Oct. 30, 1962 J. A. LAWLER ETAL 3,061,038

JET ENGINE NOISE SUPPRESSION NOZZLE WITH MULTIPLE SETTINGS

Filed Oct. 30, 1959 5 Sheets-Sheet 1

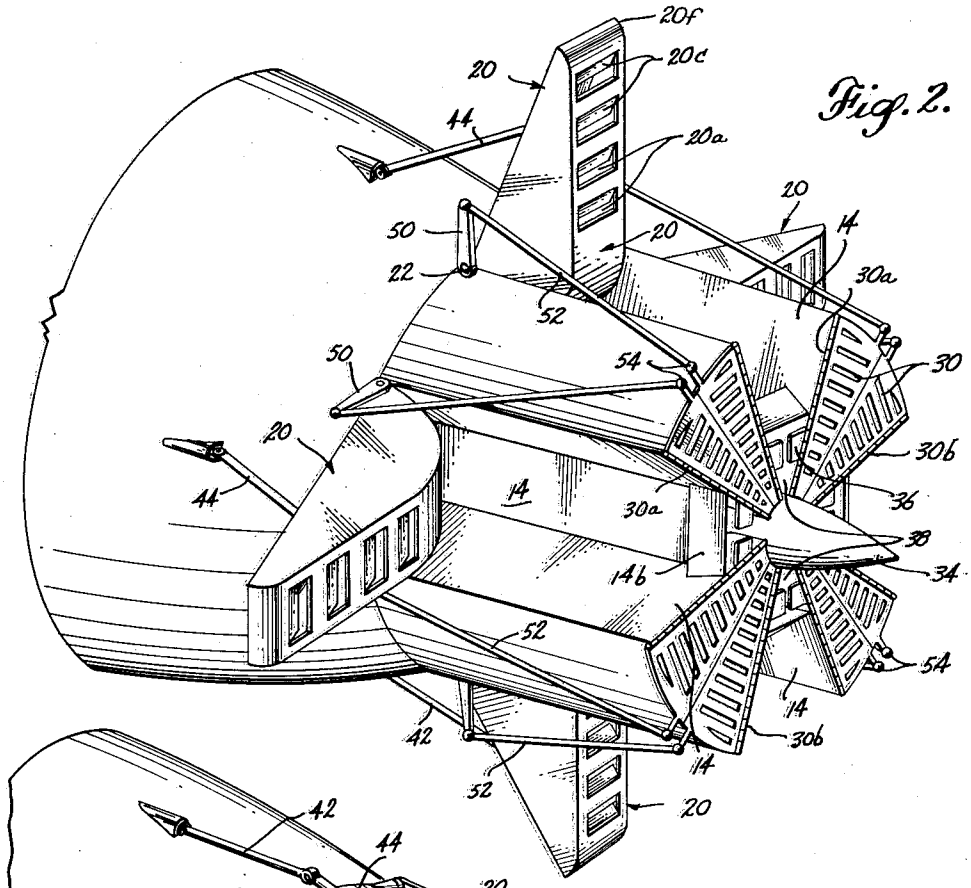


Fig. 2.

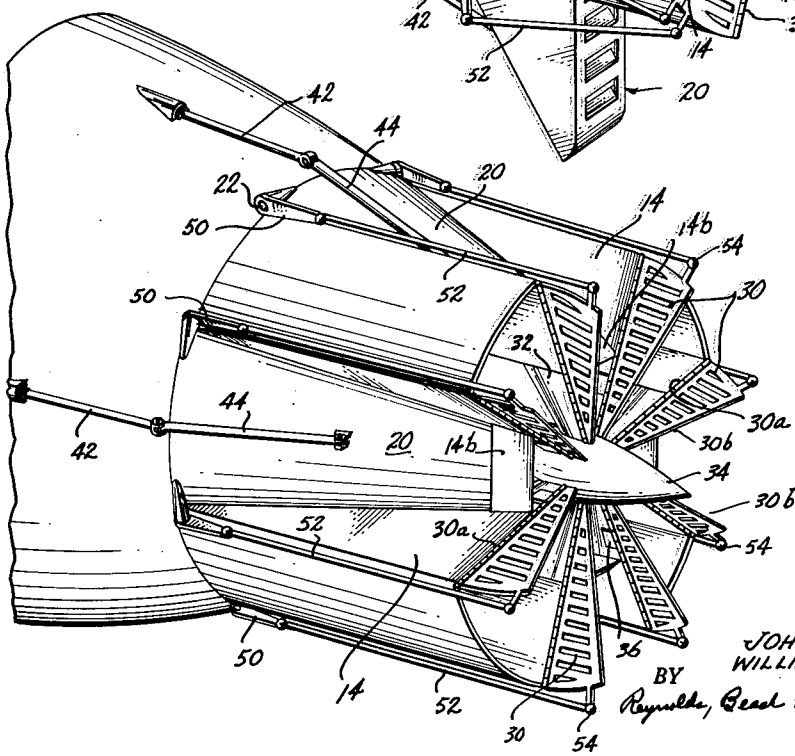


Fig. 1.

