

Aug. 5, 1958

J. M. TYLER ET AL

2,845,775

NOISE SUPPRESSORS FOR JET ENGINES

Filed June 1, 1956

3 Sheets-Sheet 1

FIG. 1

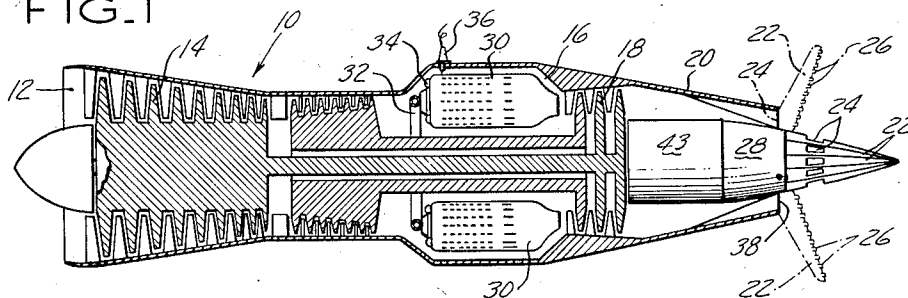


FIG. 8

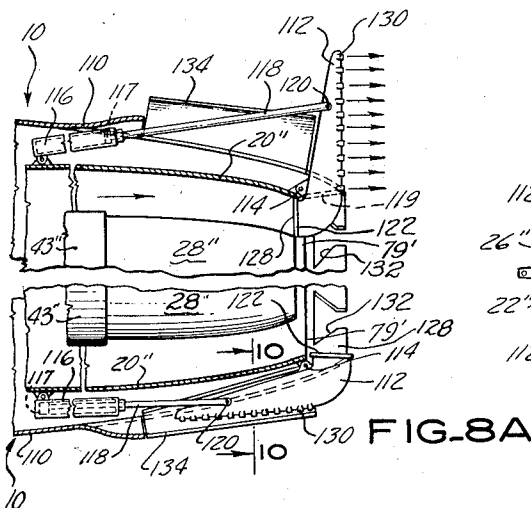


FIG. 11

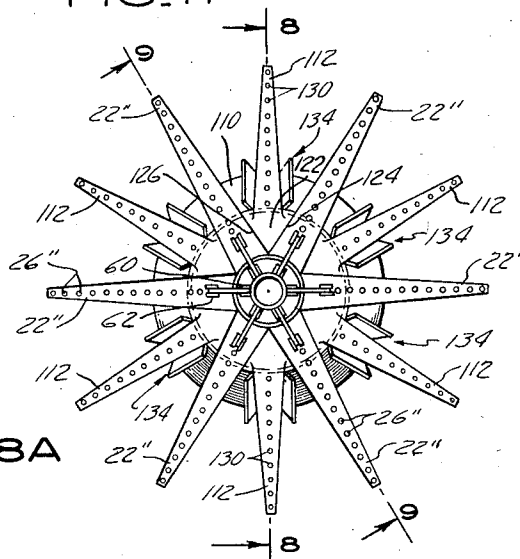


FIG. 8A

FIG. 9

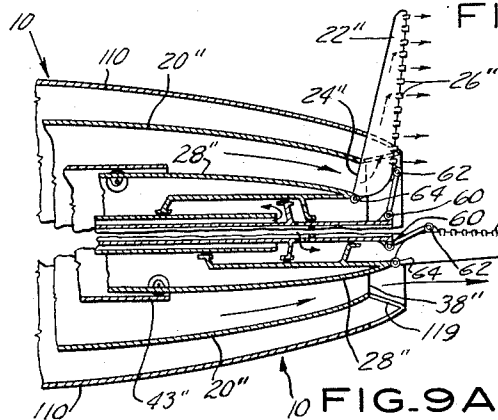


FIG. 9A

FIG. 12

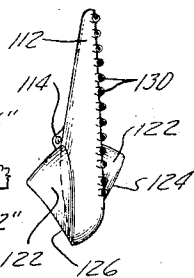
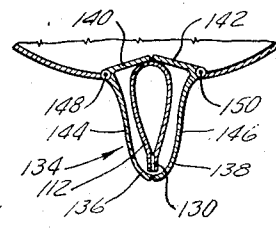


