May 31, 1960 R. E. CRUMP 2,938,992

HEATERS USING CONDUCTIVE WOVEN TAPES

Filed April 18, 1958

FIG. 1.

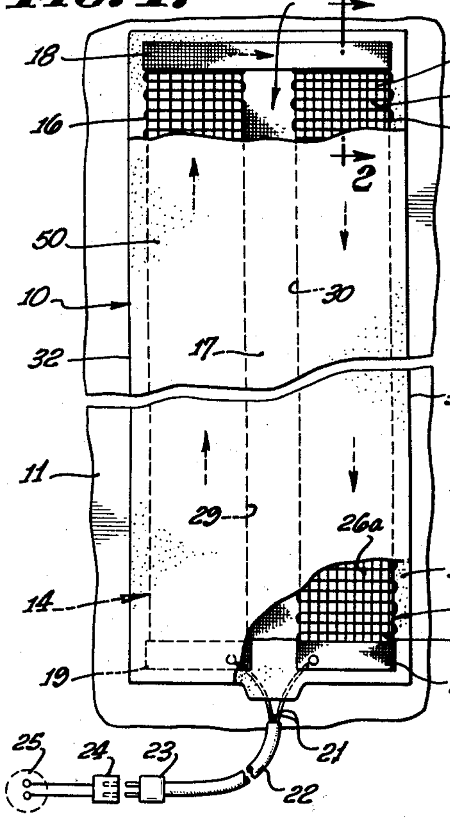

FIG. 4.

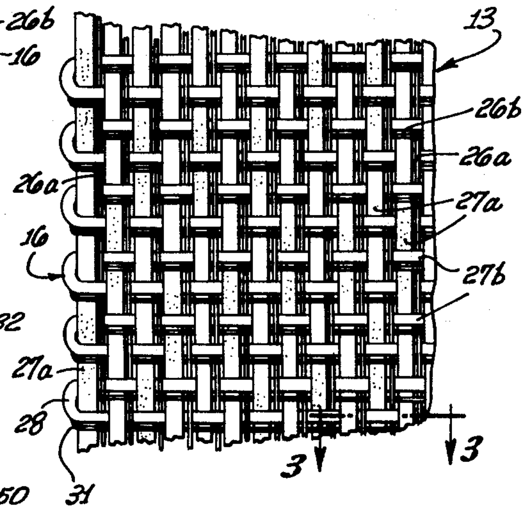

FIG. 2.

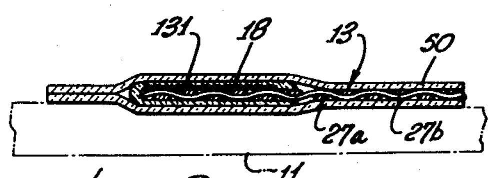

FIG. 3.

FIG. 5.

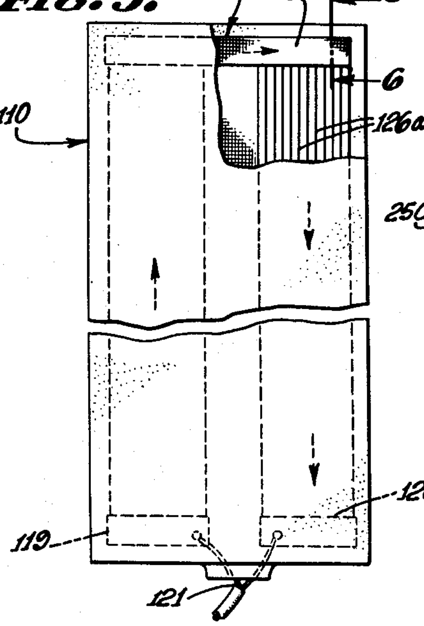

FIG. 7.

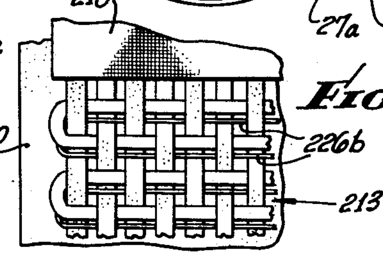

FIG. 6.

