July 10, 1945.

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2,379,931

VOLTAGE DROP CALCULATOR

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Fig. 1.

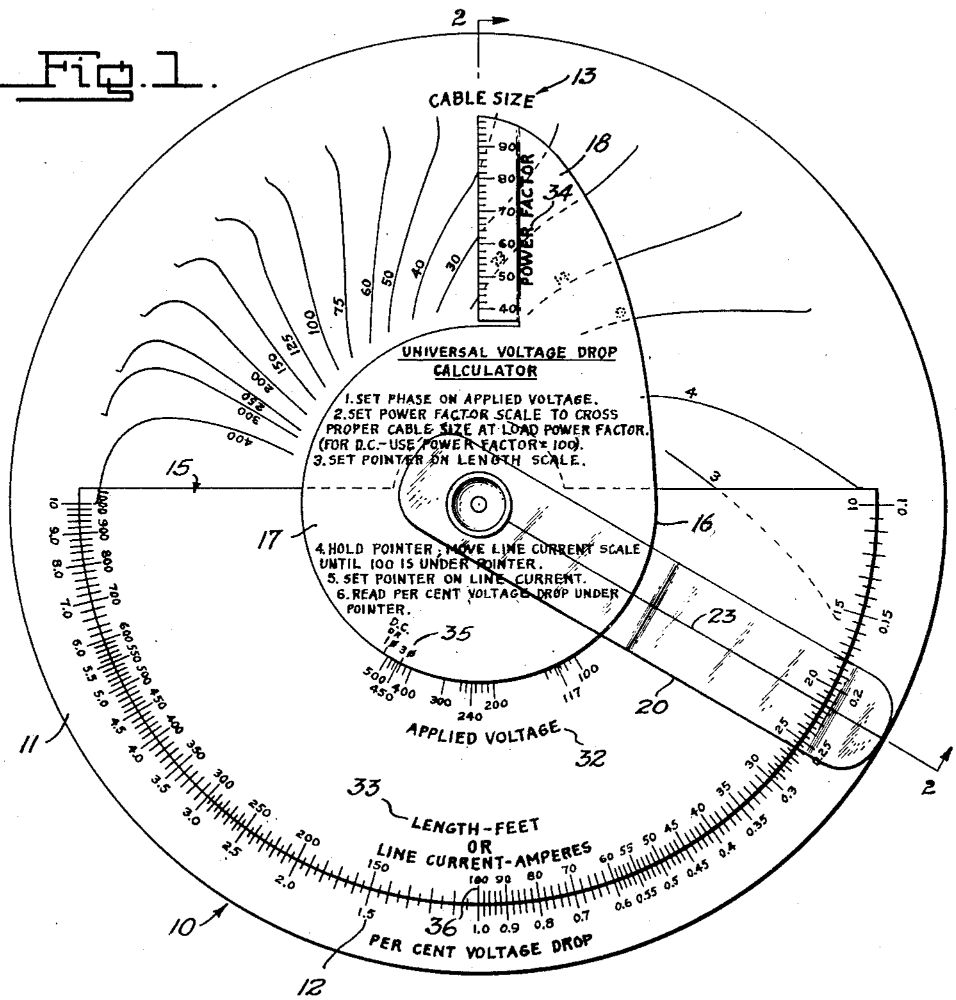


Fig. 2.

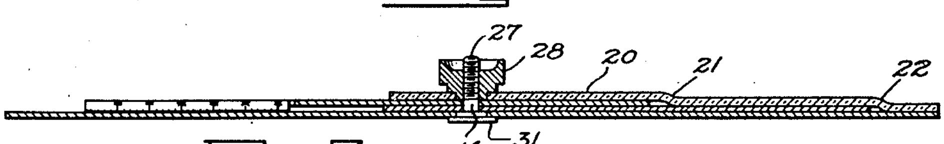
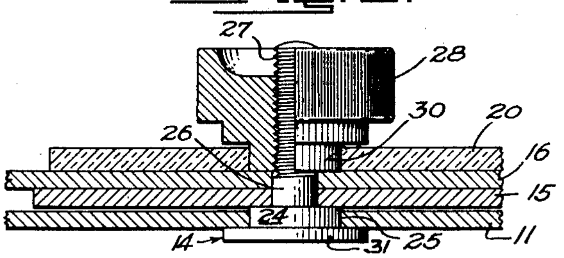


Fig. 3.



