May 8, 1962 H. E. HARDING 3,033,711

CARBO-BLAST METHOD AND UNIT

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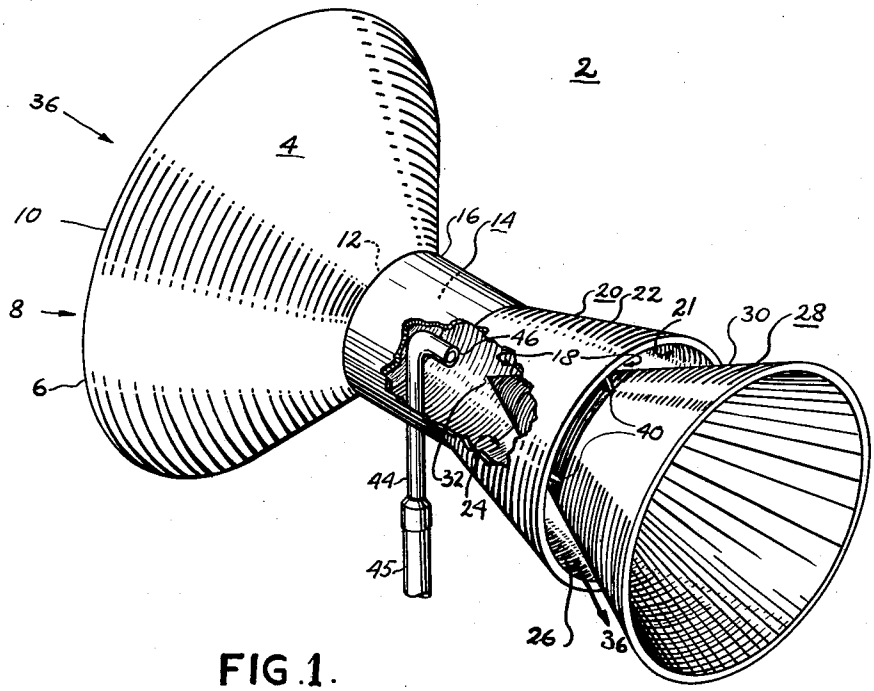

FIG. 1.

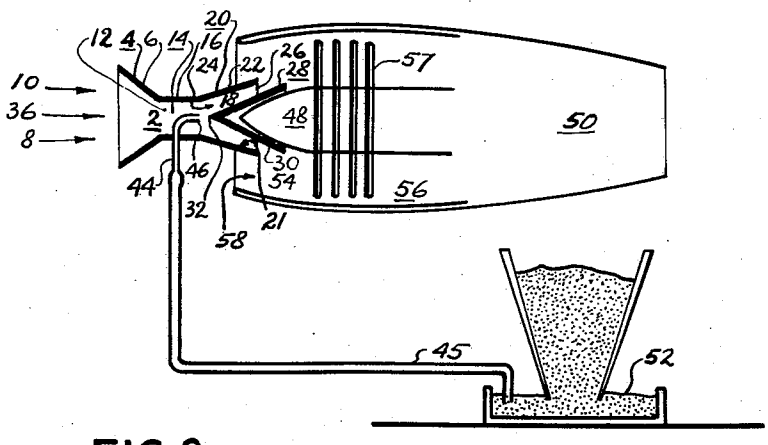

FIG. 2.

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CARBO-BLAST METHOD AND UNIT

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This invention relates to a method and device for cleaning compressors, and more particularly for cleaning the compressor blades of a jet engine.

A turbo-jet engine has a compressor in the forward portion of the engine which draws in a large flow of surrounding air, compresses the air in one or more stages, and sends this compressed air into the burner portion of the engine, where the air combines with the fuel to create the thrust of the engine. As the air passes through each stage of the compressor, the volume of the air decreases, and the temperature and pressure go up. The temperature of the air may rise to as high as 600–800° F. in the back portion of the compressor. The air carries with it small particles of foreign matter, and other foreign matter is carried by the moisture in the air. The moisture particles in the air evaporate in the hotter portions of the compressor, and much of the foreign matter, both from the air itself and the moisture in the air, forms deposits on the compressor blades. Over a period of use, the efficiency of the compressor drops because of these deposits. When water injection is used in jet engine take-offs, the problem of blade deposits is more acute, since, even though relatively mineral-free water is used, there is still a marked increase in the deposits on the compressor blades, for a given period of use. To develop full power in a jet engine, it is necessary to periodically clean the compressor blades.

