Aug. 2, 1966 N. E. HAGER, JR 3,264,595

THREE-ELECTRODE LAMINATED HEATER

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Fig. 1

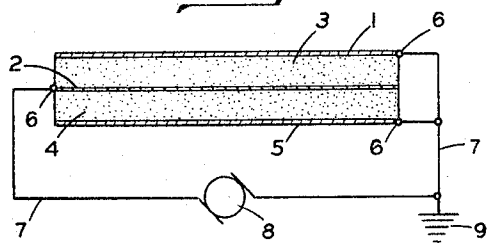


Fig. 2

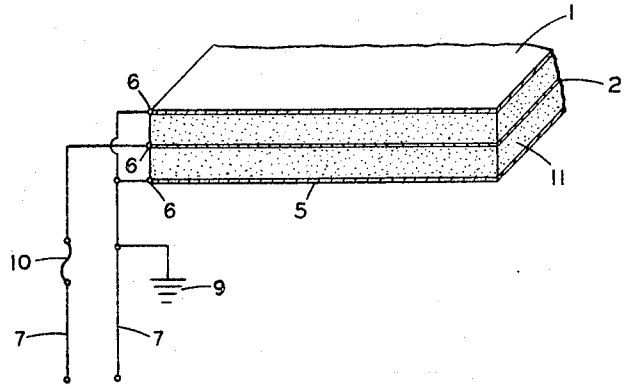
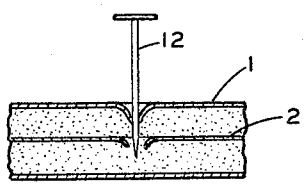


Fig. 3



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THREE-ELECTRODE LAMINATED HEATER

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This invention relates generally to an electric heater and more particularly to a three-electrode laminated heater. Still more particularly, the invention relates to a laminated unitary structure in sheet form capable of supplying heat over a large surface area. This application is a continuation-in-part of application Serial No. 307,038, filed September 6, 1963, now Patent No. 3,221,145, which in turn is a continuation-in-part of application Serial No. 132,496, filed August 18, 1961, now abandoned.

Most electric heaters in the past have been fabricated of resistant wires or resistant elements which are metallic in nature. Some work has been done and some heaters have been described which use resistance elements other than metals as a means for generating heat in electrical heaters. U.S. 3,061,501, Dittman et al., describes an electrical resistor element wherein a semi-conducting layer is positioned between two metallic foil sheets. When an electrical potential is impressed across the electrodes, current flows between the electrodes and generates heat in the semi-conducting layer. The resistor element described in that patent, while useful in many applications, nevertheless suffers from certain shortcomings. For one thing, if the power connections to the electrodes are made at adjacent sites, the electrode foils are not equipotential surfaces since the electrodes actually serve to transmit electric power down the length of the heater. A heating effect and a voltage drop takes place in the electrodes themselves due to the passage of current along the electrodes from the source region to a remote region. In the above-mentioned application Serial No. 307,038, there is described a method and a heater which overcomes this deficiency.

Even with the correction of such deficiency, there remains the problem of actual use of any of these large, flat heating elements in places where people are active. Such heaters all present a danger of electrical shock and fire which drastically reduces the applications in which the heaters would otherwise be used.

It is the primary object of the present invention to supply a laminated heater which substantially reduces or even eliminates shock and fire hazards. It is a further object of the present invention to supply a heater which may be used in almost unlimited applications without fear of shock or fire caused by shorting, penetrating, bending, breaking, or other accidents.

These objects are achieved in a straightforward and simple manner. The invention contemplates a three-electrode laminated heater comprising in combination two outer opposing metallic foil electrodes. An inner metallic foil electrode is positioned between the two outer electrodes. At least one semi-insulating layer is positioned between an outer electrode and the inner electrodes. The semi-insulating layer is in electrical contact with the inner and one of the outer electrodes and is adapted to generate heat when electrical current flows therethrough.

