Fig. 1

Fig. 2

Fig. 3

Fig. 4

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ELECTRICALLY HEATED ARTICLES

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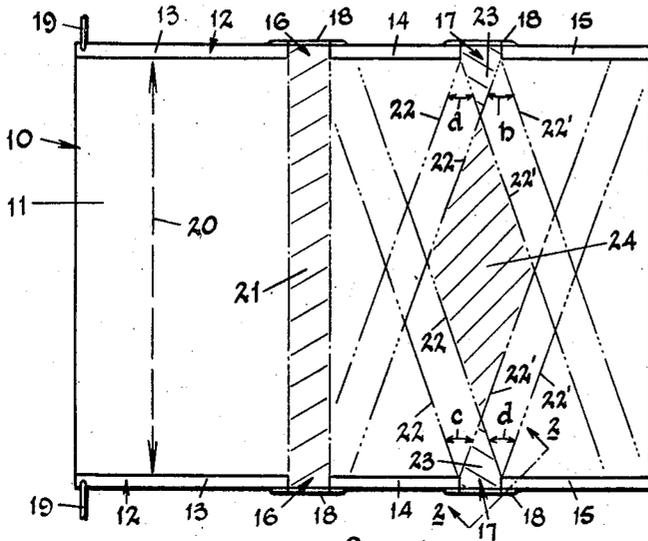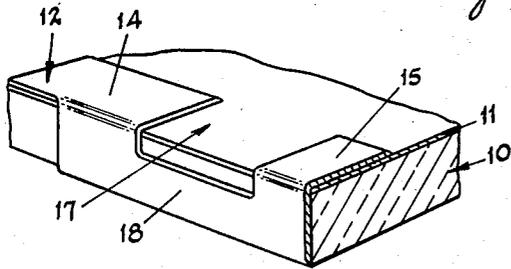
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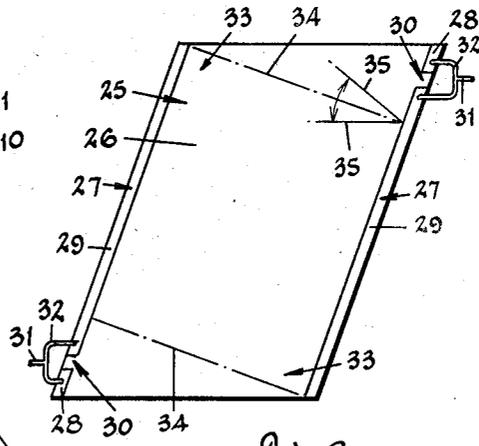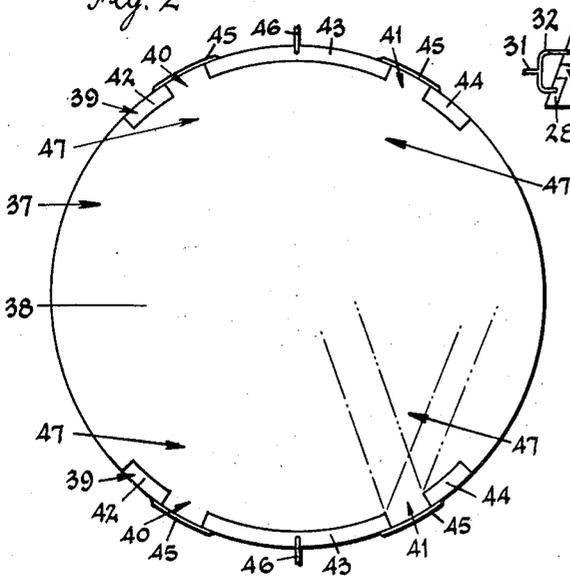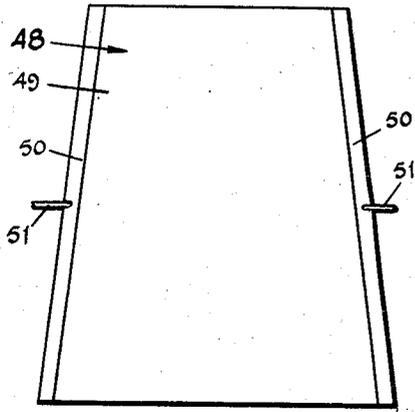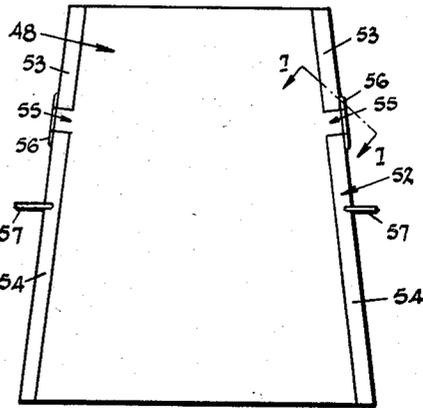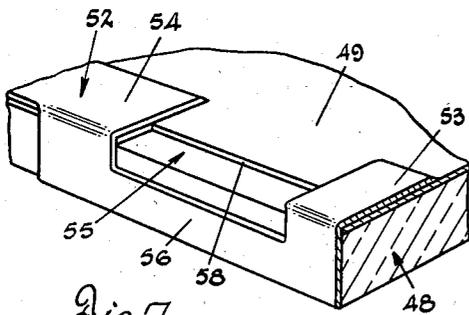
Fig. 6