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VOLTAGE DROP CALCULATOR

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5 Claims. (Cl. 235—84)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to a voltage drop calculator and has for an object to provide an improved voltage drop calculator which is compact in size and form and is extremely accurate as compared to prior calculators.

A further object of this invention is to provide a voltage drop calculator which includes all the various factors necessary for accurate calculations of a voltage drop, including the applied voltage, the power factor, the cable size, the line current, the cable length, and finally the desired result of the percent of voltage drop.

A further object of this invention is to provide a voltage drop calculator which eliminates the use of charts or slide rules and the manipulation of a straight edge with such charts and which enables the final result to be calculated directly from the various factors on this one device.

With the foregoing and other objects in view, one form of the invention consists in the construction, combination and arrangement of the parts hereinafter described and illustrated in the drawing, in which:

Fig. 1 is a plan view of the voltage drop calculator of this invention,

Fig. 2 is a sectional view on line 2—2 of Fig. 1, and

Fig. 3 is an enlarged sectional detail view through the center of the device.

There is shown at **10** the voltage drop calculator of this invention. This includes a circular base disc **11** on which is printed or engraved the percent voltage drop **12** along about one-half of its periphery, while the other half of this base disc **11** is provided with cable size curves shown at **13**. Rotatable over the center of the base disc **11** on a stepped pivot bolt **14** is a semi-circular length-or-line current disc **15** of somewhat smaller diameter than the base disc **11**. Next above the semi-circular disc **15** is pivoted a power factor disc **16** which includes a circular portion **17** of substantially smaller diameter than the disc **15**. A power factor pointer **18** extends from disc **15** to a distance slightly less than the outer periphery of the length-or-line current disc **15**. Above this is pivoted a transparent pointer **20** which, it will be observed from Fig. 2, is offset at **21** and **22** to lie snugly against the discs **15** and **11**. The pointer **20** is of a transparent material and is provided with a pointer hair line **23** extending radially from the center of the pivot to the edge of the base disc **11** so as to enable the various factors to be aligned in the calculation. The discs **11**, **15** and **17** are of any suitable material, such as metal, plastic, cardboard, etc.

The stepped pivot bolt **14** is provided with a circular boss **24** of a slightly greater thickness than the thickness of the base disc **11**, while the disc **11** is provided with a pivot opening **25** of a diameter corresponding to the diameter of the boss **24**, permitting it to revolve freely thereon. The bolt **14** is provided with a center shank **26** connecting it to the threaded portion **27** for reception of a stepped knurled nut **28**. The discs **15** and **16** have pivot openings corresponding to the diameter of the shank **26**, while the pointer **20** has a pivot opening corresponding to the diameter of a stepped boss **30** on nut **28**, the boss **30** being of greater length than the thickness of the pointer **20**. A head **31** on bolt **14** provides a support for the bottom of the base disc **11**. As a result of this construction, particularly shown in Fig. 3, it will be observed that the discs **15** and **16** may be locked to each other by tightening the nut **28** for rotation as a unit, while leaving the base disc **11** and pointer **20** free to rotate independently of the locked discs **15** and **16**.

The formula which is used for calculating voltage drops is:

$$\text{Percent voltage drop} = \frac{CI(FL)}{AV} \times \text{D. F.} \times 100\%$$

where:

C=resistivity of copper=10.8 ohms per circular mil area, one foot in length.

I=balanced current in each conductor, in amperes.

