United States Patent

[11] 3,556,246

[72] Inventor **Jack H. Hilbig**
Chula Vista, Calif.

[21] Appl. No. **833,513**
[22] Filed **June 16, 1969**
[45] Patented **Jan. 19, 1971**

[73] Assignee **Rohr Corporation**
Chula Vista, Calif.
a corporation of California

---

[54] **METHOD AND APPARATUS FOR SUPPRESSING THE NOISE OF A FAN JET ENGINE**
9 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **181/51,** 239/127.3, 239/265.13, 239/265.17
[51] **Int. Cl.** **F01n 1/14,** B64d 33/06
[50] **Field of Search** 181/33.22, 33.221, 33.222, 51, 43; 239/265.13, 265.17, 127.3, 265.39, 265.37, 265.41

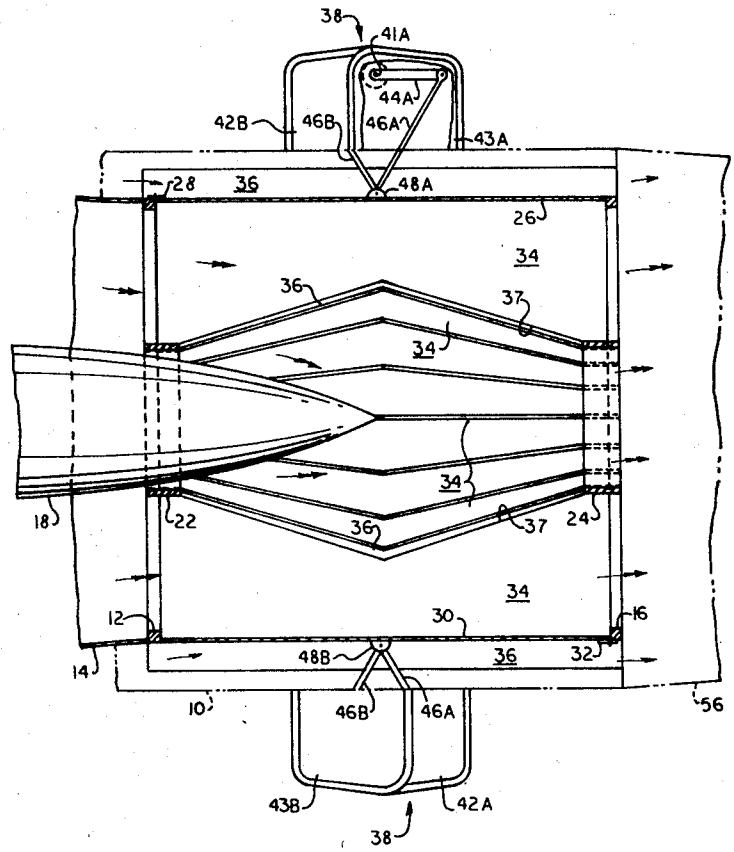
[56] **References Cited**

UNITED STATES PATENTS

2,998,092	8/1961	Brown	181/33(.221)
3,237,864	3/1966	Taylor et al.	239/265.17X
3,306,394	2/1967	Smith et al.	181/33(.221)
3,436,020	4/1969	Duthion et al.	239/265.13

Primary Examiner—Robert S. Ward, Jr.
Attorney—George E. Pearson

ABSTRACT: Vanes are mounted at the aft end of the tailpipe of a fan jet engine so that in a first position they form a tubular extension of said tailpipe. A conduit is disposed around the vanes and when the latter are in said first position the conduit defines therewith an annular passage through which secondary air of the engine is discharged. A thrust nozzle is attached to the aft end of the conduit, and when the vanes are in their first position exhaust gas flows in a columnar stream from the channel formed by said vanes and is surrounded at the forward end of the thrust nozzle by the annular stream of secondary air issuing from the passage between said vanes and said conduit. The vanes are alternately hinged at their forward and aft ends to supporting structures, and actuators are provided to rotate the same between the aforesaid first position and a second position wherein their free ends are disposed within the stream of exhaust gas issuing from the tailpipe, in which latter position part of the exhaust gas flows along alternate vanes and into the annular passage through which secondary air is discharged to the thrust nozzle and part of said secondary air flows along the other vanes and into the inner channel through which exhaust gas is discharged to said thrust nozzle.



