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June 11, 1929.

C. DANTSIZEN

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RESISTANCE ELEMENT AND METHOD OF MAKING THE SAME

Filed April 18, 1924

Fig. 1.

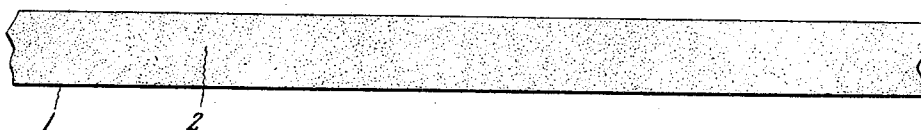


Fig. 2.

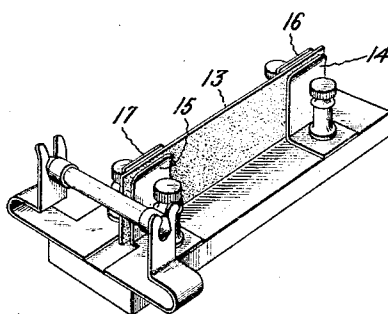


Fig. 3.

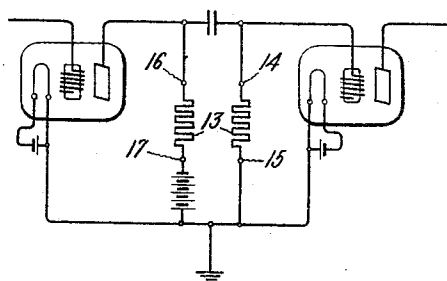
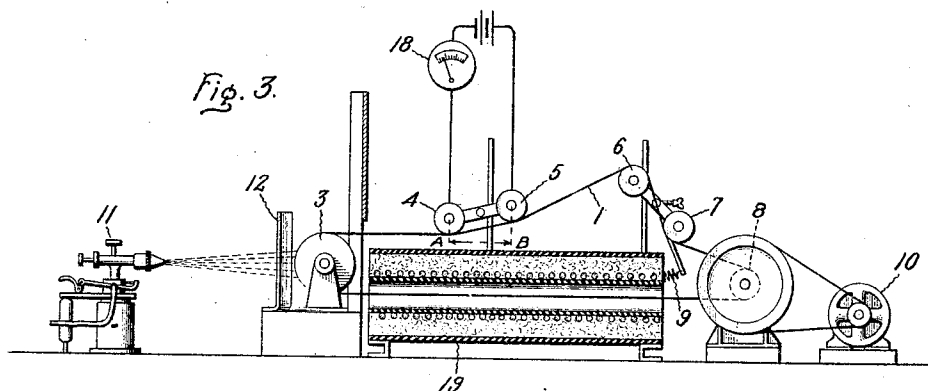


Fig. 4.

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UNITED STATES PATENT OFFICE.

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RESISTANCE ELEMENT AND METHOD OF MAKING THE SAME.

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My invention relates to a resistance element and the method of making the same.

The invention relates more specifically to that type of element suitable for use as a "grid leak" and other purposes where a resistance of a high order of magnitude is desired, and which finds extensive application in radio circuits.

The purpose of my invention is to provide a resistance element of the aforesaid type which shall be readily reproducible in convenient lengths and whose process of manufacture shall be capable of more precise control than has been possible hitherto.

Grid leaks and similar resistances of the prior art have been made by coating paper or similar supports with conducting coverings and particularly those formed from suspensions of carbon in siccative binders, commonly known as "india ink". It has also been common to make such grid leaks by applying graphite to suitable surfaces as by rubbing the graphite core of a lead pencil over such surfaces.

The resistance coating produced by the frictional application of graphite upon the surface of a paper support however, is extremely non-uniform in nature. Its unsatisfactory retention upon the support is due largely to the destruction of the superficial interstices of the support which causes the coating to exist as a more or less loosely adhering mixture of paper fibres and graphite. It has heretofore been found impossible to distribute a suitable conducting material like graphite upon a support in the form of a uniform coating without the use of a binder, but the siccative binders used are invariably hygroscopic in nature and this causes the resistance of the element to vary considerably with atmospheric conditions.

In view of the fact that the processes employed for the manufacture of such india ink and graphite resistances are very primitive and incapable of precise control it is virtually impossible to predetermine the resistance of a given strip or to control the degree of coating applied during the process of manufacture so that if quantity production of strips of definite resistance is desired expensive post-manufacturing testing manipulations must be expected.

