

Aug. 18, 1959

W. BETHGE

2,900,290

METHOD OF PRODUCING ELECTRIC SHEET-TYPE HEATER

Filed July 29, 1957

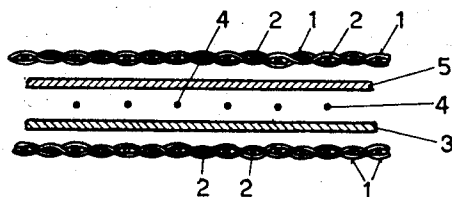


Fig. 1

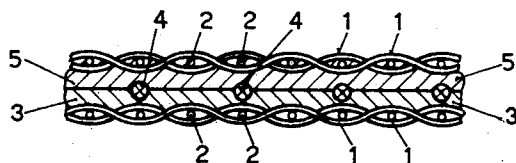


Fig. 2

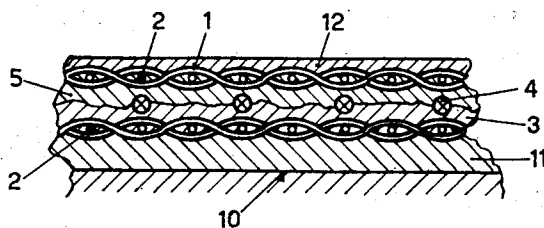


Fig. 3

INVENTOR.

Walter Bethge

BY

Walter Bethge
Patent Agent

1

2,900,290

METHOD OF PRODUCING ELECTRIC SHEET-TYPE HEATER

Walther Bethge, Moutier JB, Switzerland, assignor of
two-thirds to Jean-Pierre de Montmollin and Rene Cug-
ger, both of Neuchatel, Switzerland

Application July 29, 1957, Serial No. 674,647

Claims priority, application Switzerland April 30, 1957

1 Claim. (Cl. 154—90)

The present invention relates to an electric sheet-type heater, a method of producing same and an application thereof. Sheet-type heaters are extremely thin, areal radiators suitable for attachment to ceilings, walls and other plane or curved surfaces for the purpose of heating same or of thermal radiation.

Sheet-type heaters should meet a number of requirements which are of great importance for their safety of operation.

Sheet-type heaters must, on the one hand, have a largely uniform heat emission, i.e. they must not produce and radiate heat with intensities locally different. Furthermore, sheet-type heaters must be as thin as possible so that they start heat emission practically immediately after current is switched on. For these two reasons it is desirable for the sheet-type heaters to have the smallest possible bulk, i.e. the lowest possible thermal capacity, the distance of the heating elements from the surface of the heater being required to be as constant as possible in the interest of uniform heat emission. Besides this requirement for an extremely small cross-sectional area, the requisite electrical insulation properties must be obtained, i.e. in no place must a short-circuit be possible when the heater is touched with metallic objects. Moreover, no excessive local temperatures must be possible in sheet-type heaters in order to prevent the embedding material from being destroyed. All heating elements should therefore be in optimum thermal contact with their surroundings, so that the heat generated is conducted away immediately. Apart from these properties mentioned, sheet-type heaters must have a certain flexibility in order to be adapted to the bodies to be heated. On the other hand, a maximum of mechanical stability is required which also prevents the sheet-type heaters from being worn such as by friction in the course of time and the heating elements from being uncovered.

Several attempts have been made to achieve the said requirements, but no solution meeting all requisite conditions has so far been disclosed. The attempt has been made to apply a thin metallic layer, as by galvanic action, to a foundation and to cover same by a second layer, such as rubber. Sheet-type heaters of this kind could be produced so as to meet the desired mechanical requirements and in sufficient thinness, but it was impossible to obtain uniform heat emission with such heaters as a metallic layer always varies in thickness locally. Therefore zones of different electrical resistance existed; at the points of high resistance, a raised thermal emission occurred while the heater became overheated, while at the points of lesser resistance no heating occurred. These disadvantages rendered the sheet-type heater of this kind useless for certain applications and it has not been generally adopted.

