

Dec. 16, 1969

H. E. SHAW, JR.
COMBINATION OF ELECTRICALLY HEATED
TRANSPARENT WINDOW AND ANTENNA

3,484,583

Filed July 23, 1968

2 Sheets-Sheet 1

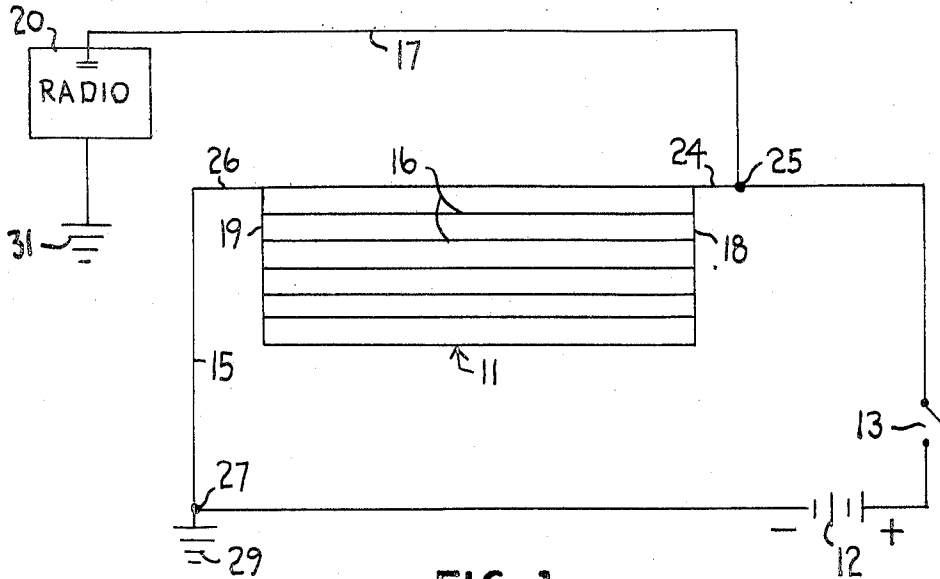


FIG. 1

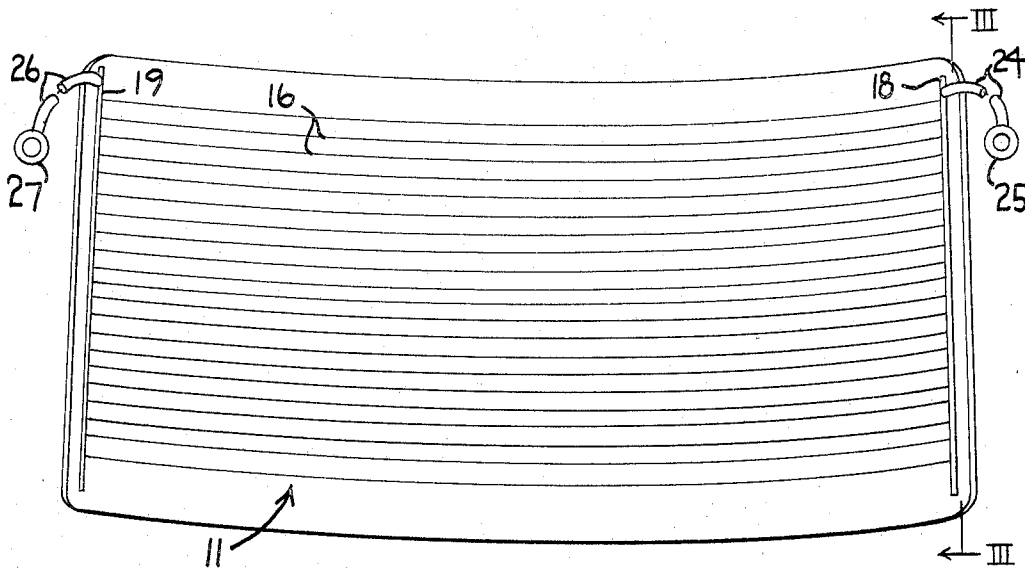


FIG. 2

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2 Sheets-Sheet 2

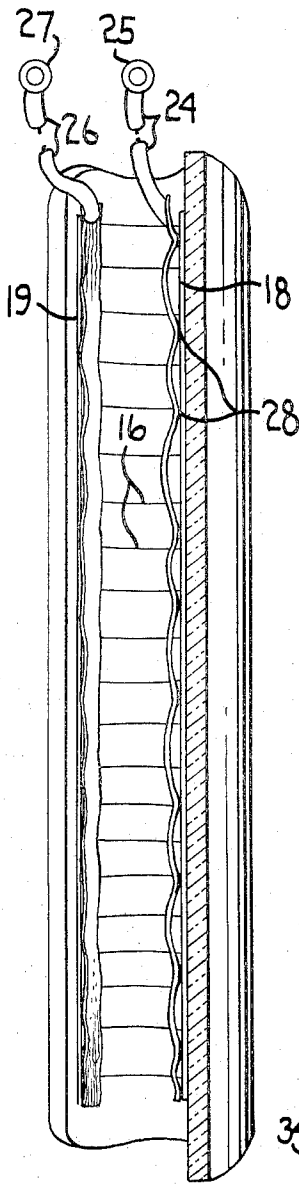


FIG. 3

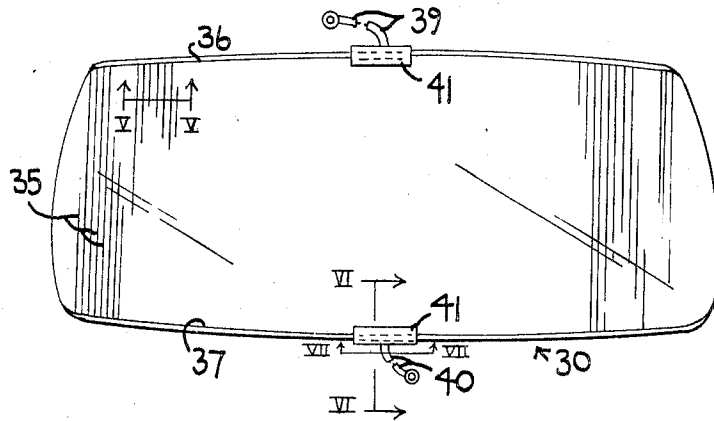


FIG. 4

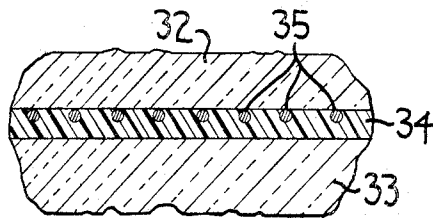


FIG. 5

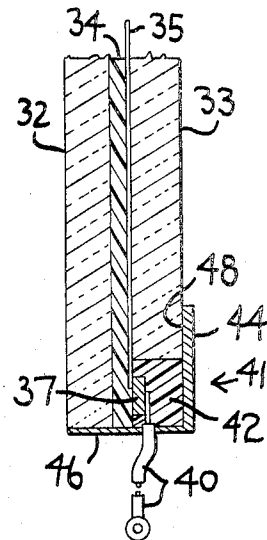


FIG. 6

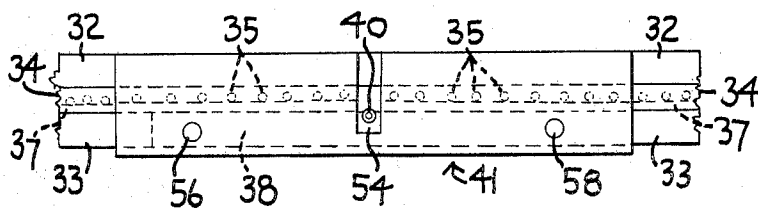


FIG. 7

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3,484,583

COMBINATION OF ELECTRICALLY HEATED TRANSPARENT WINDOW AND ANTENNA

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9 Claims

ABSTRACT OF THE DISCLOSURE

A combination antenna and heater, specifically adapted for use in an automobile, comprising an electroconductive circuit facing an area to be heated, such as all or part of a windshield or a rear window. Preferably, the circuit comprises a pair of bus bars coupled to a direct current source and an electroconductive element interconnecting the bus bars. The electroconductive element is also coupled to an antenna circuit for the automobile radio. Separate ground systems are provided for the direct current source and the radio antenna to enable the electroconductive element to serve as both an antenna for the radio and a heater element for the window area.