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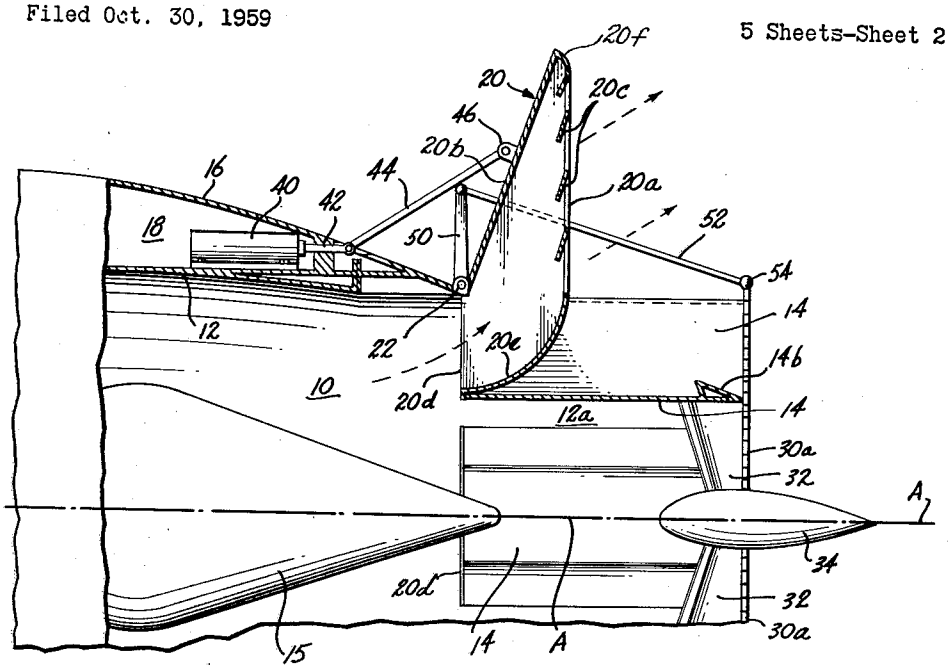


Fig. 6.

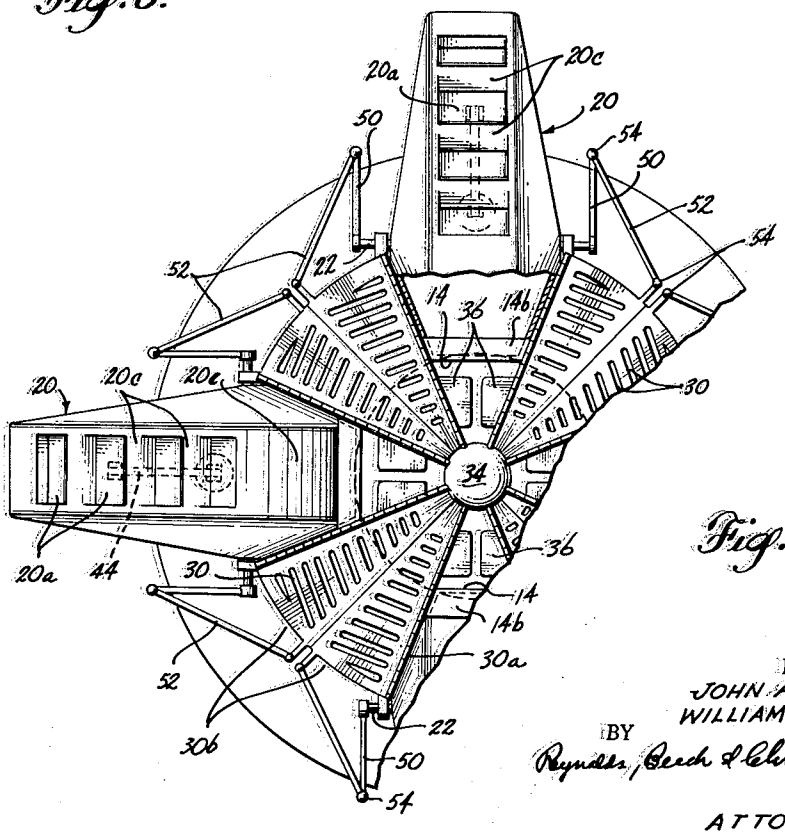


Fig. 3.