It has also been suggested to form a sheet-type heater of rubber, individual wires being embedded in the latter. While rubber possesses an elasticity sufficient for the present purpose, its thermal conductivity is unsatisfactory. If individual heating wires are embedded in the

2

rubber, dissipation of heat from these wires is so low that the wire becomes overheated and destroys the rubber around it or emits gas. This reduces heat dissipation still further so that local overheating occurs, which is not harmless. In order to eliminate this disadvantage, solid wires were replaced by strands composed of very thin wires and embedded in the rubber. Although dissipation was improved by the larger surfaces of the heating elements, unit areas could still not conduct the heat generated away to the extent necessary for many sheet-type heaters. In addition, the use of stranded wires made the sheet-type heaters comparatively thick, which may be regarded as a further drawback.

The sheet-type heater according to the present invention eliminates the said disadvantages and largely meets all requirements. It is characterized by the fact that the heating wires are embedded in a sheet formed of an organic material and containing no substances with a boiling point below 100° C., the sheet having to its two sides attached a fabric formed of inorganic fibres so that the sheet material enters the fabric and surrounds portions of the fabric fibres.

The method of producing such sheets is characterized by the fact that the heating wires are embedded in a sheet at least initially thermoplastic after local heating by heat input whereupon a further sheet of the same material is applied to the side of the first sheet holding the wires and the sheet-type radiator has its two sides covered by a fabric consisting of inorganic fibres and all parts are then pressed under heat so that the sheet material at least partly penetrates into the fabric and forms a mechanically stable connection therewith.

The sheet-type heater according to the present invention is also employed on aircraft pursuant to this invention in order to prevent ice formation.

Some embodiments of the present invention are shown in greater detail in the attached drawing, in which:

Fig. 1 is a cross-section of a sheet-type heater prior to joining the individual parts;

Fig. 2 is an enlarged cross-section of a sheet-type heater after the individual parts have been joined; and

Fig. 3 is a sheet-type heater applied to a metallic foundation such as the wing of an aircraft, shown at the same scale as that in Fig. 2.

According to the present invention, individual wires are embedded in an organic sheet of thermoplastic material, covered by a second thermoplastic sheet and subsequently covered on both sides by a fabric made of an inorganic material.

The sheet employed for embedding and supporting the heating wires may be formed of any organic material, possibly hardenable and heat resistant up to a temperature of 150° C. after hardening, which contains no substances having a boiling point below 100° C. or only traces thereof. In particular, a sheet formed of neoprene or phenolic resin or both may be employed. In manufacture, such a sheet, while still thermoplastic, has embedded therein one or simultaneously several resistance wires while heat is applied. This is preferably performed by means of a heatable tool which at the same time guides the wire.

The sheet and the tool are moved relative to one another, the tool briefly softening the sheet and at the same time embedding the wire in the softened sheet. The tool may, by way of example, be designed as a sliding pad or sliding guide. As the sheet is heated to a point only at which it becomes viscous, it will harden immediately after the wire has been embedded so that the latter remains in its pressed-in position. If desired, several heatable sliding pads may be arranged on a common tool holder relatively to which the sheet is moved while the wires, as stated above, are embedded in the sheets. In this manner, it be-

3

comes possible to produce the sheets in practically endless webs.

After embedding the wires at uniform distances in the sheet, a second sheet of the same material is applied to that side of the first sheet which holds the embedded wires. The two sides of the heating sheet so produced have applied a fabric made of an inorganic material. This fabric is provided to act as a support for the heating sheet, to enable the said sheet to dissipate sufficient heat and to combine further with the sheet so that practically no hollow spaces inhibiting transmission of heat and air inclusion will remain. Glass silk is an inorganic fabric of the type suitable for this application.

In the manufacture of a sheet-type heater, the heating sheet is first produced in the manner described and placed between two glass-silk fabrics. Subsequently, the glass silk is pressed against the heating sheet under pressure, such as by two rolls, and simultaneously subjected to a temperature which does not in any way affect the glass silk while softening the sheet. This may also be effected by heating the wires embedded in the sheet. By softening the sheet under pressure, the sheet material will penetrate into the spaces in the fabric thus attaching itself and the wires firmly to the glass-silk fabric. It may happen that portions of the two glass-silk fabrics contact one another or that the glass silk touches the wires. This does not, however, constitute a disadvantage. The sheet combined with the glass silk thus practically consists of the two glass-silk fabrics between which the wires are placed, all empty spaces between the fabrics and between the wires being filled by the thermoplastic sheet material.

