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REDUCTION OF ARCING BETWEEN ELECTRODES IN A CATHODE RAY TUBE BY CONDUCTING COATING OF RESISTANCE MATERIAL ON INNER WALL OF TUBE NECK

Filed July 30, 1964

FIG. 2

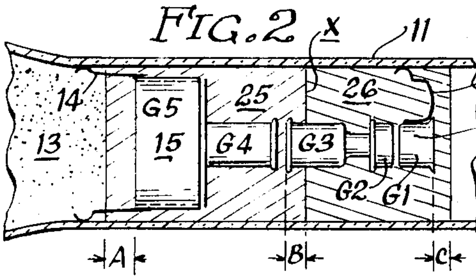
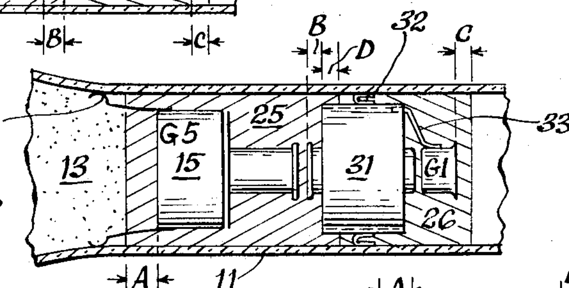


FIG. 3



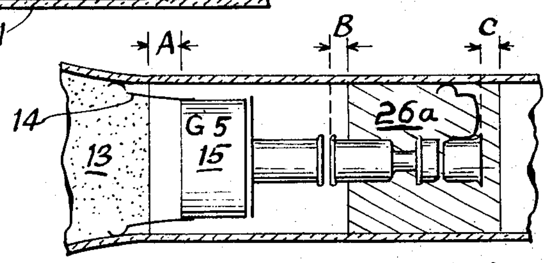


FIG. 4

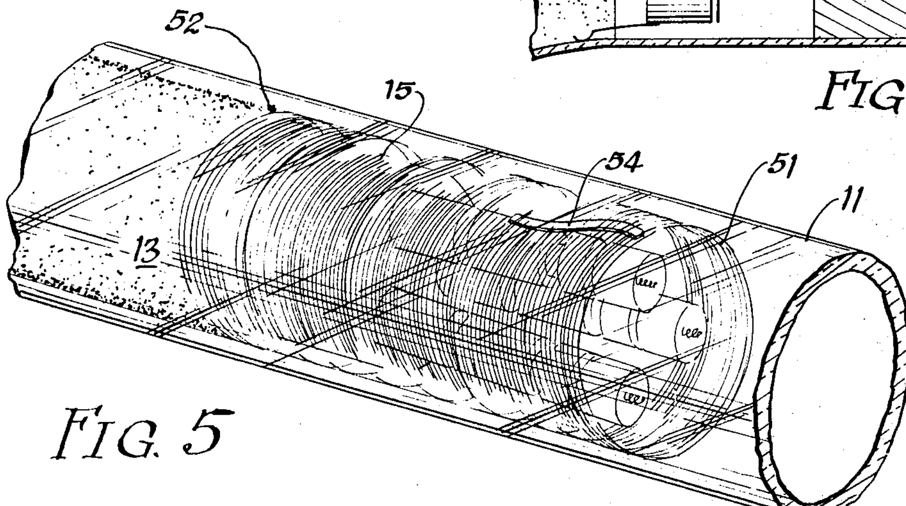


FIG. 5

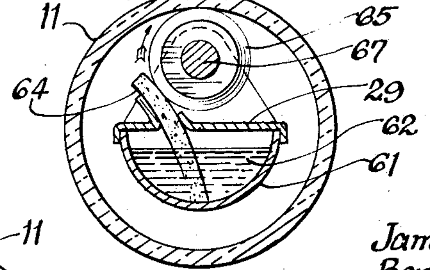


FIG. 6

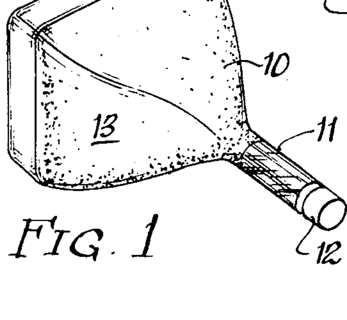


FIG. 1

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REDUCTION OF ARCING BETWEEN ELECTRODES IN A CATHODE RAY TUBE BY CONDUCTING COATING OF RESISTANCE MATERIAL ON INNER WALL OF TUBE NECK