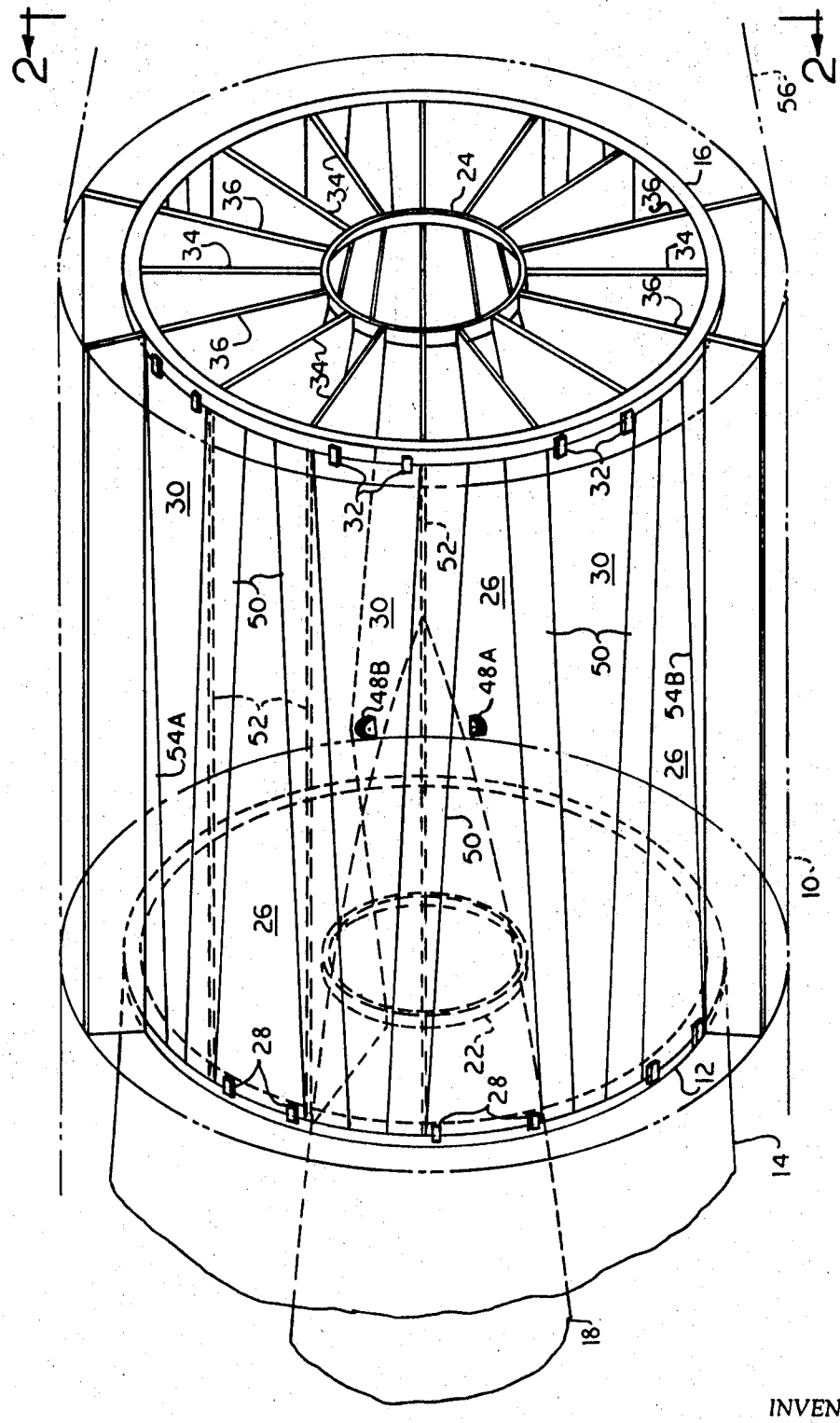


FIG. 1

INVENTOR.
JACK H. HILBIG
BY Edwin O. Grant

ATTORNEY

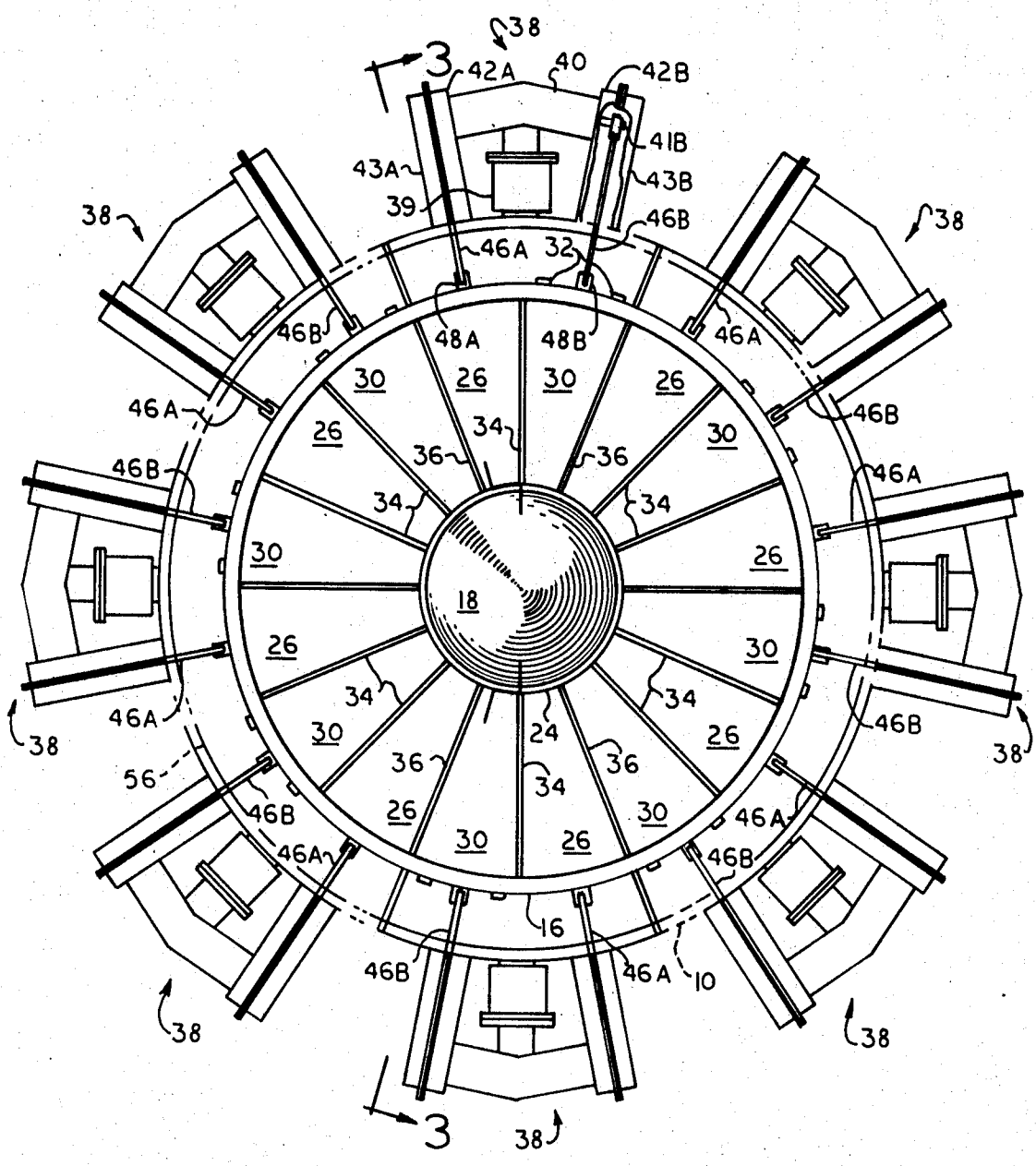


FIG. 2

INVENTOR.
JACK H. HILBIG
BY Edwin D. Grant
ATTORNEY

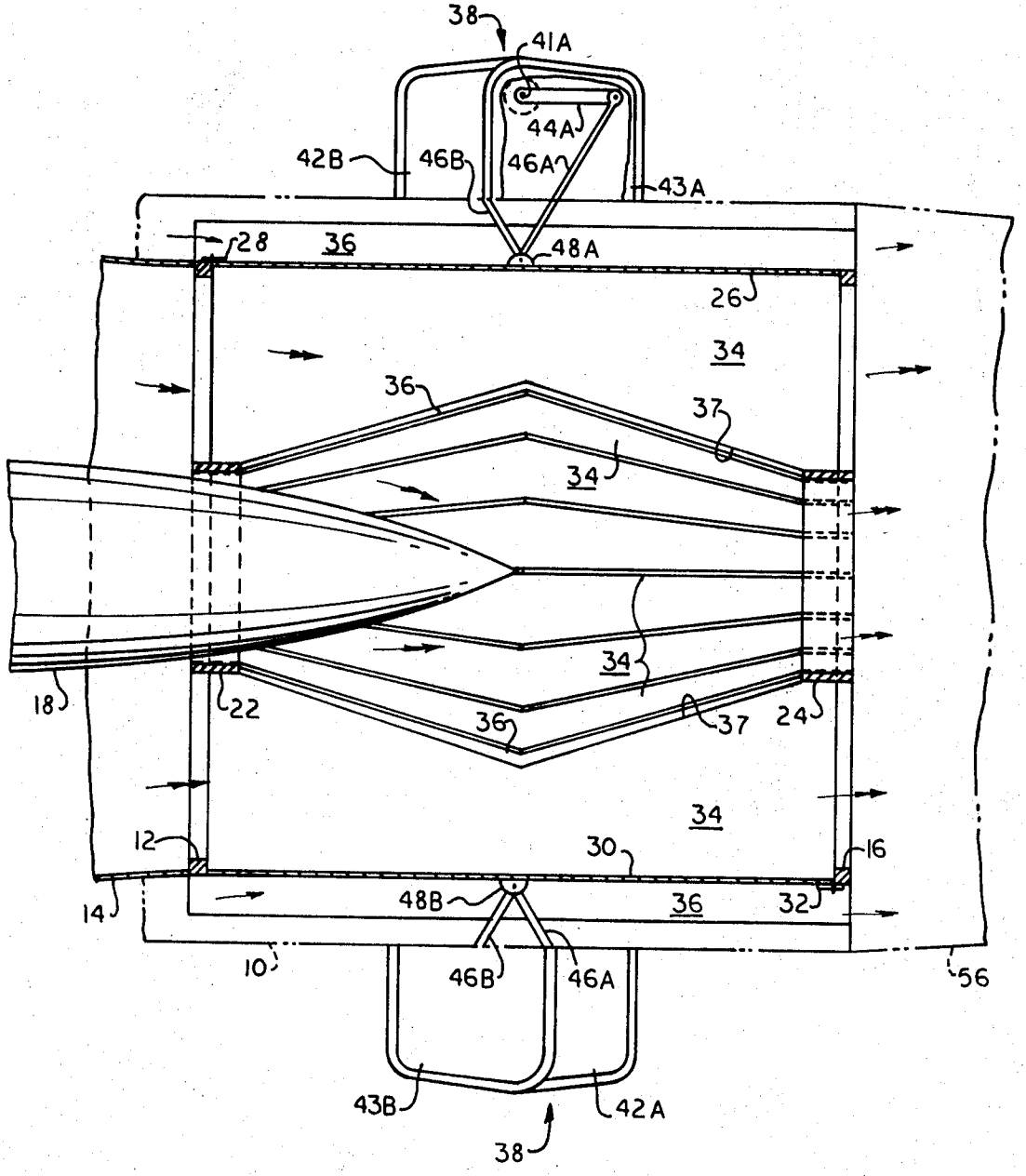


FIG. 3

INVENTOR.
JACK H. HILBIG
BY Edwin D. Grant
ATTORNEY

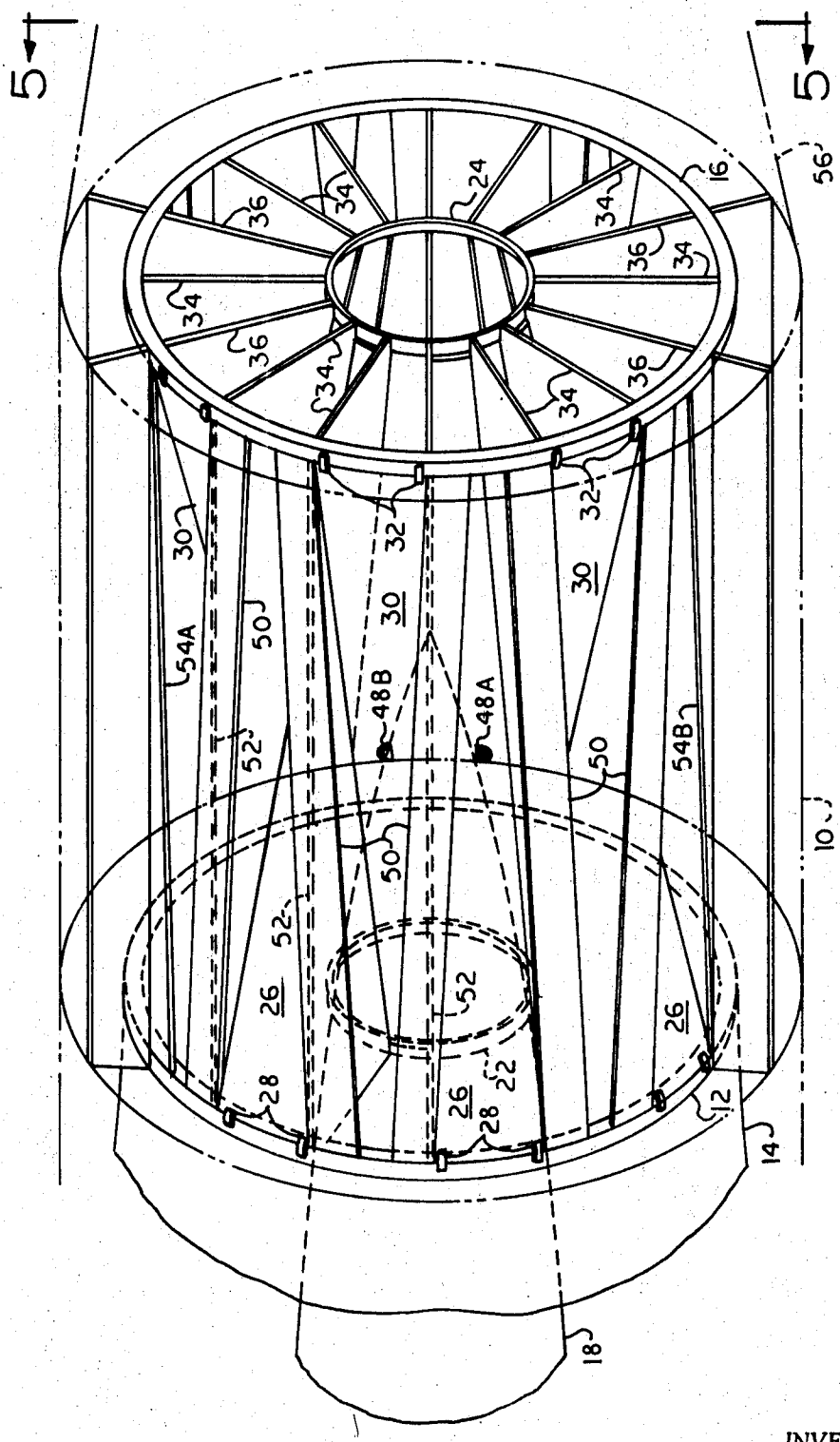


FIG. 4

INVENTOR.
JACK H. HILBIG
BY Edwin D. Grant
ATTORNEY

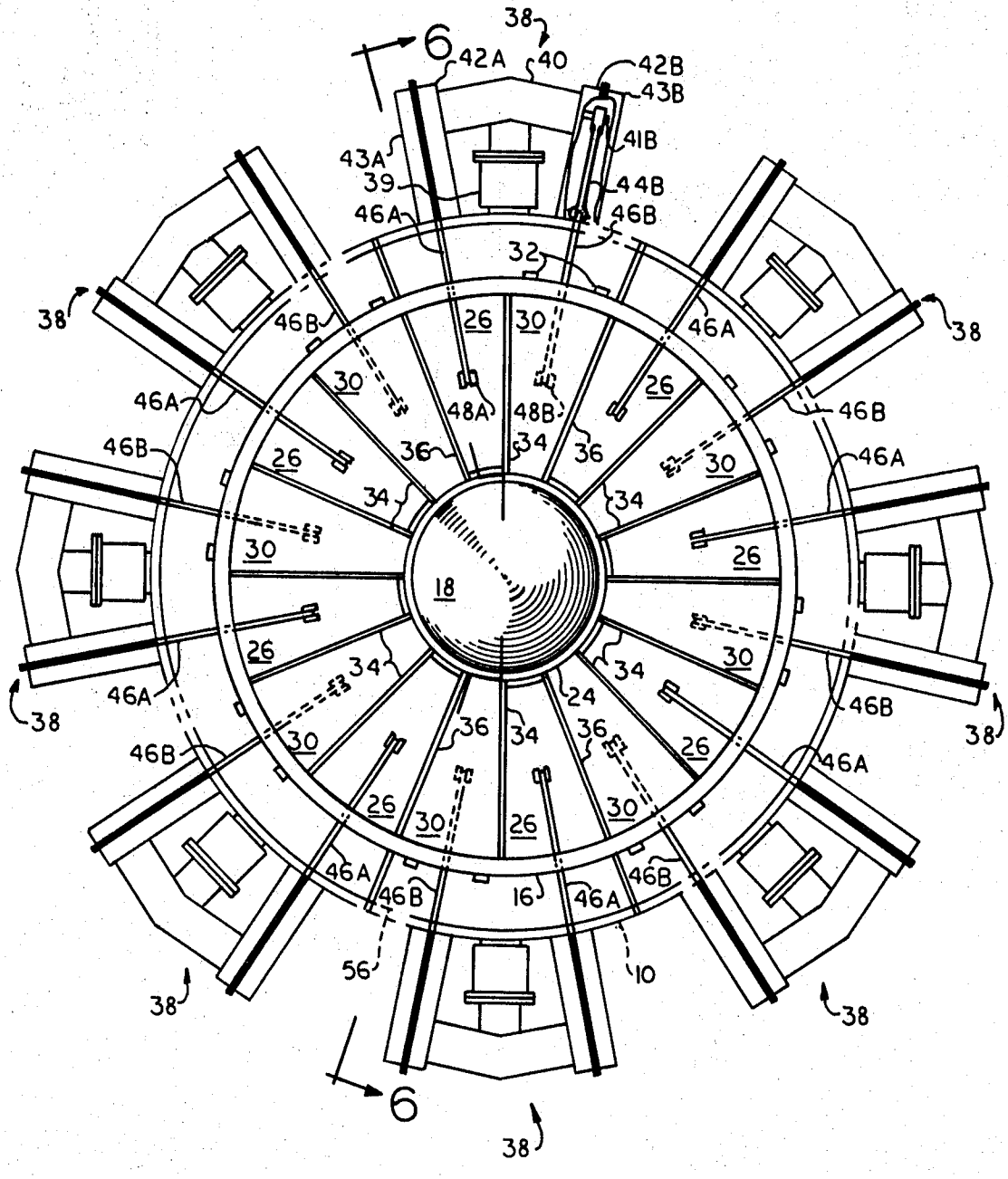


FIG. 5

INVENTOR.
JACK H. HILBIG
BY Edwin D. Grant
ATTORNEY

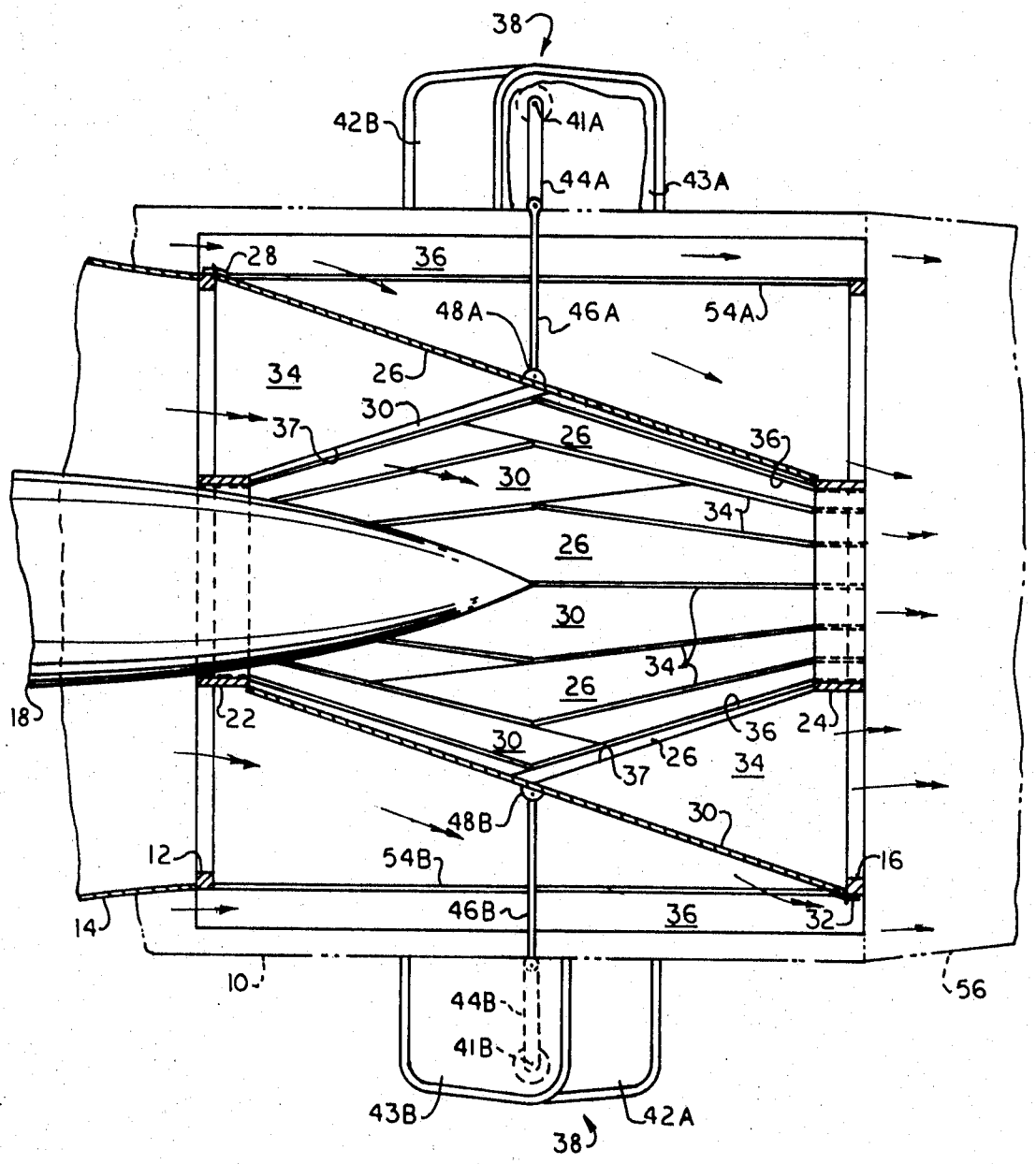


FIG. 6

INVENTOR.
JACK H. HILBIG
BY Edwin D. Grant
ATTORNEY

METHOD AND APPARATUS FOR SUPPRESSING THE NOISE OF A FAN JET ENGINE

SUMMARY OF THE INVENTION

This invention relates to jet-propelled aircraft and more particularly to a method and to apparatus for reducing the noise of aircraft provided with engines of the fan jet type.

