March 6, 1951 J. HORSFALL ET AL 2,543,970

PANEL CONSTRUCTION AND METHOD OF FORMING THE SAME

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FIG. 2

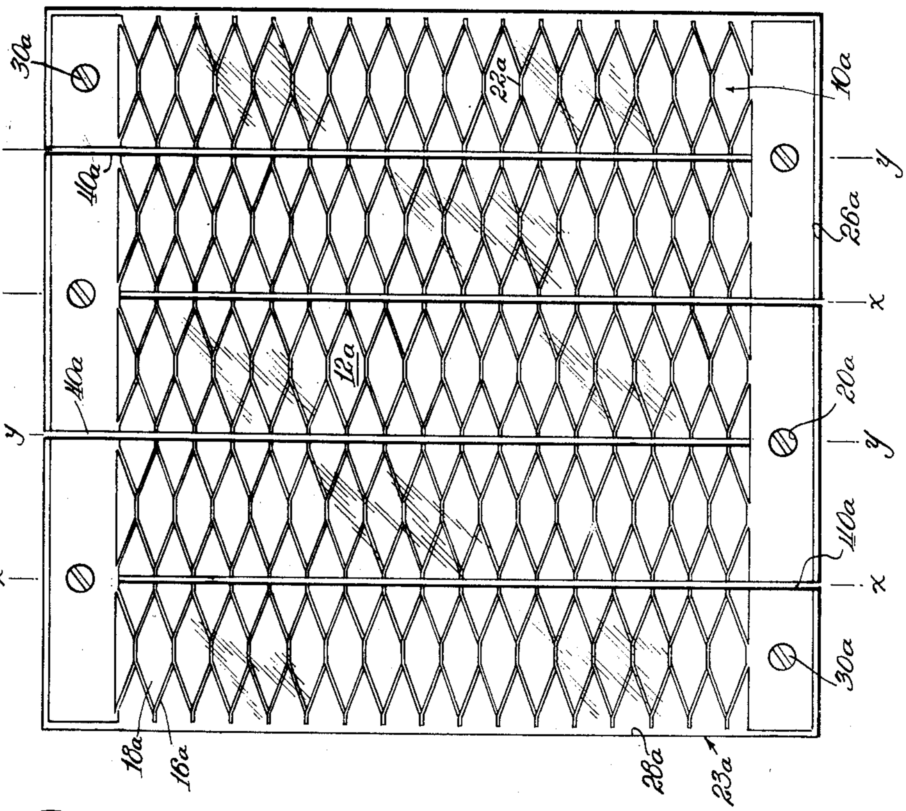
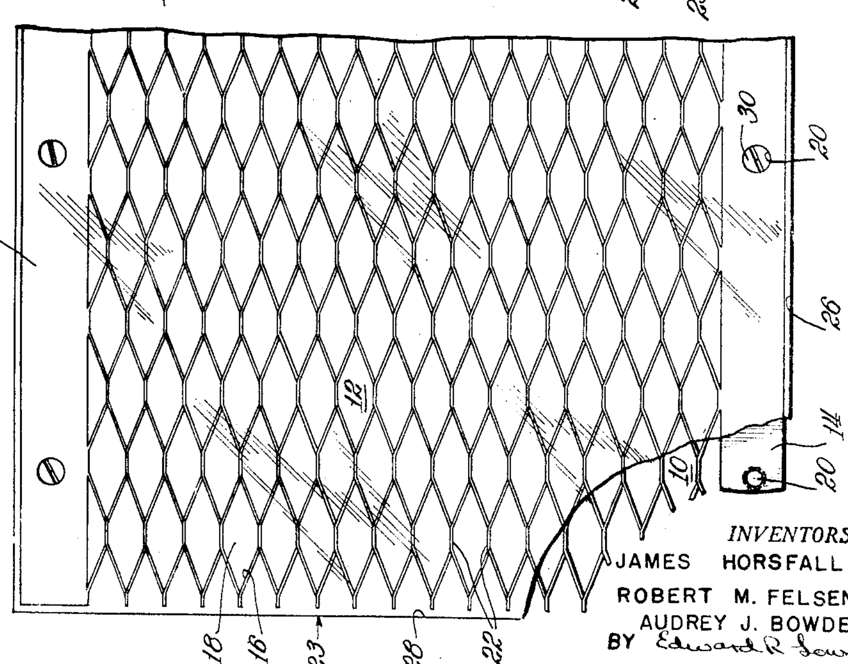



FIG. 1

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PANEL CONSTRUCTION AND METHOD OF FORMING THE SAME

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FIG. 3

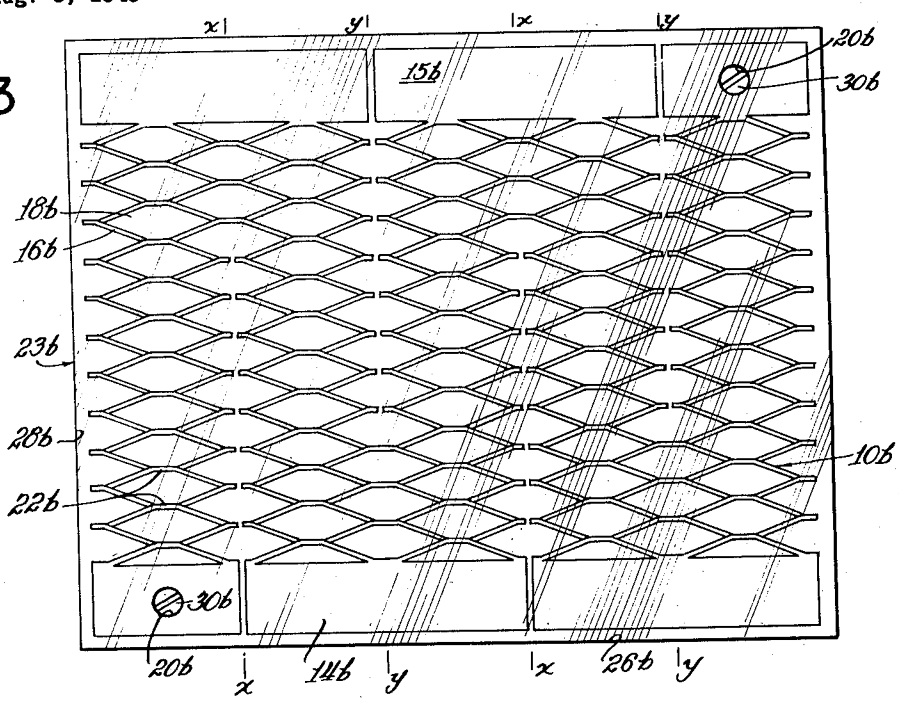
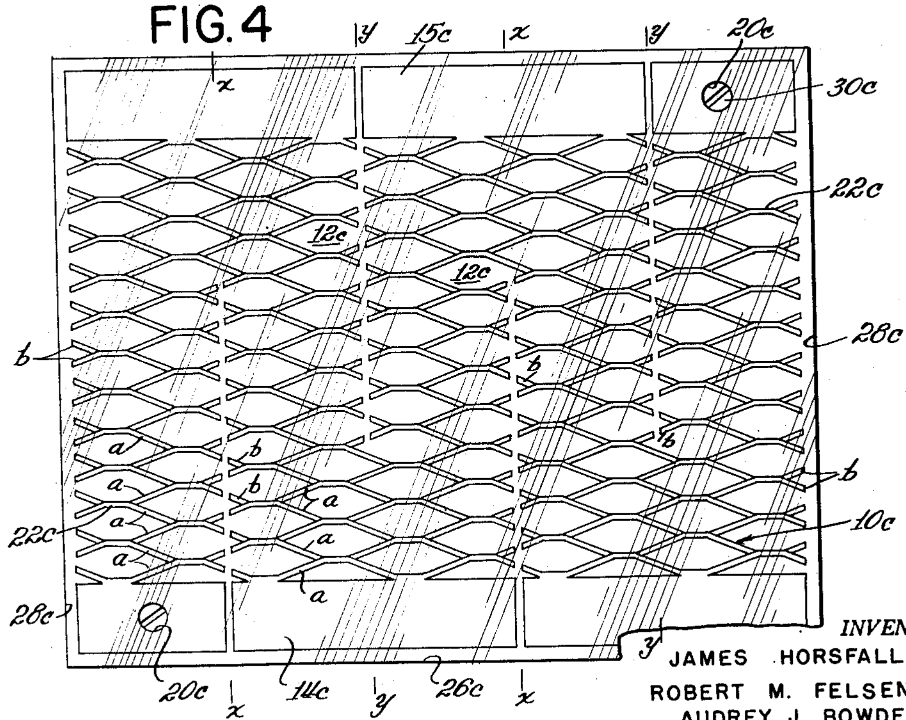



