Aug. 14, 1951 P. E. COONLY 2,564,325

HEATED PROPELLER COVERING

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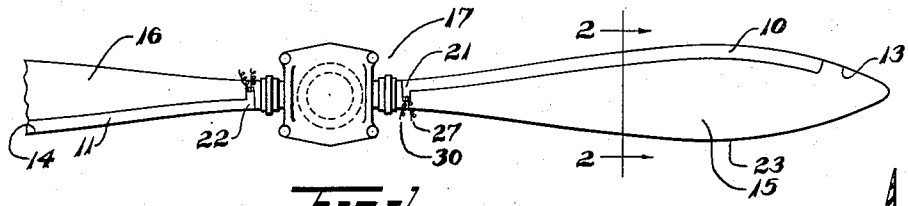

Fig-1

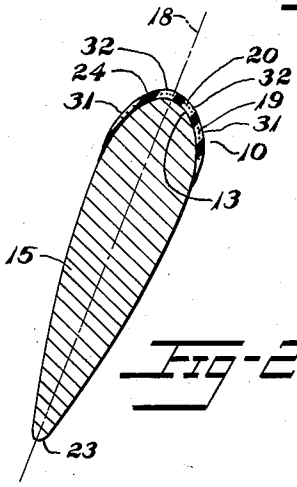

Fig-2

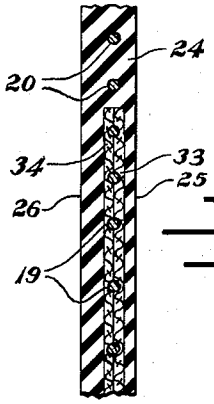

Fig-5

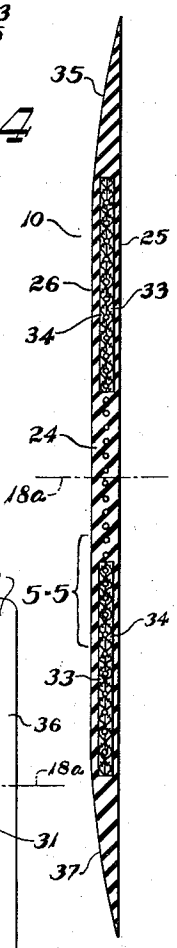

Fig-4

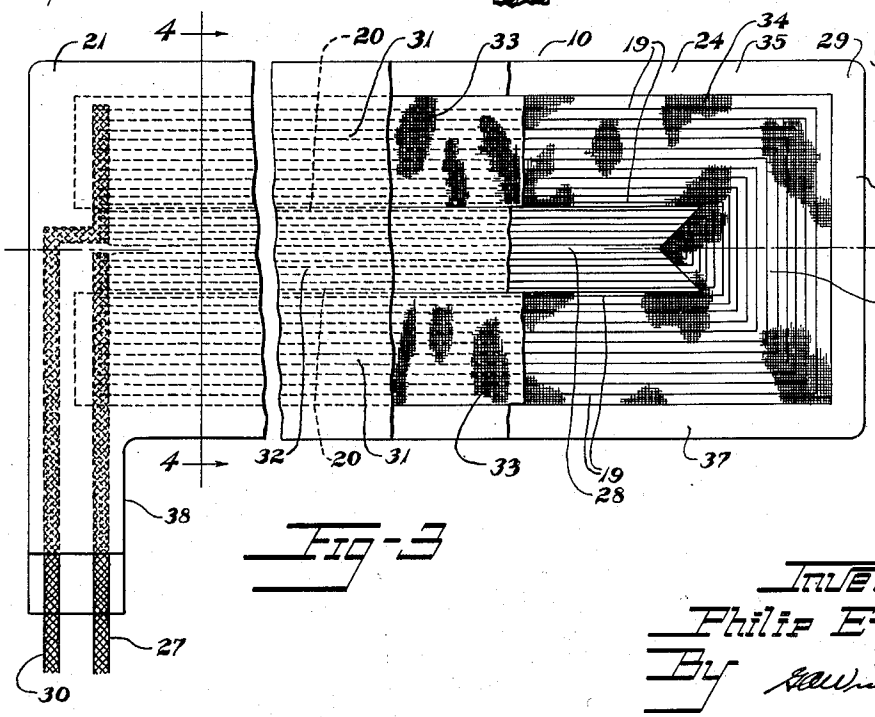

Fig-3

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HEATED PROPELLER COVERING

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5 Claims. (Cl. 244—134)

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The invention relates to heated coverings or shoes for airfoils such as propeller blades and especially to electrically heated propeller blade coverings.

