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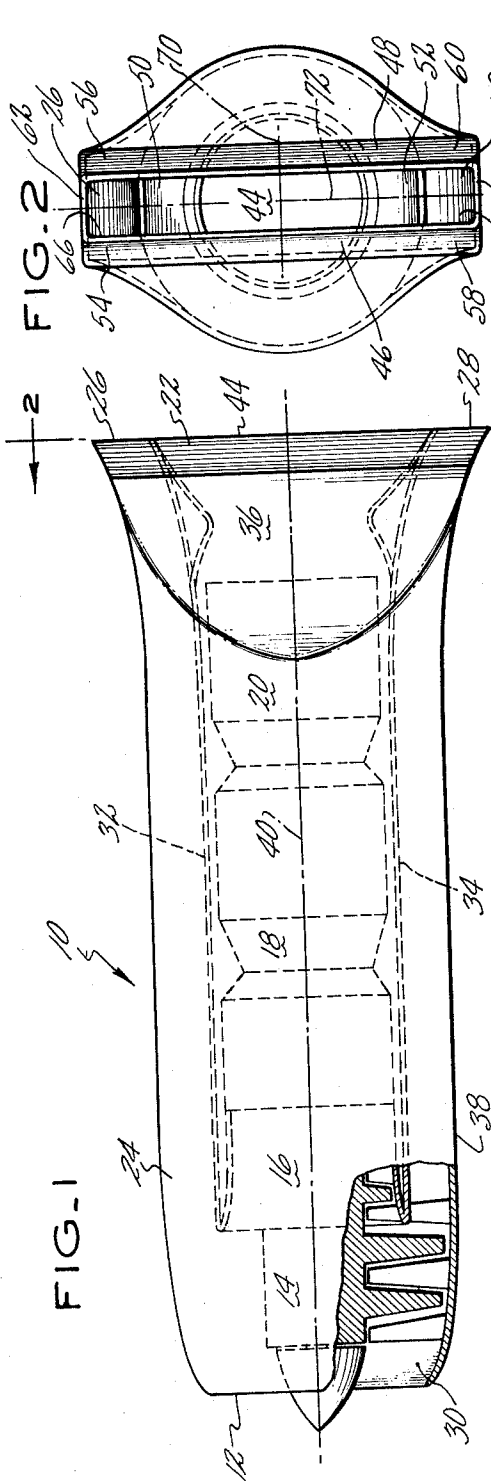
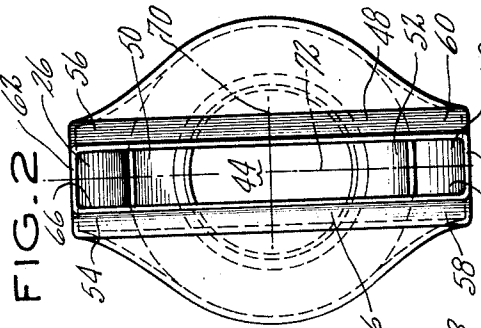
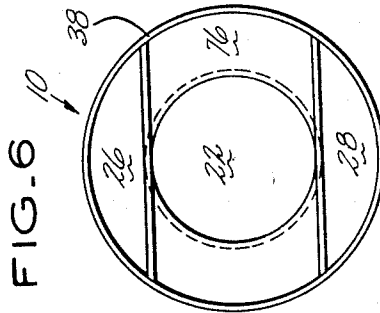
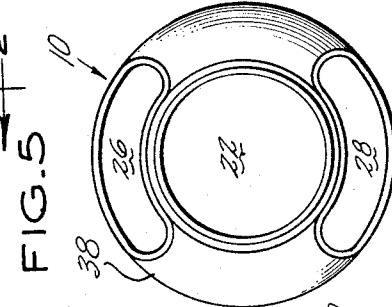
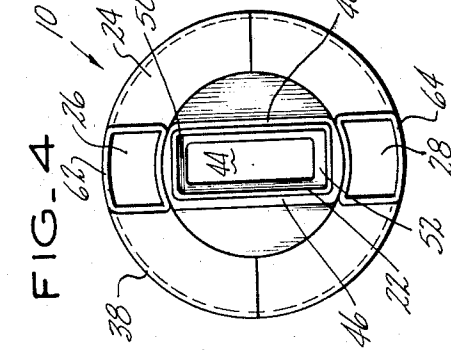
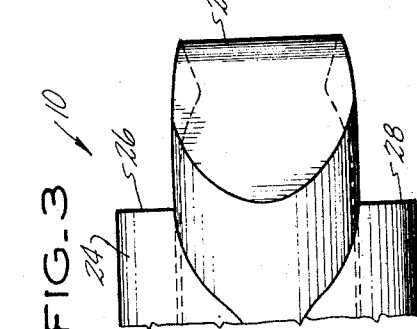
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NOISE SUPPRESSION OF FAN ENGINES

