Feb. 7, 1950 R. S. ELY ET AL **2,496,279**

FLEXIBLE ELECTRIC HEATER FOR DE-ICING AIR FOILS

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Fig. 5.

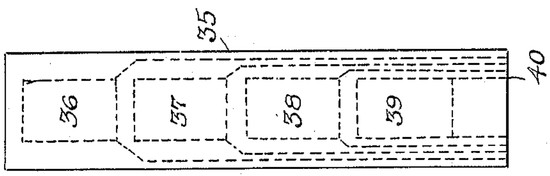


Fig. 2.

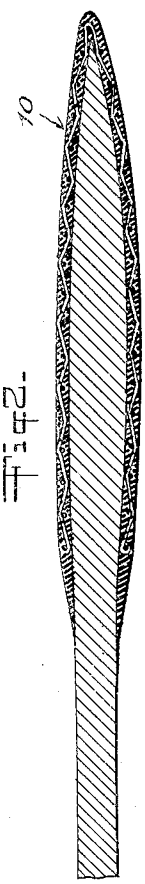


Fig. 3.

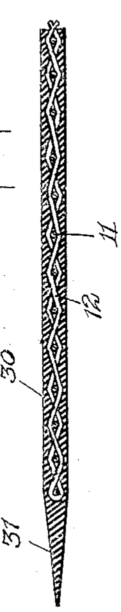


Fig. 4.

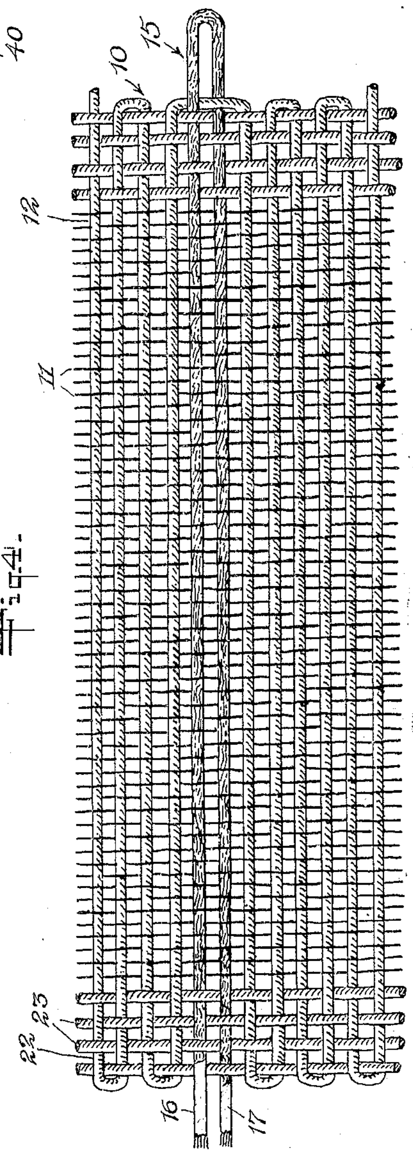
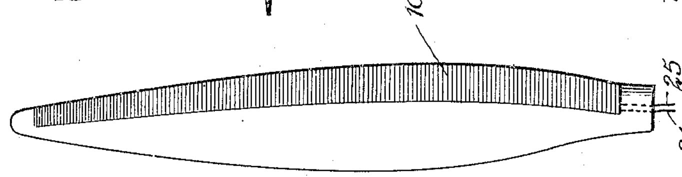


Fig. 1.



INVENTORS
Robert S. Ely
and Irving M. Ketcham
BY
Munn, Liddy & Glaccum
Attorneys

Witnesses
Geo. W. Naylor

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FLEXIBLE ELECTRIC HEATER FOR DE-ICING AIR FOILS

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Fig. 6.