FIG. 10



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FIG. 2

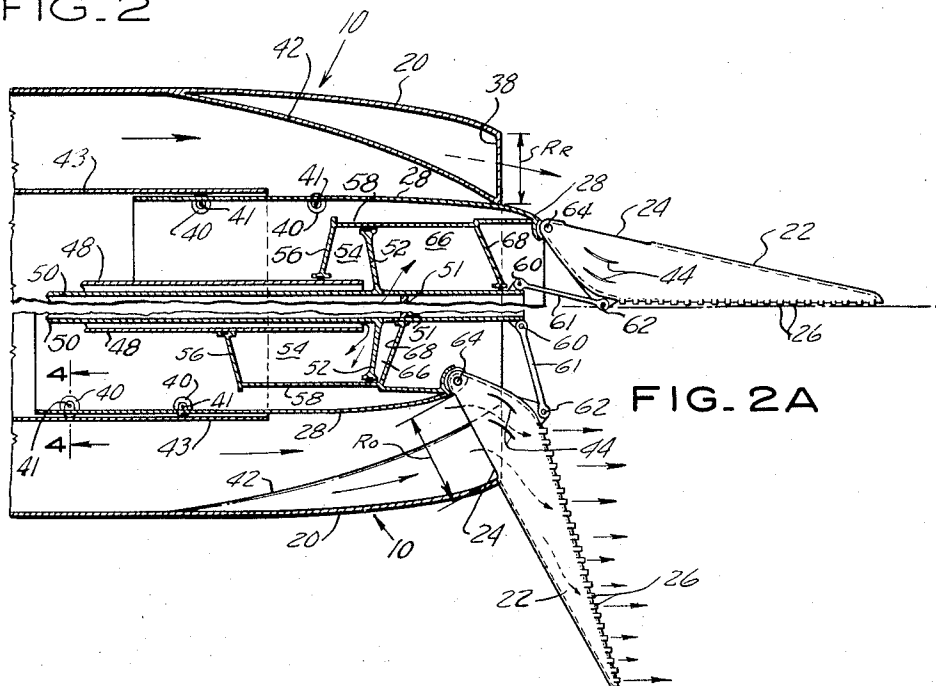


FIG. 2A

FIG. 3A

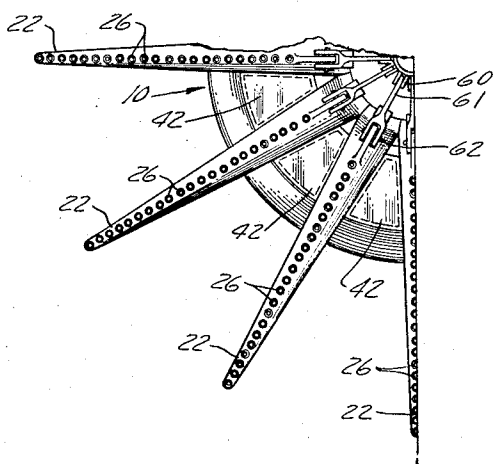


FIG. 3

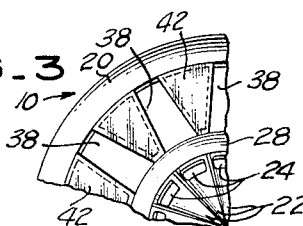
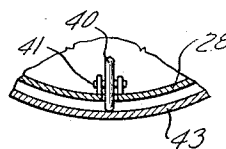


FIG. 4



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NOISE SUPPRESSORS FOR JET ENGINES

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FIG_5

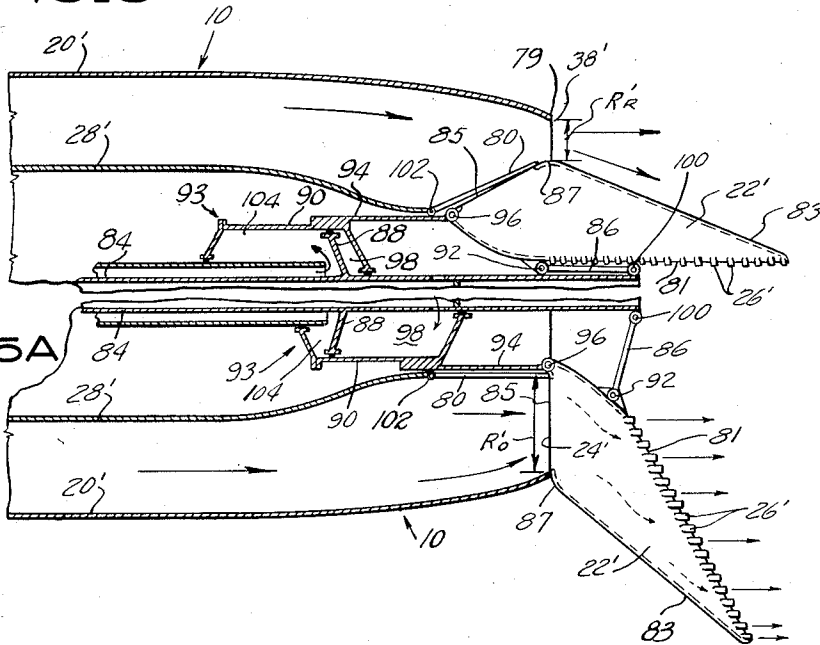


FIG. 5A

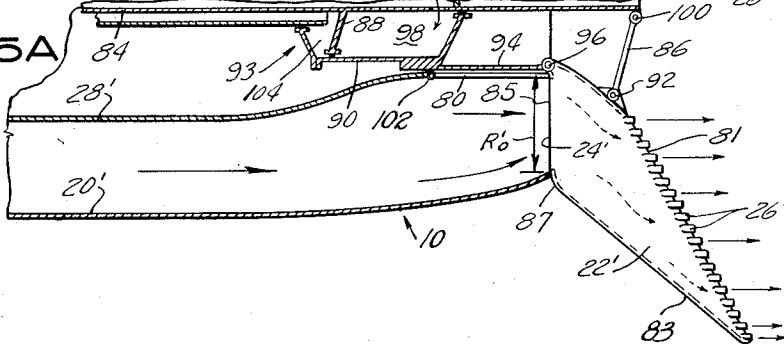


FIG. 7

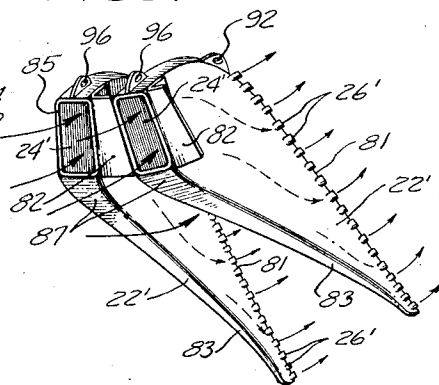
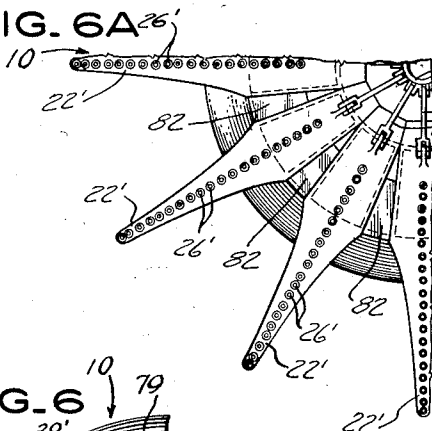
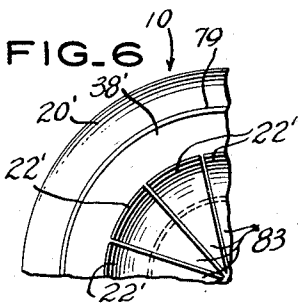
FIG. 6A²⁶⁾

FIG. 6



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NOISE SUPPRESSORS FOR JET ENGINES

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Application June 1, 1956, Serial No. 588,742

17 Claims. (Cl. 60—35.6)

This invention relates to the suppression of low frequency, audible noise and more particularly to the suppression of low frequency, audible noise from the exhaust of any type of a jet and in particular an aircraft jet engine wake.

Since a modern jet aircraft engine produces noise energy of approximately 200 horse power and since such noise would interfere with conversations at a distance of as much as 3000 feet from the engine, it is obvious that steps must be taken to control the formation of noise from the jet engine. The novel method of accomplishing this noise control taught herein is to shift the noise created to a predominately high frequency spectrum so that it will not interfere with airport personnel and the populace in the vicinity of airports.

The theory of noise creation and suppression utilized in our invention is described more fully in U. S. patent application Serial No. 581,418 to which reference may be had.

