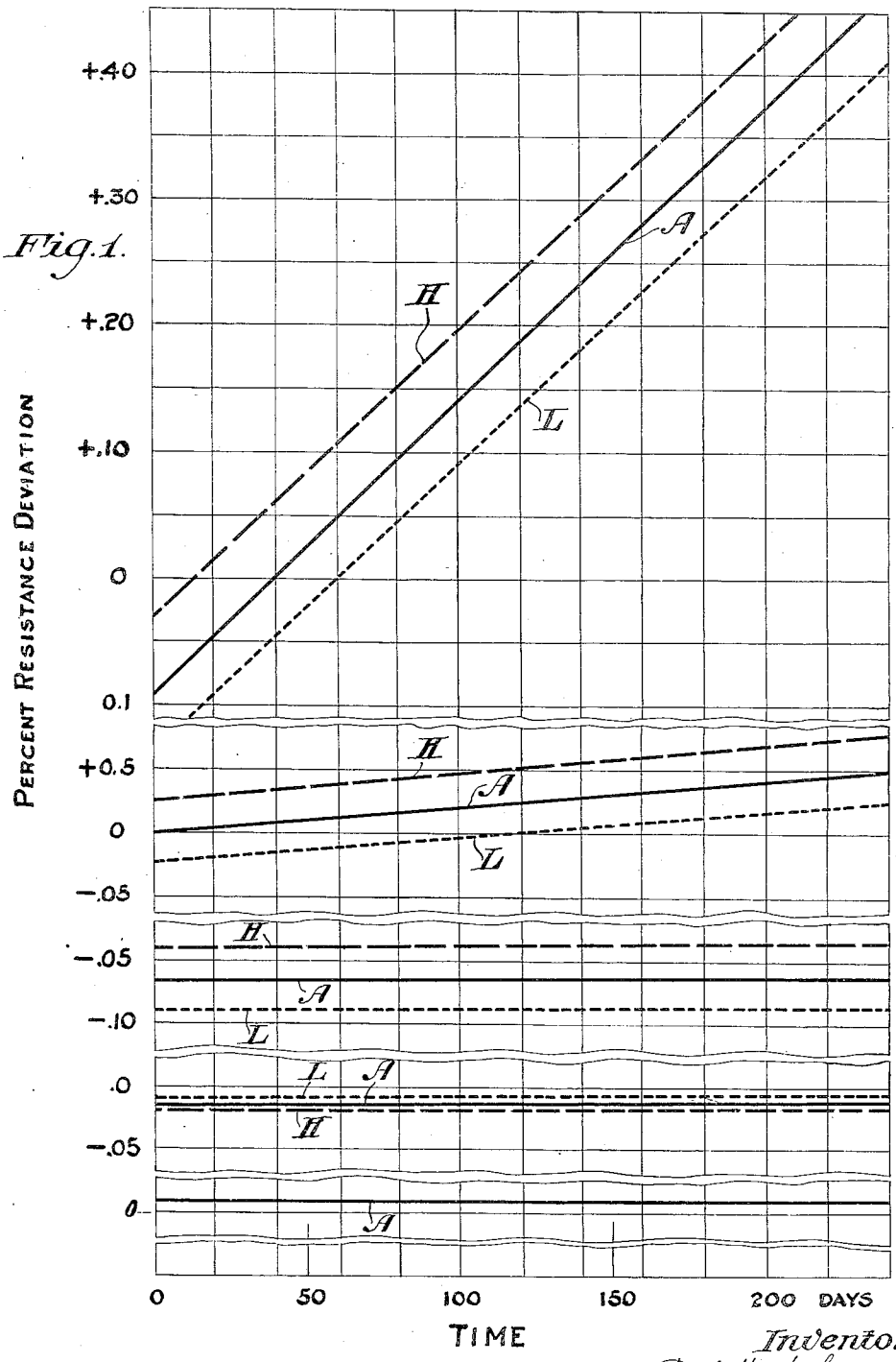
Jan. 7, 1936. P. H. DIKE 2,026,616

PRECISION RESISTANCE

Filed May 27, 1933 2 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

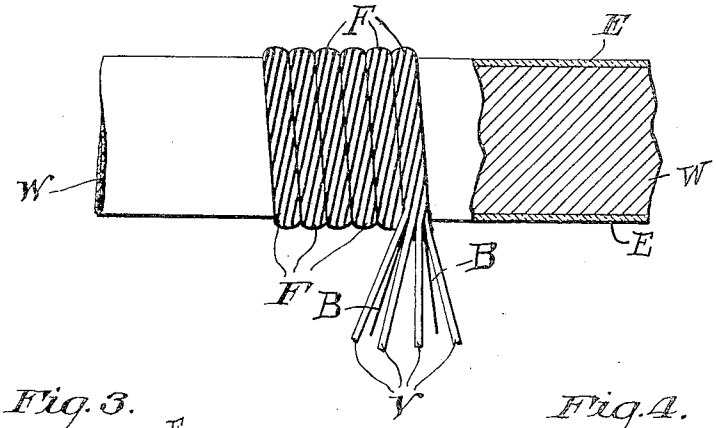


Fig. 3.

