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**Papamoschou**

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(54) **JET ENGINE NOISE SUPPRESSOR**

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(73) Assignee: **The Regents of the University of California**, Oakland, CA (US)

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(22) Filed: **Dec. 29, 2006**

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**Related U.S. Application Data**

(63) Continuation-in-part of application No. 10/393,173, filed on Mar. 20, 2003, now Pat. No. 7,293,401.

(60) Provisional application No. 60/366,379, filed on Mar. 20, 2002.

(51) **Int. Cl.**
***B64D 33/00*** (2006.01)

(52) **U.S. Cl.** ........................... **244/1 N**; 244/54; 60/262; 60/264; 239/265.19; 181/220

(58) **Field of Classification Search** ................... 244/54, 244/73 R, 1 N, 53 R; 60/226.1, 262, 264, 60/770; 239/265.19; 181/213, 220
See application file for complete search history.

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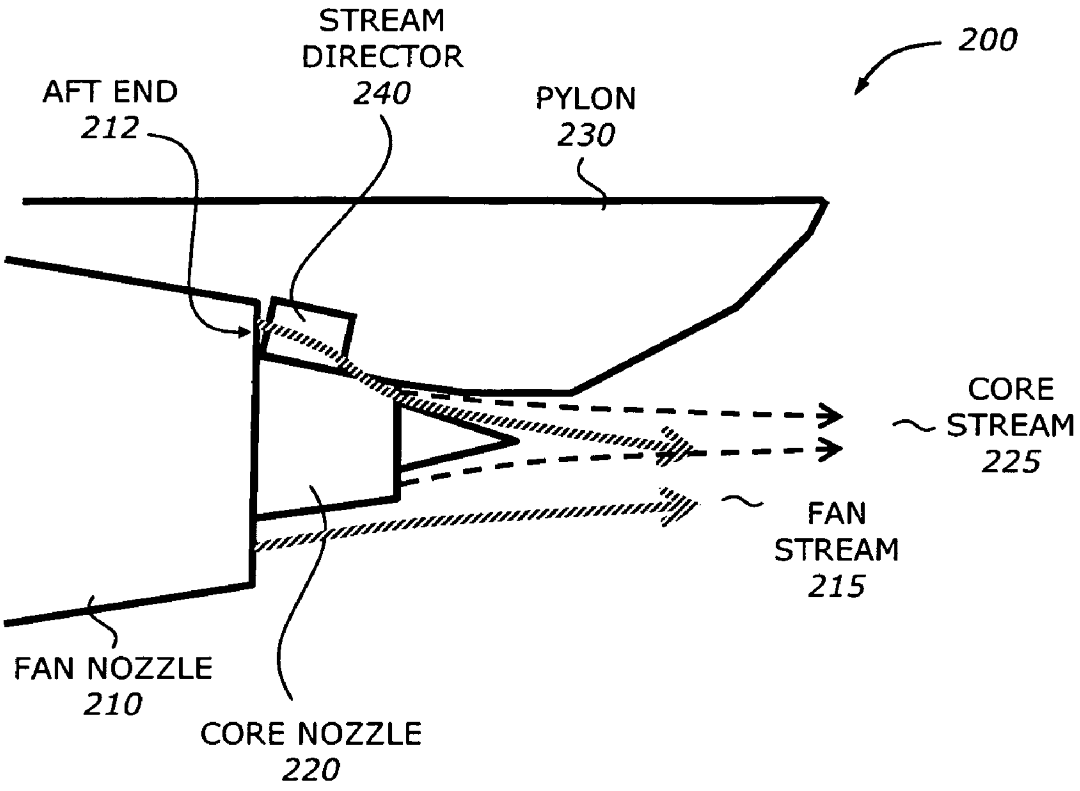
(57) **ABSTRACT**

An embodiment of the invention is a technique to suppress noise in a jet engine. A substantially annular fan nozzle is attached to a pylon and discharges a fan stream into atmosphere from an aft end thereof. A core nozzle discharges core stream into the atmosphere. The core nozzle has an exterior surface. A stream director is mounted on the pylon to direct the fan stream away from the pylon. At least a portion of the stream director is situated outside the aft end to maintain substantially constant flow area of the fan nozzle.