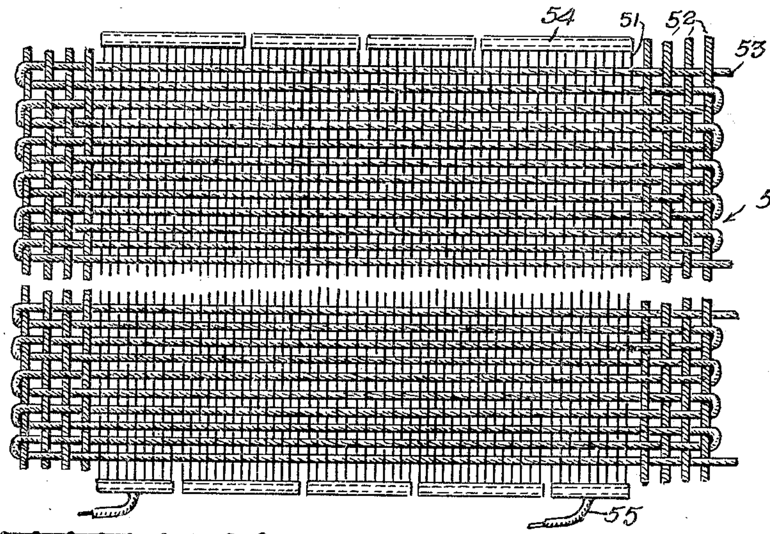


Fig. 7.

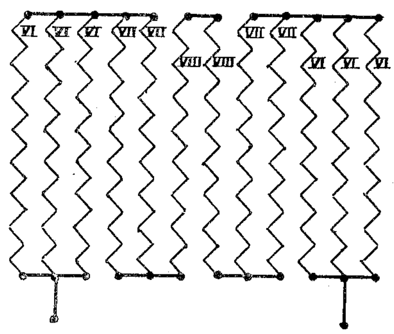


Fig. 8.

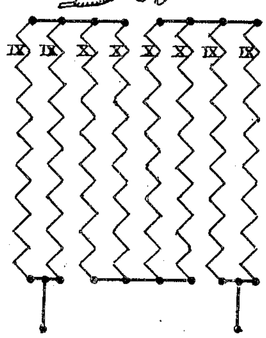


Fig. 9.

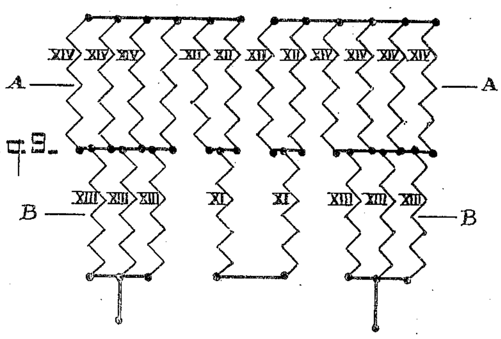


Fig. 10.

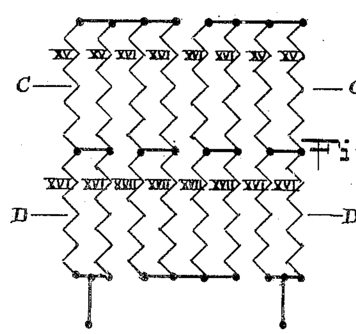
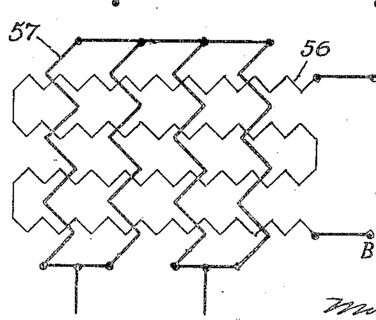


Fig. 11.



Witnesses
Geo. W. Naylor

INVENTORS
Robert S. Ely
and Irving M. Ketcham
BY
Munn, Liddy & Glaccum
Attorneys

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UNITED STATES PATENT OFFICE

2,496,279

FLEXIBLE ELECTRIC HEATER FOR DEICING AIRFOILS

Robert S. Ely, Westbury, and Irving M. Ketcham, Roslyn Heights, N. Y., assignors, by mesne assignments, to Safeway Heat Elements, Inc., New York, N. Y., a corporation of Delaware

Application February 10, 1945, Serial No. 577,232

3 Claims. (Cl. 219—19)

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Our invention relates to heaters and heater elements of the electric resistor type. While not limited to such use, the invention is particularly adapted to airplanes to prevent the formation of ice on wings, propellers and other exterior surfaces, to melt any ice which has formed on these surfaces and to prevent the formation of moisture or frost on instruments and moving parts.