Fig. 7
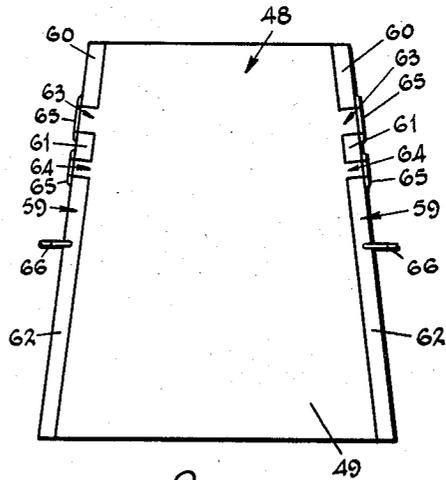
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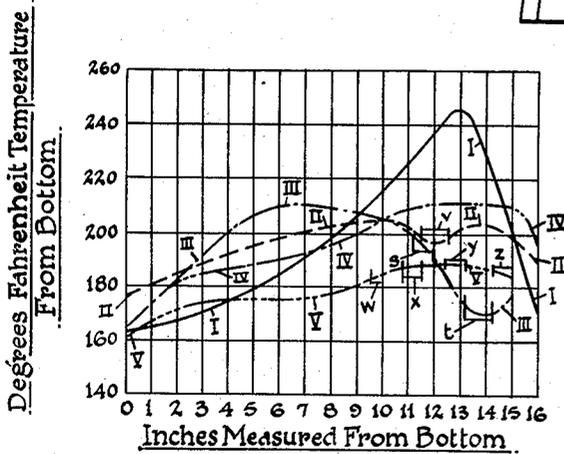
Fig. 9

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This invention relates to the control of power to electrically conductive coatings, and more particularly to the control of power to coatings on vehicular windows, instrument windows, and/or optical parts.

It is customary to place electrically conductive coatings on vehicular windows, instrument windows and the like so that the surfaces thereof may be heated to reduce or prevent fogging and icing effects. These electrically conductive coatings may be transparent coatings or opaque coatings of a metal such as gold, or of a metal oxide such as the well-known coatings of tin oxide or other metal oxides which are formed upon heated glass by the use of metal salts.

While coatings of the above type may be placed on articles of various shapes, it has been found that when the article deviates from a square or rectangular shape, the flow of current between bus bars on opposed edges of the article tends to be uneven and the coating is heated unevenly. For example, with shapes such as trapezoids having bus bars on the slanted vertical edges thereof, it is obvious that the narrow end provides an easier passage for the current because of the shorter distance between the respective bus bars. Consequently, because of the higher current concentration at the narrow end, the trapezoid heats to a higher temperature at the top than at the wider or base portion thereof. Similarly, articles circular or oval in shape are such that they do not heat evenly when opposed pairs of bus bars or electrodes are applied along their edges. While various expedients have been tried to alter the current flow within such odd shapes, they have generally been unsatisfactory and it has become customary to restrict such electrically conducting articles and windows to rectangular shapes on which two continuous electrodes are employed along two opposed edges thereof.

According to this invention, the uneven heating effects noted above may be substantially corrected or eliminated by providing articles having an electrically conductive coating thereon with a system of discontinuous or sectional opposed pairs of bus bars. These bus bar sections are spaced by open or cut-out areas and are tied together electrically either by common electrical leads external to the article, or by the application of jumper-type high-conducting areas or coatings applied either to an edge of the glass or as a connection between the bus bar sections upon the surface of the article where they are not in contact with the electrically conductive coating. By locating the open areas between the bus bar sections opposite areas in the conductive coating where the current flow is normally too great when continuous bus bars are employed, it is possible to restrict the current flow into these coated areas and thereby prevent overheating from occurring in these areas.

Thus, it is a primary object of the invention to provide bus bar elements formed of electrically connected discontinuous sections to control the electrical current flow in electrically conductive coatings.

Another object of the invention is to provide a means

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of controlling the flow of electric power within the surface of an electrically conductive article by suitable alignment of opposed bus bar elements which are composed of a multiple number of sections.

A still further object of the invention is to provide a means of securing substantially even-heating and uniform power application over electrically conductive coating on non-rectangular articles.

Other objects and advantages of the invention will become more apparent during the course of the following description when taken in connection with the accompanying drawings.

