United States Patent
Fujihara

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[54] **FLEXIBLE PANEL-TYPE HEATING UNIT**

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[30] **Foreign Application Priority Data**

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Sept. 24, 1970 Japan....................................45/94016

[52] **U.S. Cl.**..............................**219/345,** 219/213, 219/311, 219/553

[51] **Int. Cl.**..**F24h 9/02**

[58] **Field of Search**..................219/201, 213, 311, 345, 528, 219/549, 543, 553

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Primary Examiner—C. L. Albritton
Attorney—Wenderoth, Lind & Ponack

[57] **ABSTRACT**

A flexible panel-type heating unit in the form of a sealed integral assembly comprising an electrically resistive paper or felt-like porous board having at least one pair of electrodes contacting at its opposite ends. The resistive board and electrodes are sandwiched and sealed by layers of paper or cloth sheets impregnated with a synthetic resin. This new panel-type flexible heating unit has a stable electrical resistance, generates heat uniformly at the entire portions at a desired temperature, automatically maintains the given temperature, allows heating of not only planar but also curved surfaces, and eliminates the provision of temperature-controlling means such as thermostat.

8 Claims, 16 Drawing Figures

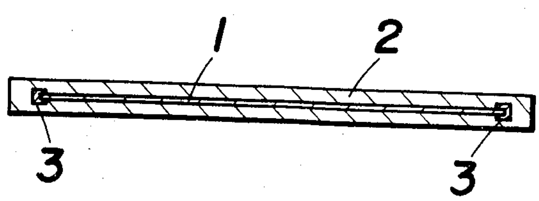

FIG. 1

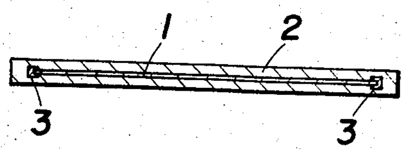

FIG. 2

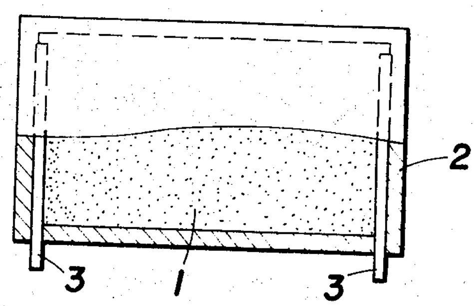

FIG. 3

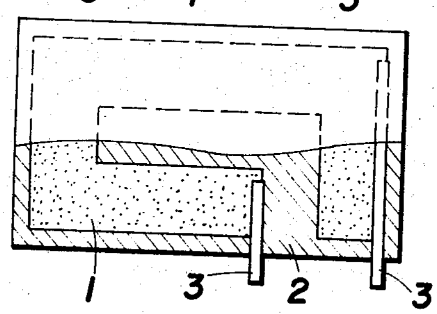

FIG. 4

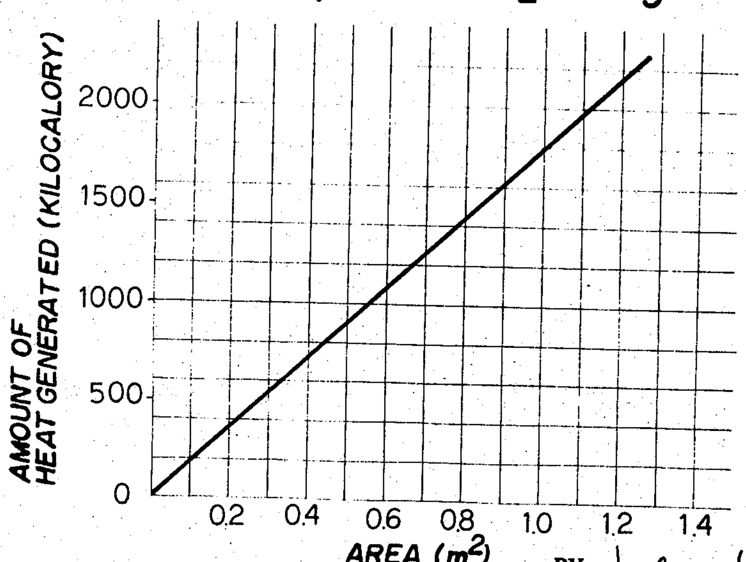

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FIG. 5

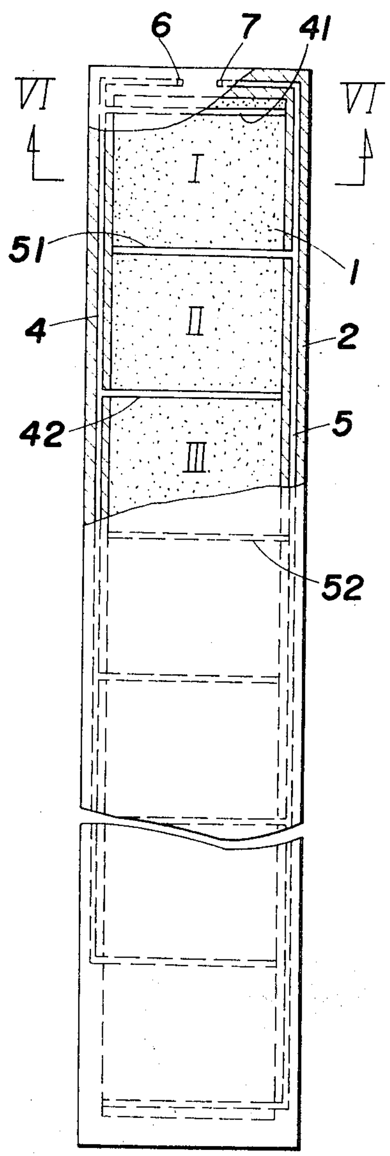

FIG. 7

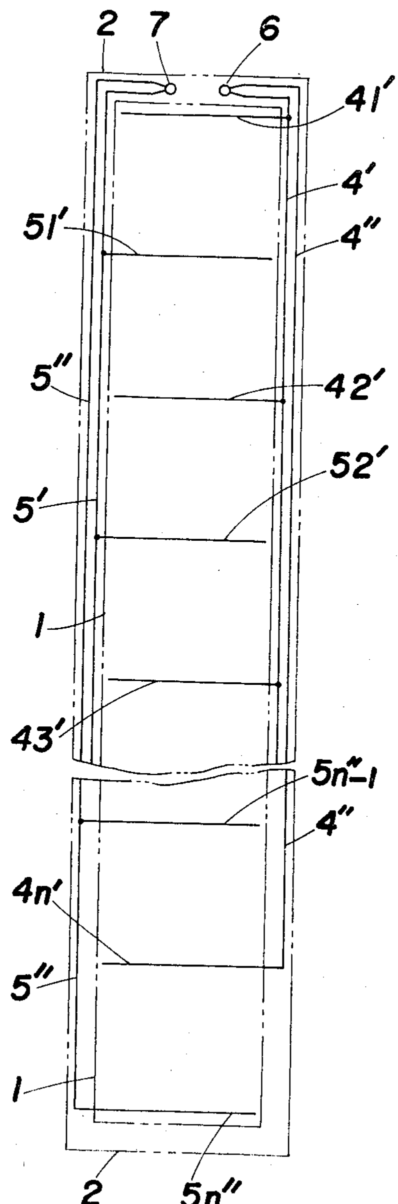

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FIG.10

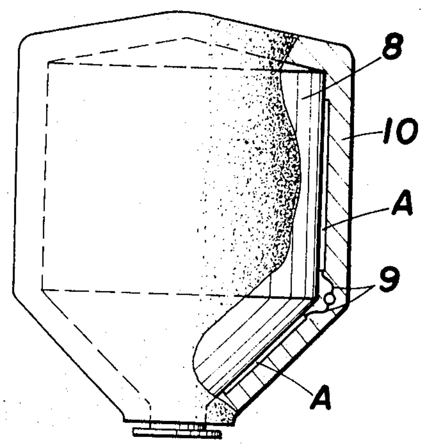

FIG.6

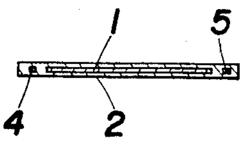

FIG.8

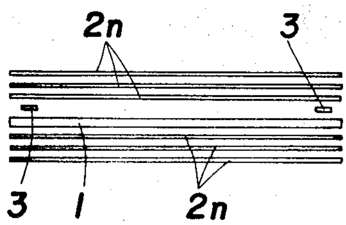

