

[54] SOUND SUPPRESSION SYSTEM FOR JET ENGINE

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[52] U.S. Cl. **181/33 E**, 181/33 HC, 181/33 HD,
 239/265.13, 239/265.17, 239/265.19
 [51] Int. Cl. **B64d 33/06**, F01n 1/14, F01n 1/16
 [58] Field of Search..... 181/33 R, 33 E, 33 HB, 33 HC,
 181/33 HD, 33 HE; 239/127.3, 265.11, 265.13,
 265.19, 265.33, 265.37, 265.17

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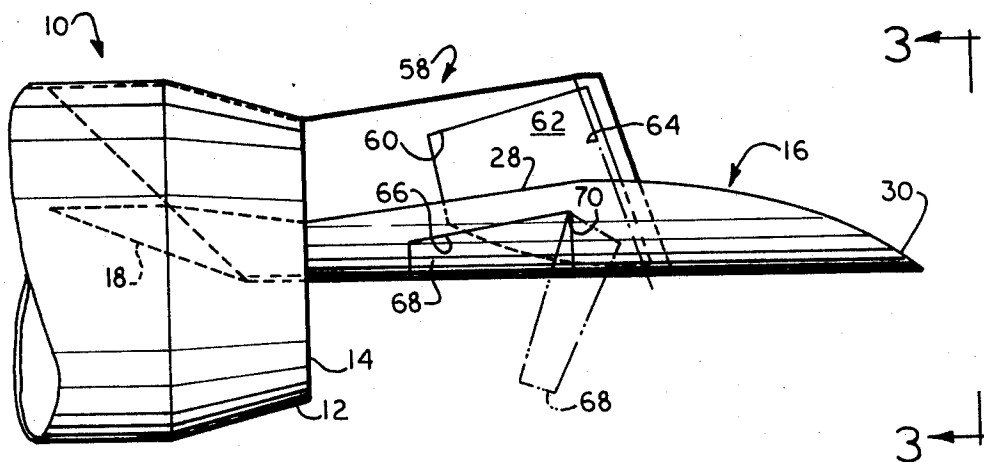
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[57]

ABSTRACT

System is intended for use with a jet engine and comprises an elongate suppressor panel which is connected to the aft end of the nozzle and extends rearward. The panel is generally rectilinear in longitudinal section and concavo-convex in transverse cross section with its concave face directed upward. The panel is generally centered in the jet stream to divide it into upper and lower portions of generally equal volume. The panel serves as a shield against downward radiation of sound waves from the upper portion of the stream and reflects them upward in a converging pattern. The convex lower face of the panel reflects the sound waves from the lower portion of the stream downward but at the same time disperses them laterally so that the unit sound intensity at the ground is substantially reduced. The noise level at the suppressor is initially substantially reduced by making the panel of a very efficient sound absorbing material such as a honeycomb core with a porous skin. The system also includes a thrust reverser. A support panel extends upward from the suppressor panel and carries a pair of blocker doors which swing laterally to block aft flow of the upper portion of the jet stream, and a single blocker door is mounted in the suppressor panel and swings downward to block aft flow of the lower portion of the jet stream. The reversing forces above and below the nozzle axis balance out the directional moments and avoid instability.