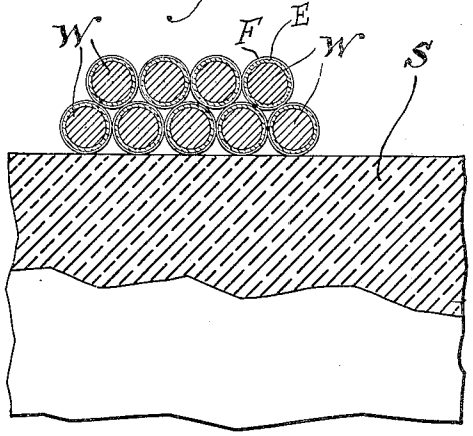


Fig. 4.

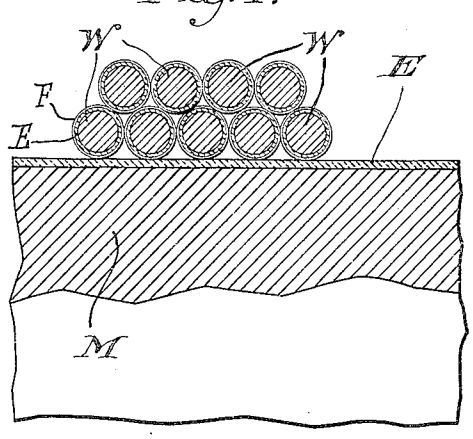
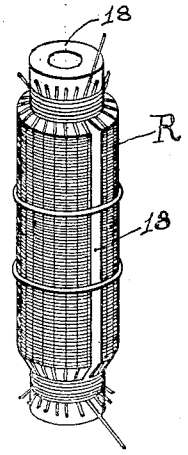


Fig. 5.



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Patented Jan. 7, 1936 2,026,616

UNITED STATES PATENT OFFICE

2,026,616

PRECISION RESISTANCE

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Application May 27, 1933, Serial No. 673,171

14 Claims. (Cl. 201—67)

My invention relates to precision resistors or resistance units, whose resistances vary at most within very small limits from absolute constancy of magnitude, utilizable, unsealed or without enclosure in a sealed container, for any purpose where a high degree of precision is desirable or essential, including use as standards of resistance, or as elements of high precision Wheatstone bridges, potentiometers, and other electrical measuring instruments and systems.

In accordance with my invention a resistance conductor or wire, coiled, woven, or otherwise arranged or disposed, and generally of low temperature-resistance coefficient, is provided with a covering or wrapping of vegetable fibre of such character that the changes in resistance due to variation in ambient relative humidity is materially changed, generally reduced; and more particularly the change in resistance due to humidity is preferably of very low order of magnitude, so reducing the total change in resistance due to changes in humidity and other causes, thereby imparting to the resistor or resistance unit a materially higher degree of stability.

Further in accordance with my invention materially to reduce the gradual and permanent increase in resistance of the conductor or resistance wire, when of metal which in its environment is subject to corrosion or other chemical effect, and especially when fine or of small diameter, the conductor is coated with insulating enamel or equivalent; and materially to reduce the aforesaid effect and the effects of humidity the wire or conductor is coated with enamel and wrapped with vegetable fibre.

My invention resides in a precision resistor or resistance unit, in the method of producing the same, and in the method of reducing the variations in resistance of a resistor or resistance unit, as hereinafter described and claimed.

For an understanding of my invention, and for an illustration of some of the forms it may take reference is had to the accompanying drawings, in which:

Fig. 1 illustrates the characteristics of a resistor whose wire or conductor is provided with different types of coverings;

Fig. 2 is a fragmentary elevational view, partly in section, of a resistance conductor having coverings in accordance with my invention;

Fig. 3 is a fragmentary sectional view of a support, ceramic in character, with the resistance conductor wound thereon;

Fig. 4 is a fragmentary sectional view of a metallic support with the resistance conductor coiled thereon;

Fig. 5 is an elevational view of a woven resistor mounted upon a support.