FIG.11

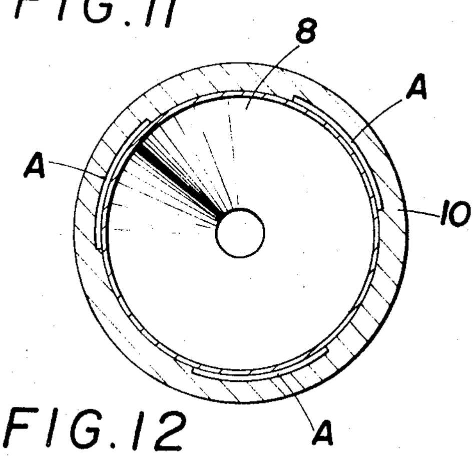

FIG.9

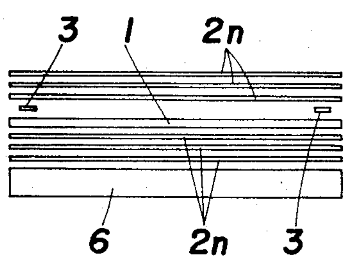

FIG.12

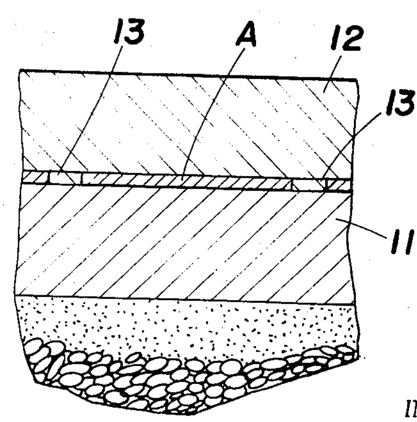

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FIG.13

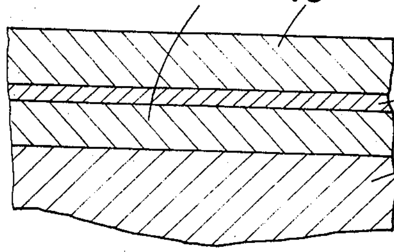


FIG.14

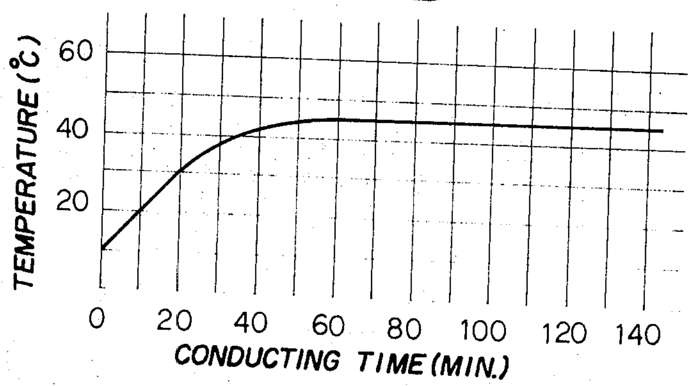
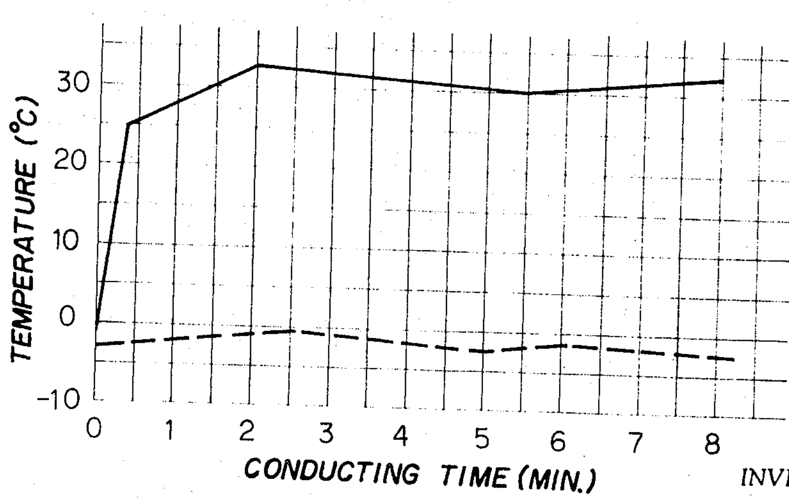


FIG.15

FIG.16



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FLEXIBLE PANEL-TYPE HEATING UNIT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is concerned with a heating device, and more particularly, it relates to a flexible, panel-type heating unit containing therein an electrically resistive porous board made mainly of carbon fibers obtained from petroleum pitch or like materials.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a novel panel-type heating unit which utilizes an electrically resistive board containing carbon fibers and which is of versatile utility in heating and heat-preservation of various objects.