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ABSTRACT OF THE DISCLOSURE

A highly resistant electrically conductive film comprised of iron and manganese oxide is disposed on the walls of the neck of a cathode ray tube adjacent the final anode of the electron gun assembly and coextensive therewith. A second conductive coating having less resistance than the film is joined to the film and is disposed around the neck of the tube adjacent to and coextensive with the electrodes of the gun which are at a potential lower than the final anode. The film is electrically connected to the higher potential final anode, and the coating is electrically connected to the lower potential electrodes so that the voltage drop between the film and coating and the electron gun assembly is essentially zero.

This invention relates to means for neutralizing tendency to arcing between the elements of an electron gun as used, for example, in a kinescope. Although the foregoing statement is in terms of one environment in which the principles of the invention may be embodied, the invention may be more broadly recited as the provision of a slightly conducting layer on or adjacent to the wall of that portion of the envelope which is generally coextensive with an electrically conductive element or assembly thereof, e.g., an electron gun. In the latter case some member of the group has a lower potential and some other member has a higher potential, although the principles of the invention are applicable to the case when only a single element or electrode is at a potential sufficiently high to cause arcing to another conductive portion of the tube. Depending upon the degree of vacuum, the composition and topography of the gun parts and inner surface of the vessel opposite the assembly and the electric potential, arcing may occur. Such arcing is generally evidenced as a brilliant white flash in the affected zone.

In television picture tubes, the recent trend has been to higher voltage at the last accelerating electrode for increased picture brightness, say as high as 24,500 volts above ground. Furthermore, the trend has been to greater deflection angles for the horizontal scan, say to 120°, which in turn, requires smaller neck diameters and therefore reduction in the spacing between the elements of the gun and the interior surface of the neck.

It is well understood that, to minimize arcing, the interior neck surface extending from the terminus of the funnel Aquadag—(trademark of Acheson Colloids Company for their brand of colloidal graphite in water) to the base should be meticulously clean. Mechanical scouring of this surface by the use of a brush and abrasive powders has been resorted to, as well as an acid wash, both of which have yielded results far from satisfactory. If some minute portion of the surface has impurities then electron impact is evidenced as a bluish island in that vicinity. Such impurities may result during operation of the tube, for example, when an arc caused to be formed between burrs, sharp edges or corners of or on components of the gun deposits vaporized metal particles on the glass, nothwithstanding steps taken to eliminate burrs and the like sharp discharge lines or points from such components.

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Stray conduction, in which electrons impinge upon the neck surfaces adjacent to the electron gun, is particularly conducive to the initiation of an arc discharge. Unless the secondary emission ratio at the impinged area is exactly unity its potential will change due to an accumulation (or depletion) of charge (electrons). At glancing angles of electron impact many insulators such as glass tend to exhibit ratios markedly in excess of unity. The impinged point then charges to a higher potential causing a greater attraction for primary electrons. This leads to a regenerative situation where sufficiently high fields and stray conduction occurs whereby gaseous ions are generated and arcing across the electrodes commences. The rather large current incident upon the path of the arc may cause serious damage to the gun parts.

Leakage due to actual or incipient arc discharge is, in the case of color tubes in particular, equivalent to the presence of deflecting plates opposite the gap between G3 and G4, whereby spurious deflection of a beam or beams may occur and proper convergence of the beams at the screen be adversely affected. The invention, by minimizing and controlling the potential gradient between the gun and envelope, and along the envelope surface, avoids this problem.

