PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

Improvements in or relating to Slide Rules

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, and BEN SECKER, a British Subject, both of Connaught House, 63, Aldwych, London, W.C.2, England, do hereby declare the nature of this invention to be as follows:—

This invention relates to slide rules for calculating purposes and has for its object to provide a slide rule to facilitate the calculation of electrical impedances from the results of measurements.

Electrical impedances are usually measured by comparing them with a resistance r and shunt capacity c: The impedance is denoted by $Z\underline{/\phi}$ and this is equivalent to $R+jX$, and these quantities are connected by the following equations:—

$$\tan\phi = \omega r c \qquad (1)$$

where $\frac{\omega}{2\pi}$ is the frequency at which the measurement is made

$$Z = r\cos\phi \qquad (2)$$

$$R = Z\cos\phi \qquad (3)$$

$$X = R\tan\phi \qquad (4)$$

The calculation of the quantities Z, R and X by means of known forms of slide rule is somewhat laborious.

The present invention, however, enables electrical impedance to be calculated with considerable ease and rapidity by means of two slide rules which are preferably arranged in a single instrument and preferably constructed as circular discs. The invention will be better understood from the following description of one embodiment thereof taken in conjunction with the accompanying drawings in which Figs. 1 and 2 show the relation between the different scales, Fig. 1 showing how the scales may be used to obtain the quantity $Z\underline{/\phi}$ and Fig. 2 how the scales may be used to obtain the terms of the expression $R+jX$.

A scale E is engraved around the periphery of a circular disc 3 mounted on a base plate for rotation about its centre. This scale E is a logarithmic scale of cosines, the angles of which the cosines are indicated increasing in a clockwise direction from 0°. Mounted below and concentrically with the disc 3 is a second circular disc independently rotatable and having an annular portion 2 raised so as to be in the same plane as disc 3. Around the inner periphery of the annular portion 2 is engraved a scale D which is a logarithmic scale of tangents of angles between 0° 34′ and 84° 18′ increasing in a clockwise direction. Around the outer periphery of the annular portion 2 is engraved a logarithmic scale C of capacities in microfarads reading from log 0.001 to log 1.0 clockwise, log 0.001 corresponding to 0° 34′ on scale D and log 0.1 corresponding to 45° on scale D.

A stationary annular portion 1 is provided surrounding the annular portion 2 and is engraved with a scale B immediately surrounding scale C on portion 2 and with a scale A on its outer periphery. Scale B is a logarithmic scale reading clockwise from 0.159 to 159. Scale A is a logarithmic scale of numbers reading anti-clockwise from 10 to log 10000, and thus 0.159 on scale B corresponds to 10000 on scale A and 159 on scale B corresponds to 10 on scale A.

Equation (1) above may be rewritten in the following terms:—

$$\frac{r}{1/c} = \frac{1/\omega}{\tan(90° - \phi)} \qquad (5)$$

This written logarithmically becomes

$$\log r - \log\frac{1}{\omega} = \log\frac{1}{c} - \log\tan(90° - \phi) \qquad (6)$$

It will be seen that this can be calculated on a slide rule by adjusting r on a direct logarithmic scale to coincide with c on an inverse logarithmic scale, whereupon ω on an inverse logarithmic scale will coincide with $90° - \phi$ on a moving logarithmic tangent scale.

Thus to find the angle ϕ in this equation with the apparatus shown in Fig. 1, the disc 3 is rotated until the reading 4 on scale E corresponding to 0°, is in line with the reading 5 on scale A corresponding to the measured resistance, and the annulus 2 is rotated until the reading 6 on scale C corresponding to the measured capacity, are in line. Then the angle is indicated by the reading 8 on the logarithmic tangent scale D which is opposite the reading 7 on scale B corresponding to the frequency used.

In order to find the impedance Z equa-

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tion (2) is written logarithmically and becomes

$$\log Z = \log r + \log \sin (90° - \phi) \qquad (7)$$

Thus Z may be read on a logarithmic scale as a simple sum. The reading 9 on scale E corresponding to the cosine of ϕ determined by the reading 8 on scale D is now therefore opposite the reading 10 on scale A corresponding to the required impedance Z.

In order to determine the quantities R and X the following logarithmic forms of equations (3) and (4) are used

$$\log R = \log Z + \log \sin (90° - \phi) \qquad (8)$$

$$\log X = \log R + \log \tan \phi$$
$$= \log R - \log \tan (90° - \phi) \qquad (9)$$

Thus, referring now to Fig. 2, the point 4 of scale E corresponding to 0° is rotated until it is opposite to the reading 10 on scale A corresponding to the impedance Z found previously. The reading 11 on scale A opposite to reading 9 on scale E representing the angle ϕ previously found gives the required value of R, in accordance with equation (8) above.

