

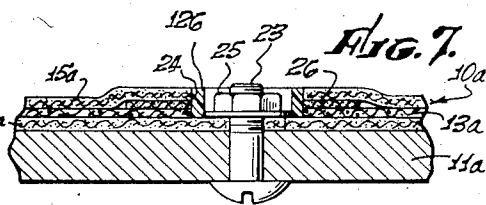
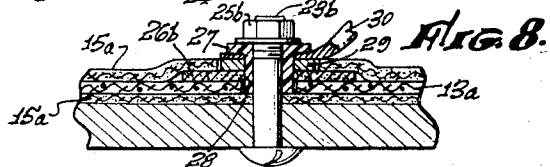
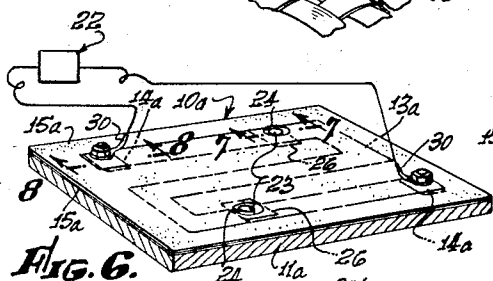
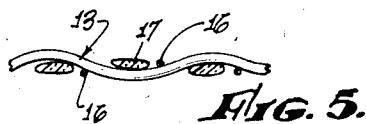
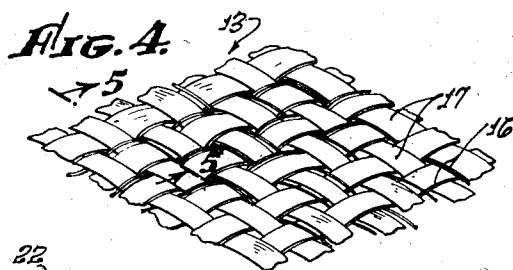
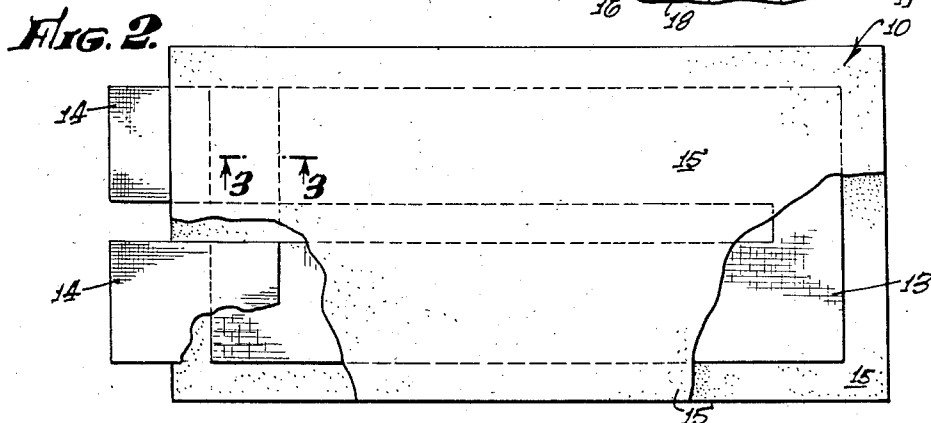
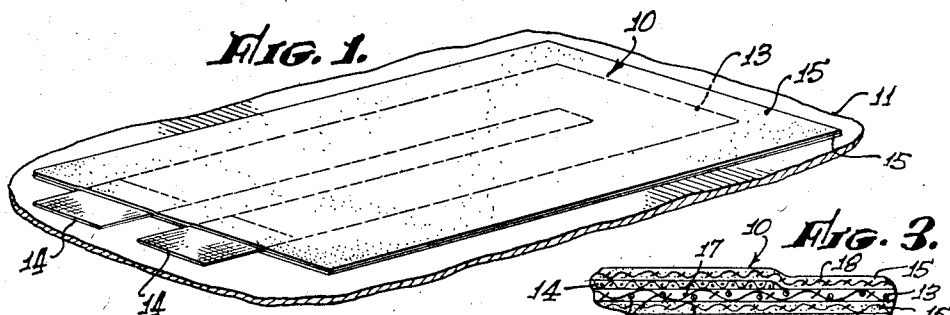
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A. N. HEATH

2,884,509

HEATING ELEMENT CONTAINING A CONDUCTIVE MESH

Filed March 5, 1957



ARTHUR N. HEATH,
INVENTOR.

By *William P. Green*
ATTORNEY.