FIG. 4

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PANEL CONSTRUCTION AND METHOD OF FORMING THE SAME

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FIG. 5

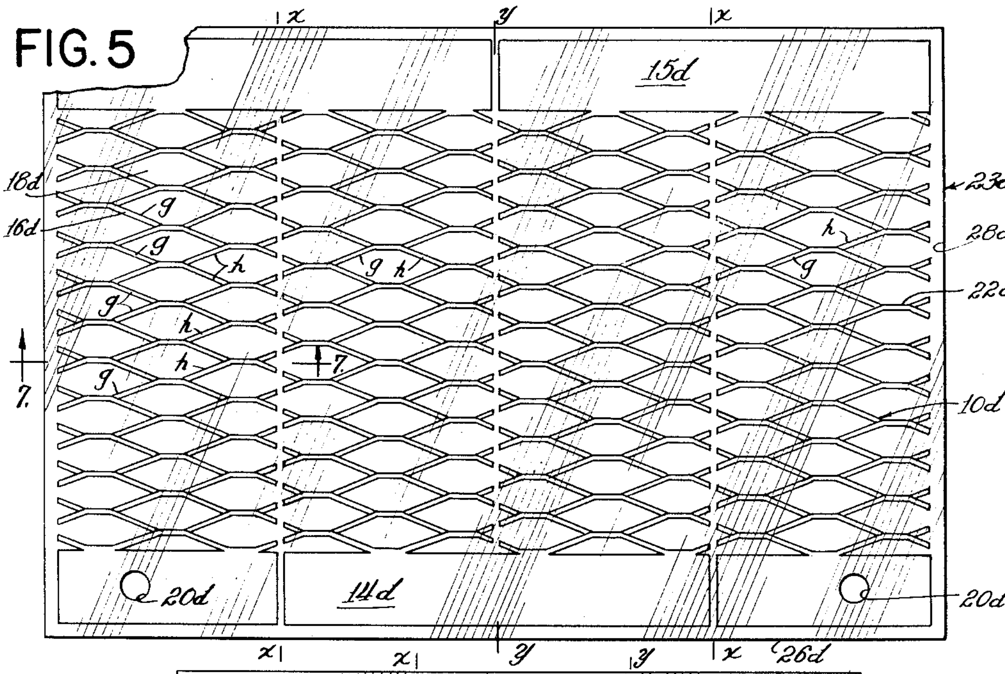



FIG. 6

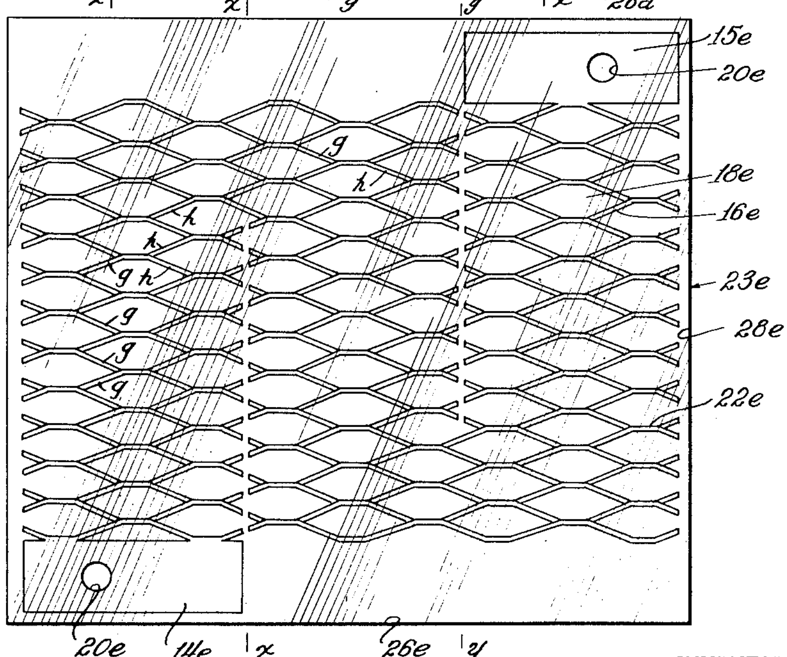
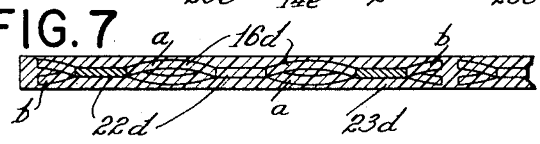



FIG. 7

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PANEL CONSTRUCTION AND METHOD OF FORMING THE SAME

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FIG.8

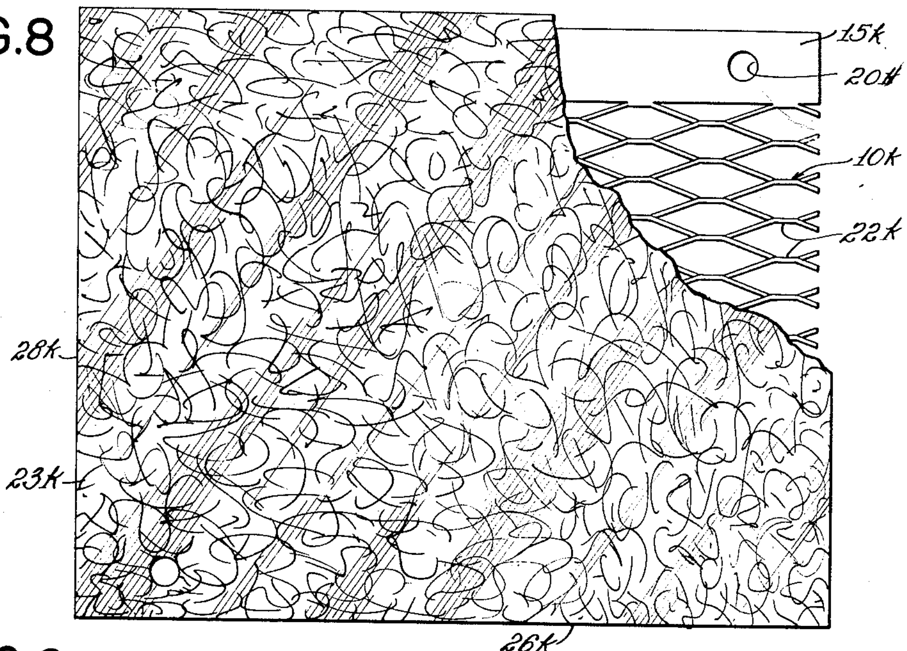



FIG.9

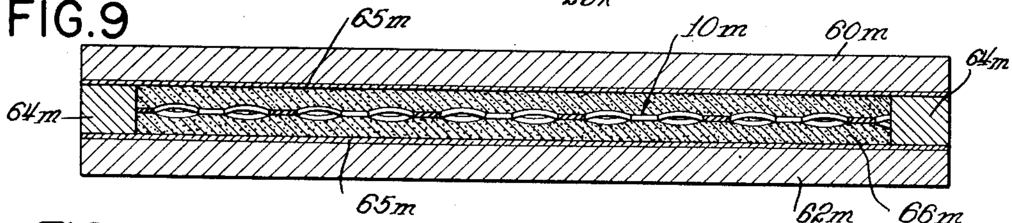
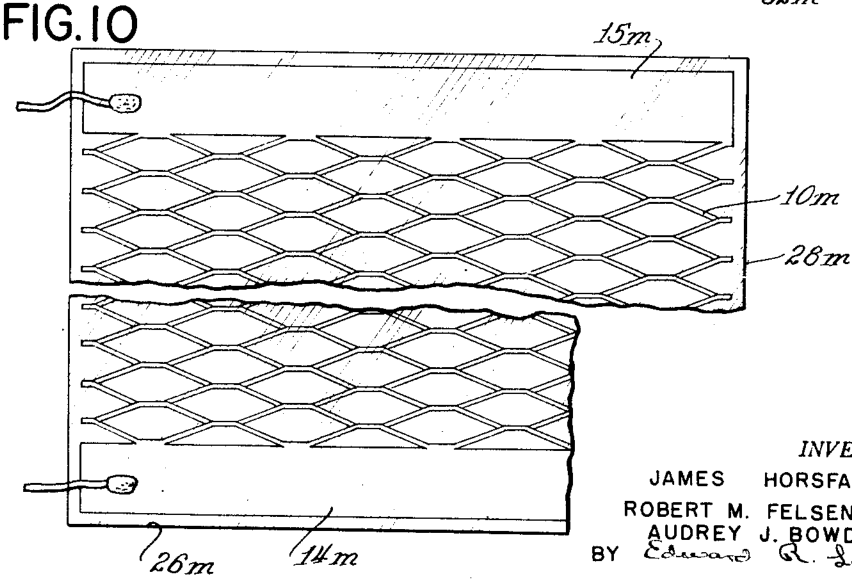