F=factor depending upon type of current and number of phases; F=2 for direct current or single phase alternating current; F=1.732 for three phase alternating current.

L=length, in feet of one conductor.

A=area of each conductor, in circular mils.

V=impressed voltage, line to line.

D. F.=ratio of voltage drop in the cable (input voltage minus output voltage) to the resistive voltage drop. This factor depends on conductor size, stranding and spacing, type of surrounding medium (i. e., magnetic or non-magnetic), and load power factor.

In designing the voltage drop calculator **10**, values of percent voltage drop **12** were calculated by the above formula and imposed on the calculator **10** by reverse procedure to produce the cable curves **13**. Assuming a constant current of 100 amperes, and a constant cable length of 100 feet, values were computed for an applied voltage **32** of 450 volts, three phase. These values were obtained for various combinations of load power factor and cable size.

For ultimate compactness in compliance with the utility desired, the form of the calculator herein described was produced in the following manner. A logarithmic scale of two cycles ranging from 0.1 to 10 was first marked out on 180 degrees of the outer rim of the disc 11. A companion logarithmic scale of 180 degrees extent of two cycles ranging from 10 to 1000 was next applied to the rim of the half disc 15. The two scales progress clockwise and are designated 12 and 33 respectively. A logarithmic scale 32 ranging from 100 to 500 was marked, progressing clockwise, on the half disc 15. The exact location, circumferentially or radially, of this scale is a matter of convenience. In the herein described calculator it was placed about half-way along the radius of the half disc 15. The mechanical center of the scale 32 was placed on approximately the index point 36 of scale 33. The angular advance of scale 32 is equal to that of scale 33 for corresponding logarithmic increments. The marks 35 on disc 16 are two points on a companion logarithmic scale to scale 32. They correspond to the values: 2 for direct current or single phase alternating current, and 1.732 for three phase alternating current, of the factor F in the previously discussed "percent voltage drop" formula. Scale 35 was marked on arm 18 so that when the 3ϕ mark of scale 35 coincided with 450 volts on scale 32, scale 34, hereinafter to be described, was on the extension of the radius on which the index point 36 was located. A uniformly graduated linear scale 34, of arbitrary length and radial location was marked on the arm 18. The range from 40% to 100% was used since this range is that most useful in calculation of voltage drops.

Although the curves 13 could now be plotted from the percent voltage drop equation above if that equation were transformed to its logarithmic form, the fact that it contains the drop factor makes this inadvisable since this factor does not vary linearly with power factor or cable size. As described in the third paragraph above, values of percent voltage drop were calculated by means of the above formula, and a set of drop factor tables, for various combinations of load, power factor and cable size.

The mechanical design of the calculator 10 and the arrangement of scales were developed by trial to achieve compactness, relative simplicity, and above all, accuracy. The point marked 100 on the "feet-ampere" scale 33 corresponds to 100 feet and 100 amperes simultaneously. Thus, by setting this point on a value of voltage drop calculated by the above formula, a point on a cable curve 13 may be plotted under the power factor for which the value was computed. By moving the index 100 point 36 to all of the values calculated for various combinations of power factor and cable size, the complete set of curves is plotted.

It is seen from the above that this calculator does not depend on the proportional variation of its indicated result with all of the factors involved in this result. Thus the variation of voltage drop with various factors can be obtained empirically and placed upon this calculator in spite of the non-logarithmic correspondence of this drop with cable size or power factor.

In using the derived curves to furnish a value of percent voltage drop, the power factor scale 34 on pointer 18 is moved until the chosen power factor is over the chosen cable size 13 (in thousands of circular mils). If the positioning thumb screw 14 is locked with the three phase point 35 on the top disc 17 over 450 volts on the middle disc 15, the index 100 point 36 will be over the percent voltage drop 12 for 450 volts, three phase applied to a cable of chosen size 100 feet long supplying 100 amperes to a load at the chosen power factor. If either or both current and length differ from 100, the feet-ampere scale 33 and the percent voltage drop scale 12 are used as ordinary logarithmic scales in multiplication.