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JET ENGINE NOISE SUPPRESSION NOZZLE WITH MULTIPLE SETTINGS

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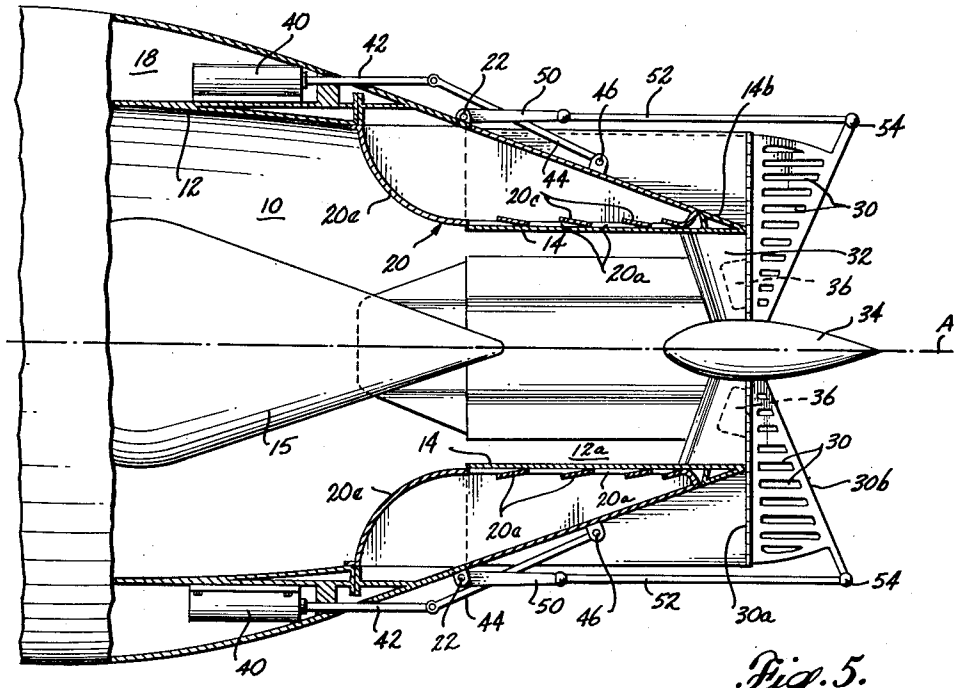


Fig. 5.

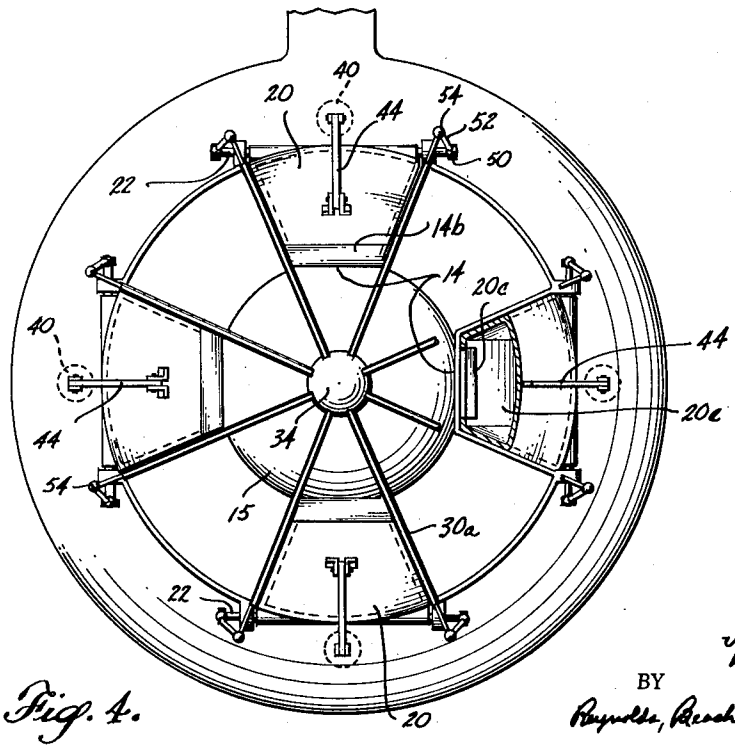


Fig. 4.

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Fig. 7.

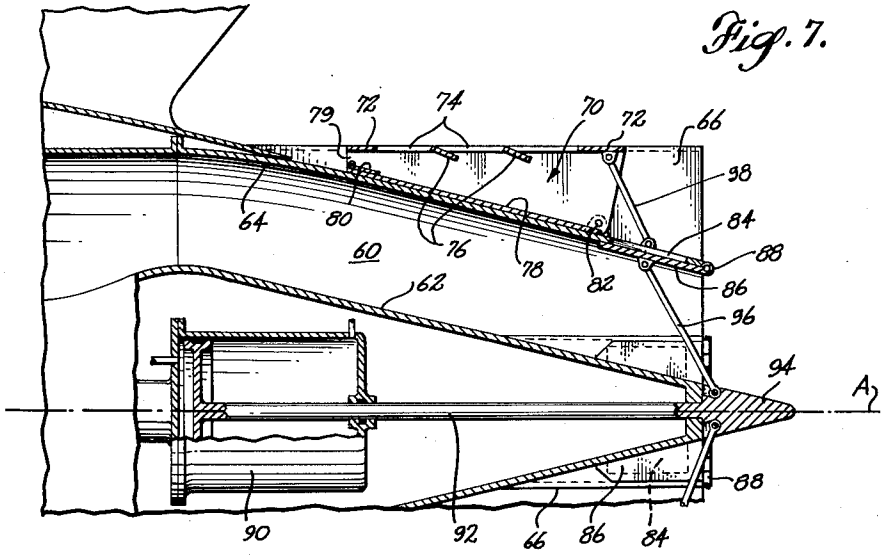
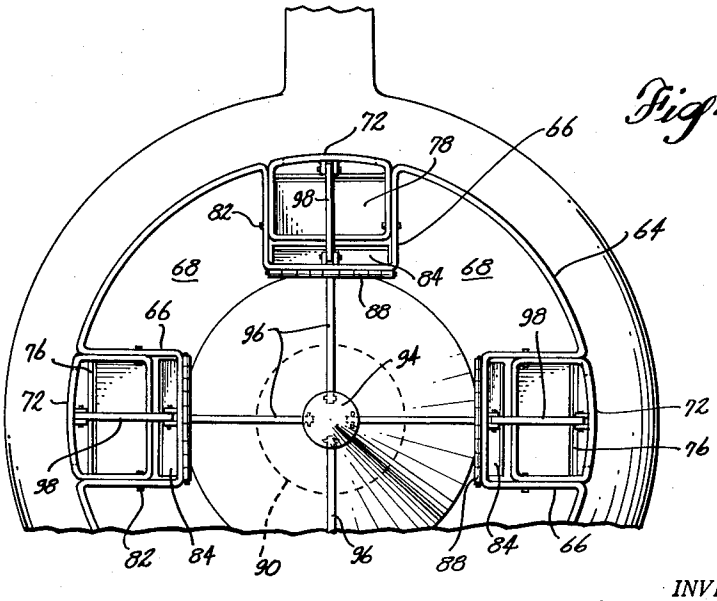