FIG.10

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PANEL CONSTRUCTION AND METHOD OF FORMING THE SAME

Filed Aug. 3, 1949 5 Sheets-Sheet 5

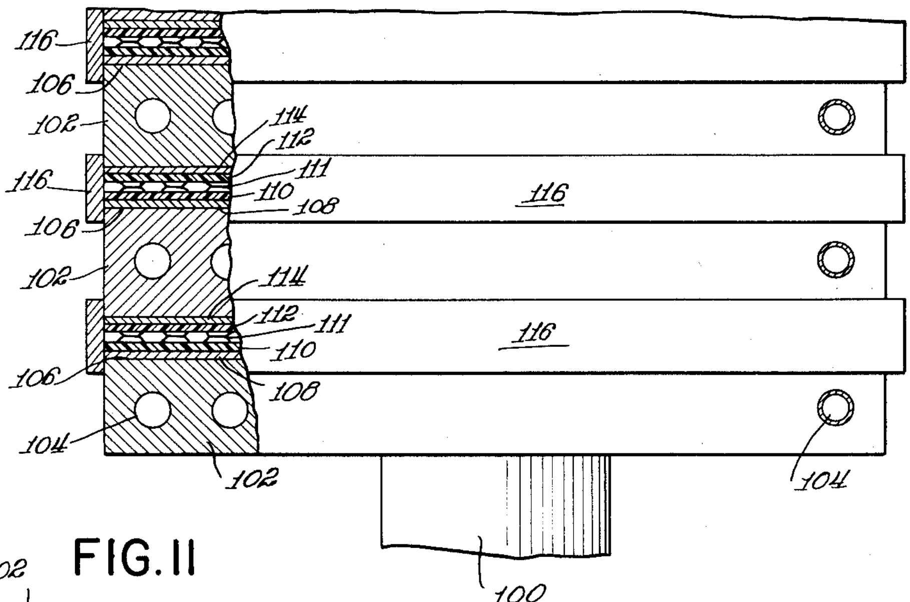



FIG. 11

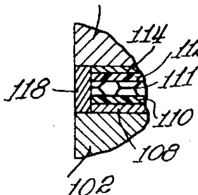
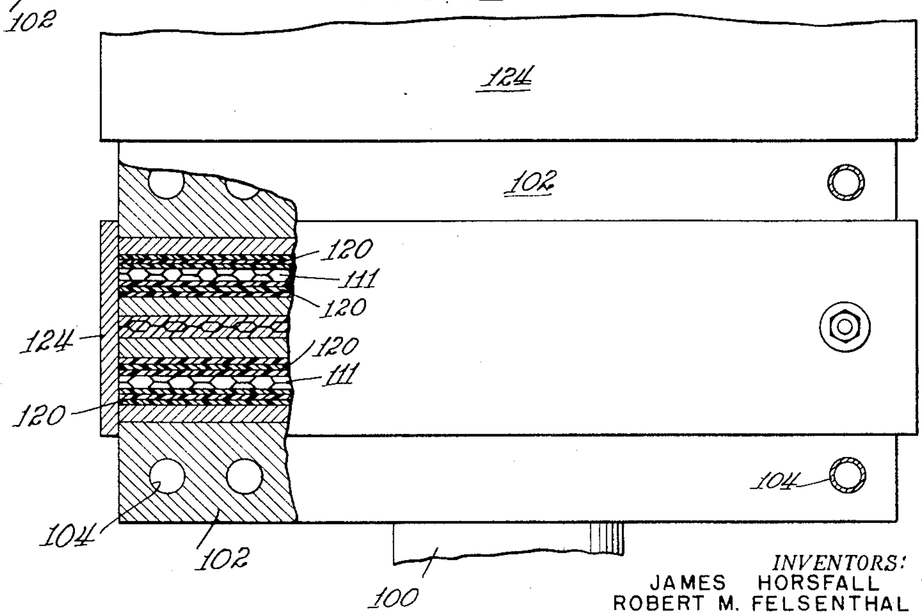



FIG. 13

FIG. 12

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Patented Mar. 6, 1951 2,543,970

# UNITED STATES PATENT OFFICE

2,543,970

## PANEL CONSTRUCTION AND METHOD OF FORMING THE SAME

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Application August 3, 1949, Serial No. 108,270

4 Claims. (Cl. 201—69)

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The present invention relates to the forming of sheet materials or panels of the general type shown and described in a copending application of James Horsfall and Audrey J. Bowden, Serial No. 52,963, filed October 8, 1948, for Decorative Articles of Manufacture and Methods of Forming the Same, and has as its generally stated object the provision of a method whereby such sheet materials or panels may conveniently and economically be formed.

In the above-mentioned copending application there is shown a method of forming an ornamental or decorative sheet or panel consisting of a sheet or area of expanded metal which is completely embedded in a thermoplastic or a thermosetting resinous material. The panel of said copending application has a decorative value in that the plastic material thereof is transparent and the embedded expanded metal material is visible to the eye and contributes in a large measure to the overall pleasing appearance of the panel as a whole. The panel relies for its utilitarian value upon the fact that it may be conveniently shaped into decorative articles by a suitable forming process. Panels constructed in accordance with the present invention may have an incidental value which is decorative, and they may be shaped into decorative articles in the same manner as described in said copending application, but they also may have a utilitarian value in an electrical sense in that the embedded expanded metal mesh material thereof may be employed as a resistance element and, by the passing of electrical current through the mesh material, the panel may be used for radiant heating purposes, all in a manner that will be fully set forth hereinafter.

Our invention therefore relates not only to novel methods for forming decorative or utilitarian articles having general use, but it also relates to panel heating in general. In one form of the invention we contemplate the provision of a novel form of panel designed for radiant heating purposes and in which an expanded metal resistance element is completely embedded and held against displacement in an insulating medium.

Panels constructed in accordance with the present invention may have a utilitarian value which is not electrical, and toward this end, they may be employed as structural members in the formation of a great variety of articles including floor coverings and the like, table tops, the structural parts of cabinets and other enclosures, and other articles too numerous to mention.

We do not wish to limit our invention to the

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use of plastic materials, either thermoplastic or thermosetting, as the embedding substance. In many instances we prefer to employ an inorganic material or compound, or an organic material which, strictly speaking, is not classified as a plastic. Nor do we wish to limit the invention to the use of a transparent embedding material since it is contemplated that we may, if desired, employ a semi-transparent, translucent or opaque material in which the expanded mesh material is concealed.

Whether the panels are employed for radiant heating purposes, or whether they are employed for other purposes, we contemplate forming them by a laminating process according to one form of the invention. Early attempts to thus form the panels utilizing a vertical or other press, together with the application of heat to the material placed in the press, was beset with difficulties, arising chiefly from the tendency of the plastic or other material to flow under heavy pressure and, in so flowing, to distort or rupture the expanded metal and to displace the same so that in the completed panel there was uneven distribution of the mesh. In the case of decorative panels, this resulted in an unsightly article and, in the case of panels designed for panel heating purposes, it resulted in a panel that was unusable due to the presence of high resistance areas or spots or of interrupted current flow or unequal current distribution throughout the panel.

