July 15, 1958 R. D. S. CRICK 2,843,711

THERMO-ELECTRIC SURFACE HEATERS

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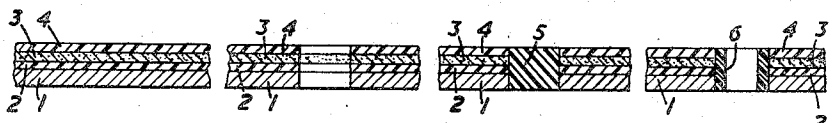

FIG. 1. FIG. 2. FIG. 3. FIG. 4.

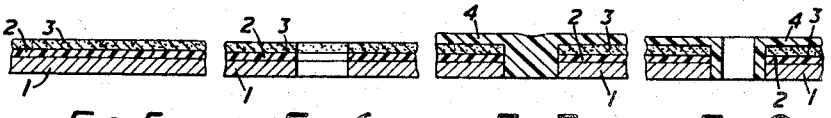

FIG. 5. FIG. 6. FIG. 7. FIG. 8.

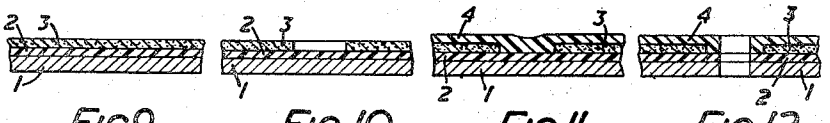

FIG. 9. FIG. 10. FIG. 11. FIG. 12.

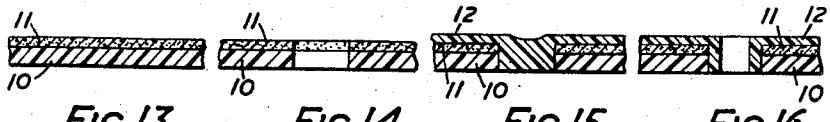

FIG. 13. FIG. 14. FIG. 15. FIG. 16.

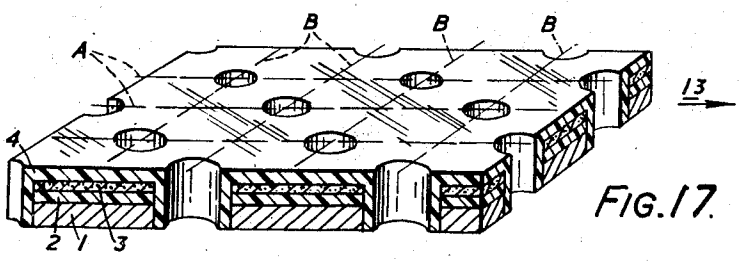

FIG. 17.

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THERMO-ELECTRIC SURFACE HEATERS

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6 Claims. (Cl. 201—73)

This invention relates to thermo electric surface heating elements of the kind comprising an electrical conducting resistance heating layer, usually of metal (hereinafter called the conducting layer) sandwiched between two insulating layers one of which may constitute a support in the form of a sheet but is usually applied to a support in the form of a sheet of metal or other material. The insulating layer constituting or applied to such a support is hereinafter referred to as the inner insulating layer while the other insulating layer which is applied over the conducting layer and forms a non-conducting outer surface layer is hereinafter referred to as the outer insulating layer.

Such surface heating elements are particularly but not exclusively applicable to the parts of aircraft on which ice tends to form, for the purpose of preventing or removing such ice formations but may also be applied to other structures or articles or parts thereof to prevent or remove formations of ice thereon and/or to provide heat for other purposes, particular forms of apparatus embodying such elements being described for example in the specification of the present applicant's United States Patent application Serial No. 304,964, now Patent No. 2,791,668, issued May 7, 1957.

It is an object of the present invention to provide a surface heating element of the kind referred to, which is formed to allow air to pass through, and is not detrimentally affected by atmospheric conditions.

In a surface heating element of the general kind referred to according to the present invention the element is perforated with a plurality of small holes extending through the insulating layers, and the conducting layer and the support (when provided) and each hole is lined with a layer of insulating material.

