April 1, 1952 C. L. COWDREY ET AL 2,590,944

ELECTRICAL HEATING APPARATUS

Filed Dec. 27, 1949 2 SHEETS—SHEET 1

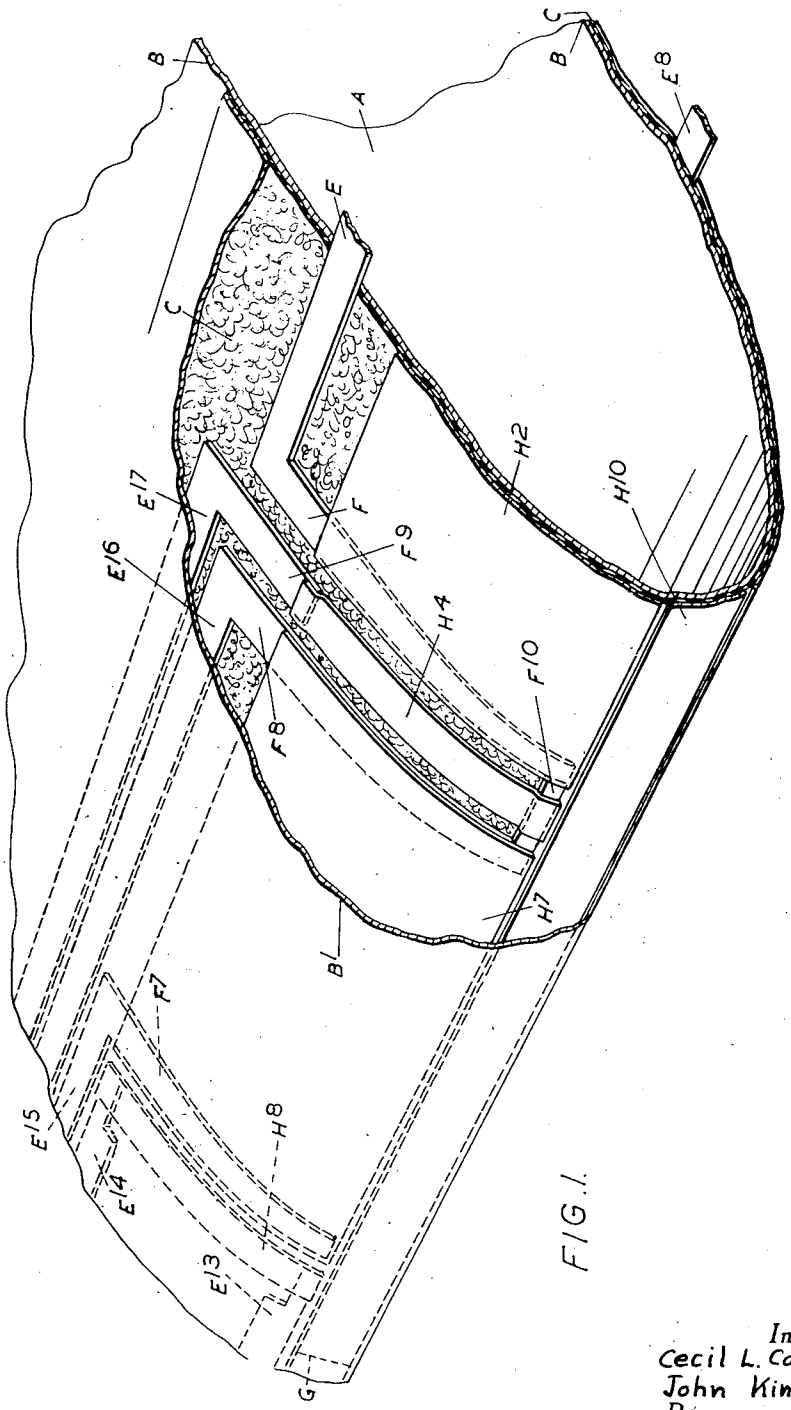

FIG. 1.