The present invention is designed to overcome the above mentioned and more or less serious limitation that is attendant upon the formation of panels of this nature and, accordingly, it is an object of the present invention to provide a method of forming such panels wherein the embedded expanded metal within the panel is evenly distributed throughout the panel area and in which the metal is neither crushed nor distorted in any manner, thus resulting in a panel which has uniform characteristics throughout.

Numerous forms or modifications of the invention are illustrated herein, both as to the structural nature of the panel and as to the method of forming it. According to one form of the invention we contemplate augmenting the usual steam heat supplied to the press in the laminating process by electrical means wherein preformed panels, made from a previous operation of the same character, are inserted in the press between alternate layers or laminations of the constituents which cooperate to make up the panels to be formed, and wherein electrical current is passed through the embedded expanded metal mesh of these inserted panels to supply internal heat to the press and assist in the forming or curing operation, all in a manner that will be made clear presently.

Where thermoplastic panels are concerned, we further contemplate, as another modification of our invention, shaping or forming completed flat panels into various shapes utilizing cold forming dies and relying upon the internal heat generated within the panel by the passage of electrical current therethrough for the required softening effect prior to performing the actual forming operation.

In still another modification of the invention, we plan to utilize the heat generated by passing electrical current through a sheet of expanded metal as the sole means for curing the plastic embedding material, either by a laminating process in the case of thermoplastic materials or by a so-called flash process in the case of thermosetting materials, as will be described presently.

In regard to the panel heating aspects of the present invention, our panels are capable of many uses of this sort among which are the heating of living spaces such as rooms or other enclosures, the interior of a vehicle such as a railway car, a passenger vehicle, a ship's cabin, compartment or other enclosure or interior. The invention is also useful for the heating of animal enclosures, as for example, chicken brooders and the like where temperature conditions must be carefully regulated and maintained constant for long periods of time. In hatcheries, the improved panel comprising the present invention will be found to be particularly useful for maintaining the interior of the hatching cabinets at a constant temperature, while at the same time permitting visual inspection of conditions within the cabinet.

Apart from such low temperature uses, the improved radiant heating panel may, with or without modification, be employed in the drying of materials, as for example, the floors of granaries, tobacco warehouses, and the like. In each instance, the temperature conditions to be met will be a controlling factor in the specific nature and construction of the particular type of panel to be employed.

At still higher temperatures and consequently with increased heat radiation, the moisture may be driven from such materials as minerals, heat resistant fibers and other materials placed in the open or in large enclosures, or the radiant heating panels may be employed for heating the interior of a large variety of drying cabinets and the like for evaporation of moisture or for the driving off of the volatile constituents from materials placed within the cabinet.

The invention further contemplates, in a modified form thereof, the provision of a panel designed for use as a radiant heat-generating panel in which a resistance unit is employed initially in the panel-forming operation or manufacturing process to generate the heat necessary for conversion or polymerization of a thermosetting material which, when converted or polymerized, constitutes the material in which the resistance unit itself is completely embedded. In such an instance, during the panel-forming process, a relatively high electrical potential is applied to the resistance unit, resulting in a relatively high current flow through the same and consequent high heat radiation and conduction to attain the desired conversion process. After conversion, during which the resistance unit becomes completely embedded in the polymerized material, the completed panel may thereafter be employed in the usual manner of low temperature radiant heating by the application to the embedded resistance element thereof of a considerably lower electrical potential, resulting in a correspondingly lower flow of current therethrough and consequent low heat radiation. It is within the scope of the invention to employ this method of constructing a panel which, when completed, has no electrical value or use but in which the resistance element or unit remains for reinforcing purposes and, in the case of a thermosetting transparent material, for decorative purposes or effect.

Our invention is not limited strictly to "panel" use and the principles of the same are capable of being employed to provide a source of radiant heat, as well as a certain amount of conductive heat, for application to the interior of waterways, conduits, air ducts and the like, of a suitable composition or character. In such instances, the resistance element may be embedded in the material of the conduit or duct. In the case of metal pipes for conducting a fluid, the necessary heat may be obtained by employing a casing, covering or jacket of suitable composition in which the resistance element is embedded.

The above description is by no means exhaustive of the wide variety of uses, as far as heating is concerned, to which the invention may be put. In general, it is thought that panels constructed in accordance with the principles of the present invention will find a wide use in connection with the heating of rooms and other living spaces, as previously indicated above.

In heating a dwelling room, assembly hall or the like by conventional methods of localized heat radiation at high temperatures, the fact that the radiating surface is small results in a very unfavorable distribution of heat and the more or less intense heat radiated from the source is objectionable to the sense of feeling. Furthermore, any dust particles that may be present in the atmosphere are burnt on the heating elements.

In an effort to overcome the above-mentioned limitations that are attendant upon the use of conventional heat radiating devices, various heat radiating panels, including some which consist of a resistance element embedded in an insulating sheet, have been devised. Such panels must necessarily operate at a low temperature and, as a consequence, this involves a rather low input as expressed in watts per square foot of heating or heat radiating surface, which in turn requires a relatively high resistance. Where individual wires or electrical channels are provided through the insulating material in which they are embedded, either an extremely long and tortuous path is required for obtaining the necessary distribution of heat or a multiplicity of wires or channels must be employed. As a consequence, difficulty is encountered in securing the wire or wires in place within the panel. This is particularly true where the panel is of large proportions, and in such instances some type of winding form or frame, as well as intermediate anchoring devices usually are employed which are necessarily left in the completed article, thus adding to the weight of the panel and destroying its uniformity.

Additionally, despite the extreme length of the resistance unit required to attain the desired high resistance, the fact that the unit is enclosed and confined within an insulating material, usually of relatively great thickness with the resistance unit centrally embedded therein, heat dissipation is greatly restricted and localized overheating and consequent burning out of the resistance unit is apt to occur.

The use of concrete-embedded resistance units for the panel heating of dwelling spaces has also been employed but the same objection of confined heat accumulation obtains with the added disadvantage that a localized rupture of the resistance unit involves the comparatively great expense of complete floor replacement since it is next to impossible to locate the rupture and repair the same.

The present invention is designed to do away with the above-noted objections that are encountered in the heating of rooms and other dwelling spaces by means of radiant heat generated from the surface of one or more of the confining walls of the room or enclosure and, toward this end, we have devised a relatively light weight, comparatively thin panel structure which, in a preferred form of the invention, is not appreciably thicker, if as thick, as ordinary wall or floor coverings such as linoleum, imitation bathroom tiling or the like. Furthermore, our panel structure may be employed for panel heating purposes, either as a permanent installation as part of a wall, floor or ceiling structure, or it may be applied to existing wall, floor or ceiling structures with comparative ease of installation. In either case, it will satisfactorily perform the required heat-radiating function without being subject to the disadvantages that are attendant upon present-day heating units.

To avoid the danger of localized heating and consequent burning out of the resistance unit, a multiple path is provided for the flow of electrical current through the embedded unit and, toward this end, we employ a screen-like resistance unit which is in the form of a grid or grille of expanded metal of the well-known type as set forth in the above mentioned copending application and wherein the product is obtained from the parallel slitting of an imperforate sheet of metal at staggered regions and the subsequent deforming or stretching of the metal in a direction transverse to the axes of the slits.

For the embedding material, we may utilize a great variety of materials and compositions, and in one form of the invention, we employ a moldable heat-resisting and electrically insulating material capable of receiving and retaining the expanded material therein. This embedding material may be of a fibrous nature, and it may be pressed into the interstices of the mesh resistance element from one side or from opposite sides under high pressure, with or without the use of a binder which hardens or polymerizes under the influence of heat and pressure, or it may be a binder or coherer containing a volatile substance adapted to have the volatile constituents thereof driven off by the application of heat.

According to one embodiment of the invention, we contemplate embedding the expanded metal resistance in a thermoplastic material which may or may not be transparent by any suitable molding operation involving the application of heat and pressure.

Such a material will have a softening or melting point well above the relatively low temperature required for radiating purposes, and it has the advantage that after the embedding operation is complete and the resistance is contained wholly within the plastic material, the panel may be reheated to the softening point and then bent or otherwise shaped to accommodate different installation contingencies.