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2,884,509

HEATING ELEMENT CONTAINING A CONDUCTIVE MESH

Arthur N. Heath, San Fernando, Calif., assignor to Electrofilm, Inc., North Hollywood, Calif., a corporation of California

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10 Claims. (Cl. 201—63)

This invention relates to improved electrical heating units of a type taking a thin sheet like form for producing heat over an extended area of the sheet. These units are in certain respects related to the heaters disclosed and claimed in my copending application Serial Number 596,064 filed July 5, 1956 on Sheet or Layer Form Heating Elements.

In my above mentioned application, I have disclosed a heating unit of a type including a sheet of conductive wire mesh interposed between and bonded to a pair of outer insulative layers. In that arrangement electricity is passed through the wire mesh, and by virtue of the resistance of that mesh acts to develop a desired amount of heat.

The heater of this prior application has proven extremely effective and very reliable for uses in which rather low resistances and high conductivity are desired. However, where very high resistances are desired, it is difficult to make or obtain a wire mesh having the extremely small wires which would have to be used to give such resistances.

A major object of the present invention is to provide a heater unit of the above discussed general type, but one which is so designed as to allow the attainment of increased electrical resistances in the unit. Specifically, this is attained by substituting for the wire mesh a woven sheet form element or mesh in which some of the strands are conductors and others of the strands are interwoven with the conductors but are themselves relatively non-conductive or electrically insulative. The number and size of conductors can then be selected as desired, without any limitation as to fineness of the conductor diameter or spacing between the conductors, because the non-conductive strands or threads are present to hold the conductors in proper interrelationship and to give strength to the composite mesh during the manufacture of the device. To serve these purposes, the total cross sectional area of the non-conductive strands extending in a particular direction with the mesh is desirably considerably greater than the total cross sectional area of the conductors, extending the same direction, and is preferably several times as great. This is preferably true as to each of the directions in which any strands extend.

The mesh is received between and bonded to two layers of insulative material, which may be formed of any of various materials capable of being hardened or set from an initially plastic state to a condition of dimensional and compositional stability that will withstand all temperatures within the range for which the heating element is designed to operate. This material may be a resinous plastic material, typically reinforced by glass

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cloth or other fabric. Electricity may be fed to the conductive mesh by any suitable terminal means, typically including a high conductivity wire mesh lying against and contacting the resistor mesh between the insulative layers.

The above and other features and objects of the present invention will be better understood from the following detailed description of the typical embodiments illustrated in the accompanying drawing in which:

Fig. 1 is a perspective view of a first form of heater unit constructed in accordance with the invention.

Fig. 2 is a plan view, partially broken away, of the Fig. 1 heater unit.

Fig. 3 is an enlarged fragmentary section taken on line 3—3 of Fig. 2.

Fig. 4 is an enlarged perspective view of the inner woven heating element of the Fig. 1 unit.

Fig. 5 is a section taken on line 5—5 of Fig. 4.

Fig. 6 is a perspective view of a variational form of the invention.

Fig. 7 is a section taken on line 7—7 of Fig. 6.

Fig. 8 is a section taken on line 8—8 of Fig. 6.

Referring first to Figs. 1—5, the heater unit 10 shown in those figures takes the form of a thin laminated composite sheet-like unit applied to the surface of a carrier member 11. This carrier member may be any of a wide variety of types of parts which it is desired to heat or to radiate heat from, as for instance an aircraft part which is to be heated to prevent icing, an electronic component or device which is to be heated to render it unsuceptible to ambient temperature fluctuations, or the wall of a room which is to be heated by the unit. In the Fig. 1 form of the invention, it may be assumed that the sheet-like carrier part 11 is itself rigid, with the unit 10 being bonded directly thereto.

The composite heater 10 includes an inner elongated strip of woven tape or mesh 13, which may have the illustrated essentially U-shaped configuration to be connectable at its opposite ends to a pair of conductor terminals 14. This woven mesh 13 is confined between and bonded to a pair of layers 15 of insulating material, which effectively insulates mesh 13 from part 11 or any other part, except as the tape is purposely connected to a source of electrical power by the terminals 14. The mesh or inner heating element 13 is formed of a number of elongated strands or wires 16 of an electrically conductive material, and a number of elongated strands 17 of a less conductive and preferably electrically insulative material. The conductive strands 16 may be formed of any suitable metal, such as a nickel chrome alloy, tungsten alloy, aluminum alloy, stainless steel, Monel metal, or the like. The insulated strands 17 are desirably formed of glass fibers, with each of the strands designated 17 in Fig. 4 being formed of a large number of very fine glass fibers grouped together to form in essence a single strand. The strands 16 and 17 are woven together in any conventional or suitable weaving pattern, so that the various conductive wires 16 are interwoven and interlocked with respect to each other and with respect to the non-conductive strands 17. Preferably, the conductors and the non-conductors both extend both longitudinally of the mesh 13 and transversely thereof, with the longitudinal conductors being in contact with the transverse conductors. As will be understood, the non-conductive strands 17 hold the conductors 16 in predetermined spaced relation, so