INVENTOR.

RALPH E. CRUMP,

BY White and Haefliger

ATTORNEYS.

United States Patent Office

2,938,992

Patented May 31, 1960

2,938,992

HEATERS USING CONDUCTIVE WOVEN TAPES

Ralph E. Crump, Granada Hills, Calif., assignor to Electrofilm, Inc., North Hollywood, Calif., a corporation of California

Filed Apr. 18, 1958, Ser. No. 729,297

9 Claims. (Cl. 219—46)

This invention relates to improved electric heating units which are in certain respects improvements on the type of heating element disclosed and claimed in co-pending applications Serial No. 596,064, filed July 5, 1956, now abandoned, by Arthur N. Heath on "Sheet Or Layer Form Heating Elements," and Serial No. 644,070 filed March 5, 1957, now Patent No. 2,884,509, by Arthur N. Heath on "Heating Element Containing a Conductive Mesh."

In the above mentioned applications, there has been disclosed a unique type of electric heater unit in which the electrically resistive heater element takes the form of a closely woven mesh. At least some of the strands forming this mesh are of electrically conductive material, and offer sufficient resistance to develop heat when current is passed through the mesh. Preferably, the heater unit includes a layer of non-conductive material, such as a suitable resinous plastic material reinforced by and impregnating a sheet of cloth, and bonded to one side of the woven mesh to hold the various strands of the mesh in fixed relative positions, and to insulate the mesh. For best results, and to provide an ultimate product of maximum usefulness, two such insulative layers are provided at the two opposite sides respectively of the mesh.

The general object of the present invention is to provide a heater of the above discussed type which is especially designed so that its mesh-form heater element may be manufactured continuously as an elongated thin tape or strip of material, which can then be cut to any desired length and be applied with maximum facility to any of numerous different uses. Particularly contemplated is a tape of this type which is so constructed that, after it has been cut to a desired length, both of the power leads to the tape can be connected to the same end of the tape. This feature has proven in practice to be of very great importance, since in many of the situations in which the present type of heater can be used, the two ends of the tape must necessarily be separated a substantial distance from one another, so that it becomes very inconvenient to connect the power leads to these two different ends of the tape.

In order to allow connection of the two power leads to a common end of the tape, I so form the tape as to have two conductive areas extending longitudinally along the tape, with a non-conductive area of the tape extending longitudinally between the two conductive areas. In forming a heater unit from this tape, the two power leads are connected to the two conductive areas at a first end of the tape, and these two areas are electrically connected together at the other end, so that current flows first in one direction along a first of the conductive areas and then in a reverse direction along the other area.

The tape includes some non-conductive strands, typically fiber glass, in addition to the conductive strands. These non-conductive strands form the non-conductive intermediate area of the tape, and also may be woven through the two conductive areas to assist in holding the conductors in accurately predetermined relation during manufacture, and to thus give the tape an accurately predeterminable and controlled resistance characteristic. The conductors may in some cases extend only longitudinally of the tape, but for optimum results they preferably also extend transversely of the tape, at the conductive areas, so that the transverse strands can function as potential equalizers for conducting equalizing current transversely between corresponding portions of different longitudinal conductors. This potential equalizing function is particularly useful if one of the conductor circuits becomes damaged and partially opened at one location, in which case the transverse conductors allow a transverse flow of current as necessary to allow the current to pass the damaged location.

The power connections to the conductive tape, and the cross connection between the two conductive areas, may be formed by bus elements engaging the conductors of the tape, and each confined between the tape and one of the insulative outer layers. These bus elements may take the form of thin metal bus bars or screens lying against the tape at the desired terminal locations, to contact the tape conditions over an extended area.