17 Claims, 8 Drawing Figures



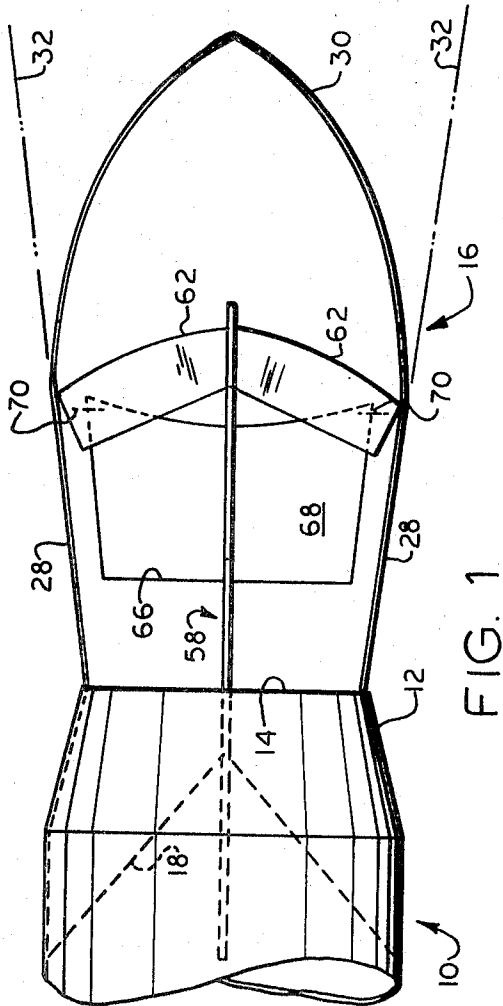


FIG. 1

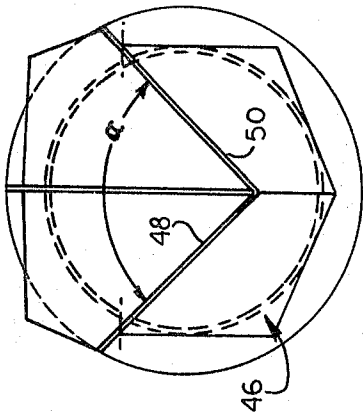


FIG. 4

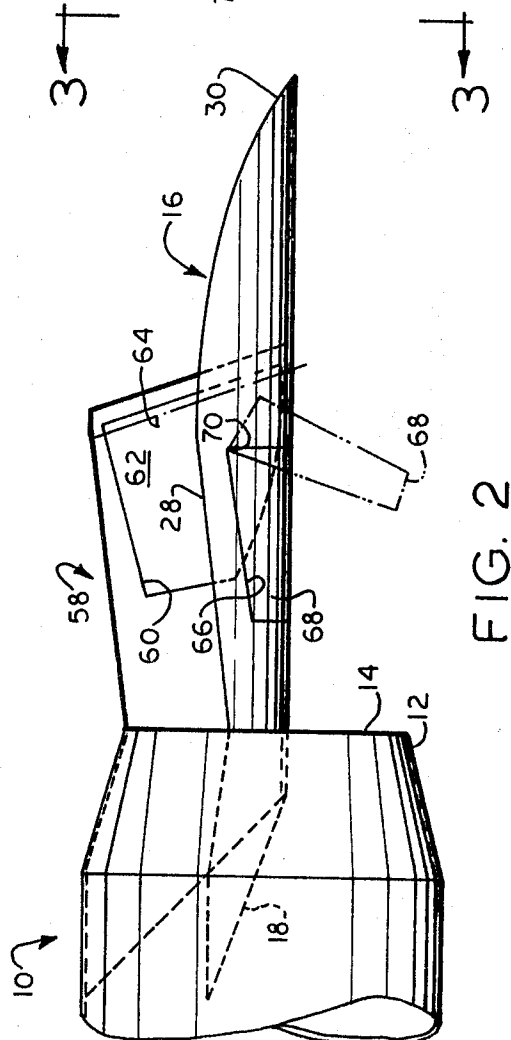


FIG. 2

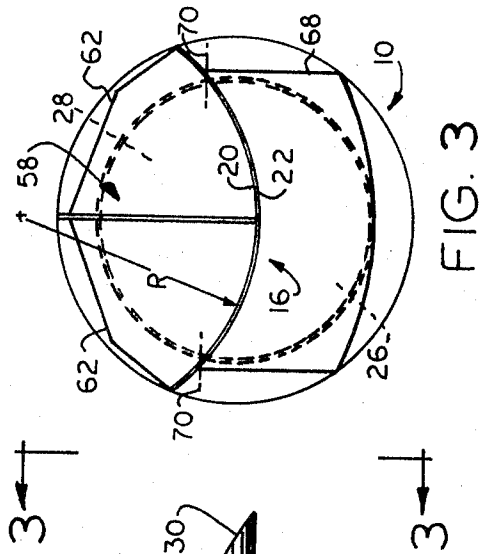


FIG. 3

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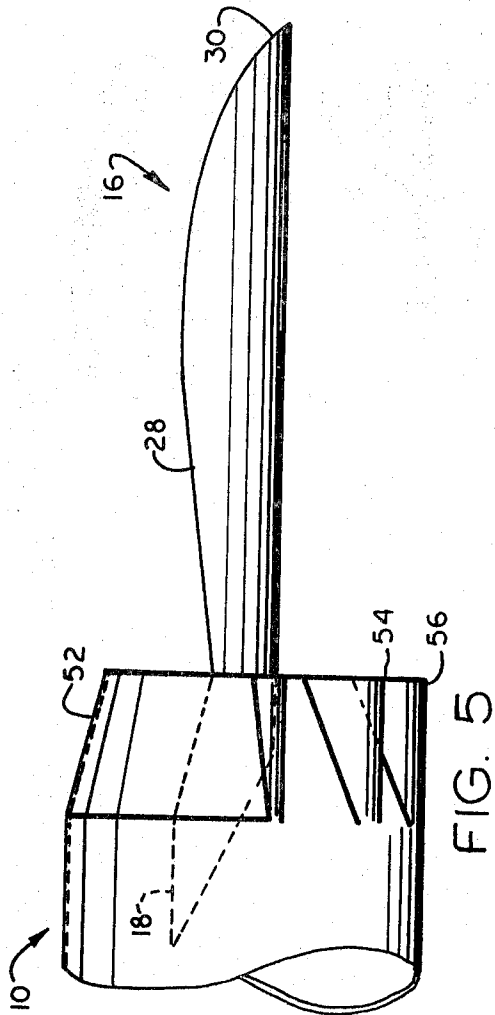


FIG. 5

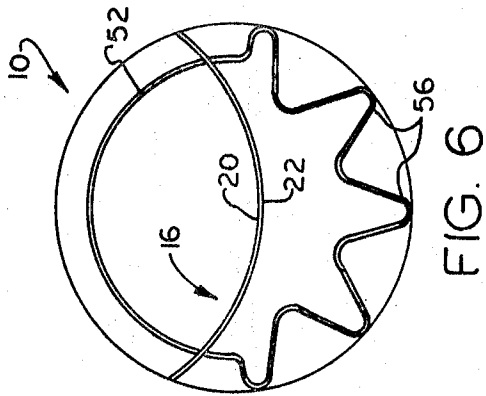


FIG. 6

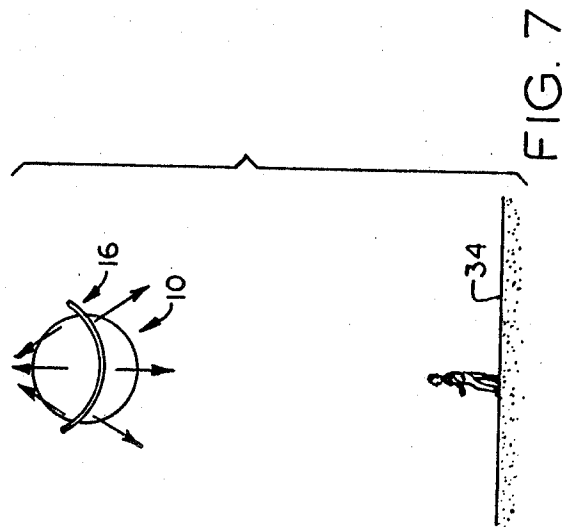


FIG. 7

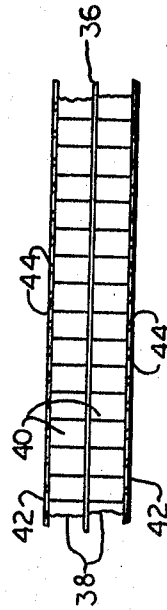


FIG. 8

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SOUND SUPPRESSION SYSTEM FOR JET ENGINE

BACKGROUND OF THE INVENTION

This invention lies in the field of sound suppression of gas turbine or jet engines, which produce reaction thrust by ejecting a high velocity stream of gas from the exhaust nozzle or tail pipe of the gas turbine. One of the problems of airplanes equipped with jet engines on which a great deal of effort has been expended is that the exhaust gas stream leaving the nozzle produces a shearing action with the ambient air, creating a very high level of sound energy or noise. The turbulent flow of the jet stream creates further noise, to which is added the noise of the rotating machinery in the engine. During aircraft takeoff, climb, and approach this noise reaches the ground at an energy level which is not acceptable to the public.