The present invention relates to a combination antenna and heater. While the article described herein has particular use in an automobile window, and will be described in such an environment, it is understood that it is adaptable for use in any environment where it is desirable to have an article serve a dual function of heater and antenna.

It is well known to use a heating circuit in windows of automobiles or aircraft to remove fog or frost that forms on a window surface. If the window is laminated, the circuit comprises heating wires carried by a thermoplastic interlayer. The heating wires extend between a pair of bus bars that are disposed along opposite side edges of the area of the window to be heated. When an electric current is passed through the wires, they heat the area, thus removing any surface film of moisture or ice. It is also possible to apply a transparent, electroconductive film to one of the transparent sheets and use a current that is passed through the film to heat the sheet for the same purpose.

Monolithic glass or plastic transparent sheets suitable for use as windows have been used as surfaces for supporting electroconductive heating circuits. For example, a pair of bus bars interconnected by either spaced heating elements, such as metallo-ceramic lines matured onto a glass surface, or electroconductive metal oxide coatings formed by pyrolyzing a metal salt on a heated glass surface have been used as heating circuits on glass sheets and vacuum evaporated metal coatings and the like have been used on glass and transparent plastic sheets.

It has also been known to embed a wire or a series of wires or other conductive elements in the interlayer or on the surface of one of the sheets forming a laminated windshield of an automobile or an airplane and to connect them to a radio antenna circuit of a radio within the vehicle to provide an antenna. However, prior to the present invention, no attempt has been made to employ the same elements that are used for a heating circuit to serve a second purpose as an antenna. The reasons for this are obvious to any student of electricity. Radio waves which are received by an antenna must be effectively shielded from ground. The heating circuit based on the output from an automobile battery utilizes the vehicle body as a ground. Therefore, a conventional heating circuit that connects the heating element to a radio to serve

as an antenna would ground the antenna and prevent the reception of signals to a radio circuit.

The present invention has devised means for isolating the high-frequency radio signals from the ground used in the battery operated heating circuit by providing a separate ground for the radio that is insulated from the ground of the battery. This arrangement permits the passage of direct current from the automobile battery supply system to the electroconductive heating element when desired without affecting the transmission of the alternating current high-frequency signal from the antenna to the radio and vice versa.

The invention will be better understood after the reader has studied a description of certain illustrative embodiments of the present invention which follows.

In the drawings which form part of the description, and wherein like reference numbers refer to like structural elements,

FIG. 1 is a schematic circuit diagram of a typical electrical circuit incorporating the gist of the present invention;

FIG. 2 is an over-all view of a monolithic glass sheet used as a curved rear window of an automobile, wherein the electroconductive circuit is supported directly on a glass surface of said rear window;

FIG. 3 is a sectional view taken along the lines III—III of FIG. 2;

FIG. 4 is an over-all view of an alternate embodiment of the present invention wherein the electroconductive circuit is carried by the interlayer of a laminated glass-plastic assembly typical of an automobile windshield;

FIG. 5 is an enlarged fragmentary sectional view of a portion of the laminated windshield of FIG. 4, showing how heating wires forming part of the electroconductive circuit are embedded in the interlayer of the laminated windshield;

FIG. 6 is an enlarged view taken along the lines VI—VI of FIG. 4; and

FIG. 7 is an enlarged end view taken along the lines VII—VII of FIG. 4.

Referring to the drawings, an electroconductive circuit 11 is shown in FIG. 1. The circuit comprises a battery 12, a switch 13, an electroconductive element 16 comprising lines of electroconductive material, and pair of bus bars 18 and 19, extending across the opposite margins of the heating area, in electrical contact with the opposite ends of the lines of electroconductive material 16. In addition, a lead line 17 forms a branch from bus bar 18 to a radio receiver 20.