In another form of the invention which is useful where panels of small over-all area are concerned, and the resistance of ordinary continuous mesh is too low to effect the desired low heat radiation, we contemplate lengthening the current path by the provision of a series of staggered alternate cuts from the opposite ends of the panel, the cuts severing the mesh strands in such a manner that a tortuous path for the flow of current through the mesh material around the ends of the various staggered cuts is provided. The cuts may be made in the panel in such a manner that the various strands of the mesh are severed at their points of juncture, or they may be made so as to sever the individual strands in between juncture points, but in either case the desired effect of lengthening the path of current flow is attained. After the cuts have been made, the plastic material is reprocessed with the application of heat and pressure, and the thus softened material is caused to flow into the saw kerfs or cuts to effectively retain the ends of the severed strands mechanically separated and to insulate them from each other.

Numerous other modifications and variations of the form of the invention just described are contemplated, as for example, the use and distribution of the selvage regions associated with the mesh resistance material or the elimination of such selvage regions, in part or entirely. These modifications will become apparent as the nature of the invention is better understood, and in each instance the particular use to which the panel unit is to be put will be the controlling factor. Furthermore, numerous modifications not actually illustrated or described will suggest themselves as the following description ensues, but it is to be distinctly understood that such embodiments as fall within the scope of the accompanying claims are contemplated.

Additionally, numerous advantages of the invention over conventional panel heating apparatus, as for example, the advantages that accrue from the use of expanded metal over ordinary mesh material will be explained in detail, while other advantages will naturally suggest themselves, as will certain objects of the invention not specifically set forth at this time. The provision of a novel method of forming panels of the character set forth above by a laminating process, and the provision of a novel form of panel adaptable for use as a radiant heating panel being among the principle objects of the invention, numerous other objects and advantages will become readily apparent as the following description ensues.

In the accompanying five sheets of drawings forming a part of this specification, several embodiments of the invention have been shown by way of illustration, but not by way of limitation.

In these drawings:

Fig. 1 is a plan view of a panel heating element constructed in accordance with the principles of the present invention. In this view a portion of the panel has been broken away to more clearly reveal the nature of the invention.

Figs. 2 to 6 inclusive are plan views similar to Fig. 1 showing various modifications of the panel heating element of Fig. 1.

Fig. 7 is a sectional view taken substantially along the line 7—7 of Fig. 5.

Fig. 8 is a plan view of another modified form of panel with certain parts broken away to reveal the nature of the invention.

Fig. 9 is a vertical sectional view taken substantially centrally through a mold and illustrating a method involved in connection with another form of the invention.

Fig. 10 is a fragmentary plan view of an article produced by the method illustrated in Fig. 9.

Fig. 11 is a fragmentary side elevational view of a vertical press illustrating one method of forming a panel by a laminating process, and

Fig. 12 is a side elevational view similar to Fig. 11 showing another method of forming a panel and illustrating the press procedure.

Fig. 13 is a detail of the panel shown in Fig. 11.

In all of the above described views, similar characters of reference are employed to designate similar parts throughout.

Referring now to the drawings in detail, in Figs. 1 to 8 inclusive and 10, several forms of panels designed for radiant heating purposes have been illustrated. These panels may be constructed in various ways including the manner of construction set forth in the above mentioned application of James Horsfall and Audrey J. Bowden. According to the present invention however we contemplate that they shall be formed according to certain methods subsequently to be described and which are illustrated in Figs. 9, 11 and 12.

For purposes of description, the panel of Fig. 1 may be regarded as a "basic" panel in that having once been fabricated, it is capable of being modified by additional processes, subsequently to be described, to form the panels of Figs. 2 to 7 inclusive. The panel of Fig. 1 has been illustrated as being in the form of a resistance heating unit but it is to be distinctly understood that it may have utilitarian purposes other than electrical and toward this end the character of the embedded expanded metal mesh material may be varied to conform to the particular use, electrical or otherwise, to which it is to be put.

One method of forming the panel of Fig. 1 is shown in Fig. 11. In this view of a fragmentary portion of a vertical press has been shown and includes the usual ram 100 and a plurality of bed plates 102 arranged in superimposed relationship. The bed plates 102 are provided with passages 104 therethrough designed for the admission of steam or a coolant to the bed plates for performing the hot and cold cycles of the process respectively.

The showing of Fig. 11, as far as the details of the press are concerned, is more or less schematic in its representation and only such structure as is necessary for an understanding of the process involves has been illustrated. It will be understood, of course, that the press is provided with various press accoutrements such as frame work, guide rods, flexible steam connections and hydraulic equipment the disclosure of which has not been deemed necessary to an understanding of the invention.

According to one method of forming the panel of Fig. 1 the press openings 106 are adapted to receive therein the various constituents which cooperate to make up the finished panel. In each mold opening 106 there is shown a hardened, polished steel plate 108 on which there is disposed a sheet of plastic material 110 which may, if desired, be of a thermoplastic nature such as Vinylite, and which is of a predetermined desired thickness. A sheet of expanded metal 111, the nature of which will be set forth in connection with a subsequent detailed description of the panel of Fig. 1, is disposed upon the plastic sheet 106 and a second sheet of plastic material 112 rests upon the expanded metal sheet 111. A second plate 114, similar to the plate 108 is disposed upon the upper plastic sheet 112 and is situated directly beneath the overlying press bed plate 102.

The use of the two polished steel plates 106 and 114 are optional and, when employed, they are designed to give a smooth and finished appearance to the surfaces of the finished panel. The specific thickness of the plastic sheets 110 and 112 and the gauge of the expanded metal material 111 will vary for different types of panel constructions and these will, of course, be chosen according to engineering exigencies to produce the desired article. And of course the hot and cold press cycles will be varied to accommodate the character of the panel ingredients as regards the thickness of the plastic sheets, the gauge and character of the expanded metal, and the specific nature of the plastic sheets with respect to its chemical make up.

By way of illustration, but not by way of limitation, the plastic sheets 110 and 112 may be .055 inch thick while the thickness of the expanded metal (i. e. its maximum or overall thickness) may be .09 inch. Thus the total thickness of the plastic materials is slightly in excess of the overall thickness of the expanded metal sheet and by this means the resulting panel will consist of metal mesh material embedded in a plastic material of sufficient bulk to completely cover the mesh sheet on each side with a relatively thin excess surface area of plastic.

A typical example of the hot and cold cycle employed for the above ingredients, and which we, in actual practice have found to produce excellent results, is given as follows:

On the basis of a press having ten openings 106, with a 15 inch ram press, the mold plates 102 were closed upon the ingredients with substantially no pressure and heat up to 290° F. was applied for some minutes by the admission of steam to the passages 104. Pressure at 425 pounds per square inch was then applied at a temperature of 300° F. The pressure was maintained for 15 minutes and, at the end of this period the cooling cycle was conducted by the admission of a coolant to the passages 104 for from 12 to 15 minutes. The formed sheets were twenty inches in one direction and fifty inches in the other.

We have found that the hot and cold cycles of the process will vary with the diameter of the press ram, the number of the plates or platens 102, the area thereof, the total thickness of the panels to be made and the character of the plastic sheets 110 and 112.

An important feature of our process is the use of a retaining piece or "chase" such as is shown at 116. This chase is in the form of an enclosing or encompassing band of metal which bears against the sides of the platens or plates 102 and against the sides of the plates 108, when employed, with a substantially tight fit to prevent egress of the materials from the mold openings 106. We have found that for accurate work and uniformly perfect articles, such a chase is essential to the process.

Where attempts were made to construct the panels without the use of such a chase, we have found that invariably the flow of plastic material out of the openings will carry with it a portion of the expanded metal, thus distorting the latter and, in some instances, rupturing the metal and severing portions of the edges of the metal from the main body thereof.

In Fig. 13 a different type of retaining piece 118 is employed. In this instance the piece 118 may be termed a distance piece inasmuch as it is contained wholly within the confines of the mold opening 106 and it determines the exact thickness of the completed panel. In the illustration given above in connection with Fig. 11, the width of the member 118 will be slightly in excess of the gauge of the expanded metal mesh material and its exact width will be calculated so that when the platens 102 are brought down on the distance piece, the press openings will be substantially filled to produce panels of a thickness slightly in excess of the total thickness of the plastic or other material plus the gauge of the mesh material before expanding.