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 plan view of a first form of heater unit constructed in accordance with the invention;

Fig. 2 is an enlarged fragmentary section taken on line **2—2** of Fig. 1;

Fig. 3 is a greatly enlarged fragmentary section taken on line **3—3** of Fig. 4, and showing only the woven mesh portion of the unit, without the insulative layers;

Fig. 4 is an enlarged fragmentary plan view of the woven mesh of Fig. 1;

Fig. 5 is a view corresponding to Fig. 1, but showing a variational form of the invention;

Fig. 6 is a section taken on line **6—6** of Fig. 5.

Fig. 7 is an enlarged fragmentary plan view of the woven mesh in another variational arrangement.

Referring first to Figs. 1 to 4, the heater unit **10** shown in those figures takes the form of a thin laminated composite sheet-like unit, typically 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 unsusceptible to ambient temperature fluctuations, or a pipe or tube carrying a chemical which should not lose its heat (e.g., liquid sodium). In the Fig. 1 form of the invention, it may be assumed that the unit **10** is bonded directly to carrier part **11**, and this carrier part may be either rigid or flexible as desired.

The composite heater **10** includes an inner elongated strip of woven tape or mesh **13**, having two spaced parallel and desirably identical conductive areas **14** and **15** adjacent its two parallel opposite side edges **16**. Between the two conductive areas **16**, the tape has a non-conductive area **17**, extending along the entire length of the tape. At one end of the heater **10**, the two conductive areas **16** are electrically connected together by a bus element **18**, while at the other end of unit **10**, areas **16** are connected respectively to a pair of individual buses **19** and **20**, to which the two leads **21** of a power supply cord **22** are connected. Cord **22** may have a conventional plug **23** connected to its end, and adapted to be plugged into a receptacle represented at **24**, which receptacle is connected to a power source represented at **25**. The power supplied to the unit by source **25** may typically be 120 v. A.C. The woven mesh **13** is confined between and bonded to a pair of layers **50** of insulative material, which effectively insulate mesh **13** from part **11** or any other part (except for the previously mentioned connection to power source **25**).

The mesh or inner heating element **13** includes a number of elongated strands or wires **26**_a_ and **26**_b_ made of an electrically conductive material, and forming the electrically conductive areas **16** of the tape. Also, the woven mesh includes a number of elongated strands **27**_a_ and **27**_b_ which are woven together across the entire width of the tape or mesh **13**, and which are formed of a less conductive and preferably electrically insulative material. The conductive strands **26**_a_ and **26**_b_ may be formed of any suitable material such as a nickel chrome alloy, tungsten alloy, alluminum alloy, stainless steel, Monel metal or the like. The insulative strands **27**_a_ and **27**_b_ are in most instances preferably formed of glass fibers, but may also be formed of asbestos or any other fibrous material able to withstand the high operating temperatures with each of the strands **27**_a_ and **27**_b_ being formed of a large number of very fine glass fibers grouped together to form in essence a single strand. The strands **26**_a_, **27**_a_ and **27**_b_ are woven together in any conventional or suitable weaving pattern, so that the various conductive wires **26**_a_ and **26**_b_ are interwoven and interlocked with respect to each other and with respect to the conductive strands **27**_a_ and **27**_b_. Preferably, the conductors and non-conductors 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 **27**_a_ and **27**_b_ hold the conductors **26**_a_ and **26**_b_ in predetermined spaced relationship, so that hte overall mesh formed by **26**_a_, **26**_b_, **27**_a_ and **27**_b_ can be given an accurately predeterminable and controlled electrical resistance and heating characteristic.