Objects of the invention are to provide improved electrically heated coverings or shoes for preventing effectively the accumulation of ice on the leading edges of the propeller blades or other airfoils; to provide for temperatures at zones of the leading edges effective for ice-removal purposes despite the super-cooling action of the flow of air about the propeller blades; to provide for minimum weight of heating structures consistent with heating requirements; to provide for flexibility of the shoes; to provide for avoiding electrical connections at the tip ends of the shoes; to provide for confining electrode connections to the shank ends of the shoes; to provide for simplicity of construction, lightweight and convenience of manufacture and installation; and to provide for effectiveness of operation.

These and other objects and advantages of the invention will be apparent from the following description.

In the drawings which form a part of this specification and in which like numerals are employed to designate like parts throughout the same,

Fig. 1 is a view of electrically heated coverings mounted at the leading edges of the blades of a propeller, and constructed in accordance with and embodying the invention, parts being broken away.

Fig. 2 is a sectional view in an enlarged scale taken along line 2—2 of Fig. 1.

Fig. 3 is a plan view from above of the covering before attachment to the propeller blade, parts being broken away.

Fig. 4 is a sectional view taken along line 4—4 of Fig. 3, and

Fig. 5 is a sectional view in an enlarged scale taken at the region 5—5 of Fig. 4, parts being broken away.

In the illustrative construction shown in the drawings, the invention provides electrically heated coverings or shoes 10, 11 of elastic material for the leading edges 13, 14 of blades 15, 16 of a propeller 17 along and across the center-line 18 of the leading edges, which coverings 10, 11 are each constructed and arranged with a plurality of heating elements or resistance wires 19, 20 of electrically conductive strip material disposed therein in a manner accomplishing electrical heating action and the desired temperature distribution at the leading edges effective to prevent the accumulation of ice thereon despite the super-cooling action of the flow of air around the blades 15, 16. The coverings 10, 11 are also constructed and arranged to facilitate the provision of electrical connections to the plurality of heating elements at the shank ends 21, 22 only of the coverings, and also to facilitate the provision of smoothness of outer surface of the covering and of thinness, light-weight and durability of construction, while maintaining the desired aerodynamic characteristics of the blades 15, 16.

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The electrically heated coverings or shoes 10, 11 are substantially alike, hence only the construction of the shoe 10 will be described in detail. The shoe 10 may be molded in flattened condition as shown in Fig. 3, and independently attached to the blade 15, the shoe extending rearwardly partway toward the trailing edge 23 of the blade 15 and extending along the major portion of the leading edge 13. The shoe may be disposed substantially symmetrically about the center-line 18 of the leading edge. The covering or shoe 10 includes a body 24 of rubber-like material, preferably resilient, which may be natural rubber or synthetic rubber such, for example, as neoprene, and the covering is desirably of elongated sheet-like form smoothly conformable to the profile and the cross-sectional contour of the blade 15.

In accordance with the invention, the construction and arrangement of the shoe provides for reducing the net weight of the heating element by minimizing the amount of electrode wire required; provides for extensive flexibility of the entire shoe by the elimination of electrode wires extending the entire length of the shoe; and provides for ease of installation on the propeller blade by eliminating an electrode extending across the shoe at the tip end of the latter. To these ends, there is provided in the shoe 10 a plurality or multiplicity of heating elements 19, 19 and 20, 20 of electrically conductive strip material, preferably resistance wires of monofil construction, although such wires may be of multiple strand construction. The heating wires are imbedded in the rubber body 24 between the outer 25 and inner 26 surfaces of the covering, the material of the outer surface having aging and abrasion resistance characteristics and the material of the inner surface having heat and electrical insulating characteristics.