Independently hereof it is also possible to employ a sheet formed of a hardenable substance so that subsequent to the connecting process with the glass-silk fabrics hardening will be effected under the action of heat.

Besides glass silk, any other fabrics may be employed which will not soften under the temperatures employed, display a certain elasticity and can be mechanically bonded to the sheet material. The fabric material must be capable of being manufactured in sufficient thinness and it must be composed of an electrical non-conductor. In the first place, the materials suitable for the purpose will be inorganic fabrics, such as mica and glass-silk fabrics, but other fabrics, possible organic ones, may be used provided that they possess the above properties.

Fig. 1 shows the sheet-type heater prior to the joining of the various members. The threads lying in the drawing plane are designated as 1, those lying normal thereto, as 2. The electric wires 4 are embedded in the sheet 3, and subsequently the sheet 5 is applied.

Fig. 2 shows the sheets after joining. It is seen that the heating wires 4 are embedded deeper in sheet 3 than in sheet 5, and that the sheet material has penetrated almost to the outer surface of the fabrics.

The sheet-type heater disclosed of the design described is suitable for practically all applications in which a sheet-type heater may be used including the heating of public conveyances, vehicles, churches and rooms. According to the energy turnover, the sheet-type heater may be used as a convection or radiation heater. By increasing energy output—such as 2 w./cm.²—radiation in a public conveyance will produce, after a few minutes, a physiologically agreeable sensation of warmth in the passengers. In application, the sheet-type heater may be attached to the walls by bonding or the like. As the heating wires are completely embedded in the sheet material, heat emission from them is very substantial; this means, however, that no excessive temperatures can occur. The sheets may therefore easily be attached to wooden walls without danger of combustion.

The sheet-type heater described has its principal importance as an anti-icing device for aircraft parts. As is well known, a heating device preventing ice-formation on the wings, tail planes and propellers of aircraft, is of exceptional importance. The sheet-type heaters according

4

to the present invention are now particularly suitable for application, by way of example, to the wing surfaces of aircraft. Since the cross-section of a complete heater may be only 1.2 mm., it takes so little space on the wing surfaces that it need not be considered in designing the aircraft. It may therefore also be applied to existing aircraft. The decisive factor in the application of the sheet-type heater is, however, that the glass silk is bonded to the metallic aircraft and wing surfaces with sufficient strength. According to this invention, this is possible by application of an organic hardenable bonding compound containing no substances having a boiling point below 100° C.

The base materials used for this bonding compound may be epoxy resins or phenolic derivatives. These substances become largely brittle with hardening, however, and require a comparatively high hardening temperature. They are also unsuitable because they commonly contain traces of water vapour. If these substances are mixed individually or with a hardening agent, the unfavourable properties can be substantially compensated. The hardening agent or agents must contain only traces of water and low-boiling substances, and must lower the hardening temperature. Suitable hardening agents are, in particular, polyamides, neoprene or Thiokols.

The components employed are mixed, largely freed from water and water-producing substances, by way of example by means of a stirring process in vacuo, and applied to the cleaned metallic surface. Subsequently the heating sheet is applied to the surface of the wing and slightly pressed thereto. The same compound as described, by way of example consisting of epoxy resin and polyamide, is knifed on as a top layer. The following hardening process is then performed by using the sheet-type heater. Application of a certain voltage to the connections of the sheet-type heater will enable it to reach the hardening temperature of the bonding compound. The sheet-type heater is kept at this temperature until the bonding compound is completely hardened. The bond obtained thereby is practically indestructible except by serious mechanical damage caused as by pointed or sharp instruments. It is notable that the glass-silk fabric and the covering layer may be severed while it is impossible to affect the bond between the glass silk and the epoxy resin layer.

In order to obtain higher heat emission to the outside, the synthetic resin layer contacting the wing surface is preferably made somewhat thicker than that in contact with the atmosphere. It becomes thereby possible to reduce heat emission inwards in favour of that in the outward direction.

