C. E. HAY & H. W. SULLIVAN.

ELECTRICAL RESISTANCE.

APPLICATION FILED MAR. 14, 1914.

1,170,811. Patented Feb. 8, 1916.

Fig. 1.

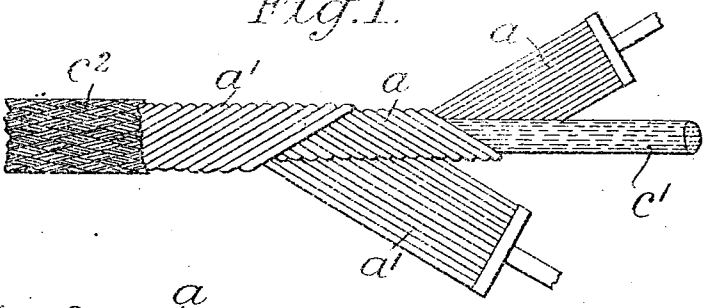



Fig. 2.

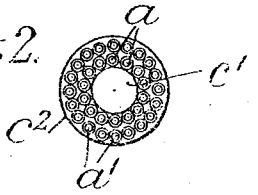



Fig. 3.

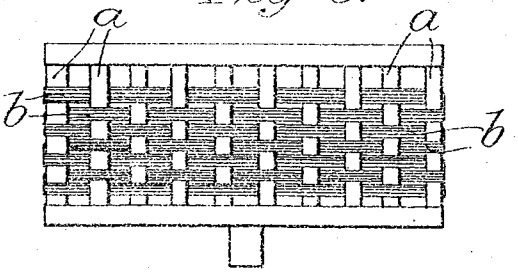



Fig. 4.

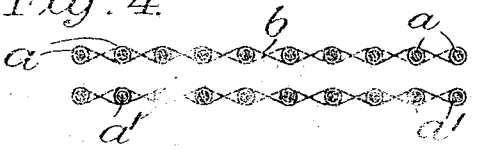
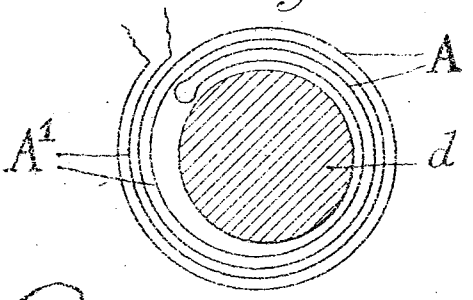



Fig. 5




Witnesses.

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# UNITED STATES PATENT OFFICE.

CHARLES E. HAY, OF ILFORD, AND HERBERT W. SULLIVAN, OF LONDON, ENGLAND.

## ELECTRICAL RESISTANCE.

1,170,811. Specification of Letters Patent. Patented Feb. 8, 1916.

Application filed March 14, 1914. Serial No. 824,695.

*To all whom it may concern:*

Be it known that we, CHARLES EDWARD HAY and HERBERT WATSON SULLIVAN, subjects of the King of Great Britain, residing, respectively, at Ilford, in the county of Essex, and at London, both in England, have invented certain new and useful Improvements in Electrical Resistances, of which the following is a specification.

The object of the present invention is to construct an improved compact electrical resistance for measurements of precision with alternating currents, at high frequencies such as are used, for example, in wireless telephony and telegraphy in which measurements it is necessary that the resistance units be non-reactive (that is to say, free from residual self-inductance or capacity effects) and that the resistance units may be readily adjusted to the high degree of ohmic accuracy necessary in instruments of precision.

