April 8, 1969 J. H. LEMELSON 3,436,816

METHOD OF MAKING HEAT TRANSFER PANELLING

Filed Oct. 22, 1965

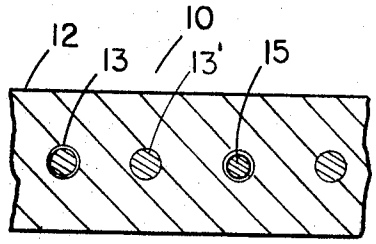

FIG. 1

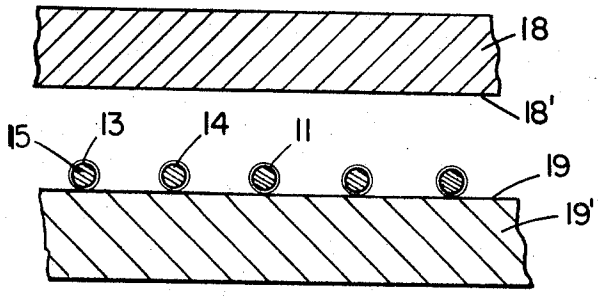

FIG. 4

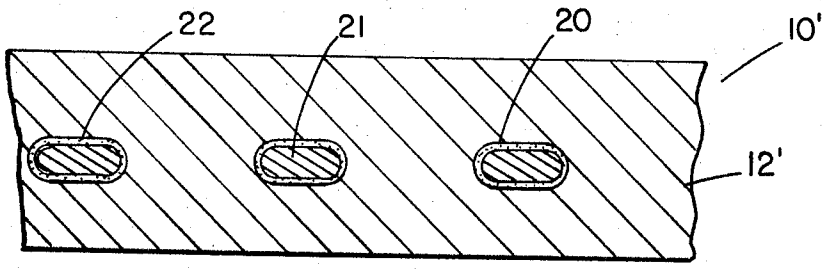

FIG. 2

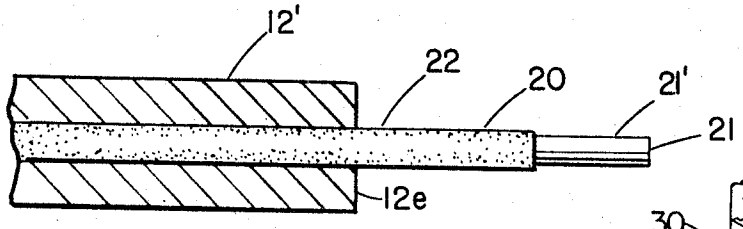

FIG. 3

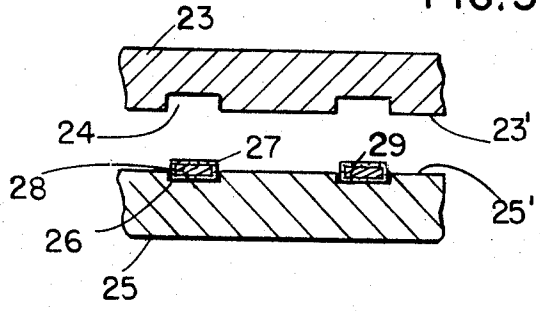

FIG. 5

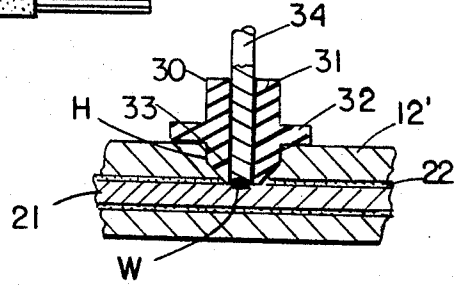

FIG. 6

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METHOD OF MAKING HEAT TRANSFER PANELLING

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Continuation-in-part of application Ser. No. 241,904, Dec. 3, 1962. This application Oct. 22, 1965, Ser. No. 500,731

Int. Cl. H01c 1/14, 17/00

U.S. Cl. 29—611 3 Claims

This invention relates to composite sheet formations and is a continuation-in-part of my copending application Ser. No. 241,904 filed Dec. 3, 1962, now Patent No. 3,276,513, for Composite Screen Assembly having a parent application Ser. No. 519,014 filed June 28, 1955 for Welding Techniques and now abandoned. More particularly, this invention concerns new and improved structures in metal sheets including sheets having embedded therein one or more insulated electrical conductors which may be operative to carry current without grounding in the sheet.