that the overall mesh formed by strands 16 and 17 can be given an accurately predeterminable and controlled electrical resistance and heating characteristic. Desirably, the total cross sectional area of the non-conductors 17, which extend longitudinally of the direction of current flow is greater than the total cross sectional area of the conductors which extend in the same direction, and preferably several times as great. The same is also preferably true of the transverse non-conductors and conductors. The individual wires 16 may be as small as .0000002 square inch in cross sectional area, and .0005 inch in diameter, while the mesh size of the heating element 13 may range typically between about 10 and 400 principal strands per inch. The two insulative layers 15, between which conductive mesh 13 is confined, may be formed of any of various materials capable of providing suitable protection to the heater unit against electrical contact with nearby parts. Suitable and preferred insulating materials may be selected from the general class of plastics, elastomeric or non-elastomeric, including such thermosetting resins as the phenol formaldehyde, urea formaldehyde, melamine modified phenol formaldehyde or urea formaldehyde, epoxide, polyester and polysiloxane resins, and such elastomers as the heat resistant silicone rubbers and neoprene. The properties and particularly the thermal resistance of all such plastics being known, it is but a matter of selecting among them one or a combination of materials capable of retaining such properties as chemical or body stability, dimensional stability and flexibility under temperature conditions to which the insulation may be subjected by the mesh heating element 13.

I prefer to reinforce the insulating layers 15 by the use of fabric like materials such as woven glass cloth. In practice the insulating layers 15 may be formed by impregnating the fabric with any of the above mentioned plastics and laminating type resinous materials, and then applying the impregnated fabric and the plastic material to opposite sides of element 13 prior to curing. The reinforcing fabric may be impregnated with the appropriate laminating plastic by any of the various possible methods, such as spraying a solvent solution of the resin (either catalyzed or uncatalyzed, depending upon the resins used) onto one or both sides of the fabric, or by dipping the fabric in the resin and then suspending the fabric vertically to drain off excess resin, or by knife coating the fabric with the resin at an appropriate and uniform thickness. Any such methods may be used to produce impregnated fabrics which may be air dried or forced hot air dried for an appropriate time to evaporate any solvents or to partially set the resins prior to a final cure which may occur during the laminating process. After drying, the fabric may be stored for subsequent use in the manufacture of the laminated heating unit. Typically, the resins are so applied to thin reinforcing fabric as to produce an impregnated sheet having a thickness range from about .001 to .30 inch. If desired, each of the insulated layers 15 may include more than one of the sheets of plastic impregnated reinforcing fabric, in order to increase the overall strength of the composite unit. In Fig. 3, the glass fabric which is contained within and reinforces insulative layers 15 is typically represented at 18.

The two terminals 14 may be formed of conventional metal screen or mesh, made up entirely of conductive metal wires woven together to produce a mesh which has considerably greater electrical conductivity and less resistance than the heater mesh 13. The screen terminals 14 may be formed of any of the same conductor metals which may be utilized as the conductors 16 in heating element 13, but the wires of screens 14 are desirably considerably larger in diameter than conductors 16, and are desirably considerably closer together than the conductors 16 of heater 13. The mesh size of screens 14 may typically range between about 30 and 400 per inch. The two screens 14 extend between the two insulative

layers 15 and overlap or overlie the two ends respectively of heater strip 13, to be in direct electrical contact with the conductors 16 of element 13 for conducting electricity thereto. Preferably, the screens 14 are soldered to conductors 16 prior to the bonding together of the insulative layers 15. Also, screens 14 of course project beyond the ends of insulative layers 15, to have outwardly projecting portions which are connectable to any desired type of power leads or terminals.

After the parts 13, 14, and 15 have all been assembled in the relation illustrated in Figs. 1 and 2, these parts may be heated under pressure to a temperature capable of curing the resin or other curable or hardenable material contained in layers 15, to bond these layers 15 tightly together and to the intermediate heater element 13 and contacted portions of the terminals 14. This bonding together of the laminates or layers may be accomplished by means of a heated hydraulic press, for example of the type used in the making of plywood. This press may typically be adapted to compress the various layers together at a pressure that may be upwards of 500 pounds per square inch, and which is sufficient to compact the layers to very thin hard form. During such compression, the resin or other curable material is heated at an appropriate curing temperature, say upwards of 350° Fahrenheit, over a suitable period of time, typically 15 minutes, to thermally polymerize or set the resin to form a composition that will remain dimensionally stable and resistant to the heat which the element is designed to generate.