In the drawings wherein like numerals are employed to designate like parts throughout the same:

Fig. 1 shows a rectangular window which has bus bar elements placed upon its two opposed longitudinal edges which are divided into three sections and spaced from one another by open areas or cut-out areas;

Fig. 2 is a fragmentary perspective view of a portion of a bus on the window of Fig. 1 taken substantially along lines 2—2 thereof;

Fig. 3 shows a coated article, skewed or rhomboid in shape, on which the opposed pair of bus bar elements each have a notch or cut-out area therein opposite an area on the other bus bar where there normally would be a concentration of current and excessive heating;

Fig. 4 shows a coated circular article which has a pair of opposed curved bus bar elements thereon each of which is notched in two places to control the current flow and the heating pattern within the coating;

Fig. 5 shows a coated window trapezoidal in shape on which there are placed two opposed continuous bus bars in a manner as is customary in the production of such coated articles;

. Fig. 6 shows a trapezoid similar to that of Fig. 5 having opposed bus bar elements thereon each of which are notched to form a discontinuous bus bar element of two sections;

Fig. 7 shows a fragmentary perspective view of the window and notched bus of Fig. 6 taken substantially along lines 7—7 thereof showing one manner of connecting the bus bar sections together;

Fig. 8 shows a trapezoid similar to those of Figs. 5 and 6 which is provided with two cut-out or notched sections in each of its bus bar elements; and

Fig. 9 is a graph showing the effect of notches on the heating characteristics of various trapezoids which were connected to the same type power supply.

It will be realized that the flow of electric current within an electrically conductive surface coating which is substantially uniformly thick will be related, in the case of odd shapes, to the distance between the bus bars, and as such distances vary, the areas lying between the bus bars where they are closer together will tend to have a greater current flow due to the shorter electrical path. The overall electrical resistance of a given shape may be determined by an ohmmeter, and with simple shapes, it may sometimes be calculated if the resistance per square area of the electrically conductive coating is known.

Electrically conductive coatings of thin transparent gold are available in a range of conductivity of from 15 to 30 ohms per square, and electrically conductive coatings of tin oxide may be easily secured on glass in the range of 60 to 150 ohms per square. By way of indicating what is meant by the term "ohms per square," it will be apparent that if a coating of 30 ohms per square is placed on a one-inch square piece of glass, there will be an electrical resistance of 30 ohms for the entire area when continuous bus bars are placed on two opposite edges thereof. It will be appreciated that for any given square area, the electrical resistance is found to be the same when

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the coating is uniformly thick. For example, if four coated squares are arranged in what amounts to a series connection by applying bus bars to a 1″ x 4″ coated piece with continuous bus bars along the one-inch edges thereof, the resistance of the piece using the same coating is found to be four times thirty or 120 ohms.

On the other hand, if the continuous bus bars are applied to the same 1″ x 4″ coated piece along the longitudinal edges thereof, the four one-inch square areas provide parallel electrical paths, and the electrical resistance will now be found to be one fourth the resistance of a single square area (¼ x 30) or 7.5 ohms for the piece. However, in a coated 2″ x 2″ square piece which has the same four square units and same total area of four square inches, it is found that when bus bars are applied to the opposite edges that the 2″ x 2″ square has the same electrical resistance as the one-inch square, or thirty ohms. It therefore becomes apparent that the electrical resistance in a thin coating is a function of shape as well as area, and is particularly affected by the location of the bus bars upon a given piece.

In view of the relationships presented above, it will be realized that the flow of electrical current within a thin conductive coating formed upon a surface such as glass is controlled by the electrical resistance of the coating and is in accordance with Ohm's law. Specifically, Ohm's law states that the electrical resistance in ohms (R) in the article to which current is applied is equal to the voltage applied to that article (E) divided by the current (I) in amperes which flows in the article or

$$I = \frac{E}{R}$$

On the other hand, it is well known that the heating effect of an electrical current in an electrically conductive coating is directly related to the power applied thereto per unit of area, which power is equal to the watts or product of the voltage and the amperage within any given area. This may also be expressed in another way in that the degree of heating in any given area is proportional to the product of the current flow within the area squared times the resistance to the flow in that area.

Thus, the generation of higher temperatures in the top of the trapezoid, such as shown in Fig. 5, using the ordinary continuous bus bars is to be expected when power is applied to the trapezoid. In this case, the voltage drop through each sectional square area of the coating near the apex would be larger and the current flow in each of these sections would be expected to be greater. The voltage drop through similar square sectional areas near the base of the trapezoid would be less than the voltage drop through a similar square sectional area near the apex end. Consequently, the power applied to any given square area is larger in the apex since both the voltage and the amperage factors are larger in the apex portion of the trapezoid, and thus, the apex area becomes heated to a much greater degree than does the base. It is understood of course that the overall voltage drop between the bus bars is substantially the same at all locations on the opposing bus bars.

As noted hereinabove, the present invention is concerned with controlling and restricting the degree of current or amperage flow in odd shaped coated areas such as in the trapezoidal sections just described where the current flow in certain areas is greater than desired. From the relationship set forth above that the product of the square of the current flow and the resistance measures the heating, it is evident that as the current flow is reduced in a given area, that the heat generated therein will be immediately decreased. In this connection it will be noted that the invention does not attempt to change the resistance within any given area as compared to any other given area, and is concerned generally with articles

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having a substantially uniformly thick electrically conductive coating thereon of uniform resistance per square.

According to the invention, the bus bar sections are placed opposite areas into which current flow is desired and open areas are provided between such bus bar sections in a way to resist current flow into areas where less power per unit of area and less heating is desired. These open or cutout areas in the bus bar elements operate to restrict the current flow in the coating even when the electrically conductive coating extends into and covers the open areas between adjacent bus bar sections. It appears that the current is not concerned with taking any longer paths between the two opposing bus bar elements than is necessary and apparently little if any current flows into such open coated sections between the adjacent bus bar elements, even when the electrically conductive coating is in electrical contact with portions of the spaced bus bar sections. Thus, the coated areas between adjacent bus bar sections carry little of the current from bus section to bus section.