A lead wire 24 connects bus bar 18 to a coupling 25. An additional lead wire 26 connects bus bar 19 to an additional coupling 27 which is grounded to the vehicle at 29. Coupling 25 connects the lead wire 24 to two wires, one of which is the antenna lead wire 17 and the other of which is connected to the battery switch 13 to the hot terminal of the battery 12. The latter is grounded at its negative terminal. It is also acceptable to reverse the polarity of the battery 12 so that battery switch 13 is connected to the negative terminal of the battery and its positive terminal is grounded.

In order to isolate the radio antenna from the ground, the radio is coupled to a counterpoise 31. To accomplish this end, the counterpoise ground for the radio is insulated from the ground 29 for the heating circuit and is at a different potential relative to the ground because of the coupling to the ungrounded battery terminal. Thus, when the battery switch 13 is closed, the DC power feeding current into the heating wires 16 through the bus bars 18 and 19 permits the circuit 11 to serve as both a radio antenna and a heating circuit to remove moisture,

such as fog or ice, from the surface of a window on which it has deposited. When the battery switch 13 is open, the heater does not operate, yet the wires 16 receive radio frequency signals and continue to serve as an antenna for the radio.

Since the electronconductive lines 16 and the bus bars 18 and 19 are preferably composed of a ceramic silver material, and the lead-in wires 24 and 26 are composed of a copper braid having a much higher coefficient of thermal expansion than the ceramic silver, it has been found most beneficial to spot solder the copper lead-in wires 24 and 26 at spaced intervals 28 along the length of the bus bars, leaving the copper wires sufficiently loose between the spaced solder points to enable the copper and the ceramic silver to change their dimensions at different rates in response to the changes of temperature that result from actuating or deactivating the heating circuit without inducing stress that weakens the bonds between the lead-in wires and the bus bars.

In commercial embodiments of the invention such as automobile rear windows or backlights, the resistance heating elements 16 and the bus bars 18 and 19 are formed of a typical ceramic conductive coating material comprising a highly conductive metal powder, such as silver, and a vitrifying binder. Typical ceramic conductive coating compositions which may be used may have the following compositions.

COMPOSITION I

Ingredient:	Percent by weight
PbO -----	7.5
B ₂ O ₃ -----	1.0
SiO ₂ -----	1.5
Flake silver -----	70.0
French fat oil -----	12.5
Turpentine -----	7.5

COMPOSITION II

Ingredient:	
Finely divided silver -----	72.6
PbO -----	9.3
SiO ₂ -----	1.7
B ₂ O ₃ -----	1.4
H ₂ O -----	7.5
Ethyl alcohol -----	7.5

COMPOSITION III

A typical commercial composition is a mixture containing 90 percent by weight of a ceramic silver composition sold under the trade name AB Silver by the O'Hommell Company of Carnegie, Pa., and 10 percent of a nonconducting mixture of metallic oxides sold under the trade name K73 Black by the Ferro Corporation of Cleveland, Ohio.

The electroconductive stripes 16 form narrow lines approximately $\frac{1}{32}$ inch wide and the bus bars 18 and 19 form transversely extending rows interconnecting the ends of the stripes 16 in widths of $\frac{1}{4}$ inch. The silver ceramic mixture is preferably applied through a stencil to form the stripes 16 and the bus bars 18 and 19 by a process known as "silk screening" to form a pattern .0005 inch thick on a surface of an automobile rear window or backlight.

The particular material described has an electrical resistance of 0.35 ohm per linear inch along the electroconductive stripes 16 whereas the bus bars 18 and 19 so deposited have an electrical resistance of 0.04 ohm per linear inch along their length. When the backlight to be coated with such a design is rectangular or a quadrilateral having substantially straight and parallel upper and lower longitudinal edges, the elongated electroconductive heated stripes 16 are spaced about one inch apart and are parallel to one another and straight. When the upper and lower edges of the backlight are bowed or are of different configurations from one another, automotive stylists prefer

the elongated electroresistant heating stripes 16 to extend between the opposed bus bars 18 and 19 in slightly changing paths, the uppermost stripe conforming in curvature substantially to the curvature of the upper longitudinal edge of the backlight and the lowest elongated electroconductive heated stripe conforming to the shape of its lower edge.