A resistor or resistance unit, to be utilized as a standard or for other purposes, comprised, in accordance with an example of prior standard practice, a metal spool or support covered with a silk ribbon saturated with shellac; upon this covering was wound or coiled a resistance wire itself insulated with a double wrapping of silk in the form of thread, yarn or the like. Thereafter the coil so constituted was saturated with shellac. A resistance coil of this type was found to be subject to the effects of ambient relative humidity, the resistance of the coil increasing with increasing humidity. To eliminate this effect, the completed coil was hermetically sealed, either in dry air or in oil, within a container. While the aforesaid change of resistance with change of humidity was ascribed to a swelling of the shellac under the influence of humidity, nevertheless the saturation of the coil with shellac was continued even when the coil was to be hermetically sealed. Where the expense of hermetcially sealing the coil was not justified, it was attempted to reduce the humidity effect by coating the coil with a wax, such as paraffin, to exclude moisture from the coil.

I have found that a resistance coil of this character, when subjected to a number of cycles of varying humidity, exhibited a cyclic variation or drift in resistance combined with a gradual or permanent change or drift in resistance. It was found that the cyclic or temporary change in resistance, due to humidity, is caused not only by the shellac, but also by the silk present in the coil construction. It was further found that the gradual and permanent increase in resistance is due to corrosion occurring at or upon the surface of the metal conductor or wire itself, the shellac failing to preserve the wire against corrosion.

It was further found by me that a resistance wire, whether or not coated with enamel, covered (as in insulating a wire by helically wrapping insulation thereon), with fibres, yarn or thread of natural silk, or of other animal fibre such as wool, or even when of artificial silk such as rayon of vegetable origin, increased in resistance with increasing humidity, presumably due to elongation of the wire with consequent reduction in its cross section due to exertion upon the wire of forces applied by its covering when swelled or acted upon by moisture.

When, however, the resistance conductor or

wire, whether or not coated with enamel, is covered with a helical wrapping of fibres, yarn or thread of natural vegetable fibre, such as cotton, the effect of humidity, I have found, is the opposite to that experienced when the covering or wrapping is of animal fibre such as silk; with the cotton covering the effect, with increasing humidity, is a decrease in resistance, or a change in resistance opposite in sense to that when the wrapping is of animal fibre. In general, when the wrapping has the humidity characteristic of cotton fibres, increase in humidity causes lesser increase in resistance, even to the extent of actual decrease in resistance.

In accordance with my invention the temporary and relatively rapid change in resistance with change in ambient relative humidity, when the conductor is covered with silk or the like, is, by virtue of a covering or wrapping of cotton, linen, pineapple fibre (from the leaves of the pineapple plant, and known as "silk grass", sometimes marketed under the name "Arghan") or other equivalent natural vegetable fibres, markedly reduced, with a change in resistance about .015% to as low as the order of .005%, for a variation of relative humidity between limits of about zero to 75 or 90%, as compared with a change in resistance of the order of .05%, for like humidity changes in the case of silk covered resistance wire.

The vegetable fibres suitable for my purposes are "natural" in the sense they are not artificial fibres such as the aforesaid rayon. The cotton, linen and equivalent fibres may be used in the condition or form in which ordinary cotton insulation is employed in covering or wrapping wire for electrical purposes.

Another feature of my invention is the great reduction in the rate of increase in resistance of the wire, when to substantial extent corrodible, by coating the same with enamel or equivalent corrosion preventive; while in prior practice the permanent drift or increase in resistance has been as great as .03% per annum in the case of manganin, by the application of corrosion preventive such as enamel or equivalent, the increase in resistance per annum may be decreased to approximately .001% per annum.

Reference to Fig. 1 will illustrate the different characteristics which may be imparted to the performance of resistance wire by different types of coverings; ordinates are percentages of resistance change or deviation, and abscissae are units of time in days.

The several characteristics relate to a resistor or resistance unit, of nominally 1,000 ohms resistance, comprising a wire of manganin, No. 41 A. W. G. (American wire gauge).

The upper characteristic concerns the case where the manganin wire has a helical wrapping or covering of double silk insulation, covered with paraffin. The high rate of upward drift or gradual and permanent increase in resistance, due to corrosion of the manganin wire at its surface, amounts to approximately .5% in seven months. The temporary or cyclic changes in resistance, due to changes in relative humidity between the limits of about 5% and 75 or 80%, amounted to the magnitudes whose upper and lower limits are indicated by the curves or lines H and L, for the highest and lowest relative humidities, respectively; the average resistance change including that due to the gradual or permanent drift is indicated by the characteristic curve or line A. The graph shows the changes in resistance due to humidity variations to be great, and that the slow or gradual drift or increase in resistance due to corrosion, which is largely due to the paraffin coating, is also large.