**45 Claims, 10 Drawing Sheets**



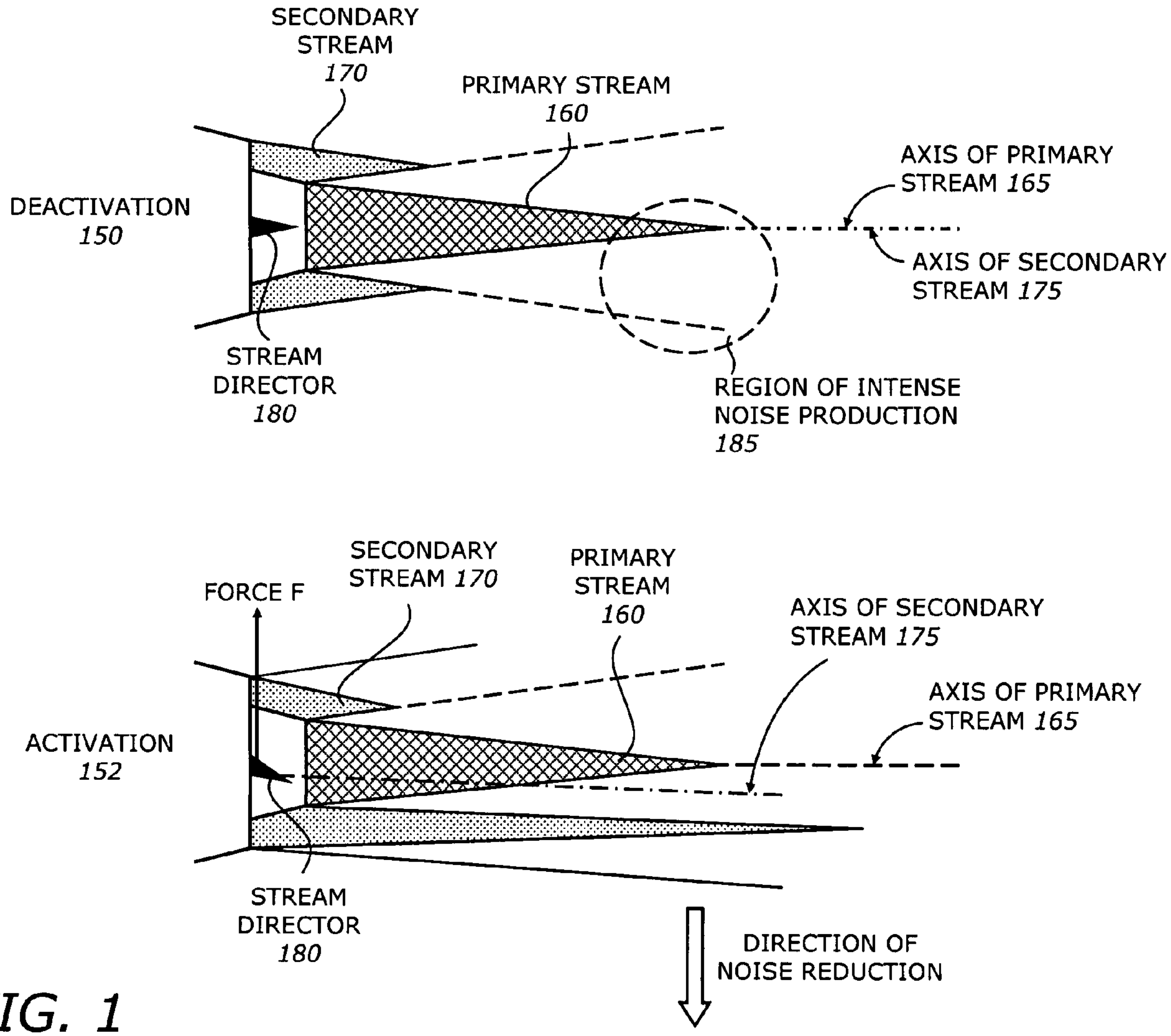

SECONDARY STREAM 170
PRIMARY STREAM 160
DEACTIVATION 150
AXIS OF PRIMARY STREAM 165
AXIS OF SECONDARY STREAM 175
STREAM DIRECTOR 180
REGION OF INTENSE NOISE PRODUCTION 185
FORCE F
SECONDARY STREAM 170
PRIMARY STREAM 160
AXIS OF SECONDARY STREAM 175
AXIS OF PRIMARY STREAM 165
ACTIVATION 152
STREAM DIRECTOR 180
DIRECTION OF NOISE REDUCTION