Since the number of phases and the input voltage enter as factors by which the voltage drop is varied, and since they usually remain fixed in a series of computations, they may be incorporated as logarithmic variations of the relative position of the feet-ampere scale 33 with respect to the power factor scale 34. Thus, for a fixed position of the power factor scale 34 the index 100 point 36 will vary its position in accordance with the logarithmic change due to varying input voltage or number of phases.

In operation, first, the phase scale 35 is set on the applied voltage scale 32, and the nut 28 is tightened to lock discs 15 and 16 together. Then the power factor scale 34 is set to cross the proper cable size 13 at the load power factor. If for direct current, use the power factor equal to 100. Then the hair line 23 of the pointer 20 is set on the length scale 33. Next, holding the end of the pointer 20 tight against disc 11, move the line current scale 33 on disc 15 until the 100 point 36 is under the pointer hair line 23. Then set the pointer line 23 on the line current along the scale 33. Now read the percent of voltage drop on the scale 12 as it appears under the pointer line 23 which will be the final result desired.

The following are specific examples showing how problems are solved with the calculator of this invention:

Problem 1.—THFA—9; power factor, 0.74; length of single conductor, 154 feet; balanced three phase current, 24 amperes; applied voltage, 450 volts. (Find % voltage drop in cable.)

Procedure: Loosen pivot screw, set 3ϕ on 450 volts, tighten pivot screw; place 0.74 power factor over curve for 9 cable size; move pointer to position over 24 amperes, hold pointer against back plate, move clamped assembly until 100 on scale 33 is under index line of pointer; move pointer only to 154 feet on length scale.

Answer: Find 1.58% voltage drop under index line.

Problem 2.—THFA—40; power factor, 0.60; direct current, 50 amperes; applied voltage, 240 volts. (Find maximum length of cable permissible for 5% voltage drop.)

Procedure: Loosen pivot screw, set D. C. on 240 volts, tighten pivot screw; place 0.60 power factor over curve for 40 cable size; move index line over 50 amperes, hold pointer against back plate, move clamped assembly until 100 on scale 33 is under index line on pointer; move pointer only to 5% voltage drop.

Answer: Find 492 feet under index line.

Problem 3.—Length of cable run, 250 feet; single phase current, 25 amperes; applied voltage, 117 volts; power factor, 1.0. (Find size of cable required to keep % voltage drop under 8%).

Procedure: Loosen pivot screw, set 1ϕ on 117 volts, tighten pivot screw; set 250 feet over 8% voltage drop; move index line on pointer to 100 on feet scale; hold pointer against back plate, move clamped assembly until 25 amperes is under pointer index line.

Answer: Find 1.0 on power factor scale between 14 and 23 cable curves. This indicates that THFA—23 cable is required.

Problem 4.—THFA—300; power factor 0.80; length of single conductor, 200 feet; applied voltage 400 volts. (Find permissible 3φ current, if voltage drop is to be limited to 2%.)

Procedure: Loosen pivot screw, set 3φ over 400 volts, tighten pivot screw; place 0.80 power factor over curve for 300 cable size; move pointer index line over 200 feet, hold pointer against back plate, move clamped assembly until 100 on length scale is under pointer index line; move pointer over 2% voltage drop.

Answer: Find 460 amperes under index line.

Other modifications and changes in the proportions and arrangements of the parts may be made by those skilled in the art without departing from the nature and scope of the invention, as defined in the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. In a voltage drop calculator of the character described, a circular disc having a series of cable size curves extending somewhat radially over about a semi-circular half of said disc, a logarithmic scale of percent voltage drop extending along the periphery of the other half of said disc, a semi-circular disc of slightly smaller diameter rotatable over said first mentioned disc and bearing a logarithmic scale of length in feet or line current in amperes, said logarithmic scale corresponding to the first mentioned logarithmic scale, a smaller disc having a power factor scale pointer extending radially therefrom and adapted to cooperate with said above mentioned cable size curves, a phase scale on said power factor disc adjacent its periphery, and an applied voltage scale on said semi-circular disc adjacent the periphery of said power factor disc to cooperate with said phase scale thereon, and a pointer line member pivoted to rotate over said three discs.