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ELECTRICAL HEATING APPARATUS

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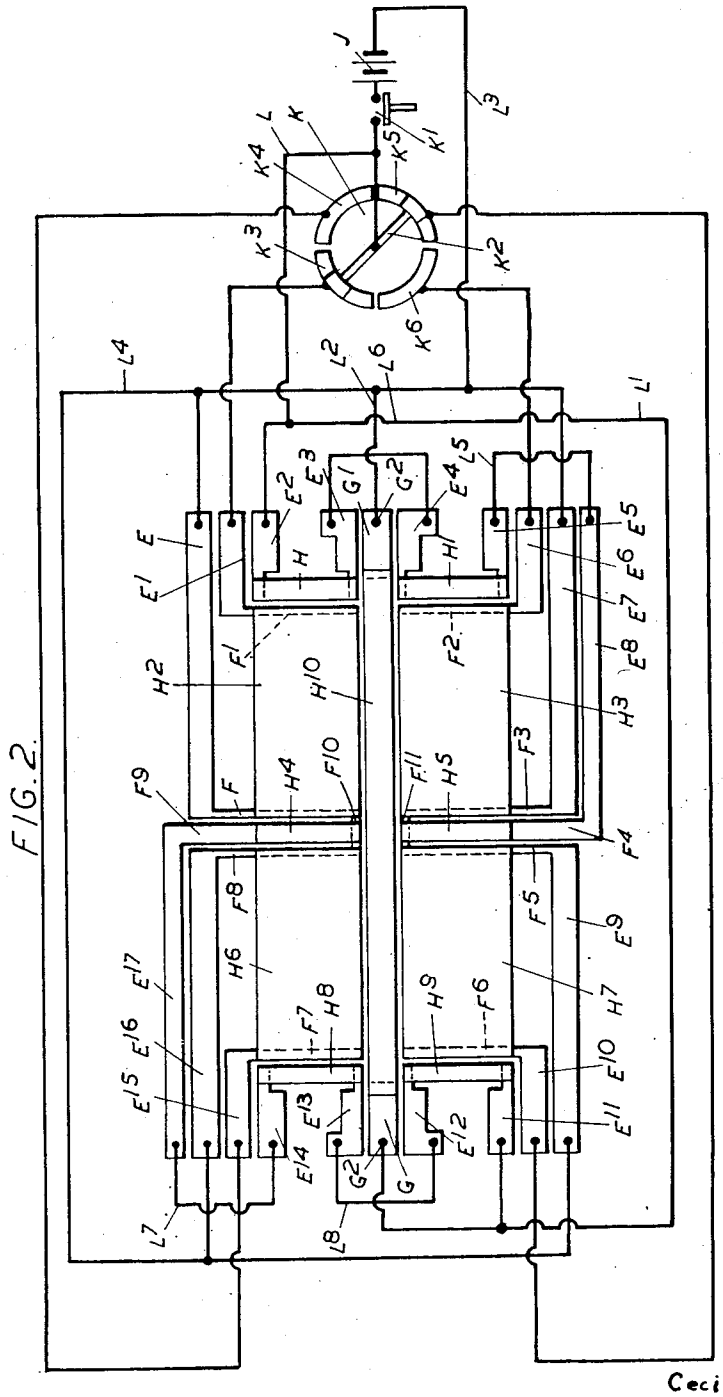

FIG. 2.

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Patented Apr. 1, 1952

2,590,944

UNITED STATES PATENT OFFICE

2,590,944

ELECTRICAL HEATING APPARATUS

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Application December 27, 1949, Serial No. 135,182
In Great Britain January 3, 1949

7 Claims. (Cl. 244—134)

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This invention relates to electrical heating apparatus of the kind comprising one or more metallic resistance elements arranged so as to be heated by the passage of electric current therethrough and is particularly but not exclusively applicable to the heating of surfaces, for example the surfaces of heating panels, for space or other heating purposes, or the surfaces of parts of aircraft or aircraft power units for the purpose of preventing the formation of ice thereon.