FIG. 1

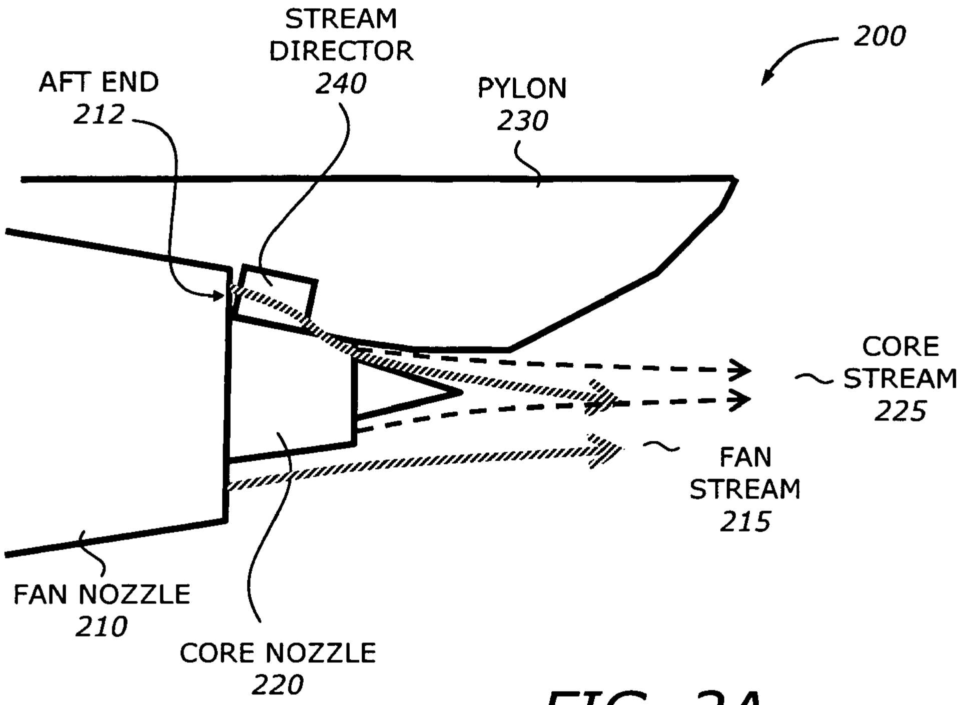

STREAM DIRECTOR 240
200
AFT END 212
PYLON 230
CORE STREAM 225
FAN STREAM 215
FAN NOZZLE 210
CORE NOZZLE 220

FIG. 2A

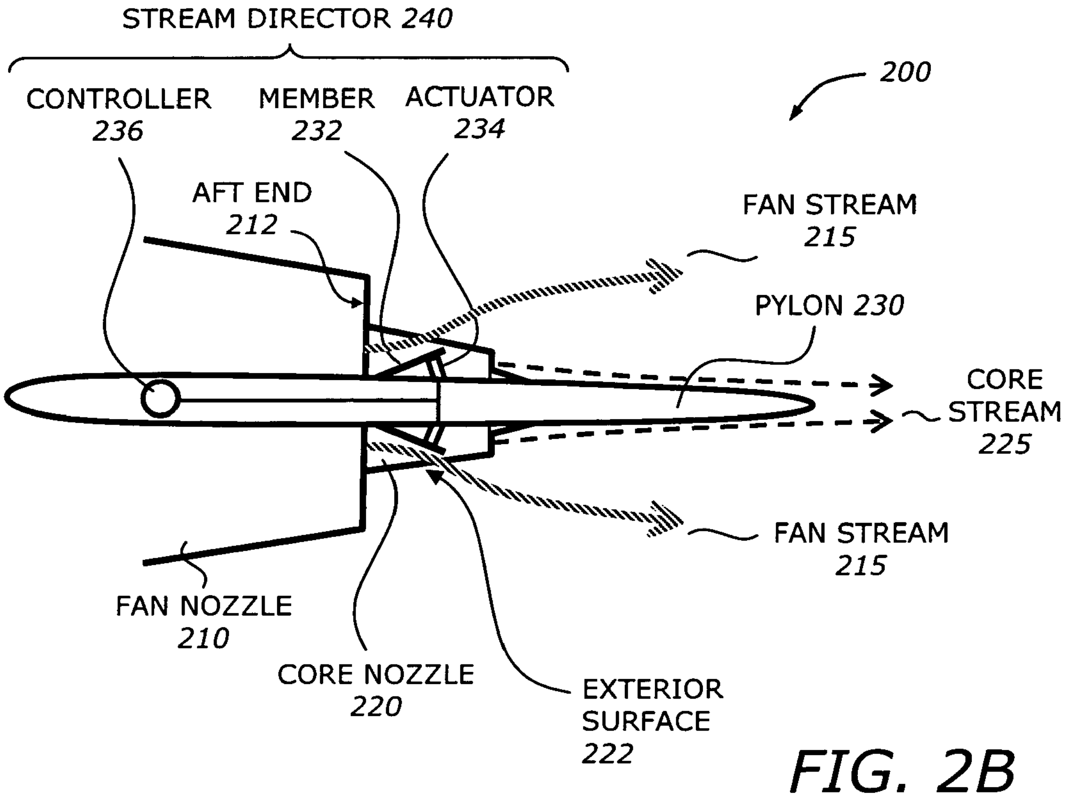

STREAM DIRECTOR 240
CONTROLLER 236
MEMBER 232
ACTUATOR 234
200
AFT END 212
FAN STREAM 215
PYLON 230
CORE STREAM 225
FAN STREAM 215
FAN NOZZLE 210
CORE NOZZLE 220
EXTERIOR SURFACE 222