In this connection, it will be apparent that for such conditions to prevail, that the electrical conductivity of the bus bar sections, and of the bus bar connections between such sections or of any external electrical leads tying together such sections, must be of a relatively higher degree of electrical conductivity than the electrically conductive coating so that there will be little current flow in the coated area between the bus bar sections. It has been found that bus bars need be only 1/16 to ¼ of an inch wide and only a few thousandths of an inch thick to carry twenty amperes of current. The various bus bar sections employed therefore may be quite narrow and may be thin stripe-like coatings or thin sectional strips of metal pressed against the coated surface.

Suitable bus bar coatings may be made by the use of gold, silver or platinum coatings fired on by the methods used in the ceramic trades, or of a silver metallic flake dispersed in a polymerizable polyester resin base. Such bus bars may show an electrical resistance of 0.01 ohm per square which is relatively low as compared to the electrically conductive coatings employed in the invention which for example may be within the range of 10 to 150 ohms per square and higher. The bus bar sections may also be of relatively thick gold, silver, copper, aluminum, or platinum of approximately 500 to 1000 Angstrom units thick applied by thermal evaporation, electroplating, or other means.

In the preferred form of the invention there is provided a direct connection or jumper between the various bus bar sections which is formed of the same bus bar material as are the bus bars but does not touch or contact the electrically conductive coating in the areas between the said bus bar sections. Through these connecting strips of bus bar material between the bus bar sections, most of the current flows, and the strips or ties operate to form a unitary bus bar element to which a single external lead may be connected. The bus bar connections together with the areas where the electrically conductive coating lies between and in contact with adjacent bus bar sections thus provide parallel electrical circuits. However, in the parallel circuits thus formed, the flow in the coating between bus bar sections is only a small fraction of the total current flow between the adjacent bus bar sections, the fraction of amount of current being related to the relative electrical resistance of the two paths of flow. As a result, the flow through the coating between the adjacent bus bar sections is very small and areas between the bus bar sections may be completely free of the electrically conductive coating if desired.

In the manufacture of electrically conducting articles it is convenient in many applications to apply metallic electrically conductive coatings by thermal evaporation in a high vacuum over an entire surface of the glass; the same is true if a metal oxide is to be applied to the

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glass by spraying, fuming, or dipping procedures upon the hot glass with metal salts.

While it is generally undesirable to have the sum total of the bus bar sections of one bus bar element of a different length than those of an opposed bus bar element because of power concentration effects along the shorter bus bar element, it is however not necessary that the bus bar sections and the open areas therebetween be located opposite each other along the two opposed bus bar elements although this is a preferred form in most cases.

As an illustration of one use of the bus bars of the invention, it has been found that due to edge cooling effects and the concentration or piling up of current flow paths, that large rectangular coated areas tend to heat to higher temperatures in the central portion thereof than do the coated areas near the edges of the article. By means of the discontinuous bus bar sections provided herein, it is possible to decrease the current flow within the central coated area and thus directly control the heating pattern of the coating.

For a specific illustration, reference is made to Fig. 1 of the drawings wherein there is shown a rectangular window 10 of considerable size having an electrically conductive coating 11 thereon on which two opposed bus bar elements designated generally by the numeral 12 are placed along the edges thereof. The bus bar elements are each subdivided into three sections 13, 14 and 15 by small notched or cut-out areas 16 and 17 placed therebetween to restrict the amount of current flow in the central portion of the rectangular coated areas, the cut-out areas 16 being located between the bus bar sections 13 and 14, and the cut out areas 17 being located between the sections 14 and 15.

The electrically conductive coating 11 is placed over the entire area of the rectangular window 10 and each of the bus bar sections 13, 14 and 15 are in direct contact with the said coating. Each of the respective bus bar sections are connected to one another in jumper fashion by segments 18 of the bus bar material which extend along the edge surface of the sheet or plate and into contact with the said bus bar sections as will be seen in Fig. 2. Thus, when power is applied to the bus bar elements 12 by means of leads 19 the current will flow along the bus bar section 13, and thence across the jumper area 18 bridging the cut-out area 16 to the bus bar section 14, from where it will flow to the bus bar section 15 by means of another jumper 18 which bridges the cut-out area 17. Of course, since the bus bar elements are of a relatively higher electrical conductivity that the electrically conductive coating 11, the current will first travel through the bus bar before it will pass to the opposite bus bar element through the electrically conductive coating.

Heretofore, it has been generally assumed that the electrical flow within an electrically conductive coating, such as shown in Fig. 1, generally followed the shortest straight line path between opposed bus bars, or in other words, a direct path as illustrated by dotted line 20 of Fig. 1. This being the case, it would be expected that the crosshatched portion of the coating 11 indicated by the numeral 21 between the cut-out areas 16 would have no current flow therein and would not be heated when power was applied to the bus bars 12. However, this is not found to be the case unless the cut-out sections in the bus bar elements are quite large. It has been found that while the current flows to a considerable degree along a straight path which is perpendicular to the bus bar elements, as indicated by the line 20, that the current is also subject to a spreading effect as it moves outwardly from each and every point on the bus bar elements. This spreading effect has been found to be confined to a conical angle which approximates a 40 degree spread, centered for example on the dotted line 20.