The prior art method of cleaning the compressor blades is to run the jet engine and feed into the air intake portion of the engine a cleaning material, which is a frangible granular material, consisting mostly of ground-up walnut shells. The flow of air sucks the particles of walnut shells into the compressor, where the particles impinge on the blade surfaces and knock loose the deposits from the blades. The walnut shell particles pass into the burner portion of the jet engine, burn, and pass harmlessly out of the engine as exhaust. The cleaning material should be hard enough to knock the deposits loose, yet not so hard as to score the engine parts, and preferably easily combustible so as to burn before passing out the exhaust. Ground-up walnut shells provide a cheap and readily available cleaning material. For proper cleaning, it is necessary to get a uniform distribution of cleaning material in the mouth of the compressor, or at least to get sufficient cleaning material over all portions of the mouth of the compressor, so that all parts of the blades are cleaned.

Therefore an object of my invention is to provide a cleaning device to fit in front of the air intake of a compressor, such as exists in a jet engine, for distributing cleaning material uniformly over the air intake.

A further object is to provide a cleaning device with an air scoop with a converging passageway, for obtaining an increased velocity of air, through the cleaning device, so as to cause a pressure drop to draw cleaning material into the air stream passing through the cleaning device and impel the cleaning material at a high velocity into the air intake of the engine.

Another object is to provide for a radial velocity component to the cleaning material passing into the compressor inlet to clean the entire area of the turbine blades in the compressor.

Another object is to vary the radial dispersion of the cleaning material, adjustable by varying the speed of the jet engine.

These and other objects of this invention will be apparent from the following description, taken in accordance with the accompanying drawing, throughout which like reference characters indicate like parts, which drawing forms a part of this application and in which:

FIGURE 1 shows the applicator portion of my device which is fitted in front of the air intake portion of a jet engine.

FIGURE 2 shows the entire apparatus of my invention, in place on a jet engine.

FIGURE 1 shows the applicator or venturi-shaped member, designated generally as 2, of my compressor cleaning device. At the front part of the applicator 2 is a convergent air inlet scoop 4 whose side wall 6 is in the form of a truncated cone with an open base, which forms the entrance 8 of a converging passageway 10, and an open top forming the narrow exit portion 12 of the converging passageway 10. The convergent passageway portion 10 leads into a narrow central passageway portion 14 which is the throat of the venturi-shaped member 2 and is defined by a cylindrical side wall 16, which is open at either end and firmly attached to the narrow end of the conical side wall 6 of the air inlet scoop 4. The narrow central passageway 14 leads into a divergent annular passageway portion 18, whose outer boundary is defined by the inner surface 21 of the divergent outlet 20 whose side wall 22 is a truncated cone, the small front end of the outlet 20 being firmly attached to the other open end of the side wall 16 of the narrow passageway portion 14. The small end of the divergent outlet 20 is the entrance or inlet 24 of the divergent annular passageway portion 18, and the large end of the divergent outlet 20 is the exit or outlet portion 26 of the annular passageway portion 18. The inside boundary of the annular passageway portion 18 is defined by a divergent deflector 28 in the shape of a cone, whose tip 32 is pointed toward the inlet 4 and is located at the entrance 24 of the divergent outlet 20. The side wall 30 of the deflector 28 diverges at a slightly sharper angle than the side wall 22 of the divergent outlet 20, so that the walls 30 and 22 are closer to each other near the exit portion of the annular passageway 18, and the cross-sectional area of the annular passageway portion 18 remains substantially constant throughout its length.