It is known in the art to fabricate electrical heating devices by weaving or otherwise securing metal wires or strips to asbestos cloth or other flexible materials which will not melt or deteriorate when the elements are electrically energized. These structures suffer a number of disadvantages and shortcomings including, among others, inability to resist penetration and abrasion, inability to support loads and, in many instances, the inability to operate at temperatures of more than several hundred degrees centigrade. Heating panels have been fabricated by applying an insulating coating to the surface of a metal sheet and bonding on said coating one or more strips of metal capable of conducting electricity but such structures suffer the shortcoming that the conducting strips may be easily penetrated and severed or abraded to cause a break or short-circuit. Furthermore, such conducting panels are not easily fabricated into many articles by bending the sheet or rolling same in a mill.

Accordingly, it is a primary object of this invention to provide a new and improved structure in a sheet containing one or more electrical conductors encapsulated within said sheet.

Another object is to provide an improved heating panel made substantially completely of metal capable of supporting a substantial load and being fabricated into a structural support member.

Another object is to provide a heating panel made of metal with heating elements embedded therein and protected by metal on both sides from abrasion, penetration or shearing actions resulting from contact with objects while in use.

Another object is to provide an improved heating sheet which may be easily formed to shape by bending, rolling, stamping or other means so as to permit same to be easily fabricated into equipment components such as tubing, beams, wall panels, rings, flanges, aircraft skin structures and the like.

Another object is to provide an improved structure in a metal sheet containing a plurality of conducting elements embedded therein with means provided for insulating and connecting individual elements to external circuits, the sheet being applicable as a wall or other structural component of an article of manufacture and serving to hide and support said conducting elements.

Another object is to provide a metal sheet containing conducting wires embedded therein which serve to reinforce the sheet.

Another object is to provide an improved method for fabricating composite metal sheets.

Another object is to provide an improved electrically conducting panel in which the conductors serve to substantially reinforce the panel. With the above and such

other objects in view as may hereafter more fully appear, the invention consists of the novel constructions, combinations and arrangements or parts as will be more fully described and illustrated in the accompanying drawings, but it is to be understood that changes, variations and modifications may be resorted to which fall within the scope of the invention as claimed.

In the drawings:

FIG. 1 is an end view in cross section of a panel made in accordance with the teachings of this invention;

FIG. 2 is an end view in cross section of a fragment of a modified form of the panel of FIG. 1;

FIG. 3 is a side view in partial cross section showing the edge of a fragment of a panel of the type illustrated in FIG. 2;

FIG. 4 is an end view in cross section of the components of a panel in most respects to that illustrated in FIG. 1 prior to the fabrication thereof;

FIG. 5 is an end view in cross section of portions of members utilized to fabricate a modified form of the invention; and

FIG. 6 is a side view in cross section of a fragment of a panel of the type defining this invention showing means for electrically connecting a lead to a conductor encapsulated within the panel.

The nature of the invention, as to its objects and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawing forming a part thereof in which:

FIG. 1 illustrates a structure in a composite metal sheet applicable for the fabrication of various articles of manufacture which employ as a component thereof, a screen, grid or grating made of plural wire-like elements capable of conducting electricity and/or reinforcing the sheet. The sheet assembly **10** may include, in addition to the components and structure illustrated, additional components and structural features defining the completed article or product.