Part of the noise associated with the operation of jet-propelled aircraft results from the passage of a high velocity jet stream through the atmosphere, and the amount of sound energy so generated depends upon the velocity of the jet stream. The present invention provides for the mixing of the high velocity primary jet stream of a fan jet engine with the stream of relatively low velocity fan air of said engine, which mixing is effected by a plurality of vanes disposed forward of a thrust nozzle through which the two streams are discharged to the atmosphere. Hence when the vanes are positioned to produce the aforesaid mixing of exhaust gas and fan air, the combined jet stream that is discharged to the atmosphere has a lower velocity than that of the exhaust gas when the latter is discharged as a separate stream, and the sound energy generated by passage of the combined jet stream through the atmosphere is thus less than that which is generated when the exhaust gas and fan air are discharged as separate streams. The combined jet stream has a lower temperature than that of the exhaust gas alone, which also reduces the noise generated downstream from the propulsion assembly.

In a preferred embodiment of the invention a first support ring is attached to the aft end of the tailpipe of a fan jet engine, and a set of first vanes extend rearwardly from said first ring and are spaced apart circumferentially thereof, the forward ends of said first vanes being hinged to the first ring so that the vanes can be rotated between a first position wherein their longitudinal axes are parallel with the longitudinal axis of the tailpipe and a second position wherein their longitudinal axes are inclined toward the longitudinal axis of said tailpipe. A second support ring is fixedly mounted in coaxial relation with the first support ring and is located downstream therefrom, the aft ends of the first vanes being even with the forward edge of this second ring when said vanes are positioned parallel with the longitudinal axis of the tailpipe. A plurality of second vanes are respectively disposed between the first vanes and extend longitudinally thereof. More specifically, the longitudinal edges of the second vanes are spaced from the longitudinal edges of the first vanes, and the second vanes are hinged at their aft ends to the second ring so that they can be rotated between a first position wherein their longitudinal axes are parallel with the longitudinal axis of the tailpipe and a second position wherein their longitudinal axes are inclined toward the longitudinal axis of said tailpipe. The forward ends of the second vanes are even with the aft edge of the first ring when the second vanes are disposed parallel with the longitudinal axis of the tailpipe.