If desired, the laminating process may be performed by means of the known vacuum bag technique, in which the various layers to be bonded are placed in a plastic, rubber or metal foil bag from which the air is evacuated. The evacuated bag is then placed in a controlled temperature oven to cure the resins and form the laminating bonds at reduced pressure. This method may be utilized to fasten flexible laminated heating elements onto parts requiring heating of the layers in deformed or non-planar shapes which can not be formed practically by hydraulic press lamination.

As will be apparent, the pressure curing of the resin in layers 15 will force that resin into the interstices or apertures formed between the strands 16 and 17 of heater element 13, to tightly bond the resin to the strip 13, while the two layers 15 are being correspondingly bonded tightly together about the periphery of element 13, and are being bonded to opposite sides of the terminals 14 at the ends of element 13.

It is contemplated that where the carrier part 11 is of a type permitting bonding of the heater unit 10 directly thereto during formation of the heater unit, such direct bonding will be effected by placing the part 11 in the hydraulic press or other laminating equipment together with the parts 13, 14 and 15 of unit 10. The laminating process then cures the resin of the under layer 15 while it is directly in contact with part 11, to tightly bond the resin and unit 10 to part 11 over the entire area of unit 10.

Figs. 6, 7 and 8 illustrate another form of the invention in which the composite unit 10a is made to have flexibility and therefore is formed independently of the relatively rigid supporting plate 11a. Here the conductive heater unit or mesh 13a (corresponding to 13 in Fig. 1) is shown to be laminated between two very thin fabric reinforced insulated layers 15a, with the composite unit having sufficient flexibility to enable it to be formed to conformance with irregular or non-planar portions of base member 11a. As will be understood, the thickness of the element as shown in Fig. 7 is greatly enlarged, since in actual practice the thickness of the combined laminations in all forms of the invention may range between about .003 and .050 inch.

The heater element 13a in Fig. 6 may be doubled back with respect to itself, to increase its length, or may of

course have any of various other configurations which may prove desirable for a particular application. The terminals in this case may be formed by short pieces of conductive metal screen 14a which are interposed between the heater strip 13a and one of the insulative layers 15a, and may be soldered to the conductors of strips 13a and to a pair of wires 20 and 21 respectively leading to the exterior of the unit for attachment to an electric power source 22. The laminating process tightly bonds screens 14a and wires 20 and 21 in place within unit 10a.

In Figs. 6, 7 and 8, it may be desirable to provide for mounting studs or other fasteners 23 for securing unit 10a to base 11a. At the location of each of these studs, a circular opening or recess 24 may be drilled into the unit 10a to the depth of its lower or inner insulative layer 15a, so that the stud 23 and its nut 25 may tighten that layer 15a and part 11a together. Since part 11a is often of an electrically conductive material, studs 23 and their nuts (and washers 26) should be spaced from and out of electrical contact with heater strip 13a.

If the studs 23 extend directly through strip 13a itself, it is desirable to provide some means for compensating for the resistance increase resulting from the reduction in cross sectional area of the strip 13a at the stud locations. For this purpose, I may provide, within the portion of the heating unit directly about opening 24, and between one of the insulative layers 15a and heater strip 13a a thin electrically conductive patch 26 adapted to locally supplement and increase the conductivity at that location. This patch 26 may be formed of any of various conductors, such as mesh of greater conductivity than heater 13a, or as a conductive coating on mesh 13a, or as a thin composition consisting of fine conductive metal particles (e.g. silver, copper, iron, nickel, etc.) uniformly dispersed in a thermosetting resin which is cured simultaneously with the curing of layers 15a. The patch 26 is so designed that the overall conductivity of a strip 13a and the patch (in the direction of current flow) will be the same at the stud locations as is the conductivity of strip 13a at most and preferably all other points along its length. An annular plastic insulative ring 126 may be mounted within recess 24 about the stud, being suitably cemented or bonded in place, to insulate the inner edges of layers 13a and 26.