FIG. 2B

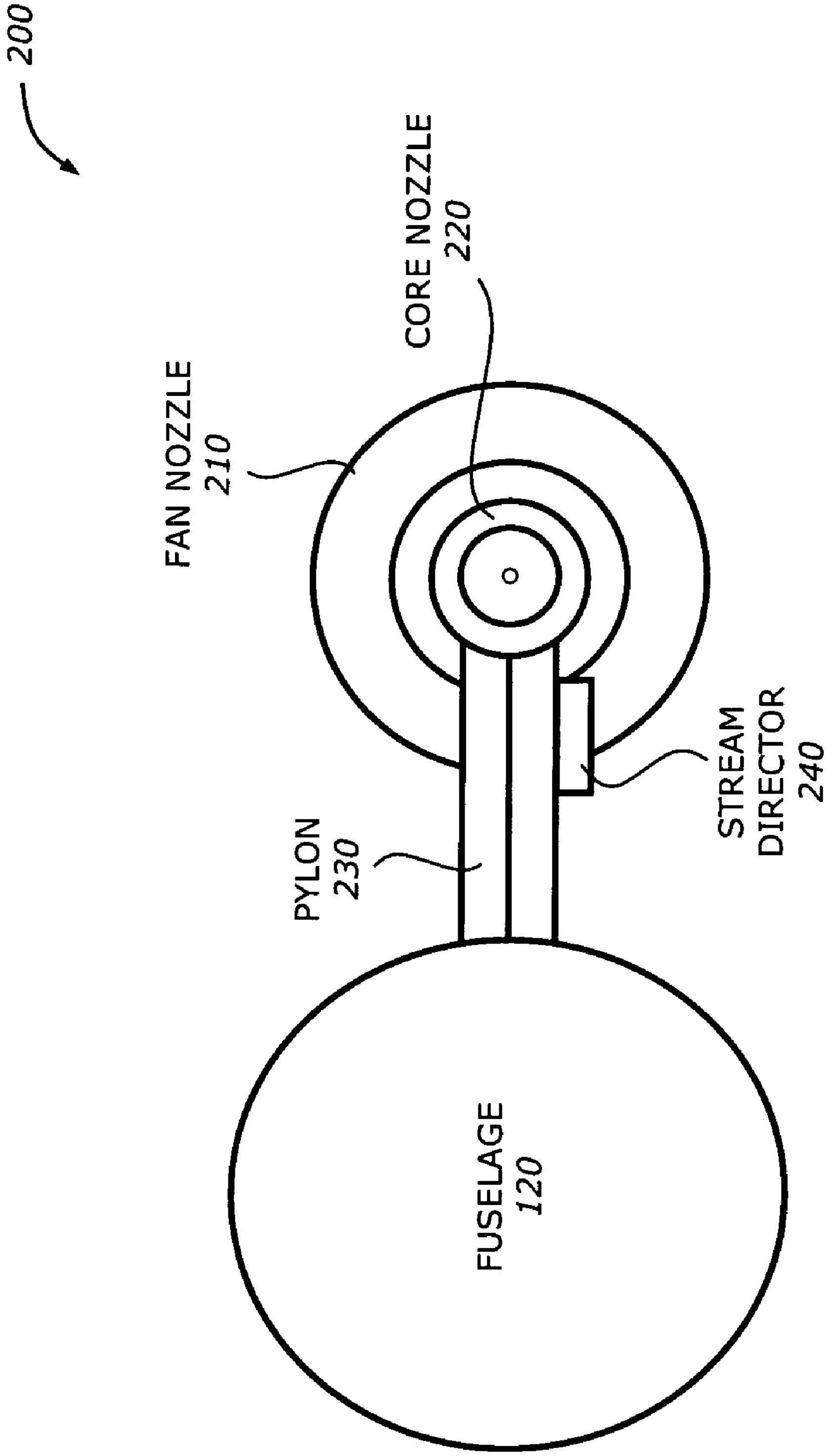

200
FAN NOZZLE 210
CORE NOZZLE 220
PYLON 230
STREAM DIRECTOR 240
FUSELAGE 120

FIG. 2C

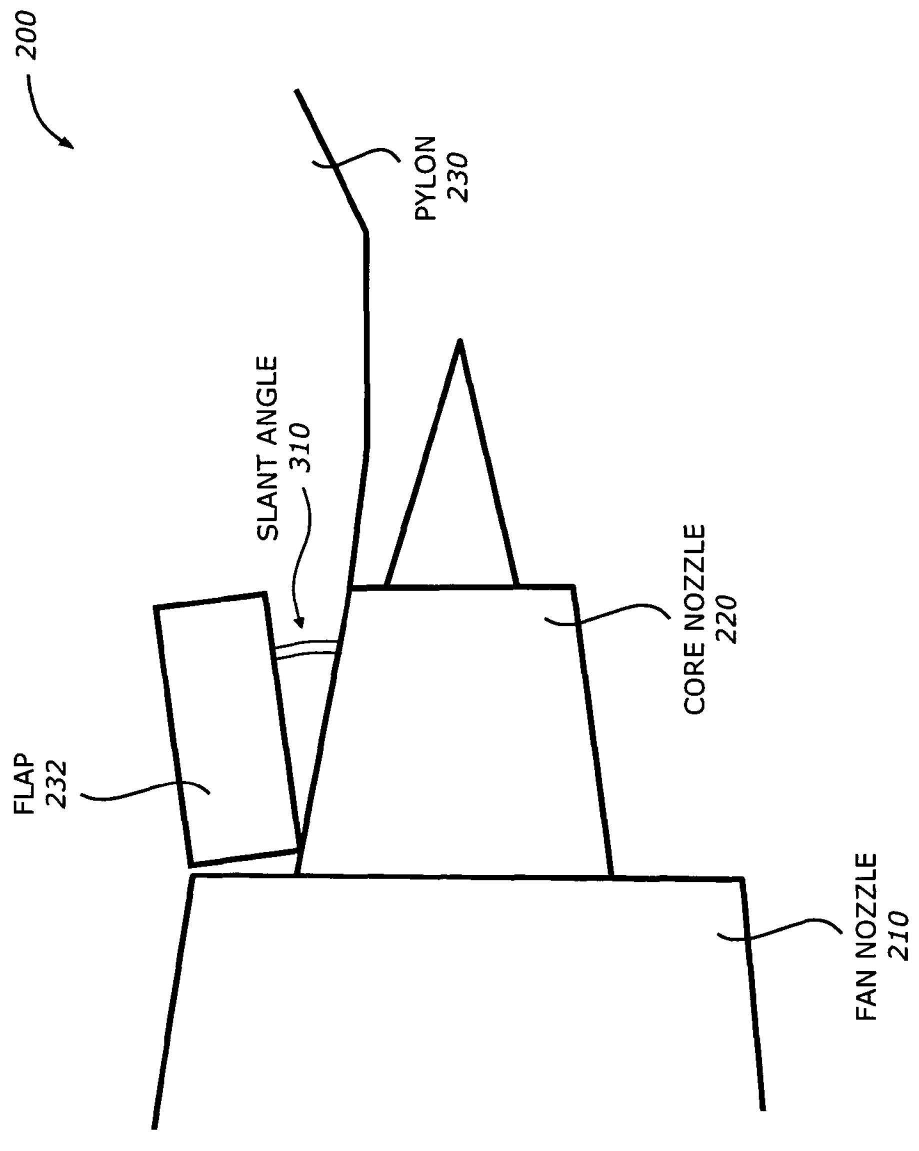