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2 Sheets-Sheet 1



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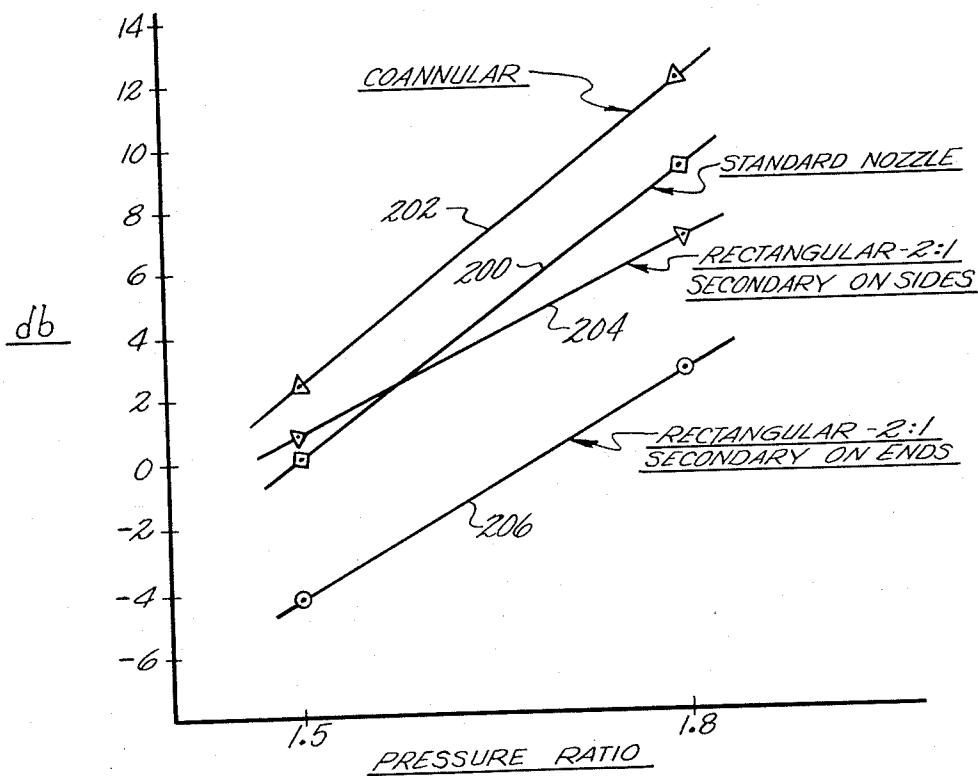
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FIG. 7



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NOISE SUPPRESSION OF FAN ENGINES

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This invention relates to turbofan engines and more particularly to suppressing the wake noise thereof.

It is an object of this invention to teach apparatus and method for suppressing the jet wake noise of a turbofan engine.

It is a further object of this invention to teach apparatus for suppressing the noise of a turbofan engine comprising discharging primary or engine exhaust gas to atmosphere through a vertically extending, slot-shaped nozzle of rectangular cross section and discharging the fan by-pass air to atmosphere through at least one exhaust nozzle which is positioned between the primary exhaust nozzle and the direction of minimum desired noise but preferably a fan air exhaust nozzle on the opposite side also.

It is still a further object of this invention to teach such a turbofan noise suppressor system wherein the fan ducted or by-pass air exhaust nozzle outlets are coplanar with the primary exhaust nozzle outlet or may terminate forward thereof.

It is a further object of this invention to teach jet wake noise suppression apparatus and method for a turbofan type engine wherein the engine gas exhaust wake is maintained to be of minimum dimension in the direction perpendicular to the direction of minimum desired noise.

It is a further object of this invention to provide such noise suppression apparatus wherein the side walls defining the aforementioned vertical slot primary exhaust nozzle and the secondary nozzles above and below the primary nozzle, are convergent whereas the top and bottom walls of the primary nozzle are divergent and the corresponding walls of the secondary nozzle are substantially parallel therewith.

Other objects and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

FIG. 1 is a side view of a typical turbofan engine, partially broken away to illustrate our invention.

FIG. 2 is a view taken along line 2—2 of FIG. 1.

FIG. 3 is a fragmentary showing of the after end of a turbofan engine with the secondary exhaust nozzles located forward of the primary exhaust nozzle.

FIG. 4 is a rear view of the FIG. 3 construction.