The annulus 2 is rotated until the reading 8 on scale D is opposite reading 9 on scale E. The reading 13 on scale A opposite the reading 12 on scale D corresponding to 45° gives the value of X.

Dated this 12th day of September, 1939.

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COMPLETE SPECIFICATION

Improvements in or relating to Slide Rules

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, and BEN SECKER, a British Subject, both of Connaught House, 63, Aldwych, London, W.C.2, England, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to slide rules and has for its object to provide slide rules for performing calculations involving vector quantities e.g. complex electrical impedances.

It is well known that vectors may be expressed either in polar co-ordinates as $p\,/\underline{\theta}$ wherein p is the numerical length of the vector and θ is the angle it makes with the zero axis, or in rectangular co-ordinates as $x + jy$ wherein x is the component in the horizontal direction and y is the component in the vertical direction.

The second vector may be transformed into the first kind by means of the equations

$$\tan \theta = \frac{y}{x}$$

$$p^2 = x^2 + y^2$$

whilst the first kind of vector may be transformed into the second kind by means of the equations

$$x = p \cos \theta$$

$$y = p \sin \theta$$

Calculations involving functions of the angle θ as in the case of the above equations are somewhat laborious when employing known forms of slide rule.

As an example of such measurements reference may be made to the practical problem of determining electrical impedances as vector quantities from the result of electrical measurements made upon the impedance in question. These electrical measurements are normally made by balancing the impedance under measurement against variable resistances and capacities so as to obtain the equivalent resistance r and capacity c which when connected in parallel have the same impedance as the impedance under test at the frequency f (which is commonly expressed as $\frac{\omega}{2\pi}$) at which the measurement is made. In this parallel circuit of r and c the current in the circuit will lead the voltage across the circuit by a phase angle ϕ such that

$$\tan \phi = \omega\, c\, r \qquad (1)$$

so that as both c and r are known, ϕ may also be found. In this parallel circuit the reciprocal of the impedance is equal to the reciprocal of the reactance of the capacity branch plus the reciprocal of the resistance of the resistance branch, so that from the corresponding vector triangle the impedance Z may be found from the equation.

$$Z = r \cos \phi \qquad (2)$$

By equations (1) and (2) therefore the impedance vector in polar co-ordinates as $Z\,/\underline{\phi}$ may be found from the values c and r.

In certain cases it is desired to express the impedance vector in rectangular co-ordinates as $R + jX$. For this purpose the value of R may be found by utilising the values of ϕ and Z obtained from equations (1) and (2) and substituting them in the following equation

$$R = Z \cos \phi \qquad (3)$$

and the value of X is then obtained from the following equation

$$X = R \tan \phi \qquad (4)$$

The calculations of ϕ, Z, R and X from these equations by means of known forms of slide rule is somewhat laborious, and an object of the present invention is to provide a slide rule for enabling these calculations to be carried out with greater facility.

An embodiment of the invention will now be described by way of example reference being made to the accompanying drawing which shows the scales of a slide rule according to the invention provided with one fixed and two rotatable circular graduated discs for performing calculations relating to vector quantities, more especially complex electrical impedances. In order to explain certain of the uses of the slide rule, reference will also be made to the drawing left with the Provisional Specification comprising Figs. 1 and 2.

Fig. 1 shows how the scales may be used to obtain the vector quantities Z and ϕ from the measured values of r and c.

Fig. 2 shows how the scales may be used to obtain the vector quantities R and X from the quantities Z and ϕ obtained according to Fig. 1. The slide rule of the drawings has an inner circular disc 3 mounted on a base plate for rotation about its centre. Mounted below and concentrically with the disc 3 is a second circular disc which is independently rotatable and has an annular portion 2 raised so as to be in the same plane as the disc 3. The annulus 2 is surrounded by an outer stationary annulus 1 secured to the base plate. A suitable rotatable cursor (not shown) is also provided for setting selected graduations on the different scales in alignment with one another in known manner.

The slide rule is engraved with five circular logarithmic scales A, B, C, D and E. Scales A and B are engraved on the outer annulus 1, scales C and D are engraved on the intermediate annulus 2 whilst scale E is engraved on the inner disc 3.