Thus the applicator 2 forms one continuous passageway 36, the front portion being the converging passageway 10, of diminishing cross-sectional area, the middle portion being the narrow central passageway 14 of substantially uniform cross section, and the exit portion being the diverging annular passageway portion 18 of substantially the same cross-sectional area throughout its length as the narrow central passageway 14. The divergent outlet 20 is firmly connected to deflector 28 by vanes 40 which extend through the annular passageway portion 18 and are parallel to the length of the annular passageway portion 18, so as to guide the flow of air through the annular passageway portion 18. Suitable support means may be placed in the interior of the deflector 28 so that the entire applicator 2 may be centrally located with respect to, and firmly attached to, the air inlet section 54 of a jet engine so as to cover the central nose section 48 of a jet engine 50, and so that the diverging passageway 18 leads to a low pressure area of the air inlet portion 54. Thus the deflector 28 functions both to define the inside boundary of the annular passageway 18, and to protect the central nose section 48 of the jet engine 50. A feed tube 44 is mounted in the middle of the central passageway portion 14 with its outlet 46 centered in front of the tip 32 of the deflector cone 28, so that cleaning material from the feed tube 44 will be distributed evenly over the conical surface of the

deflector 28. However, in some applications, more even distribution is obtained by placing the tube outlet 46 slightly off center from the longitudinal axis passing through the tip 32, if the cleaning material 52 should concentrate along one side of the tube 44 because of a bend in the tube 44.

I shall now explain the operation of my invention by reference to FIGURE 2, which shows the full apparatus of my invention with the applicator 2 in place on the nose cone 48 of a jet engine 50. The outlet end of applicator 2 is attached to the nose cone 48 of the jet engine 50. The feed tube 44 extends from the applicator 2 to connect to a feed hose 45 which fits loosely in a source of cleaning material 52, to allow a supply of the cleaning particles to flow to the applicator 2, which cleaning material, as mentioned before, generally consists of ground-up walnut shells. When this device is in use to clean a jet engine, the applicator 2 is firmly attached to the nose cone 48 so that the applicator 2 is centrally located immediately in front of and centrally of the intake portion 54 of the jet engine 50. (However, in some applications for ease of installation it has been found convenient to replace the nose cone 48 with a substitute nose cone, which is permanently attached to the deflector 28.) The jet engine 50 is started, and the compressor portion 56 of the jet engine 50 begins to draw in air at a high velocity throughout the front area of the intake 54, thereby drawing air into the convergent passageway portion 10. As the cross-sectional area of the continuous passageway 36 in the applicator 2 decreases, the velocity of the air increases, so that air rushes at an increased velocity through the relatively narrow central passageway portion 14 and maintains substantially this same increased velocity throughout the length of the annular passageway portion 18. Since the velocity of air increases as it passes through the narrow passageway portion 14, there is a drop in pressure at this area of increased air velocity. This drop in pressure causes a flow of air through the feed hose 45 and out the tube opening 46. Since the opposite end of the feed hose 45 is loosely fitted in a supply of cleaning material 52, the particles of cleaning material 52 are drawn through the hose 45 and out of the tube outlet 46 to pass over the point 32 of the deflector 28, so that the cleaning particles 52 are distributed evenly to each portion of the annular passageway portion 18. Since the annular passageway portion 18 diverges, the cleaning particles 52 follow this diverging path and receive a radial velocity component in addition to the axial velocity component, thereby deflecting the cleaning particles outwardly from the nose cone 48 in a conical pattern. Therefore the cleaning particles 52 enter the main stream of air 58, which flows into the jet engine, at an angle to the direction of flow of the main stream of air 58. Also, because of the increased velocity of the air stream through the narrow central passageway portion 14 and through the annular passageway 18, the cleaning particles enter the main air stream 58 at a relatively high velocity. The effect of this high velocity and the radial velocity component causes a dispersion of the cleaning particles 52 over the air intake area of the jet engine 50 so that all portions of the blades 57 of the compressor 56 are impinged upon by the cleaning particles 52. Also, in the process of cleaning the jet engine 50, the speed of the engine 50 is constantly varied from idle to nearly full throttle and back again to idle, so that the velocity of the air stream 58 and the consequent velocity of the flow through the continuous passageway 36 of the applicator 2 vary from higher to lower values, which in turn vary the velocity of the cleaning particles 52, thereby varying the radial concentration of the cleaning particles 52 either to the inside portions of the compressor blades 57 or to the outside portion of the compressor blades 57 in the compressor 56, so as to clean the compressor blades 57 from their root section to their tips.