It should be borne in mind that in our invention we are not reducing the intensity of noise which has already formed but, we are controlling the creation of noise by passing the jet exhaust gas through a plurality of small nozzles instead of through a single large nozzle. The result accomplished is to have noise created in a predominately high frequency spectrum as opposed to a low frequency spectrum. Low frequency spectrums provide objectionable noise while a high frequency spectrum provides noise which is of a lesser audible intensity. Our invention lies in the apparatus for accomplishing this spectrum change.

It is an object of this invention to prevent the creation of audible noise, or control the creation of audible noise during the ground operation of aircraft jet engines and other jets and also during flight operation of aircraft jet engines.

It is a further object of this invention to control the creation of noise from an aircraft jet engine wake by causing the exhaust gases of the engine to be discharged through a plurality of small nozzles in the trailing edges of hollow radial extending vanes, which vanes may be retracted to form the engine tailcone.

It is a further object of this invention to provide a noise suppression apparatus which will not interfere with the thrust created by an aircraft jet engine both in flight and during ground operation, which will not unduly increase the engine diameter, in fact, which will not increase the engine diameter at all in certain embodiments, which will not require sealing or valving, which will not create drag and which is so constructed that a smaller exhaust gas outlet is presented by the engine parts, not including the noise suppressor parts, during normal operation as opposed to operation with the noise suppression apparatus functioning.

While we choose to show our invention with respect to the control of the creation of noise by an aircraft turbo-jet engine, such is done for purposes of illustration only, and it should be borne in mind that the principles dis-

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closed herein are applicable to noise creation control on any type of aerodynamic exhaust. In the drawing:

Fig. 1 shows a cross sectional view of a typical turbo-jet engine with an embodiment of our invention attached thereto and shown in its retracted position in solid lines while shown in its operative position in phantom.

Fig. 2 is a fragmentary cross sectional view of an embodiment of our invention with the noise suppressor vanes retracted.

Fig. 2A is a fragmentary cross sectional view of an embodiment of our invention with the noise suppressor vanes in their operable position,

Fig. 3 is a partial rear view of the embodiment shown in Fig. 2.

Fig. 3A is a partial rear view of the embodiment shown in Fig. 2A.

Fig. 4 is a view taken along line 4—4 of Fig. 2A.

Fig. 5 is a fragmentary cross sectional view of another embodiment of our invention which shows the noise suppressor vanes in their retracted position.

Fig. 5A is a fragmentary cross sectional view of another embodiment of our invention which shows the noise suppressor vanes in their operable position.

Fig. 6 is a partial rear view of the embodiment shown in Fig. 5.

Fig. 6A is a partial rear view of the embodiment shown in Fig. 5A.

Fig. 7 is a perspective view of adjacent noise suppressor vanes of the type used in Figs. 5, 5A and 6.

Fig. 8 is a fragmentary cross sectional view of the embodiment of our invention shown in Fig. 11 showing the externally clustered vanes in their operable position.

Fig. 8A is a fragmentary cross sectional view of the embodiment of our invention shown in Fig. 11 showing the externally clustered vanes in their retracted position.

Fig. 9 is a fragmentary cross sectional view of the embodiment of our invention shown in Fig. 11 showing the internally clustered vanes in their operable position.

Fig. 9A is a fragmentary cross sectional view of the embodiment of our invention shown in Fig. 11 showing the internally clustered vanes in their retracted position.

Fig. 10 is a view thru line 10—10 of Fig. 8A, enlarged.

Fig. 11 is a rear view of another embodiment of our invention which consists of both a plurality of internally clustered vanes and a plurality of externally clustered vanes.

Fig. 12 is a perspective view of the externally mounted vane shown in Figs. 8, 8A and 11.

Referring to Fig. 1 we see aircraft jet engine 10 which consists of air inlet 12, compressor section 14, combustion chamber section 16, turbine section 18, and exhaust outlet section or tailpipe 20. It will be noted that Fig. 1 shows a plurality of hollow, fin-type vanes 22 which have a single hole 24 in the forward edge of each vane and a plurality of small holes or nozzles 26 in the trailing edge of each vane. Vanes 22 are shown clustered in their inoperative position (solid lines) to form the engine tailcone in combination with movable inner body 28. Vanes 22 are also shown in their operable or silencing position in phantom. With vanes 22 in their operating position, inner body 28 has moved forward as shown in Fig. 2A in this embodiment.

Air enters engine 10 through air inlet 12 and is compressed as it passes through compressor section 14. The air is then heated as it passes through combustion chamber section 16 due to the combustion which takes place within combustion chamber 30. Fuel enters combustion chamber 30 through fuel manifold 32 and fuel nozzles 34. Spark plug 36 causes the ignition of the atomized fuel from fuel nozzle 34 within combustion chamber 30. As the heated air leaves combustion chamber section

16 it passes through turbine 18 and then is discharged through the gas passage which is formed between tailpipe 20 and inner body 28. When vanes 22 are in their retracted position, so as to be clustered downstream of inner body 28 to form a conical continuation thereof the exhaust gas passes through exhaust outlet 38, which exhaust outlet 38 is formed by tailpipe 20 and inner body 28, which is concentric with tailpipe 20 and contained therein. The exhaust gases are permitted to pass through exhaust outlet 38 when noise suppression is not desired. As mentioned supra and more fully described in U. S. application Serial No. 58,418 entitled, "Ground Exhaust Noise Suppressors," and filed April 30, 1956, the discharge of the exhaust gases through the large nozzle or exhaust outlet 38 creates a low frequency noise. When noise suppression is desired, vanes 22 are pivoted radially outward into their extended position so as to extend through or across the gas passage formed by tailpipe 20 and inner body 28 and extend radially outward of tailpipe 20. Relatively large hole or aperture 24 in the forward edge of vane 22 intercepts or is presented to the gas passage and causes the exhaust gases to pass through hollow vane or fin 22 and be discharged through the plurality of relatively small holes, nozzles or apertures 26 in the trailing edge of vane 22. As mentioned supra and more fully described in referenced application, this causes the noise created by the jet wake to fall into a predominately high frequency noise spectrum.

Figs. 2, 2A, 3 and 3A show one embodiment of our invention of a jet engine exhaust noise suppressor mechanism in greater detail.

It should be noted that Figs. 2 and 3 demonstrate the suppression mechanism in its retracted or non-silencing position while Figs. 2A and 3A show the noise suppression mechanism in its operable position. When the vanes 22 are in their retracted position (as in Figs. 2 and 3), axially movable inner body 28 has moved rearwardly on rollers 40 which pivot in inner body at 41 and bear against support member 43 so as to form a smooth tailcone with the plurality of retracted vanes 22 which are clustered to form a cone just downstream of inner body 28.