Another object of the present invention is to provide a heating unit of the type described, which can generate heat at a desired temperature because of the stabilized resistance of the electrically resistive board.

Still another object of the present invention is to provide a heating unit of the type described, which is capable of generating heat substantially uniformly at the entire faces of the panel while automatically maintaining the given temperature.

Yet another object of the present invention is to provide a heating unit of the type described, which is suitable for the heating or heat-preservation of flat planar surfaces of various construction materials.

A further object of the present invention is to provide a heating unit of the type described, which can be obtained in the form of panel of a substantially great length and yet is capable of generating heat at a desired temperature substantially uniformly at the entire surfaces of the panel.

A still further object of the present invention is to provide a flexible heating unit of the type described, which is suitable for the heating of curved surfaces of cylindrical tanks or like constructions.

Yet a further object of the present invention is to provide a heating unit of the type described, which is intended for use in space heating by applying the unit to the floor and/or walls of a room so that the room can be heated at a relatively low temperature for human being.

Another object of the present invention is to provide a heating unit of the type described which is useful in melting the snow or ice at the surface of roads or roofs of buildings.

Other objects, features and advantages of the present invention will become apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view of an embodiment of the panel-type heating unit of the present invention;

FIG. 2 is a plan view, partly broken away, of the heating unit shown in FIG. 1;

FIG. 3 is a plan view, partly broken away, showing another embodiment;

FIG. 4 is a chart showing an example of the relationship between the surface area and the amount of heat generated of the panel-type heating unit embodying the present invention;

FIGS. 5 through 7 are examples of the heating unit of a long type embodying the present invention, in which:

FIG. 5 is a plan view with parts broken away;

FIG. 6 is a sectional view taken along the line VI—VI in FIG. 5; and

FIG. 7 is an explanatory plan view of a modified example of FIG. 5;

FIG. 8 is an illustration explaining the manufacturing process of the panel-type heating unit embodying the present invention;

FIG. 9 is an illustration explaining the manufacturing process of a modified example of the heating unit of the present invention;

FIG. 10 is an explanatory side view, partly in section, showing an example of use of flexible panel-type heating units of the present invention, in which it is used for the purpose of heat-preservation of a tank;

FIG. 11 is an explanatory cross sectional view of FIG. 10;

FIG. 12 is an explanatory sectional view, showing an example of the use of the panel-type heating unit of the present invention where it is used in snow-melting or floor-heating by being embedded in a road structure or concrete floor structure;

FIG. 13 is a sectional view, showing an example of the use of the panel-type heating unit where it is placed under a carpet for heating a room;

FIG. 14 is a chart showing the surface temperature characteristic of the carpet in the example of FIG. 13;

FIG. 15 is an explanatory sectional view showing another example of the use of the panel-type heating unit of the present invention where it is used as a roofing member for melting snow on the roof; and

FIG. 16 is a chart showing the surface temperature characteristic of the roofing utilizing the roofing member shown in FIG. 15.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In FIGS. 1 through 3, reference numeral 1 represents an electrically resistive porous board which is a non-woven fabric but which is made of paper or felt containing therein a number of carbon fibers oriented in random directions. Numeral 2 represents a layer made of a plurality of paper or cloth sheets impregnated with a synthetic resin which are to be subjected to heat-pressing to form an integral body with the board. Numerals 3 represent a pair of electrodes made of metal foils or like material and arranged at the opposite ends of the electrically resistive board 1 in contact therewith. The electrically resistive board 1, the layer 2 and the electrodes 3 are formed into an integral body by subjecting these members to heat-pressing.

More specifically, the panel-type heating unit of the present invention may be made according to the process as shown in FIG. 8. Two electrodes 3 which are made of metal foils are provisionally secured, by known technique, to the opposite ends of the electrically resistive board 1 containing therein a number of carbon fibers. Paper sheets $2n$ of a required number which are impregnated with a synthetic resin are then arranged on both sides of the electrically resistive board 1 which carries the two spaced electrodes 3 thereon (In the example of FIG. 8, three sheets of resin-impregnated paper are arranged on each side of said board 1). These members are then subjected to heat-pressing to form them into an integral body.