The cross-sectional area of the entrance 8 of the continuous air passageway 36 of the applicator 2 is relatively large compared to the narrow central passageway portion 14, so that there is a large increase of velocity in air flow from the entrance to the central passageway portion 14. The thickness of the annular passageway portion 18 is decreased as the annular passageway portion 18 diverges so that the cross-sectional area of the annular passageway portion 18 remains substantially constant so that the cleaning particles maintain their high velocity as they leave the continuous passageway 36 at the exit 26. This configuration of the continuous passageway 36 functions: to cause a pressure drop in the narrow passageway portion 14 to draw the cleaning particles 52 into the air stream; to cause a high velocity of flow of air and consequently of the flow of the cleaning particles 52; to provide a radial velocity component to the flow of air and the flow of the cleaning particles 52; and to vary the radial concentration of cleaning particles 52 by means of variation of the speed of the jet engine 50.

While the present invention has been shown in one form only, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope thereof.

I claim as my invention:

1. In a cleaning device for feeding and directing cleaning material into a jet engine having an inlet section which defines a low pressure area and a compressor section which includes a plurality of rotatable blades, the combination comprising; a venturi-shaped member having a converging inlet, a throat, and a diverging outlet having an inner surface; feeding means for supplying cleaning material within the throat of said venturi-shaped member; and a deflector diverging in the same direction as the diverging outlet of said venturi-shaped member and being disposed to establish a diverging annular passageway having an inlet and an outlet, the diverging annular passageway being located between said diverging deflector and the inner surface of the diverging outlet of said venturi-shaped member, and the outlet of said diverging annular passageway being located within the low pressure area defined by the inlet section of the jet engine, so that upon and as a result of rotation of the rotatable blades of the compressor section the cleaning material is drawn through the throat of said venturi-shaped member into the inlet of said diverging annular passageway and through the outlet of said diverging annular passageway where the cleaning material is emitted into the low pressure area defined by the inlet section of the jet engine and thence drawn into the compressor section to thereby effect a cleaning of the rotatable blades of the compressor section.

2. A cleaning device as claimed in claim 1 in which said diverging annular passageway is of substantially uniform cross-sectional area throughout.

3. In a cleaning device for feeding and directing walnut shell particles into a jet engine having an inlet section which defines a low pressure area and a compressor section which includes a plurality of rotatable blades, the combination comprising; feeding means having an inlet and an outlet, the inlet of said feeding means being disposed to receive the walnut shell particles and the outlet of said feeding means being disposed to emit the walnut shell particles centrally of the inlet section of the jet engine; a deflector disposed centrally of the inlet section of the jet engine and between the rotatable blades of the compressor section and the outlet of said feeding means; and a venturi-shaped member one end of which is exposed to the atmosphere and the other end of which is disposed around said deflector so as to establish a passageway of substantially uniform cross-sectional area that diverges outwardly in the direction of said rotatable blades, the outlet of said diverging passageway being located within the low pressure area defined by the inlet section of the jet engine, and the cross-sectional area of said passageway being substantially equal to the cross-sectional area

of the throat of said venturi-shaped member, the outlet of said feeding means being disposed within the throat of said venturi-shaped member, so that upon and as a result of the rotation of the rotatable blades of the compressor section of the jet engine the walnut shell particles are drawn through the inlet of said feeding means to the outlet of said feeding means where the walnut shell particles are emitted within the throat of said venturi-shaped member and thence drawn through said diverging passageway onto the rotatable blades of the compressor section of the jet engine, to thereby effect a cleaning of the rotatable blades.

4. A method for removing foreign deposits from the blades of a compressor of a jet engine when said jet engine is placed in operation and comprising the steps of; exposing the inlet of a feeding means to a supply of cleaning particles, disposing the outlet of said feeding means centrally in a low pressure area at the intake of the compressor of an operating jet engine, thus drawing said cleaning particles through said feeding means and

disposing the same in said low pressure area, deflecting said cleaning particles in a conical pattern so as to pass in a diverging path through said compressor, and varying the rate of rotation of said jet engine compressor blades from a high to a low value so as to simultaneously vary the diverging conical pattern of said cleaning particles, whereby said compressor blades are cleaned from the root section to the tip.

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