One object of the invention is to provide a heater which will emit different amounts of heat per unit of surface from different areas of the heater. A further object of the invention is to provide a heater which is flexible enough to be cemented or otherwise affixed in heat exchange relationship to curved or uneven surfaces.

Devices in use for de-icing of the pulsating boot type are heavy, expensive to maintain and uncertain in their function. The resistor type heaters used heretofore, for this purpose emit uniform amounts of heat from all parts of their surface whereas it has been found that greater concentrations of heat are demanded in some areas and less heat in others.

In our invention these objects to construction of the prior art are overcome by providing a heater which is woven in the form of a flexible blanket or tape in which different concentrations of heat are emitted at various parts of the heater so that when it is used for de-icing the greatest amount of heat will be given off at the places where ice forms the fastest. In the preferred embodiment of the invention the heater fabric consists of flexible resistor wires forming the warp and the woof is woven with thread made from glass, asbestos or other heat resisting dielectric material. In some cases we may use resistor wire in both the warp and the woof of the fabric. In this case the warp or woof wires or both would be insulated with a heat resisting dielectric such as braided glass or asbestos sleeving. We may also use some dielectric threads in the warp to reinforce the fabric at the edges and between the groups of wires.

In the preferred form the different heat concentrations are achieved by serially connecting warp wires of different resistance or by serially connecting groups of warp wires of different resistance. In a series circuit the greatest wattage will develop where the resistance is highest. It is thus possible to provide a heater in which the heat varies in longitudinal strips or in lateral bands or in both strips and bands. When heater wires are used for both the warp and the woof, we may connect the warp and woof circuits in series or in parallel or each may be connected to operate independently of the other. Thermostatic means may be provided to control the operation of either circuit.

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To give mechanical strength and dielectric protection the heater fabric may be impregnated with rubber, silicone, resin or other flexible binder. Where additional protection or a smooth surface is required, we may encase the heater in a sheath of rubber or other suitable material such as neoprene. The sheath may be moulded or vulcanized directly to the heater or it may be removable.

These and other features and objects of our invention will appear from the following description thereof in which reference is made to the accompanying figures of the drawings.

In the drawings—

Figure 1 is a side elevation of a propeller blade embodying a form of our invention;

Figure 2 is an enlarged cross sectional view of the leading edge of a surface carrying one of our de-icers;

Figure 3 is a cross sectional enlarged view of one of the de-icers;

Figure 4 is a view of the heating element;

Figure 5 is a schematic view of a series of elements adapted to be positioned within one cover;

Figure 6 is another view of a heating element woven in the form of a flexible fabric;

Figures 7 to 11 inclusive are wiring diagrams.

Referring more particularly to the drawings, Figure 4 discloses a heating element **10** made up of warp wires **11** and woof members **12**. The warp is made of flexible resistor wires while the woof is woven of thread made of glass, asbestos, or other heat resisting dielectric material. The length of unit **10** depends upon the area to be covered and, in the case of the propeller blade, this would be determined by the length of the blade. As the unit is woven and completed a copper element **15** is woven into the fabric adjacent the end of the unit to form two strands **16** and **17**. It will be noticed that the strand **16** passes under the copper wires which the strand **17** passes over so that each wire is contacted on both sides by the copper element. This element may then be soldered to the warp wires **11** and then cut in sections to form separate connection members, as illustrated in Figure 6. The type of cutting members shown in Figure 6 are slightly different but the effect of cutting the copper element **15** is the same. For strength and to form a proper edge **22** the glass fibers **23** may be used as warp threads rather than the resistor wires. It will be understood that lead wires **24** and **25**, as shown in Figure 1, will be connected to the element similar to the lead **55** shown in Figure 6.

In making the unit the copper element **15** is cut so that the connecting element in the center of the unit connects fewer wires than those at the outer edge. This results in increased heating in the central zones and of varying watt density per square inch.

The heating element 10 is preferably engaged in a suitable cover 30 which is feathered at 31 for smooth installation. It has been found that the heating element 10 may be readily encased in uncured neoprene which may then be cured and fused about the heating element to form a flexible covering which may be cemented on the leading edge of the plane wing or on the leading edge of a propeller blade, as shown in Figure 2. If the area to be heated is such that the continuous heat of the entire surface will overtax the capacity of the generator furnishing the current the area may be divided into zones, each supplied by a separate heating element, as shown in Figure 5. There the area 35 is divided into zones by separate heating elements 36, 37, 38 and 39 having separate leads 40. By any conventional means the current may be alternately or successively fed to selected zones. Similarly a four-blade propeller having a unit on each blade may be heated by successively feeding the current for a predetermined time, thus using a minimum amount of current to prevent the formation of ice.