With more specific reference to the particular weave pattern illustrated in Figs. 1 to 4, it is noted that in this arrangement the non-conductive strands designated **27**_a_ extend directly longitudinally of the woven mesh **13**, that is, directly parallel to the opposite side edges **16** of the mesh or tape. These longitudinal non-conductive strands are spaced unformly and rather closely across the entire width of mesh **13** (that is, between the two opposite side edges **16**). The non-conductive strands designated **27**_b_ in Fig. 4 extend directly transversely of strands **27**_a_. and therefore directly transversely of the tape **13**. These non-conductors **27**_b_ are spaced uniformly and closely along the entire length of the woven mesh **13**, and each of the transverse conductors **27**_b_ desirably extends across the entire width of the mesh, from one of the edges **16** to the other edge **16**. Preferably, all of the transverse strands **27** of the mesh are portions of a single continuous strand, which first extends across the tape in one direction, is then doubled back at one of the edges **16** (as at **28** in Fig. 4) to extend across the tape in the opposite direction, and then is doubled back at the opposite edge **16** to return again in the first mentioned direction, etc., so that a single strand may form all of the transverse non-conductors for the entire length of the tape. As will be apparent, each of the strands **27**_a_ or **27**_b_ is woven alternately over and then under successive strands extending in the opposite direction, so that the strands are all effectively integrated into the overall woven tape, as shown in Fig. 3 and 4.

In the Figs. 1 to 4 arrangement, the conductive strands **26**_a_ extend longitudinally of the tape **13**, and parallel to side edges **16**, and are spaced uniformly and closely across the width of each of the two conductive areas **14** and **15**. That is, for conductive area **14**, the strands **26**_a_ are provided between the left hand edge **16** in Fig. 1, and a line **29** which defines the inner edge of conductive area **14**. Similarly, for conductive area **15**, the strands **26**_a_ are provided at closely spaced and uniformly spaced locations between the right hand edge **16** in Fig. 1, and the inner edge **30** of conductive area **15**. These edges **29** and **30** of the two conductive areas extend parallel to one another and parallel to side edges **16** of the tape, and are spaced apart a substantial distance to provide the non-conductive central area **17**. The width of area **14** is desirably the same as the width of area **15**. Preferably, one of the longitudinal conductors **26**_a_ is provided for each of the longitudinal non-conductors **27**_a_, across the widths of the areas **14** and **15**, with each of the conductors **26**_a_ being woven in and out with respect to the transverse strands in unison with, and along with, the associated one of the non-conductive longitudinal strands **27**_a_. That is, referring to Fig. 4, the first strand **27**_a_ at the left side of that figure is woven up and down along with the closely adjacent first conductive strand **26**_a_, while the next two strands **27**_a_ and **26**_a_ are also woven in unison. However, the in and out weaving of the second two longitudinal strands is of course out of step with the first two strands, that is, when the first two longitudinal strands extend upwardly over a particular transverse strand, the second two longitudinal strands extend under that transverse strand, and vice versa.

The transverse conductors **26**_b_ of each of the non-conductive areas **14** or **15** may comprise portions of a single elongated wire, which is woven alternately in opposite transverse directions in somewhat the same manner as has been previously described in connection with transverse non-conductive strands **27**_b_. More specifically, the wire forming the transverse strands **26**_b_ of conductive area **14** can first extend in one transverse direction, and then be doubled back at one of the side edges **16** (see **31** in Fig. 4), following which the wire extends in the reverse transverse direction to the location of inner edge **29** of the conductive area, at which location the wire is doubled back (as at **32** in Fig. 1) to return toward edge **16**, etc., for entire length of the tape. As the wire **26**_b_ extends transversely, it may on each run be woven over and under the longitudinal strands in unison with an associated one of the transverse non-conductive strands or runs **27**_b_. At each of the points at which one of the transvers conductors **26**_b_ crosses one of the longitudinal conductors **26**_a_, the transverse and longitudinal conductors are preferably in direct electrical contact so that the conductors of each of the areas **14** and **15** form together a woven conductive mesh, with the wires of this mesh being held in predetermined relation by the associated non-conductive strands **27**_a_ and **27**_b_.

Desirably, the total cross sectional area of the longitudinal non-conductors **27**_a_ within each conductive area **14** or **15** is greater than the total cross sectional area of the longitudinal conductors **26**_a_ in that same conductive area, and is preferably several times as great. The same is also preferably true of the relationship between the cross sectional areas (taken in any longitudinal plane within area **14** or **15**) of the transverse non-conductors and conductors. The individual wires **26**_a_ and **26**_b_ may be as small as .0002 square inch in cross sectional area (.04 circular mills), and .0005 inch in diameter. Non-conductive strands **27**_a_ and **27**_b_ may have cross sectional area of .0005 to .060 inch (total cross section of all glass fibers forming one strand). The mesh size of the heating element many range between about 10 and 400 of the glass strands per inch.