A third support ring having a diameter smaller than that of the first ring is axially aligned with said first ring and disposed in concentric relation therewith. Likewise, a fourth support ring having a diameter smaller than that of the second ring is axially aligned with said second ring and disposed in concentric relation therewith. A plurality of elongate panels are attached to each of the aforementioned rings and extend therebetween, said panels being spaced apart circumferentially of the rings and respectively disposed between the first and second vanes. Each of the first vanes decreases in width in the downstream direction, whereas each of the second vanes decreases in width in the upstream direction. More particularly, the vanes are shaped so that their longitudinal edges fit closely against the sides of respective pairs of said panels when the vanes are moved to the aforesaid second position thereof. Since the vanes are tapered, there are gaps between their longitudinal edges when they are in the first position wherein their longitudinal axes are parallel with the longitudinal axis of the tailpipe. However, these gaps are closed by fillets which are respectively positioned between the first and second vanes and secured to the first and second rings.

A conduit is disposed around the tailpipe and the vanes aft thereof, with the aft end of said conduit being longitudinally aligned with the second and fourth rings. The thrust nozzle of the propulsion unit is attached to the aft end of the conduit, and some of the aforedescribed panels project radially from the first and second rings and are joined to the inner surface of the conduit. Actuators are mounted on the outer side of the conduit and respectively connected by links to the first and second vanes so that the latter can be selectively rotated to their first and second positions. When the vanes are in the first position they cooperate with the fillets therebetween to provide a tubular extension of the tailpipe, through which extension the primary jet stream of the fan jet engine flows to the thrust nozzle. Furthermore, when the vanes are in the first position they also cooperate with the conduit to provide an annular passage which surrounds the tubular extension formed by the vanes and fillets, through which passage the fan air of the engine is discharged to the thrust nozzle. Thus when the vanes are in the first position fan air flows through the thrust nozzle in an annular stream that encircles the column of exhaust gas flowing through said nozzle. However, when the actuators are operated to move the vanes to the second position, the free ends of the vanes extend into the stream of exhaust gas flowing from the aft end of the tailpipe, and part of said gas impinges upon the outer surfaces of the second vanes and flows therealong and into the fan air flowing through the space between the first and second rings and the surrounding conduit. Part of the fan air also flows along the outer surfaces of the first vanes and into the portion of the exhaust gas which is not deflected outwardly by the second vanes and which therefore continues to flow into the central section of the thrust nozzle. Thus when the vanes are in the second position there is thorough mixing of the exhaust gas and fan air before the same reach the atmosphere, and the velocity and temperature of the combined stream of exhaust gas and fan air are less than the velocity and temperature of the exhaust gas prior to such mixing, which suppresses the noise associated with the operation of the fan jet engine.

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a pictorial representation of an exemplary embodiment of the invention, certain components thereof being illustrated in phantom and other components being omitted from the drawing to avoid making the same confusingly complicated;

FIG. 2 is a cross section taken along the plane represented by line 2–2 in FIG. 1 and in the direction indicated therein, the drawing illustrating components which are omitted in FIG. 1 and a portion of a casing being cut away in order to show components enclosed within said casings;

FIG. 3 is a longitudinal section taken along the planes represented by line 3–3 in FIG. 2 and in the direction indicated therein;

FIG. 4 is a pictorial representation of the same embodiment, taken from the same viewpoint as the view of FIG. 1 but illustrating a different position of the operating components;

FIG. 5 is a cross section taken along the plane represented by line 5–5 in FIG. 4 and in the direction indicated therein; and

FIG. 6 is a longitudinal section taken along the planes represented by line 6–6 in FIG. 5 and in the direction indicated therein.

Throughout the drawings and the following specification, the same numbers refer to the same parts.

DETAILED DESCRIPTION

In FIG. 1 the broken lines 10 represent a cylindrical conduit that is surrounded by the aft portion of a housing which may be either a fuselage or nacelle containing a fan jet engine, said

housing and engine not being illustrated. A first ring **12** is attached by suitable means to the aft edge of the tailpipe **14** of this engine, which tailpipe is coaxial with conduit **10**. By means which will become apparent as the description proceeds, a second ring **16** is fixed in position downstream from first ring **12**, said first and second rings being coaxial and having the same diameter in the embodiment of the invention which is described and illustrated herein. However, it should be understood that the invention is not limited to the single embodiment thereof which will be disclosed, since various modifications can obviously be made thereto without departing from the principles of the invention. For example, in some cases the diameters of the first and second rings **12**, **16** may be different.

Coaxially positioned with tailpipe **14** and projecting from the aft end thereof is a hollow inner cone **18**. This inner cone is fixedly supported by structure which is not illustrated, and at its forward end contains a bearing (not shown) in which the drive shaft (not shown) of the aforesaid fan jet engine is journaled. A third ring **22** is attached to panels which will be described hereinafter and is disposed in coaxial, spaced relation around inner cone **18** and in axial alignment with first ring **12**. A fourth ring **24** is connected to the same panels which are attached to third ring **22**, and is disposed in coaxial relation with the longitudinal axis of tailpipe **14**. In the embodiment of the invention which is being described, the fourth ring has the same diameter as third ring **22**, and it is axially aligned with second ring **16**.

As illustrated in FIG. **1**, the forward ends of a plurality of first vanes **26** are pivotally connected to the aft edge of first ring **12** by means of hinges **28**. These vanes are spaced apart circumferentially of said first ring and when disposed in a first position are parallel with the longitudinal axis of tailpipe **14** with the aft ends thereof adjacent the forward edge of second ring **16**. It will be noted in FIG. **1** that the width of each first vane gradually decreases in the downstream direction. The aft ends of a set of second vanes **30** are pivotally connected to the forward edge of second ring **16** by means of hinges **32**, these vanes being respectively disposed between first vanes **26** and spaced from the longitudinal edges thereof. When disposed in the first position second vanes **30** are also parallel with the longitudinal axis of tailpipe **14** and their forward ends are adjacent the aft edge of first ring **12**. It can also be seen in FIG. **1** that the width of second vanes **30** gradually decreases in the upstream direction.