200
PYLON
230
SLANT ANGLE
310
FLAP
232
CORE NOZZLE
220
FAN NOZZLE
210

FIG. 3

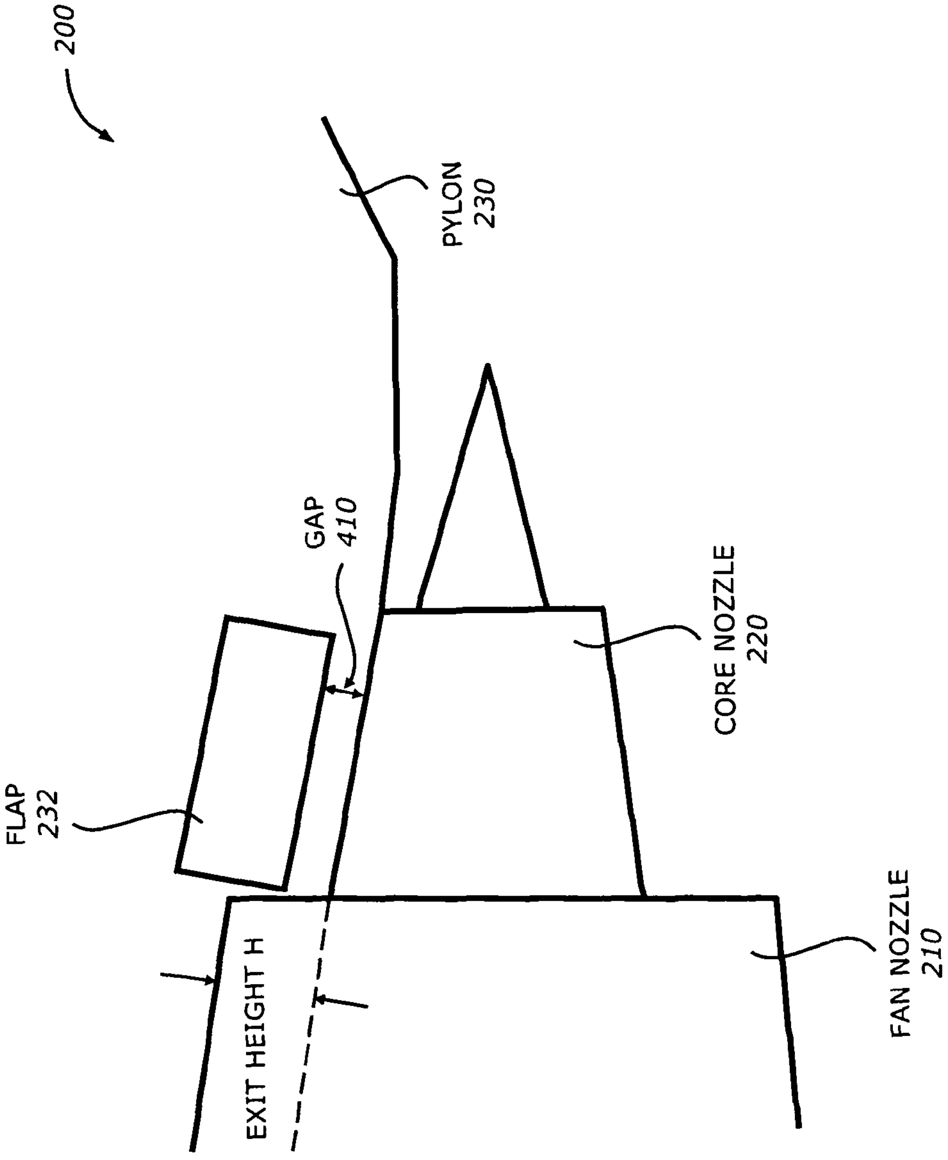

200
PYLON 230
GAP 410
CORE NOZZLE 220
FLAP 232
EXIT HEIGHT H
