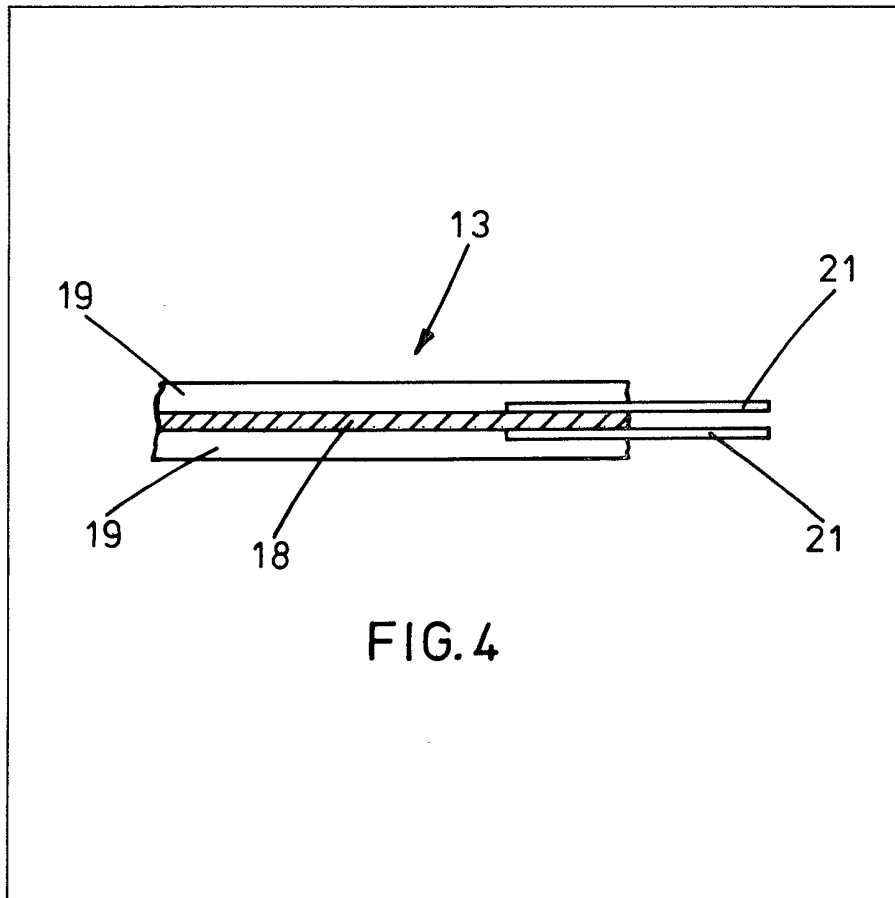


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(54) **Aircraft de-icing apparatus**

(57) Aircraft de-icing apparatus comprises a pre-formed laminate including a layer of electrically conducting non-metallic fibres 18 encased in layers of insulating non-metallic fibres 19. In one embodiment, the electrically conducting layers comprise carbon fibres and the insulating layers comprise glass fibres. Electrical connectors 21 are provided at the ends of the laminate and the apparatus can be adapted for de-icing fixed and rotating wings, control surfaces and engine intake ducts.