Scale A is designated " Ohms " and is graduated anti-clockwise from 10 ohms to 10000 ohms, according to a logarithmic scale.

Scale B is designated " Frequency " and is graduated clockwise from 0.150 kilocycles to 150 kilocycles according to a logarithmic scale.

Scale C is designated " Microfarads " and is graduated clockwise from 0.001 to 1.0 microfarads according to a logarithmic scale.

Scale D is designated " Degrees " and is graduated clockwise from 0.6° to 84° according to a logarithmic tangent scale.

Scale E is a logarithmic cosine scale graduated clockwise from 0° to 84°.

The two scales A to B on the annulus 1 are so arranged with respect to one another that the graduation 1.0 on scale B is opposite the graduation 1000 on scale A, and that the graduation 100 on scale A is opposite the graduation 10 on scale B.

The two scales C and D on the disc 2 are so arranged with respect to one another that the graduation 45° on scale D is opposite the graduation 0.159 on scale C.

A description will now be given of a few of the calculations which may be performed by the use of the slide rule.

(1) To obtain $Z\angle\phi$ from r, c.

Equation (1) above may be rewritten in the following form:—

$$\frac{r}{1/c} = \frac{1/\omega}{\tan(90^\circ - \phi)} \qquad (5)$$

This written logarithmically becomes

$$\log r - \log\frac{1}{\omega} = \log\frac{1}{c} - \log\tan(90^\circ - \phi) \qquad (6)$$

It will be seen that this can be calculated on a slide rule by adjusting r on a direct logarithmic scale to coincide with c on an inverse logarithmic scale, whereupon ω on an inverse logarithmic scale will coincide with $90^\circ - \phi$ on a moving logarithmic tangent scale.

Thus to find the angle ϕ in this equation with the scales shown in Fig. 1, the disc 3 is rotated until the reading 4 on scale E corresponding to 0° is in line with the reading 5 on scale A corresponding to the measured resistance, and the annulus 2 is rotated until the reading 6 on scale C corresponding to the measured capacity, are in line. Then the angle is indicated by the reading 8 on the logarithmic tangent scale D which is opposite the reading 7 on scale B corresponding to the frequency used.

(2) To obtain $R + jX$ from $Z\angle\phi$.

In order to find the impedance Z, equation (2) is written logarithmically and becomes

$$\log Z = \log r + \log \sin(90^\circ - \phi) \qquad (7)$$

Thus Z may be read on a logarithmic scale as a simple sum. The reading 9 on scale E corresponding to the cosine of ϕ determined by the reading 8 on scale D is now therefore opposite the reading 10 on scale A corresponding to the required impedance Z.

In order to determine the quantities R and X the following logarithmic forms of equations (3) and (4) are used

$$\log R = \log Z + \log \sin(90^\circ - \phi) \qquad (8)$$

$$\log X = \log R + \log \tan \phi = \log R - \log \tan(90^\circ - \phi) \qquad (9)$$

Thus, referring now to Fig. 2, the point

4 of scale E corresponding to 0° is rotated until it is opposite to the reading 10 on scale A corresponding to the impedance Z found previously. The reading 11 on scale A opposite to reading 9 on scale E representing the angle ϕ previously found gives the required value of R, in accordance with equation (8) above.

The annulus 2 is rotated until the reading 8 on scale D is opposite reading 9 on scale E. The reading 13 on scale A opposite the reading 12 on scale D corresponding to 45° gives the value of X.

(3) To obtain the reactance of a capacity at a specified frequency.

Bring 45° on scale D opposite the frequency on scale B. The desired reactance value is then read off on scale A opposite the value of the capacity on scale C.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A slide rule comprising three graduated members movable relatively to one another for performing calculations relating to vector quantities in which one member is graduated in accordance with a logarithmic scale, the second member is graduated in accordance with a logarithmic tangent scale, and the third member is graduated in accordance with a logarithmic cosine scale.

2. A slide rule comprising three graduated members movable relatively to one another for performing calculations relating to complex electrical impedances in which one member is provided with a logarithmic resistance scale, the second member is provided with a logarithmic degree scale, and the third member is provided with a logarithmic degree scale.

3. A slide rule as claimed in claim 1 in which the first member is also graduated in accordance with a second logarithmic scale, and the second member is also graduated in accordance with a logarithmic scale.

4. A slide rule as claimed in claim 2, in which the first member is also provided with a logarithmic frequency scale and the second member is also provided with a logarithmic capacity scale.

5. A slide rule as claimed in claim 1, 2, 3 or 4, in which said members are arranged concentrically for rotation with respect to one another.