It is the primary object of my invention to provide a resistance element which shall be suitable for grid leak and other radio uses, and which shall overcome the defects inherent in the prior art structures, particularly hygroscopicity, non-uniformity and non-retention of conducting coating.

It is a further purpose of my invention so to arrange the operative features of the process and elements of the apparatus used in the production of the resistance that the amount of conducting coating applied and hence the degree of resistance obtained may be readily controlled during the progress of manufacture to the end that grid leaks of any predetermined degree of resistance may be secured in any desired quantity.

My invention will be more completely understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 represents a fragment of my improved resistance element.

Fig. 2 shows an illustrative method of using the improved resistance element in connection with a suitable terminal structure.

Fig. 3 illustrates a schematic layout of apparatus suitable for producing my improved resistance structure.

Fig. 4 depicts a conventional radio circuit in which a double-coated resistance element of the invention is used both as a grid leak and as a plate resistance.

Referring now in detail to the drawings, the resistance element of Fig. 1 consists of a flexible support 1, preferably a bibulous variety of paper, upon the surface of which a continuous layer of conducting material 2, such as graphite, is uniformly and permanently distributed in a manner set forth with greater particularity below. The conducting coating may also be applied to both sides as hereinafter set forth. The conducting coating is preferably produced by spraying a graphite-bearing liquid, for example, a colloidal suspension of graphite in water commonly known as "aquadag", upon the paper support by means of a spray gun when said support is carried past by means of suitable apparatus. The latter may consist, for example, of a system of rollers, 3, 4, 5, 6, 7, 8, upon which the paper or other support 1 is disposed after the fashion of an endless belt.

The rollers 6 and 7 are tensioned by a spring 9 and serve as idlers to keep the workpiece taut upon the driving system. In order to insure uniform speed of progression of the paper strip or workpiece over the roller system, recourse may be had to a flywheel type of speed equalizing roller 8 over the hub of which the said workpiece strip is passed. The system is preferably driven by an electric motor 10. The workpiece or paper strip 1 is caused to pass over the roller system, and as it passes over the roller 3 a spray or jet of graphite-bearing liquid is projected against the surface of said workpiece by the spray gun 11. The path of the spray is confined by means of a suitable diaphragm 12, which not only insures uniformity of workpiece area covered but likewise prevents undue spattering of the graphite-bearing material over the other parts of the machine. As the strip leaves the roller 3 it enters a drying oven 19, which is preferably electrically heated, and in which the fluid components of the graphite-bearing material are evaporated. The strip being endless, the process is continuous and the amount of graphite-bearing material deposited increases with the length of time that the workpiece is caused to traverse the roller system and pass in front of the spray gun.

In order to control the amount of coating deposited means are provided for continuously indicating the current passing through the workpiece, since this furnishes a convenient method of determining the resistance of the graphite surface whenever desired without necessitating the stopping of the apparatus or the removal of the strip. Means suitable for accomplishing this purpose are conventionally illustrated in Fig. 3 where 4 and 5 denote two current conducting rollers insulated from each other, which contact with the graphite layer of the workpiece strip.

These contact rollers together with the measuring instrument 18 electrically associated therewith constitute a convenient system for measuring the resistance of a unit length of the workpiece surface, represented by the distance A B. The resistance of A B, however, is in parallel with the resistance of that length of strip represented by the piece extending from B over the rollers 6, 7, 8, through oven 19, roller 3, to the point A.

The resistance of A B is furnished by the well-known equation

$$\frac{1}{R} = \frac{1}{R'} + \frac{1}{R^2}$$

where R represents the resistance of the parallel circuits as measured by the meter 18, R' the resistance of the unit strip A B, and R² the resistance of the remaining surface of the strip extending from B over the rollers 6, 7, 8 back to A.