In addition to studs 23, there may be provided two studs 23b, which are used as terminal posts having insulated electrical connection with the heater mesh 13a. This stud 23b extends through the insulative grommet 27, which is received within a recess 28 formed in the unit to the depth of the bottom layer 15a. A conductive metal ring 29 is placed within the recess in contact with the conductive patch 26b which is in turn in contact with mesh 13a. A conductive terminal 30 is clamped between ring 29 and a flange on grommet 27 by tightening nut 25b.

As an example of a unit made in accordance with the present invention, a steel plate of approximately .050 inch in thickness was degreased and sandblasted to provide surface irregularization. Two layers of approximately 60 mesh close weave glass cloth impregnated with phenolic resin were then laid on the steel plate, over which was applied a mesh heating element such as that shown at 13 in Figs. 1-5 and cut to approximately a U shape as shown. The heating strip had one conductor 16 for each principal glass strand 17 and had approximately 40 of each per linear inch, both transversely and longitudinally of a strip 13. Each principal glass strand 17 included a large number of glass fibers. The cross sectional area of the longitudinal glass fibers was about 20 times as great as the cross sectional area of the longitudinal conductors 16, and the same was true of the transverse glass and conductive strands. The conductors 16 used in the example had a diameter of about .002 inch, and were formed of stainless steel, while the com-

posite cross sectional area of all of the glass fibers in each strand 17 was about .000006 square inch. The weave utilized was the type referred to as a "common" weave.

Over the strip 13, there was applied another layer of the resin-impregnated glass cloth, with terminal screens of 400 mesh Monel metal being positioned as shown in Fig. 1, and being soldered to the conductors of the heater strip 13. All of these layers and the base plate were then covered on both sides with double thicknesses of uniformly textured blotter paper and placed in a hydraulic press whose flat platens were heated to 350° F., and which were then closed upon the layers at a pressure of approximately 500 p.s.i. for approximately 15 minutes.

As a second example, the foregoing procedure was employed using, in place of the impregnating resin mentioned before, a phenolic-epoxide resin sold by Narmco Resins and Coatings Co. as Conolon 506. Also, the heater strip 13 was pre-impregnated with uncured Conolon 506 resin prior to the lamination process, to assure thorough bonding of the strip 13 to the other parts. The fabric utilized in this example was formed of glass fibers and conductive fibers of substantially the same sizes, mesh, etc. as in the first example, except that the mesh was a twilled weave. There was one conductor for each principle strand of nonconductive material.

A third example was made using as the insulating layers a silicone resin impregnated onto a glass fabric. The heating unit was a "common" weave, and included one of the conductors 16 (.002 inch diameter) for every third principle glass strand 17. The heater strip was pre-treated with Dupont Volan to enhance the adhesion of the resin to the glass fibers. This unit was not applied over a rigid backing plate, but was laminated in such a manner that it produced a free standing and flexible unit which was subsequently bent to fit over a part of non-planar shape, and was secured thereto by fasteners such as those shown in Fig. 7. The terminals in this example corresponded to the terminals of Fig. 6.

Any of the described laminations, after being bonded as described, may be coated with an insulating varnish that favors preservation and protection of the product, and enhances its appearance.

I claim:

1. The combination comprising a heating element in the form of a thin woven mesh composed of interwoven and intersecting electrically conductive wires running longitudinally and transversely of the element and in direct conductive contact at their intersections, and non-conductive strands interwoven with said wires to maintain them including their points of intersection in predetermined spacing, a layer of non-conductive insulating material bonded to said mesh, and means for providing electrical connection with said wires at spaced locations along the mesh.

2. The combination recited in claim 1, in which said non-conductive strands are formed of glass.

3. The combination recited in claim 1, in which said layer of insulating material is a resin-impregnated non-conductive fabric.

4. The combination recited in claim 1, in which said layer of insulating material is a resin-impregnated non-conductive fabric bonded continuously to one side of said mesh, and the opposite side of the mesh is coated with an insulative resin.

5. The combination recited in claim 1, in which said non-conductive strands run between and parallel the wires both longitudinally and transversely of the mesh.

6. The combination recited in claim 1, in which the total cross-sectional areas of the non-conductive strands is a plurality of times the total cross-sectional areas of the wires running in the same direction.

7. The combination recited in claim 1, in which said mesh is closely woven uniformly of said wires and strands throughout the area of the mesh.

8. The combination recited in claim 7, in which the uniformly woven extent of the mesh extends outwardly from between a pair of insulative layers.

9. The combination as recited in claim 5, in which said mesh has an area of reduced width between said locations and in the direction of current flow through the mesh, and conductive means providing for by-passing current flowing through the mesh at the location of said area.

10. The combination as recited in claim 9, in which conductive means comprise finely divided conductive particles in a non-conductive binder.

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