The metallic foil electrodes of the present invention may be made of any suitable metal foil having a thickness generally in the range 0.0001–0.01 inch. This thickness will allow flexibility in the laminated heater and also minimizes the heat capacity of the heater itself. Metal foils of aluminum, copper, stainless steel, and the like may be used. It is preferred that the two outer electrodes be fabricated of a stainless steel or steel foil. Not only are such materials generally inert and unresponsive

to atmospheric conditions, but they are made of a high-melting metal which may melt as high as 2500–2700° F. The inner electrode will also be fabricated of a metallic foil, preferably one having a lower melting point than that of the two outer electrodes. The low-melting, fusible alloys are particularly useful. Additionally, the inner electrode may be made thinner than the two outer electrodes. Hence the inner electrode may be made of tin, aluminum, copper, lead, any of the alloys, or some other foil which is preferably both thinner and lower-melting than the foil used to fabricate the two outer electrodes.

In actual use, the two outer electrodes may be grounded in order that no shock or fire hazard exists there. Alternatively, only one outer electrode need be grounded when exposure to the heater is limited to one side. The inner electrode will be the power electrode which will supply the electrical current which will pass through the semi-insulating layer to the grounded electrode.

The semi-insulating layer is preferably a flexible, adhesive, and slightly conductive layer bonded or fused to the electrodes to give good electrical contact with each of the electrodes. To maintain flexibility and low heat capacity in the heater, the semi-insulating layer should have a thickness in the range of about 0.2–0.001 inch. To obtain gentle heating with the normal 120 volts, the resistivity of this semi-insulating layer will preferably be in the range of 4×10^3 to 4×10^7 ohm-inches (10^4–10^8 ohm-centimeters). The semi-insulating layer is not a good electrical conductor. The electrical volume resistivity, simply called resistivity in this application, is measured by the resistance of a body of unit cross section and of unit length. The resistivities are those measured under the same conditions prevailing when the heater is in use. The resistivity of the semi-insulating layer or film, and its thickness, control the heat output of the unit area of the heater of the present invention at a given potential difference across the film from electrode to opposing electrode.

The semi-insulating layer or film may be fabricated of any material having the requisite resistivity while maintaining a good bond and electrical contact with the opposing sheet electrodes. One suitable material is an epoxy resin which is the reaction product of epichlorohydrin and a bis-phenol. The resin may be in a solid state in which case it should preferably be melted before application to the sheet electrode. Where the condensation between the bis-phenol and epichlorohydrin is not carried as far, the epoxy resin will be a liquid and may be applied in the form of a film to the sheet electrode without heat. Any conventional method of applying film such as reverse roller coating may be used. A hardening agent or catalyst should be admixed with the epoxy resin before application to the sheet electrodes in order to cause cure or crosslinking of the epoxy resin. These hardening agents are well known in the art and generally comprise amines or amides, the amines or amides frequently being of relatively long-chain in order to retard the otherwise rapid curing action of the catalyst. Conductive carbon black should be incorporated into the epoxy resin in an amount sufficient to adjust the resistivity of the final film to within the limits stated earlier. A particular advantage of the epoxy resin semi-insulating film is that it is substantially incombustible.

Other suitable materials for forming the semi-insulating layer or film are the thermoplastic resins such as poly(vinyl acetate), vinyl chloride-vinyl acetate copolymers, vinyl acetate-ethyl acrylate copolymers, acrylic ester copolymers, poly(vinyl chloride), poly(vinyl alcohol), and the like. In each case the film must be bonded tightly to the sheet electrodes in order to have a good elec-

trical contact therewith. Suitable amounts of conductive carbon black or graphite may be admixed with such resins, and the resulting mixture doctored, sprayed, rolled, or otherwise suitably applied to one or both opposing surfaces of the electrodes. Conducting ceramic materials, particularly the cermets, may be used to allow use of higher temperatures in the heater. It will be appreciated that the film thickness of the semi-insulating layer should remain substantially constant throughout the entire heater in order to obtain uniform heating.

The film containing the requisite amount of conducting material such as carbon black may be applied to one surface of both foils to serve as outer electrodes, and dried. The same film may also be applied to the inner electrode on both faces. In this manner the two outer electrodes and the inner electrode may be brought into contact in a corresponding face-to-face position This may be done on a calender or flat bed press, or on any suitable rolling or pressing means. Heat will generally be required in order that the film may flow or in order that a curable semi-insulating film be crosslinked or cured. Once the three metal sheets have been laminated by means of the semi-insulating film of the requisite resistivity, power connections will be made on the sheets. The power connections may be left protruding from the sheet if desired if such are to be used, or one entire edge of the heating sheet may be left uncoated in order that it may serve as an edge power connection.