One component of the sheet or panel **10** comprises one or more strips, wires or rods **13** provided per se in parallel array or defining a mesh, grid, screen or grating encapsulated or embedded within a metal member **12** which may comprise a plate or sheet or portion of a frame or edge support for the wires or grid. The member **12** is preferably, although not necessarily, made of a non-ferrous metal such as aluminum, copper, titanium, brass, zinc, or other non-ferrous metals or alloys capable of being extruded, forged, cast or otherwise provided in the desired sheet or plate shape. The wires **13** may be made of a ferrous metal, electrical resistance material or alloys such as steel or any suitable metal provided per se or insulated with an outer skin or coating **13'** of electrical insulating material from the metal of member **12**.

The grid or wire array **14** is shown as being made of a plurality of individual wires or filaments **13** of metal cylindrical in shape and shown in cross section which may extend in one direction parallel each other or may be joined by a plurality of longitudinal filaments (not shown) which define a grid or grating.

In FIG. 2 is shown a panel **10'** including wires or strips **20** having electrically conductive core portions **21** which are respectively coated with insulating layers **22** of non-conductive material such as aluminum oxide, aluminum fluoride, other ceramic or glass, and said coatings are deformed in situ thereon or on the outer surface strata of the metal as a thin coating or film. Such wires **20** are disposed between two sheets of metal, as in FIG. 2, which are compressively engaged and caused to flow completely around said elements in a manner to encapsulate them within the resulting sheet **12'** as described, a new

article of manufacture will be provided which is capable of serving as both a structural and a heating element. By connecting the conducting portions of the filaments or grid elements with a source of sufficient electrical energy, they may be made to serve as resistance heating elements which transfer heat to the surrounding metal and the resulting sheeting may be used as the skin of a housing aircraft or vehicle or heat transfer device requiring the conductive transfer of heat to one or both surfaces thereof. The insulated conducting wires **20** may also be used as conductors per se of electricity if the assembly **10'** is to be used as the wall of an article, vehicle or panel serving to support said electrical conductors while carrying electricity without heating same.

In FIG. 3, the ends **21'** of one or more of the encapsulated elements **21** are shown extending from the side edge **12***e* of the metal sheet **12'** and may be bared of insulation **22** beyond sheet **12'** for electrically connecting same to a source of electrical energy.

The panel assemblies described may be fabricated by various techniques such as those illustrated in FIGS. 3 and 4. In FIG. 4 wires **13** are shown positioned between two members **18** and **19** such as sheets or plates of metal such as pressure weldable aluminum. The plates **18** and **19** may be roll bonded or otherwise compressed in a press or rolling mill operative for compressively engaging the other faces of said plates and causing the metal of each to flow around the wires or through the openings in the grid thereof to cause said two members **18** and **19** to become molecularly bonded together after completely encapsulating the elements **13** therebetween. The faces **18'** and **19'** of the two sheet or plate members **18** and **19** are preferably cleaned and deoxidized just prior to performing the operation of encapsulating the wires **13** or screen **14** therebetween so that pressure welding of the assembly will be simplified and such cleaning may be effected continuously by brushes rotating in line with the rolling mill.

Following the encapsulation of at least a portion of the wires or screen **14** within the metal member **12** as illustrated in FIG. 1, further operations such as bending or rolling may be performed on the assembly **10** to make articles such as containers, wall panels, tubing or the like thereof.

A screen assembly of the type illustrated in FIG. 1 may be produced by means other than that illustrated in FIG. 2. The means to compressively engage the upper and lower sheets to cause flow of the metal around wires **13** or between the spaces or voids in the grid thereof, may be replaced by a plurality of aligned roller elements such as those of a rolling mill through which the two sheets **18** and **19** and wire or grid members are passed which rollers are adapted to continuously compressively deform the two sheet members in a manner to flow and molecular bonding of material of each so as to become welded together to define the unitary structure or edge support illustrated in FIG. 1.

In one form of the invention the composite structure so fabricated will provide a new type of aluminum or non-ferrous metal sheet which is internally supported and substantially enhanced in such characteristics as rigidity, flexural strength, or ability to resist buckling.