FAN NOZZLE 210

FIG. 4

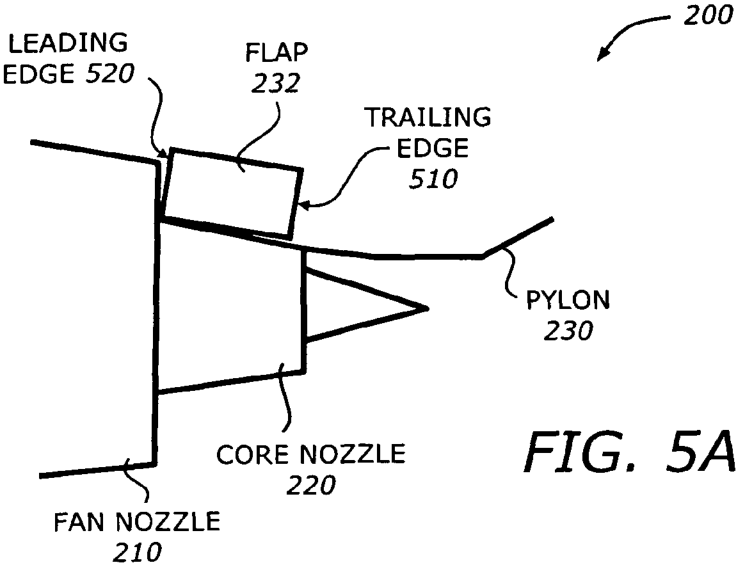


FIG. 5A

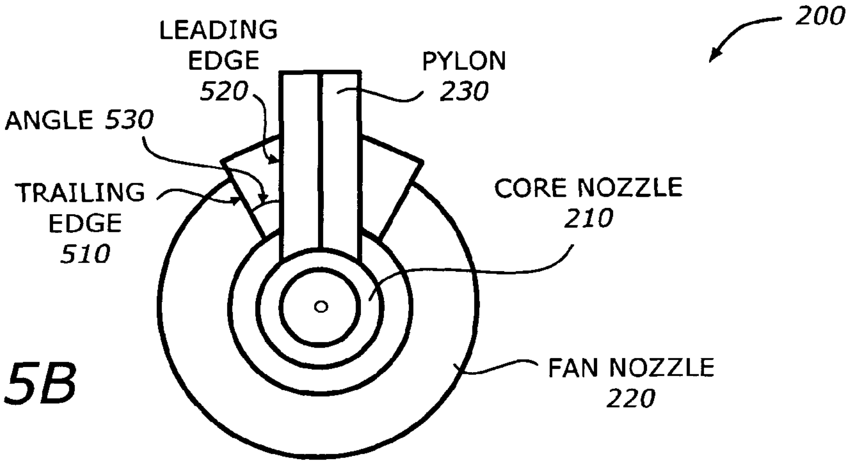


FIG. 5B

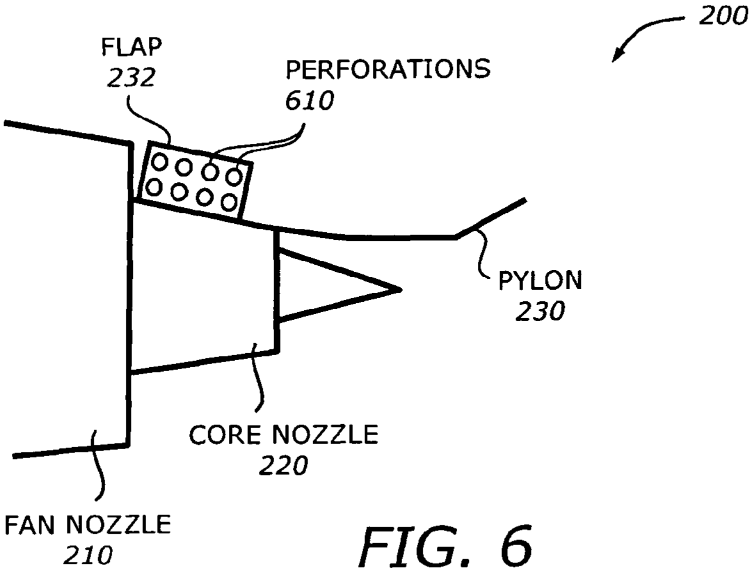


FIG. 6