6. A slide rule substantially as described herein with reference to the accompanying drawing.

Dated this 9th day of July, 1940.

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[This Drawing is a reproduction of the Original on a reduced scale.]

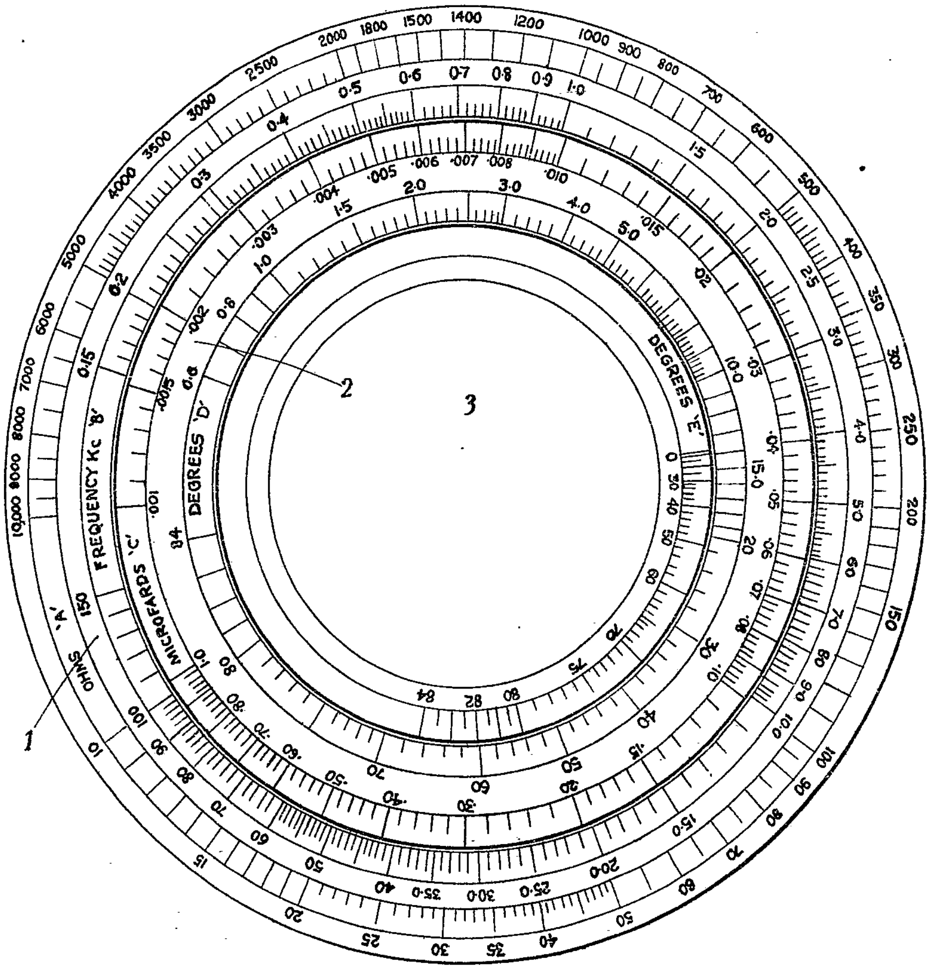

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Fig. 1.