Fig. 8.



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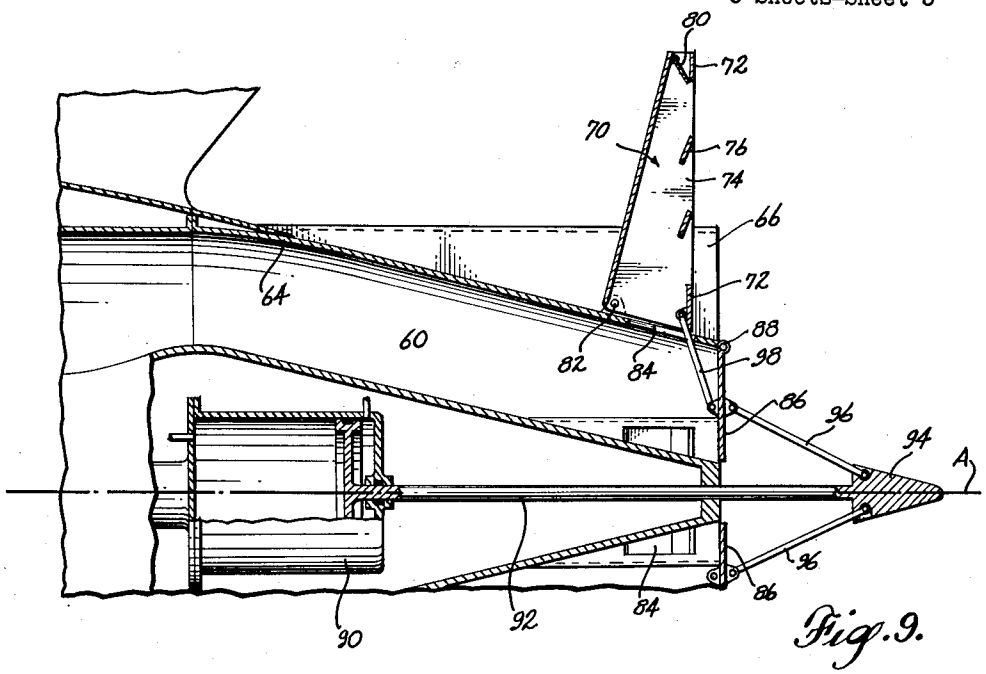


Fig. 9.

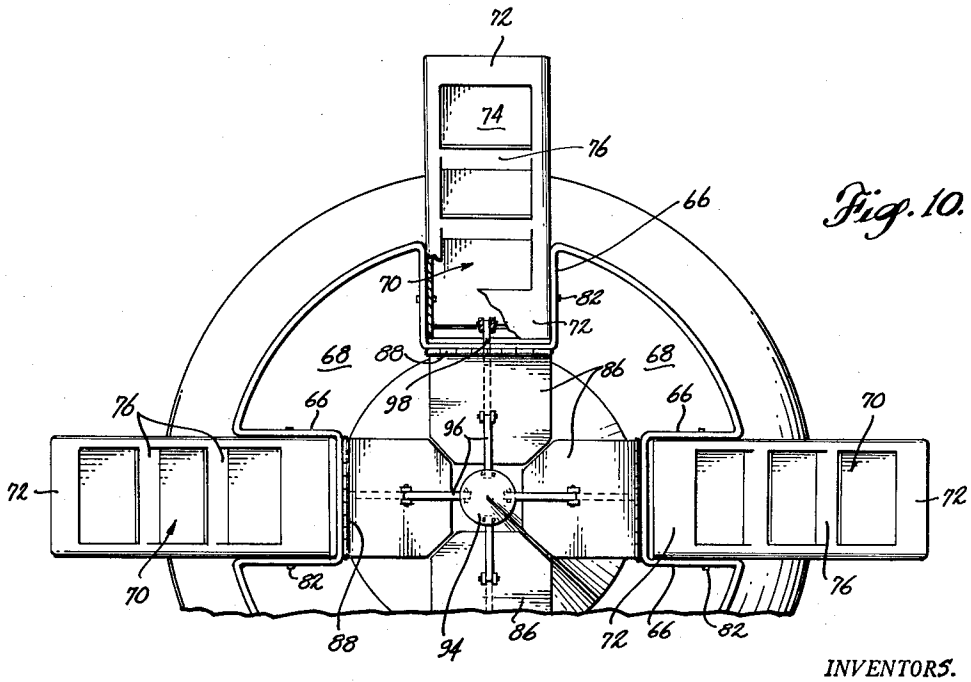


Fig. 10.