The aforesaid electrically resistive board containing carbon fibers is either a paper-like or felt-like board made of a mixture of a number of carbon fibers made of petroleum pitch, for example, hydrocarbon pitch and a number of non-meltable fibers. It should be understood, however, that the carbon fibers which are used in the electrically resistive board 1 are not limited to the aforesaid fibers made of petroleum pitch, but that they may be made of other non-meltable man-made fibers having electrical resistivity, such as cellulose fibers, polyacrylonitrile fibers and polyvinyl alcohol fibers. It should be noted also that the terms "paper-like" and "felt-like" are not used in their particularly restricted meanings, but they are used to mean a porous matrix in which the aforesaid non-meltable electrically resistive fibers such as carbon fibers are arranged in random directions in such a way that these fibers are at least partially in contact with each other. The non-meltable fibers which are mixed with these electrically resistive carbon fibers need only be unmeltable when the electrically resistive board 1 is rendered conductive by connecting the electrodes to a power source. These non-meltable fibers may employ, for example, glass fibers, mineral fibers such as asbestos fibers, natural fibers such as wooden pulp, and man-made fibers to be used as a reinforcing element of the board. If required, a filler or a binder such as titanium dioxide, zinc white or thermosetting resins may be added.

Next, the physical properties of the carbon fibers and the board which is a mixed structure of essentially carbon fibers and non-meltable fibers will be shown hereunder.

PHYSICAL PROPERTY OF CARBON FIBERS

Diameter:	7–12μ
Length:	0.5–20.0 mm
Tensile strength:	12 t/cm²
Elongability:	1.5%
Modulus of elasticity:	800 t/cm²
Specific electrical resistance:	$(5–8)\times10^{-3}$ Ω cm
Expansion coefficient:	1.7×10^{-6}/° C
Heat resistivity (in N_2 atmosphere):	2,000° C
Purity (carbon content):	99.8%

PHYSICAL PROPERTY OF CARBON FIBER MIXTURE BOARD

Fibers to be mixed:	Wooden pulp
Mixing ratio of carbon fibers and pulp:	40:60
Binder (synthetic resin):	Some
Thickness of mixed paper board:	0.22 mm
Weight of same:	220–250 gr/m²
Electric resistance (20 cm square board, with two electrodes arranged at opposite ends thereof):	12 Ω
Temperature when used:	110° C or less

The aforesaid synthetic resin-impregnated sheets which constitute the layer **2** may each be made of a material which is either a paper formed with organo fibers, such as overlay paper (transparent), pattern paper (with printed pattern), barrier paper and core paper, or a paper or cloth formed with inorganic fibers or like fibrous components, such as glass fiber cloth or asbestos paper, or the material may be a paper or a cloth formed with a mixture of the organic and inorganic fibrous components mentioned above. The synthetic resin which is used to impregnate these paper or cloth sheets may be a thermo-setting synthetic resin such as di-allyl phthalate resin, benzo-guanamine resin, epoxide resin, unsaturated polyester resin, melamine resin, or phenol resin. However, from the viewpoint of good heat conductivity, the use of di-allyl phthalate is preferred.

As stated above, the panel-type heating unit of the present invention uses a paper- or felt-like electrically resistive porous board containing therein carbon fibers, and this board which carries two spaced electrodes is sealed by being embedded within a layer which is formed by heat-pressing the synthetic resin-impregnated paper or cloth sheets together with the board. Thus, this assembly is capable of functioning as a stabilized panel-type heating unit as will be itemized below.

1. By selecting, as desired, the amount of carbon fibers per unit area and by selecting, as desired, the mixing ratio of carbon fibers and other fibers, the electrically resistive board may have a desired resistance value.

2. The electrically resistive board which is used in the present invention is a porous board in which carbon fibers are arranged in irregular directions and in which the carbon fibers are at least partially in contact with each other. This porous board is sandwiched between synthetic resin-impregnated paper or cloth sheets and the resulting members are heat-pressed together. As a consequence, the resin is allowed to flow into the pores and is set there to form bridges between fibers. Thus, the mutual contact relations of the carbon fibers are fixed thereby. As a result, the resulting electrically resistive board can have an extremely stabilized resistance value.

3. Since carbon fibers are fixed relative to each other as described above, it should be understood that when the temperature of the electrically resistive board rises as the result of its being connected to the power source, the synthetic resin which has till then been fixed to the respective carbon fibers will expand slightly to locally reduce its holding power on the fixed relation of the respective carbon fibers. As a consequence, when the temperature reaches a certain level, there will occur an abrupt rise in the resistance value of the device to hamper the conduction of electricity. This hampered conduction will in turn serve to restore the power of the synthetic resin to hold the relation of the fixed carbon fibers, so that the resistance value will return to the original predetermined level. In this way, the board will automatically maintain a substantially constant temperature. Thus, the panel-like heating unit of the present invention is able to automatically maintain a constant temperature without requiring a thermostat or any other temperature controlling means at all.