Electrical heating apparatus according to the present invention comprises an electrically insulating surface, one or more electrical resistance elements each in the form of a thin metallic layer applied to the insulating surface so as to adhere to it, and terminals or their equivalent situated so that when connected to a source of electric current the layer or layers will be heated by the passage of electric current therethrough.

Preferably the metallic layer or layers are applied to the insulating surface by metal spraying. Moreover, in any case the metallic layer or layers are preferably covered by a protective layer of insulating material, for example in the form of an insulating paint or plastic material applied over the metallic layer by spraying or brushing.

The electrically insulating surface to which the metallic layer or layers are applied may be the surface of a layer of insulating material, for example of fabric or of an insulating paint or plastic substance applied by spraying or brushing to the surface of an insulating or non-insulating supporting member, or may be constituted by the surface of an insulating supporting member formed for example of plastic or other insulating material.

The metallic layer or layers are preferably in any case applied to the insulating surface in the form of one or more comparatively long narrow strips which in the case of two or more strips are separated from one another by small gaps so as to provide comparatively long electrical resistance paths. Such strips may be straight, zigzag or of other formation and may be arranged in any way which suits the shape of the surface to which they are applied.

The thickness of the metallic layers according to the invention may vary, but preferably does not exceed approximately .005". Further any convenient metal may be employed but preferably a metal having a comparatively high electrical resistance such as Nichrome is used. It has been found that metal applied by spraying

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has a resistance which is considerably greater than the resistance of the normal metal and this must be taken into account in determining the thickness which the metallic layer according to the invention should have for a given resistance.

The invention is particularly applicable to the leading edge portions of aircraft wings, control surfaces, air intakes and the like on which air impinges during flight and on which, therefore, under certain atmospheric conditions ice tends to form, and one form of the invention as applied to the leading edge of a wing of an aircraft is illustrated somewhat diagrammatically in the accompanying drawings, in which

Figure 1 is a perspective view, partly in section of a part of the leading edge portion of the wing to which the invention is applied, parts of various layers being removed to show the construction more clearly, and

Figure 2 is a diagram showing the wiring circuits by which the heating elements for a section of the leading edge portion of the wing are connected to a source of electrical supply and the general arrangement of the heating elements as it would appear if the leading edge portion of the wing were bent into vertical flat form.

In the construction illustrated the aircraft wing A has a metal skin B. Applied over this skin so as to cover the leading edge portion thereof is a layer C of electrical insulating material, which may also have good heat insulating characteristics, and may either be in the form of a sheet of insulating material applied to the skin B and attached to it by adhesive or may be constituted by a layer of insulating material applied to the skin B in liquid form by spraying or brushing.

Arranged on the insulating layer C are a series of sheet metal strips indicated by the reference letters E to E^{17} inclusive some of which have end portions F, F^1, F^2, F^3, F^4, F^5, F^6, F^7, F^8 directed towards the leading edge of the wing as shown, while terminal plates G, G^1 lie against the outer surface of the layer C at the extreme leading edge of the wing and are in contact with electric terminals G^2 extending through insulated bushes in a manner known per se into the interior of the wing. The ends of the strip portions F and F^8 are further united by a contact plate F^{10} while the ends of the strip portions F^3 and F^5 are similarly united by a contact plate F^{11}.

Applied to the outer surface of the layer C by metal spraying are a series of resistance heating elements in the form of strip-like layers of metal indicated by the reference letters H to H^9 inclu-

sive each of which extends between and overlaps two of the strips or strip portions E to E^{17}, F to F^8 or the plates G, G^1 as shown.

Thus by connecting the two sheet metal strips or plates between which any one of the strip-like layers H to H^9 of sprayed metal extend, to a source of electric supply, current will be caused to flow through and heat the strip-like layer.