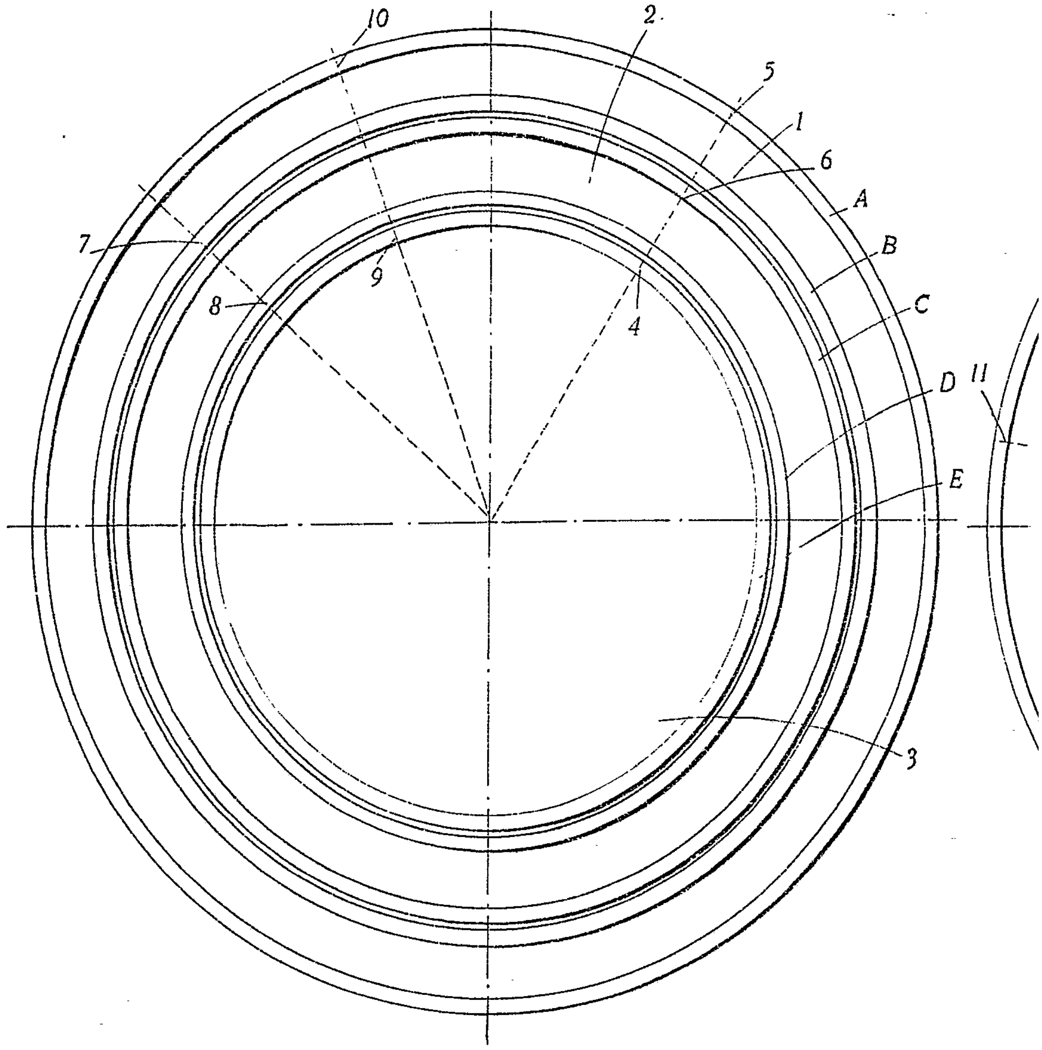


Fig. 2

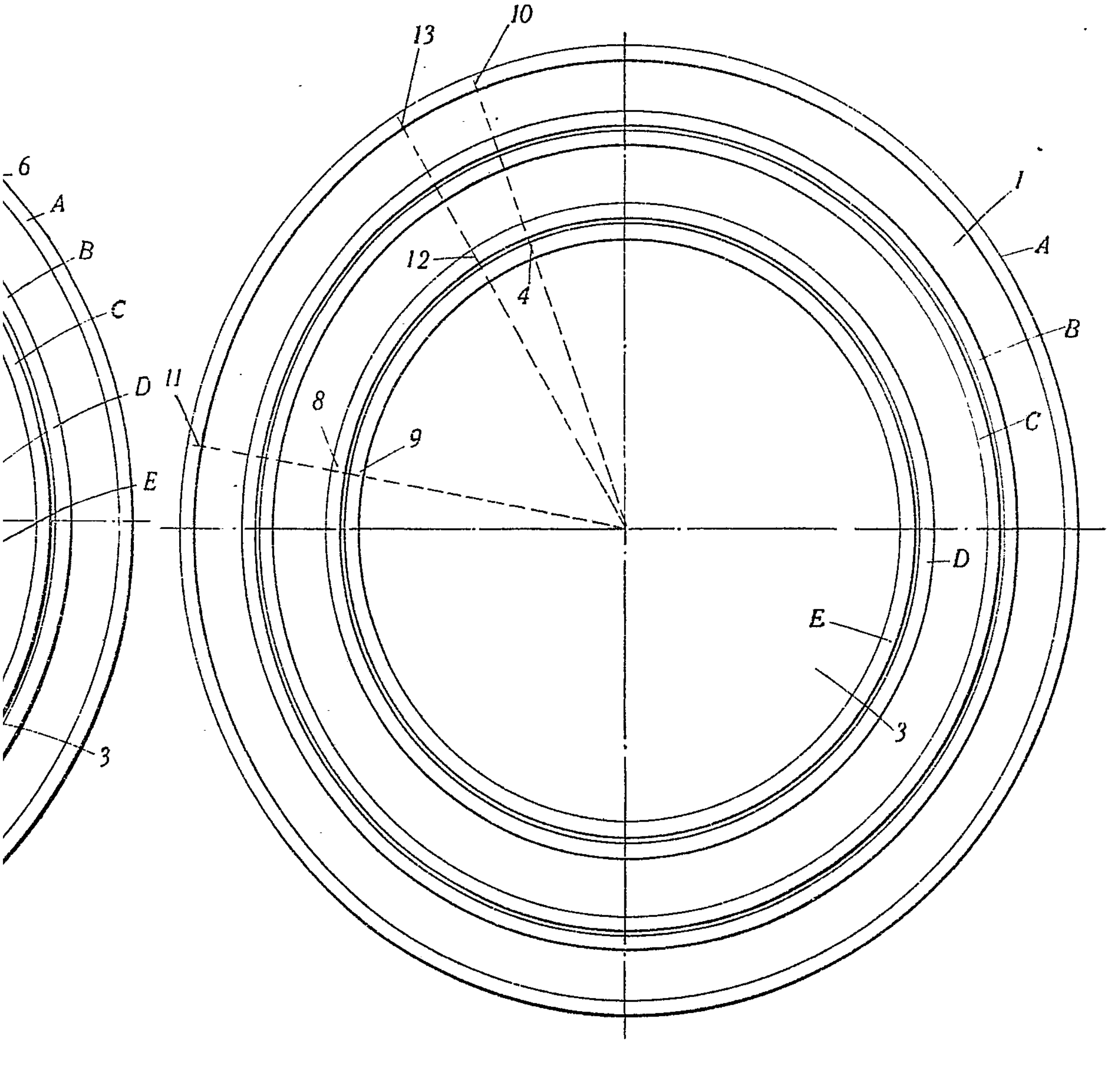


Fig. 1.

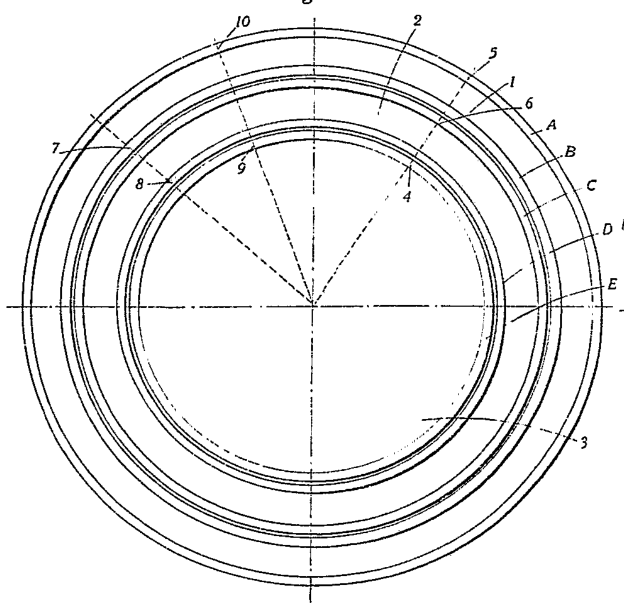