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3,061,038

JET ENGINE NOISE SUPPRESSION NOZZLE WITH MULTIPLE SETTINGS

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Filed Oct. 30, 1959, Ser. No. 849,826
10 Claims. (Cl. 181—33)

This invention relates to improvements in low-noise nozzles for jet propulsion engines and is directed primarily to the provision of efficient and practicable nozzles which, in their cruise setting, achieve moderate but sufficient noise suppression for operating requirements, whereas in the take-off setting produce maximum noise suppression. The invention is herein illustratively described by reference to the presently preferred embodiments thereof; however, it will be recognized that certain modifications and changes therein with respect to details may be made without departing from the underlying essentials involved.

Experience has shown that a moderate amount of jet noise suppression is desirable during normal flight conditions in order to avoid structural vibration problems and passenger discomfort in jet aircraft. However, when a jet airplane is climbing in the vicinity of an airport, such as from an altitude of 400 to 1200 feet, much greater noise suppression is desirable in order to avoid disturbance of nearby residential communities. No satisfactory fixed-type suppression nozzle has yet been discovered which achieves suppression for take-off and climb operation which does not also introduce excessive performance losses, both internal and external, for efficient operation during normal flight or cruise conditions. Nevertheless, fairly large losses can be tolerated during climb if necessary in order to gain the requisite noise reduction.

With these considerations in mind, together with others hereinafter mentioned or known in the art, the present invention proceeds to the provision of a multiple setting noise suppression nozzle which satisfies the different operating requirements mentioned above in a practicable and efficient manner.

More specifically the invention provides a compact and efficient nozzle of this type which in the stowed position of the extendable elements imposes minimum drag accompanied by efficient jet operation with moderate noise suppression. In the extended position of the nozzle elements, for achieving maximum noise suppression, net effective orifice area in the exit plane, matching engine load requirements, is maintained approximately the same as in the cruise setting.

In the disclosed, preferred embodiments the peripheral nozzle troughs or channels, which guide slipstream air into the regions between jet stream branches or lobes formed by these troughs, produce moderate noise suppression for cruise operation. In both illustrated emmodiments this basic nozzle configuration is modified for attaining maximum noise suppression by raising or extending a plurality of auxiliary nozzle ducts, normally stowed in the channels. When extended, these auxiliary ducts "scoop" gas from the nozzle and discharge it rearwardly and outwardly at spaced locations about the nozzle periphery, hence in a dispersed manner promoting rapid admixture with slipstream air. Partial reduction of the normal exit opening is effected in one case by multiply apertured doors which close with auxiliary nozzle extension, and thereby permit restricted discharge of gases supplementally to that from the auxiliary ducts. In another case the cruise lobes are enhanced or deepened by extension of tabs or doors into the jet core region in conjunction with auxiliary duct extension.

An important feature of the invention resides in the nesting of the extendable nozzle ducts in the channels or troughs which define the cruise orifice lobes. A further feature pertains to the pivotal mounting of these auxiliary ducts between the trough sides so that when swung outwardly to radially extended position their inner ends communicate with the nozzle interior to intercept or receive gases for discharge.

An additional feature resides in the arrangement by which the retracted auxiliary ducts themselves serve as guiding or fairing surfaces along which slipstream air flows efficiently into the regions between jet stream lobes, thus producing noise suppression with minimum loss from drag in the cruise condition.

The foregoing and other features, objects and advantages of the invention will become more fully evident from the following description based on the accompanying drawings.

FIGURE 1 is a rear perspective view of the preferred form of the improved multiple setting nozzle in cruise position.

FIGURE 2 is a similar view with the nozzle in maximum noise suppression or take-off position.

FIGURE 3 is a rear view of the nozzle in the position shown in FIGURE 2, with parts broken away for convenience in illustration.

FIGURE 4 is a rear view of the nozzle in the position shown in FIGURE 1.

FIGURE 5 is a side view of the improved nozzle in cruise position with parts broken away approximately along a longitudinal midplane in order to show details of construction.

FIGURE 6 is a view similar to FIGURE 5 with the nozzle in the take-off setting and with still other parts broken away for convenience of illustration.

FIGURE 7 is a sectional side view with parts broken away showing a modified nozzle configuration, with the nozzle parts in the cruise setting.

FIGURE 8 is a rear view with parts broken away showing the same modification with the parts positioned as in FIGURE 7.

FIGURE 9 is a view similar to FIGURE 7 of the modified nozzle with parts broken away to show certain details, with the nozzle parts in the take-off or maximum noise suppression setting.

FIGURE 10 is a rear view with parts broken away showing the nozzle positioned as in FIGURE 9.