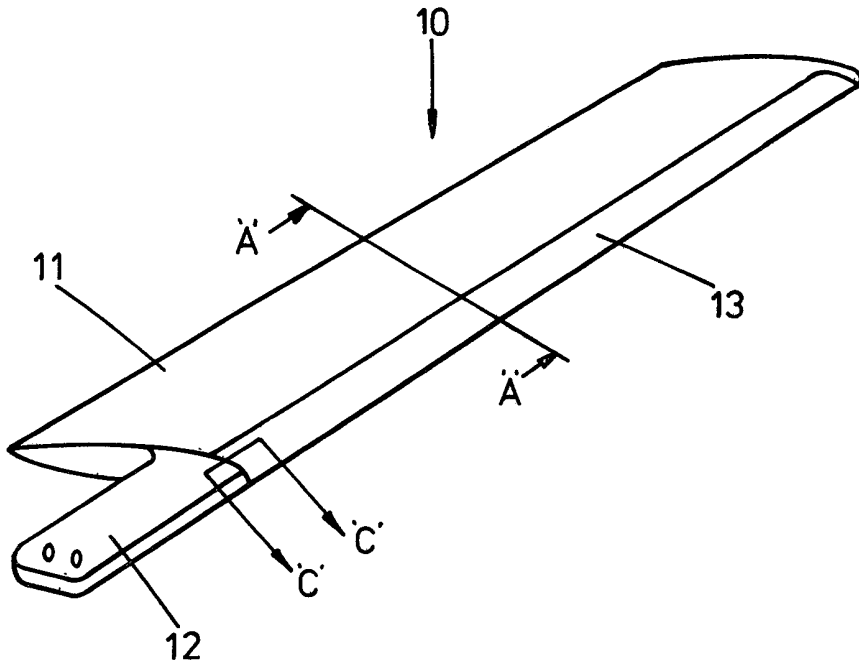


FIG. 1

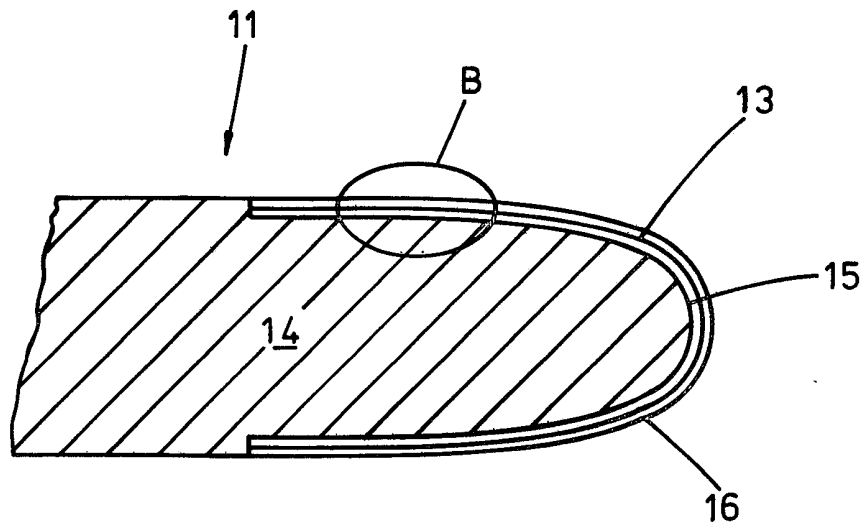


FIG. 2

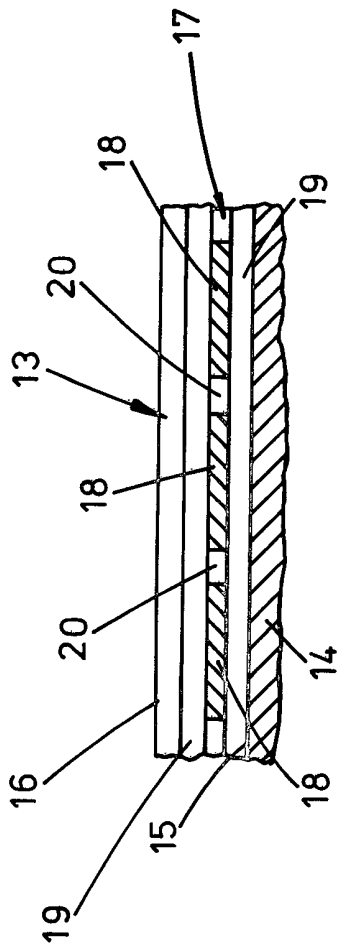


FIG. 3

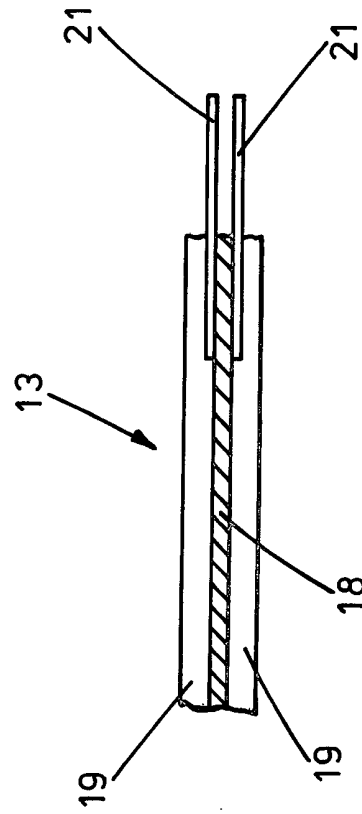


FIG. 4

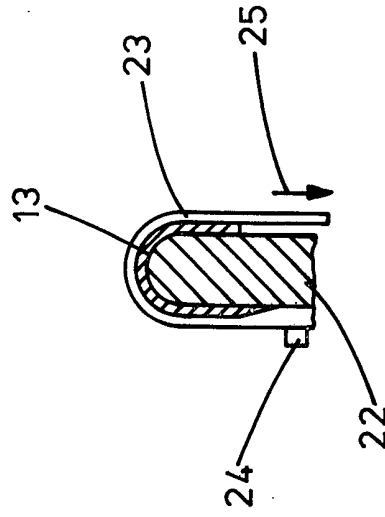


FIG. 5

## SPECIFICATION

**Aircraft de-icing apparatus**

5 This invention relates to aircraft de-icing apparatus and particularly to apparatus for de-icing fixed or rotating wings, control surfaces and engine intake ducts.

Conventionally, de-icing apparatus for rotating wings such as helicopter rotor blades consists of a de-icing mat secured around the leading edge of the blade aerofoil section, the mat comprising a plurality of longitudinally extending electrically conducting strips of metal, metal spray or woven wire embedded in a resilient casing for example a rubber or elastomer casing. The mat is attached to the blade leading edge by a suitable adhesive and is usually covered by a metal erosion shield.

The advent of composite helicopter rotor blades, i.e. rotor blades constructed wholly from fibre-reinforced plastics materials, is now widespread, such blades having improved operating lives and better damage tolerance than prior metal blades. Consequently, there is a need to provide de-icing apparatus for such blades with compatible properties.

It has been proposed to provide de-icing of engine intakes by ducting hot air from the compressor stage of the engine. This is wasteful of engine power and requires appropriate air directing channels, pipes and control valves which are complex and costly.

Accordingly, this invention provides aircraft de-icing apparatus comprising a pre-formed laminate including a layer of electrically conducting non-metallic fibres encased in layers of insulating non-metallic fibres and means for connecting the electrically conducting fibres to an external electrical supply.