4. Since the electrically resistive material which is used in the present invention consists of carbon fibers, it is chemically extremely stable. Besides, this board is sealed within a layer of synthetic resin-impregnated paper or cloth sheets by heat-pressing of the layer and the board to exclude the ambient air therefrom. As a result, the complete heating unit is of a prolonged service life and it can be used semi-permanently.

An experiment was conducted by the use of the aforesaid panel-like heating unit of the present invention. It was confirmed from the result that the amount of the heat (calory) generated is in a proportional relationship with the area at which heat is generated, as shown in FIG. **4**. This shows the fact that the panel-like heating unit of the present invention is of an extremely stabilized electrical resistance value and that this applies to the entire area of the unit.

Another experiment was conducted by setting the temperature of the heat produced by the heating unit to 100° C. and the unit was supplied with power continuously for 6,000 hours. It was found that the surface temperature distribution was held at 100° C. ± 3° C. without the use of any temperature controlling means, and no appreciable change in temperature with lapse of time was noted.

The heating unit example shown in FIG. **3** is basically identical in principle with the one shown in FIGS. **1** and **2**. The only difference lies in that the intermediate portion of the electrically resistive board **1** is cut out into a substantially G-shape and that the electrodes **3** are arranged in a closer relation relative to each other.

As stated above, the panel-like heating unit of the present invention is such that power is supplied between the two electrodes provided on the opposite ends of the electrically resistive board to generate heat over the entire faces of the unit. Since the resistance value of the board is constant, the temperature of the heat generated is determined by the distance between the two electrodes and the voltage applied. Accordingly, the temperature of the heat generated will decrease with an increase in the distance between the electrodes in case the electrically resistive board has a prolonged length. In such a case, no desired temperature will be obtained unless a very high voltage is applied.

In the event that the electrodes are arranged along the opposite side lines extending longitudinally of the electrically resistive board, there will be impressed a power source voltage in that portion of the board located close to the power terminals. However, the voltage impressed will decrease in those portions of the board located farther from the power terminals. When the length of the board exceeds a certain limit, it will become impossible to generate heat uniformly throughout the entire area of the board.

FIGS. **5** through **7** show examples of a panel-like heating unit arranged so that heat is generated at a desired temperature at substantially the entire portions of the panel irrespective of its length.

In FIGS. **5** and **6**, reference numeral **1** represents an electrically resistive board. Numeral **2** represents a layer which is formed by heat-pressing paper or cloth sheets impregnated with a synthetic resin. Numerals **4** and **5** represent lead wires arranged to extend along the opposite side lines longitudinally of the board 1 but at positions slightly away from the edges of the board. Numerals 41, 42, . . . represent a group of electrodes which extend, in a direction traversing the length of the board, from one of the lead wires 4 and are spaced from each other at predetermined intervals along the surface of the board and in contact therewith. Numerals 51, 52, . . . represent another group of electrodes which extend, in a fashion similar to the electrodes 41, 42, . . ., from the other lead wire 5. These lead wires and the electrodes are both embedded, together with the board, within the layer 2. These lead wires and electrodes are made with thin metal foils such as copper foils having a thickness of 0.1 mm and a breadth of 5–10 mm.

The electrodes described above are arranged in such a manner that those extending from lead wire 4 are in alternate side-by-side spaced relationship with those extending from lead wire 5, with predetermined distances being left between the respective adjacent electrodes.

The power terminals 6 and 7 of the panel-like heating unit having the foregoing arrangement are connected to a power source. Whereupon, a power source voltage is impressed between each pair of adjacent electrodes 41 and 51; 51 and 42; 42 and 52; and so forth. Therefore, by arranging so that the distances between the respective adjacent electrodes are constant, it is possible to generate heat of a substantially constant temperature in the respective region I, II, III of the panel and so on which are sandwiched between adjacent electrodes.

FIGS. 5 and 6 show an example of the panel-like heating unit in which the current flowing through all the electrodes is borne by the lead wires 4 and 5 which are arranged so as to extend along the opposite side of the board, respectively. As a result, the amount of current flowing through the lead wires will increase in those portions of the lead wires located closer to the power terminals. For this reason, it will become necessary to use lead wires having an increased thickness which may vary depending on their capacity of the current passed therethrough in instances where there is an increase in the number of the electrodes used.

