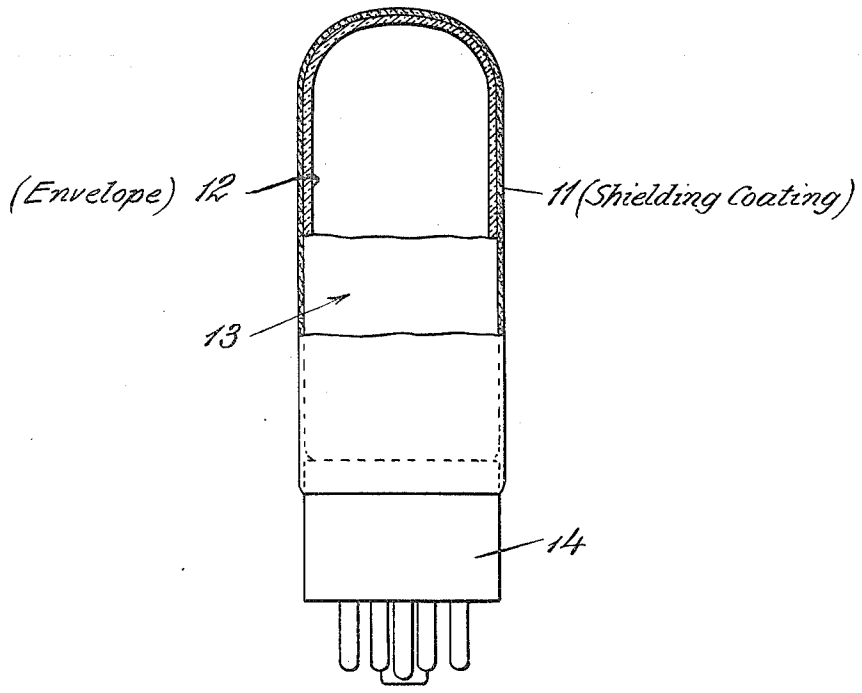
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SHIELDED RADIO TUBE

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SHIELDED RADIO TUBE

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This invention relates to shielded electronic tubes, and is particularly applicable to radio tubes.

For many applications, electronic tubes require shielding. This is particularly true in the case of radio tubes used, for example, in the radio and intermediate frequency circuits of a receiver.

For many years radio tubes were constructed almost entirely with glass envelopes. In recent years tubes with metal envelopes have been developed, and at the present time the two types are used more or less interchangeably. Each type possess certain advantages over the other. The metal tube, by virtue of its metal shell, is fairly adequately shielded. Also, metal tubes are sometimes considered to have the advantage of having smaller interelectrode capacitances. On the other hand, glass envelope tubes are usually easier to seal and evacuate. One reason for this is that elements in the tube can be effectively heated by induced currents so as to drive off adsorbed and absorbed gases. This cannot be done in metal tubes, so that reliance must be placed on the getter to maintain a high vacuum during use.

Glass tubes, particularly when used in radio frequency circuits, are often provided with external shields. Although the most common shield is a simple cylinder of metal, form-ftting shields are also employed. These form-fitting shields not only effectively shield the tube, but also have been found useful in decreasing interelectrode capacitance of electrodes within the tube. In such case, it is found that the spacing of the shield from the tube elements may be very important, and that a small increase in spacing may markedly change the interelectrode capacitance.

In accordance with the present invention, a coating composition is prepared containing finely-divided particles of electrically conductive material, for example, flake metal particles, in a suitable bonding medium or vehicle. A coating of this composition is then applied directly to the glass envelope of the electronic tube. The applied coating, which may be of high resistance, is then activated in accordance with the invention so as to reduce the resistance thereof to a value sufficiently low to serve as an effective shield.

In this manner the tube can be effectively shielded, and the spacing of the shield with respect to the elements of the tube can be rendered uniform and permanent. Thus a glass tube can be produced which has the advantage of a metal tube in being self-shielded, and also possesses the other desirable attributes of the glass tube. Furthermore, by having the shield affixed directly to the glass tube, savings in set manufacture can be effected since additional shields and the cost of assembling them may largely be dispensed with.

Activation of the applied coating is preferably carried out by direct electric treatment. High voltage, high frequency potentials are advantageously employed, but common direct or alternating current low-voltage potentials may be employed if desired. Such activation has been found especially useful since it can be employed with a wide variety of coating compositions. In some cases, however, activation by heating to a sufficient temperature and for a sufficient period has been employed with success.