As stated above, we find that the use of the chase 116 or distance piece 118 is essential to our process, but this is true only where flat surface platens are employed. If desired, tightly interfitting press platens may be employed having peripheral telescopic flange portions which cooperate to retain the materials within the mold.

Fig. 12 illustrates another method of forming the panels. In this instance the press may be substantially identical with the press of Fig. 11. By way of illustration of this method, three sheets of the plastic material 120 of a thickness of .0183, making up a total thickness of .055 are employed on each side of the expanded metal mesh material 111 and the latter is of a gauge or thickness of .090, these dimensions being in inches as before. The hot and cold press cycles employed remain substantially the same as given for the method involved in connection with Fig. 11. An external type of chase 124 may be employed or, if desired, an internal distance piece similar to the distance pieces 116, or interfitting mold parts may be used, but, regardless of these details in the manufacturing process, the essential features of the invention are at all times preserved.

It is obvious that any number of laminations of the plastic material 120 may be employed and we have successfully employed as many as 22 laminations, 11 on each side of the expanded metal mesh material.

In another modified process of constructing the panels we contemplate utilization of a press such as is shown in Figs. 11 and 13 and placing in the mold opening one or more sheets or laminations of plastic material with the metal mesh material resting on the upper surface thereof. Pressure is then applied at a temperature of approximately 290° F., assuming the plastic and mesh dimensions are the same as given above, for five minutes and the mesh material is pressed into the plastic material to a predetermined desired depth. A cooling cycle may then be resorted to. The next step in the process is to evenly distribute a quantity of plastic molding powder of a weight equal to the weight of the plastic sheet or sheets originally introduced into the press upon the face of the sheet on the side thereof where the metal mesh is exposed. The powdered material is evenly distributed into the interstices of the mesh material, insofar as practicable, and the materials are returned to the press and substantially the same hot and cold cycles are repeated under pressure.

In yet another method of forming the panels we contemplate a single pressing operation utilizing the same materials as outlined above. In this instance, after the expanded metal mesh material is placed on the plastic sheet or sheets, the molding powder is applied to the interstices of the mesh and the materials are thus introduced to the press preparatory to initiation of the hot and cold press cycles.

In the manual performance of the various above-described processes, the various ingredients which cooperate to make up the completed panels may be assembled separately in units and subsequently be bodily placed in the mold openings.

The last two described methods have been found useful where it is desired to construct a panel having an opaque appearance on one side of the mesh material and a transparent appearance on the other side thereof. In such an instance the plastic sheet or sheets become the opaque and the powder becomes the transparent part of the panel.

To return now to the radiant heating aspect or phase of the present invention, reference may be had to Fig. 1 wherein one form of our improved panel is shown. The resistance unit is designated in its entirety at 10 and includes a medial mesh portion 12 and a pair of selvage portions 14 and 15 at opposite sides thereof. The mesh portion 12 may be formed of expanded metal having mesh strands 16 defining open mesh portions 18 therebetween. The selvage portions 14 and 15 are adapted to serve as electrical terminals for the application thereto of an electrical potential by connection to a suitable current source (not shown) and, toward this end, these terminal portions may be provided with attachment or anchorage holes 20. Obviously, if the panel, which may be constructed in accordance with the methods outlined above, is not to be used as a resistance heating panel and is without electrical significance, the anchorage holes 20 may be eliminated.

Expanded metal per se is not new, and neither is its use for electrical purposes. One example of an expanded metal resistance unit is given in the United States patent to Hamilton, No. 2,087,573, dated July 20, 1937, for "Electrical Resistance and Electrical Heater and Method of Producing the Same." However because of the fact that our heat radiating panel is adapted to operate at fairly low power input values, a relatively high resistance is required and, since conventional expanded metal processes usually produce a mesh which provides a relatively low resistance path for the electrical current, we have made a departure from such practice and, in the forming thereof, we utilize in the expanding operation a die of special construction which gives an opening that is compartively long as regards its width. By way of illustration, we have found that an opening of $1\frac{1}{8}$ inches in the transverse direction of the sheet, with 60 meshes per foot in the longitudinal direction, will give the desired results for panels which have a relatively large radiating area and are suitable for use in heating large living spaces. Obviously, the particular character and dimensions of the mesh material will vary for different installations, but in each case the particular dimensions employed will be carefully calculated according to engineering exigencies, and for most installations where large panels are concerned, the mesh dimensions given above will suffice.

Where smaller panels are contemplated, the same mesh dimensions may obtain, but special treatment is given the panel in accordance with the principles involved in various modifications of the panel subsequently to be described with reference to the accompanying drawings.

The resistance unit is subsequently entirely embedded in an insulating material or sheet 23 which may be formed of various materials, the particular material illustrated being a suitable thermoplastic resin having a melting or softening point well above the temperature to which the metal of the resistance unit is to be raised for heat-radiating purposes. Obviously, other materials are contemplated, and the embedding material may be of a thermosetting character, or it may be in the form of a filler unit which is pressed into the interstices of the mesh from one or both sides thereof and which, if desired, may have impressed therein a suitable binder material such as a resinous compound of a thermosetting nature capable of becoming polymerized upon application thereto of heat and pressure. Upon such application of heat and pressure, the material becomes set to bind the filler material and produce a durable surface, as well as to anchor the resistance unit 10 in position within the sheet.

In some installations we expect to employ the thermoplastic material of a transparent nature for the reason that in certain modified forms of the panel we resort to a cutting of both the panel and the mesh, with the mesh being cut along precise lines as will be described presently. When the embedding material of the panel is transparent, a visual indication of the proper lines of cutting or cleavage is available and, for reasons of manufacturing economy, the panels of Fig. 1, when formed of transparent material, may readily be converted into the panels represented by the other illustrated forms of the invention.

Since the embedding material is capable of being reheated and softened when it is formed of thermoplastic material, and since the embedded mesh is quite flexible, it is a comparatively easy matter to reheat and deform the completed panel of Fig. 1 into various shapes, as for example where it is desired to resort to the jacket heating of water pipes or the like. In other words, the panel may, in actual manufacture, be stockpiled for direct use without alteration for conversion subsequently into the various modified forms which have been contemplated to accommodate different installations. Such reforming of the panels may be practiced in accordance with the principles of the invention set forth in the above mentioned copending application of James Horsfall and Audrey J. Bowden.

The advantages of the use of continuous, expanded metal mesh material as a resistance unit in any sheet of embedding material are manifold, and of primary importance is the fact that the expanded metal has a certain degree of depth. It is to be noted (and Fig. 7 is illustrative in this respect) that the embedding material is but a few thousandths of an inch, preferably less than .030 inch thicker than the depth of the expanded metal mesh material and that the mesh is substantially centered in the embedding material. Because of this fact, a very even distribution of heat throughout the embedding material is obtained by virtue of the relatively large surface area afforded by the metal and its face-to-face contact with an equally large inner or contacting embedding surface area of the plastic material. Where ordinary mesh wire of circular cross sectional configuration is employed, a minimum of surface area is afforded and, as a consequence, to secure the same heat-radiating properties as expanded metal mesh, a higher temperature must be reached within the metal of the mesh, and this higher degree of heat, being confined in a smaller space more remote from the surface of the embedding material, must find its way through the plastic material to the surface of the panel for heat radiating purposes. It will be obvious therefore that in the immediate vicinity of the surface of the mesh, the temperature of the plastic will be inordinately high and the material of the plastic adjacent the mesh will be subject to softening or melting which, if continued for a long period of time, will cause sagging of the mesh within the body of the plastic due to its weight and for lack of support when the plastic becomes soft. Prolonged and repeated use of the panel may thus cause the metal mesh to creep completely out of the panel and thus become exposed to the atmosphere or to the support on which the panel may be mounted.

The use of expanded metal mesh as a resistance unit presents one distinct advantage in that multiple current paths which are in electrical parallel are provided for the flow of current from one terminal or selvage to the other. In the case of large installations, so many multiple paths are provided that severing of a single mesh strand will have no appreciable effect upon the overall heating effect of the panel, whereas in the case of single-strand, tortuous-path resistance wire, severing thereof at any one point due to localized overheating or a defect in the strand, or due to faulty manufacture of the panel, or accidental severance after installation, will open the electrical circuit of the resistance and render the panel inoperative for the purposes intended.