Inasmuch as the ratio of R' to R² is the

ratio of the lengths of the resistance coatings we have the equation

$$R' : R^2 = 1 : x$$

or in other words,

$$\frac{1}{R} = \frac{1}{R'} + \frac{1}{xR'}$$

In order to produce an element of a definite resistance, say a megohm, we need but to interpolate in the above formula the proper voltage value, and by observing said voltage by means of the measuring device 18 as well as by controlling the speed of the apparatus, and the amount of aquadag released by the spray gun the conducting coating produced will be of such uniform character that upon removal of the workpiece from the machine it may be cut into unit lengths represented by the distance A—B, or in other words, the distance between the contact rollers 4 and 5. If said contact rollers 4 and 5 are adjustably mounted, as shown, the unit of length may be varied. The distance between the rollers 4 and 5 furnishes a suitable criterion for the rapid repetitive quantity production of units of definite length, and it will be evident that inasmuch as the coating applied to the strip is substantially uniformly distributed over the entire surface the strip or workpiece when removed from the machine may be cut up into any suitable lengths whether represented by the distance A—B or not.

For some purposes it may be desirable to provide both sides of the insulating support with a conducting coating. In such a case after one surface is coated the endless workpiece strip may be removed from the coating apparatus, turned inside out, and replaced to permit of the deposition of a similar coating upon the other side. The ease with which the degree of coating applied may be controlled by measuring the resistance thereof becomes particularly obvious when it is desired to impart the same resistance to both sides since the coating process may be stopped at any desired stage.

It is evident that the deposition of the conducting coating may be so controlled that the resistance of one side of the element is of the same order of magnitude as that of the other side. One resistance may be different from that of the other side and the two resistances may for some purposes even bear a definite ratio to each other. The force with which the graphite bearing material is applied to the workpiece, aided by the relatively porous nature of the support, the finely divided condition of the graphite, and the speed with which the strip is carried past the diaphragm results in the deposition of a uniform layer or film of graphite upon the surface of the support, which when the liquid medium evaporates is firmly retained in the superficial interstices of the support.

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The resistance element of my invention is characterized by properties which are quite unique. Inasmuch as the graphite is retained in the superficial interstices of the support there is no danger that it will flake off and thus affect the continuity and uniformity of the conducting coating. The graphite coating furthermore is retained in binderless relation upon the support thus obviating all danger of variation in resistance due to the hygroscopic nature of the varnishes and adhesives commonly used. Furthermore, whereas the prior art grid leaks and similar resistances composed of frictionally applied graphite or of dried india ink coatings are suitable only for resistances in excess of a megohm and practically unsuitable for lower resistances, my improved structure is suitable for resistances from 1000 to 1,000,000 ohms, and thus offers a far wider range of usefulness.

The resistance strip produced in accordance with the process of the invention may be used as illustrated in Fig. 2 where it is shown mounted in a suitable clamping device. In this case the resistance element 13 is coated on both sides and for purposes of illustration it is shown mounted as for use in the circuit of Fig. 4, the terminals 14, 15, and 16, 17 of Fig. 2 corresponding to similar reference numerals in Fig. 4, which latter figure indicates how such a double-coated resistance may be used both as a grid-leak and as a plate resistance in a radio circuit, one of the coatings being connected into the plate circuit of the first space current device while the other acts as a grid leak between the condenser and ground.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. A resistance element comprising a fibrous support, a uniform continuous graphite coating disposed upon said support and retained thereon in binderless relation in the superficial interstices of said support.

2. A resistance element comprising a paper support, a uniform continuous conducting graphite coating disposed upon said support and retained thereon in binderless relation in the superficial interstices of said support.

3. A resistance element comprising a strip of fibrous insulating material, a uniform continuous conducting coating disposed upon the surface of each side of said strip and retained thereon in binderless relation in the superficial interstices of said surface.

4. A resistance element comprising a strip of insulating material, a uniform, continuous graphite coating disposed upon the surface of each side of said strip and retained thereon in binderless relation in the superficial interstices of said surface, the resistance of the coating of one side being of the same order of magnitude as the resistance of the other side.

5. The method of making resistances comprising spraying a colloidal suspension of a conducting material in a fluid medium onto an insulating support, moving the support at a substantially constant speed past the spray and evaporating said medium to cause the superficial interstices of said support to retain the conducting material in the form of a continuous uniform conducting surface coating without the aid of a binder.

6. The method of making resistances comprising applying a colloidal suspension of a conducting material in a fluid medium to an insulating support, evaporating said medium to cause the superficial interstices of said support to retain said conducting material in the form of a continuous uniform conducting surface coating without the aid of a binder, and indicating the resistance of the coating continuously during the course of its application to serve as a control for the amount of coating applied.

In witness whereof, I have hereunto set my hand this 17th day of April 1924.

CHRISTIAN DANTSIZEN.