The ends of adjacent stripes 16 at their points of contact with the bus bars are spaced approximately one inch from the adjacent stripe connected to the same bus bar and the configuration of the intermediate stripes is graduated from stripe to stripe to provide a gradual change from the configuration of the uppermost stripe to that of the lowest stripe. The heating pattern resulting from subjecting the opposite bus bars 18 and 19 to a potential difference of 12 volts results in a substantially uniform heating pattern of about 25 to 30 watts per square foot throughout the entire extent of the vision area of the backlight.

To protect the heating element and bus bars from excessive exposure to atmospheric conditions, the stripes 16 and bus bars 18 and 19 are all applied to the inner surface of the backlight when installed. Under such circumstances, no protective coating has been found necessary.

The stripes 16 and the bus bars 18 and 19 are applied simultaneously through the silk screening technique described previously. The coated glass sheet is then mounted on a bending mold having an outline shaping rail of concave elevation conforming in elevation and outline but of slightly smaller area than the glass sheet after bending.

The glass laden mold is introduced into a furnace where the glass is heated to a temperature sufficient to sag the glass sheet into conformity to the mold shaping surface. During this heating, the finely divided metal ceramic frit fuses onto the glass surface which faces upward and which becomes curved concavely during the bending operation. When the glass bending is completed, the glass sheet is removed from the hot atmosphere and chilled as rapidly as possible to produce a tempered glass sheet. Since the stripes 16 and the bus bars 18 and 19 have fused onto the upper, concave glass surface during the heating operation, they remain in the exact configuration in which they were applied to the cold glass through the stencil in the silk screening process when the glass is chilled.

Preferably, each lead-in wire is a flat copper braid of sufficient current carrying capacity, such as the equivalent of No. 14 solid copper wire, to minimize any loss of power in the bus bars which result in heated bus bars rather than the heat being dissipated throughout the extent of the stripes 16. The free ends of the lead-in wires 24 and 26 are loosely laid over the attached ceramic silver bus bar 18 or 19 and attached to its adjacent bus bar by spaced solder connections 28, preferably at about 2 inch intervals. For example, a flat tin copper braid sold as Preparation No. 1231, equivalent to No. 14 AWG, made by the Alpha Wire Corporation of Elizabeth, N.J., is soldered to the ceramic silver bus bars 18 and 19 using a tin-lead-silver solder containing 70 percent by weight of lead, 27 percent of tin and 3 percent of silver, sold by the Belmont Smelting and Refining Company of Brooklyn, N.Y., as No. 5701 solder. A suitable flux for the solder is sold under the trade name Nokorode solder paste made by the M. W. Dunton Company of Providence, R.I.

The multiple attachments of the lead-in wires to each of the bus bars reduces the length of the current path through any part of the bus bar to a reasonable distance which does not cause undue loss of electrical energy to heat the bus bars. The looseness of the attachment of the lead-in wires to the bus bars permits the lead-in wires to extend loosely between the spaced connections 28. At the same time, only the portions of lead-in wires 24 and 26 that are not disposed over the bus bars 18 and 19 are covered with insulation. This increases the area of con-

tact between the lead-in wires 24 and 26 and the bus bars 18 and 19 to reduce the heat loss in the bus bars even further, thus enabling the heating elements 16 to provide as large a proportion of the total resistance of the heating circuit as possible.

The embodiment depicted in FIGS. 4 to 7 shows a laminated windshield 30 comprising a first glass sheet 32, a second glass sheet 33 and a thermoplastic interlayer 34 of a material such as plasticized polyvinyl butyral bonded between the glass sheets. Electroconductive wires 35 of a material such as Nichrome or tungsten or the like are embedded on the surface of the plastic interlayer 34 and extend between a pair of electrodes or bus bars 36 and 37 extending adjacent the opposite elongated side edges of the area of the interlayer 34 to be heated.

The glass sheets 32 and 33 and the interlayer 34 have matched curvatures and substantially identical outlines except for a notched portion 38 along each longitudinally extending side margin of the glass sheet 33. The notched portion has a lateral dimension sufficient to enable it to extend laterally inward of the inner boundary of the bus bar 36 or 37.