Preferably, the conducting layer of non-metallic fibres comprise unidirectional fibres pre-impregnated with a thermo-setting resin.

The electrically conducting layer may comprise a plurality of individual spaced-apart strips of said conducting non-metallic fibres, separated by strips of insulating non-metallic fibres. The electrically conducting fibres may comprise carbon fibres and the insulating fibres may comprise glass fibres.

The connecting means may comprise metal strips each having one end located in contact with electrically conducting fibres of the laminate and the other end protruding from the end of the laminate for connection to the electrical supply.

In one form of the invention the pre-formed laminate may be substantially U-shaped in cross section. Conveniently the U-shaped cross section may comprise an aerofoil cross section adapted when in use to form the leading edge of an aerofoil on which it is fitted.

One embodiment of the invention adapted particularly for de-icing helicopter rotor blades will now be described by way of example only and with reference to the accompanying drawings in which:-

*Figure 1* is a perspective illustration of a helicopter rotor blade including de-icing apparatus according to the invention,

*Figure 2* is a fragmentary cross section view taken along lines A-A of *Figure 1*,

*Figure 3* is a fragmentary sectioned view on an enlarged scale of part of the de-icing apparatus of *Figures 1 and 2* taken from within area B of *Figure 2*,

*Figure 4* is a fragmentary sectioned view taken along lines C-C of *Figure 1*, and

*Figure 5* is a sectioned end elevation illustrating one method of manufacturing de-icing apparatus according to the invention.

