Chapter 4

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NAPIER SURFACE HEATER SYSTEM

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LIST OF ILLUSTRATIONS

INTRODUCTION

General

1. Thermal methods of protection of aircraft against ice formation involve two distinct principles, anti-icing and de-icing. ANTI-ICING is the prevention of ice formation, and can be either (1) wet anti-icing, by which water present is kept just liquid so that it can flow back to form ice behind the heated surface (which limits its application), or (2) dry anti-icing, by which all water is completely evaporated. DE-ICING permits limited ice formation and periodically sheds the ice by intermittently heating the surface.

2. In icing conditions certain surface areas of an aircraft require continuous heating to attain anti-icing, while other areas require only intermittent heating to attain satisfactory de-icing. The requirements for protection against ice will vary with the type and rôle of aircraft, and can, with reasonable economy, be met by the use of suitably controlled electrical heating.

3. The leading edges of main and tail planes, fins and of air intakes are typical of surfaces requiring continuous heating, since, without some form of anti-icing, the ice formation would be held by aerodynamic force. In the hypothetical system depicted at fig. 1 these areas are indicated in black. Immediately behind and on either side of the continuously heated strips are areas, indicated by the dotted shading, upon which limited ice formation is permissible, but which require periodical de-icing, termed "cyclic de-icing". To ensure a clean break away of ice from these areas they are sub-divided into smaller areas by "breaker strips" which are continuously heated.

4. A limited application of the electrical heating system may only require an ON–OFF

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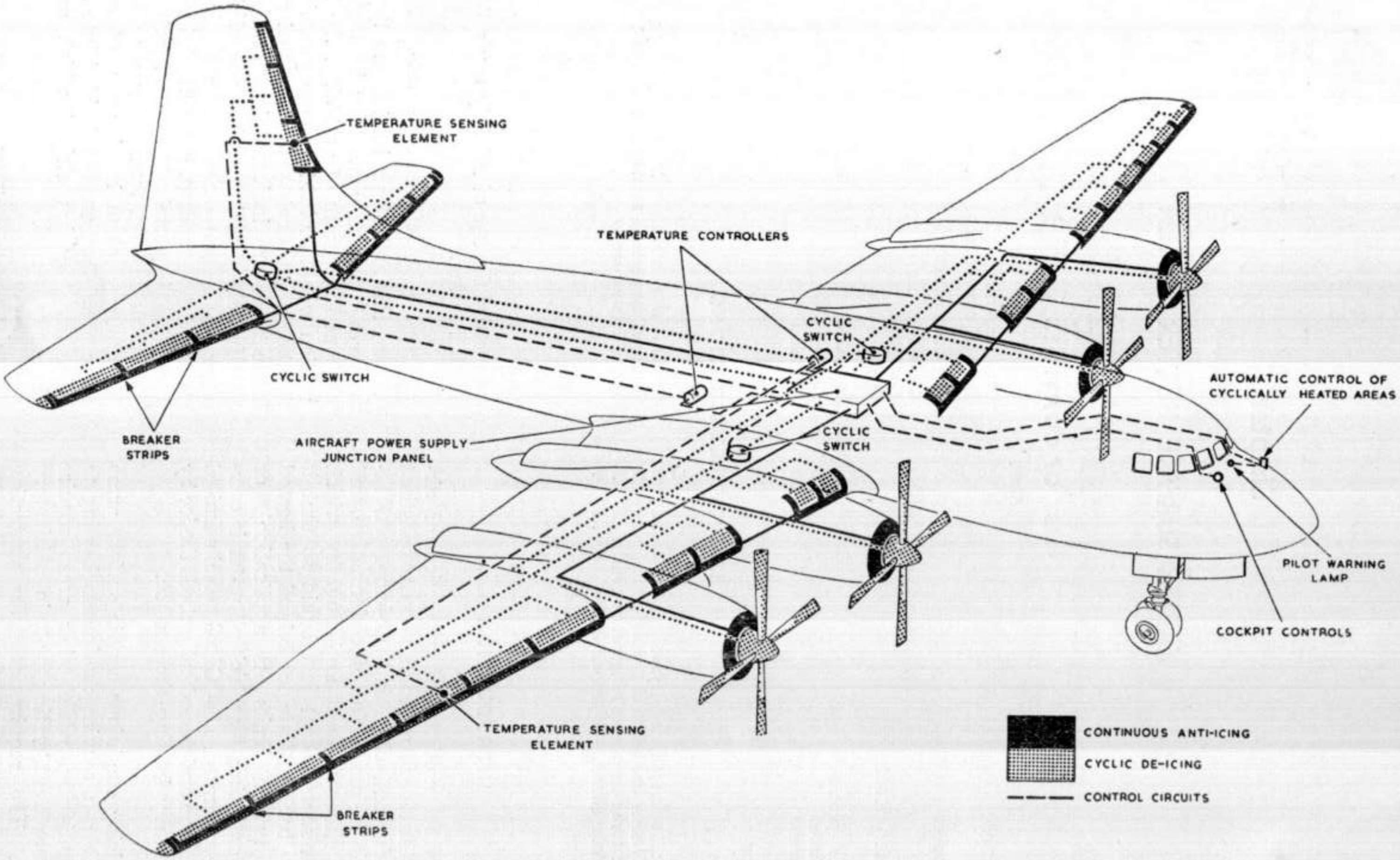