Referring to the drawings, in the embodiment shown in FIGURES 1 to 6, inclusive, the nozzle discharge opening **10**, generally of annular form is defined between the outer wall or tail pipe **12** and the central tail cone or plug **15** which tapers rearwardly to a tip and is so shaped in relation to the outer wall as to define a convergent-divergent orifice. Tail pipe **12** has a rearward extension **12***a*, which commences at a location in the vicinity of the rear terminus of plug **15** and which is of essentially constant or uniform cross section. This extension **12***a* is characterized by longitudinal troughs **14**, located at regular intervals about its periphery. These troughs open upstream into the nozzle interior **10**. In the example, four such troughs at 90 degree spacings are formed in the nozzle extension **12***a*, but it will be recognized that the number and spacing thereof is subject to variation.

An external cowl or nacelle wall **16** surrounds the nozzle wall **12**, with spacing **18** therebetween for housing mechanical and electrical controls and actuators including those to be described. Suitable structural reinforcing flanges provide means for interconnecting the cowl and nozzle walls and imparting the necessary rigidity and strength thereto, but are of secondary concern for present purposes, hence require no detailed description herein.

Auxiliary nozzle ducts **20** normally lie nested in the respective troughs **14**. The then inner wall **20***a* of each duct lies in close proximity to or in contact with the trough base whereas its outer wall **20***b*, converging rearwardly with the inner wall **20***a*, lies at an incline to the nozzle axis A and in general extends the rearwardly tapered contour of the outer cowl **16**. The forward edge of outer wall **20***b* is pivoted at **22** on a transverse axis which lies generally in a plane perpendicular to the engine axis A, which plane is substantially coincident with the plane defined by the forward edges of the troughs **14**. This pivotal support for the auxiliary ducts **20** permits them to be swung from their nested position, shown in FIGURE 5, outwardly to their extended position shown in FIGURE 6 in which their former inner walls **20***a* are now approximately perpendicular to the engine axis A. The walls **20***a* are multiply apertured and preferably include louvers or vanes **20***c* which are slanted outwardly and to the rear in order to direct the gases which flow through the extended auxiliary ducts **20** in a rearward and outward direction for noise suppression operation. As will be noted, the ducts **20** are formed with open sides **20***d* which, with the ducts extended, face directly upstream and largely occupy the cross-section of the troughs **14** fronting upstream into the nozzle interior **10**. A curved wall portion **20***e* extends rearwardly and outwardly from the inner edge of opening **20***d* in an arc centered on axis **22** to the wall **20***a*. This curved wall **20***e* provides an efficient directing or turning surface for air scooped into the duct opening **20***d* with the duct extended, directing such air outwardly and through the opening defined through the slanted vane **20***c*. In the retracted or nested position of the ducts **20**, the curved surfaces **20***e* extend forwardly and outwardly from the forward edges of the troughs **14** to the nozzle outer wall **12** and thus provide fairing surfaces which efficiently turn the gases inwardly past the trough ends and toward the tail cone **15**.

Thus, the troughs **14** serve as stream divider elements in the nozzle orifice splitting the jet into lobes or branches and at the same time channeling slipstream air into the spaces between lobes for rapid mixture therewith in the cruise setting of the nozzle.

In the extended or raised position of the auxiliary ducts **20**, gases scooped into these ducts through the openings **20***d* are discharged in rearwardly and outwardly fanning streams which in themselves are broken up for a rapid admixture with slipstream air, thereby adding to the effect of the main nozzle corrugations **14** in reducing engine jet noise.

Nozzle area compensation in this embodiment is achieved by providing multiply apertured doors **30**, which are swung into blocking position across the discharge ends of the nozzle orifice lobes **14** (FIGURE 2) when the auxiliary ducts **20** are extended. These doors are formed in two parts respectively hinged at **30***a* and **30***b* to the generally aligned rear edges of the troughs **14** and struts **32**. The inner ends of the struts terminate on an island member **34** of streamline configuration centered on engine axis A. Preferably tabs **36**, hinged with the door sections, partially close the elements of orifice area lying generally between the base circle of the troughs and the island member **34** when the doors close. The residual open area provided around these tabs, the composite area afforded by the apertures in doors **30**, and the effective open area through the auxiliary ducts, total approximately the same as the open area through the orifice in the cruise setting.

While any suitable actuating means for controlling the position of the auxiliary ducts **20** and of the doors **30** may be employed consistent with the design requirements of jet engine nozzles, that illustrated performs the necessary functions in a direct and simple manner. Thus, within the space **18** pneumatic or hydraulic actuators **40** having piston rods **42** are connected to actuator links **44** which extend generally rearwardly to pivotal connections **46** with the outer sides **20***b* of the respective ducts **20**.

These actuators and actuating connections provide for extension and retraction movements of the doors and the auxiliary ducts. Crank arms **50**, rigidly connected to the ducts **20** to pivot therewith about pivots **22**, are connected by actuator links **52** to the outer ends of the doors at **54**, through universal couplings, in order to swing the doors conjointly with movement of the ducts, so that the doors close when the ducts **20** are extended, and open when the ducts are retracted as depicted. There are two such crank arms **50** associated with each auxiliary duct **20**, one on either side thereof, and an actuating link **52** connected between the swinging end of each such crank arm and one door of each of the adjacent sets (FIGURE 3).