FIG. 7 shows an arrangement in which a plurality of lead wires are used to overcome the problem encountered in the instances where there is an increase in the amount of current passed through the lead wires described above. More specifically, there are provided a plurality of lead wires 4' and 4'' along one side of the board and also a plurality of lead wires 5' and 5'' along the other side of the board. From a pair of lead wires 4' and 5', there extend a group of electrodes 41', 42', . . ., and 51', 52', ... This first group of electrodes is limited to such a number as will not surpass the electric capacity of the lead wires 4' and 5'. For those portions of the board beyond the aforesaid groups of electrodes, there is provided another or second group of electrodes 4n''-1, 4n'', . . . and 5n''-1, 5n'', . . . *which extend from the other pair of lead wires 4'' and 5''. Thus, the flow of current is shared by the first group of lead wires 4'* and 5' and the second group of lead wires 4'' and 5''.

Description will next be made on the examples of use of the panel-like heating unit of the present invention.

FIG. 9 shows an example wherein a panel-like heating unit of the present invention is formed integrally with an arbitrary plank. On top of a desired plank 6 are superposed a plurality of paper sheets 2n impregnated with a synthetic resin, a board 1 of a mixture of carbon fibers and other fibers, and a plurality of paper sheets 2n impregnated with a synthetic resin in this order. These components of the heating unit are then subjected to heat-pressing to produce a bonded integral structure. The plank 6 may be either veneer board, hard board, slate, metal plate, heat-insulating plate made of a material such as foamed polyurethane, or any other appropriate plates or planks. By forming an integral body of the plank 6 and the panel-like heating unit in this way, the resulting assembly itself can be used as a board having the capability of functioning as a panel-like heating unit. By providing the top face of the synthetic resin-impregnated paper sheet with printed patterns, the resulting panel-like heating unit may be used as a beautiful decorative plank for use in construction and for other purposes.

FIGS. 10 and 11 show another example of use of the panel-like heating unit of the present invention in which the latter is used in the preservation of heat of a tank. A plurality of the panel-like heating units A of the invention (the type shown in FIG. 8) are attached, at appropriate intervals, to the surface of the tank 8. These heating units A are connected to a power source (not shown) via lead wires generally indicated at 9. The entire surface of the tank 8 including the panel-like heating units A attached thereto is further surrounded by a heat-preserving member 10 made of a material such as foamed polyurethane. In this example, the panel-like heating unit A employed is the same as that shown in FIG. 8 which is flexible. Therefore, the heating unit A conforms well to the curved surface of the tank 8, and thus, the liquid contained in the tank can be heated or the temperature of this liquid can be preserved. In a similar way as this, the liquid or gas contained in a pipe or conduit can be heated or preserved of its temperature.

FIG. 12 shows still another example of use of the heating unit of the invention wherein it is embedded in the layer of concrete to effect floor heating or melting of snow on the road. In the drawing, numeral 10 represents a base layer of concrete, and numeral 11 represent a surface layer of concrete. The panel-like heating unit A is provided with perforations formed therethrough at various sites thereof so that the base layer of concrete 10 is integrally united with the surface layer of concrete 11. From the viewpoint that the base layer of concrete should have a heat-insulating property, it is preferred to use a heat-insulating concrete which is a mixture of cement and pearlite, prepared with a mixing ratio of 1 : 4. This pearlite is produced by allowing perlite or obsidian to swell rapidly by the application of heat. The resulting pearlite is a powder or granular product of white to gray-white in color having a number of small independent air cells scattered thereinside. The chemical composition of the pearlite is roughly as follows:

SiO_2	75.5
Al_2O_3	15.3
Fe_2O_3	0.9
CaO	0.12
K_2O	4.0
Na_2O	3.5

In the aforesaid example of use of the heating unit of the invention, it is preferred to use a surface layer of concrete which is of the quickly driable type. It is needless to say that man-made marble or other stones may be provided on top of the surface layer of concrete.

In this instance, the panel-like heating unit A which is the same as that shown in FIG. 8 is provided with perforations 11 formed therethrough at various sites to unite the base layer of concrete integrally with the surface layer of concrete. Therefore, even in case the panel-like heating unit itself expands to some extent as a result of its being connected to the power source, there arises no such inconvenience that the upper and the lower layers of concrete become detached from each other. Instead, heat is generated at a constant temperature for as much as extended time as desired, so that floor-heating or snow-melting on the road may be effected without any trouble.