The two insulative layers **50** 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 if desired, under the temperature conditions to which the insulation may be subjected by the mesh heating element 13.

I prefer to reinforce either or both insulating layers **50** by the use of woven fabric such as woven glass. In practice the insulating layers **50** 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 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. If desired, each of the insulative layers **50** may include more than one of the sheets of plastic impregnated reinforcing fabric, in order to increase the overall strength of the composite unit.

The three terminals or bus elements **18, 19** and **20** 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 buses **18, 19** and **20** may be formed of any of the same conductive metals which may be utilized as the conductors **26***a* and **26***b* in heating element **13**, but the wires of screens **18, 19** and **20** are desirably considerably larger in diameter than conductors **26***a* and **26***b*, and are desirably considerably closer together than the conductors **26***a* and **26***b* of heater **13**. The mesh size of screens **18, 19** and **20** may typically range between about 30 and 400 per inch. The two screens **19** and **20** lie across the upper sides of first ends of conductive areas **14** and **15**, between the mesh and the upper insulative layer **26**, and are in direct electrical contact with the conductors **26***a* and **26***b* of element **13** for conducting electricity thereto. Screen **18** is similar but extends across the entire width of the woven tape, to form an electrical connection between second ends of the two areas **14** and **15**. Preferably, the screens, **18, 19** and **20** are soldered to conductors **26***a* and **26***b* prior to the bonding together of the insulative layers **26**. Also, the wire leads are soldered to the two buses **19** and **20**, so that current will flow from one of these buses along a first of the conductive areas **14** and **15**, then across the bus **18**, and then back along the second conductive area. Before layers **50** are placed about the inner heater parts, an uncured resin may be applied as at **131** about the buses **18, 19** and **20** and associated portions of the mesh **13**, to completely encapsulate and protect the terminal areas. This resin may be of the same composition as that used in layers **50**, and may be cured at the same time as those layers. Preferably, layers **50** have peripheral edge portions at **32** extending laterally beyond the tape and terminals at all points, to form a continuous peripheral area at which layers **50** are directly bonded together.

After the parts **13, 26, 18, 19, 20** and **131** 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 **50** and regions **131**, to bond these layers **50** tightly together and to the intermediate heater element **13** and bus assemblies. 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 **50** and regions **131** will force that resin into the interstices or apertures formed between the strands **26***a*, **26***b*, **27***a*, and **27***b* of heater element **13**, to tightly bond the resin to the strip **13**, while the two layers **50** are being correspondingly bonded tightly together about the periphery of element **13**, and are being bonded to the buses 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, 26**, etc. of unit **10**. The laminating process then cures the resin of the under layer **50** 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. 5 and 6 illustrate another form of the invention which may be identical with that of Figs. 1 to 4 except for the arrangement of the conductors in woven mesh **113**, and the formation of the bus elements **118, 119** and **120**. Specifically, the mesh **113** includes longitudinal conductors **126***a*, corresponding to those shown at **26***a* in Figs. 1 to 4, but does not include transverse conductors such as those shown at **26***b* in Figs. 1 to 4. The arrangement of the glass strands, insulative layers **150**, encapsulating resin **231**, and power leads **121** may all be substantially the same in Figs. 5 and 6 as in the first form of the invention.

In Figs. 5 and 6, the bus elements **118, 119** and **120** may be thin sheet metal "shim" stock, of copper, stainless steel, or the like, with this shim stock being doubled to the Fig. 6 U-shaped configuration, to electrically engage both sides of tape **113**. Preferably, the shim stock is precoated with solder, and after being deformed to the Fig. 7 condition, is heated to melt the solder, while part **118, 119** or **120** is tightly clamped against the tape, to thus form a conductive solder connection between the bus elements and the conductors of tape **113**. The encapsulating resin **231**, and the insulative outer layers **150**, are then applied in the same manner as in Figs. 1–4.