Fig. 1. Hypothetical aircraft system layout

switch to be manually operated. A comprehensive system of heaters, involving differing intensities of anti-icing and cyclic de-icing, may involve the incorporation of one or more cyclic switches with associated intervalometer, temperature sensing units and thermostatic control units. Power to such a system would probably be automatically switched ON or OFF, monitored by ice detecting devices. The scheme of heaters and control system in any aircraft will be detailed in the relevant aircraft handbook.

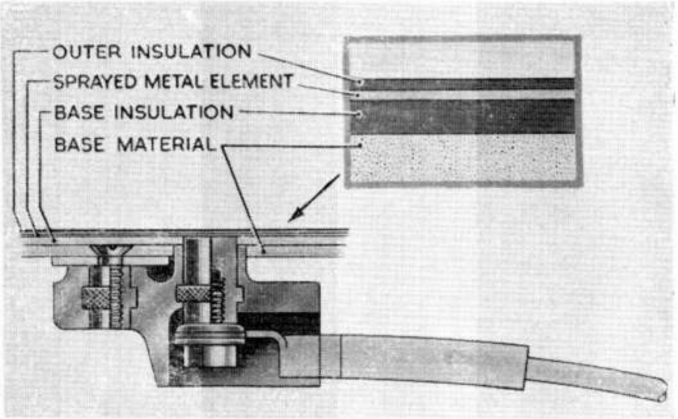

Fig. 2. Section of heater and terminal

Power supplies

5. The source of power may be d.c. or single-phase or three-phase a.c. In a three-phase a.c. system the heated areas would be arranged to obtain balanced loading of phases for both anti-icing and de-icing circuits, if possible. De-icing heaters are connected in such a manner that, as far as practicable, current distribution is at a constant load. To