It will be noted that hole 24 in the forward edge of vane 22 is not blocking off when vane 22 is retracted as it is not deemed necessary since there is no significant pressure drop across the inlet hole 24 and the outlet holes 26 of vane 22.

With vanes 22 in their retracted position, exhaust gas flow is through the gas passage formed between tailpipe 20 and inner body 28 such that the exhaust gas passes through exhaust outlet 38. It will be noted that tailcone 20 has inwardly directed scallops, trough or dimples 42 which butt against or come into close proximity to inner body 28 in several places about the inner periphery of tailpipe 20 as best shown in Fig. 3. The function performed by the plurality of progressively inwardly directed troughs 42 is to block off the exhaust gas passage between adjacent hollow vanes 22 when they are in their extended position, as shown in Figs. 2A and 3A. If this area were not blocking off, the optimum effect of passing the exhaust gas through nozzles 26 would not be realized since the pie shaped segments formed between adjacent hollow vanes 22 when extended, would present large nozzle areas from which exhaust flow and low frequency noise would be created. It is necessary, to avoid drag, that troughs 42 be smoothly faired forwardly or upstream so that it gradually and smoothly blends into tailpipe 20 at their forward end. While inwardly directed troughs 42 may be integral with tailpipes 20 as by being formed from the same piece of sheet metal as tailpipe 20, it is also possible that they may be separate pieces affixed to tailpipe 20.

Referring to Fig. 3 we see that during normal flight operation, which will be a non-silencing operation, the engine exhaust gas passes through a plurality of openings

38 which are formed between inner body 28 and tailcone 20 and are bounded by adjacent inwardly directed troughs 42. In this configuration, due to the existence of inwardly directed troughs 42 a symmetrical but interrupted and non-continuous exhaust outlet is presented. This is contrary to the usual concept of an exhaust outlet which presents a continuous exhaust area which is formed between two concentric members of circular cross section.

Now referring to Figs. 2A and 3A, we see hollow noise suppressor vane 22 in its extended or operable position. With vanes 22 in this position the exhaust gas flow passes between tailpipe 20 and inner body 28, which is now in a position forward or upstream of what it was when the vanes were retracted, and then enters hole 24 in the forward edge of vane 22 and may be turned substantially radially outward by turning vanes 44 and after passing through hollow vane 22 to be discharged rearwardly into atmosphere through the plurality of rearwardly directed nozzle 26 on the trailing edge of vane 22. As best shown in the lower half of Fig. 3 since the inwardly directed troughs 42 block off the area between vanes 22, all of the exhaust gas must pass through vanes 22 and then through small area holes or nozzles 26. By use of the apparatus just described, the result of discharging the exhaust gases through a plurality of small nozzles as opposed to one nozzle is accomplished, thereby causing the noise created by the discharged exhaust gas to be predominately in a high frequency, inaudible spectrum instead of a predominately low frequency spectrum.

It is important that the thrust generated by engine 10 in normal flight be unaffected by the silencing operation. For this reason, the number and size of vanes 22 and nozzles 26 are so selected that the tested flow characteristics of the gas flow through exhaust outlet 38 is the same as through nozzles or holes 26.

Now referring to Figs. 2 and 2A relative to the mechanism which is used to actuate the plurality of hollow vanes 22 to either rotate radially inward or cluster into conical form and form the engine tailcone in combination with inner body 28 and also to rotate radially outwardly and through the exhaust gas passage formed between tailpipe 20 and inner body 28 so that the hole 24 in the forward edge of vane 22 intercepts or traverses this passage and such that the remainder of the vane projects radially outward of tailpipe 20 so as to cause nozzles 26 to be directed rearwardly of engine 10. It will be noted that inner body 28 rolls on rollers 40 which are rotatably supported in inner body 28 and contact support cylinder 43, as shown in Fig. 4.

Fixed member 48, which may be cylindrical in shape, is provided, together with fixed member 50, which is also cylindrical in shape and concentrically located in fixed member 48, to form passages for pressurized actuating fluids. Seal 51 is provided to seal fluid in member 50. Fixed member 50 includes hydraulic cylindrical wall member or piston 52 at its rearward end. If it is desired to cause the plurality of hollow vanes 22 to assume their operative, silencing or radially extended position as shown in Figs. 2A and 3A, a source of compressed fluid, probably compressed air from compressor section 14 of engine 10, may be passed through the gas passage formed between fixed members 48 and 50 to be directed into hydraulic compartment 54. The force of the compressed air acts against face 56 of movable hydraulic cylinder 58 causing the hydraulic cylinder 58 to move to its far left position as shown in Fig. 2A. Since hydraulic or pneumatic cylinder piston unit 58 is rigidly attached to inner body 28, the leftward movement of cylinder 58 causes the leftward or forward movement of inner body 28 such that the inner body is moved to the far left or forward position shown in Fig. 2A and the plurality of vanes 22, which pivot both about fixed pivot point 60 and movable pivot points 62 and 64. Movable pivot point 64 joins vane 22 to inner body 28 such that the

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forward or upstream movement of inner body 28 causes vane 22 to pivot or rotate radially outward to assume the position shown in Figs. 2A and 3A. It will be noted, that with vanes 22 in this extended position and with inner body 28 in its upstream or forward position, the gas passage formed between inner body 28 and tailpipe 22 is of greater radial dimension R_o , than the radial dimension R_r of the gas passage when the plurality of noise suppressor vanes are retracted radially inward to cluster and form the engine tailcone with inner body 28. To cause vanes 22 to retract uniformly, the compressor air source is no longer directed into hydraulic compartment 54 but is now directed through fixed member 50 into hydraulic compartment 66 so as to cause a rearwardly directed force against face 68 of hydraulic cylinder 58 to cause hydraulic cylinder 58 and inner body 28 to move to the right, rearward or downstream to assume the position shown in Figs. 2 and 3. The movement of inner body 28 caused by the movement of hydraulic cylinder 58 and the pivot action which occurs at pivots 60, 62 and 64, previously described, causes hollow suppressor vanes 22 to rotate radially inward and rearwardly to cluster into conical form as shown in Figs. 2 and 3.

It will be noted that this embodiment has accomplished noise suppression without the need for valving or sealing flaps.