The structure of such a heating device for wing surfaces is shown in greater detail in Fig. 3. The metallic surface of the aircraft is designated by 10, the synthetic resin layer above it by 11. There follows the sheet-type heater described in conjunction with Figs. 1 and 2, the same reference numerals being employed. The top layer again consists of synthetic resin 12 and, as seen from the drawing, it is about one-half as thick as base layer 11.

As the surface is subject not only to certain mechanical stresses but to abrading forces and influences, it may be advantageous to give this layer additional wear-resistance by adding an inorganic crystal powder. Suitable materials for this purpose are mica, quartz powder, graphite and titanium oxide. These solid particles in the resin substantially increase resistance against abrasion. Furthermore, these inorganic crystals adapt the coefficient of expansion of the synthetic resin to that of glass so that no detrimental thermal stresses can occur when the heater is in use.

When the synthetic resin layers are applied, care must be taken to avoid forming air inclusions between the layers since they could expand and cause the layer to tear. After application of the layer, the surface may be ground in order to obtain the surface polish required for the requisite flight properties.

By way of example, the method is hereunder described in the application of a sheet-type heater to aircraft, together with the materials used and the temperature values.

Resistance wires with a thickness of .03 to .3 mm. are embedded at distances of 1 to 2 mm. in a synthetic resin sheet composed of phenolic resin and neoprene—the latter also contributing to hardening—having a thickness of .2 mm., by means of a tool briefly softening the sheet by heating. A sheet formed of the same materials and of .2 mm. thickness is applied to the side of the first sheet holding the wires. Afterwards a glass-silk fabric, i.e. a fabric formed of fine glass fibres, of approximately .3 mm. thickness is applied to both sides and pressed with the sheet under pressure and heating by means of two or more rolls until all hollow spaces are filled by the sheet material. Although the aggregate thickness of the layers adds up to 1 mm., the heating sheet so produced is only .7 mm. thick since the sheet material has penetrated the glass-silk fabric.

The same results may be obtained by using, instead of phenolic resin, by way of example plastic epoxy resin and, instead of neoprene, thiokone, which favours hardening of the epoxy resin.

The sheet-type heaters described may have applied, without detrimental effects, outputs of up to 35 kw./m.² when employed as anti-icers.

If the sheet is to be applied to an aircraft wing surface, a bonding compound of the following composition is prepared:

	Percent
Unhardened epoxy resin	40
Polyamide	30
Titanium oxide	22
Quartz powder	8

The percentages relate to weights. These substances are stirred in vacuo so that practically all substances boiling below 100° C. and therefore likely to cause generation of gas, are removed. The percentage of these substances must be reduced to at least .1%. Titanium oxide gives the compound its white colour, which is de-

sirable in wing surfaces, while the quartz powder increases the abrasion resistance of the compound while substantially reducing the thermal expansion coefficient. The metallic surface of the wing is then cleaned, the bonding compound prepared applied in a thickness of 13 mm. and the sheet-type heater placed on top. The said bonding compound is then again applied on top of the sheet-type heater as a protection, as has been stated above. A voltage is then applied to the heater, which heats the entire body to 70 to 80° C., thus causing the bonding compound to be hardened. This temperature is maintained about 40 to 50 minutes for complete hardening. Finally, the surface is ground in accordance with aerodynamic requirements.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

A method of producing a sheet-type heater comprising the steps of: softening a first sheet of thermosetting hardenable organic material, embedding electrical heating wires in the softened portions of said first sheet, covering said first sheet of organic material with the wires embedded therein with a second sheet of thermosetting organic material, covering said two sheets at both sides thereof with two fabrics consisting of electrically insulating inorganic fibers, and subjecting the thus formed heater to pressure and heat to an extent sufficient to cause said organic material to penetrate into said fabrics until said wires contact at least one of said fabrics and to harden.

References Cited in the file of this patent

UNITED STATES PATENTS

1,376,987	Wirt	May 3, 1921
1,943,062	Driscoll	Jan. 9, 1934
2,022,827	Ruben	Dec. 3, 1935
2,528,360	Greenice	Oct. 31, 1950
2,566,921	Briscoe	Sept. 4, 1951
2,741,692	Luke	Apr. 10, 1956