FIGS. 5 and 6 are comparable to FIG. 2 but show primary and secondary exhaust nozzles of modified shapes.

FIG. 7 is a graphic illustration of the noise suppression advantage to be gained by our turbofan noise suppressor construction as opposed to the conventional circular primary nozzle without noise suppression, the circular primary nozzle with an enveloping annular secondary nozzle, and the rectangular primary nozzle with the secondary exhaust nozzles located on each side thereof.

Referring to FIG. 1 we see turbofan ducted fan, or by-pass engine 10, which is symmetric about axis 40, and which except for my noise suppressor embodiment could be of the type taught in U.S. Patents Nos. 3,063,661 and 2,887,845, comprises air inlet section 12, fan section 14, compressor section 16, burner section 18, turbine section 20, primary exhaust nozzle 22, and fan by-pass ducting 24 which defines secondary or fan by-pass air exhaust nozzles 26 and 28. Air enters turbofan engine 10 through air inlet section 12 and is partially compressed

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by fan section 14 from whence a portion of it will proceed through fan duct system 24 which is shaped, as a bifurcated duct having an annular inlet 30 and upper and lower axially extending ducts 32 and 34, respectively, communicating with and extending from annular inlet 30 and extending for the full length of turbofan engine 10 and culminating in reduced area secondary exhaust nozzles 26 and 28. The remainder of the air which is compressed by fan section 14 passes through compressor section 16 where it is further compressed, then through burner section 18 where it has energy added thereto in the form of heat and then through turbine section 20, where sufficient energy is extracted therefrom to drive compressor 16, and thence rearwardly through primary exhaust duct 36 which culminates in primary exhaust nozzle 22. Compressor 16, burner 18 and turbine 20 are enveloped by engine case 38, which is of substantially circular cross section and concentric about axis 40. Exhaust duct 36 preferably changes from circular cross section at its forward end to rectangular cross section at its after end where it defines primary exhaust nozzle 22 and exhaust outlet 44.

Turbofan engine 10 performs the function of generating thrust by discharging the engine exhaust gases from the turbojet engine which basically comprises compressor 16, burner 18 and turbine 20, through primary exhaust nozzle 22 and the fan by-pass air from fan section 14 through secondary exhaust nozzles 26 and 28.

In the conventional turbofan engine construction of the type shown in U.S. Patent No. 2,887,845 the fan by-pass air is discharged to atmosphere through an annular secondary exhaust nozzle which envelops the primary exhaust nozzle which is of circular cross section.

Quite unexpectedly we have found that noise suppression of a jet engine wake can be accomplished by creating and maintaining the wake to be of minimum dimension in the direction perpendicular to the direction of minimum desired noise and structurally this can be accomplished by fabricating the primary exhaust nozzle to constitute a vertically extending slot of rectangular cross section (see FIGS. 2 and 4) since the groundward direction is the direction of minimum desired noise because noise suppression requirements are maximum during airport approach or takeoff at which time the aircraft is flying at low altitudes over thickly populated areas. The minimum wake dimension configuration can be attained in a turbofan engine by placing the secondary exhaust nozzle in vertical alignment with the primary exhaust nozzle and preferably between the primary exhaust nozzle and the point of minimum desired noise since it appears that the relatively low velocity fan air also serves as an acoustic barrier for the relatively high velocity engine exhaust gas wake. We have found as a practical matter, however, that it is possibly preferable to place a secondary exhaust nozzle above and below the vertical slot primary nozzle as shown in FIGS. 2 and 4 although it should be borne in mind that secondary exhaust nozzle 26 could be removed so that all fan by-pass air passes through secondary exhaust nozzle 28. For the reasons described more fully in our U.S. Patent No. 3,033,494, primary exhaust nozzle 22 includes vertically extending slot-shaped outlet 44 which is defined by vertically extending and convergent side walls 46 and 48 and horizontally extending and diverging top and bottom walls 50 and 52. To carry out the creation of the narrowest possible wake dimension perpendicular to the direction of minimum desired noise, it will be noted in FIGS. 2 and 4 that secondary exhaust nozzles 26 and 28 are defined by convergent side walls 54 and 56, and 58 and 60, respectively, which side walls constitute a continuation of convergent side walls 46 and 48. In addition, the

end walls 62 and 64 which cooperate with end walls 50 and 52 of primary nozzle outlet 44 to define secondary outlets 66 and 68 are parallel to divergent walls 50 and 52, respectively.

With such a construction it will be obvious to one skilled in the art that the minimum dimension wake will be formed along axis 70 which is perpendicular to the groundward direction, the direction of minimum desired noise as represented by axis 72.