As distinguished from such single-strand panels, any tendency for failure of the mesh material of our improved panel at any one point therein will be minimized by virtue of the large multiplicity of alternate paths that are afforded by the adjacent meshes which tend to divert the flow of current away from the weaker strand. Such protection of the weaker strands does not occur in the case of individual wire panels having no interconnections between terminals.

In the construction of our panels, we prefer that the mesh portion 12 be completely embedded in the plastic material, and that the plastic material overlap the selvage edge portions 14 and 15 as shown at 26, and that it extend beyond the edges of the mesh portion as shown at 28 at each side of the sheet so that a completely insulated mesh resistance unit 10 is provided.

For electrical access to the selvage portions 14 and 15, i. e. to facilitate electrical connections to these terminal portions, a terminal screw such as is shown at 30 may be extended through the plastic material of the panel and into the holes 20 so as to make contact with the selvage regions at suitably selected points therealong. If desired, a wire may be electrically connected to the terminal portions or selvage regions and extended through the plastic material as shown at 30*g* in Fig. 10.

As stated above, the panel of Fig. 1 is suitable for use where large installations and large radiating areas are involved, as for example, in home heating. This is true because of the relatively great distance between the selvage portions and the possibility of connecting several of the panels in series will permit sufficiently high resistance to be obtained that with a low power input, the desired heat-radiating effect will be attained.

Panels such as have been illustrated in Fig. 1, when made of smaller dimensions, may be employed where higher degrees of heat radiation are desired. Such panels are found to be useful in drying cabinets, heating of conduits and other uses heretofore mentioned. Where smaller units and low heat radiation are concerned, the formation of the panels shown in Figs. 2 to 7 inclusive are applicable.

Referring now to Fig. 2, the panel shown therein is designed for use for low heat radiation and involves a relatively small surface area. Even with the use of fine grade expanded metal mesh having 60 or more meshes to the foot, measured longitudinally, the resistance afforded by this mesh is too low to accomplish the low input necessary to attain the desired low degree of heat radiation. To effect lengthening of the current path, we prefer to construct the panel in the same manner employed in connection with the construction of Fig. 1, i. e. in the manner previously set forth in connection with the methods illustrated in Figs. 11 and 12, and thereafter to create a series of staggered cuts in the panel in such a manner as to sever certain of the strands of the mesh while at the same time maintain a continuous flow of current from one selvage portion on one side of the panel to another such portion on the other side thereof.

To avoid repetitious description of parts, similar characters of reference have been applied to the corresponding elements shown in Figs. 1 and 2.

To construct the panel of Fig. 2, a series of cuts **40***a* are made in the panel of Fig. 1 from one edge thereof along the axes *x*—*x* and from the other edge thereof along the axes *y*—*y*. The cuts are staggered and those taken along the *x*—*x* axes completely sever the selvage **14***a* but extend only to the inner edge of the selvage **15***a*. The cuts along the *y*—*y* axes completely sever the selvage **15***a* but extend only to the inner edge of the selvage **14***a*.

As shown, the cuts through the panel extend through the mesh strands at their points of juncture, and the distance between adjacent cuts is equal to the width of a single mesh or, in other words, is "one mesh wide."

The severed panel, by virtue of the cuts effected therein, is materially weakened and, in order to restore the original rigidity of the panel as an entirety, we reprocess the same by placing the panel in a press and applying sufficient heat thereto to soften the thermoplastic material and cause the same to flow into the voids presented by the cuts. Additional plastic material in the form of strips may be supplied and inserted in the cuts or placed in the proper position in the press so that when softened, the material will flow into the cuts. We have found however that ordinarily the application of pressure and heat will, without the addition of plastic material, cause a readjustment of the plastic material so that the panel will emerge from the press when cooled with accurate and smooth plane surfaces. Such flow of the plastic material into the cuts has the multiple effect of restoring the panel to its original rigidity, of providing electrical and mechanical insulation for the exposed ends of the mesh strands, and of providing a barrier tending to prevent the opposed ends of the mesh from merging into contact with each other when normal thermal expansion occurs in the resistance unit due to subsequent use of the panel as a heating and radiating element.

The flow of current through the panel will obviously be from one corner thereof across the ends of the various lines of severance of the mesh strands to a diagonally opposed corner and, accordingly, anchor points may be selected as desired and terminal screws **30***a* employed as in the case of the panel of Fig. 1. Ordinarily the terminal screws **30***a* existing at the lower left hand corner of the panel and at the right upper corner will be employed for causing a back and forth flow of current completely across the panel, but, if desired, any two terminal screws **30***a* may be selected for connection to a source of current to obtain various localized heating effects.

Panels such as are shown in Fig. 2 may be employed where it is desired to radiate heat in the conditioning of small enclosures. For use in conditioning larger enclosures, we contemplate using a number of the panels arranged electrically in parallel, although series connections may be effectively employed under certain conditions, and if the electrical characteristics of the mesh are adapted for such connections.

In Fig. 3, as in Fig. 1, the same similarity of reference characters has been preserved for the sake of conformity and of eliminating needless description. In this form of the invention, the staggered cuts made in the panel do not extend to the edges of the selvage portions **14***b* and **15***b* but terminate short thereof. This will cause the electrical current to have a tortuous path around the ends of the various cuts within the mesh proper, and there will be substantially no current flow through the selvage sections at the ends of the cuts. The inert selvage sections between adjacent cuts on the axes *x*—*x* and *y*—*y* may be removed if desired leaving the diagonally opposed sections with their anchoring holes **20***b* intact.

The panel of Fig. 4 isimilar to that of Fig. 2 and in this instance the various cuts made in the panel are likewise one mesh apart. However these cuts extend to the inner edges of the selvage regions **14***c* and **15***c* and, unlike the cuts of Fig. 2, they pass through the medial regions of single mesh strands as shown. The effect of such cutting of the mesh is to provide a single zig-zag path of channel across the panel as indicated by the strands which have been labelled *a*, *a*, *a*, etc. Current flows from the left and short section of the selvage **14***c*, through the zig-zag path *a*, *a*, *a*, to the long section of the selvage section **15***c*, and from thence back and forth across the panel, ultimately reaching the other short section of the selvage portion **15***c*. The two short sections of the selvage sections **14***c* and **15***c* constitute the electrical terminals for the unit.

It is to be noted that certain strands such as those labelled *b*, *b*, *b*, etc. are electrically inert, which is to say, they do not constitute a portion of the current path. These loose ends have an advantageous function in the panel unit. Except for the entirely negligible amount of surface area which may be lost in the cutting operation, and which is at least in part compenated for by the provision of the extreme exposed transverse ends of the severed strands, these strands offer a combined surface area which is substantially equal to twice the combined surface area of all of the strands which are electrically conductive. These inert strands thus present effective radiating surfaces inasmuch as they acquire heat by conduction from the electrically active strands *a*, *a*, *a*, which they adjoin and, as a consequence they act as heat-radiating and distributing elements.

The panel of Fig. 4 may have a small surface area inasmuch as the circuitous path offered by the panel presents a high resistance per square foot of paneling, while the normal heat radiating area is not diminished appreciably, as compared to uncut, expanded metal mesh.

The panel of Figs. 5 and 7 is similar to the panel of Fig. 2, with the exception that the adjacent cuts along the axes $x—x$ and $y—y$ are made in such a manner that the various embedded mesh strands are severed medially and the distance between adjacent staggered cuts is one and one-half meshes wide. The mesh material between adjacent cuts includes a single complete mesh opening with two "loose ends" or strands at each end thereof. By such an arrangement, a dual parallel zig-zag current path through the strands *g*, *g*, and *h*, *h*, is provided from selvage to selvage, back and forth across the panel. In this form of the invention, the total radiating area of all of the mesh strands is one and one-half times the radiating area of the electrically active strands.

It will be noted from an inspection of Fig. 7 that the overall thickness of the plastic material of the panel is only slightly greater than the overall thickness of the embedded mesh material. This results in a heat radiating panel in which the heat is effectively and evenly distributed throughout the entire panel and in which a very high thermal efficiency is maintained by virtue of the fact that there is no necessity for the heat radiated from the surface of the metal to take a long path through the molecular structure of the plastic material before it emerges from the surface of the panel as radiated heat.