Extending between the upstream pair of rings **12**, **22** and the downstream pair of rings **16**, **24** are a plurality of panels **34**, **36**. More particularly, panels **34** are connected at the forward and aft ends of their V-shaped inner edges **37** (see FIG. **3**) to rings **22** and **24**, respectively, and are connected at the forward and aft ends of their linear outer edges to rings **12** and **16**, respectively. Panels **36** are also connected at the forward and aft ends of their V-shaped inner edges to rings **22** and **24**, respectively, but are fixedly connected along their linear outer edges to the inner surface of conduit **10**.

Circumferentially spaced apart on the outer side of conduit **10** are a plurality of actuators which are generally designated by the number **38** and each of which comprises a first portion **39** secured at one end thereof to said conduit, a second T-shaped portion **40** the stem of which is bolted to said first portion, and a pair of drive shafts **41A**, **41B** respectively mounted in the apertured arms of said second portion for rotation about their own longitudinal axes, which axes lie in a plane disposed perpendicular to the longitudinal axis of conduit **10**. Each drive shaft is journaled in the sidewall of a first casing **42A**, **42B** one edge of which is fixedly attached by suitable means to the conduit, said sidewall being bolted to the flanged end of the actuator arm adjacent thereto. A second casing section **43A**, **43B** is bolted to the flanged edge of each first casing section which is remote from the actuator arm, thereby providing a housing the interior of which is closed to the spaced outside conduit **10** but which communicates with the interior of said conduit through a respective one of a plurality of slots formed in the wall of the conduit and spaced apart circumferentially thereof. Arms **44A**, **44B** are respectively fixedly connected at one end thereof to the ends of drive shafts **41A**, **41B** which project into the interior of the housings formed by casings **42A** **42B**, **43A**, **43B**, said arms extending in opposite directions longitudinally of conduit **10** when disposed in a first position as illustrated in FIG. **3**. A link **46A** is pivotally connected at one end thereof to the free end of each arm **44A** and is pivotally connected at the other end thereof to a connector **48A** fastened to the outer surface of a respective one of the vanes **26**. Likewise, a link **46B** is pivotally connected at one end thereof to the free end of each arm **44B** and is pivotally connected at the other end thereof to a connector **48B** fastened to the outer surface of a respective one of the vanes **30**. Actuators **38** also comprise suitable drive means, such as electric motors or hydraulically operated mechanisms, which can be operated from a remote point to simultaneously rotate drive shafts **41A**, **41B** in opposite directions and thereby move vanes **26** and **30** between the first position thereof which is illustrated in FIGS. **1—3** and the second position thereof which is illustrated in **4—6**, in which latter position the free ends of vanes **26** are disposed adjacent the forward edge of ring **24** and the free ends of vanes **30** are disposed adjacent the aft edge of ring **22**. Panels **34** and **36** are of course positioned so that vanes **26** and **30** can be disposed therebetween when rotated to the second position. Furthermore, the arrangement of the vanes and panels is such that when the vanes are in the second position their longitudinal edges are adjacent the sides of the panels and respectively extend along either the forward or rear segments of the V-shaped edges **37** of adjacent panels. Extending between rings **12** and **14** are a plurality of fillets **50** each of which is joined both to said rings and to the outer longitudinal edge **52** (see FIG. **1**) of a respective one of the panels **34**. It will be observed in the last-mentioned drawing that each fillet **50** is obliquely disposed across the panel **34** lying thereunder, i.e., one side of the panel is even with one edge of the fillet at the rear edge of ring **12** and the other side of the panel is even with the other edge of the fillet at the forward edge of ring **16**. Fillets **50** are of such size that their longitudinal edges are close to the longitudinal edges of adjacent vanes **26**, **30** when the latter are in the first position thereof. A pair of fillets **54A**, **54B** also respectively extend along and are fixedly joined to opposite sides of each panel **36**, one of these fillets being attached to the rear edge of ring **12** and gradually decreasing in width in the downstream direction so that its outer longitudinal edge (i.e., the edge facing the adjacent vane **26** or **30**) reaches the side of the associated panel at the forward edge of ring **16**, and the other fillet being attached to the forward edge of said ring **16** and gradually decreasing in width in the forward direction so that its outer edge reaches the side of said panel at the rear edge of ring **12**. The width of fillets **50**, **52A**, and **52B** is also such that there is only a narrow gap between the longitudinal edges of the fillets and the longitudinal edges of vanes **26** and **30** when the latter are in their first positions.

The aft edge of conduit **10** is fixedly joined to the forward edge of a thrust nozzle **56**, which may be of any conventional type and which is schematically illustrated in fragmentary section form in the drawings.

OPERATION

During normal flight of the aircraft equipped with the above-described apparatus, vanes **26** and **30** are disposed parallel with the longitudinal axis of tailpipe **14** and, together with fillets **50**, **54A** and **54B** therebetween, form a tubular extension of said tailpipe, as illustrated in FIGS. **3** and **6**. Fan air (which is conducted to the annulus between the tailpipe and conduit **10** through ducts communicating therewith) thus flows through the space between the vanes and said conduit and enters the forward portion of thrust nozzle **54** in a stream which encircles the column of exhaust gas issuing from the tube formed by the vanes and fillets. In FIG. **3** single-headed

arrows represent the flow of fan air and double-headed arrows represent the flow of exhaust gas.

When it is necessary to reduce the noise associated with the flow of fan air and exhaust gas through the atmosphere downstream from thrust nozzle **56**, actuators **38** are simultaneously operated to rotate the free ends of arms **44A**, **44B** to the position illustrated in FIG. **6**, thus moving vanes **26** and **30** into the stream of exhaust gas flowing from the aft end of tailpipe **14**. Thereafter part of the exhaust gas flows along the outer surfaces of second vanes **30** and into the stream of fan air flowing along the inner surface of conduit **10** at points radially aligned with said second vanes. At the same time part of the fan air flows along the outer surfaces of first vanes **26** and into that part of the exhaust gas which is not deflected outwardly by second vanes **30**. It will be recognized that panels **34** and **36**, being respectively disposed between vanes **26** and **30**, separate the outward flow of exhaust gas along vanes **30** from the inward flow of fan air along vanes **26** (as illustrated by the single-headed and double-headed arrows which are also employed in FIG. **6** to represent fan air and exhaust gas, respectively).