It has already been proposed by several inventors to construct resistances free from residual inductance or capacity effects. For instance, it has been proposed to construct a compensated resistance from woven material, in which wires were to be used as the warp and joined in series. In one arrangement a non-inductive resistance of disk form is made by winding one turn of a strip of such material on a former, then doubling the strip back on itself and winding a turn in the opposite direction and repeating this process. Other inventors have proposed to construct compensated coils for comparatively low resistances in which, as ordinarily constructed, the self-induction effect usually preponderates, by employing sheet strip or ribbon doubled on itself, the contiguous parts being separated by a thin layer or layers of insulating material, preferably of high specific inductive capacity. The double strip thus formed is in some cases, for instance, when an ordinary bridge coil is to be made, covered with insulating material and formed into a coil or wound on a bobbin so as not to occupy a very large space. This coiling increases the capacity effect considerably and enables shorter and narrower sheet, strips or ribbon to be used than would otherwise be required, or it enables thicker insulating material, or insulating material of smaller specific inductive capacity, to be used. This resistance was to be adjusted, if necessary, in any ordinary manner, and the compensation was to be effected by varying the proximity of the ends of the parts, or the character of the insulating material, or both. It was also proposed to effect the compensation by sliding one end transversely over the other end, parallel to their own planes. Having made a number of compensated coils of such strip, it was proposed to join a number of them in multiple arc or parallel, in order to obtain low resistance units or to arrange two or more of the coils in series to produce moderate or large resistances.

According to our invention we employ a multiple conductor consisting of a number of wires arranged side by side in a plane and suitably insulated from each other. A pair of these multiple conductors is laid up obliquely or transversely around a core of insulating material. When laid up obliquely one layer may be wound reversely to the other. While we have shown the layers of the multiple conductors as laid up in opposite directions, such an arrangement is not necessary and, from an electrical point of view, better results will be obtained if the conductors be laid up in the same direction. The two layers thus form practically tubular conductors arranged concentrically. When wound transversely at right angles to the core, the multiple conductor may be bent back upon itself, and the two layers may be wound simultaneously upon a core. The wires composing each layer are joined in parallel, and one layer forms the "go" part of the circuit and the other the "return" part. The distance between the "go" and the "return" parts or layers is predetermined by calculation according to the resistance value of the unit required, which calculation is based on well-known electrical laws and the distance differs with the nature of the metal or alloy, the gage of the wires and the di-electric medium surrounding the wires. The distance between the wires forming each multiple conductor is governed in all cases by the distance separating the "go" and "return" layers. The number of wires forming the conductor in each layer may or may not be equal in number or gage.

With a resistance constructed according to our invention the relation of capacity to inductance is uniformly maintained

throughout the windings, and therefore has not to be adjusted by manipulating the ends or varying the proximity of the ends of the wires. Furthermore, the use of a subdivided conductor connected in parallel enables us to use a winding of such length as to admit of the rapid and accurate ohmic adjustment without disturbing the balance of capacity reactance and inductance reactance. Again this mode of construction enables us more readily to annul the residual inductance of our resistance coils by reason of the increased capacity of conductors so designed.

Another advantage of our invention is that eddy currents are reduced to a minimum owing to the sub-division of the conductors, and circulatory currents within the unit of resistance are suppressed owing to the wires forming the unit having the same electrical constants (resistance, capacity inductance and leakance).

The invention is illustrated in the accompanying drawings, in which:—

Figure 1 is a side elevation of a resistance made up of multiple conductors in the form of a strand or wire rope and Fig. 2 is a cross section of the same. Fig. 3 is a plan of a portion of a woven multiple conductor and Fig. 4 is a cross section through two layers of the same. Fig. 5 is a cross section of a resistance in which the woven material shown in Figs. 3 and 4 is wound on a bobbin at right angles to the axis.

Figs. 1 and 2 show a resistance in which the two multiple conductors, each consisting of separate insulated wires, are wound spirally around a core $c^1$ of cotton or other insulating material. One of these multiple conductors, for instance, the inner one, consisting of the wires $a$, is the "go" conductor, and the other, consisting of the wires $a^1$, is the "return" conductor. The wires $a$ are so wound that there is a complete tubular covering on the core $c^1$, and the wires $a^1$ are wound so that there is a complete tubular covering on the wires $a$. $c^2$ is on outer protecting sheath of insulating material. The number of wires forming each multiple conductor, and their gage and the thickness of their insulating covering, depend upon the resistance of the unit to be constructed. The number of wires in the two tubular coverings and the gage of the wires in one covering may vary from that in the other covering. The distance between the adjacent wires $a$ of the one conductor and of the adjacent wires $a^1$ of the other conductor depends upon the distance apart of the concentric layers and is governed as hereinbefore described.