It is possible to construct the three-electrode heater of the present invention wherein only a single semi-insulating layer is used. This single semi-insulating layer would be positioned between one of the two outer electrodes and the inner electrode. An electrically insulating layer may be used between the remaining outer electrode and the inner electrode. All the safety features of the laminated heater of the present invention will be preserved, merely at the expense of a certain amount of heater output which may not be needed in some applications. The non-conducting, electrically insulating layer may be any of the earlier described binder materials which are non-conductive. Most of these materials are rendered conductive simply by the addition of an electrically conductive carbon black or graphite thereto. Therefore, by simply not adding conductive materials to the resins and other polymers, an electrically insulating layer will normally result. Additionally, such known electrical insulating films as lacquers and varnishes, or paper and glass fiber sheets saturated with materials such as resins, silicon compounds, and the like, may be used.

The invention will be better understood by reference to the accompanying drawing, in which

FIG. 1 shows a simplified, cross-sectional view of the three-electrode heater of the present invention;

FIG. 2 shows a fragment of an isometric view of another embodiment; and

FIG. 3 shows how the heater responds to an electrical short situation.

Referring to FIG. 1, the top outer electrode **1** is separated from the inner electrode **2** by the top semi-insulating layer **3**. The bottom semi-insulating layer **4** separates the middle electrode **2** from the bottom outer electrode **5**. Electrical power connectors **6** serve to connect the leads **7** with a suitable power source such as electrical generator **8**. It can be seen that the two outer electrodes **1** and **5** are grounded at **9**.

FIG. 2 shows an embodiment of the heater where the top outer electrode **1** and bottom outer electrode **5** are substantially thicker than the inner electrode **2**. The connections **6** are connected by means of the leads **7** to 120 volts alternating current. One side of the line is grounded at **9** and the other is fused at **10**. Instead of a semi-insulating layer separating the bottom electrode **5** and the

inner electrode **2**, a non-conducting, preferably flexible, electrically insulating layer **11** may be used in place of one of the semi-insulating layers.

FIG. 3 shows an enlarged view of a nail being driven into a heater of the present invention. The nail **12**, as it penetrates a preferred embodiment of the present invention, is in good electrical contact with the upper outer electrode **1** where the electrode **1** presses against the nail. Hence the nail **12** remains grounded. The inner electrode **2**, being thinner than either of the outer electrodes **1**, is much more readily fusible and much less able to maintain good electrical contact with the nail **12** as the nail **12** penetrates the system. Any sparking caused by the short between the inner electrode **2** and the nail **12** quickly causes fusion of the inner electrode **2** and thus a breaking of the short circuit.

An actual three-electrode laminated heater was made with two semi-insulating layers between electrodes, the outer electrodes being copper of a thickness of 0.0008 inch and the inner electrode being aluminum of a thickness of 0.0002 inch. A voltage of 25 volts was impressed from the inner electrode across to the two grounded outer electrodes. The resistivity of the two semi-insulating layers was such that 6 amperes flowed through the system giving a watt density of 50 watts per square foot which resulted in a steady state heating temperature of 145° F. The heater was then jabbed and slashed with a knife through tissue paper. No scorching of the tissue occurred, nor was there any visible change in the ammeter reading of the current through the heater. No voltage appeared between the knife blade and ground.

I claim:

1. A three-electrode laminated heater comprising in combination two outer opposing metallic foil electrodes having electrical power connections thereon, an inner metallic foil electrode having an electrical power connection thereon and positioned correspondingly between the outer electrodes, and two semi-insulating layers positioned respectively between an outer electrode and the inner electrode in electrical contact therewith and adapted to generate the heat output of the heater when electrical current flows through the thickness thereof in a direction perpendicular to the plane of the electrodes.

2. A heater according to claim **1** wherein said outer electrodes are made of a stainless steel.

3. A heater according to claim **1** wherein the thickness of said inner electrode is less than the thickness of said outer electrode.

4. A heater according to claim **1** wherein said inner electrode has a lower melting point than said outer electrode.

5. A heater according to claim **1** wherein said two outer electrodes are maintained at ground potential.

6. A heater according to claim **1** wherein said semi-insulating layer contains conductive carbon particles.

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