Wires 35 have a small diameter, .0002 inch to .002 inch being preferred. They are arranged in parallel, substantially equi-distant, arrangement, about 8 to 12 to the inch, and extend from bus bar 36 to bus bar 37. The bus bars are preferably thin strips of conductive metal, such as copper, superimposed over the opposite ends of the wires 35. The copper strips are about $\frac{5}{16}$ inch wide and about .005 inch thick and extend with their outer sides about $\frac{1}{16}$ inch inside the windshield margin.

An angle member 41 of moisture-impervious material, such as a thin bent sheet of aluminum, encloses the notched portion 38 to form a chamber that is filled with a resin 42, as will be described later. Member 41 comprises a solid wall 44 parallel to a major surface of the laminated windshield 30 and an apertured, slotted wall 46 disposed at an angle to the solid wall 44 to engage the edge surfaces of glass sheets 32 and 22. A layer of pressure sensitive adhesive 48 is located on the inner surfaces of the walls 44 and 46. The angle member 41 is slightly longer than the notched portion 38, with solid wall 44 slightly higher than the width of the notched portion and apertured slotted wall 46 having a width substantially equal to the thickness of the laminated windshield 30.

Bus bars 36 and 37 are adhered by pressure and an adhesive comprising a thin film of polyvinyl butyral dissolved in chloroform along the length adjacent the opposite sides of the interlayer including the portion of the interlayer that faces the notched portions 38. Each bus bar 36 or 37 has a width slightly less than that of the notched portion so that its outer edge is recessed within the outer edge surface of the portion of the glass sheet 32 that faces the notched portion 38 adjacent thereto.

A lead-in wire 39 similar to lead-in wire 24 is soldered to bus bar 36 within the notched portion 38 along the upper edge of the windshield 30, while a lead-in wire 40 similar to lead-in wire 26 is soldered to the bus bar 37 within the notched portion 38 along the lower longitudinal edge of the windshield 30. The lead-in wires 39 and 40 are encased with insulation except for their free inner ends. The uninsulated free ends are soldered to the bus bars 36 and 37, respectively. The electroconductive wires 35 have their ends in electrical contact with the bus bars 36 and 37. Therefore, the bus bars 36 and 37 serve as means to connect the lead-in wires 39 and 40 to the antenna or heating wires 35.

The chamber, defined by the notched portion 38, is filled with a filler 42 of moisture-resistant, electrically insulating material. This may be a preformed member of an insulation material such as a fiber glass reinforced resin coated with a pressure sensitive adhesive, for example. However, such a preformed member must conform exactly in shape to that of the notched portion 38 containing the lead-in wire to bus bar connection. The

technique to be described immediately below has been found to be most suitable for insulating the exposed wires and their connecting means from electrical contact with the metal frame during a test simulating mass production.

With particular emphasis on FIGS. 6 and 7, the apertured slotted wall 46 is provided with a centrally disposed slot 54 of just sufficient width to provide clearance to enable the angle member 41 to fit over the lead-in wire 39 or 40 when the angle member is applied against the central portion of one of the edges of the windshield to encompass the notched-out portion 38 of the notched glass sheet. In addition, apertures 56 and 58 are provided in the apertured slotted wall 46. One of the apertures is used for injection molding a rapidly setting resin of electrical insulation material, while the other aperture and the slot 54 permit air to escape from the chamber when the resin is injected.

The article described above is made in the following manner. A pair of glass sheets 32 and 33 are mounted in superimposed relation with a suitable parting material disposed between the sheets. Sheet 33 having the notched-out portions 38 is disposed below sheet 32. The two glass sheets are usually made of plate glass or float glass of commercial soda-lime-silica composition. The two sheets are superimposed in the manner recited in bending relation to a glass bending mold having an upward facing outline shaping surface of concave contour in elevation. The glass laden mold is exposed to sufficient heat to cause the glass sheets to conform to the upward facing shaping surface of the bending mold.

After the sheets have bent to the desired curvature and cooled according to a controlled pattern of cooling, they are removed from the bending mold and are assembled to form a sandwich with a sheet of plasticized polyvinyl butyral having the antenna wires embedded therein with excess wire extending from the plastic. The wires are embedded in the plastic sheet 16 by a battery of hot needles. A typical technique for sewing a thin wire into a sheet of insulating material, such as the plastic interlayer sheet 34, is shown in U.S. Patent No. 2,813,960 to Egle and Bethge. While the wires 35 are shown as extending in straight lines, they may be sewn in sinuous configuration to reduce any diffraction patterns if desired.

