May 8, 1956 H. S. RAINBOW ET AL 2,744,680

ELECTRICAL HEATING AND MOUNTING OF AXIAL FLOW COMPRESSOR BLADES

Filed July 16, 1952 2 Sheets-Sheet 1

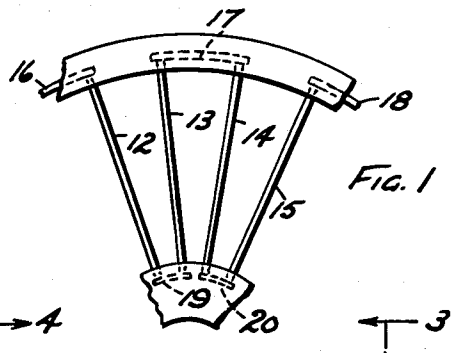


FIG. 1

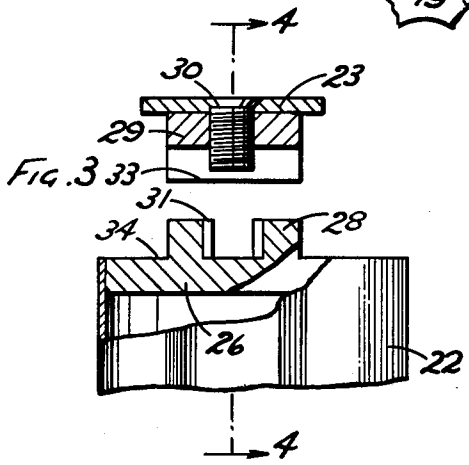


FIG. 3

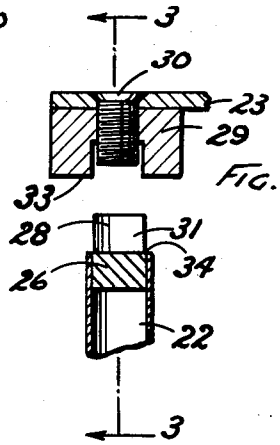


FIG. 4

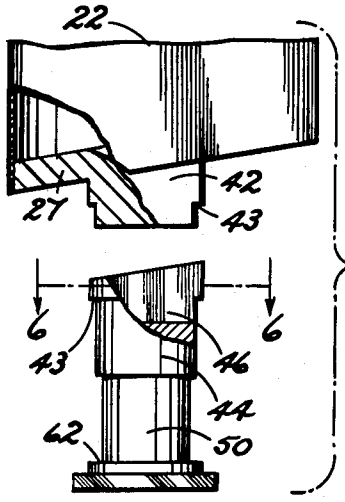


FIG. 5

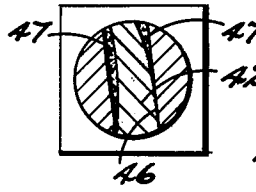


FIG. 6

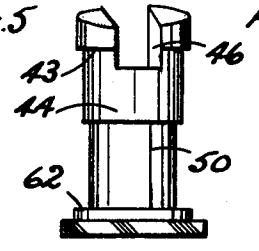


FIG. 7

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May 8, 1956 H. S. RAINBOW ET AL 2,744,680

ELECTRICAL HEATING AND MOUNTING OF AXIAL FLOW COMPRESSOR BLADES

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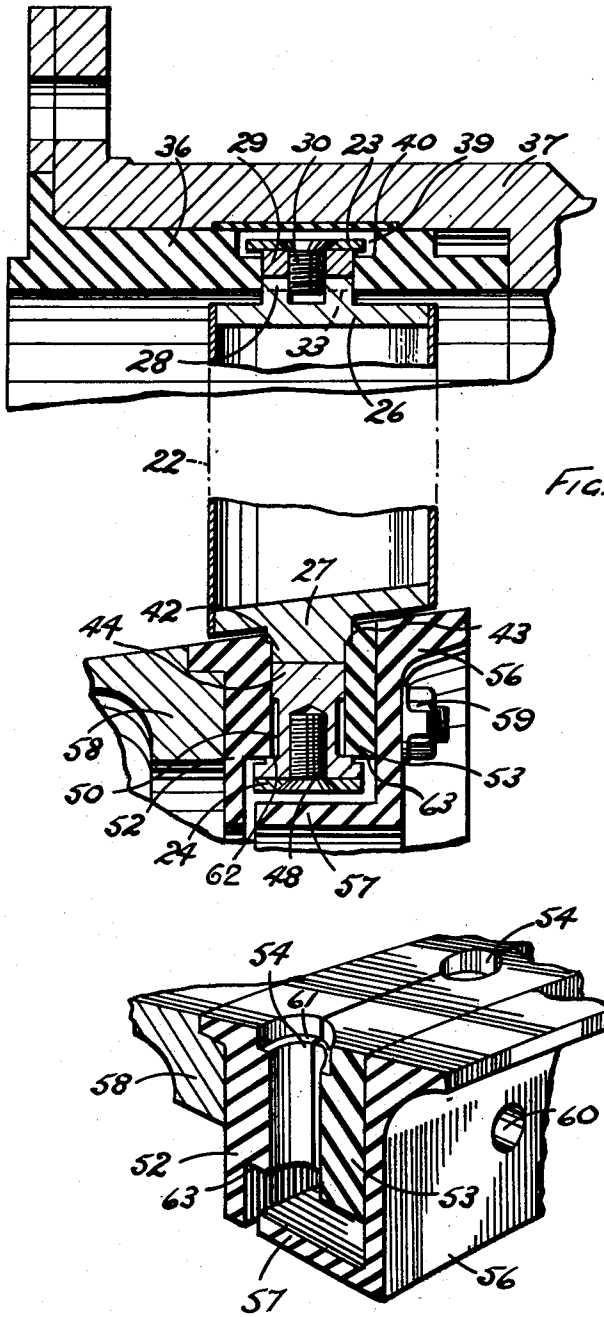