FIG. 13 shows a further example of use of the panel-like heating unit of the present invention in which case the heating unit is laid on a floor under a carpet to effect space-heating of a room. In the drawing, numeral 14 represents the surface of the floor made of a plywood. Numeral 15 represents a heat-insulating material made of foamed polyurethane. Numeral 16 represent a carpet. In this instance of use, there was conducted an experiment by the use of a panel-like heating unit which was capable of generating heat at the rate of 300 W/m^2 at the power source voltage of 100 volts AC. The surface temperature of the carpet showed the characteristic as shown in FIG. 14. The ambient temperature during this experiment was 5° C. As will be noted from this result, the panel-like heating unit of the present invention is capable of performing the heating of a surface at a temperature of the order of 44° C. which is pleasant to human being.

FIG. 15 shows another example of use of the panel-like heating unit of the present invention it is used as a roofing-heater to melt snow at the surface of the roofing. An experiment relating to this was conducted in the following manner. A roofing was constructed by bonding a panel-like heating unit A of 500 × 1,000 mm in size to the central portion of the reverse side of a roofing iron plate **17**. (In practice, the roofing is constructed in a way similar to the method shown in FIG. **9**, or more specifically, the iron plate **15** is heat-bonded to the panel-like heating unit simultaneously at the time the latter is formed by heat-pressing). The roof was constructed, by known technique, by utilizing those portions **18** of the iron plate which are located outside the edges of the panel-like heating unit bonded to the iron plate. This heating unit A was impressed with 200 volts AC to effect heat-generation at the rate of 250 W/sheet. Thus, a temperature characteristic as shown in FIG. **16** was obtained.

FIG. **16** shows an instance in which the panel-like heating unit was connected to a power sources when the thickness of snow was 10 cm. The dotted line represents the ambient temperature, and the solid line represents the surface temperature of those portions of the iron plate contacting the panel-like heating unit. Snow fell during the connection to the power source. However, a very satisfactory effect of melting snow was obtained.

What we claim is:

1. A flexible panel-like heating unit comprising an electrically resistive porous board comprising a mixture of carbon fibers having a diameter of 7–12 microns and a length of 0.5–20 mm, and unmeltable fibers selected from the group consisting of glass fibers, mineral fibers including asbestos fibers, natural fibers including wooden pulp, and man-made fibers, said carbon fibers being arranged in a mutually connecting relation; a pair of electrodes arranged in spaced relation on said electrically resistive board in contact therewith; and a plurality of sheets impregnated with a thermo-setting synthetic resin and arranged so as to sandwich said board and said electrodes to seal them from the ambient atmosphere; said plurality of sheets and said board being heat-pressed such that said resin is forced into the pores in said board to form bridges between said fibers, the arrangement being such that said mutually connecting relation of said carbon fibers is fixed by said resin bridges; said electrodes being connectable to a power source to generate heat at the carbon fibers contained in the board.

2. A flexible panel-like heating unit according to claim **1**, in which said sheet impregnated with a synthetic resin is a paper sheet impregnated with diallyl phthalate resin.

3. A flexible panel-like heating unit according to claim **1**, in which said heating unit is bonded integrally to the surface of a planar object including veneer plate, plywood plate, metal plate to provide a panel-like plank capable of generating heat as an entirety.

4. A flexible panel-like heating unit according to claim **1**, which is of a substantially great length and comprises a pair of lead wires running along the opposite sides of said electrically resistive board longitudinally thereof in spaced non-contacting relation relative to said board, a plurality of electrodes extending from the respective lead wires in alternate fashion in the direction traversing said board and in contact therewith at predetermined distances between the respective adjacent electrodes so that a full voltage may be applied between the resulting plurality of electrodes extending from said pair of opposing lead wires.

5. A flexible panel-like heating unit according to claim **4**, in which each of said pair of lead wires is composed of a plurality of lead wires so that the flow of current passing through the electrodes is shared by these plurality of lead wires.

6. A flexible panel-like heating unit according to claim **4**, in which the adjacent electrodes are arranged at a uniform distance relative to each other.

7. A flexible panel-like heating unit according to claim **5**, in which the adjacent electrodes are arranged at a uniform distance relative to each other.

8. A flexible panel-like heating unit according to claim **1**, in which said sheet impregnated with a synthetic resin is a cloth sheet impregnated with diallyl phthalate resin.

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