In another method of fabricating a panel of the type described, either or both the sheets of non-ferrous metal used to encapsulate the conductors therein may be shaped to preposition and retain the insulated conductors or reinforcing elements in place as shown in FIG. 5. An upper sheet or plate **23** is shown having channels **24** therein aligned with an insulated conducting strip or strips **27** also shown disposed in channels **26** in the lower plate **25**. Thus, the facing surfaces **23'** and **25'** of the sheets **23** and **25** may be brought into abutment with each other and molecularly bonded or welded together without exerting a shearing action on the insulation **28** coating or covering conductive core metal **29** of the strips **27**. The shape of the channels in sheets **23** and **24** and strips **27** may be such as to cause the strips to be lightly engaged in the resulting passageways when the sheets **23** and **25** are welded. Strips **27** may be preshaped, insulated wires positioned within the channels **26** in sheet **25** or disposed on the flat upper surafce **25'** of sheet **25** on a continuous basis in alignment with respective channels **24** as the two sheets are rolled to shape, extruded or otherwise continuously fed to the bite of the roll bonding mill rolls. Strips **27** may also be applied as a plurality of layers of insulating material and a conducting or resistance heating material disposed therebetween, which layers are sprayed, screened, extruded, rolled or otherwise applied to channels **26** or surface **25'** just prior to roll bonding or welding sheets **23** and **25** together.

While a circuit joining technique involving extending one or more of the encapulated conductors **20** beyond an edge of the sheet, as in FIG. 3, may be employed to connect electrical energy to the wires within the sheet, in certain applications it may be more desirable to apply the technique of FIG. 6 to effect such coupling. FIG. 6 shows sheet **12'** having a hole H drilled or otherwise provided therein and extending to element **20**. The drilling is effected in a manner to bare insulation **22** from **20** so as to expose a portion of the upper surface of wire or conductor **21**. A fitting **30** holding a pin or wire conductor **34** is adapted to frictionally fit a hole H and position the end of pin **34** against the bared portion of encapsulated conductor **21**. Thus **34** may be welded as indicated at W to **21** by resistance welding or other means if core **21** is engaged by another similar fitting wire or otherwise grounded.

Fitting **30** is preferably non-conducting material such as a ceramic or plastic resin and has an upper sleeve **31** terminating at a flange **32** engaging the surface of **12'** and a lower shank **33** shaped to conform to tapered hole H to insulate the conductors from grounding on the wall of said hole.

Other means for providing the grid wire elements **20** or grating thereof encapsulated within a sheet or panel of metal include (a) extruding said metal directly onto and causing it to flow through the voids of said grid, (b) casting or molding liquid metal around said grid or (c) feeding powdered metal between rollers through which the grid or grating is also fed and compressively compacting said powdered metal to form a unitary sheet or sent to the particles thereof with the elements of the grid or grating encapsulated between the surfaces of the fused or sintered sheet. Extrusion encapsulation of the grid or wire elements may be effected by extruding two sheets of metal such as aluminum, one adjacent the other and continuously guiding them towards each other while feeding a web of the screening therebetween and guiding the three members between rolls of a roll bonding mill whlie the metal sheets are still at a high temperature to facilitate molecular bonding and compressively engaging said sheets to cause them to flow together around and between the elements of the grid or screen and to be continuously molecularly bonded into a unitary sheet or plate with the grid encapsulated therein. The screen may be fed so that a portion will protrude from one or more edges of the finished metal plate or sheet, if used as a resistance heating element or may be totally encapsulated and hidden within the sheet if used solely as a reinforcing means for the sheet. Such techniques may also be employed using ceramics or resins as the sheet and encapsulating material.