The present invention proposes to eliminate the interior surface of the glass as a potential source of the difficulties aforesaid by interposing an active circuit element between the gun and neck. Such element comprises an electrically partially-conductive element preferably in the form of a layer or film applied to the surface of the envelope in a predetermined zone calculated to establish, in cooperation with the element or elements capable of initiating the arc discharge, a current path of high resistivity whereby a controlled surface potential may be established. Thus, a potential at some transverse plane of the gun which would otherwise serve as a source of stray emission at a lower potential "sees," instead, a substantially equal potential interposed between it and the envelope. Accordingly, since the space is bounded by essentially the same potential arcing is precluded. The layer is desirably continuous from one end to the other regarded axially of the gun assembly and in the form of a cylinder or helix. One end of the partially-conductive element is connected to the gun at a point of some chosen low potential and the opposite end to a point of some chosen higher potential. Stated otherwise, the interposition of the partially-conductive element provides a controlled potential gradient along the neck surface and minimizes the field which would otherwise exist between areas of or on the glass and the gun.

Another object of the invention is to provide the conductive means referred to in the preceding paragraph by spraying, "painting," or otherwise depositing the same on the interior surface of the neck in an area generally coextensive axially with that element or element of the gun which, but for the conductive means, represents a possible source of arcing. The conductive means is characterized in that the same will not run during application, will, upon drying, become a tenacious, permanent film able to accept end terminals and to withstand such friction as may be created as the gun is inserted in the neck; it being understood that at least the forward end of the gun is provided with resilient fingers locating the same coaxially with the neck.

A further object resides in providing the interposed conducting means as a conductive helix supported on or secured to, the interior surface of the glass as contrasted with the "painted," sprayed or otherwise applied layer just referred to.

An additional object resides in providing a conductive film, preferably continuous, over that portion of the interior of the neck whereat the potentials due to the elements of the gun are likely to induce arcing, and the connection of the forward and rearward edges thereof to high and low potentials respectively, in order to establish a gradually increasing potential across the axial extent of the film corresponding substantially with the potential measured along the generally coextensive length of the gun, in order that only a very small field will subsist between the film and gun in any transverse plane.

Another object resides in providing such film of a composition which will yield the desired voltage drop from end to end by the application thereof in the form of an exceedingly thin, uniform film applied to the glass.

A further object is to provide a film as aforesaid, together with a contiguous or overlapping edge portion of greater thickness to which electrical connection may be more readily made.

Another object is to provide a film as aforesaid characterized by a plurality of thicknesses from one end to the other whereby the conductivity, and therefore the voltage drops therealong may be predetermined at specific peripheral zones thereof, and in which each zone may be of different composition for variation in conductivity.

Still another object is to provide a conducting layer for the purpose aforesaid which will not draw current of a value tending to overload the power supply to which the several electrodes of the gun are connected.

A further object of the invention is to prevent a regenerative buildup of stray emission to the neck walls of the kinescope.

A further object is to provide a surface coating for the neck of the kinescope which exhibits very low electron emission.

A further object resides in providing conductive means to neutralize the tendency to arcing in the neck region of the tube which will permit greatly increased sparking voltages when the tube is subjected to a break-down test following assembly thereof.

Another object is to provide conductive means for the purpose mentioned which may be incorporated with the neck portion of the tube envelope prior to its assembly with the funnel portion thereof and which will withstand the high temperature to which the assembly is subjected in uniting said portions without degradation of the conductive means.

It will be understood that, where herein, reference is made to "conductive means" the words are intended to have a relative meaning. In practice, the resistance thereof is high in order to obtain, in a relatively short conductor, a relatively high drop in voltage corresponding essentially with the difference between the highest and lowest voltages at which different electrodes of the gun are operated.

Other advantages of the invention will become evident from the ensuing description which, taken with the accompanying drawing discloses a preferred form of embodying the invention in practice.

In this drawing:

FIG. 1 is a perspective view of a typical configuration of cathode ray tube as adapted to the reception of television transmission;

FIGS. 2, 3 and 4 are somewhat schematic representations of a neck portion of a television picture tube, as in FIG. 1, enclosing a triple electron gun assembly as used in the N.T.S.C. (National Television System Committee) color system, the electrodes of two of the guns being omitted for clarity, although G5 is shown. The differences in the three figures constitute alternative embodiments of the electrically conductive means;

FIG. 5 is a somewhat enlarged view of the neck of the tube of FIG. 1, with the base portion thereof broken away to illustrate a further embodiment; and

FIG. 6 is a transerse cross-section through the neck to show part of an implement capable of use in applying the conductive means of FIG. 5