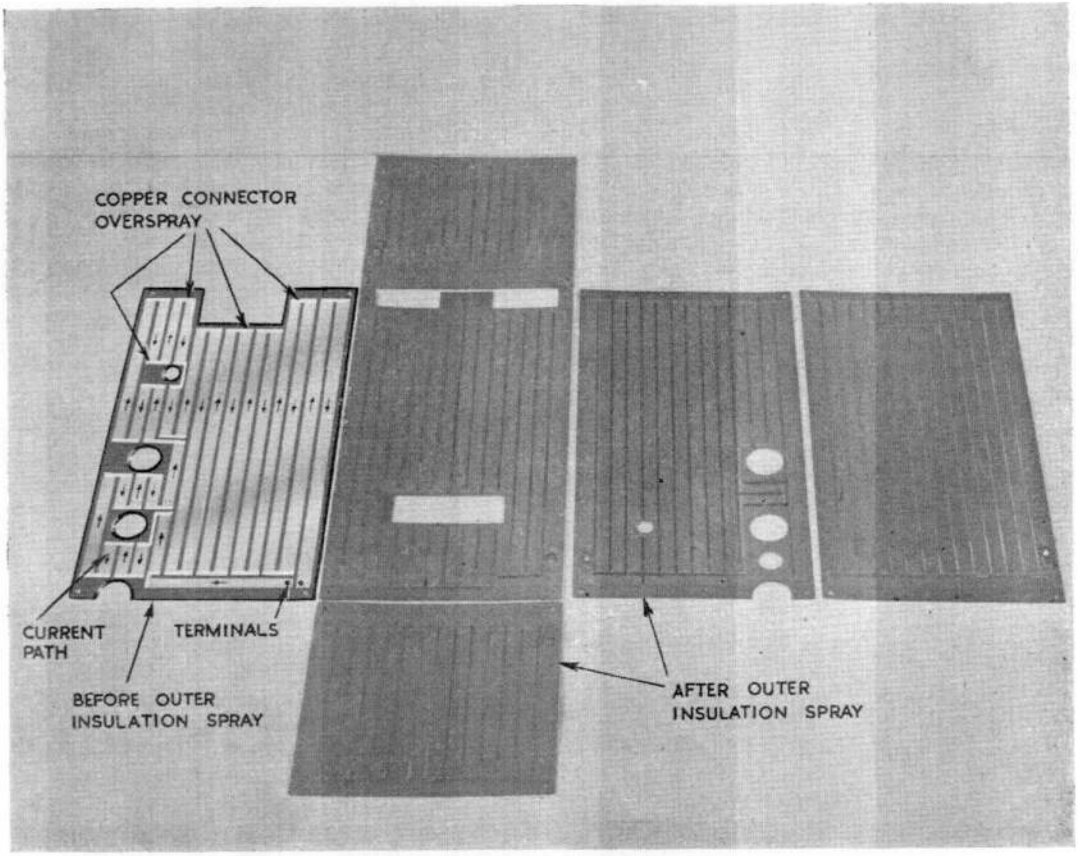

Fig. 3. Heater for boxed component temperature control

do this, the "OFF" period for certain areas will be the "ON" period for others, and a typical "ON" to "OFF" time ratio is 1 to 10. It will be seen that where cyclic de-icing is applicable the TOTAL power requirement, for anti-icing and de-icing, will be considerably less than that required if all areas were continuously heated.

THE NAPIER HEATER

General

6. The Napier surface heater is built up by spraying process (*fig.* 2). Its application to aircraft is particularly convenient since the spraying can be done directly on to the surface to be heated, but it can also be applied to space heating and to the temperature control of individual equipments. Fig. 3 shows the scheme of heaters for a boxed radio component. The heater is constructed in three layers: (1) a base insulation (of synthetic resin), which in the ice prevention application is relatively thick, usually 0·03 in., to prevent heat dissipation into the aircraft structure, (2) the heater element of sprayed metal, (3) the outer insulation, which is relatively thin, about 0·01 in., to ensure maximum heat dissipation at the outer surface, upon which ice would form.

Note . . .

It is occasionally impracticable to fit the heater externally. In such cases the heater is built up behind or under the surface to be protected and the base insulation will be thin while the outer insulation will be thick to ensure heat dissipation toward the protected surface.