Another problem is that airplanes driven by jet engines fly and land at much higher speeds than propeller driven airplanes. Their high landing speed puts a great burden on the wheel brakes and of course they do not have propellers which are readily reversible to produce reverse thrust. Therefore it is highly desirable to provide apparatus to reverse the gas stream to accomplish this result.

Sound suppression systems and thrust reversers have been applied to the same engines in the past but have frequently left much to be desired. Since their nature and function are completely different, it has been found in many cases that one has interfered with the other or the solution has been quite complicated.

SUMMARY OF THE INVENTION

The present invention accomplishes both of the desirable functions mentioned above with a minimum of complication. Generally stated, the system includes an elongate suppressor panel which is connected to the aft end of the nozzle and trails rearward. The panel is generally rectilinear in longitudinal section and concavo-convex in transverse cross section with its concave face directed upward. The panel is mounted generally central of the exhaust jet stream to divide the stream into substantially equal upper and lower portions. The panel acts as a shield to prevent the sound waves of the upper portion from radiating down toward the ground and reflects them upward in a generally converging pattern. Thus, half of the noise is barred from the ground at its inception. The sound waves of the lower portion are reflected downward but the convex form of the panel disperses them laterally so that the unit intensity at any given ground point is greatly reduced. In addition, the panel is made of very efficient sound absorbing material which further reduces the sound energy at the source.

The addition of a thrust reverser to this system requires a minimum of complication. For this purpose, a support panel is added which is connected to the suppressor panel and extends in a fore and aft vertical plane containing the axis of the nozzle in the nature of a vertical fin. A pair of blocker doors are carried by the support panel and pivoted to it at their aft ends to swing laterally from stowed position flush with the panel to deployed position diverging forward. A single blocker door is mounted to the suppressor panel and pivoted at its aft end to swing from stowed position flush with the panel downward and outward to deployed position diverging forwardly. Thus, the two portions of the jet stream are diverted laterally and forwardly to produce balanced reverse thrust.

BRIEF DESCRIPTION OF THE DRAWINGS

Various advantages and features of novelty will become apparent as the description proceeds in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic top plan view of the sound suppression system attached to the exhaust nozzle and with the reverser mechanism incorporated;

FIG. 2 is a side elevational view of the apparatus of FIG. 1;

FIG. 3 is a rear end elevational view of the apparatus of FIG. 2, looking forward on line 3-3;

FIG. 4 is a view similar to FIG. 3, showing a modified form of the suppressor panel;

FIG. 5 is a schematic side elevational view of the suppressor panel of FIG. 1 with a modified form of exhaust nozzle and with the reverser mechanism omitted for clarity;

FIG. 6 is an end elevational view of the apparatus of FIG. 5;

FIG. 7 is a schematic view showing the principle of operation of the sound suppression system; and

FIG. 8 is a sectional view through the structure of the panel.

DESCRIPTION OF PREFERRED EMBODIMENTS

The general arrangement of the system of the invention is illustrated in FIG. 1, in which a typical jet engine, not shown, is provided with a rearwardly discharging tail pipe or jet nozzle 10 having a convergent aft nozzle section 12 with an exit plane 14. A suppressor panel 16 is connected to the nozzle and its forward end 18 projects inside the nozzle. As indicated in FIG. 2, the longitudinal section is rectilinear although the shape may be modified to some extent for special design considerations. As may be seen in FIG. 3, the transverse cross section of the panel is concavo-convex, with the concave face 20 directed toward and the convex face 22 directed downward.