The graph immediately below the foregoing exemplifies the behavior of a similar resistance coil (1,000 ohms, manganin) again having a double silk wrapping of insulation, but ceresin substituted for paraffin. Ceresin, a more or less refined ozocerite, reduces the effect of corrosion, because chemically neutral or substantially so. It is to a high degree free of acid and other corrosive chemical compounds, and so minimizes corrosion, with the result, as indicated by the graph, that the rate of permanent drift or increase in resistance, though still substantial, is markedly less than in the case where the silk covered resistance coil is covered or saturated with paraffin. Nevertheless the spread between the curves or lines H and L is still great, showing continuance of wide variation in resistance with changes in ambient relative humidity. The ceresin does not eliminate the effect of humidity or moisture upon the silk covering of the resistance wire. Such permanent drift or increase in resistance as remains is believed to be due to the corrosive action of the surrounding atmosphere.

In the graph next below, the coil is again the same (1,000 ohms, manganin), but the wire in this case is coated with enamel, such as commonly used for insulating wires, in turn covered with double silk insulation and coated or saturated with ceresin. In this case the permanent drift or rate of increase in resistance due to corrosive effects is further markedly reduced, because the enamel reduces the corrosive effect remaining notwithstanding the presence of ceresin; the permanent rise in resistance per annum is of very low magnitude. There still remains, however, the wide spread between the lines or curves H and L, showing continuance of relatively great changes in resistance due to variations in humidity.

The graph next below illustrates the properties of a resistance coil (1,000 ohms, manganin) similar to that last above described to the extent the wire is coated with enamel and the coil coated or saturated with ceresin; but in lieu of the silk wrapping, one of natural vegetable fibres, cotton or linen is employed. Here again, because of the enamel coating, the gradual permanent drift is extremely small as in the case of the immediately preceding case. The most marked effect, however, is that of substitution for silk of the vegetable fibre wrapping or insulation, in reducing the fluctuations in resistance due to humidity varying between the limits of the preceding examples. The spread between the two characteristics H and L is now very markedly reduced showing that the resistance unit, due to the use of natural vegetable fibre, is rendered all but completely immune to variations in humidity. In fact, the characteristics H and L have become reversed in their positions relative to the average characteristic A. This shows that the correction for humidity variations as induced by the vegetable fibre wrapping has overcompensated for variations in ambient relative humidity. This graph illustrates the fact that, though the vegetable fibre wrapping is that of single linen or cotton covering, the amount of the vegetable fibre or its distribution along the resistance wire or conductor may be such as to go too far in the matter of correction for humidity changes.

Substantially ideal or perfect compensation for humidity variations, illustrated by the lowermost

graph, may be obtained by suitable choice in the species of vegetable fibre covering, the amount thereof employed in the wrapping, and its disposition upon a resistance wire. The slope of the characteristic A in this case is nearly zero, as in the preceding cases, effected, for example, by coating the wire with enamel and by application of ceresin; and the substantially complete elimination of variation of resistance changes due to variation in ambient relative humidity, as exemplified by the fact there is zero spread between characteristics H and L which coincide with characteristic A in this graph, may be effected by tempering the vegetable fibre by employing therewith, in any one of various ways hereinafter described, animal fibre, such as silk or wool, with the vegetable fibre predominating. The effect of increase of moisture or humidity upon the animal fibre component of the wrapping is to cause the wire to tend to increase in resistance, while the vegetable fibre component has a predominating effect in the opposite sense. By suitably choosing the ratio of amount of animal to vegetable fibre in the wrapping, there will not be over-compensation for humidity, as was the case in the graph immediately above; on the contrary, the effects of the animal and vegetable fibres balance, and so render the resistance wire substantially completely immune to changes in humidity.

Bare resistance wire, or enameled resistance wire without fibre covering, is not substantially affected, as to resistance change, by humidity. However, since the wire of resistance unit or a resistor must be electrically insulated, enamel coating may be employed for that purpose. When the covering is solely enamel, the insulation afforded by it frequently fails, causing short circuiting between neighboring turns or neighboring layers, so destroying the value of a resistor as a standard or as an element of a precision instrument or system. It is accordingly necessary or desirable to apply a fibre or like wrapping, to ensure maintenance of adequate insulation of the wire. However, when such a fibre wrapping is employed, the above described effects of humidity occur. It is not essential, insofar as humidity effects are concerned, that the wire be covered by enamel or equivalent. It may be insulated solely by the fibre wrapping which, however, should be of natural vegetable fibre as described, or a combination thereof with animal fibre, to reduce or eliminate resistance changes due to humidity.