Figs. 5, 5A, 6, 6A and 7 show another embodiment of our invention in which the hollow vane noise suppressors are shown in their retracted positions in Figs. 5 and 6 and in their extended or silencing positions in Figs. 5A and 6A. In the non-silencing or vane retracted position the exhaust gas flow is between tailpipe 20' and inner body 28', which is fixed and terminates short of said tailpipe 20'. It will be noted that the plurality of hollow noise suppression vanes 22' cluster in conical formation downstream of inner body 28' so as to form the engine tailcone and to act in unison with tailpipe 20' to provide a continuous exhaust gas outlet 38' between vanes 22' and outlet 79 of tailpipe 20'. It will be noted that due to the particular shape of hollow noise suppressor vanes 22', a relatively small and probably supersonic exhaust outlet or nozzle 38' is provided for use during flight or non-noise suppression operation. Hollow vanes 22' have the plurality of small holes or nozzles 26' in their trailing edge and the single large opening 24' in its forward or leading edge. A plurality of pivotable flaps 80 are shown in Fig. 5 to be pivotable about inner body 28' at pivots 102 and to be in abutting or sealing relation one to the other and lying against the forward edge of hollow vane 22' so as to block off holes 24' in the forward edge of hollow edge 22' so that no exhaust gas passes into hollow vanes 22' when the vanes are in their retracted or non-silencing position. To permit air to flow into these vanes from the high pressure area in which hole 24' is located would be to introduce inefficiency into the jet engine propulsion system area.

It will be noted that vanes 22' are shown in Figs. 5 and 6 to be in a clustered position downstream of inner body 28' where they form first an expanding and then a contracting conical continuation of inner body 28'. Vanes 22 are roughly triangular in longitudinal cross section of which trailing edge 81 forms the base of the triangle, and the forward edge of the vane contains the other two triangle legs 83 and 85 plus apex 37.

To cause hollow vanes 22 to move in unison from their retracted or tailcone position as is shown in Figs. 5 and 6 to their operable or suppressing positions as shown in Figs. 5A and 6A, vanes 22 must be rotated radially outward at the same time that they are moved rearwardly or downstream. Figs. 5A and 6A show hollow vanes 22' in their operable position such that the exhaust gas flow passes between tailpipe 20' and inner body 28', through opening or hole 24' in the forward edge of hollow vane 22', then through hollow vane 22' 75

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to be discharged rearwardly through the plurality of small holes or nozzles 26' which direct the jet exhaust downstream so as to effect thrust propulsion. In this embodiment, vanes 22' are shaped to nearly abut one another in their extended positions thereby diminishing the problem of the spacing between them referred to previously. In this configuration a sealing flap 82 is made integral with vane 22' to perform a sealing function between adjacent vanes 22' when in their extended positions thereby preventing the discharge of exhaust gas through the area between adjacent vanes. Because sealing flap 82 is of small size, the drag problem introduced by its use is negligible, therefore, it is virtually radially extending.

The actuating mechanism 93 to move the plurality of vanes 22' in unison is shown in Figs. 5 and 5A. The actuating system consists of fixed hollow rod or cylinder 84 which pivotally carries link or arm 86 which, in turn, pivotally attaches to the trailing edge of each hollow vane 22' at 92. Fixed member 84 also carries fixed piston 88, which extends substantially radially therefrom to engage the inner surface of axially movable hydraulic or pneumatic cylinder 90 to form pressurizable compartments 98 and 104 therewith. Vane 22' is pivotally attached to link 86 by pivot 92 and is further pivotally attached to cylindrical sealing unit 94, which projects from or is part of movable cylinder 90, at pivot 96. As a high pressure fluid source, such as the air from compressor section 14, is introduced into chamber 98, cylinder 90 moves rearwardly or to the right and since it is integrally attached to sealing cylinder 94, it moves cylinder 94 with it. The rearward or right movement of cylinder 90 causes vanes 22' to move from their retracted position as shown in Figs. 5 and 6 to their operable or extended positions as shown in Figs. 5A and 6A. This is accomplished by the pivot, in unison, of vanes 22' about pivots 96 on sealing cylinder 94 and about pivots 92 on connecting links 86, which is in turn pivoting about fixed unit 84 at pivot point 100. When movable cylinder 90 reaches its far right or rear position, vanes 22' are in their extended position and the plurality of flaps 80 have rotated about their pivot points 102, by which they are pivotally attached to inner body 28' and come to rest against sealing cylinder 94 or abut against any stop lug. With vanes 22' so extended, the exhaust gas flow passes through them and through the small holes or nozzles 26' to effect noise suppression as described previously.

To cause vanes 22 to move in unison to their non-operative or tailcone position as shown in Figs. 5 and 6, a pressure source is introduced into chamber 104 of cylinder 90 and is removed from chamber 98 of cylinder 90 to cause movable cylinder 90 to move to its upstream or far left position, carrying sealing cylinder 94 therewith. In unison, an inward and forward movement of pivot point 96 and the radially inward movement of pivot point 92 as connecting link or rod 86 pivots about pivot 100 on fixed member 84. Due to this angularity of this motion, the plurality of flaps 80 move radially outward along edge 85 of hollow vanes 22' until they are seated to cover the plurality of holes 24' in the forward edge of vanes 22' and abut one another to perform a sealing function. By way of comparison, to demonstrate that a smaller exhaust outlet is presented radiuswise by continuously exhaust outlet 38', it will be noted that radial dimension of continuous outlet 38' which is effective when the vanes are in their retracted, inoperable position is indicated as R_r' in Fig. 5 while the radial dimension through which exhaust gas flows to get into hollow vanes 22' when in their operable position is designated as R_o' in Fig. 5A. This difference in radial dimension is desirable since it is the intention of this noise suppression mechanism to be operable with-

out adversely effecting engine thrust. To accomplish this, the thrust created by passing the exhaust gas through outlet 38' during non-silencing operation must be the same as that created by passing the exhaust gases through the plurality of small nozzles 26' during silencing or noise suppression operation.

The larger radial dimension of the exhaust outlet into hollow vanes 22', Ro', is necessary for the exhaust outlet presented by holes 24' is not continuous circumferentially as is outlet 38'.

Further, when the noise suppression mechanism is in its retracted position, the exhaust nozzle area at 38' is sized to engine requirements such that the exhaust gases are caused to increase to supersonic velocity at the nozzle throat (smallest area). If exhaust gases were introduced into noise suppressor vanes 22' as supersonic velocity, there would be damaging pressure and engine thrust losses. To prevent thrust loss, the gas passage area is increased in dimension, as from Rr' to Ro', thereby reducing gas velocity to reduce thrust losses by permitting the gas to more smoothly turn into vane 22'. The exhaust gas velocity is increased in velocity for thrust purposes as it passes through small holes, apertures or nozzles 26' which direct the exhaust gases downstream during silencing operation.