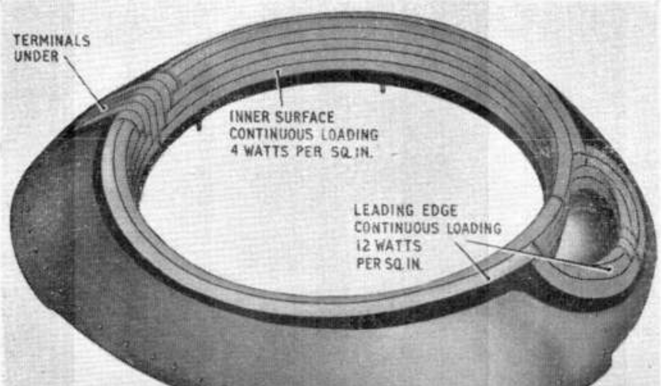

Fig. 4. Graded heater element—engine air intake

7. The finished heater thickness is between 0·05 in. and 0·06 in., depending upon the thickness of the electrical element. The outer insulation is polished to a smooth surface which has high resistance to rain erosion and is unaffected by fluids used in aircraft. The surface may be the natural colour of the synthetic resin, or the final spraying may be pigmented to match surrounding surfaces.

Construction procedure

8. A typical heater is described in the following paragraphs by following the actual construction procedure in stages. The surface to be protected against ice formation is degreased, thoroughly cleaned and slightly roughened. The areas to be covered for anti-icing, de-icing and "breaker" elements having been planned for this surface, the siting of convenient terminal positions is determined. At these positions the structure is drilled to accept the terminal fitting securing screw and the terminal stud. The terminal stud with its insulating moulding or sleeve will stand slightly proud of the surface to be sprayed.

Base insulation

9. The whole area to be covered by the heater, including the terminal studs, is sprayed with a synthetic resin by a flame spray gun. Each layer of spraying is heat cured, and these processes are repeated until a thickness of 0·03 in. is attained. Mounds formed over the terminal studs are now filed down until the stud is exposed and flush with the surrounding insulation surface. The spraying process excludes all air and the terminal is completely sealed against ingress of moisture.

Heater element

10. The surface of the base insulation is now slightly roughened to provide a good key for the element. The layout of the heater element is then transferred from drawings, by hand or by stencil, to this surface and will start and finish over a terminal stud. Areas of the surface to be kept free of metal spray are then covered with masking tape. A suitable metal spray, either aluminium or copper manganese alloy, is next applied to the surface and good electrical connection is assured at the terminal stud. The heater element is usually in the form of parallel strips joined as necessary by narrower strips oversprayed with copper. This copper overspray prevents local over-heating at points where the element changes direction. It is also used when " lead-in " connections are required from terminals which cannot be sited under the heater because of inaccessibility. When metal spraying is complete the masking tape is removed (*fig.* 4 *and* 5).

11. The thickness of the elements must be uniform along its length if area heating is to be uniform. The thickness of the element inversely affects its electrical resistance. This is now checked by passing a known steady current through the element, and recording millivolt drop readings. These readings are obtained using prods suitably spaced in a hand tool which is moved along the element. Where the readings indicate low resistance the element is too thick, and, conversely, where the tests indicate high resistance the element is too thin. Adjustments are made until uniformity of resistance is obtained to within ±5 per cent for heater elements for ice prevention.

12. In some applications the element resistance may be graded along its length, to give differing heat intensity, by varying the thickness or width (normally width) of the element as in fig. 4, which shows an engine air intake element before the outer insulation has been sprayed on. In this example the element strips at the leading edge are loaded to 12 watts per sq. in., while the resistance of succeeding strips toward the inner surface is graded down, by increasing their width, until at the innermost strip the loading is 4 watts per sq. in. The copper overspray connections between element strips are clearly defined. Fig. 5 (a) and (b) show the element arrangement and current path for a small intake cowl where the terminals have to be remote from the heated surface. In this example the element strips were equally graded to give a loading of 20 watts per sq. in.