For purposes of illustration, there is shown in Fig. 1,

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particularly adjacent the cut-out areas 17, a series of dotted lines 22 and 22' which illustrate the above mentioned angular spreading effect of the current flow from any one point on the bus bar elements across the electrically conductive coating 11. The angles defined by each pair of dotted lines 22 and 22' are indicated by the letters a, b, c and d. It will be apparent from the showing in Fig. 1 that the two cross-hatched areas 23 directly in front of the notched areas 17 and also the diamond shape area 24 in the central portion of the window will have very little current flow therein. That is, the current flow in such areas will be at a lower density than that found in other portions of the coating which are not influenced by cut-out or open areas in the bus bars. By locating the open areas in the bus bar elements directly opposite one another, the heating in the central portion of the coating may thus be uniformly controlled.

The amount of temperature change in any specific area may be controlled by increasing or decreasing the size of the openings or cut-out areas between the respective bus bar sections. In this connection, it has been found that the longer the cut-out areas between the bus bar sections, the greater will be the effect, and that open areas between the bus bar sections of less than ¼ inch in length have little if any effect upon the current flow and heating pattern. On the other hand, cut-out or open areas greater than ½ inch in length have considerable effect, with the most desirable results being obtained when the cut-out areas are between ½ and 1½ inches long. The open or cut-out areas within the bus bar elements are thus generally placed at points along the bus bar elements opposite and in alignment with an area within the central portion of the coated article wherein less power should be delivered and wherein less heating is desired.

While the discontinuous bus bar elements of the invention may be used to assure the uniform heating of an electrically conductive coating, it will also be apparent that the bus bar sections may be employed to produce controlled uneven heating effects in such coatings. If this is desirable, the open areas between the bus bar sections would possibly be as long or longer than the length of the respective bus bar sections. However, in general, where it is desired to secure even heating within a coating, the lengths of all of the open spaces or cut-out areas between the bus bar sections will be relatively small as compared to the total length of all of the bus bar sections forming the bus bar element.

An alternate use of the bus bars of the invention is illustrated by Fig. 3, wherein there is shown a piece of glass 25, rhomboid in shape, which has an electrically conductive coating 26 over its entire upper surface on which there are bus bar elements 27 upon two opposing edges thereof. The bus bar elements 27 are divided into two bus bar sections 28 and 29 which are spaced from one another by cut-out areas 30. Power is supplied to the respective sections by leads 31 which are connected to jumpers 32 bridging the cut-out areas 30 of each of the bus bar sections. The cut-out areas 30 are placed opposite areas of the coating indicated generally at 33 which generally heat unevenly because of the concentration of current paths in such areas caused by the uneven shape of the rhomboid. Since the current coming from the bus bar elements tends to flow primarily in a straight line perpendicular to the bus bar elements as indicated by the dotted lines 34, and also within a conical angle as described hereinabove and indicated by the dotted lines 35, it will be evident that by providing the cut-out areas 30 between the bus bar sections opposite the hot-spot areas 33, that the current flow therein may be reduced and the coating thus heated substantially uniformly over its entire area.

In Fig. 4 there is shown a circular window member 37 having an electrically conductive coating 38 thereon, which for example may be a gold coating having a re-

sistivity of 20 ohms per square. Two opposing bus bar elements 39 are placed upon the conductive coating and are provided with cut-out areas 40 and 41 which divide the bus bar elements into sections 42, 43 and 44. The respective bus bar sections are tied together by jumpers of the bus bar coating 45 in a manner similar to that shown in Fig. 2. Power is supplied to the bus bar elements and coating by means of leads 46. This arrangement of bus bar sections allows the conductive coating 38 to be heated substantially uniformly which was not the case when continuous bus bar elements were used because of the tendency of the current to build up in the areas indicated at 47 adjacent the bus bar elements. It has been found that the provision of these small open or cut-out areas 40 and 41 between the bus bar sections of approximately ¾ of an inch in length opposite the areas 47 provides a means whereby the current concentration and the heat can be controlled.

In Figs. 5, 6 and 7 there are shown views of three similar trapezoidally shaped windows 48 having an electrically conductive coating 49 thereon. The window of Fig. 5 has continuous bus bar elements 50 placed along opposite edges thereof as has been customary in past practice and which have attached thereto power leads 51. Because of the narrow upper portion of the trapezoid, it has always been difficult to secure uniform heating of the window since the current tends to concentrate at the upper portion as a result of the shorter conductive path across the conductive coating 49 afforded between the bus bars 50 at that end.

In Fig. 6 there is shown a similar trapezoid 48 with discontinuous bus bar elements 52 thereon which tend to somewhat eliminate the over-heating effects which are usually prevalent along the upper portion of the trapezoid when the continuous bus bars as shown in Fig. 5 are used. In this instance, bus bar elements 52 are placed upon opposed edges of the trapezoid and are divided into two bus bar sections 53 and 54 by cut-out or open areas 55. Jumpers 56 tie the said bus bar sections together and power is supplied thereto by leads 57.