When the resistance wire is enameled or coated with equivalent material, the wrapping of fibres may be more sparingly applied, may be so called "single" cotton or like covering, and may actually take the form of a helix with spacing between neighboring turns of the fibre strands, yarn or thread; in such case, to overcome the effects of humidity, the wrapping upon the enamel coating should be of natural vegetable fibre, such as cotton, linen or equivalent, or in combination with animal fibre as above described.

While the leakage effect of humidity or moisture upon a resistance coil or resistor is to reduce its resistance, that is a matter distinct from the reduction of resistance effected by the aforesaid vegetable fibre. For relative humidities of about 80%, the decrease in resistance of linen or cotton covered wire with increase in humidity is more than 1,000 times too great to be accounted for by leakage.

It is preferred, as usual, and as well understood in the art, that the wire or conductor of which the resistor or resistance unit is constructed shall have low temperature-resistance coefficient, whereby the effects of temperature upon the total resistance of the unit shall be minimized.

When using a wire of low temperature coefficient the change in resistance due to changes in temperature, such as fifteen or twenty degrees centigrade from about 20° C., may be of the same order of magnitude as the changes due to humidity variations, as through ranges from about five to seventy-five or eighty degrees relative humidity, when the wrapping is of vegetable fibre; and in some cases the change in resistance due to humidity variations may be less than that due to the aforesaid extent of variation in temperature.

The preferred material for the resistance wire is manganin, an alloy comprising about 84% copper, about 12% manganese and about 4% nickel, having a resistance-temperature coefficient of about 8×10^{-6} ohm per ohm per degree C.

Manganin corrodes, and in consequence there is a permanent drift in its resistance which increases gradually with time. To reduce the corrosion or other chemical effect and thereby minimize the permanent drift in resistance, the wire is preferably coated with enamel, such as commonly used in insulating wires, though any equivalent coating may be employed. The enamel may be in the nature of a varnish comprising a natural gum such as kauri with linseed, China-wood or equivalent oil. Or there may be used a synthetic resin varnish. In general, the enamel or equivalent coating should be substantially chemically neutral with respect to the wire, elastic or flexible, and impervious to moisture. By the term "enamel", as used hereinafter in the specification and claims, is meant an enamel of the type just described, elastic or flexible, substantially impervious to moisture, chemically neutral with respect to the wire to which it is applied, and one which may suitably be applied to the resistance conductor before fabrication into a resistor unit. From this term is specifically excluded vitreous enamels applied solely to a complete resistor unit after fabrication, which are unsuitable to the practicing of my invention.

Constantan may also be used for the resistance wire; it is a nickel copper alloy generally of about 60% copper and 40% nickel; its temperature coefficient is about 2×10^{-6}. A silk covered resistance wire of constantan changes more in resistance due to humidity than a silk covered wire of manganin. Constantan is somewhat less corrodible than manganin, and to reduce its gradual and permanent increase in resistance should be coated with an enamel or equivalent such as above described.

A copper manganese aluminum alloy may be employed. Its temperature coefficient is approximately 1×10^{-6} for a composition of about 85% copper, about 13% manganese and about 2% aluminum.

The resistance-temperature coefficient of the wire employed should be less than 500×10^{-6}, and preferably not be greater than about 50×10^{-6}; the temperature-resistance coefficient is desirably not greater than 10×10^{-6}, though my invention comprehends, in some of its aspects, the employment of alloys of chromium and nickel. One such alloy comprising about 60% nickel, about

15% chromium and about 25% iron, has a temperature coefficient of about 400×10^{-6}. Another alloy comprising about 80% nickel and 20% chromium has a temperature coefficient of about 100×10^{-6}. These nickel chromium alloys corrode but little, if at all, and need not be coated with enamel or equivalent in order to reduce the gradual drift in resistance causing a permanent increase in resistance of the resistor. However, enamel is useful as a coating for nickel chromium alloy wire for insulation purposes; in such case the application of the vegetable fibres, in accordance with my invention, in lieu of silk or the like for a covering to ensure against the effects of possible breakdown or failure of the enamel insulation, is of advantage in reducing or eliminating the temporary changes or drift in resistance due to changes in ambient relative humidity otherwise occurring were silk employed.