In order to limit the radially projecting length of the ducts **20** to that which is useful for auxiliary nozzle purposes, and so that drag will be minimized, the rearwardly tapered (when nested) form of these ducts does not extend to a point or tip, but terminates in a blunt end **20***f*. This assures that the outermost aperture in the wall **20***a* with the duct extended may be located near the end without the volumetric flow through it being restricted unduly by undue narrowing of the duct at that point. Preferably the aft end of each duct **20** in nested position lies forwardly of the aft end of the associated trough **14** and the resulting discontinuity which otherwise occurs is filled or occupied by a fairing plug **14***b* secured to the base wall of the associated trough **14** and extending transversely between opposite sides thereof as shown.

In the modification shown in FIGURES 7 through 10 the generally annular nozzle discharge space **60**, defined between the plug or tail cone **62** and outer wall **64**, is modified by the presence of the troughs **66**. A corrugated or lobed orifice effect results comprising the lobe spaces **68** formed between the troughs, and which are joined with the generally open central region within the nozzle. The troughs **66** increase rearwardly in depth, whereas the peripheral duct wall between troughs remains of substantially constant diameter over the length of the troughs. The troughed formations extend substantially from a point, lengthwise of the nozzle, approximately opposite the maximum diameter point of the tail cone, to the after end or exit plane of the nozzle. Such a nozzle configuration has moderate noise suppression characteristics and low drag. Slipstream air flows rearwardly and inwardly through the troughs to discharge into the spaces between the jet lobes issuing from regions **68**. The ducts **70** viewed in nested position (FIGURE 7) are of rearwardly tapered form so as to place their inner walls **78** in proximity to or in contact with the inclined base walls of the troughs **66** while their outer walls **72** lie substantially coplanar with the outer edges of the troughs. Although the troughs are occupied by the auxiliary ducts **70** in the cruise position, the presence of these ducts in the troughs does not appreciably interfere with such flow of slipstream air into and along the troughs because the outer walls **72** of the ducts **70** have a pluraliy tof apertures **74** therein defined between the slanted louvers or vanes **76**, which are inclined rearwardly and inwardly (FIGURE 7). Slipstream air enters through these apertures and through the end opening **79** to discharge rearwardly as described. A flap valve **80**, normally open, is forced closed by gas pressure to seal the end opening **79** when the duct **70** is extended as in FIGURE 9.

The rearward end of the troughs **70** in their nested position lie forwardly of the aft end of the nozzle and are pivoted at **82** on transverse axes at their inner rearward edges so as to permit swinging thereof between the nested position of FIGURE 7 and the extended position of FIGURE 9 wherein they lie substantially at right angles to the engine axis A. Just aft of the pivot point **82**, the base of each trough **66** is provided with a relatively large opening **84** through which gases may flow radially outward into the interior of the duct **70** in its extended position (FIGURE 9). Normally, this opening **84** is closed by a flap

86 which pivots at 88 on a transverse axis located at the after edge of the trough base. This cover flap 86 is swung into a position transverse to the axis A, however, when the duct 70 is extended so as to block flow of gases rearwardly from the nozzle in the region directly behind aperture 84. Resultant blockage of flow gives rise to the requisite outflow of gases into the extended ducts 70 and at the same time reduces the normal orifice area approximately by the amount that such area is effectively increased by the extension of the ducts and uncovering of side openings 84. Consequently, the effective nozzle area remains approximately the same in the cruise position as in the maximum thrust position and is thereby continuously matched to engine requirements.

For actuation purposes, a pneumatic or hydraulic actuator 90 is housed within the hollow interior of the tail cone 62 and has a piston rod 92 which extends axially through the after end thereof. This rod carries on its outer end a fitting 94 which comprises the conical terminus of the tail cone when the actuator is retracted (FIGURE 7). This fitting 94 serves as a means by which to connect the after end of the piston rod 92 to the flaps 86 through actuating links 96, thereby to swing the flaps downwardly into the position of FIGURE 9 by extension of the piston rod 92, and to swing the flaps upwardly into the position closing the openings 84 (FIGURE 7) by retraction of the piston rod. Additional actuating links 98 interconnecting the flaps 86 with the auxiliary ducts 70, through openings 84, serve to actuate the ducts between their extended and retracted positions conjointly with movement of the flaps.

These and other aspects of the invention, including details of design and operation of the preferred embodiments shown, will be evident to those skilled in the art, after becoming familiar with the present disclosure of such embodiments.

We claim as our invention:

1. Jet propulsion engine noise suppression nozzle means comprising a nozzle discharge duct opening rearwardly for discharge of gases therethrough, said nozzle duct having a plurality of elongated flow divider elements extending longitudinally thereof at spaced locations about the duct periphery and, at the duct's discharge end, projecting generally radially inward to produce a corrugated nozzle effect dividing at least the jet periphery into a plurality of spaced lobes between which slipstream air is drawn with attendant moderate jet noise reduction, said flow divider elements comprising channels laterally open to the slipstream, and means to increase noise reduction comprising a plurality of elongated auxiliary ducts normally nested in the respective channels extending lengthwise therein with their then outer sides inclined rearwardly and inwardly of the nozzle, said auxiliary ducts being pivotally mounted by their forward ends therein to swing outwardly into extended position disposed generally transversely to the direction of discharge, said extended auxiliary ducts having apertured discharge sides which face aft and having reception openings at their pivoted inner ends which communicate with the nozzle interior to admit gases for discharge through said apertured sides, compensating means operable to restrict nozzle opening approximately equally to the increase thereof effectively produced by auxiliary duct extension, and means operable to extend the auxiliary ducts and operate the compensating means in conjunction therewith, thereby to increase noise reduction and maintain effective nozzle opening approximately constant.