When the vanes are inclined relative to the common longitudinal axis of tailpipe **14** and thrust nozzle **54** there is thorough mixing of the high-velocity exhaust gas with the relatively low-velocity fan air. Thus the combined stream of exhaust gas and fan air which is discharged from thrust nozzle **54** has a lower velocity than that of the exhaust gas when the latter is discharged as a separate jet stream. The mixing of fan air with exhaust gas also lowers the temperature of the latter. Since the sound energy emitted by a jet stream flowing through the atmosphere is proportional to both the velocity and temperature of the jet stream, the disclosed apparatus and method of operating a fan jet propulsion unit effectively reduces the noise of operation of said propulsion unit. This advantage is produced by components which are light in weight and simple to manufacture and install in aircraft propelled by fan jet engines.

Although the invention has been described with reference to a particular embodiment of the same, it should not be considered to be limited thereto for various modifications could be made therein by one having ordinary skill in the art without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed as new and useful and is desired to be secured by a U.S. Patent.

I claim:

1. In an aircraft housing enclosing a fan jet engine and a tailpipe through which exhaust gas of said engine is discharged, the combination comprising:

a conduit operatively associated with said housing and disposed in spaced relation around said tailpipe to provide for flow of secondary air of said engine therebetween, said conduit projecting from the aft end of said tailpipe;

a thrust nozzle attached to the aft end of said conduit;

a set of first vanes operatively associated with said housing and extending rearwardly from the aft end of said tailpipe to a point adjacent the aft end of said conduit, said vanes being spaced apart circumferentially of said tailpipe and pivoted at their forward ends for rotation about axes disposed transverse to the longitudinal axis of said tailpipe;

a set of second vanes operatively associated with said housing and extending rearwardly from the aft end of said tailpipe to a point adjacent the aft end of said conduit, said second vanes being respectively disposed between said first vanes and pivoted at their aft ends for rotation about axes disposed transverse to the longitudinal axis of said tailpipe, said first and second vanes being movable between a first position wherein their longitudinal axes are substantially parallel with the longitudinal axis of said tailpipe and a second position wherein their longitudinal axes are inclined relative to said tailpipe longitudinal axis, whereby when said first and second vanes are in said first position said exhaust gas flows through the channel bounded by the inner surfaces of said vanes and said secondary air flows between the outer surfaces of said vanes and the inner surface of said conduit, and when said first and second vanes are in said second position part of said exhaust gas flows along the outer surfaces of said second vanes toward said conduit and part of said secondary air flows along the outer surfaces of said first vanes toward the longitudinal axis of said tailpipe; and

means for moving said first and second vanes between said first and second positions thereof.

2. The combination defined in claim **1** including a plurality of panels extending axially of said housing between the aft end of said tailpipe and the aft end of said conduit and spaced apart circumferentially of said tailpipe, said panels being respectively positioned between said first and second vanes to thereby separate flow of said exhaust gas along said second vanes from flow of said secondary air along said first vanes when said vanes are in said second position thereof.

3. The combination defined in claim **2** wherein a plurality of said panels are attached to the inner surface of said conduit.

4. The combination defined in claim **2** wherein the inner longitudinal edge of each of said panels is V-shaped.

5. The combination defined in claim **1** wherein said first and second vanes decrease in width in the direction of the free ends thereof, and including a plurality of fillets which extend rearwardly from the aft end of said tailpipe and the longitudinal edges of which are respectively disposed adjacent the longitudinal edges of said first and second vanes when the latter are in said first position thereof.

6. The combination defined in claim **1** including a pair of rings disposed in coaxial relation with the longitudinal axis of said tailpipe and spaced apart longitudinally thereon, said first and second vanes being respectively pivoted to said rings.

7. The combination defined in claim **1** wherein said means for moving said first and second vanes comprises a plurality of actuators mounted on said conduit and provided with drive shafts rotatable about their own longitudinal axes, which axes lie in a plane perpendicular to the longitudinal axis of said tailpipe, crank arms each fixedly connected at one end thereof to a respective one of said drive shafts, and links each pivotally connected at one end thereof to the free end of a respective one of said crank arms and pivotally connected at the other end thereof to a respective one of said vanes.

8. A method of operating an aircraft having a fan jet engine, which comprises:

in a first operational mode of said aircraft, flowing exhaust gas of said engine to a thrust nozzle in a columnar stream, and flowing secondary air of said engine to said thrust nozzle in a stream disposed around said stream of exhaust gas; and

in a second operational mode of said aircraft, flowing part of said exhaust gas outwardly into said stream of secondary air at points spaced around the inner boundary of the latter, and flowing part of said secondary air inwardly into said stream of exhaust gas at points spaced around the perimeter of the latter.

9. A method of operating an aircraft having a fan jet engine, which comprises:

in a first operational mode of said aircraft, (a) discharging exhaust gas of said engine to a thrust nozzle by flowing it through a tube the wall of which is at least partially formed of a plurality of axially extending vanes, said vanes being alternately hinged at their forward and aft ends for rotation about axes disposed transverse to the longitudinal axis of said wall, the aft end of said tube being substantially coterminous with the forward end of said thrust nozzle and spaced inwardly thereof so that said exhaust gas is discharged into the central portion of the throat of said thrust nozzle, and (b) discharging fan air of said engine to said thrust nozzle by flowing it through the space between said tube and a conduit disposed in spaced

relation around the latter, the aft edge of said conduit being joined to the forward edge of said thrust nozzle, fan air thus flowing into the throat of said thrust nozzle in an annular stream which surrounds said exhaust gas; and

in a second operational mode of said aircraft, moving the free ends of said vanes toward the longitudinal axis of said tube thereby to deflect part of said exhaust gas outwardly into fan air flowing along the inner surface of said conduit and to permit flow of part of said fan air inwardly into the part of said exhaust not deflected outwardly as aforesaid, said exhaust gas and fan air thus flowing into the throat of said thrust nozzle in an intermixed stream.