The size or diameter of the resistance wire employed will generally be smaller than No. 20 A. W. G., and most frequently, particularly when a resistance of high magnitude is to be obtained within small compass, will be smaller or finer than No. 36 A. W. G. By way of example merely, it may be stated that for 1,000 ohm resistors the wire may be No. 41 and for 10,000 ohm resistance units No. 44 A. W. G or finer.

Fine wires, which for the purposes of the present invention may be considered those of No. 30 A. W. G. and finer, when composed of manganin or other corrodible or chemically affected metal or alloy, exhibit the greatest relative permanent drift or increase in resistance, and accordingly for resistors of fine wires it is of greater importance to prevent chemical effect or corrosion, as by coating with enamel or equivalent, and preferably additionally applying ceresin or equivalent.

As indicated, the wrapping, in accordance with one aspect of my invention, for the resistance conductor of wire, comprises natural vegetable fibre; natural vegetable fibres, such as those of cotton, pineapple plant, linen, hemp, jute or sisal may be employed. It will generally be found of advantage to soften the fibres of linen, hemp, jute or sisal, if used, with a suitable oil. The fibrous wrapping of the character aforesaid may be applied as such or in the form of yarn or thread helically upon the wire as in the case of application of silk and cotton as commonly practiced in insulating copper and other wires. The wrapping may be applied to a wire coated with enamel or it may itself constitute the sole or substantially sole electrical insulation of the wire.

While the application of shellac, as hereinbefore described as practiced in the prior art, and which was to less extent than the silk covering responsible for increase in resistance due to humidity, is preferably to be avoided, nevertheless its use is not excluded, for in event the humidity effects are reduced or substantially eliminated by the vegetable fibre covering of the wire, shellac may be employed and will to appreciable extent retard progress of moisture to the covered wire from a humid atmosphere.

It is preferred, however, that there be used for impregnating or coating the resistance coil, as hereafter described, a wax, which should, however, be free of acid or other chemical compound, originally in the wax or later produced within it, which would affect the wire or resistance conductor as by way of corrosion. For this purpose a paraffin wax free of acid or other wire corroding chemical compound may be utilized. Among the paraffin waxes found suitable is that marketed under the name "Superlawax". However, ozocerite, a wax found in nature, and more particularly yellow ceresin, a refined ozocerite, is preferred. The yellow ceresin is preferred over the white, which latter is more highly refined ozocerite than the yellow ceresin, and would more likely contain acid or other wire-corroding chemical compound.

In Fig. 2 there is illustrated on magnified scale a resistance wire or conductor W, of manganin for example. It is provided with the coating E of enamel or equivalent, particularly when the metal of which the wire is composed is subject to corrosion under the conditions or in the environment herein described. Whether or not so coated, it is wrapped with the helically disposed turns F of fibrous material, in any suitable form as strands, yarn or thread. The turns F may be continuous, as illustrated, especially when in the absence of the enamel coating the fibre wrapping constitutes the insulation for the wire; or they may be spaced from each other when an enamel or equivalent coating is present. In the example illustrated, the wrapping consists of a thread comprising several ends or elements V of yarn or strands of natural vegetable fibres, such as cotton, linen or any of the others herein contemplated. The yarn or thread may also include one or more elements B of animal fibre, such as silk or equivalent, to effect the herein described mixture of animal and natural vegetable fibres more exactly or completely to compensate each other to effect a composite wrapping which renders the wire or conductor W substantially completely immune against the effects of variations in ambient relative humidity.

The material for the composite wrapping of natural vegetable and animal fibres may also be produced by carding a mixture of the vegetable and animal fibres, so yielding a more intimate mixture, or a more uniform distribution of the animal fibres in the mixture, which may be applied in strands or spun into ends or yarn and so applied, or the ends or yarn may be twisted into a thread and then applied to the wire. Or upon the wire may be wound side by side a plurality of strands, ends or threads of the vegetable fibre, and beside them one or more threads of the animal fibre.

The support for the resistance wire is preferably other than wood, synthetic resin or the like, commonly heretofore employed with wrappings or coverings. For my purposes I prefer, for high frequency precision resistors or resistance units, utilizable at radio and other frequencies higher than usual commercial frequencies, a support, ceramic in type, which may be glazed, though preferably unglazed. For example, there may be used a spool or support, comprising largely magnesium polysilicate ceramic.

For use in the fields of direct current and low frequency alternating currents, such as commercial frequencies, the support may be a ceramic as before, or, and preferably, of metal such as brass, with an enamel coating which may be baked thereon.