Broadly regarded, the invention comprehends the provision in a cathode ray tube in a zone generally coextensive with the axial extent of the element or elements capable of initiating arcing, e.g., an electron gun, of conductive means having its ends connected respectively to points of high and low potential of the gun. It will be understood that the words, "high" and "low," are employed in this specification as relative terms and that the potentials utilized are such as to achieve the principal object of the invention, namely, neutralization of the tendency of an arc to form between an element or elements of the gun and/or the interior surface of the neck. In a preferred form, the conductive means includes a resistance element which is applied to the interior surface as a liquid which, when dried, possesses a sufficiently high electrical resistance and, therefore, substantially provides the desired voltage drop between its ends. By "desired voltage drop" it is intended to comprehend a drop which is essentially the same as that subsisting between the points of highest and lowest potential of the gun, say from 25,000 volts to 500 volts at the respective ends. Moreover, by virtue of the thus specified drop, the conductive means will be incapable of passing current of a value which will cause excessive heating or overload the power supply. The liquid employed will be characterized by rapidly drying to a permanent film tenaciously adherent to the glass, and of a iscosity precluding gumming during application and yet not so fluid as to run whereby to yield a non-uniform layer. In order to establish the required potentials at the ends of the conductive film, the ends of the element are electrically connected to the corresponding potential points of the gun by means of straps capable of being connected to such ends by pressure contact or by adhesive means which are also desirably of an electrically-conductive nature. In the case of a helical film, short-circuiting between adjacent turns of the helical element may be avoided by striking a suitable compromise between the voltage drop per turn and the voltage drop between any given turn and the neighboring portions of the gun.

Commercial production of television picture tubes has demonstrated that, using optimum techniques, potential difference between the gun and neck will not cause arcing. However, the procedures required are expensive and depend upon utmost skill on the part of the operatives. Obviously this represents an idealized situation not easily realized in practice. Moreover, the present tendency is towards substantially increased maximum electrode voltage. For example, a tube for color television according to the N.T.S.C. System currently operates with a drop from ultor to cathode (of each gun) of 25,000 volts. ("Ultor" is an accepted term referring to the final anode.)

In accordance with the invention, the conductive means may be applied to the neck as a disconnected component and this latter fused to the funnel, or the neck may already be part of the tube. In either event, the neck or tube, as the case may be, may be supported to rotate the axis of the neck whereby to permit uniform application of the film to the surface of the glass without skipping or variation in cross-sectional area.

Thus, referring to FIG. 1, there is shown, by way of example, a television receiving tube including a funnel **10** merging into a neck **11** terminating in a base **12** which carries the plurality of terminal prongs (not shown). In accordance with common practice, the interior of the funnel and a forward portion of the neck is coated with colloidal graphite (Aquadag) **13** with which the high voltage input terminal (not shown) makes contact. The electron gun is conventionally provided with a plurality of resilient fingers **14** to press against the Aquadag whereby the high voltage, say 25,000 volts, is applied to the appropriate electrode **15** (G5) of the gun, and G4 (sometimes termed the "ultor"). These fingers **14** also assist in centering the gun on the axis of the neck. As mentioned and for illustrative purposes, the gun shown in phantom in FIG. 5 is of the three-color type, but it will be understood that the gun could equally be of the monochrome type. Moreover, the terminals extending from the gun to the base are omitted for clarity. All of the features just alluded to are well understood in this art and have been recited in order to set forth a typical environment in which the principles of the invention may be carried into practice. It is to be recalled that the gun assembly of FIGS. 2, 3 and 4 is shown schematically and that the same may be as in FIG. 5.