A 10 ohm resistance coil constructed according to Figs. 1 and 2 may have the following dimensions:—First layer—nine wires (Eureka) 9.2 mils., standard double silk covered, 1.125 ohms per yard. Second layer—twenty one wires (Eureka), 6.0 mils., standard single silk covered 1.134 ohms per yard. The diameter of the core is not important so long as it is covered with a continuous layer of wires.

In Figs. 3 and 4, $a$, $a$, represent the insulated wires of the multiple conductor, which are joined in parallel, and $b$, $b$, represent the weft made of silk, cotton or the like. Instead of winding the multiple conductor obliquely in two layers around a core, as shown in Figs. 1 and 2, we may fold a long strip upon itself and wind the two strips or layers simultaneously around a cylindrical tube or bobbin $d$ and at right angles to the axis of the bobbin, as shown in Fig. 5. The one strip, A, will contain the "go" wires $a$, and the other strip, $A^1$, the "return" wires $a^1$, the distance between adjacent wires in one strip and the distance between the strips A, $A^1$, being regulated as hereinbefore described.

A 10 ohm resistance coil constructed from woven material having wires for the warp joined in parallel may have the following dimensions:—Ten wires—gage 6 mils. (bare). The wire is woven in such a way that the distance between the wires forming the tape is greater than 3 mils., and the distance between the "go" and "return" tape is 3 mils. Resistance=2.38 ohms per yard for Eureka. Another example: Ten wires—gage 9 mils. (bare). Distance between tapes=13.5 mils. Distance between wires in tape=not less than 13.5 mils. Resistance=1.013 ohms per yard for Eureka.

It will be understood that in all the constructions, all the wires $a$ will be connected together to form one terminal or end, and all the wires $a^1$ will be connected together to form the other terminal or end.

What we claim is:—

1. An electrical resistance comprising two conductors each formed of a plurality of insulated wires placed side by side and wound upon a core of insulating material in two layers, the wires of each conductor being in parallel, one layer forming the outgoing conductor and the other layer forming the return conductor, the distance between adjacent wires in each conductor being proportioned to the distance separating the conductors, whereby reaction due to self inductance is balanced by the counter reaction due to capacity.

2. An electrical resistance comprising two conductors each formed of a plurality of insulated wires placed side by side, and wound obliquely upon a core of insulating material in superposed layers, the wires of each conductor being joined in parallel, one layer forming the outgoing conductor and the other layer forming the return conductor, the distance between adjacent wires in each conductor being proportioned to the dis-

tance separating the conductors, whereby reaction due to self inductance is balanced by the counter reaction due to capacity.

3. An electrical resistance comprising two conductors each formed of a plurality of insulated wires placed side by side, and wound obliquely upon a core of insulating material in superposed layers, the wires of each conductor being joined in parallel, one layer forming the outgoing conductor and the other layer forming the return conductor, whereby reaction due to self inductance is balanced by the counter reaction due to capacity, the layers being insulated from each other the distance between adjacent wires in each conductor being proportioned to the distance separating the conductors.

4. An electrical resistance comprising a multiple conductor formed of woven material, having a warp of conducting material, the strands of which are connected in parallel, a weft of fibrous insulating, material covering the conductors and spacing them apart, said multiple conductor being wound upon a core, a second multiple conductor formed of a woven material having a warp composed of conducting material the strands of which are connected in parallel, a weft of fibrous, insulating material covering the conductors and spacing them apart, said second multiple conductor being wound upon the first mentioned multiple conductor and connected in series therewith.

In witness whereof we have hereunto set our hands in presence of two witnesses.

CHARLES E. HAY.
HERBERT W. SULLIVAN.

Witnesses:
WM. GIRLING,
O. J. WORTH.