The panel is generally centered in the jet stream to divide it into two portions 24 and 26 of approximately equal volume. The forward end 18 of the panel segregates these portions before they are discharged from the nozzle. The side edges 28 of the panel diverge substantially along the stream lines 32 of the jet expansion flow preferably for a distance at least equal to the diameter of the nozzle at its exit plane in order to work with the entire body of the stream. The total length of the panel may be from two to six nozzle diameters, being determined by test for each installation. The longer panels have generally parallel side edges aft of the initial flare. The trailing edge 30 of the panel converges rearward substantially to a point along lines generally corresponding to the jet velocity profile, the velocity being highest at the center and tapering of toward the edges.

It will be apparent that the panel itself operates as a shield to prevent sound waves generated in the upper portion 24 of the stream from radiating downward toward the ground. Its concave upper face 20 reflects these sound waves upward in a generally converging pattern which is not objectionable because they are merely attenuated in the upper atmosphere. At the same time the sound waves generated in the lower portion 26 of the stream are reflected downward toward the ground by convex face 22, but its convex shape disperses the sound waves laterally, so that the unit intensity of the noise at any given ground point is greatly reduced. This action is schematically illustrated in FIG. 7, where it is evident that the unit sound intensity in the area 34 is far less than it would be under ordinary circumstances.

A further reduction of noise at the source is accomplished by the panel structure itself which is sound absorbent or may be said to have sound absorbent surfaces. A preferred form is illustrated in FIG. 8, where a hollow core includes a solid septum 36 mounted between two honeycomb layers 38, the cells of which define a multiplicity of resonant chambers 40. The skins 42 overlying and substantially closing the cells may be or porous material or may contain a multiplicity of perforations 44 in communication with the cells 40. A substantial portion of the sound waves striking the panel surface will be absorbed rather than reflected, thus reducing the noise level initially.

Another example of a concavo-convex panel is illustrated in rear elevation in FIG. 4, where the panel 46 is V-shape in cross section with the concave face 48 up and the convex face 50 down. The principle of operation is basically the same as with arcuate panel 16. In the case of the arcuate panel it has been found that a suitable curvature is obtained with a radius R, FIG. 3, which is approximately equal to the length of the chord of a 90° segment of the nozzle exit circle. In FIG. 4, the angle α between the two flat panel sections is approximately 90° and its attach points are practically the same as for panel

16 to divide the flow into generally equal parts. Although other cross sections may be used, those described above have been found to be very satisfactory.

The further modified form of the invention shown in FIGS. 5 and 6 is basically the same as those already described, and panel 16 is the same in all principal respects, including the sound absorbing construction. The upper part 52 of the aft section of nozzle 10 which is swept by the upper portion of the jet stream is arcuate as in the previous forms, but the lower portion 54, below the arcuate panel is fluted to provide a series of lobes 56 which, in addition to deflecting the sound waves laterally, split the lower portion of the gas stream and induce free stream air into mixing contact with the gas stream to add mass and lower the temperature and velocity, all of which act to reduce the level of the noise generated.

The basic design and construction of the suppressor panel make a very good foundation for the provision of thrust reversing means. As shown in FIGS. 1 to 3, a support panel 58 is secured to suppressor panel 16 and extends upward from panel 16 in a substantially vertical fore and aft plane containing the axis of the nozzle. An opening 60 is formed in panel 58 and preferably extends entirely through it. In this opening are located a pair of blocker doors 62, each of which is pivoted near its aft edge to panel 58 on a generally upright axis 64. Conventional actuators, not shown, swing doors 62 between stowed position flush with panel 58, as seen in FIG. 2 and deployed position diverging forward, as seen in FIG. 1. Thus, these two doors block and reverse the flow of all of the upper portion of the jet stream.

Panel 16 is formed with a generally rectangular aperture 66 to receive a lower blocker door 68 which is pivotally mounted near its aft end to the panel on a transverse axis 70. Another conventional actuator, not shown, swings door 68 between stowed position flush with the panel and deployed position shown in broken lines in FIG. 2 diverging forward. In this position it blocks and reverses the flow of all of the lower portion of the jet stream. Since the two portions can communicate through the opening 66 and the two sets of doors block the entire stream, the reversing forces are well balanced and directional moments are canceled out.