Referring now to *Figure 1*, a helicopter rotor blade 10 includes lift producing portion 11 having an aerofoil cross-sectional shape and extending throughout a span dimension. An integral root end fitting 12 protrudes from a root end of the blade 10 and is adapted for connection to a helicopter rotor hub (not shown). A de-icing apparatus 13 according to this invention is attached around the leading edge of the lift producing portion 11 and extends throughout the major portion of the blade span.

As illustrated more clearly in *Figure 2*, the portion 11 of the rotor blade includes a fibre-reinforced composite spar 14 having a recessed leading edge portion 15. The de-icing apparatus 13 is bonded to the recessed portion 15 of the spar 14 and is covered by a metal erosion shield 16, the depth of the recessed portion 15 being such as to accommodate the de-icing apparatus 13 and erosion shield 16 and produce a smooth and continuous external aerofoil shape.

The de-icing apparatus (*Figures 2 and 3*) comprises a pre-formed U-shaped laminate including a central layer 17 consisting of a plurality of spaced-apart strips 18 of pre-impregnated unidirectional carbon fibres arranged with the fibres extending longitudinally of portion 11 of rotor blade 10 (*Figure 1*). The layer 17 is sandwiched between layers 19 of pre-impregnated woven or unidirectional glass fibres, and the strips 18 of carbon fibres are separated by insulating strips 20, conveniently of a material similar to the layers 19 and having a width of about 2.0mm.

Electrical connectors are provided at the ends of the strips 18 of carbon fibres and, as shown in *Figure 4*, comprise nickel plated copper strips 21. Inner ends of pairs of strips 21 sandwich the ends of strips 18 of carbon fibres and are themselves sandwiched by the layers 19 of woven glass fibres. As shown in *Figure 4*, the copper strips 21 at the end of one of the strips 18 protrude from the end of the laminate that is at the root end of the rotor blade 10 (*Figure 1*) to provide one of the connections to an electrical supply.

Preferably, the respective pairs of copper strips 21 at the root ends of the strips 18 are suitably interconnected to provide a pair of connections to the electrical supply and, at the blade tip end of the apparatus, i.e. the end adjacent a tip of the blade 10 when the apparatus is fitted, the copper strips 21 of all of the strips 18 of carbon fibres are interconnected and embedded in the insulating layers 19. Thus, in operation, electrical current is fed from one connection at the root end along one or more of the strips 18 and returns through the remainder of the strips 18 to the respective connection at the root end.

A method of manufacturing de-icing apparatus according to the invention for use in the above described embodiment will now be described with reference to Figure 5. The laminate comprising the apparatus 13 is first laid up on a flat surface and may typically be about 1.25 mm in overall thickness. The laminate is then partially cured in the flat configuration under vacuum-applied pressure at 70°C for 1½ hours.

The partially cured laminate is then carefully wrapped around a male tool 22 (Figure 5) pre-warmed to a temperature of 50°C and having an external profile corresponding to the profile of the recessed portion 15 of the spar 14 of the rotor blade. A neoprene rubber strap 23, clamped at one end of the tool 22 as indicated at 24 in Figure 5, is then wrapped over the partially cured apparatus 13 and is loaded under tension at about 0.35 kg/cm span as indicated by arrow 25. Final curing is then undertaken under vacuum-applied pressure for about 2 hours and at 120°C, and the preformed laminate comprising the de-icing apparatus 13 is removed from the tool. Alternatively, the final curing can be accomplished in an autoclave at a pressure of about 1.75 kg/sq cm.

The electrical resistance and therefore the heat output of the de-icing apparatus of this invention for a given current value is determined by the thickness of the carbon fibre strips 18. The required heat intensity for blade de-icing varies along the blade span, and the present invention facilitates the achievement of ideal localised intensities simply by varying the thickness of the carbon fibre layer in different areas of the apparatus and, by suitable selection of different numbers of plies of the carbon fibre material during lay up.

Controlled symmetrical ice shedding of identical area on each of a number of rotor blades is essential to maintain dynamic integrity, and this may be achieved with the apparatus of this invention by subdividing the apparatus 13 spanwise of the blade 10 and energising various selected segments simultaneously on different blades using a sequencing device that will be well known to those skilled in the art.