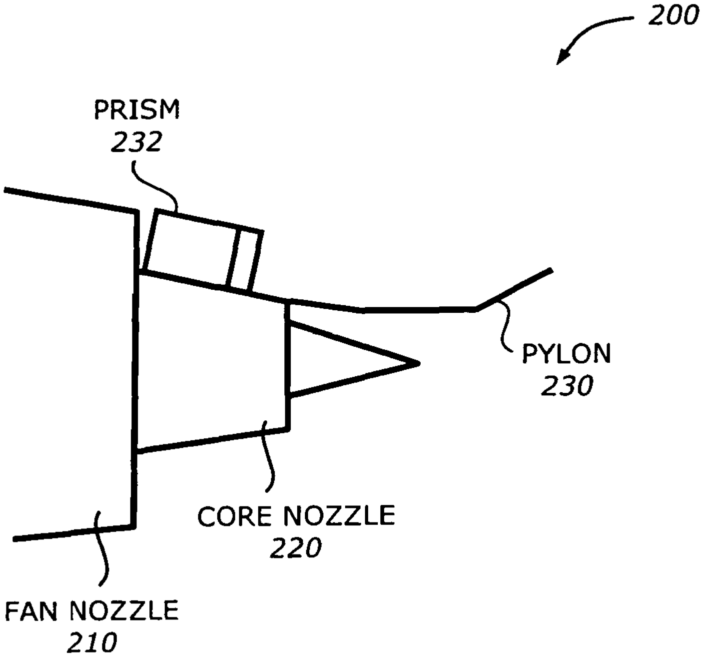

200
PRISM
232
PYLON
230
CORE NOZZLE
220
FAN NOZZLE
210

FIG. 7A

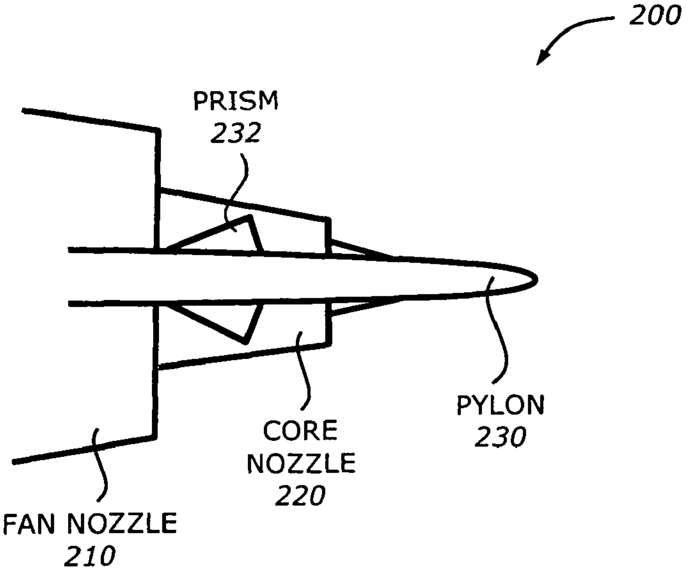

200
PRISM
232
CORE
NOZZLE
220
PYLON