13. Before the outer insulation is applied the base insulation resistance is tested. A 500-volt insulation tester is connected between the element terminals and earth. A reading of not less than 12·5 sq. ft. megohms is acceptable, i.e., the insulation resistance of each circuit in megohms is multiplied by the area in sq. ft. covered by the conducting element, and this product must exceed 12·5 to be acceptable. The " sq. ft. megohms " figures

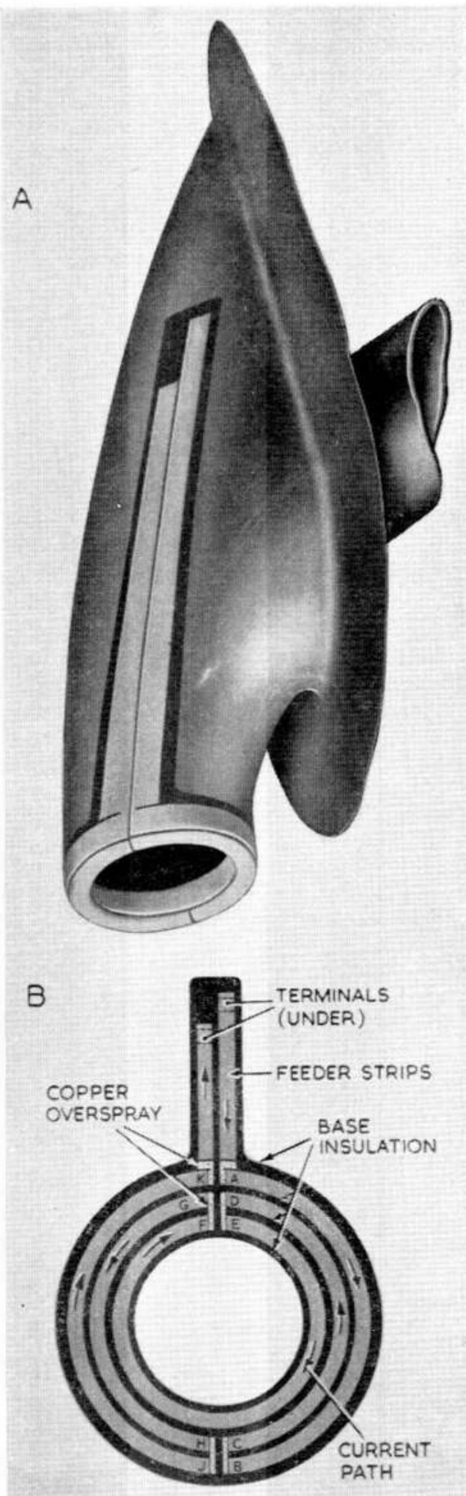

Fig. 5. Heater having remote terminals

for particular applications will be given in the relevant Aircraft Handbook.

Outer insulation

14. The outer insulation is next sprayed on and heat cured, spraying and curing being repeated until the requisite thickness is built up. This spraying fills all spaces between the element strips and completely seals the element. The heater is again checked for insulation resistance. A test pressure of either 1,000 volts or 8 times the working voltage, whichever is the greater, is applied between terminals and earth for one minute. This is followed by testing again with a 500-volt insulation tester as stated at para. 13. A separate check is made between the heater terminals and a wet cotton wool swab wiped over the outer insulation surface of the heater using a 500-volt tester. At no points on the outer surface shall the reading be less than 50 megohms.

Terminal connections (*fig.* 2)

15. Various types of terminal blocks are used, the detail of each being dependent upon such factors as the curvature of the base material and the type of cable end to be accommodated. In general the external heaters on aircraft will have terminals mounted on the back of the skin with contact studs which pass through the base material and base insulation to make contact with the metal spray when the element is formed. It will be unnecessary to pierce the base material in most other applications, and the terminals will be surface mounted.