After the glass-plastic sandwich has been assembled with the bent glass sheets on opposite sides of the wire-containing plastic interlayer, the assembly is subjected to a commercial laminating operation. A suitable operation is described and claimed in U.S. Patent No. 2,948,645 to Laurence A. Keim, assigned to PPG Industries, Inc. This laminating method comprises first enclosing the periphery and margin only of the assembly within a flexible, channel-shaped member made of a fluid-impervious material to form a conduit adjacent the periphery of the interfaces between the interlayer and the bent glass sheets, evacuating air from the conduit to remove air from between the interlayer and the glass sheets, continuing the evacuation while heating the enclosed assembly in a furnace at a temperature between about 150 degrees Fahrenheit and 350 degrees Fahrenheit with the furnace at substantially atmospheric pressure, removing the channel-shaped member when the marginal portion is bonded, and subjecting the assembly to a final lamination at a pressure of between about 100 and 250 pounds per square inch at a temperature between about 190 and 325 degrees Fahrenheit until the entire area of the assembly is clear.

After the assembly is laminated, it is cleaned with particular care being taken to remove oil from the notched portion of the assembly in case the final laminating step is performed in an oil autoclave. Any excess plastic is trimmed and the plastic edge sealed more intimately to the glass surfaces by edge rolling. U.S. Patent No. 2,999,779 to John W. Morris shows a typical edge rolling process and apparatus. Then, the lead-in wire 39

or 40 is carefully soldered to the exposed surface of bus bar 37.

The angle member 41 is then adhered by the pressure sensitive adhesive 48 to abut against the windshield 11 and completely cover the notched portion 38. In doing so, the slot 54 slides around the lead-in wire 39 or 40 to form the chamber defined by the notched portion 38. Suitable adhesives include plasticized polyvinyl butyral, and any of the following commercially available materials sold under the following trade names by the following corporations: Poly EM sold by Gulf Oil Corporation of Pittsburgh, Pa.; Eastman 910 sold by Eastman Kodak Corporation of Rochester, N.Y.; and Tackmaster 1477 sold by PPG Industries, Inc. of Pittsburgh, Pa.

The angle member 41 is preferably formed of any material that is moisture impervious. Thin aluminum sheeting has been found to be quite suitable. For a typical notched portion 2 inches long and about 0.4 inch wide, a partially tempered, flat aluminum sheet $3\frac{1}{2}$ inches long and $\frac{3}{4}$ inch wide is perforated to form the apertures 56 and 58 and the slot 54 and then bent along an axis extending lengthwise of the sheet to form a slotted, apertured wall 46 having a width of $\frac{1}{4}$ inch and a solid wall 44 having a width of $\frac{1}{2}$ inch. Other suitable materials are lead foil tape, copper sheeting, and the like.

After the windshield has passed an optical inspection and the angle member 41 has been secured to the windshield 30 to convert the notched portion 38 into an enclosed chamber, the windshield is oriented with holes 56 and 58 of the angle member 41 facing upward and the filler 42 of electrical insulator material is injection molded through one of the apertures 56 or 58 of the angle member 41. A rapidly curing, water-resistant resin is used, such as a polysulfide resin called Thiokol sold by the Thiokol Chemical Corporation, Bristol, Pa., or a room temperature vulcanizable silicone, such as 615 RTV silicone supplied by General Electric Company, Schenectady, N.Y., or Scotchcast 225 electrical resin sold by Minnesota Mining and Manufacturing Company, St. Paul, Minn. Any filler material having the ability to set within 24 hours is termed a "rapid setting" material for the purposes of filling the chamber with insulation.

When excess resin flows out through the other aperture 58 and the centrally disposed slot 54, the chamber enclosed by the walls 44 and 46 of the angle member 41 is completely filled with resin 42. Any excess resin that is inserted in a chamber oriented with its apertures facing upward forms small mushroom-shaped domes that mechanically lock the angle member in place. The resin provides sufficient insulation to insulate the free uninsulated end of the insulated lead-in wire 39 or 40 as well as the connecting means comprising the bus bar and the heating wires from any electric connection with the metal of the automobile body in which the windshield is to be installed.