Adverting to FIGS. 2, 3 and 4, the gun electrode **15** will, in the example, operate at approximately 25,000 volts with respect to the cathode and grid **21** (G1) at approximately 400 volts, or a difference of approximately 21,000 volts. Thus, in order to obviate arcing, the invention contemplates the interposition between the glass neck and the electrode assembly, or selected portions of the latter, of a conductive, yet highly resistive film or layer. In order to avoid points in the film whereby the beneficial effects thereof are adversely affected, it is important that the film be free of particles which would otherwise act as emission points, it being remembered that density of the field at a pointed electrode varies inversely as the radius of the point. Accordingly, a fluid vehicle containing resistive particles is to be avoided. Additionally, the material of the film should possess the lowest possible rate of secondary emission under bombardment by electrons emitted from the components of the gun. In addition to causing a regenerative positive charging of the secondary emission arcs, electrons may serve as a conductive connection between the gun and film and therefore would tend to provide a path for the initiation of arcing. A further desired characteristic of the film is a high degree of adherence to the glass. Obviously, the silicates, such as sodium or potassium silicate, would provide suitable vehicles for a highly resistive particulate substance, and similarly with regard to certain ceramic cements. However, these vehicles are known to be readily emissive in both a primary and secondary sense. It is also necessary that the film, following de-gassing of the tube, be incapable of further emission of gases, in order that the hardness of the tube, following sealing off, remain relatively unaffected. Nor should the film be capable of electrical breakdown at the highest potential to which it may be subjected.

The conductive film is preferably applied in liquid form by spraying. To this end the tube is supported with the axis coaxial with the nozzle of a spray gun or the like, whereby the liquid is deposited on the glass as a mist. Obviously suitable masks are employed to limit the two end boundaries of the applied film. A suitable mask is a thin, flat, axially slit, resilient cylinder snapped into the neck of the tube with its ends overlapping. To provide utmost uniformity of thickness of the film either the tube or the nozzle is reciprocated axially and/or both relatively rotated.

Experiments have demonstrated that the most suitable substances for the conductive film are of the P-type (as such terminology is used with reference to semi-conductors). In fact, the conductive element comprehended by the present invention, being of a highly resistive nature, may also be justifiably referred to as a semi-conductor. In the foregoing connection, it is recognized that P-type materials have very low rates of primary and secondary emission.

Further referring to FIGS. 2, 3 and 4, the conductive layer is applied to the inside of the neck **11** continuously around the circumference thereof, and extends from the Aquadag **13** to a line X which is rearwardly of the forward end of G3 (Dimension B). The area is cross-hatched with lines inclined downwardly from right to left (not only in this figure but in FIGS. 3 and 4). A coating **26** merges with film **25** at the line X and continues slightly beyond G1 (Dimension C).

In one preferred embodiment, the layer or film **25** is applied as an aqueous solution having the following formula:

$Fe(NO_3)_3 \cdot 9H_2O$	g	0.58
$Mn(NO_3)_2$ (51% sol.)	ml	28
H_2O	ml	200

During baking, the water is driven off and the nitrates are decomposed to yield a tenacious durable film which consists esentially of the oxides of iron and manganese, the resistance per square whereof is on the order of 10^9 to 10^{12} ohms. (Resistance per square is defined in The Encyclopedia of Electronics, Rehinhold Publishing Corporation, New York, 1962, at page 721.) If desired, the glass may be heated during spraying in order to set the film and avoid running.

Although the preferred formula just specified includes the nitrates of the metals, other soluble metallic salts are within contemplation such as the hydroxides, chlorides and sulfides.

In general, it may be stated that at least one component of the solution is a good electrical conductor and the other one is relatively poor. Thus by varying the proportions of each, a film may be achieved which possesses the optimum resistance per square.

In the example of FIG. 2, the conductive coating **26** (shown by cross-hatching downwardly from left to right) has the formula:

$Fe(NO_3)_3 \cdot 9HO$	g	10
H_2O	liter	1

providing a resistance per square of several thousand ohms. Electrical contact of this coating to a point of low potential is effected by means of a resilient finger **29** extending from G1 and pressing against the coating. Alternatively, the coating **26** may be Aquadag.

From the foregoing it will have become apparent that the film **25** provides a path of high resistance having a decreasing potential distribution along its length from the potential of G5 to the potential of G1, or from say 25,000 volts to 400 volts. Accordingly, considering any transverse plane through the film **25** the several electrodes "see" a substantially equivalent potential at the glass and the potential difference which otherwise would have been responsible for arcing has been eliminated.

In the example, and assuming a configuration of electron gun per FIG. 1, R.C.A. specifications for the 21CYP22 picture tube (Radio Corporation of America, Harrison, N.J., published May 1957), the dimensions A, B and C are ¼", ⅛" and ⅛" plus or minus $\frac{1}{16}$" more or less. It will be noted that C represents an extension of coating **26** beyond the rear end of **G1**.