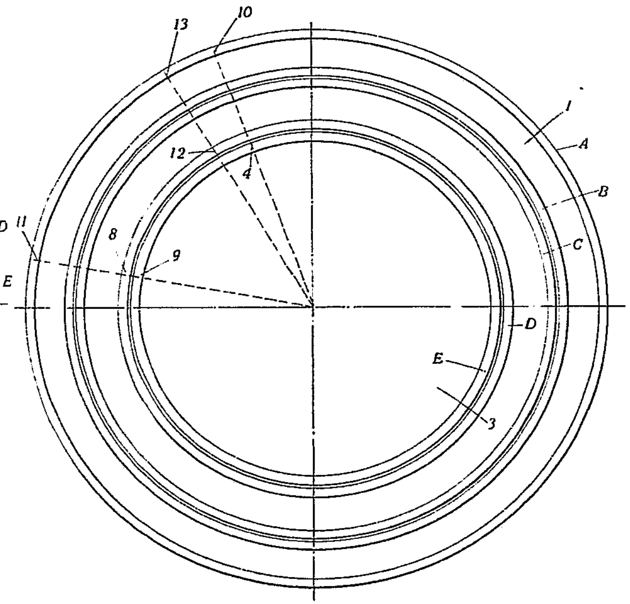


Fig. 2



[This Drawing is a reproduction of the Original on a reduced scale.]

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