As will be noted in Fig. 7 the electrically conductive coating 49 does not extend to the edges of the trapezoid in the areas lying between the bus bar sections as indicated at 58. However, it should be pointed out that the extension of the electrically conductive coating to the edges of the trapezoid does not adversely affect the results obtained by the cut-out areas since the conical or spray effect of the electrons does not allow the electrons to move through the conductive coating between the cut-out areas to adjacent bus bar sections. This is clearly shown in Fig. 1 where the coating 11 was extended to the edge of the window, but the current flow was restricted to the area within the angular path lines 22 and 22'.

A further improvement in the uniform heat control of a trapezoidally shaped window can be obtained by placing additional cut-out or open areas in the bus bar elements opposite the high temperature areas as is illustrated in Fig. 8. As shown therein, the bus bar elements 59 placed on opposite edges of the trapezoid are divided into three bus bar sections 60, 61 and 62 by cut-out areas 63 and 64. The respective bus bar sections are connected together by jumper strips of bus bar material 65 in a manner similar to that shown in Figs. 2 and 7. Power is supplied to the bus bar elements 59 by leads 66 connected to an external source not shown.

An indication of the effect that the cut-out areas of the discontinuous bus bar sections have on odd shaped articles will be apparent from the following examples given hereinbelow.

Example I

Five trapezoidal shapes somewhat similar to Fig. 5 were cut out of plate glass. Each of the trapezoids was

18.44 inches measured vertically between the top and bottom edges and the area of each was 1.58 square feet upon which there was applied an electrically conductive transparent coating of gold 45 Angstrom units thick. The gold coating was deposited upon an adhesive thin film of a transparent metal oxide which was previously deposited as shown in U. S. Patent 2,628,927.

The first trapezoid had continuous bus bars applied to it similar to those shown in Fig. 5 which were screen-printed as continuous strips using a high concentration of metallic silver flake dispersed in a polymerizable polyester resin. The application of the bus bars to this piece and the other pieces was by the use of suitable silk screens conforming to the desired bus bar patterns. Where the bus bar coating was applied to the edge of the glass it was readily applied thereto by a suitable roller or pressure-fed striper. After the application of the bus bar coating to this piece and the other pieces described hereafter, the pieces were placed in an oven and heated at a temperature of between 250° to 450° F. for a suitable time to cause the resin to polymerize and to cause the bus bar thus produced to adhere to the electrically conductive coating thereunder and to the glass.

When the coated trapezoid thus formed was supported upon corks in free air and a voltage of 50 volts was applied to the bus bars by suitably attached leads, there was found to be a current flow of 3.12 amperes and an electrical resistance of 16 ohms. The total power thus applied to the piece amounted to 156 watts, or 99 watts per square foot. After the piece had thus been heated for approximately one hour, the surface temperatures were determined by a surface pyrometer at various positions along a central line measured from the bottom of the trapezoid to the top. The temperature in degrees Fahrenheit thus determined are indicated by the solid line graph I shown in Fig. 9. It will be noted that there is a continuous rise in temperature from the base of the trapezoid to a point 13 inches above the bottom at which point the maximum temperature was reached after which there is a sharp drop in temperature near the top edge thereof.

Example II

In accordance with the invention, the bus bars applied to a second trapezoid were discontinuous as shown in Fig. 6 and each had one open area between the sections although in the product here described, the electrically conductive coating did not extend to the edges of the glass at all parts of the surface area as shown in Fig. 7. It was found that the distance along the edge of the trapezoid upon which each of the bus bars were applied, measured 17¼ inches. With the trapezoid of this example along each of the bus bar edges, a continuous section of bus bar ran 11¾ inches up from the bottom edge of the trapezoid after which there was provided an open area one-inch long followed by another section of the bus bar element running up to the top edge of the trapezoid. The two bus bar sections on each side were connected by similar bus bar material applied on the edge of the glass which did not however contact the conducting coating in the open areas as shown in Fig. 7.

When 50 volts were applied by leads to the electrically conductive coating on the glass trapezoid supported as described in connection with the first example, the temperatures thereon were as shown in graph II of Fig. 9. It will be noted immediately that less heating occurred in the area opposite the location of the open areas in the bus bar, which areas extended between 11¾ inches and 12¾ inches from the bottom of the trapezoid and are indicated between the short vertical lines v which intersect the graph. It will also be noted along the cut areas on graph II that there is actually a slight dip in temperature and that the high peak temperature of the first described trapezoid which used continuous bus bars has

been reduced as can be easily seen by comparing graphs I and II.

Example III

To a similar trapezoid which had an electrically conductive coating applied over its entire area, bus bar elements as shown in Fig. 8 were applied along a pair of opposed edges thereof. Each bus bar element had two cut-out sections or open areas therein, one placed between 11¼ inches and 12 inches from the base and indicated between the short vertical lines *s* on graph III of Fig. 9, and the other placed between 13⅛ inches and 14⅜ inches from the base and indicated between the short vertical lines *t* on the graph. Thus, one set of open areas was ¾ inch in length and the other set of open areas or cut-outs was 1¼ inches in length. The bus bar coating on the coated surface of the glass was ⅜ inch wide and jumper connections of the same material were applied on the narrow glass edge around the open areas in the bus bar elements to connect the bus bar sections together.