The same types of blocker doors operate in the same way in the modifications of FIGS. 4, 5, and 6. The shapes of the doors in FIG. 4 are, of course, altered to correspond to the modified shape of the suppressor panel.

It will be apparent that the invention provides a highly effective sound suppression system which operates with no moving parts whatsoever, as well as thrust reversing means which may be added to and mounted on the suppressor structure with a minimum of parts or complication.

Having thus described the invention, what is claimed as new and useful and desired to be secured by U. S. Letters Patent is:

1. A sound suppression system for use in combination with a jet engine having a rearwardly discharging exhaust gas nozzle, comprising: an elongate suppressor panel connected to the aft end of the nozzle and extending rearwardly therefrom; the panel being generally rectilinear in longitudinal section and concavo-convex in transverse cross section with its concave face directed upward and its convex face directed downward; the panel being generally centered in the exhaust jet stream at the exit plane of the nozzle to divide the stream into upper and lower portions of generally equal volume, the panel serving as a shield against radiation of sound waves downward from the upper portion of the jet stream; the concave upper face of the panel reflecting sound waves from the upper portion of the jet stream upwardly and concentrating them; and the convex lower face of the panel reflecting sound waves from the lower portion of the jet stream downwardly and dispersing them

laterally to reduce the unit intensity.

2. A system as claimed in claim 1; the forward end of the panel extending into the aft portion of the nozzle to segregate the upper and lower portions of the jet stream prior to discharge from the nozzle.

3. A system as claimed in claim 1; the panel being provided with sound absorbing surfaces.

4. A system as claimed in claim 1; the panel comprising a hollow core containing a multiplicity of discrete sound absorbing cells; and a skin overlying the cells and provided with a multiplicity of apertures therethrough in communication with the cells.

5. A system as claimed in claim 1; the length of the panel aft of the nozzle being at least twice the diameter of the nozzle at its exit plane.

6. A system as claimed in claim 1; the length of the panel aft of the nozzle being in the range of two to six times the diameter of the nozzle at its exit plane.

7. A system as claimed in claim 1; the side edges of the panel diverging rearward generally along the marginal stream lines of the jet expansion flow for a distance at least equal to the diameter of the nozzle at its exit plane.

8. A system as claimed in claim 7; the trailing edge of the panel converging rearward along lines generally corresponding to the jet velocity profile.

9. A system as claimed in claim 1; the cross sectional shape of the panel being generally arcuate.

10. A system as claimed in claim 1; the cross sectional shape of the panel being generally in the form of a V.

11. A system as claimed in claim 1; the aft portion of the nozzle above the panel being generally arcuate; and the aft portion of the nozzle below the panel being fluted to define a plurality of lobes for mixing free stream air with the gas to further reduce the noise level.

12. A system as claimed in claim 1; and a plurality of blockers carried by the panel and swingable between stowed position parallel to the jet stream and deployed position diverging forward to deflect the jet stream laterally and forwardly and produce reverse thrust.

13. A system as claimed in claim 12; including a blocker door pivotally mounted adjacent to its aft end to the panel about a transverse axis and swingable from stowed position substantially flush with the lower surface of the panel downward to deployed position diverging forward.

14. A system as claimed in claim 12; the panel having a blocker-receiving opening therein, and at least one of the blockers in stowed position fitting into the opening.

15. A system as claimed in claim 12; including a support panel connected to the suppressor panel and extending upward therefrom in a substantially vertical fore and aft plane containing the axis of the nozzle; and a pair of blocker doors pivotally mounted adjacent to their aft ends to the support panel and swingable laterally from stowed position substantially flush with the faces of the support panel to deployed position diverging forward.

16. A system as claimed in claim 15; the support panel having a door receiving opening therein and the blocker doors in stowed position fitting into the opening.

17. A method of suppressing the sound of the exhaust jet stream from a jet engine, comprising: segregating the stream longitudinally into upper and lower portions; directing upwardly substantially all of the sound waves emitted by the upper portion; directing downwardly substantially of the sound waves emitted by the lower portion; and dispersing the downwardly directed sound waves laterally to reduce their unit intensity.

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