Referring to Figure 6, this particular unit 50 is made up with a warp composed of 60 heater wires 51 of equal resistance and eight glass threads 52. The woof 53 is a glass thread. The warp wires are connected in series of groups by connectors 54 made of flexible braided copper tabs. The numerical grouping of the sixty wires is as follows—9-8-7-6-6-7-8-9. The amount of heat emitted per unit of surface will be greatest in the central longitudinal strip covered by the six wire groups and the heat will decrease in three successive steps toward each edge. The entire circuit is connected to a source of electric power by lead wires 55.

It will be appreciated that the ends of each adjacent group at one end of the unit are connected by one of the connectors 54.

Figure 7 is a simplified diagram of the type of circuit shown in Figure 6. The twelve equal resistance wires VI, VII and VIII are arranged in serially connected groups having the numerical ratio 3, 2, 1–1, 2, 3. The greatest amount of heat is emitted by wires VIII, less is emitted by wires VII and least by wires VI.

In Figure 8 the modification of circuit shown in Figures 6 and 7 is shown. The wires IX and X are serially connected in groups of 2-2-2 with wires X having greater resistance than wires IX. With this arrangement more heat is emitted by the two center strips than by the two outer strips.

In Figure 9 is shown a heater composed of equal resistors in which the heat decreases from the center to the edges and also from the bottom to the top. Thus a section through the line B—B will emit more heat than a section through the line A—A.

Figure 10 is a modification of the circuit shown in Figure 9. The wires XVII have the greatest resistance, wires XVI have less and wires XV the least resistance. Here again the heat will decrease from the center to the edges and from the bottom to the top. A section through the line D—D will be hotter than a section through the line C—C.

In Figure 11 a diagram of a heater is shown in which the woof 56 forms one or more electric heater circuits woven through but insulated from the warp 57. The warp circuits may consist of

any combination of resistors including the arrangements shown in Figures 1–5. The warp and woof circuits may be connected in series, in parallel or they may be separated by separate controls.

It will be understood that the foregoing are merely examples of the application of our invention and are typical of the embodiments which may be employed. However, numerous changes and modifications may be made in the form and the arrangement of parts without departing from the spirit of the invention and it should be understood that we do not intend the invention to be limited to the illustrative embodiments set forth.

We claim:

1. A flexible heating element for heating the leading edge of an air foil, said element comprising a woven fabric, the warp of said fabric running parallel to said airfoil edge and consisting of a plurality of resistor wires and the woof of heat resisting dielectric material, electrical conducting elements woven into said heating element, said conducting elements contacting and connecting certain of said resistor wires in mechanically and electrically parallel groups and connecting said groups electrically in series whereby the heat intensity developed in said groups will vary in inverse proportion to the number of wires in each group.

2. A flexible heating element for heating the leading edge of an air foil, said element comprising a woven fabric, the warp of said fabric running parallel to said air foil edge and consisting of a plurality of resistor wires and the woof of heat resisting dielectric material, electrical conducting elements woven into said heating element, said conducting elements contacting and connecting certain of said resistor wires in mechanically and electrically parallel groups and connecting said groups electrically in series whereby the heat producing area of the greatest intensity is in closest proximity to the edge of the air foil paralleling the same, the second heat producing area of intermediate intensity is spaced from the first and the third heat producing area of least intensity is spaced from the second area.

3. A flexible heating element for heating the leading edge of an airfoil, said element comprising a woven fabric encased in a protective covering, the warp of said fabric running parallel to said airfoil edge and consisting of a plurality of resistor wires, and the woof consisting of heat resisting dielectric material, said resistor wires being grouped with the ends of each group being connected and with each group connected to the adjacent group, a conducting element connected to each of the outside groups whereby the heat intensity developed in said groups will vary in inverse proportion to the number of wires in each group.

ROBERT S. ELY.
IRVING M. KETCHAM.

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