The particular activation treatment selected will depend on the particular results desired, the character of the coating composition, and the conditions surrounding the use of the process. High-frequency high-voltage discharge activation has been found particularly advantageous since a low resistance coating may be obtained without substantial heating of the coating or the object surface, and only a relatively short period of activation is required.

In the present invention, the elements may be completely assembled and the envelope evacuated and sealed prior to the application of the coating composition. Thus the heating of the tube elements, as by induction means, during the evacuation thereof is not interferred with by the presence of a conductive coating over the envelope.

In general, it may be stated that the coating composition may be made with any suitably finely divided particles of an electrically conductive material dispersed in a bonding vehicle capable of being reduced to and applied in liquid form (for example, by solvents or by heat) and capable of being acted upon after application by electrical current or by heat to form with the particles a coating of substantially reduced resistance.

Generally the particles should be fine enough to be easily sprayable and to afford uniformly good coverage, but should not be so fine as to offer too high a resistance due to an abnormally increased number of contacts from particle surface to particle surface which a passing current must negotiate. There appears to be resistance to flow of current from each particle to the next particle due not only to the non-conductive

vehicle but also to a great extent to the condition of the particle surface itself, such as oxide films or adsorbed gases, etc. Electrical activation appears to have a tendency to burn and destroy the coating when excessively fine metal particles are employed.

The figure of the drawing shows a glass envelope radio tube, partly in cross section provided with a shielding in accordance with the invention.

The conductive shielding coating 11 is applied directly to the glass envelope 12 of the radio tube 13. The elements of the tube are omitted for the sake of simplicity of illustration. The tube is also provided with the usual base 14.

The high-frequency high-voltage activation treatment will be described first.

A coating composition is prepared containing finely-divided particles of an electrically conductive material dispersed in a binding vehicle. The coating composition is preferably liquid, so as to permit ready application, as by spraying, dipping, painting, etc.

The vehicle may be any suitable bonding vehicle. Nitro-cellulose lacquers, cellulose acetate, and similar bonding vehicles may be employed. For example, the lacquer sold under the trade name Du Pont No. 1130 has been found suitable. Also the lacquer sold as Du Pont No. 1907 has been employed with success. These are believed to be lacquers of the nitro-cellulose type. Synthetic resins, such as phthalic anhydride glycerol esters known as alkyd resins, glyptal, etc., may be employed if desired. Suitable solvents may be employed to render them liquid. Resins known under the trade name "Vinylite" may be employed. For example, such a resin used as a coating composition, containing vinyl chloride and vinyl acetate in a solvent, has been employed with success. Ordinary paint and varnish vehicles may be used with more or less success, as well as bituminous vehicles of the nature of fatty acid pitches, natural elastic bitumens, and the asphaltites (gilsonite, glance pitch and grahamite), rendered liquid by solvents thereof. Other suitable vehicles may be employed if desired.

In selecting the particular vehicle for a particular tube, the operating temperature of the tube should be kept in mind, and a vehicle chosen which will withstand the heating which occurs during use. Also, considerations such as durability and attractive appearance will be kept in mind.

Finely divided metals may be used for the particles of electrically conductive material. Copper flakes have been found advantageous since copper has relatively high conductivity and is relatively inexpensive, and is especially suitable for producing a coating of very low resistance, such as is desirable in a shield. Other metals in either flake or powder form, or both, may be employed if desired. For example, aluminum, a copper alloy sold under the trade-name "Tungum," nickel, a copper-nickel alloy, the alloy known under the trade-name "Monel" metal, stainless steel, or zinc may be employed with more or less success.

When applied to the glass envelope of a tube and air dried, these coatings commonly have very high resistances. To illustrate the order of resistances often encountered, the coating composition may be applied to a flat surface over a square 5 inches on a side. Such tests give resistances of the order of megohms across the square for the air dried coatings. Nevertheless, the resistance may be reduced to a very low value by the activation treatment. The actual value of the final resistance after activation varies with the different metals. When dispersed in Du Pont No. 1130 and with the high-frequency high-voltage discharge activation, resistances under 10 ohms across a 5-inch square have been obtained for all these metals, the resistance with aluminum (in flake form) being as low as approximately one ohm, and with copper approximately one-half ohm.