While our preferred embodiment is illustrated in FIG. 2, there are other embodiments in which the teaching of this application may be carried out. For example, in the configuration shown in FIGS. 3 and 4 an embodiment is shown which is comparable in all respects to the configuration shown in FIGS. 1 and 2 except that the fan by-passed ducting 24 defines secondary exhaust nozzles 26 and 28 which are positioned axially forward or upstream of primary nozzle 22. The FIGS. 5 and 6 constructions illustrate embodiments of our inventions for use with other than rectangular primary exhaust nozzles. In the FIG. 5 construction a circular primary exhaust nozzle 22 is shown with oppositely directed kidney-shaped secondary exhaust nozzles 26 and 28 positioned above and below the primary exhaust nozzle 22, respectively. In the FIG. 6 configuration primary exhaust nozzle 22 is positioned between secondary exhaust nozzles 26 and 28 and cooperates therewith to define a total circular exhaust outlet 76.

The embodiments shown in FIGS. 1 through 4 constitute the preferred embodiments of our invention because with such embodiments the total engine exhaust gas wake is created to be of minimum dimension along axis 70, that is, in a direction perpendicular to the direction of minimum desired noise (ground) and because the relatively low velocity secondary exhaust gas wake created by discharging fan by-pass air through secondary exhaust nozzle outlet 78 serves as an acoustic barrier for the main source of noise, the primary exhaust nozzle wake which is created by discharging engine gases at high velocity through primary outlet 44 of nozzle 22.

Referring to FIG. 7 we see a graphic illustration of the advantages of our preferred embodiment over other types of exhaust nozzles including turbofan configurations. It will be noted that curve 200 represents the noise difference in decibels created by a standard circular exhaust nozzle without secondary air flow at a 1.5 and a 1.8 pressure ratio. The noise output of such a nozzle at the lower of the two pressure ratios is plotted at the zero level in this "noise difference" graph. Curve 202 represents an exhaust nozzle in which the primary air is passed through a standard circular nozzle as for line 200 and secondary air is passed through an enshrouding annular nozzle with an outlet coplanar with an outlet of the standard circular nozzle. This is called a coplanar construction. Graph 204 represents the noise created in a vertical slot primary exhaust nozzle of rectangular cross section with a 2:1 aspect ratio, that is, the vertical dimension twice the horizontal dimension, and with the secondary fan air being discharged on opposite, lateral sides thereof. Curve 206 represents the plot of our exhaust nozzle which is a vertically extending rectangular nozzle of 2:1 aspect ratio through which the primary exhaust gas is discharged and with the secondary or fan air being discharged at the ends of the top and bottom thereof.

It will be seen from the FIG. 7 graph that our exhaust nozzle produces substantial noise reduction in decibels over the other exhaust nozzles tested at both pressure ratios.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described but may be used in other ways without departure from its spirit as defined by the following claims.

We claim:

1. A turbofan engine having a primary exhaust nozzle comprising a vertically extending slot-shaped outlet of rectangular cross section having a vertical axis and a horizontal axis and comprising vertically extending and converging side walls and horizontally extending and diverging top and bottom walls through which the primary exhaust gas flows, and also having discharge means through which the bypass fan air flows comprising at least one exhaust nozzle adjacent to and in vertical alignment with said primary exhaust nozzle and having converging side walls constituting continuations of said primary nozzle converging side walls and further having top and bottom walls parallel to the diverging wall of said primary nozzle adjacent thereto, one of said primary nozzle top and bottom walls being substantially coincident with one of said bypass nozzle top and bottom walls whereby said primary and bypass flows have a substantially common boundary surface, and further whereby said primary and bypass flows are induced to flow in ever decreasing dimension along said horizontal axis and ever increasing dimension along said vertical axis.

2. A turbofan engine having a primary exhaust nozzle comprising a vertically extending slot-shaped outlet of rectangular cross section having a vertical axis and a horizontal axis and comprising vertically extending and convergent side walls and horizontally extending and diverging top and bottom walls through which the primary exhaust gas flows and also having discharge means through which the bypass fan air flows comprising outlets positioned at the top and bottom of said slot-shaped outlet, each defined by converging side walls constituting continuations of said primary nozzle converging side walls and further having top and bottom walls parallel to the diverging wall of said primary nozzle adjacent thereto, each of said diverging primary nozzle top and bottom walls forming a common boundary between said primary exhaust gas flow and said bypass fan air flow whereby said primary and bypass flows have a substantially common boundary surface and further whereby said primary and bypass flows are induced to flow in ever decreasing dimension along said horizontal axis and ever increasing dimension along said vertical axis.

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