The foregoing embodiment is characterized in that the film **25** is coextensive axially with those electrodes operating in the range of higher potentials, namely, G5, G4 and G3 or from say 25,000 volts to 6000 volts, any lower potentials being disregarded as not apt to give rise to arcing. It will be observed that the coating **26** serves to join film **25** to the mechanical terminal **29** and, for that purpose, may be somewhat thicker than the latter and that, for this purpose, the latter will overlap or be overlapped by, the former.

The embodiment of FIG. 3 may be regarded as analogous to that of FIG. 2 except for the interposition of a cylindrical sleeve **31** concentric with the axis of the neck and there located and retained by a plurality of resilient spacers **32**. In this case the sleeve is put at ground potential or operated at the most negative potential available at the gun. The latter alternative is best realized by means of an electrical connection between the sleeve **31** and G1, e.g., a jumper **33**. A sleeve of this character provides electrostatic isolation of the coating **26** where this is characterized by the inclusion of particles providing high concentration of electrostatic stress and therefore sparking, for example, when Aquadag is used. Although grounding of the Aquadag would provide an equivalent result this presents some operational problems. The sleeve is generally coextensive with those components of the gun which operate at sufficiently high potentials as to induce sparking at the "points" of the Aquadag. The sleeve should extend forwardly slightly beyond the junction of films **25** and coating **26** but not so far as to extend into a region where the potential of film **25** is of high value nor so little beyond such junction that leakage may cause a significant field capable of initiating arcing in the region of the coating **26**. In this embodiment B indicates the rearward displacement of the forward edge of the sleeve **31** from the forward face of G3 while D indicates the position of the plane of merger between layers **25** and **26** with respect to the forward edge of the sleeve. In this example A and C have the same significance as before. Specifically, $A=\frac{1}{4}''$, $B=\frac{1}{8}''$, $C=\frac{1}{8}''$, $D=\frac{1}{8}''$, with tolerances as previously mentioned.

The embodiment of FIG. 4 involves the use of a single resistive coating on the neck wall. Its purpose is to prevent the potential of wall sections adjacent to low voltage gun parts from rising to excessively high levels which are capable of causing excessive emission of the gas, and eventual arcing. The regenerative tendency heretofore referred to, is one in which a small amount of stray emission from a low voltage gun electrode strikes a portion of the neck, thereby liberating secondary electrons which then travel toward, and are collected by a high voltage gun electrode. If more electrons are liberated than strike the surface, the secondary emission ratio is such as to exceed unity.

In such case, the area impinged upon will become more positive due to depletion of negative charges. This will create a higher voltage in the vicinity and more electrons will be attracted to that area of the neck. More electrons striking mean more electrons leaving, and the creation of an even more positive potential area on the neck. The potential of the area so affected may rise by many thousands of volts.

The ever increasing current and striking energy of the stray electrons in this region of the neck may cause the liberation of gas which may then become ionized whereby to serve as a path for the initiation of an arc discharge within the neck space. One method of preventing this type of regenerative (run-away) situation is to control the surface potential of the neck, as in the previous embodiments.

The embodiment of FIG. 4, however, provides such control over only a limited region, i.e., normally only adjacent to the low voltage gun members. Negation of the regenerative condition may be realized by preventing electrons from striking the neck. In FIG. 4 this is accomplished by making the neck area adjacent to the low voltage electrodes at least as negative as that of any electrode. The fields between this neck region and adjacent gun electrodes will then be such as to repel the electrons and whereby essentially none will actually impinge on the neck in the coated region.

Since the rearward end of the cathode is apt to emit electrons, the coating portion **26***a* is similar to coating **26** in FIGS. 2 and 3 and serves as an effective suppressor of this and other sources of stray emission.

In the example of FIG. 4, the dimensions are: $A=\frac{1}{4}''$, $B=\frac{1}{8}''$ and $C=\frac{1}{8}''$, with the tolerances similar to those heretofore given.