Thus, the described embodiment provides de-icing apparatus for use with composite helicopter rotor blades and which is constructed of materials compatible with those of the rotor blade itself. The apparatus can be arranged to provide the required temperature for efficient de-icing in selected areas and is damage tolerant to the extent that as long as electrical continuity is maintained through at least two of the carbon fibre strips connected across the external circuit, at least a degree of de-icing is obtainable. Apart from its main function of de-icing, the apparatus, being of similar materials to those used in construction of the composite blade, can be utilised in providing the desired dynamic characteristics of a rotor blade during its design and manufacture. In the event of a complete failure of the apparatus, the laminate can be stripped off the blade and replaced with a new unit without affecting the dynamic characteristics of the rotor blade. The generally U-shaped cross section and the method of

manufacture of the described embodiment is also suitable for use as de-icing apparatus for installation in the leading edges of fixed or movable wings, stabilisers, fins or control surfaces and is also particularly suitable for use on the leading edge of an engine air intake to provide de-icing thereof. In such application, the apparatus may either be adhesively bonded to a generally solid recessed surface as hereinbefore described or may be retained by bolts or screws, conveniently with the attaching bolts or screws located between the spaced-apart strips of carbon fibres.

Alternatively, because of the inherent stiffness of the pre-cured laminate, the apparatus of this invention can be self-supporting and need not necessarily rely on the provision of a firm, suitably shaped, attachment surface as is necessary with conventional de-icing mats. Consequently, in installations such as engine air intakes, the apparatus of this invention may form both a structural member and a de-icing facility. In the case of the U-shaped laminate hereinbefore described this may be achieved by attaching overlapping portions of the free ends of the U-shaped laminate to the end of an existing structure such as an engine cowling.

In its application to engine intake de-icing, the apparatus of this invention eliminates the complexity of the prior art hot air bleed systems, does not deleteriously affect the power output of the engine and provides an independent de-icing system that is replaceable in the event of damage.

It will be understood that the apparatus of this invention is not limited to the U-shaped cross section hereinbefore described, and can be provided in any desired shape depending on the intended application. The use of pre-impregnated fibre reinforced materials which can easily be formed into complex shapes and then cured to retain that shape is therefore another important feature of this invention.

Whilst several embodiments have been described and illustrated it will be understood that various modifications may be made without departing from the scope of the invention as defined in the appended claims. Other suitable fibre reinforced materials may be used, for example material comprising carbon fibres coated with electroplated nickel and available under the Trade Name CYMET may be used for the electrically conducting layers, and materials available under the Trade Name KEVLAR may be used for the insulating layers.

#### CLAIMS

1. Aircraft de-icing apparatus comprising a pre-formed laminate including a layer of electrically conducting non-metallic fibres encased in layers of insulating non-metallic fibres, and means for connecting the electrically conducting fibres to an external electrical supply.

2. Apparatus as claimed in Claim 1, wherein the conducting layer of non-metallic fibres comprise unidirectional fibres pre-impregnated with a thermo-setting resin.

3. Apparatus as claimed in Claim 1 or Claim 2,

wherein the electrically conducting layer comprises a plurality of individual spaced-apart strips of said conducting non-metallic fibres, separated by strips of insulating non-metallic fibres.

5 4. Apparatus as claimed in any preceding claim, wherein the electrically conducting fibres comprise carbon fibres.

5. Apparatus as claimed in any preceding Claim, wherein the insulating fibres comprise glass fibres.

10 6. Apparatus as claimed in any preceding Claims, wherein said connecting means comprise metal strips each having one end located in contact with electrically conducting fibres of the laminate and the other end protruding from the laminate for  
15 connection to the electrical supply.

7. Apparatus as claimed in any preceding Claim, wherein the laminate is substantially U-shaped in cross section.

8. Apparatus as claimed in Claim 7, wherein said  
20 U-shaped section comprises an aerofoil cross section adapted when in use to form the leading edge of an aerofoil on which it is fitted.

9. Every novel feature and every novel combination of features disclosed herein.