FIG. 2

FIG. 8

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ELECTRICAL HEATING AND MOUNTING OF AXIAL FLOW COMPRESSOR BLADES

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8 Claims. (Cl. 230—132)

The main object of this invention is the protection of an axial flow compressor against ice formation on the blades, and particularly the inlet guide vanes or blades and the early stator blades.

The invention is particularly concerned with a method of electrically heating such blades, and with the mounting thereof to facilitate such heating in an efficient manner.

Broadly, the invention involves electrically connecting all, or groups of, the blades of a row, such as the inlet guide blades, in series so that the blades form resistance heating elements in an electric circuit, the ends of the blades having terminals mounted in concentric rings of insulating material at least one of which is supported in a structural member of the compressor, the mounting of the terminals in the insulating rings being such as to locate the blades at their correct angle of incidence and to provide radial location for the blades at one end only. These requirements may be effected from the same ends of the blades, but it is preferred that the location as regards the angle of incidence is effected at one end whilst the radial location is effected at the other.

According to a further feature, the blades are connected in series by connecting the terminals on the appropriate blade ends with conducting strips which are arranged only to contact the said terminals, whereby to leave clearance between the conducting strips and the adjacent insulating rings.

According to a further feature of the invention, the conducting strips are of an electrical resistance material so as, in operation, to be heated to a sufficient extent to compensate for heat loss from the blade ends to the mounting. In this way it is possible to maintain the blades, throughout their lengths, at a substantially constant, uniform temperature.

It is not always possible to arrange for the individual blades to be of exactly the same electrical resistance, and, according to a still further feature of the invention, the connecting strips are selected or adjusted to be of appropriate electrical resistance for compensating for variations in resistance of individual blades. In this way an overall resistance of all the series-connected blades and their connecting strips can be arranged to be within a specified tolerance.

In the accompanying drawings:

Figure 1 is a fragmentary diagram showing four adjacent stationary blades of a compressor row which are electrically connected in series with one another;

Figure 2 is a sectional elevation through one of these stationary blades;

Figure 3 is a corresponding part-sectional elevation, though to a larger scale, of the radially-outer end of the blade of Figure 2, and of its terminal and the associated electrical connecting strip, the section being taken on the line 3—3 of Figure 4, which in turn is a section taken on the line 4—4 of Figure 3, the terminal portions being shown separated from one another in both Figures 3 and 4;

Figure 5 is a corresponding view to that of Figure 3 of the lower end of the blade and its terminal, Figure 6 being a cross-section taken on the line 6—6 of Figure 5 but with the terminal portions joined to one another, and Figure 7 being an elevation, of the radially-inner terminal portion, at right angles to that of Figure 5; and

Figure 8 is a fragmentary perspective view in section of the support for the radially-inner end of the blade and the associated parts.

In Figure 1 there are only four blades shown, marked 12, 13, 14 and 15, these being electrically connected in series by means of radially-outer connectors 16, 17 and 18 and radially-inner connectors 19 and 20. A group of adjacent blades is thus connected and supplied with current by means not shown; and, as will be well understood, the group may comprise all the blades in a blade row.

Figure 2 shows one of these blades at 22, having a radially-outer connector 23 extending in one circumferential direction and a radially-inner connector 24 extending in the other circumferential direction, towards the next adjacent blades, to which they are connected in each case.