In another form of the invention one or both of the metal sheets extruded to form the composite sheet may comprise a material other than metal such as ceramic, plastic, glass, etc. which may be extruded, roller coated or otherwise applied to a surface of the other sheet and screening prvided thereon. For example, a thermosetting plastic may be applied as a spray, flow of powder or roller coated fluid as a layer onto a sheet of metal against

which a screen web is fed and retained by roller means. Similarly, particles of glass or other ceramic material may be deposited as a layer which covers the screening and fills the voids therein after which heating applied by any suitable means may be used to fuse the layer into a hard coating. Electrostatic positively charging the particles while negatively charging the base metal sheet and/or screening may be utilized to attract, uniformly distribute and retain the particles in place until heated to form a unitary coating or layer encapsulating the screening. In still another form of the invention, a metal grid, grating or screen may be negatively charged and guided between two pairs of drive rolls through free space. Positively electrostatically charged particles of material (glass, ceramic, plastic or metal) are directed by conventional spray equipment against that portion of the negatively charged screening or grating traveling between the drive means at such a flow rate and in a manner to effect the deposition of particles in a uniform layer or coating around each grid or grating element after which heat is applied by radiant, induction or other means to melt the deposited layer of particles into a unitary coating around each element whereafter they are allowed to solidify as a protective coating. Two structures of the finished article may be produced. In one, the particles are deposited to such a depth that, upon heating and fusing into a coating, spaces or voids between the elements of the grid or grating will remain so that the grid still retains its identity as a grid. In another method, the particles may be electrostatically deposited to such a depth on the grating or screening that, upon melting or fusing into a coating, the voids between grating elements will be filled with the particle material. Additional quantities of particles material may be so electrostatically deposited prior to heat fusion the first time or after heat fusion of the first material deposited to provide, when melted and fused, not only material coating and filling the voids, but also as a further layer extending beyond either or both faces of the screening to encapsulate said screening therein as illustrated in FIG. 1. The deposited and solidified coating may be subsequently hot or cold worked, if metal or ceramic, to improve its characteristics.

Noted variations in the panel structures illustrated in FIGS. 1 to 5 include fabrication of the main panel body such as **12** and **12'** or the formation of FIG. 5 of glass or ceramic materials which are made from freshly formed sheets of such materials which are roll bonded or otherwise fused together in a continuous rolling mill or press. If made of metal, panels **12** and **12'** may be bent or fabricated by rolling into tubing and other structural shapes.

I claim:

1. A method of fabricating a metal panel having an electrically conducting element encapsulated therein comprising:

(a) jacketing an electrically conducting wire in an abrasion-resistant hard electrically insulating coating disposed completely around said wire,

(b) disposing said wire between two pressure weldable metal members,

(c) compressively engaging said metal members and causing same to deform and flow over and around said wires without removing said insulating coating therefrom and pressing the members together to cause molecular bonding of their surfaces and to encapsulate said electrical conductors in a unitary structure.

2. A method of fabricating an electrically conducting panel comprising:

(a) depositing on a first surface of a metal member a first strip of electrically insulating material,

(b) depositing a flat strip electrical conductor on said first strip of insulating material so as to insulate said conductor from said metal member,

(c) depositing insulating material over said electrical conducting strip and

(d) thereafter providing metal against the surface of said first metal member and pressure welding said metal thereto in a manner to completely encapsulate the metal strip with said non-conducting material insulating said metal strip from the metal of said first metal member and that welded thereto.

3. A method of forming a metal panel having a plurality of electrically conducting elements insulatedly encapsulated within the panel comprising the steps of:

(a) exposing the surface of a wire made of electrically conducting metal to an oxidizing atmosphere thereby forming a hard, abrasion-resistant compound on the surface of said metal defining an electrically insulating coating,

(b) disposing said wire against a first surface of a first member of pressure weldable metal,

(c) bringing a second pressure-weldable metal into surface abutment with the coated wire,

(d) compressively engaging said first and second members to cause flow of metal of at least one of said members over and around said wire and so as to cause the metal of both said members to flow together,

(d) and continuing the compressive engagement of said metal members to completely encapsulate substantially all of the wire without removing the hard surface coating thereof and to cause the welding of the two metal members together into a unitary structure.

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U.S. Cl. X.R.

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