The coating composition is applied to the envelope of the tube and then activated. The activation is carried out by directly applying to the surface of the coating an electric current from a high-frequency high-voltage source. It is considered advantageous to allow the coating to dry completely before activation.

An edge of the applied coating is advantageously grounded, or placed near enough to a grounded object to permit the high-frequency high-voltage current to leak away. If the glass tube has a metal base and the coating composition is applied to overlap the metal base, placing the tube in a grounded metal socket is found satisfactory. Then the terminal of the high-frequency high-voltage source is passed over the coating in close proximity therewith so as to permit a discharge of current to the coating. It is found advantageous to have the terminal close to the coating, but slightly separated therefrom, and to move the terminal to and fro over the coating so as to cover substantially the entire area. However, the terminal may lightly contact the coating, if desired. A more or less continual sparking is noticed during treatment.

It will, of course, be understood that when the terminal of the high-frequency high-voltage generator is near to or touching the applied coating, particularly as the treatment proceeds, the actual voltage may be much lower than the maximum voltage which the generator is capable of producing, since the latter is usually based on the distance in air across which a spark may be produced.

Specific Example 1

The coating composition was prepared by mixing five pounds of copper flake powder No. 150 (all particles passing through a 150-mesh screen) and one gallon of Du Pont No. 1130 (believed to be a cellulose ester lacquer) until air carried in with the powder had escaped and the powder had been thoroughly wetted. Care was taken not to whip in air by the mixing propeller, as this would tend to thicken the mixture and necessitate thinning to facilitate proper spraying of the mixture. If necessary for smooth spraying, a small amount of thinner could be added.

The coating composition was sprayed in a thin coating over the glass envelope of a type 6SK7–GT tube, and was allowed to dry for a few hours at room temperature. This tube is of the type used in radio frequency and intermediate frequency circuits of radio receivers. The tube has a metal base which is grounded to one of the pins of the base. Therefore, the coating was sprayed to overlap the metal base, thus providing a convenient ground connection. The resistance from the top of the tube to the ground connection was found to be over a megohm (the maximum reading of the ohmmeter used).

The applied coating was then activated with the high-frequency high-voltage treatment. The particular generator used was one made by the Lepel High Frequency Laboratories, Inc., of New

York city, and called "Model E-2." This generator employs an oscillator of the quenched gap type and has an output rated at a frequency of approximately 2500 kilocycles, a maximum voltage to produce a spark approximately one inch in length, and a maximum current of 100 milliamperes, with an input rated at 110 volts, 60 cycles and 0.35 ampere. The generator terminated in a brush composed of a dozen or so short strands of wire.

In activating, the tube was placed in a grounded metal socket. Then the brush of the generator was moved back and forth over the coating endeavoring to treat all areas of the coating equally. The brush was held only a slight distance away from the coating, and sometimes touched the coating. A more or less continual, relatively slight sparking between brush and applied coating was noticed during treatment, but was not excessive. Care was taken not to burn the coating. The final resistance varied with the duration of the treatment, the resistance decreasing rapidly at first and then more slowly until a fairly constant value appeared to be reached. For a treatment of several minutes in the manner described in this specific example, a final resistance of less than an ohm between the top of the tube and the ground pin was obtained, the resistance in some cases being down to approximately one-half an ohm.

With more powerful high-frequency high-voltage equipment, and with refinement of the character and proportions of the coating composition and the thickness of the applied coating, even lower resistances may be expected for the same length of treatment, or the same resistance for a shorter treatment.

It should be understood that this particular high-frequency high-voltage generator is mentioned only by way of example, and that other suitable high-frequency high-voltage equipment may be employed if desired. Also, in commercial practice the apparatus may be designed and arranged in accordance with the particular conditions surrounding the use of the method so as to activate the applied coating in a manner suitable for commercial purposes.

A high-voltage generator of considerably lower frequency than the specific generator just described has also been found to give good results.

The electrical activation may also be carried out with either direct current or 60-cycle alternating current, and at low voltages, by directly applying the voltage to the coated surface. Two conductors, between which the low voltage is impressed, may be placed in contact with separated areas of the applied coating. In this manner the resistance of the coating may be markedly decreased. In order to make the entire area of the coating of relatively low resistance, one or both of the conductors may be moved over the surface of the coating.