It will be observed that the blade is a hollow one, the ends of which are closed by radially-outer and radially-inner plugs 26 and 27, respectively, which are brazed or welded in position. The radially-outer plug 26 has formed on it a terminal boss 28 which coacts with and is brazed or otherwise rigidly secured to a terminal portion 29 to provide the radially-outer terminal, the terminal portion 29 straddling the boss and having the adjacent connector 23 secured to it by means of a screw 30. The boss conforms to the shape of the plug 26 and is secured in the slot of the terminal portion 29 substantially as hereinafter described in connection with the boss 42, and the terminal portion 44—see Figure 6. The screw 30, as shown most clearly by Figures 3 and 4, has clearance from a bore 31 in the boss provided for the purpose. The radially-inner edge 33 (Figures 3 and 4) does not extend quite as far as the adjacent face 34 of the end plug 26.

The radially-outer terminal comprising the terminal portion 29 and the boss 28 is of noncircular section (e. g., rectangular, as in the construction illustrated), and it is slidingly fitted in a hole of corresponding shape provided for the purpose in an annulus 36 of insulating material.

The annulus 36 provides a circumferential groove 39 to receive the radially-outer connector strips (such as that marked 23), and arranged round it is a thin annulus 40 of insulating material to protect the connecting strips from contact with the casing 37.

Thus, the radially-outer end of the blade is located against torque, radial location for the blade being provided at the radially-inner end of the blade.

At the radially-inner end of the blade the closing plug 27 is formed with a boss 42 which is externally stepped as shown dependently upon a corresponding step 43 formed in a terminal portion 44 which is generally of circular periphery. The terminal portion 44 has a plain slot 46 to receive the boss 42 which, being shaped dependently upon the contour of the plug, can be secured in position by means of brazing or the like, indicated at 47. The radially-inner connector 24 is connected to the terminal portion 44 by means of a screw 48. The terminal portion 44 is relieved at 50 in order there to have clearance from the supporting structure, so as to reduce the area of heat transfer.

The radially-inner supporting structure is a built up one comprising two insulating rings 52, 53 (Figures 2 and 8) which jointly provide radial holes 54 (Figure 8) of circular section to receive the radially-inner terminals.

In addition, a third insulating ring 56 is provided with a radially-inner flange 57, the three insulating rings being bolted to the compressor structure 58 by means of a number of axial bolts 59 (only one appearing in Figure 2) passing through holes provided for the purpose, such as that indicated at 60 in Figure 8.

With such an arrangement the blades of a row, conducting strips and insulating rings can be readily built up as a unit before assembly into the compressor. Thus, the non-circular terminals, 28, 29, are first inserted through the insulating ring 36 and the two insulating rings 52, 53 can then be engaged with the terminals 42, 44 at the inner ends of the blades and clamped together axially. Thereupon, the conducting strips can be connected by the screws 30, 48 to the appropriate terminals.

It should be noted that, at each end of a blade, the insulating rings have clearance both from the blade itself and from the connecting strips.

Preferably the contacting parts of the two terminal portions 29, 44 and the adjacent connector strips 23, 24 are tinned before they are connected together so that the unit can subsequently be heated to solder the parts together, thereby supplementing the screw attachments and ensuring good electrical contact. Such a connection at the radially-outer ends of the blades acts to take the torque reaction about each blade and thus relieves the non-circular holes in the insulating ring 36, engaged by the radially-outer terminals, thereby reducing the crushing load on the relatively soft insulating material.

The terminal portions 29, 44 for a blade may be of a dissimilar metal from that of the blade, having a low resistance and good conducting properties with great strength. An example of a suitable material for the terminal portions is beryllium-copper alloy.

Furthermore, if the connecting strips are of a material having a low resistance and good conducting properties, heat can in some cases be transferred from the blade ends, through the terminals, to the insulating mounting rings, this resulting in an unequal temperature rise along the lengths of the blades. In other words, the blades might be so much cooler at their ends than between their ends as to be unable to prevent ice formation at their ends. That disadvantage could be met by increasing the current supply, but in that event the intermediate portions of the blades would develop higher temperatures than were necessary for the particular icing conditions. Therefore, in some cases it is preferred that the connecting strips should be of an electrical resistance material chosen so that, in operation, they would be heated to a sufficient extent to compensate for the heat loss from the blade ends to the mounting rings.

In addition, the connecting strips may, if desired, be chosen or adjusted to be of appropriate electrical resistance for compensating for variations in the resistance of individual blades, which latter, obviously, may not have exactly the same electrical resistances. In this way, an overall resistance of all the series-connected blades and their connecting strips can be arranged to be within a specified tolerance.