In any event, the supports are preferably nonhygroscopic or of a material upon which moisture has no such effect as to cause it to exert a force or otherwise affect the resistance of the wire.

In Fig. 3 there is shown, in fragmentary cross section, a support or spool S of ceramic, upon which the resistance wire W is fabricated or

wound in the form of a coil in one or more layers. The wire may be of any of the types herein described, including that specifically shown in Fig. 2. In brief, the wire may be coated with enamel, or wrapped with vegetable fibre or a mixture of animal and vegetable fibres, both coated and wrapped.

In Fig. 4 the spool or support M is of metal, such as brass, upon which is baked or otherwise applied a coating E of enamel or equivalent upon which is fabricated or wound, in one or more layers, a coil of resistance wire W of any of the characters herein described. For direct current or low frequency alternating current the coil is preferably wound bi-filar.

When the resistance wire is fabricated in the form of a woven cloth, the weave may comprise a warp of silk, cotton or other suitable material, and the filler or woof will be any of the resistance wires contemplated by my invention.

As indicated in Fig. 5, the woven resistor R is wrapped around and secured to a support 18 of ceramic or other suitable material, all generally as described in Tarpley's application Serial No. 586,518, filed January 14, 1932, since issued as Patent 1,972,499, dated Sept. 4, 1934.

A feature of my invention is the method of very greatly reducing or eliminating the resistance changes due to variation in ambient relative humidity, by wrapping the resistance wire with natural vegetable fibre, in some instances with an admixture of suitable proportion of animal fibre such as silk, the wrapping generally being a so-called single covering as understood in the art of insulating wires in general with cotton or silk; the wrapping or covering serving as the insulation for the resistance wire, particularly when the wire is not coated with enamel, or when an enamel coating is applied thereon having the double advantage of ensuring against failure of the enamel and procuring the aforesaid immunity against humidity.

A further feature resides in the method of reducing the gradual and permanent increase in resistance due to corrosion or other chemical effect upon the surface of the wire when corrodible, by applying a coating of enamel or the like, when the wire is of small diameter or size, upon which the corrosive or chemical effects in general are most pronounced in the matter of permanent drift or increase in resistance.

A wound resistor, that in the form of a coil, is produced by winding the resistance wire, coated and/or wrapped, as and for the purposes herein described, upon a spool or support of ceramic or of metal insulated with enamel. The coil is then aged by holding it in an air bath for about forty-eight hours at a temperature of about 140° C. After cooling to room temperature, it is adjusted to its assigned value or magnitude of resistance. The coil is then heated in air to a temperature of about 75° C., momentarily dipped in molten wax such as ceresin or equivalent, at about 100° C., allowed to cool, and again momentarily dipped in the molten wax.

In the production of woven resistors, the resistance wire, enameled and/or wrapped with the covering of vegetable fibre or a mixture of animal and vegetable fibres, is woven with a warp of silk, cotton, or other suitable material; the woven resistor is then aged in air in an air bath for about forty-eight hours at a temperature of about 140° C. After cooling the woven resistor is then mounted upon its ceramic or other support, and adjusted to its assigned value or magnitude of resistance. The unit so formed is then dipped in the molten wax one or more times as described above in connection with coil type resistors.

Whatever the form of the resistor, whether coiled, woven or otherwise disposed, the joints, soldered or otherwise produced, are preferably thoroughly coated with enamel.

It having been found that in some cases a permanent change in resistance results from first exposure to high relative humidity such as 75 or 80%, the resistance thereafter becoming stable as regards humidity, the coiled or woven resistor may with advantage be exposed to a relative humidity of about 75% at room temperature for about three weeks, either before assigning or adjusting to its nominal or desired magnitude or value, or before installing the unit in a measuring instrument, bridge, potentiometer, or other precision circuit or system.

In accordance with my invention precision resistors or resistance units become available with a stability or constancy of resistance represented by less than .01% change in resistance due to humidity, and with a gradual upward drift in resistance at a rate of .001% or less per annum. It shall be understood, however, that my invention is not limited to these magnitudes, but is present when the variation in resistance due to relative humidity variations up to 75 or 80%, or for short periods up to about 90%, is less than .05%, commonly as little as .015%, and in some instances as low as .005%; and when the permanent upward drift or increase in resistance is less than .01% or .02% per annum.