Small balls of steel wool about one inch in diameter have been found suitable. Small flat terminals of copper or silver may be employed if desired. The conductors are connected to the power mains, preferably through a current limiting resistance. A voltmeter may be connected across the resistance to give an indication of the progress of the activation, or electric lamps may be employed to limit the current and the glow of the lamps used to indicate the progress of the activation. The mains may be 110-volt, 60-cycle alternating current or direct current, or 220 volts or higher if desired.

One or both conductors may be moved over the coating to reduce the resistance thereof. One procedure found effective to reduce the resistance over the entire area of the coating is to hold a steel wool ball in each hand (the balls having a taped grip to provide insulation), and simultaneously move the balls to and fro over the entire area with a dabbing motion, maintaining an approximate spacing of one inch between the balls.

As an example, two steel wool terminals about one inch diameter may be connected to a 220-volt direct current source through two 40-watt, 110-volt lamps in series. One or both terminals may then be moved back and forth over the coating for a few minutes, endeavoring to touch all parts of the coating. At first little or no current will flow across the coating, as indicated by the lamps staying dark, and the terminals may be brought fairly near to each other. At the finish, however, enough current will flow between extreme points of the coating to light the lamps brightly, substantially no dimming by the coating resistance being noticed.

As another example, steel wool balls may be connected to a 110-volt 60-cycle source through a 1500 ohm resistance. With the dabbing treatment just described, a low resistance may be obtained after a short treatment.

Reduction of resistance can be obtained by moving the terminals over the surface of the coating, maintaining the terminals in contact with the coating and maintaining a small separation between the terminals. However, the dabbing motion appears to give a greater decrease in resistance for the same length of treatment, and a lower final resistance. This may be due to a discharge current flowing when the dabbing motion is employed, since the electric circuit is made and broken by the dabbing, thus interrupting the current, although no actual sparks may be observed with low voltage and current such as results from the use of the 110-volt, 60-cycle source and the 1500 ohm series resistance.

The actual resistance obtained depends upon a number of different factors. In general, a metal having good electrical conductivity, such as copper, is desirable when a low resistance is wanted, as is the case in shielding a radio tube. Also, in general, increasing the quantity of metal for a given quantity of vehicle and increasing the thickness of the applied coating may be expected to give a lower resistance in the final coating, at least within limits. If too little metal is employed, a lower conductivity is obtained, as is to be expected. If too much metal is employed, the composition will be difficult to apply and adhesion may be poor. For economy, it is of course desirable to use the smallest quantity of the particular conductive material selected which will give the desired result with the particular activation treatment employed. After activation, the vehicle continues to bond the conductive coating to the underlying base.

As before stated, activation by heat treatment may be employed with many applied coatings. This may be accomplished by baking the applied coating on the base in an oven for an appropriate length of time and to an appropriate temperature. If desired, heating can be obtained by the careful application of a direct flame, as from a blow-torch. In such case the coating should be heated gradually to avoid blistering, and the torching should not be continued to an extent such that the vehicle is completely destroyed.

High-frequency induction heating could also be employed, if desired, with more or less success.

For the heat treatment, the vehicle should be sufficiently heat-resistant to withstand the heat treatment and form a non-blistered bonding residue to retain the conductive particles in position on the envelope. Applying the coating composition relatively thinly and raising the temperature gradually has been found helpful in avoiding blistering.

The heat-resistant bituminous organic compounds mentioned hereinbefore have been found suitable for this purpose. Heat-resistant lacquers or varnishes may also be employed. Lacquers having alkyd resins, vinyl resins or urea formaldehyde condensation products as bases are examples of such lacquers. If copper flakes are employed, they appear to have a tendency to oxidize if heat is applied, especially when used in a cellulose ester vehicle. Therefore, if a low final resistance is desired, it is advantageous to employ vehicles which will have the effect of retarding oxidation and which appear to serve as active reducing agents at the baking temperatures employed, thus tending to reduce any oxide films which may be originally present on the particles or which may tend to be formed and offer electrical resistance. The heating may also be carried out in a reducing atmosphere. It is considered advantageous to use heat-resistant organic compounds, such as pitch, or heat-resistant synthetic resins such as the phthalic anhydride glycerol esters known as alkyd resins, glyptal, etc. Upon the application of heat, these vehicles are converted to residues which retain the conductive particles firmly bonded to the base.