The panel unit of Fig. 6 is similar to that of Fig. 5 with the exception that the cuts which are made along the axes $x—x$ and $y—y$ do not extend to the inner edges of the selvage regions but terminate short thereof and, in the finished product, all the selvage regions or sections **14***g* and **15***g* except the terminal sections have been removed.

The panel unit of Fig. 8 is similar to that of Fig. 1, but in this form of the invention the embedding material **23***h* is formed of a fibrous insulating material which may be asbestos, rock wool, glass fibers or the like which is impregnated with a thermosetting compound which, upon subsequent application of heat and pressure to the impregnated material, becomes hardened or set by a polymerization process, leaving the resistance unit embedded therein. The panel may be formed by pressing the material into the interstices of the mesh from one side or both sides thereof and thereafter performing the impregnating and polymerizing process.

If desired, the impregnating material may be a suitable binder or coherer containing a volatile substance, and in such an instance the volatile constituents are adapted to be driven off by the application of heat, leaving the resistance unit embedded therein.

If panels of the nature set forth in connection with Fig. 8 are cut according to any of the methods outlined in connection with the form of the invention shown in Figs. 2 to 7 inclusive, the lack of transparency of the panel may require severing of the mesh material before the embedding operation and the omission of the severing of the formed panel.

Figs. 9 and 10 disclose a novel method of forming a panel unit in which heat generated by passing electrical current through the expanded metal resistance unit or element **10***m* is employed to effect conversion of a thermoplastic material, curing of a thermosetting material, driving the volatile constituents from a substance in which the expanded metal resistance unit ultimately remains embedded, or evaporating moisture from the substance in which the resistance unit remains embedded.

For illustrative purposes only, there is disclosed in Figs. 9 and 10 a method of forming a finished panel unit consisting of a lower layer **61***m* of an inorganic material and an upper layer of similar material between which layers there is embedded or sandwiched a sheet of expanded metal mesh **10***m*. It will be understood however that various materials may be employed as the embedding substance as, for example, matted sheets of fiberglass or the like dipped in silicones, resinous materials, or inorganic materials such as cement and asbestos or resinous thermosetting materials.

According to our process, we prefer to make up a "sandwich" or laminate assembly on a separate table removed from the press and to thereafter insert the materials of the laminate assembly into the press openings. This we perform by placing on the table a sheet of mild steel of substantially the dimensions of the press platens. The inorganic material, which may be in the nature of a heavy viscous liquid and which, for want of a better term, may be referred to as a "sludge" is spread upon this sheet of steel. The expanded metal mesh material is then placed on the layer of sludge and another layer of the sludge material is spread upon the metal mesh. A distance piece **64***m* is then placed about the laminate assembly thus built up and a second sheet of mild steel is placed on top thereof. The whole laminate assembly, together with the distance piece is then inserted into the press openings and the press platens are then closed upon the assembly. Current is then passed through the mesh material **10***m* and, in the case of the sludge material, a baking or curing operation takes place while, in the case of a thermosetting material being employed instead of the sludge, conversion takes place so that the plastic material substantially fills the interstices of the mesh and the latter becomes completely embedded in the plastic material to make up the completed panel unit.

The completed article may retain the original selvage portions **14***m* and **15***m* or, if desired, the selvage portions may be removed. If the selvage portions are retained, the panel may be employed in the manner of Figs. 1 to 7. If the panel is to have no further electrical function and the selvage portions are removed, the mesh material will serve as a reinforcing element.

In constructing any of the panels described in this application, we prefer to resort to the separate construction of a "sandwich" or laminate assembly before introduction of the materials into the mold opening or openings.

According to our invention, we further contemplate that the internal heat generated by passing electrical current through the resistance elements or units of any of the panels shown in Figs. 1 to 7 inclusive may be utilized to produce a softening action of the thermoplastic material of the already constructed panels.

To produce such a softening action, sufficient current flow is resorted to to attain the necessary degree of heat and this will obviously be somewhat below the flow temperature of the embedding material of the panel. Thus the completed panels may be placed in a suitable mold, such as the mold shown and described in the above mentioned copending application of James Horsfall and Audrey J. Bowden, and, when the electrical current is passed through the mesh resistance element, it may be employed to generate internal heat to augment the heat applied to the mold dies, or it may constitute the sole heat for producing the necessary softening action to permit shaping of the article in the mold.

In constructing our panels, we have found that there is a close mathematical relationship between the surface temperature of the panels and the input expressed in watts per square foot of radiating area. This we have determined by empirical methods and we have found that it holds true regardless of the character of the embedding or of the embedded material.

In support of our conclusions in this regard, we advance the theoretical considerations that, given a piece of expanded metal mesh material and, considering the flow of current from one selvage region to the other, the resistance of the piece will be directly proportional to the length of the mesh between the selvage regions and inversely proportional to the number of meshes in the transverse direction.

Stated mathematically, if L is the distance between the terminals and W is the measurement of the number of mesh widths, then for any given combination of mesh size, wire size, or strand cross section, and the resistance coefficient of the metal, the resistance of the piece will be expressed by the formula

$$R=\frac{L}{W}\times K$$

where K is a constant determined by the characteristics of the mesh material.

For a fixed voltage E, the power input is expressed by

$$\frac{E^2}{R}$$

and substituting this value for R in the above formula, the power input equals

$$\frac{E^2W}{LK}$$

The area of a given piece of mesh material is WL and the input per square foot is therefore the above value divided by WL or

$$\frac{E^2}{L^2K}$$

It will be seen from the above that the input per unit of area is independent of the width and varies inversely as the square of the length.

The above discussion has had reference to a piece of conducting mesh material. If this material is embedded in a heat conducting, electrically insulating material such as shown in connection with Figs. 1 to 8 inclusive, and 10, the same general relationship will hold inasmuch as after a period of operation under stable conditions the output heat radiated from the surface of the panel must necessarily equal exactly the input of electrical energy into the mesh material and also equal exactly the output of heat emanating from the mesh material which converts the input of electrical energy into heat. It follows therefore that the above algebraic expression is valid for radiant heating panels constructed in accordance with the principles of our invention as well as for open mesh material.

In the case of mesh that has been cut alternately from end to end as shown in Figs. 2 to 7 inclusive, the value L in the above expression becomes the total length of the conducting path, disregarding the low resistance selvage regions at the ends of the panel.

While we have described our invention in connection with certain specific embodiments thereof, it is to be understood that this is by way of illustration and not by way of limitation and the scope of our invention is defined solely by the appended claims which should be construed as broadly as the prior art will permit.

We claim:

1. The method of forming a heat radiating panel which comprises embedding a resistance unit having a medial expanded region and terminal selvage regions on opposite sides thereof in a sheet of thermoplastic material having an overall thickness only slightly greater than the overall thickness of the expanded region of the resistance unit, providing a series of staggered cuts in the thus assembled panel which extend inwardly from opposite ends of the panel, each of said cuts passing completely through one selvage region, across the expanded region and to the inner edge of the oppositely disposed selvage region, thus providing a tortuous path for the flow of current through the panel in a generally longitudinal direction.

2. The method comprising the steps set forth in claim 1 and the additional step of placing the thus cut panel assembly in a press, applying heat thereto and causing the softened plastic material of the sheet to flow into the staggered cuts to electrically and mechanically isolate the opposed ends of the mesh strands which are created by virtue of the cuts from one another and to restore the panel to its original rigidity.

3. The method of forming a panel consisting of an embedded sheet of expanded metal surrounded by an embedding material which comprises placing the sheet of expanded metal upon a sheet of the embedding material, placing a second sheet of the embedding material upon the expanded metal sheet, placing a heat-radiating panel consisting of a sheet of expanded metal embedded in an insulating material upon said second sheet of embedding material, placing a third sheet of embedding material upon said heat-radiating panel, placing a second sheet of expanded metal upon said third sheet, placing a fourth sheet of embedding material upon said second sheet of expanded metal, inserting the thus positioned sheets and panels in a press, and applying pressure thereto in the press while simultaneously passing electrical current through the expanded metal of the heat-radiating panel and utilizing the thus generated heat to soften the embedding material and cause formation of a panel on each side of the heat-radiating panel.

4. The method set forth in claim 3 in which additional heat is applied externally to the materials within the press opening from the press platens.

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AUDREY J. BOWDEN.

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