It will be noted that the radial location of the blades at their inner ends is effected by the shoulders 43 coacting with surfaces 61 (Figure 8) at the radially-outer ends of the holes 54 in the two-part insulating ring when these two parts are drawn together, and by shoulders 62 at the other ends of the terminal portions 44 coacting with shoulders 63 at the radially-inner ends of the holes 54. By radially locating the blades from one end only they are free to expand radially when being heated without imposing any undue stresses tending to bend or distort them.

As previously mentioned, the ends of the blades, when in position, have a slight clearance from the adjacent surfaces of the associated insulating rings to provide for expansion, and this, coupled with the method of mounting, ensures minimum thermal and electrical losses.

What we claim as our invention and desire to secure by Letters Patent of the United States is:

1. An axial flow compressor having a plurality of blades in a row, said blades being made of a metallic, electrical conducting, heat resistant material, coaxial inner and outer rings of insulating material, means supporting said blades by their ends in said rings, and electrical connectors at the remote cylindrical sides of said rings connecting the ends of said blades in series so that they can form resistance heating elements in an electric circuit.

2. A compressor, according to claim 1, in which said connectors are of an electrical resistance material so as, in operation, to become electrically heated and to conduct this heat to the blade ends whereby to compensate for any heat loss from the blade ends to the insulating rings and to preserve an even temperature throughout the lengths of the blades.

3. A compressor, according to claim 1, in which said connectors are selected to be of appropriate electrical resistances so as in conjunction with the resistances of the blades to aggregate a desired value.

4. An axial flow compressor having a row of blades, said blades being made of a metallic, electrical conducting, heat resistant material, coaxial inner and outer rings of insulating material, and a structural member, at least one of said insulating rings supported by said structural member, a number of adjacent blades in a row having terminals carried in holes in said insulating rings, electrical connectors connecting said terminals in series so that the blades can form resistance heating elements in an electric circuit, said terminals at the one end of said blades and the coacting holes in one of said insulating rings being non-circular so as to locate the blades at their correct angle of incidence at one end only, and means securing the other ends of said blades to the other insulating ring to provide radial location for the blades at that end only.

5. An axial flow compressor having a row of stationary blades, said blades being made of a metallic, electrical conducting, heat resistant material, coaxial inner and outer rings of insulating material, and a structural member, at least one of said rings supported by said structural member, said blades having at one end terminals of non-circular cross-section to be received in corresponding holes in one of said insulating rings whereby to locate said blades at their correct angle of incidence, said adjacent blades having terminals of circular cross-section at their other ends, the adjacent insulating ring having corresponding holes to receive said circular terminals whereby to provide radial location for the blades, one of said rings being split circumferentially to jointly provide said holes, and electrical connectors connecting said terminals in series so that said adjacent blades can form resistance heating elements in an electric circuit.

6. An axial flow compressor having a row of blades, said blades being made of a metallic, electrical conducting, heat resistant material, coaxial inner and outer rings of insulating material, and a structural member, at least one of said insulating rings supported by said structural member, each of said blades being hollow and closed by end plugs, said end plugs carrying terminals, and electrical connectors connecting said terminals so that the blades can form series resistance heating elements in an electric circuit, said terminals carried in holes in said insulating rings.

7. An axial flow compressor having a row of blades, said blades being made of a metallic, electrical conducting, heat resistant material, coaxial inner and outer rings of insulating material, and a structural member, at least one of said insulating rings supported by said structural member, each of said blades being hollow and closed by end plugs, said end plugs carrying terminals, and electri-

cal connectors connecting the said terminals so that the blades can form series resistance heating elements in an electric circuit, said terminals at the one end of said blades being non-circular in cross-section and carried in coacting holes in one of said insulating rings so as to locate the blades at their correct angle of incidence at one end only, and means securing the other ends of said blades to the other insulating ring to provide radial location for the blades at that end only.

8. An axial flow compressor having a row of blades, said blades being made of a metallic, electrical conducting, heat resistant material, coaxial inner and outer rings of insulating material, and a structural member, at least one of said insulating rings supported by said structural member, each of said blades being hollow and closed by end plugs, each of said end plugs formed with a terminal boss, a slotted terminal portion for each of said terminal bosses to receive said bosses respectively in the slots of said terminal portions, said bosses being secured therein,

and electrical connectors connecting said terminal portions so that the blades can form series resistance heating elements in an electric circuit, said terminal portions at the one end of said blades being non-circular in cross-section and carried in coacting holes in one of said insulating rings so as to locate the blades at their correct angle of incidence at one end only, and means securing the other ends of said blades to the other insulating ring to provide radial location for the blades at that end only.

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