2. In a voltage drop calculator of the character described, a circular disc having a series of cable size curves extending somewhat radially over about a semi-circular half of said disc, a logarithmic scale of percent voltage drop extending along the periphery of the other half of said disc, a semi-circular disc of slightly smaller diameter rotatable over said first mentioned disc and bearing a logarithmic scale of length in feet or line current in amperes, said logarithmic scale corresponding to the first mentioned logarithmic scale, a smaller disc having a power factor scale pointer extending radially therefrom and adapted to cooperate with said above mentioned cable size curves, a phase scale on said power factor disc adjacent its periphery, and an applied voltage scale on said semi-circular disc adjacent the periphery of said power factor disc to cooperate with said phase scale thereon, a pointer line member pivoted to rotate over said three discs, and means for pivoting said discs and pointer together including means for locking said semi-circular disc and said power factor disc for unitary rotation.

3. In a voltage drop calculator of the character described, a circular disc having a series of cable size curves extending somewhat radially over about a semi-circular half of said disc, a logarithmic scale of percent voltage drop extending along the periphery of the other half of said disc, a semi-circular disc of slightly smaller diameter rotatable over said first mentioned disc and bearing a logarithmic scale of length in feet or line current and amperes, said logarithmic scale corresponding to the first mentioned logarithmic scale, a still smaller disc having a power factor scale pointer extending radially therefrom and adapted to cooperate with said above mentioned cable size curves, a phase scale on said power factor disc adjacent its periphery, and an applied voltage scale on said semi-circular disc adjacent the periphery of said power factor disc to cooperate with said phase scale thereon, a transparent pointer line member pivoted to rotate over said three discs, and means for pivoting said discs and pointer together including means for locking said semi-circular disc and said power factor disc for unitary rotation, said locking means including a stepped pivot bolt and a stepped pivot nut, said circular disc and said pointer member being rotatable on steps of said stepped bolt and of said stepped nut, said semi-circular and power factor discs being rotatable on the shank of said bolt and adapted to be locked between the steps of said bolt and said nut.

4. A voltage drop calculator comprising a disc having delineated thereon a semi-circular logarithmic scale for percent voltage drop and a semi-circular grouping of cable size curves, a semi-circular disc pivotally mounted thereover having a peripheral logarithmic scale delineated thereon for length or line current, said logarithmic scales corresponding to each other, a power factor disc pivotally mounted thereover having a radially extending power factor scale cooperative with said power factor curves on said circular disc, a phase setting scale on the disc of said power factor pointer and an applied voltage scale on said semi-circular disc adapted to cooperate with said phase setting scale on said power factor disc and a transparent pointer arm having a radially extending hair line index thereon.

5. A voltage drop calculator comprising a disc having delineated thereon a semi-circular logarithmic scale for percent voltage drop and a semi-circular grouping of cable size curves, a semi-circular disc pivotally mounted thereover having a peripheral logarithmic scale delineated thereon for length or line current, said logarithmic scales corresponding to each other, a power factor disc pivotally mounted thereover having a radially extending power factor scale cooperative with said cable size curves on said circular disc, a phase setting scale on the disc of said power factor pointer and an applied voltage scale on said semi-circular disc adapted to cooperate with said phase setting scale on said power factor disc and a transparent pointer arm having a radially extending hair line index thereon, said pointer arm being stepped to closely overlie the scales of said disc and stepped bolt and nut means for pivoting said discs and arms freely and for locking said semi-circular and power factor discs for unitary rotation relative to said circular disc and said pointer arm.

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