In this way any risk is avoided of short-circuiting electrical conducting path being formed between different parts of the conducting layer or between the conducting layer and the sheet metal support, when provided, or with some other earthed conducting member, e. g. by droplets of water which may form in or enter the perforations and/or by moisture extending into the perforations and over the surface of the element or by other foreign matter which may collect in such perforations or on the surface of the element.

Surface heating elements according to the invention may be made in various ways. In one example, after application of the conducting layer and the outer insulating layer, for example as described in the specification of the present applicant's United States Patent application Serial No. 304,964, now Patent No. 2,791,668, issued May 7, 1957, the element as a whole is perforated with holes of a larger cross sectional area than those finally required, the holes so formed are then filled or partially filled with an adhesive synthetic plastic resin insulating material of a kind which sets or can be caused to set, as for example by curing, and, after such insulating material has set or been caused to set, holes of the smaller desired cross sectional area but in the same

general positions as the larger holes originally formed, are punched or otherwise formed through the element.

The synthetic plastic resin used to fill the holes is preferably that sold under the registered trade mark "Araldite" as "Araldite Type No. 1 Natural." This consists of a resinous condensation product of 4:4'-di-oxydiphenyl - dimethyl - methane and epichlorohydrin, which is solid at room temperature and is admixed with dicyandiamide in the proportion of 4–6 parts of the latter to 100 parts of the resin.

This resin is also preferably employed for the outer insulating layer, and in many cases also for the inner insulating layer.

In an alternative method of forming a surface heating element according to the invention the conducting layer is applied to the inner insulating layer and the conducting layer, the insulating layer and the support (when provided) are then perforated with holes of larger cross sectional area than those finally required. The outer insulating layer is then applied over the conducting layer, so that, in addition to covering the conducting layer, it substantially fills the perforations. This outer insulating layer is then allowed or caused to set, as by curing, and holes of the desired smaller size are then punched or similarly formed in the complete element in the same position as the larger holes originally formed.

In a still further method of forming a surface heating element according to the invention after the conducting layer is applied to the inner insulating layer, small areas of the conducting layer, where the perforations are to be formed are removed, each of these areas being larger than the cross section of the prospective associated perforation. The outer insulating layer is then applied and, after such outer layer has set or been caused to set, the perforations are formed in the complete element in the same positions where the areas of the conducting layer have been removed from the conducting layer.

The invention may be formed in various ways and some particular embodiments will now be described by way of example with reference to the accompanying diagrammatic drawings, in which:

Figures 1 to 4 represent the various stages of one method of applying the invention to the outer sheet metallic skin of an aircraft wing surface,

Figures 5 to 8 illustrate the various steps of a second method,

Figures 9 to 12 illustrate the various steps of a third method, and

Figures 13 to 16 illustrate the various steps of one method of applying the invention to an insulating surface.

Figure 17 is a perspective view of the final perforated heater element when manufactured in accordance with the first method of Figures 1 to 4.

Referring first to Figures 1 to 4 a sheet metal layer **1** which in this case constitutes an aircraft outer skin is first coated with a layer **2** of an adhesive synthetic plastic resin such as that sold under the registered trademark Araldite as "Araldite Type 1 Natural." An intimate mixture of three parts by weight of this resin with one part by weight of powdered mica is for this purpose applied to the surface of the sheet metal layer **1** by a flame type spraying gun, for example a gun sold under the registered trademark "Schori."

This layer is then cured by heat treatment for approximately one hour at a temperature of between 170° C. and 190° C. A layer of aluminum **3** which constitutes the electrical resistance layer, is then applied to the surface of the cured insulating layer **2** by a similar flame spraying process to cause this metal layer to adhere to the inner insulating layer **2**. Finally an outer insulating layer **4** of the same synthetic plastic resin Araldite is applied over the metallic resistance layer **3**.

This first step in the process of manufacturing the heater element is described in United States Patent application Serial No. 304,964, now Patent No. 2,791,668 issued May 7, 1957.

In the next step in the process a series of perforations, one of which is shown in Figure 2, are formed through the complete heater element. The lateral dimensions of these perforations are slightly greater than the dimensions of the final required perforations.

In the next step the perforations are filled, as shown at **5**, with an adhesive synthetic resin which is preferably the same resin "Araldite Type 1 Natural" referred to above, as illustrated in Figure 3. This forms an intimate bond with the walls of the perforations.