Fig. 7 is similar to Fig. 4, but illustrates fragmentarily the woven mesh portion of another form of the invention. This third form is identical with that of Figs. 1–4, except for the deletion of the longitudinally extending conductors **26***a* of Figs. 1–4. That is, the mesh **213** of Fig. 7 has only transverse conductors (**226***b*), corresponding to conductors **26***b* of Figs. 1–4. As in the first form of the invention, all of these transverse conductors (in each of the two conductive areas) are portions of a single wire which is woven back and forth as in Fig. 4, and whose ends are in electrical contact with the bus elements (see bus **218** in Fig. 7). Thus, current flowing through the heater of Fig. 7 must follow a very circuitous back and forth path, to give to the element a very high electrical resistance.

In all of the forms of the invention, the total overall thickness of the unit **10**, including mesh **13**, **113** or **213**, and layers **50**, **150** or **250** (but not taken at the locations of buses **18**, **19**, **20**, etc.) may typically be between about .015 inch and ¼ of an inch. The insulative layers **50**, **150** and **250** may typically be between about .001 inch and ⅛ of an inch. The number of longitudinal conductors present in each form of the invention is preferably between about 0 and 100 per inch, and the number of transverse conductors is preferably between about 0 and 50 per inch. In the case of both the longitudinal and transverse conductors, it may be desirable in some cases to provide conductors at only alternate non-conductive fibers, or at every second or third non-conductor, or even less frequently where necessary to achieve a desired overall result.

In using any of the three forms of heater, the user merely connects plug **23** into power socket **24**, so that current flows through the conductive areas **14** and **15** in opposite directions, to produce heat. The overall resistance of these areas is such as to develop a desired amount of heat at a particular predetermined operating voltage. Since the two power leads **21** (or **121**) are connected to the same end of unit **10** (or **110**), the unit may be very long if desired, and may be applied to a carrier part of virtually any shape. For instance, if the part **11** is left off of the Fig. 1 arrangement, and the resin and other parts are chosen to give the tape flexibility, the heater unit may be wrapped as a long tape about a pipe, or may be wrapped about a work piece of virtually any other shape. This would not be as easily attained if the two leads **21** came out of opposite ends of the elongated tape like unit.

As an example of a particular 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. 1–4. The heat or strip had one conductor **26*a*** or **26*b*** for each principal glass strand **27*a*** or **27*b***, and had approximately 40 of each per linear inch. Each principal glass strand **27*a*** or **27*b*** 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 **26*a***, and the same was true of the transverse glass and conductive strands. The conductors **26*a*** and **26*b*** used in the example had a diameter of about .002 inch, and were formed of constantan while the composite cross sectional area of all of the glass fibers in each strand **27*a*** or **27*b*** was about .000006 square inch.

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 at **18**, **19** and **20** in Fig. 1, and being soldered to the conductors of the heater strip **13**, and encapsulated in phenolic resin as at **131**. All of these layer 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 and encapsulating resin mentioned before, a phenolic-epoxide resin sold by Narmco Resins and Coatings Co. as Conolon 506. Also, the heater strip **13** was preimpregnated with uncurde 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 strands of substantially the same sizes, mesh, etc. as in the first example, except that no transverse conductors **26*b*** were used (see Figs. 5 and 6). The bus terminals were made as shown in Figs. 5 and 6.

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 as shown in Fig. 4, but included one of the conductors **26*a*** or **26*b*** (.002 inch diameter) for every third principal glass strand **27*a*** or **27*b*** (in areas **14** and **15**). 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.