When the trapezoid was suspended on corks and 50 volts were applied across the bus bars, there was a current flow of 2.75 amperes. Thus, even though the electrically conductive coating was the same, the resistance of this trapezoid was slightly higher than that of the first described trapezoid which was similar in size and shape but which had continuous bus bars on each opposed edge. The resistance thus obtained was 18.2 ohms as compared with 16.0 ohms for the trapezoid with continuous bus bars made in accordance with the prior art methods. According to the above values, the power applied was 138 watts or 88 watts per square foot. The temperature values measured along a central vertical line were as shown in graph III of Fig. 9. As will be noted from the graph, the open areas in the bus bar elements between the short vertical lines *s—s* and *t—t* clearly show the effect of such open areas on the heating pattern of the electrical conductive coating falling between the said open areas. In this case, it will be apparent from the graph that the top area of the trapezoid, which would ordinarily run very hot, was actually too cool because of the large reduction in current flow brought about by the cut-out or open areas.

Thus, it is clearly obvious from graphs I, II, and III that the use of discontinuous bus bar sections to form a bus bar element provides a means whereby the current flow into different areas of an electrically conductive coating may be controlled. Graph III also shows that when power is restricted from flowing in certain areas by open areas in the bus bar elements, that more power is then caused to flow out and into the other areas adjacent the bus bar sections, and particularly into areas located between the opposite bus bar sections. This of course causes such portions of the coated surface area to heat to a higher temperature than would ordinarily be the case if continuous bus bars were used. As will be noted in Fig. 9, higher temperatures are apparent in the lower middle and close to the bottom or base areas of the trapezoids of Examples II and III wherein the discontinuous bus bar elements were used as compared to temperatures in similar areas of Example I wherein the continuous bus bars were used.

Example IV

On the fourth trapezoid, similar to those used above and having the same electrically conductive coating thereon, the bus bar elements applied to the opposed edges were alike and made up of eleven sections separated by ten cut-out or open areas. Each of the bus bar elements started from the base of the trapezoid with a bus bar section 4¼ inches in length. A cut-out or open area ⅛ inch long was then provided between the first bus bar section and the second bus bar section. The second bus bar section extended between points 4⅜ inches and 5⅜ inches

from the base, after which there was provided another open area ⅛ inch long. The third bus bar section was located between 5½ inches and 6½ inches from the base and was separated from the next section by a cut-out area ⅜6 inch long. The fourth bus bar section ran from 6¹¹⁄₁₆ to 7¹¹⁄₁₆ inches from the base and was separated from the next section by a cut-out area ⅜6 inch long. The fifth bus bar section ran from 7⅞ to 8⅞ inches and the next cut-out or open section was ⅜6 inch long. The sixth bus bar section was located between 9¹⁄₁₆ to 10¹⁄₁₆ inches from the bottom of the trapezoid and the next cut-out or open section was ¼ inch long. The seventh bus bar section was between 10⁵⁄₁₆ and 11⁵⁄₁₆ inches from the trapezoid base and was separated from the next bus bar section by a cut-out ⁵⁄₁₆ inch long. The eighth bus bar section ran from 11½ to 12½ inches and was separated from the next section by a cut-out opening ⁵⁄₁₆ inch long. The ninth bus bar section ran from 12¹³⁄₁₆ to 13¹³⁄₁₆ inches and was separated from the next section by a cut-out opening ⁷⁄₁₆ inch long. The tenth section of the bus bar ran from 13¼ to 15¼ inches from the trapezoid base and was separated by a ½ inch open or cut-out area from the final top bus bar section which ran to the top edge of the trapezoid.

In this example the bus bar sections were mostly of uniform length, although this might be varied, and the open areas between the sections going from bottom to top were made progressively larger. For convenience, the location of the cut-out areas have not been shown in graph IV since they were too numerous and relatively narrow as compared to the cut-out areas in Examples II and III. However, the width of the cut-out openings was largely proportioned in accord with the distance between the opposing bus bar elements at the location at which the open area in the bus bar elements was provided. This provides one simple means of proportioning the width of open areas in the bus bar elements. The various sections of the respective bus bar elements were tied together on each edge of the glass by a continuous jumper or tie-strip of bus bar coating, while care was taken to avoid placing any of the tie-strip in contact with the electrically conductive coating.

When this piece of glass was supported upon corks in the air and 50 volts applied across the bus bar elements, there was a current flow of 2.9 amperes indicating an overall resistance of 17.2 ohms which again is slightly higher than the resistance found in the first described trapezoid which had continuous opposed bus bars as shown in Fig. 5. The power flow in the present trapezoid provided with the plurality of bus bar sections and open areas in the bus bar elements was 145 watts overall, or 92 watts per square foot, and thus was closely similar to the power applied per square foot to the other trapezoids.

As will be seen from temperature curve IV of Fig. 9, a relatively uniform temperature has been secured in the upper part of the trapezoid which is not too much higher than that secured in the lower part thereof. It is apparent also that if the first 4 or 5 open or cut-out areas in the bus bar elements near the base of the trapezoid were eliminated, and if the open areas in the upper half of the bus bar elements were made slightly larger, that the heating in the lower portion would be increased and the heating in the upper portion decreased.