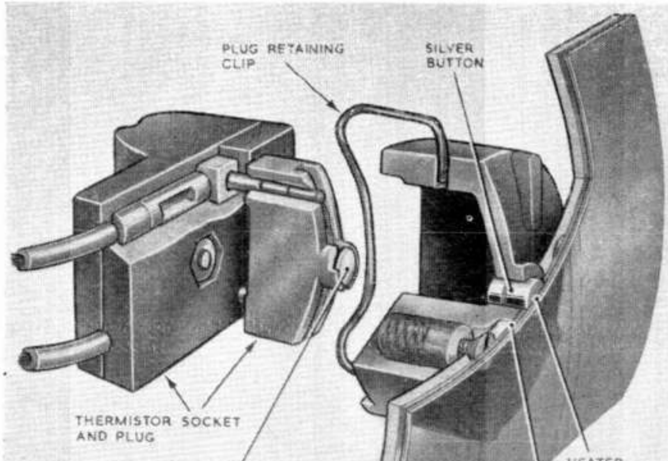

Fig. 6. Section of temperature sensing unit

THE CONTROL SYSTEM

General

16. As stated at para. 4, the heater system and its controls will vary with the aircraft requirement. In general the controls may be classified into two main types: (1) that for continuous anti-icing, and (2) that for cyclic de-icing.

Anti-icing

17. Where required, continuously heated areas can be set to operate over a given range of heater mat temperature by having a temperature sensing device embedded in the mat (*fig.* 6). The sensing element has a silver button close to but insulated from the mat heater element and serves to convey heat from the mat to a thermister plug. The resistance of a thermister bead in this plug varies with temperature, a rise in temperature causing a fall in resistance. This property is used to operate the supply contactors for an area through a thermostatic controller set to cut in or cut out at the extremities of a pre-set temperature range. In a limited application the control may be manual.

Cyclic de-icing

18. Cyclic de-icing areas are normally arranged in groups, each group, or a combination of groups, being connected to a cyclic switch. Typical groups are (1) mainplanes, (2) tailplane and fin, (3) engine air intakes, (4) propellers. Connection of heater circuits to the cyclic switch would be arranged to maintain even loading of the power supply in so far as practicable. The detailed design of the cyclic switch will depend upon this loading and the type of supply, i.e., d.c. or three-phase a.c.

19. The operating of the cyclic switches will be controlled by timed impulses either from an intervalometer (*fig.* 7), or by a device built into the switch. These timed impulses will require occasional adjustment because "rate of icing" varies with atmospheric conditions. At high ambient temperature (say 0 deg. C.) the atmospheric water content is likely to be high, and the rate of icing will be high, but little heating time will be required to shed the ice. The heating "time on" and "time off" periods will be relatively short. At very low temperatures the atmospheric water content will be less and the rate of icing will be less, but longer

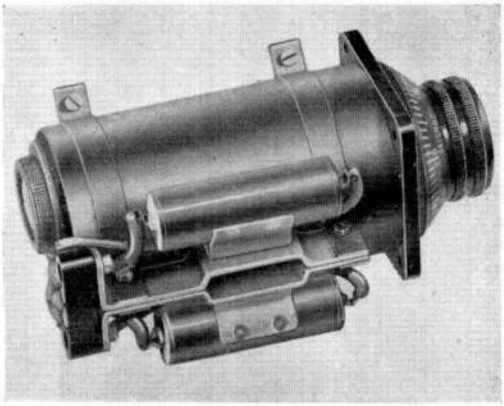

Fig. 7. Typical intervalometer

heating periods will be required for shedding. The "time on" and "time off" periods will now be longer, but the ratio "time on" to "time off" remains unchanged.

20. Setting the intervalometer, or the cyclic switch, timing may be manual, by the aircrew, estimated from indications of an ambient air temperature thermometer and personal observations of icing severity. Automatic control of timing is under development, in which it is probable that a "rate of icing" indicator or a thermometer, or combination of these, will monitor the intervalometer and relays controlling power ON/OFF switching.

SERVICING

General

21. The surface heaters should be inspected for indications of mechanical damage and accidental over-heating. Where necessary, the repair schemes detailed in A.P.1464D, Vol. 1, Part 2, Sect. 4 should be applied

Electrical tests

22. The heaters may be tested for insulation resistance, at heater terminals or a convenient junction box, as explained at para. 13 and 14. Insulation will be little impaired except by mechanical damage or extraordinary hail erosion equivalent to mechanical damage. Continuity tests of circuits can be made, but the resistance values will be peculiar to individual schemes, and reference will be necessary to the relevant Aircraft Handbook.

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