The whole assembly comprising the metal strips E to E^{17} with the end portions F to F^8 and the metal layers H to H^9 is covered by an outer protective coating or layer B^1 of insulating paint or the like applied by spraying or brushing.

Means, shown diagrammatically in Figure 2, are provided for connecting the strips E to E^{17} and the plates G, G^1 to a source of electric supply indicated diagrammatically at J, these means comprising electrical circuits arranged as shown, an interrupter switch or distributor K controlling the supply of current to certain of the circuits and a master switch K^1 controlling the whole supply of electric current from the source J to the apparatus.

When the apparatus is in operation the master switch K^1 is closed and a motor rotating the distributor arm K^2 of the interrupter switch K, which has four contacts K^3, K^4, K^5 and K^6, in a manner known per se is set in motion.

It will then be seen that the heating element H^{10} extending along the extreme leading edge of the wing will be connected continuously to the source of electric supply by way of a circuit comprising the conductors L and L^1 the plate G, the strip H^{10} and the conductors L^2 and L^3.

It will also be seen that while the metal strips E, E^7, E^9 and E^{16} are continuously connected to the negative side of the source of current J by way of the conductors L^3 and L^4, the interrupter switch K alternately connects the strips E^6 and E^{15} and the strips E^1 and E^{10} to the positive side of the current source J. Further it will be seen that a continuous circuit is established when the master switch K^1 is closed, from the negative side of the current source, through the conductor L^3, the conductor L^4, the strip E^7, F^3, the plate F^{11}, the heating element H^5, the strip F^4, E^8, a conductor L^5, the strip E^5, the heating element H^1, the strip E^4, a conductor L^6, the strip E^3, the heating element H, the strip E^2, and the conductor L to the positive side of the current source J. A similar circuit is also continuously completed through the conductor L^3, the conductor L^4, the strip E^{16}, F^8, the strip F^{10}, the heating element H^4 the strip F^9, E^{17}, a conductor L^7, the strip E^{14}, the heating element H^8, the strip E^{13}, a conductor L^8, the strip E^{12}, the heating element H^9, the strip E^{11} and the conductors L^1 and L to the positive side of the current source J.

It will therefore be seen that when the apparatus is in operation the heating elements H^2, H^3, H^6 and H^7 will each be intermittently connected in circuit with the current source J while the heating elements H^{10}, H, H^1, H^4, H^5, H^8 and H^9 will be continuously in circuit with the current source J. Thus, the heating element H^{10}, which covers the area most prone to ice formation is heated continuously, each of the short strip-like heating elements H, H^1, H^4, H^5, H^8 and H^9 is similarly heated continuously so as to provide strips on which ice cannot form, while if the conditions are such that during the period when any one of the heating elements H^2, H^3, H^6 and H^7 is not in circuit ice forms thereon, such ice will be loosened by its inner surface being melted when the element is brought then readily into circuit and will be dislodged by the airstream since its ends and forward edge are not connected to any other ice but terminate at continuously heated heating elements.

With such an arrangement consumption of electric current tends to be minimised since not only is the total area which has to be heated at any moment reduced as compared with an arrangement in which the whole of the area prone to ice formation has to be heated continuously but the heating of the elements H^2, H^3, H^6 and H^7 only has to be sufficient to loosen the ice from the areas covered by them and not to melt the whole body of ice which may accumulate thereon.

It is to be understood that the arrangement shown diagrammatically in Figure 2 would usually represent only the section of the apparatus sealing with one part of the length of the leading edge portion of an aircraft wing and that in practice the arrangement would usually be extended or manipulated so as to provide any appropriate number of intermittently heated heating elements similar to the elements H^2, H^3, H^6 and H^7 separated by continuously heated strip-like elements similar to H, H^1, H^4, H^5, H^8 and H^9 to cover the length of the leading edge of the wing, the heating element H^{10} being similarly extended or a series of such elements being arranged end to end along the extreme leading edge of the wing, as may be found convenient.