2. Jet propulsion engine noise suppression nozzle means comprising a nozzle discharge duct opening rearwardly for discharge of gases therethrough, said nozzle duct having a plurality of elongated trough-like elements extending longitudinally thereof at spaced locations about the duct periphery and exposed laterally to the slipstream to produce a corrugated nozzle effect at the discharge end of said duct, and means to increase noise reduction comprising a plurality of elongated auxiliary ducts normally nested in the bases of the respective troughs and pivotally mounted therein to swing outwardly into extended position disposed generally transversely to the direction of discharge, said extended auxiliary ducts having apertured discharge sides which face aft and having entrance openings at their pivoted inner ends communicating with the nozzle interior to admit gases from the nozzle interior for discharge through said apertured sides, compensating means operable to restrict the composite nozzle opening approximately equally to the increase thereof effectively produced by auxiliary duct extension, and means operable to extend the auxilary ducts and operate the compensating means in conjunction therewith, thereby to increase noise reduction and maintain effective nozzle opening approximately constant, the troughs at the discharge end of the nozzle being deeper than the auxiliary ducts nested therein, whereby the corrugated nozzle effect is maintained with the auxiliary ducts in nested position.

3. The nozzle means defined in claim 2, wherein the compensating means comprise door-like flaps hinged on the ends of the trough-like elements to swing between retracted position substantially parallel to the nozzle discharge and operative position partially blocking the discharge of gas through the nozzle.

4. The nozzle means defined in claim 3, wherein the door-like flaps are hinged in pairs on respectively opposite sides of the trough-like elements and have a plurality of spaced discharge apertures therein permitting limited discharge of gases therethrough when in closed position.

5. The nozzle means defined in claim 3, wherein the trough-like elements have less depth than the distance to the nozzle center at the exit plane to produce a jet form having a central core region with surrounding lobes, and the door-like flaps are hinged on the base edges of the trough-like elements to project into and divide said core region thereby to increase the depth of said lobes.

6. The nozzle means defined in claim 2, wherein the apertured discharge sides of the extended auxiliary ducts include flow-directing louvers slanted outwardly and rearwardly therein.

7. Jet propulsion engine noise suppression nozzle means comprising a nozzle discharge duct opening rearwardly for discharge of gases therethrough, said nozzle duct having a plurality of elongated trough-like elements extending longitudinally thereof at spaced locations about the duct periphery and exposed laterally to the slipstream to produce a corrugated nozzle effect at the discharge end of said duct, and means to increase noise reduction comprising a plurality of elongated auxiliary ducts normally nested in the bases of the respective troughs with their outer walls set inwardly from the nozzle periphery therein to maintain the corrugated nozzle effect at the discharge end of the nozzle, said auxiliary ducts being pivotally mounted in the respective troughs to swing outwardly into extended position disposed generally transversely to the direction of discharge, said extended auxiliary ducts having apertured discharge sides which face aft and having means to scoop gases from the nozzle interior for discharge through said apertured sides, and compensating means operable to restrict nozzle opening approximately equally to the increase thereof effectively produced by auxiliary duct extension in conjunction therewith, thereby to increase noise reduction and maintain effective nozzle opening approximately constant.

8. The nozzle means defined in claim 7, wherein the trough-like elements are open-ended fore and aft with the forward end thereof being open within the nozzle duct, and wherein the retracted auxiliary duct apertured discharge sides lie in proximate relation to the respective trough bases, and such elements have a deflecting side which then extends forwardly and outwardly to the nozzle duct wall as a fairing surface covering said open forward end, said retracted trough-like elements respec-

tively being hinged at their forward ends at their sides opposite said discharge sides, whereby said deflecting sides become a scoop for directing gases into the auxiliry ducts when extended.

9. The nozzle means defined in claim 7, wherein the trough-like elements increase progressively in depth to the exit plane of the nozzle and have an aperture in the base thereof located forwardly of said exit plane, hinged cover means normally covering said aperture and pivoted at their rear edges on the nozzle duct, the retracted auxiliary ducts being pivoted at their rearward inner corners in the trough-like elements at a location therein situated just forwardly of said apertures and being open at least at their aft ends, whereby extension of said auxiliary ducts places them in communication with said aperture, and means to swing said cover means inwardly into transversely disposed position with extension of said auxiliary ducts, thereby to obstruct rearward gas flow behind said aperture and direct such gases outwardly through said aperture.

10. The nozzle means defined in claim 9, wherein the apertured discharge side of the extended auxiliary ducts has louvers therein which slant rearwardly and outwardly, thereby to direct the gas discharge rearwardly and outwardly, while permitting free inflow of slipstream air into and through the trough spaces with such auxiliary ducts retracted.

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