The heating wires 19, 19 and 20, 20 may be

each of generally U-shape with a leg thereof connected to an electrode i. e. conductor 27 at the shank end 21 of the covering and extending along the covering to one side of an intermediate region 28 of the covering, thence across the region 28 at the tip end 29 of the covering, and returning along the other side of the intermediate region 28 to a second electrode 30 at the shank end 21 and connected to the latter electrode 30. The electrodes 27, 30 may be of electrically conductive flat strip material imbedded in the rubber body 24 at the shank end 21 and may be of flexible, braided wire construction. The electrodes 27, 30 are connected to a source of electrical heating current and power in any suitable manner.

The heating wires 19, 19 and 20, 20 may extend in side-by-side spaced-apart relation to one another throughout their entire extent including the legs at each side of the intermediate region 28 at the center-line 18a of the covering, so as to be substantially non-devious in each leg, as shown especially in Fig. 3, providing outer heating zones 31, 31 of generally U-shape defining an inner heating zone 32 at the intermediate region 26 of the covering. The spacing of the heating wires 20, 20 in the inner heating zone 32 may be less than that of the heating wires 19, 19 in the outer heating zones 31, 31 for effecting relatively higher temperatures at the inner heating zone than in the outer heating zones. This arrangement is advantageous for economy of heating current while effecting the prompt removal of ice; since the inner heating zone 32 may be disposed substantially symmetrically about the center-line 18 of the leading edge of the blade at which immediate leading edge region relatively heavy ice-caps tend to form, the higher temperatures at the zone 32 tending to "burn" the ice-caps loose and reduce the adhesive bond between the ice and covering.

Although the desired heating action at the inner and outer heating zones is provided by the described construction and arrangement of the heating wires at such zones, it is to be understood that any desired temperature distribution may be effected by other arrangements, as by using wires of different electrical conductivity characteristics, or by varying the spacing of the wires, or by both. Also, if desired, the temperatures may be uniform or varied both laterally and longitudinally of the covering, and good results are obtained with the described arrangement shown in the drawings.

The inner heating zone 32 having the relatively higher temperatures extends along the immediate leading edge region of the blade throughout the major portion of the length of the covering providing effective temperatures for removal of the relatively thick ice at such zone, and the lower temperatures at the outer heating zones 31, 31 are effective for preventing the accumulation of the thinner ice rearwardly of the immediate leading edge. The lower temperature at the outer heating zone 31 at the tip end 29 of the covering is effective for removing the ice even at the immediate leading edge region because of the coacting effect of the relatively greater centrifugal force at the tip of the blade tending to throw off the ice-deposit loosened by the heating action at the tip end 29 of the covering.

Since the covering 10 in the preferred construction is manufactured in the flat condition shown especially in Figs. 3 and 4 and subsequently mounted conformingly to the profile and cross-sectional contour of the leading edge of the blade 15, the rubber body 24, especially at the outer heating zones 31, 31 including the tip end of the covering, is in a stretched condition at such heating zones. The mounting operation also tends to distort and buckle the heating wires 19, 19 and 20, 20. To the ends of preventing distortion of the wires and sustaining the stretching stresses at the outer heating zones 31, 31, the invention provides a generally U-shaped reinforcement 33 of flexible, heat-resisting woven fabric material in the rubber body 24 at the heating wires 19, 19 and overlying such wires continuously throughout their extent.

The fabric reinforcement 33 is desirably coated or impregnated with neoprene on both sides and effectively prevents the formation of localized bulges at the outer surface 25 of the covering by maintaining the heating wires 19, 19 in position and resisting buckling of the latter under conformance of the covering to the blade 15. A similar fabric reinforcement 34 is disposed in the rubber body 24 underneath the heating wires 19, 19 effectively preventing the heating wires from cutting through the underlying rubber material between the wires and the inner surface 26 of the covering. The reinforcements 33, 34 at the tip end 29 of the covering are especially effective in preventing the heating wires from distorting and from cutting through the underlying rubber material despite the snubbing action on the covering at the tip end region of the blade 15. In this manner smoothness of the outer surface 25 is maintained facilitating aerodynamic flow of air about the covering or shoe and blade.