It will be seen that when the present invention is applied to a surface, heat is supplied substantially directly to such surface so that, in the case of surfaces on which ice formation is to be resisted, as in the example of the invention particularly described above, high thermal efficiency is obtained. Further, whether for preventing ice formation or for other purposes, the invention is readily capable of being applied to existing surfaces substantially irrespective of the shape of such surfaces and requires no highly skilled technique or the manufacture of special heating elements. Moreover, the current carrying metallic layers constituting the heating elements are not readily damaged in ordinary use, will withstand reasonable wear and tear and can readily be renewed or repaired if they become damaged.

The external finish provided, for example by the layer B^1 can also be smooth and in fact need not differ greatly from a surface to which the invention has not been applied.

The method of applying the metallic layers according to the invention may vary but in one convenient arrangement such layers are applied by spraying the metal through a suitably formed stencil.

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

1. Means for reducing or preventing the formation of ice on a surface comprising a series of resistance heating elements in the form of thin metallic layers covering different areas of the surface and electrically insulated from one another, terminals electrically connected to said layers, respectively, and adapted to be connected to a source of electric heating current supply, control means associated with at least one of said terminals whereby the corresponding heating element is connected continuously to such current source when said control means is in operation, and an interrupter switch apparatus connected to another of said terminals including automatic operating mechanism which when said control means is in operation connects at least one other of the elements intermittently at predetermined

time intervals and for predetermined time intervals to the current source.

2. Means for reducing or preventing the formation of ice on a surface as claimed in claim 1, in which the resistance heating elements include spaced elements covering comparatively large areas of the surface separated from one another by strip-like elements covering comparatively small areas of the surface and the control means connect the strip-like elements continuously to the source of current supply while the elements covering the comparatively large areas are connected to the current source through the interrupter switch apparatus.

3. Means for reducing or preventing the formation of ice on the surface as claimed in claim 2, applied to the leading edge portion of an aircraft wing in which a strip-like element extends longitudinally along the extreme leading edge portion of the wing and the areas adjacent to but in rear of the extreme leading edge portion are covered by alternate wide and narrow elements, the narrow elements extending at right angles to the strip-like element extending along the extreme leading edge portion, and said control means connecting said strip-like element and said narrow elements continuously to the electric current source.

4. Means for reducing or preventing the formation of ice on a surface of an aircraft, including a series of resistance heating elements in the form of thin metallic layers, each element covering a different relatively large area of the surface and at least one similar resistance heating element covering a relatively small area of the surface lying between two of the said relatively large areas, adjacent resistance heating elements being electrically insulated from one another, control means for continuously connecting said resistance heating element covering the relatively small area to a source of electric current, and distributing switch apparatus comprising automatic mechanism operating to control the supply of current to the heating elements covering the said relatively large areas in a predetermined sequence, each of said heating elements being connected to the source of current intermittently for a predetermined period of time at predetermined time intervals.

5. Means for reducing or preventing the formation of ice on a surface of an aircraft as claimed in claim 4 in which each of the heating elements covering a relatively small surface area is of strip-like form.

6. Means for reducing or preventing the formation of ice on the surface of an aircraft wing as claimed in claim 5 in which one of the said strip-like heating elements extends along the extreme leading edge of the wing.

7. Means for reducing or preventing the formation of ice on the surface of an aircraft wing as claimed in claim 6 in which the areas adjacent to but in rear of the extreme leading edge portion of the wing are covered by alternating wide and narrow heating elements, the narrow elements extending at right angles to the strip-like element which extends along the leading edge of the wing, means being provided for connecting the narrow elements continuously to the source of electric current, whereas the supply of electric current to the wider elements takes place through the distributing switch apparatus whereby these wider elements are connected to the electric current source in sequence and each for predetermined periods at predetermined time intervals.

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JOHN KINSELLA.

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