The duration and temperature of the heat treatment should be selected in accordance with the particular vehicle employed, the particular conductive particles used, and the electrical conductivity desired in the coating. The necessary temperature and duration of heating may be readily determined for any particular coating composition by placing an object coated with the composition in an oven whose temperature can be regulated, and slowly increasing the temperature while at the same time measuring the resistance across the coating. This measurement can be readily made by affixing leads to opposite sides of the coating and bringing the leads outside the oven to a voltage source. By measuring current through the coating and voltage across it, the resistance can readily be ascertained. Or, an indication can be obtained by connecting the leads to the voltage source through a current limiting resistance of appropriate size, and placing a voltmeter across the resistance.

If this is done, experience has shown that at low temperatures no marked decrease in resistance is obtained in general, but as the temperature is increased a point is reached at which the resistance begins to decrease quite rapidly. Generally, temperatures above about 500° F. have been found desirable, although with certain combinations of metal particles and vehicle somewhat lower temperatures may be employed. For example, with copper flakes in Vinylite resin, appreciable conductivity begins to develop within the range 350–400° F. On the other hand, with aluminum flakes in a cotton-seed pitch vehicle, no appreciable conductivity has been developed even after heating up as high as 900° F., possibly due to the highly inert and difficultly reducible aluminum oxide films on the multitude of aluminum flakes.

As an example of what may be obtained with the heat treatment, the following specific example will be given:

Specific Example 2

The vehicle is prepared by mixing 112 pounds of a hard, high-melting-point cottonseed-oil pitch with 15 gallons of orthodichlorobenzene and 75 gallons of coal tar naphtha. One gallon of this vehicle and 5 pounds of copper No. 150 are mixed and sprayed in a fairly thin coating on the glass envelope of the tube. The coated tubes are dried at room temperature and placed in an oven. Upon slowly heating from room temperature to 350° F. in one hour it is found that the coating still has a very high resistance, of the order of megohms. Upon heating from room temperature to 500° F. in two hours, the resistance of the coating markedly decreases but is still fairly high, of the order of thousands of ohms. Upon heating from room temperature to 625° F. in three hours, the resistance may be reduced to the order of an ohm.

At a temperature of about 500° F., the vehicle was converted to a bonding residue resistant to ordinary solvents of organic materials such as those suitable for initially preparing the coating composition. At the temperature of 625° F. the residue still remained and tenaciously adhered to both the metal particles and the underlying surface, retaining the particles in position.

Copper flakes in glyptal and a solvent, when applied and heated slowly to 625° F., has also given excellent conductivity. With both glyptal and cottonseed-oil pitch, a residue remains which firmly adheres the coating to the base.

Carrying out the heat treatment in a reducing atmosphere instead of in air is sometimes advantageous. For example, coatings of copper flakes in cottonseed-oil pitch or in an alkyd resin, when raised from room temperature to 625° F. in two hours in a mildly reducing atmosphere of 93 per cent nitrogen and seven per cent hydrogen, have given excellent conductivity.

In general, the bonding vehicle chosen should be such as will withstand the heat treatment necessary to produce the desired conductivity without being driven off or burned away and will retain its bonding ability despite that heat treatment.

As to the conductive materials which may be employed with the heat treatment, copper flakes have been found particularly suitable, and firmly adhering coatings of excellent conductivity have been obtained. Among other metals which may be used with more or less success, if desired are nickel and zinc. With these two metals, somewhat higher temperatures have been found desirable in order to obtain a low resistance. For example, in a vehicle of cottonseed-oil pitch, temperatures of about 700° F. or higher for nickel and about 800° F. or slightly higher for zinc, have been found advantageous.

The theory lying behind the various types of activation described herein has not been satisfactorily developed at the present time. It appears likely that both electrical and heat treatments act on the surface films, as well as on the bonding vehicle, by rupturing, heating or removal thereof, to thereby diminish the resistance, although this is not insisted upon. However, as described with proper activation it has been found possible to reduce the resistance of suitable coatings applied to a tube to sufficiently low values to effectively shield the tube, even though the

coating composition is made with a bonding vehicle of high electrical resistance and with metal flakes such as bronzing powders also offering resistance, in the form of a multitude of contact resistances due to surface films of one kind or another, and even though the applied coating be of high resistance prior to activation. In general, it is found at the present time that the electrical activation treatments, particularly the high-frequency high-voltage discharge treatment, is perhaps more widely applicable to coatings of more widely different types than the heat treatment.