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

I claim:

1. An electrical heating element comprising an elongated thin electrically conductive woven mesh tape composed of elongated strands of material extending in at least two different directions and each closely interwoven in a predetermined pattern with a series of the other strands, some of said strands of material being electrically conductive and offering sufficient resistance to develop heat upon passage of electricity therethrough, said conductive strands being arranged to form two conductive areas extending longitudinally of the tape and spaced laterally apart and insulated from one another for an extended distance, others of said strands being relatively non-conductive of electricity and being interwoven with said conductive strands and forming a non-conductive area elongated longitudinally of the tape and located laterally between said two conductive areas said conductive strands including wires running continuously back and forth transversely of and at opposite sidse of said non-conductive area.

2. An electrical heating element as recited in claim 1, including means for connecting two sides of an electric power source to said two conductive areas respectively at a first location along the tape, and cross connecting means for electrically connecting said two conductive areas together at a second location along the tape spaced longitudinally of the tape from said first location and so that current from said source will flow in a first direction longitudinally of the tape along one of said conductive areas and then through said cross connecting means to flow back along the other conductive area in the second longitudinal direction for return to said source.

3. An electrical heating element as recited in claim 1, including a layer of non-conductive insulating material bonded to and insulating at least one side of said woven mesh tape.

4. An electrical heating element as recited in claim 1, in which some of said conductive strands extend longitudinally of the tape and are interwoven with a series of the non-conductive strands extending transversely of the tape.

5. An electrical heating element as recited in claim 1, in which said conductive strands extend both longitudinally and transversely of the tape and are interwoven with one another and with the non-conductive strands along said two conductive areas, but are discontinued at said intermediate non-conductive area, said non-conductive strands extending both longitudinally and trans-

versely of the tape throughout both said conductive areas and said intermediate non-conductive areas.

6. An electrical heating element comprising an elongated thin electrically conductive woven mesh tape composed of elongated strands of material extending in at least two different directions and each closely interwoven in a predetermined pattern with a series of the other strands, some of said strands of material being electrically conductive and offering sufficient resistance to develop heat upon passage of electricity therethrough, said conductive strands being arranged to form two conductive areas extending longitudinally of the tape and spaced laterally apart and insulated from one another for an extended distance, others of said strands being relatively non-conductive of electricity and being interwoven with said conductive strands and forming a non-conductive area elongated longitudinally of the tape and located laterally between said two conductive areas, said conductive strands including wires running back and forth transversely of and at opposite sides of said non-conductive area, first connector means for connecting two sides of an electric power source to said two conductive areas respectively at a first location along the tape, cross connecting means for electrically connecting said two conductive areas together at a second location along said tape spaced longitudinally of the tape from said first location and so that current from said source will flow in a first direction longitudinally of the tape along one of said conductive areas and then through said cross connecting means to flow back along the other conductive area in the second longitudinal direction for return to said source, and two layers of non-conductive insulating material bonded to and insulating the opposite sides of said woven mesh tape.

7. An electrical heating element as recited in claim 6, in which said first connector means and said cross connecting means are buses contacting said conductive strands and confined between the tape and said non-conductive layers.

8. An electrical heating element as recited in claim 6, in which some of said conductive strands extend longitudinally of the tape and are interwoven with said wires running transversely of and at opposite sides of said non-conductive area.

9. An electrical heating element as recited in claim 6, in which said conductive strands extend both longitudinally and transversely of the tape and are interwoven with one another and with the non-conductive strands along said two conductive areas, but are discontinued at said intermediate non-conductive area, said non-conductive strands extending both longitudinally and transversely of the tape throughout both said conductive areas and said intermediate non-conductive areas.

References Cited in the file of this patent

UNITED STATES PATENTS

1,615,294	Turver	Jan. 25, 1927
2,345,300	Simpson et al.	Mar. 28, 1944
2,496,279	Ely et al.	Feb. 7, 1950
2,503,457	Speir et al.	Apr. 11, 1950
2,511,540	Osterheld	June 13, 1950
2,522,542	Schaefer	Sept. 19, 1950
2,533,409	Tice	Dec. 12, 1950
2,643,320	Pfenninger	June 23, 1953
2,719,907	Combs	Oct. 4, 1955
2,759,092	Fortin	Aug. 14, 1956
2,817,737	Morris	Dec. 24, 1957