Example V

In a trapezoid of the same dimensions as those described in the above examples, bus bar elements were again applied to the same two opposed vertical edges of a piece of glass which had been previously coated with a similar electrically conductive coating but of slightly higher conductivity than used in the other examples. The bus bars were constructed with four cut-out areas in each bus bar element and the first bus bar section was 9½ inches long measured from the bottom of the trapezoid and the cut-out areas were ½ inch wide which are indicated between the short vertical lines *w* on the graph. A

second section of bus bar then ran from between 10 and 10¾ inches from the trapezoid base and was followed by opposed open or cut-out areas ¾ inch in length designated by the short vertical lines *x* on the graph. The third bus bar section ⅞ inch long, ran from 11½ inches to 12⅜ inches and was followed by a third cut-out area ¾ inch in length between 12⅜ and 13⅛ inches and indicated between the short vertical lines *y*. The next bus bar section was placed along the edge at 13⅛ inches up to 14⅛ inches and this in turn was followed by a fourth open or cut-out area ⅞ inch long shown on the graph between the short vertical lines *z*. A continuous section of bus bar ran from a point 15 inches up from the base of the trapezoid to the top thereof.

Thus, each bus bar element had four open areas in it and five bus bar sections of different sizes. The sections were tied together electrically by printing a continuous strip of bus bar material on the opposite face of the glass along the edge thereof. The bus bar sections overlying the coated conducting areas were connected to the continuous tie-strip by bus bar material which was extended down along the side edge of the glass excepting in the areas corresponding to the open or cut-out areas in the bus bar.

This trapezoid was connected to a 42 volt source of power which gave a current flow of 3.5 amperes thus indicating a power supply of 147 watts, or 93 watts per square foot, and an electrical resistance of 12 ohms. The temperatures as determined along a central line from the bottom to the top of the trapezoid are indicated by graph V of Fig. 9 wherein it will be noted that the temperatures are fairly uniform and that the extreme variation in temperature throughout most of the trapezoid was from 171° F. to 187° F., or a range of 16° F. If the two extreme readings at the extreme edges of the trapezoid which are subjected to edge cooling effects are included, the range is slightly greater, running from 165° F. upwardly to 187° F. On the whole, the trapezoid was found to heat reasonably uniformly within such range, and such heating makes possible the use of trapezoidally shaped electrically conducting windows, whereas windows made in accordance with the prior art methods as shown in Fig. 5 could not be employed since they would be subjected to thermal stresses and cracking difficulties because of their uneven heating characteristics.

I claim:

1. An electrically conducting article, comprising a support, an electrically conductive coating on a surface thereof, bus bar elements of relatively higher electrical conductivity than said coating in contact with said coating on said support surface for bringing a major portion of the current carried by the article to said coating, at least one of said bus bar elements being discontinuous along said coated surface and being formed of a plurality of sections having an open area therebetween along said coated surface, the area between said sections serving to reduce the flow of current from the bus bar elements to portions of said coating adjacent said area, and means of relatively higher electrical conductivity than said coating connecting the said bus bar sections together.

2. An electrically conducting article as described in claim 1, in which the conductive coating extends completely across the surface of the support and in the open area between said sections of the bus bar elements.

3. An electrically conducting article as described in claim 1, in which the said means connecting the bus bar sections by-passes said coating and is located upon and in contact with a surface of said support.

4. An electrically conducting article, comprising a support, a continuous electrically conductive coating on a surface of said support, bus bar elements of relatively higher electrical conductivity than said coating in contact with said coating, at least one of said bus bar elements being formed of a plurality of aligned sections spaced from one another, the spaces between said sections serving to reduce the flow of current from the bus bar element to areas of said coating adjacent said spaces, and means out of contact with said conductive coating connecting said spaced bus bar sections together.

5. A transparent electrically conductive article, comprising a transparent support body, a continuous transparent electrically conductive coating on a surface of said support body, bus bar elements in contact with said electrically conductive coating, at least one of said bus bars being formed of a plurality of spaced sections, the spaces between said sections providing a discontinuity along the coated surface between said sections which offers a resistance to current flow which is greater than the resistance of said bus bar sections, and means out of contact with said electrically conductive film connecting said bus bar sections together and by-passing said open areas.

6. The method of producing electrically conductive articles, which comprises depositing an electrically conductive coating on a surface of a support body, placing aligned spaced sections of a material of greater electrical conductivity than said coating in contact with said coating such that spaces are provided between said sections opposite an area of said coating wherein a decrease in current flow is desired, and conecting said spaced sections electrically by by-passing the conductive coating opposite said spaces with a material which is placed out of electrical contact with said electrically conductive coating.

7. An electrically conducting article, comprising a support, an electrically conductive coating on a surface thereof, bus bar elements of relatively higher electrical conductivity than said coating in contact with said coating on said support surface for bringing a major portion of the current carried by the article to said coating, at least one of said bus bar elements being discontinuous along said coated surface and being formed of a plurality of sections having an open area therebetween along said coated surface, and means of relatively higher electrical conductivity than said coating connecting the said bus bar sections together, said means by-passing said coating and being located upon and in contact with a surface of said support.

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