For further promoting smoothness of flow of air across the blade, the margins 35, 36 and 37 of the covering are tapered in cross-section to a relatively thin edge, as shown especially in Fig. 4. The covering may have a strap-like extension 38 of suitable rubber-like material for facilitating the secure attachment of the covering to the blade. The covering or shoe is mounted securely and conformingly upon the blade at the leading edge desirably by adhesive attachment thereto throughout the entire extent of the covering. The fabric and rubber parts of the covering are preferably united integrally as by molding and vulcanizing under pressure.

In the operation of the covering for the mounted condition, electrical heating current, for example, is conducted through the electrode 27 to the series of heating wires 19, 19 and 20, 20 connected thereto. These heating wires conduct the current along their generally U-shaped extent to the other electrode 30, which latter conducts the heating current back to the source of supply. The passage of the electrical current through the heating wires provides a resistance heating action effecting the desired temperatures at the outer surface 25 of the covering and provides the desired temperature distribution throughout the extent of the covering at such surface for effective ice-removal. The relatively high temperatures at the inner heating zone along the intermediate region 28 act to "burn" the ice loose and the lower temperatures at the outer heating zone act to reduce the adhesive bond of the ice deposited on the covering. Both actions facilitate the thorough removal of the ice under rotation of the propeller blade and coact with the resultant action of centrifugal

force upon the loosened ice, especially at the tip end 29 of the covering in effecting ice-removal. In this manner the accumulation of ice upon the leading edge of the blade is prevented with economy of heating current requirements and effectively maintaining the desired aerodynamic characteristics of the blade and also maintaining the desired aerodynamic balance of the propeller advantageously promoting the safety and the effective operation of the aircraft.

The hereinabove described construction has among its advantages the fact that the weight of the heating structure is minimized as a result of the small amount of electrode wire required, and extensive flexibility of the entire shoe is provided by avoiding electrode wires extending the entire length of the shoe. The arrangement also facilitates ease of installation on the propeller blade by avoiding an electrode extending transversely of the shoe at the tip end thereof. All such features facilitate the convenient installation of the shoes on the propeller blades and the smooth conformance of the shoes with the compound curvature of the leading edges of the blades.

Variations may be made without departing from the scope of the invention as it is defined in the following claims.

I claim:

1. An electrically heated propeller blade shoe of greater length than width having a shank end and an outer end remote from said shank end, said shoe comprising a body of flexible material for mounting upon the propeller blade with said shank end of the shoe at the shank of the blade and said outer end of the shoe remote from the shank of the blade, said body having a leading edge center-line portion extending longitudinally of the shoe from said shank end to said outer end for disposition along the leading edge center-line of the blade and said body having side portions on opposite sides of said center-line portion of the shoe for disposition to opposite sides of said center-line of the blade, electrical conductors of flexible material extending in and across said shank end of the shoe, flexible strip heating elements in said shoe individually connected to said conductors, a group of said heating elements extending longitudinally of the shoe in spaced-apart substantially parallel relation in one of said side portions and in substantially parallel relation to said center-line portion from said shank end toward said outer end and occupying substantially the entire side portion, a second group of said heating elements extending longitudinally of the shoe in spaced-apart substantially parallel relation in the other side portion of the shoe and in substantially parallel relation to said center-line portion from said shank end toward said outer end and occupying substantially the entire said other side portion, and a third group of flexible strip heating elements in said shoe extending in spaced-apart relation directly across said center-line portion of the shoe at the outer ends of said heating elements of the first group and said second group, each of which heating elements of said third group connects one of the heating elements of the first group with a corresponding heating element of the second group.

2. An electrically heated propeller blade shoe of greater length than width having a shank end and an outer end remote from said shank end, said shoe comprising a body of resilient rubber-like material for mounting upon the propeller blade with said shank end of the shoe at the shank of the blade and said outer end of the shoe remote from the shank of the blade, said body having a leading edge center-line portion extending longitudinally of the shoe in a substantially straight course from said shank end to said outer end for disposition along the leading edge center-line of the blade and said body having side portions on opposite sides of said center-line portion of the shoe for disposition to opposite sides of said center-line of the blade, electrical conductors of flexible material extending in and across said shank end of the shoe, heating wire elements in said shoe individually connected to said conductors, a group of said wire elements extending longitudinally of the shoe in spaced-apart substantially parallel relation in a substantially straight course in one of said side portions and in substantially parallel relation to said center-line portion from said shank end to substantially said outer end and occupying substantially the entire side portion, a second group of said wire elements extending longitudinally of the shoe in spaced-apart substantially parallel relation in a substantially straight course in the other side portion of the shoe and in substantially parallel relation to said center-line portion from said shank end to substantially said outer end and occupying substantially the entire said other side portion, and a third group of heating wire elements in said shoe extending in spaced-apart relation directly across said center-line portion of the shoe at the outer ends of said wire elements of the first group and said second group, each of which wire elements of said third group connects one of the wire elements of the first group with the corresponding wire element of the second group.