A second injection molding operation is preferably conducted to fill the opposite notched portion after soldering the other lead-in wire 40 or 39 to bus bar 36 or 37, respectively and after the laminated windshields have been mounted on a shipping pallet for shipping with the windshields oriented so that the opposite notched portion 38 to be filled with resin faces upward. The materials suitable for the filler have a short pot life on the order of a few hours, subject to variation depending on the choice and quantity of accelerator used as explained in the literature of the suppliers of these materials. After 24 hours, these materials are sufficiently set so that the windshields can be transported without danger of the system losing its moisture-resistant characteristics. It is necessary that the racks be stored for sufficient time for the resin to set before the windshields in the pallet are installed. To be safe, each rack containing a number of windshields is stored overnight after the second injection molding operation to insure that the resin is set before shipping the rack of windshields.

It is understood that the present invention encompasses

alternative systems to enable an electroconductive element to serve as both an antenna at radio frequencies and an electroresistant heating element of a direct current circuit. For example, the electroconductive element 16 may be coupled to the grounded battery terminal instead of the ungrounded terminal. Also, the 12 volt battery operated system may be grounded by a separate bus bar that is insulated from the metal vehicle body which serves as a ground for the antenna and vice versa, or, if the automobile body is a nonconductor electrically, such as one made of fiber glass, a wire radio antenna ground may be insulated electrically from a separate wire ground for the battery-operated direct current system.

The form of the invention shown and described in this disclosure represents certain preferred illustrative embodiments thereof. It is understood that various changes may be made, such as using a glass sheet surface rather than the interlayer to support the electroconductive elements in a laminated glass unit or orienting the electroconductive elements in any orientation desired regardless of the monolithic or laminated nature of the window, for example, without departing from the spirit of the invention as defined and claimed in the subject matter which follows.

What is claimed is:

1. In combination, a transparent window having an area to be heated, an electroconductive circuit comprising an electroconductive element facing said area and a source of DC potential having a pair of terminals, one of which is grounded and the other of which is at a potential difference to said grounded terminal, electrically conductive means to connect said electroconductive element to said source in series to form a grounded heating circuit, electrically conductive means to connect a radio antenna circuit to said ungrounded terminal, and a counterpoise ground connected to said radio antenna circuit on the side opposite said ungrounded terminal to enable said electroconductive element to simultaneously serve as a heater and as an antenna.

2. The combination as in claim 1, wherein the vehicle body comprises one of the group consisting of the ground for said grounded terminal and the counterpoise for said antenna circuit and an electroconductive means insulated from said vehicle body constitutes the other of said group.

3. The combination as in claim 1, further comprising a pair of spaced bus bars extending adjacent a spaced pair of opposite side edges of said area, a lead-in wire connected to each of said bus bars, one of said lead-in wires coupling one of said bus bars to an ungrounded terminal of said DC source and the other of said lead-in wires coupling the other of said bus bars to a grounded terminal of said DC source, an antenna lead wire coupling said counterpoised radio antenna circuit to the one of said bus bars that is coupled to said ungrounded terminal.

4. The combination as in claim 3, wherein said electroconductive element interconnecting said bus bars comprises a series of substantially parallel lines of electroconductive material.

5. The combination as in claim 3, wherein said bus bars and said lines of electroconductive material are attached to a surface of said window.

6. The combination as in claim 5, wherein said window is composed of a monolithic glass sheet.

7. The combination as in claim 4, wherein said window comprises a pair of glass sheets laminated to opposite sides of a transparent, thermoplastic interlayer and said lines of electroconductive material are supported by said interlayer.

8. The combination as in claim 4, wherein said bus bars extend in directions transverse to the length of said area along the opposite longitudinal edges of the area and said lines of electroconductive material extend substantially lengthwise of said area.

9. The combination as in claim 4, wherein said bus bars extend substantially lengthwise of said area along the opposite lateral edges of the area and said lines of

electroconductive material extend transversely of said area.

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U.S. Cl. X.R.

219—203; 244—134; 343—704