It is contemplated that the conductive coating, activated either by electrical or heat treatment as described hereinbefore, will usually be used as the shielding element without further treatment. It will be understood, however, that further treatment may be employed if desired. Thus the activated coating may be used as a base for electrolytic deposition. Also, if desired, several coatings may be applied in superposition on the glass envelope of the tube. In the latter case, different coating compositions and different methods of activation may be employed for various ones of the plurality of coatings, if desired, or one or more coatings might be left unactivated.

The high-frequency high-voltage discharge activation treatment is especially advantageous since the coating can be applied and activated after the tube is completely assembled, or can be applied to the envelope after the elements have been mounted therein and the tube evacuated, but before the base 14 is affixed. By applying the coating after sealing and evacuation, the elements can be inductively heated without interference. Of course, the coating could be applied at other points during the course of manufacture of the tube if desired.

Although activation by heating can be employed if desired, the required heat may in some cases injure the elements of the tube, or adversely affect the getter. If the base of the tube is of a composition which will not withstand the necessary heating, the coating may be applied prior to affixing the base to the envelope.

The shield may be grounded in any desired manner. For example, a ring may be placed around the base of the coating and connected to ground. Or, the coating may be connected to one of the pins of the tube which in turn may be grounded. If a metal base is used for the tube, the coating may be connected to the metal base which in turn may be grounded. It is found that with thin coatings the resistance through the coating is sufficiently low to permit good grounding by making contact with the under surface of the applied coating, as in the case of a metal-base tube in which the coating overlaps the base.

Although envelopes of glass have been specifically mentioned, it is clear that the shielding coating may be of use in case envelopes of other materials which are nonconductive, or insufficiently conductive, are employed. Furthermore, although radio tubes are particularly mentioned, the invention can be used in the case of other types of electronic tubes requiring shielding, if desired.

It will be apparent that the present invention provides a shielded radio tube and the like, and method of producing the same, which is highly advantageous. Numerous changes in the details of the invention may of course be made without departing from the spirit and scope of the invention.

The method of producing an electrically conductive coating, and the product, per se, are claimed in co-pending application Serial No. 334,462, filed concurrently herewith.

We claim:

1. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a composition comprising finely-divided particles of an electrically conductive material and a bonding medium, and treating the applied coating with an electrical discharge current to substantially reduce the electrical resistance thereof, whereby a closely-adherent shield may be produced.

2. The method of shielding radio tubes and the like having non-conductive envelopes which comprises applying to the non-conductive envelope of the tube a coating of a coating composition comprising finely-divided particles of an electrically conductive material and a relatively non-conductive bonding medium, the applied coating being of relatively high electrical resistance, and directly applying current from a source of electric potential to the surface of said applied coating to reduce the electrical resistance thereof substantially, whereby a closely-adherent shield may be produced.

3. The method of shielding radio tubes and the like having non-conductive envelopes which comprises applying to the non-conductive envelope of the tube a coating of a coating composition comprising finely-divided particles of an electrically conductive metal and a relatively non-conductive bonding medium, the applied coating being of relatively high electrical resistance, and reducing the resistance of the applied coating to a relatively low value suitable for a shield by subjecting said applied coating to an electrical discharge current, whereby a closely-adherent shield may be produced.

4. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a coating composition comprising finely-divided particles of an electrically conductive material and a bonding medium, impressing an electrical potential on a conductor, and reducing the electrical resistance of the applied coating by placing said conductor in close proximity to areas of said coating to cause current to flow thereto, whereby a closely-adherent shield may be produced.

5. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a coating composition comprising finely-divided particles of an electrically conductive metal and a bonding medium, the applied coating being of relatively high electrical resistance, connecting a conductor in circuit with a source of electric energy and said applied coating to create a potential difference between said conductor and an area of said coating, and substantially reducing the electrical resistance of said area of the applied coating by placing said conductor in close proximity to said area to cause current to flow thereto.

6. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a coating composition comprising finely-divided particles of an

electrically conductive material and a bonding medium, the applied coating being of relatively high electrical resistance, connecting a conductor in circuit with a source of electric energy and said applied coating to create a potential difference between said conductor and an area of said coating, and substantially reducing the electrical resistance of said area of the applied coating by causing an interrupted current to flow between said conductor and said area.

7. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a coating composition comprising finely-divided particles of an electrically conductive material and a bonding medium, the applied coating being of relatively high electrical resistance, impressing a voltage between two conductors, and placing said conductors in close proximity to separated areas of said applied coating to cause current to flow and thereby substantially reduce the electrical resistance of the coating between said separated areas.

8. The method of shielding radio tubes and the like having non-conductive envelopes which comprises applying to the non-conductive envelope of the tube a coating of a coating composition comprising finely-divided particles of an electrically conductive material and a bonding medium, the applied coating being of relatively high electrical resistance, impressing a voltage between two conductors, placing said conductors in close proximity to separated areas of said applied coating to cause current to flow and thereby substantially reduce the electrical resistance of the coating between said separated areas, and passing at least one of said conductors over the surface of the applied coating to reduce the electrical resistance of substantially the whole of said surface to a value suitable for a shield, whereby a closely-adherent shield may be produced.

9. The method of shielding radio tubes and the like having non-conductive envelopes which comprises applying to the non-conductive envelope of the tube a coating of a coating composition comprising finely-divided particles of an electrically conductive metal and a relatively non-conductive bonding vehicle, the applied coating being of relatively high electrical resistance, impressing a voltage between two conductors, and treating the applied coating with said conductors in such a manner as to cause an electrical discharge current to flow to areas of said coating and thereby decrease the electrical resistance of said areas, whereby a closely-adherent shield may be produced.

10. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a composition comprising finely-divided particles of an electrically conductive material and a bonding medium, and substantially reducing the electrical resistance of the applied coating by directly applying thereto current from a high-frequency high-voltage source, whereby a closely-adherent shield may be produced.

11. The method of shielding radio tubes and the like having non-conductive envelopes which comprises applying to the non-conductive envelope of the tube a coating of a coating composition comprising finely-divided particles of an electrically conductive metal and a relatively non-conductive bonding medium, the applied coating being of relatively high electrical resistance, and directly applying over the surface of said coating current from a high-frequency high-voltage source to reduce the electrical resistance thereof to a low value suitable for a shield, whereby a closely-adherent shield may be produced.

12. The method of shielding radio tubes and the like having non-conductive envelopes which comprises applying to the non-conductive envelope of the tube a coating of a liquid coating composition comprising finely-divided particles of an electrically conductive metal and a relatively non-conductive bonding vehicle, said coating being applied to the tube after the evacuation and sealing thereof, allowing the coating to dry, the dried coating being of relatively high electrical resistance, treating said dried coating by directly applying thereto current from a high-frequency high-voltage source, the voltage and frequency of said source being correlated with the length of said treatment to yield a relatively low resistance suitable for a shield, whereby a closely-adherent shield may be produced.

13. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a composition comprising finely-divided metal particles and a bonding medium, and heating the applied coating to reduce markedly the electrical resistance thereof without destroying the bonding ability of said bonding medium.

14. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a composition comprising finely-divided metal particles and an organic bonding medium, and heating the applied coating to a temperature and for a period of time sufficient to reduce the electrical resistance thereof to a relatively low value suitable for a shield without destroying the bonding characteristics of said bonding medium, whereby a closely-adherent shield may be produced.

15. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of the tube a coating of a liquid coating composition comprising finely-divided particles of a metal of the type which acquires a film of one or more relatively non-conductive compounds of the metal and an organic reducing bonding medium, the applied coating when dry being of relatively high electrical resistance, and heating the applied coating to an elevated temperature and for a period of time sufficient to convert the organic reducing bonding medium to a non-blistered bonding residue and decrease the resistance at the surfaces of the metal particles to reduce the electrical resistance of the coating to a relatively low value.

16. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating of a coating composition comprising finely-divided metal particles and a bonding medium, the applied coating when dry being of relatively high electrical resistance, and heating the applied coating in a reducing atmosphere to a temperature and for a period of time sufficient to reduce the electrical resistance of the applied coating substantially.

17. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope

of said electronic tube a coating of a composition comprising finely-divided metal particles and an organic heat-resistant bonding vehicle, and heating the applied coating to a temperature in excess of about 350° F. and for a period of time sufficient to convert said organic bonding vehicle to a non-blistered bonding residue firmly bonding the conductive coating to the base and reduce the resistance of the coating to a relatively low value.