Fig. 7 is shown to give a clearer demonstration of how the exhaust gas passes through holes 24' at the forward edge of vanes 22', then through vanes 22' to be discharged rearwardly through the plurality of holes or nozzles 26'.

Now referring to Figs. 8, 8A, 9, 9A and 11 we see another embodiment of our invention in which both internal and external hollow vane noise suppressors are used.

Figs. 9 and 9A show jet engine 10 with convergent tailpipe 20'' and inner body 28'' and nacelle 110. Hollow vanes 22'' are actuated and operated in the same fashion as the vanes shown and described in Figs. 2 and 2A. Vanes 22'' are hollow vanes which may be rotated radially outward through the exhaust gas outlet 38'' and extend radially beyond the tailpipe 20'' and nacelle 110. Vanes 22'' have a plurality of small holes, apertures or nozzles 26'' in their trailing edge and of a single aperture or hole 24'' in their forward edge.

It will be recalled that in referring to the structure shown in Figs. 2 and 2A it was necessary to provide inwardly directed troughs 42 to block off the area of the exhaust gas outlet between hollow vanes 22 when they were in their extended or operable position. This was necessary so that exhaust gas would be caused to pass through the plurality of small holes or nozzles 26, since these holes or nozzles would be the only exhaust area available for the gas. The configuration shown in Figs. 8, 8A, 9, 9A and 11 and Fig. 8A (see Fig. 8) utilizes the plurality of external hollow vanes 112, which are pivoted about the outlet 79' of tailpipe 20'' at pivot 114 and are actuated by any suitable unit such a pivotable hydraulic or pneumatic cylinder and piston unit 116 which is located externally of tailpipe 20'' and nacelle 110 and carries actuating rod 118 which is pivotally attached to hollow vane 112 at pivot point 120. As compressed air or any other fluid source is provided to one or the other side of piston 117, which is located within cylinder 116, the force created will cause linkage 118 and hollow vane 112 to rotate or pivot either in a forward or rearward direction. As shown in Figs. 8 and 11, vanes 112 are in their extended or noise suppressing position. As shown in Fig. 8A, vanes 112 are in their retracted or forward position, which is their inoperative position where they lie longitudinally against tailpipe 20'' or nacelle 110. Vanes 112 are positioned alternately between vanes 22'' and carry pie shaped segment 122 which abuts against adjacent sides 124 and 126 of vanes 22'' and have an opening or aperture 128 in a forward edge so that, when extended as shown in Figs. 8

and 11, the exhaust gas passes through the exhaust outlet formed by tailpipe 20'' and inner body 28'', through opening 128 in the forward edge of vane 112, thence through vane 112 to be discharged rearwardly through the plurality of small holes or nozzles 130 in the trailing edge of vane 112. It will be noted in Fig. 8 that engine nacelle 110 projects beyond outlet 79' of tailpipe 20'' so as to form a convergent-divergent exhaust nozzle therewith when the vanes are in their retracted or non-operative Fig. 5A, 6A position. It will be noted that surface 119 of nacelle 110 is divergent radially outward from exhaust outlet 38''.

By use of the embodiment shown in Figs. 8, 8A, 9, 9A and 11, all the area of exhaust outlet 38'' is not only blocked off to the normal gas flow so as to cause all exhaust gas to pass through the plurality of small holes or nozzles 26'' or 130, but also, the entire exhaust outlet 38'' is utilized effectively during noise suppression operation, and further, so that when vanes 112 and 22'' are in their retracted or non-silencing positions, a continuous and probably supersonic, exhaust outlet 38'' of convergent or convergent-divergent nozzle type is presented for cruise or normal flight operation.

Now referring to Fig. 8A we see engine nacelle 110 which encloses tailpipe 20'' and into which externally retractable vanes 112 are nested in their retracted position. As a forwardly directed force is placed upon vanes 112 by connecting rods 118 due to the proper pressurizing of vane actuating unit 116, so as to retract the vanes, it will be noted that pie shaped segment 122 of vane 112 will snugly fit into pie shaped aperture 132 of nacelle 110 so as to perform an exhaust gas blocking action and provide a smooth exhaust outlet for engine 10.

Pivotable doors 134 serve to enclose retracted vanes 112 when in their retracted positions. Doors 134 are shown in cross section in Fig. 10 and consist of two pivotable units 136 and 138 which have base members 140 and 142 which are integrally attached to curved members 144 and 146 and each pivots about points 148 and 150. In operation, when hollow vane 112 is rotated so as to go into its inoperative or retracted position, the forward edge of vane 112 contracts and depresses base members 140 and 142 to cause them to pivot about points 148 and 150 thereby closing the door unit 134 about the retracted vane 112 as shown on Fig. 10. Base members 140 and 142 are provided at the forward end of door unit 134 only. When vane 112 is to be rotated into its operable position, a forward movement by linkage 118 is translated into a rotary motion in vane 112 so as to release the pressure against base units 140 and 142 and apply a similar pressure to units 144 and 146, to cause them to open and permit the vane to go into its operable position. Here again, it will be noted that we have caused the engine exhaust gas to pass through a plurality of small apertures so that predominately high frequency, noise is created. Further, as described supra, the total flow characteristics through exhaust outlet 38'' is the same as through apertures 130 and 26''. Due to the movement of inner body 28'', a relatively small area exhaust outlet 38'' of convergent-divergent type is presented during normal flight when the exhaust gases may be at supersonic speed while a larger, lower velocity opening is provided during noise suppression operation to diminish aerodynamic losses in causing the exhaust gas to turn into vanes 22'' and 112. It should be borne in mind that while not necessarily so limited, the construction and actuation of vanes 22'' of Fig. 9 is identical to the construction and actuation of vanes 22 of Fig. 2.

It will be obvious to those skilled in the art that limits of vane movement are defined by vane abutment in the clustered position and by vane abutment against tail pipe 20 in the operable position.

It should be noted that in any of our configurations, turning vanes may be used at the inlet of the hollow vanes to assist exhaust gas turning.

We claim:

1. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe, an inner body substantially concentric with and contained within said tailpipe so as to form a gas passage therebetween, a plurality of hollow vanes each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said vanes being rotatably mounted on said device for movement from a clustered position downstream of said inner body, where they form a conical continuation of the inner body, outwardly to present said large apertures to said gas passage with the plurality of relatively small holes in the other side directed downstream, and means defining the limits of movement of said vanes.

2. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe, an inner body substantially concentric with and contained within said tailpipe so as to form a gas passage therebetween, a plurality of hollow vanes mounted on said device and each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, means to move said vanes from a clustered position downstream of said inner body, where they form a conical continuation of the inner body, outwardly to present said large apertures to said gas passage with the plurality of relatively small holes in the other side directed downstream, and means to block off said gas passage between adjacent vanes when the vanes are moved outward.

3. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe, an inner body substantially concentric with and contained within said tailpipe so as to form a gas passage therebetween, a plurality of hollow vanes each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said vanes being mounted on said device for movement to a clustered position downstream of said inner body, where they form a conical continuation of the inner body, and to an outwardly extended position to present said large aperture to said gas passage with the plurality of relatively small holes in the other side directed downstream, means to so move said vanes, and means to substantially block off said gas passage between adjacent vanes when in the outwardly extended position.

4. A noise suppression mechanism comprising an outer duct and inner body concentric with and located within said outer duct so as to form a gas passage therebetween, a plurality of elongated hollow vanes attached to said inner body and each having one hole in the forward edge thereof and a plurality of rearwardly directed small holes in the trailing edge thereof, an actuating mechanism connected to said vanes for moving them so that they may be clustered in conical form to provide a conical extension of said inner body when in their inoperative position and so that they may be extended radially outward beyond said outer duct while extending across said gas passage so that said forward holes are presented to said gas passage whereby said hollow vanes provide a passage between said small holes and said gas passage, and means to block off said gas passage between said vanes when the vanes are in their extended position.

5. A noise suppression mechanism comprising an outer duct and inner body concentric with and located within said outer duct so as to form a gas passage therebetween, a plurality of hollow vanes attached to said inner body and each having one hole in the forward edge thereof and a plurality of rearwardly directed small holes in the trailing edge thereof, an actuating mechanism connected to said vanes for moving them to a clustered position to form a conical extension of said inner body when in their inoperative position and to an operable position in which the vanes extend radially outward beyond said outer duct while traversing said gas passage so that said forward hole is presented to said gas passage and said hollow vane connects said small holes to said gas

passage while said small holes are directed downstream, and a plurality of inwardly directed troughs each projecting from said outer duct to said inner body so that said troughs blend smoothly into said outer duct at their forward ends and project progressively inward until they are in close relation to said inner body at their downstream ends to block said gas passage between said vanes when said vanes are in said operable position.

6. In combination with an aircraft jet engine having a compressor section, a combustion chamber section and a turbine section, a noise suppression mechanism attached to the downstream end of said turbine section comprising an outer duct of circular cross-section, and inner body of circular cross-section concentric with and located within said outer duct so as to form the engine exhaust gas passage therebetween, a plurality of hollow vanes attached to said inner body and each having one hole in the forward edge thereof and a plurality of rearwardly directed small holes in the trailing edge thereof, and an actuating mechanism connected to said vanes for moving them so that they may be clustered in conical form just downstream of said inner body when in their inoperative position to form the engine tailcone therewith and so that said vanes may be extended radially outward beyond said outer duct while traversing said exhaust passage whereby said forward holes connect said exhaust gas passage through said hollow vanes to said small holes to cause the engine exhaust gas passing through said gas passage to pass through said vanes and be discharged rearwardly through said small holes.

7. A noise suppression mechanism comprising an outer duct of circular cross-section, and axially movable inner body of circular cross-section concentric with and located within said outer duct so as to form a gas passage therebetween, a plurality of hollow vanes attached to said inner body and each having one hole in the forward edge thereof and a plurality of rearwardly directed small holes in the trailing edge thereof, an actuating mechanism connected to said vanes for moving them to a clustered position of conical form to provide a conical extension of said inner body when said inner body is in its farthest rearward position and said vanes are in their inoperative position and for moving them to an operable position in which the vanes extend radially outward beyond said outer duct while extending across said gas passage so that said forward hole is presented to said gas passage when said inner body is in its farthest forward position so that said hollow vanes form passages between said gas passage and said small holes which are now rearwardly directed.

8. A device for suppressing the noise of a jet engine exhaust comprising a convergent tailpipe of circular cross-section, a convergent and axially movable inner body substantially concentric with and contained within said tailpipe so as to form a gas passage therebetween and form an exhaust outlet therewith, and a plurality progressively inwardly directed troughs circumferentially spaced about said tailpipe and each projecting from said tailpipe to said inner body such that the forward ends of said troughs blend smoothly with said tailpipe while the rearward ends of said troughs are in close relation to said inner body so as to cause said gas passage to be symmetrical but non-continuous, a plurality of elongated hollow vanes mounted on said device for movement and each having a relatively large aperture near the base of its leading edge and having a plurality of relatively small apertures in its trailing edge, vane actuating means attached to said vanes comprising a pressurized cylinder-piston unit to move said vanes into a clustered position immediately downstream of said inner body when said inner body is in its farthest downstream position in which clustered position the vanes form a smooth conical continuation of the inner body to form an engine tailcone therewith, said tailcone being of such size to

form an exhaust outlet of relatively small total area with said tailpipe, said actuating means also adapted to move said vanes outwardly to present said large leading edge apertures to said gas passage while said vanes abut said tailpipe, said inner body and adjacent troughs while said inner body is in its farthest upstream position where said inner body forms a larger gas passage with said tailpipe due to its convergent shape and while the plurality of relatively small trailing edge holes are directed downstream, said actuating means also actuating said inner body.

9. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe having an outlet, an inner body substantially concentric with and contained within said tail pipe and terminating short of said tailpipe outlet so as to form a gas passage therebetween, a plurality of hollow vanes each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said vanes being movable from a clustered position downstream of said inner body, where they form first an expanding and then a contracting conical continuation of said inner body so that a relatively small exhaust outlet is formed between said tailpipe and said vanes so clustered, outwardly to an operable position in which said large apertures are presented to an enlarged gas passage due to the movement and positioning of said vanes rearwardly while the plurality of relatively small holes in the other sides of said vanes are directed downstream, and means to block off said gas passage between adjacent vanes when said vanes are in said operable position.

10. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe having an outlet, an inner body substantially concentric with and contained within said tailpipe and terminating short of said tailpipe outlet so as to form a gas passage therebetween, a plurality of hollow vanes each having a relatively large aperture in a first side and a plurality of relatively small apertures in a second side, said vanes being mounted on said device for movement to a clustered position downstream of said inner body where they form first an expanding and then a contracting conical continuation of said inner body due to the shape of said vanes so that a relatively small exhaust outlet is formed between said tailpipe and said vanes so clustered, and for movement from said clustered position outwardly to an operable position to present said large aperture to an enlarged gas passage due to the movement and positioning of said vanes rearwardly while the plurality of relatively small holes in the second sides are directed downstream, and means to block off said gas passage between adjacent vanes when said vanes are in said operable position, and means to so move said vanes.

11. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe having an outlet, a fixed inner body substantially concentric with and contained within said tailpipe and terminating short of said tailpipe outlet so as to form a gas passage therebetween, a plurality of hollow vanes each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said vanes being positionable in a clustered position downstream of said inner body where they form first an expanding and then a contracting conical continuation of said inner body so that a relatively small exhaust outlet is formed between said tailpipe and said vanes so clustered, means to seal said large vane apertures from said gas passage when said vanes are so clustered, said vanes also being positionable outward to present said large apertures to an enlarged gas passage due to the movement of said vanes and sealing means while the plurality of relatively small holes are directed downstream, means to block off said gas passage between adjacent vanes when said vanes are moved outward, and means to so position said vanes.

12. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe having an outlet, a fixed inner body substantially concentric with and contained within said tailpipe and terminating short of said tailpipe outlet to form a gas passage therebetween, a plurality of hollow vanes each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said vanes being movable to a clustered position downstream of said inner body where they form first an expanding and then a contracting conical continuation of said inner body whereby a relatively small continuous exhaust outlet is formed between said tailpipe and said vanes so clustered, means to seal said large apertures from said gas passage when said vanes are so clustered, said vanes also being movable in unison and rearwardly and outwardly simultaneously to an operable position to present said large aperture to an enlarged gas passage due to the movement and positioning of said vanes rearwardly and in which operable position the plurality of relatively small holes in the other sides are directed downstream, means to block off said gas passage between adjacent vanes when said vanes are in said operable position, and vane actuating means comprising a pressurizable cylinder unit which is axially movable and to which each of said vanes pivotally attach, a fixed piston unit contained within and forming pressurizable compartments with said movable cylinder, and an arm pivotally attached to each of said vanes and being pivotally attached to a fixed point in said actuating means.

13. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe having an outlet, an inner body substantially concentric with and contained within said tailpipe and terminating short of said tailpipe outlet to form a gas passage therebetween, a plurality of hollow vanes each having a relatively large aperture in its forward edge and a plurality of relatively small apertures in its trailing edge, each of said vanes being roughly triangular in longitudinal cross-section with said trailing edge as the triangle base and which forward edge includes the other triangle legs including the triangle apex, said vanes being retractable to a clustered position downstream of said inner body where they form first an expanding and then a contracting conical continuation of said inner body due to the shape of said vanes whereby a relatively small supersonic exhaust outlet is formed between said tailpipe outlet and said vane apexes, said vanes also being movable rearwardly and outwardly to an operable position to present said large aperture to an enlarged gas passage due to the movement and positioning of said vanes rearwardly while the plurality of relatively small holes in the other edge directed downstream, means to block off said gas passage between adjacent vanes when said vanes are in said operable position, and means to actuate said vanes.

14. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe, an inner body substantially concentric with and contained within said tailpipe so as to form a gas passage therebetween, a first plurality of hollow vanes mounted on said device for movement and each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said vanes being movable from a clustered position downstream of said inner body, where they form a conical continuation of the inner body, outwardly to an operable position to present said large apertures to said gas passage while the plurality of relatively small holes in the other edges are directed downstream, and a second plurality of hollow vanes mounted on said device for movement and each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said second plurality of vanes being movable from a retracted position external of said tailpipe outwardly to an operable position to present said large aperture to said gas passage in locations between the vanes of said first plurality while the plurality of rela-

tively small holes in said second vane plurality are directed downstream.

15. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe, an inner body substantially concentric with and contained within said tailpipe so as to form a gas passage therebetween, a first plurality of hollow vanes mounted on said device for movement and each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said vanes being movable from a clustered position downstream of said inner body, where they form a conical continuation of the inner body, outwardly to an operable position to present said large apertures to said gas passage while the plurality of relatively small apertures are directed downstream, a second plurality of hollow vanes mounted on said device for movement and each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said second plurality of vanes being movable from a retracted position external of and longitudinally against said tailpipe outwardly to an operable position to present said large aperture to said gas passage in locations between the vanes of said first plurality while the plurality of relatively small holes in said second vane plurality are directed downstream, means to actuate said first plurality of vanes, and means to actuate said second plurality of vanes.

16. A device for suppressing the noise of a jet engine exhaust comprising a tailpipe, an axially movable inner body substantially concentric with and contained within said tailpipe so as to form a gas passage therebetween, a first plurality of elongated hollow vanes each pivotally attached to said inner body and each having a relatively large aperture in its leading edge and a plurality of relatively small apertures in its trailing edge, said vanes being movable from a clustered position downstream of said inner body, where they form a conical continuation of said inner body, outwardly to an operable position to present said large aperture to said gas passage while the plurality of relatively small holes are directed downstream, a second plurality of hollow vanes

mounted on said device for movement and located externally of said tailpipe and each having a relatively large aperture in one side and a plurality of relatively small apertures in another side, said second plurality of vanes being movable between a retracted position longitudinally against said tailpipe outwardly to an operable position to present said large aperture to said gas passage in locations between the vanes of said first plurality while the plurality of relatively small holes in said second vane plurality are directed downstream, means to actuate said first plurality of vanes, means to actuate said second plurality of vanes, and means to actuate said inner body.

17. A device for suppressing the noise of a jet engine exhaust comprising a convergent tailpipe of circular cross-section, a convergent and axially movable inner body substantially concentric with and contained within said tailpipe to form a gas passage therebetween and form an exhaust outlet therewith, a plurality of elongated hollow vanes each having a relatively large aperture near the base of their leading edge and having a plurality of relatively small apertures in their trailing edge, vane actuating means attached to said vanes comprising a pressurized cylinder-piston unit to move said vanes into a clustered position immediately downstream of said inner body when said inner body is at one end of its travel where the vanes form a smooth conical continuation of the inner body to form an engine tailcone therewith, said tailcone being of such size to form an exhaust gas outlet of relatively small total area with said tailpipe, said actuating means also moving said vanes outwardly to an extended position to present said large leading edge apertures to a larger gas passage formed when said inner body is at the opposite end of its travel where said inner body forms a larger gas passage with said tailpipe due to its convergent shape, and while the plurality of relatively small trailing edge holes are directed downstream.

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