In any of the foregoing embodiments and those to be referred to hereinafter, it is within contemplation to apply separate films to the conventional glass supports whereby the several electrodes of the gun are supported, on the basis that such supports may function much in the same manner as the glass constituting the neck of the tube. The formulation of the resistive film and the application thereof to these supports will generally follow the principles laid down in connection with the neck of the tube.

It will be apparent that other formulations for the film **25** may be employed, for example, soluble salts of iron and titanium in proportions such as would yield resistance per square on the order of from 10^9 to 10^{12} ohms. However, it has been found that, in many cases, the change in resistance is extremely sensitive to variations in the mix and therefore extreme care must be taken to main the predetermined proportions. This is particularly the case for the salts of iron and titanium where a 2% change in the proportion of titanium to iron results in a change of resistance per square by a factor of three or more.

FIGS. 5 and 6 relate to an alternative embodiment where the conductive means comprises an element **51** of high resistance in accordance with the broad concept heretofore set forth. In the present case the element **51** is preferably applied to the interior surface of the neck in the form of a helix having an axial length generally coextensive with the length of the gun or some predetermined portion thereof whereat arcing has been found to present a problem. More specifically expressed, the ends of the helix should, in general, be substantially opposite those portions of the electron gun whereat the highest and lowest potentials exist. Since G4 is at the highest potential, one end of the helix will be opposite or slightly beyond, in a forward-looking sense those portions of the gun which are effectively at the same potential as G4. Since, as will appear, the pitch of the turns of the helix should be a maximum consistent with other considerations, a preferred termination of the helix would be opposite the distal end of the fingers **14** which contact the Aquadag. If such termination is to be desirably short of the Aquadag, then a strap or similar device may be employed between the forward end of the helix and G4, or a part electrically joined thereto. By way of example, FIG. 5 shows the forward termination of the helix merging with the Aquadag at **52**.

The opposite end of the element **51** is positioned opposite some suitable point of low potential which, but for the element **51**, could give rise to arcing. While a point of lowest potential of the gun could be utilized, such connection would give rise to a greater voltage drop over the length of the element **51** and corresponding difficulty because of the greater drop between turns and danger of arcing or breakdown as to the element per se. Consequently, it is preferred to connect the rear termination of the element to **G3** which, in the R.C.A. gun heretofore referred to, operates at a potential of 4,500 volts. The connection may be made by means of a strap **54** secured to G3 and pressing against or united with, the termination of the helix. Such latter termination may be connected in any suitable fashion, either by rendering the strap resilient to bear on the termination or by means of an adherent substance, e.g., Aquadag.

A preferred mode of applying the element **51** is by painting a helix of appropriate cross-section, coefficient of resistivity and effective length as will yield a safe value of current and substantially the required voltage drop. Any known electrically-conductive fluid having the required characteristics will serve, provided that the same retains a substantially uniform viscosity for flow from the painting implement onto the glass, will withstand the friction of the forward resilient fingers of the gun as this latter is inserted in the neck, will resist the baking temperature necessary to set the helix and any higher temperature to which the neck is subjected during processing subsequent to application thereof; and which will not deteriorate as the tube ages.

A preferred mode of applying the helix is indicated in FIG. 6 wherein a reservoir **61** holds a quantity of suitable "paint" **62**. A wick **64** bearing on an applicator wheel **65** transfers the paint to the periphery thereof. A fixed rod **67** supports the wheel **65** for free rotation and the reservoir is freely suspended on the rod **67**. The periphery of the wheel will be such as to be frictionally rotated by contact with the neck, this latter being rotated while supported in a cradle in any well-known manner. Means (not shown) such as a lead screw and a nut secured to the rod **67**, are provided to advance the wheel, reservoir, etc. at a constant rate corresponding to the pitch of the helix. Thus, as the neck and wheel rotate in synchronism, the paint is fed from the reservoir onto the neck to produce the helical element. A gentle flow of air into the neck while applying the paint will avoid condensation of volatile components of the paint. Following completion of the element, the applicator means is retracted radially inwardly of the tube neck and withdrawn, whereafter the still moist element may be baked to a solid consistency.

As alluded to hereinbefore, in the present case and in any of the other embodiments, the element may be applied to a separate neck section, baked and the section attached to the funnel of the tube or the same may be applied where the neck is already a part of the tube.