When the resistance wire has a temperature coefficient of less than 10×10^{-6}, for sizes or diameters of .01 inch or less, and when corrodible having an enamel coating, and with a wrapping comprising predominantly natural vegetable fibre, there is procured a precision or high stability represented by a change of resistance of .025% and as low as .01% for a temperature variation of about 20° C. from usual or room temperature simultaneous with variations of relative humidity to approximately 80%, and including the slow permanent drift or increase in resistance.

For brevity in the appended claims the term "corrodible" refers to chemical effects in general, including corrosion; the term "fine", with relation to the size or diameter of the resistance wire, includes a diameter of .01 inch and much less; and the term "enamel" is generic to the enamels herein more specifically described and their equivalents.

What I claim is:

1. An unsealed precision resistor comprising a resistance conductor having low temperature coefficient, and means for reducing the changes of resistance of said conductor due to variations of humidity comprising a covering consisting of a mixture of natural vegetable fibre and animal fibre.

2. An unsealed precision resistor comprising a resistance conductor having low temperature coefficient, and means for reducing the changes of resistance of said conductor due to variations of humidity comprising a covering consisting of a mixture of natural vegetable fibre and a less quantity of animal fibre.

3. An unsealed precision resistor comprising a manganin conductor having a covering comprising a mixture of natural vegetable fibre and animal fibre.

4. An unsealed precision resistor comprising a manganin conductor, coated with enamel, and

having a covering comprising a mixture of natural vegetable fibre and a less quantity of animal fibre.

5. An unsealed precision resistor comprising a fabricated corrodible resistance conductor, having a temperature coefficient less than 500×10^{-6}, and having a covering of natural vegetable fibre, the whole impregnated with a chemically neutral wax, such as ceresin.

6. An unsealed precision resistor comprising a fabricated corrodible resistance conductor, having a temperature coefficient less than 500×10^{-6}, coated with enamel, and having a covering of natural vegetable fibre, the whole impregnated with a chemically neutral wax, such as ceresin, substantially free of conductor-corroding compounds.

7. An unsealed precision resistor comprising a fabricated corrodible resistance conductor, having a temperature coefficient less than 500×10^{-6}, coated with enamel and having a covering of natural vegetable fibre, and a non-hygroscopic support upon which the fabricated resistance conductor is mounted, the whole intimately covered with a chemically neutral wax, such as ceresin.

8. An unsealed precision resistor comprising a resistance conductor of corrodible material having a temperature coefficient less than 500×10^{-6}, and means for substantially eliminating permanent drift from the nominal value of said resistor comprising an enamel coating on said resistance conductor.

9. An unsealed precision resistor comprising a fine resistance conductor of corrodible material having a temperature coefficient of less than 50×10^{-6}, and means for substantially eliminating permanent drift from the nominal value of said resistor comprising an enamel coating on said fine resistance conductor.

10. An unsealed precision resistor comprising a corrodible resistance conductor having a temperature coefficient of less than 500×10^{-6}, means for substantially eliminating permanent drift from the nominal value of said resistor comprising a coating of enamel on said conductor, and means for enhancing the insulation resistance of said resistor without introduction of substantial variation of the value of said resistor from its nominal value for widely different humidities comprising a covering over said enamel and comprised at least predominantly of natural vegetable fibre.

11. An unsealed precision resistor comprising a corrodible resistance conductor having a temperature coefficient of less than 50×10^{-6}, means for substantially eliminating permanent drift from the nominal value of said resistor comprising a coating of enamel on said conductor, and means for enhancing the insulation resistance of said resistor without introduction of substantial variation of the value of said resistor from its nominal value for widely different humidities comprising a covering of natural vegetable fibre over said enamel coating.

12. An unsealed precision resistor comprising a conductor of manganin, and means for substantially eliminating permanent drift from the nominal value of said resistor comprising a coating of enamel on said conductor.

13. An unsealed precision resistor comprising a conductor of manganin, means for substantially eliminating permanent drift from the nominal value of said resistor comprising a coating of enamel on said conductor, and means for enhancing the insulation resistance of said resistor without introduction of substantial variation of the value of the resistor from its nominal value at widely different humidities comprising a covering of natural vegetable fibre over said enamel.

14. An unsealed precision resistor comprising a corrodible resistance conductor having a temperature coefficient less than 500×10^{-6}, means for substantially eliminating permanent drift from the nominal value of said conductor comprising an enamel coating, means for enhancing the insulation resistance of said resistor without introduction of substantial variation of the value of said resistor from its nominal value for widely different humidities comprising a covering over said enamel comprised at least predominantly of natural vegetable fibre, and a non-hygroscopic support upon which said conductor is mounted.

PAUL H. DIKE.