18. The method of shielding radio tubes and the like having non-conductive envelopes which comprises applying to the non-conductive envelope of the tube a thin coating of a liquid composition comprising finely-divided particles of an electrically conductive material selected from the group consisting of copper, nickel and zinc, and an organic heat-resistant bonding vehicle selected from the group consisting of fatty acid pitches, asphaltites, vinyl and alkyd resins, and solvent therefor; and gradually heating the applied coating to a temperature in excess of about 350° F. and for a period of time sufficient to convert said organic bonding vehicle to a non-blistered bonding residue and reduce the electrical resistance of the coating to a relatively low value suitable for a shield, whereby a closely-adherent shield may be produced.

19. A shielded electronic tube which comprises an envelope of substantially non-conductive material and an electrically conductive shielding coating adherent thereto, said shielding coating being formed by an electrically-treated applied coating of a coating composition comprising finely-divided particles of an electrically conductive material and a bonding medium, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value by the direct application thereto of current from an electric potential source.

20. A shielded electronic tube which comprises an envelope of substantially non-conductive material and an electrically coductive shielding coating adherent thereto, said shielding coating being formed by an electric-discharge-current treated applied coating of a coating composition comprising finely-divided particles of an electrically conductive material and a bonding medium, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value by the application thereto of an electric discharge current.

21. A shielded radio tube or the like which comprises an envelope of substantially non-conductive material and an electrically conductive shielding coating adherent thereto, said shielding coating being formed by an electric-current-treated applied coating of a coating composition comprising finely-divided metal particles and a bonding vehicle, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value suitable for a shield by the direct application to areas of said coating of current from an electric potential source.

22. A shielded electronic tube which comprises an envelope of substantially non-conductive material and an electrically conductive shielding coating adherent to the external side of said envelope, said shielding coating being formed by a high-frequency high-voltage electric-discharge-current treated applied coating of a coating composition comprising finely-divided particles of an electrically conductive material and a bonding medium, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value by the direct application to areas of said coating of a high-frequency high-voltage electric discharge current.

23. A shielded radio tube or the like which comprises an envelope of substantially non-conductive material, a base of conducting material, and an electrically conductive shielding coating adherent to the external side of said envelope and overlapping said base, said shielding coating being formed by an electric-discharge-current treated applied coating of a coating composition comprising finely-divided particles of an electrically conductive material and a bonding medium, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value suitable for a shield by the application thereto of an electric discharge current.

24. A shielded electronic tube which comprises an envelope of substantially non-conductive material and an electrically conductive shielding coating adherent thereto, said shielding coating being formed by a heat-treated applied coating of a coating composition comprising finely-divided metal particles and a bonding medium, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value by said heat-treatment without destroying the bonding ability of the bonding medium.

25. A shielded radio tube or the like which comprises an envelope of substantially non-conductive material and an electrically conductive shielding coating adherent thereto, said shielding coating being formed by a heat-treated applied coating of a coating composition comprising finely-divided metal particles and an organic bonding vehicle, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value sufficient to form an effective shield and the bonding vehicle converted to a bonding residue by said heat-treatment thereof.

26. A shielded electronic tube which comprises an envelope of substantially non-conductive material and an electrically conductive shielding coating adherent thereto, said shielding coating being formed by a heat-treated applied coating of a coating composition comprising finely-divided particles of an electrically conductive material selected from the group consisting of copper, nickel and zinc and an organic heat-resistant bonding vehicle selected from the group consisting of fatty acid pitches, asphaltites and heat-resistance resins, which coating composition in dried form is of relatively high electrical resistance, the electrical resistance of the applied coating being reduced to a relatively low value and the bonding vehicle converted to a bonding residue by said heat-treatment thereof.

27. The method of shielding an electronic tube having a non-conductive envelope which comprises applying to the non-conductive envelope of said electronic tube a coating composition comprising a fluid organic bonding vehicle and finely-divided particles of a metal of the type

of copper, nickel and zinc which acquires a film of one or more relatively non-conductive compounds upon exposure to the atmosphere, the applied coating being initially of relatively low conductivity, and heating the applied coating to a temperature sufficiently high and for a period sufficiently long to effect a reaction in the coating composition so as to alter the electrical characteristics of the metal particles and produce a relatively highly conductive coating without destroying the bonding medium, whereby a highly-conductive closely-adherent shield may be produced.

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