3. An electrically heated propeller blade shoe of greater length than width having a shank end and an outer end remote from said shank end, said shoe comprising a body of resilient rubber-like material for mounting upon the propeller blade with said shank end of the shoe at the shank of the blade and said outer end of the shoe remote from the shank of the blade, said body having a leading edge center-line portion extending longitudinally of the shoe from said shank end to said outer end for disposition along the leading edge center-line of the blade and said body having side portions on opposite sides of said center-line portion of the shoe for disposition to opposite sides of said center-line of the blade, electrical conductors of flexible material extending in and across said shank end of the shoe, heating wire elements in said shoe individually connected to said conductors, a group of said wire elements extending longitudinally of the said shoe in spaced-apart substantially parallel relation in a substantially straight course in one of said side portions and in substantially parallel relation to said center-line portion from said shank end to substantially said outer end and occupying substantially the entire side portion, a second group of said wire elements extending longitudinally of the shoe in spaced-apart substantially parallel relation in a substantially straight course in the other side portion of the shoe and in substantially parallel relation to said center-line portion from said shank end to substantially said outer end and occupying substantially the entire said other side portion, and a third group of heating wire elements in said shoe extending in spaced-apart relation directly across said center-line portion of the shoe at the outer ends of said wire elements of the first group and said second group, each of which wire elements of said third group connects

one of the wire elements of the first group with a corresponding wire element of the second group, said wire elements of the first group and said second group being spaced in the group a greater distance from one another at positions away from said center-line portion than at positions nearer said center-line portion.

4. An electrically heated propeller blade shoe of greater length than width having a shank end and an outer end remote from said shank end, said shoe comprising a body of resilient rubber-like material for mounting upon the propeller blade with said shank end of the shoe at the shank of the blade and said outer end of the shoe remote from the shank of the blade and with the longitudinal center-line of the shoe extending along the leading edge center-line of the blade, said body having portions on opposite sides of said longitudinal center-line of the shoe for disposition to opposite sides of said center-line of the blade, electrical conductors of flexible material extending in and across said shank end of the shoe, heating wire elements in said shoe individually connected to said conductors, a group of said wire elements extending longitudinally of the shoe in spaced-apart substantially parallel relation in a substantially straight course in one of said portions at one side of said longitudinal center-line and in substantially parallel relation to said longitudinal center-line from said shank end to substantially said outer end and occupying substantially the entire portion at said one side of said longitudinal center-line, a second group of said wire elements extending longitudinally of the shoe in spaced-apart substantially parallel relation in a substantially straight course in the other of said portions at the other side of said longitudinal center-line and in substantially parallel relation to said longitudinal center-line from said shank end to substantially said outer end and occupying substantially the entire other portion of the shoe, and a third group of heating wire elements in said shoe extending in spaced-apart relation directly across said longitudinal center-line of the shoe at the outer ends

of said wire elements of the first group and said second group, each of which wire elements of said third group connects one of the wire elements of the first group with a corresponding wire element of the second group, said wire elements of said first group and said second group being spaced in the group a greater distance from one another at positions away from said longitudinal center-line than at positions nearer said longitudinal center-line.

5. An electrically heated propeller blade shoe as defined in claim 4 in which reinforcing sheet material of woven textile fabric is disposed longitudinally in said body at opposite sides of and in spaced-apart relation to said longitudinal center-line of the shoe and in overlying and underlying relation to part only of the wire elements of said first and said second group, and is disposed laterally in said body in overlying and underlying relation to the corresponding connecting wire elements of said third group at said outer ends of the wire elements of said first and said second group.

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