform cross section, comprising a carriage having track wheels, a gear wheel mounted on said carriage, a second gear wheel meshing with the first gear wheel on said carriage, said second gear wheel having twice the angular motion of the first gear wheel, a rolling and sliding measuring wheel mounted in each gear wheel having its axis horizontal, the horizontal angular movement of the axis of one measuring wheel being twice that of the axis of the other, a tracing arm pivotally secured to said carriage and controlling the movement of said gear wheels, a tracing point adjustably mounted on said arm adapted to compass the contour of a diametral cross section of circular bodies, a straight track on which the track wheels are mounted, said track having a parallel side adapted to be placed coincident with or parallel to the central axis of the contour of the cross section of the circular article being weighed, said parallel side being located to cause its prolongation to intersect the prolongation of the vertical axis of rotation of the radial arm.

In testimony whereof, I have hereunto set my hand.

WILLIAM S. BUVINGER.

Witnesses:

GEO. B. BLEMING,
R. M. SMELTZ.