Finally holes of the required final slightly smaller cross sectional area are formed in the centre of the previous perforations leaving a skin **6** of the insulating material around the walls of the perforations as shown in Figure 4.

In the method illustrated in Figures 5 and 8 the inner insulating layer **2** and the metallic layer **3** are applied to the base supporting metallic skin **1** in the same way, as shown in Figure 5. Before applying the outer insulating layer however the partly formed heater element is perforated as shown in Figure 6, the lateral dimensions of these perforations being again somewhat greater than the dimensions of the final holes. The outer insulating layer **4** is then applied overall, as shown in Figure 7, and is caused to fill the holes previously formed. Finally perforations of the required cross sectional area are formed as shown in Figure 8 through the complete element leaving the part of the outer layer **4** as a skin around the walls of the holes.

In the method illustrated in Figures 9 to 12 the inner insulating layer **2** and the metallic layer **3** are again applied in the same way to the base metallic support **1**, parts of the resistance layer **3** are then removed, as shown in Figure 10 over areas somewhat greater than the required dimensions of the final holes. The outer insulating layer **4** is then applied overall as shown in Figure 11, and caused to fill the gaps in the metallic resistance layer **3**. Finally the holes of the required size are formed as shown in Figure 12 leaving part of the outer insulating layer **4** as a skin around the upper part of the walls and each hole, this skin begin united to the inner insulating layer **2** around these walls.

In the method illustrated in Figures 13 to 16 the heater element is applied direct to a layer of insulating material **10** such as a synthetic plastic sheet, rather than to the metallic base support **1**. In such case an extra inner insulating material may be unnecessary since the metallic resistance layer can be applied direct to the insulating support **10**. Thus in this method a metallic resistance layer **11** is applied to the insulating support **10** by spraying powdered metal through a flame spraying gun as described above. The partly formed heater element is then perforated as shown in Figure 14 and an outer insulating layer **12** is then applied overall and caused to fill the perforations as shown in Figure 15. Finally the holes of the required size are former as shown in Figure 16 in the same manner as previously described with reference to Figure 4, thus leaving part of the layer **12** in the form of a skin around the walls of the holes.

In all such cases it will be appreciated that in the final form the metallic resistance layer is totally enclosed between two insulating layers and is not exposed even at the perforations. Thus there is no possibility of short circuiting due to water droplets or other atmospheric particles coming in contact with the resistance layer.

The perforations are preferably arranged in rows as illustrated at A in Figure 17, and are staggered between adjacent rows so that imaginary lines B, transverse to the direction of current flow as shown by arrow **13**, will pass through perforations in alternate rows.

It is to be understood that the perforations in surface heating elements according to the invention may be of circular, oval, or other cross section to suit requirements and that the perforations in any one element may be all of the same shape and/or size or of different shapes and/or sizes in different areas of the element and may be spaced evenly or otherwise from one another.

One application of the invention is to aircraft parts on which anti-icing or de-icing apparatus is required as well as provision for the flow of air in or out through perforations therein for the purpose of assisting in maintaining flow of an appropriate boundary layer over the surface of the part.

What we claim as our invention and desire to secure by Letters Patent is:

1. A surface heating element of the kind comprising a metallic electric conducting resitance heating layer sandwiched between two insulating layers in which the element is perforated with a plurality of small holes extending through the insulating and metallic conducting layers, and each hole is lined with a layer of insulating material.

2. A surface heating element as claimed in claim 1, in which the perforations are staggered laterally in relation to the direction of current flow through the conducting layer.

3. A surface heating element as claimed in claim 1, in which the lining layer of insulating material in each hole is continuous with one of the two insulating layers of the heating element.

4. A surface heating element as claimed in claim 1, in which the lining layer of insulating material in each hole is in close contact but a non-continuous with both of the two insulating layers of the heating element.

5. A surface heating element as claimed in claim 1, in which the lining layer of insulating material in each hole is in the form of a distinct bush, applied separately from the two insulating layers of the heating element.

6. A surface heating element as claimed in claim 1, in which part of the lining layer of insulating material in each hole is continuous with one of the insulating layers of the heating element, and the remaining part of the lining layer of insulating material in each hole is continuous with the other insulating layer of the heating element.

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