If the power supply serving the electron gun is of such character that connection of the low potential end of the element to **G3** is contra-indicated, as for example, by reason of unavoidable variation in cross-section in the helix, it is within the scope of the invention to extend the helix rearwardly and to connect that termination to a point of lower potential or even to ground.

As one specific embodiment of the invention as applied to the 21CYP22 tube, a total length of helix of 2¾″ is selected and calculated to provide a drop of say 20,000 volts, i.e., 24,500 volts at **G4** and 4,500 volts at G3. The drop per inch will then be

$$\frac{20,000}{2.75}=7300$$

volts per inch, approximately. Assuming a practical width of each turn of the helix as 0.010″ spaced apart 0.010″, or a pitch of 0.020″, the turns per inch will be 50, or a drop per turn of

$$\frac{7300}{50}=146$$

volts. Sparking between turns at this voltage in vacuo is not likely but, as a precaution, insulation may be added in the form of say ferric oxide (Fe_2O_3) in a suitable vehicle.

It will be evident that the cross-sectional area of the element and the coefficient of resistivity will be so related to the voltage drop over a predetermined total length of helix as to provide a safe value of current. Assuming a value of current of 5 μa. and a drop from end to end of 20,000 volts, the total resistance will be 4000 megohms. Inasmuch as the width of the helix has been assumed to be 0.010″ and its thickness will, as a "painted" helix, be of an even lesser order, its power dissipation will be low.

It is within contemplation to provide the element as a helix wound of suitable wire and to cement the same on the inner surface of the neck. In such case the relatively flimsy helix may be supported on a temporary cage pending setting of the adhesive. Such cage could be of a collapsible nature in order that, when the adhesive has set, the cage could be collapsed radially for removal. Obviously, the cement will be of a composition which will not give rise to deleterious gases when the tube is subjected to later steps at high temperatures or, even if this should occur, any gas which may be generated will be substantially completely removed upon evacuation of the tube, and any residue captured by the getter.

Where, herein, reference is made to a difference of potential between points of high and low potential the same is intended to have a purely relative meaning depending upon the structure which, relative to the envelope, and in the absence of the invention improvement, may give rise to arcing. Depending upon the use to which the tube is put, such difference in potential may range from approximately 10,000 volts to 50,000 volts.

While we have shown particular embodiments of our invention, it will be understood, of course, that we do not wish to be limited thereto since many modifications may be made and we, therefore, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of the invention.

We claim:

1. In combination with an evacuated tube including an envelope having a neck portion and an electron gun positioned in the neck portion to provide a beam of electrons for impingement on a target forming part of the tube, the gun comprising a plurality of electrodes, one of which operates at some lower potential, the neck portion including an interior surface portion adjacent the electrodes, the spacing between the electrodes and the surface portion and at least one of the potentials both being such that incipient arc discharge between a first point of one electrode and a second point of another electrode may occur, the improvement comprising means to neutralize arcing including: an electrically conductive film having a relatively high resistance applied to the surface portion of the neck substantially adjacent the electrode of higher potential, a conductive coating having a resistance lower than said film, said coating applied to the surface portion of the neck substantially adjacent the electrode of lower potential, said film and said coating contacting each other and being substantially coextensive with the electron gun, said film being electrically connected to the higher potential electrode and said coating being electrically connected to the lower potential electrode, whereby the voltage drop between said film and coating and the electron gun is essentially zero.

2. The combination in accordance with claim **1** wherein the resistance of said film in relation to its thickness and the length between its ends is such that current flow is a minimum consistent with a controlled potential distribution along its length.

3. The combination in accordance with claim **1** wherein the difference in potential between the higher and lower potentials is in the range of from 10,000 to 50,000 volts.

4. The combination in accordance with claim **3** wherein the film includes iron oxide and manganese oxide in such proportions as to provide a resistance per square of from 10^9 to 10^{12} ohms, and said coating includes iron oxide having a resistance substantially less than said film.

5. The combination in accordance with claim **1** further characterized by an electrically conductive sleeve shielding the electrode operating at a lower potential and being intermediate said coating and the electrode, said sleeve being electrically connected to said coating.

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