230
FAN NOZZLE
210

FIG. 7B

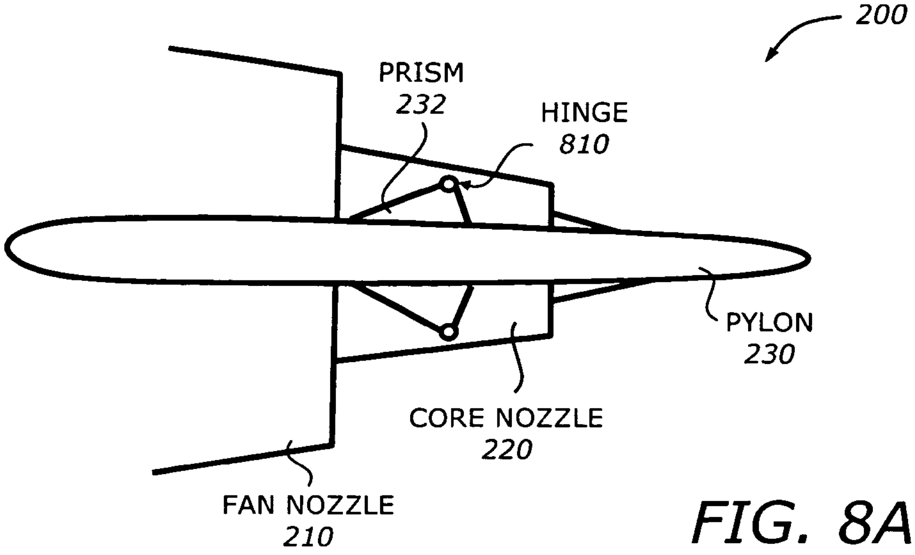


FIG. 8A

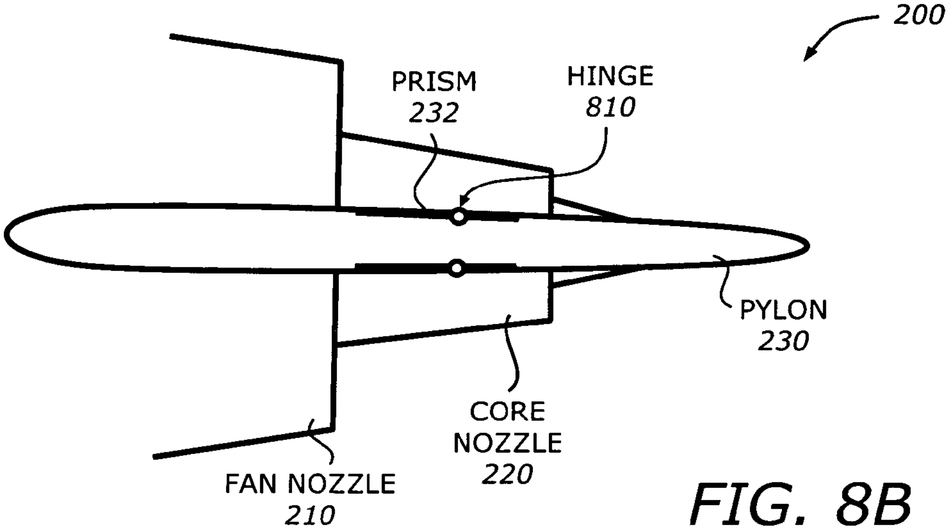


FIG. 8B

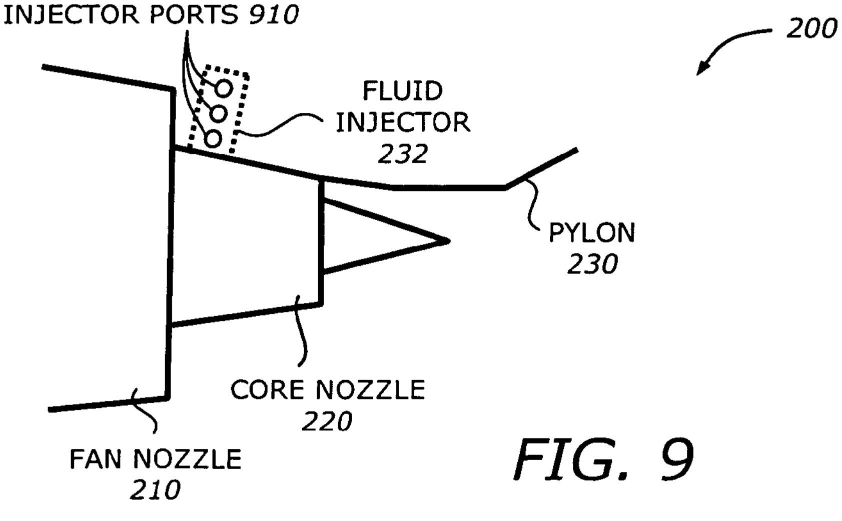


FIG. 9

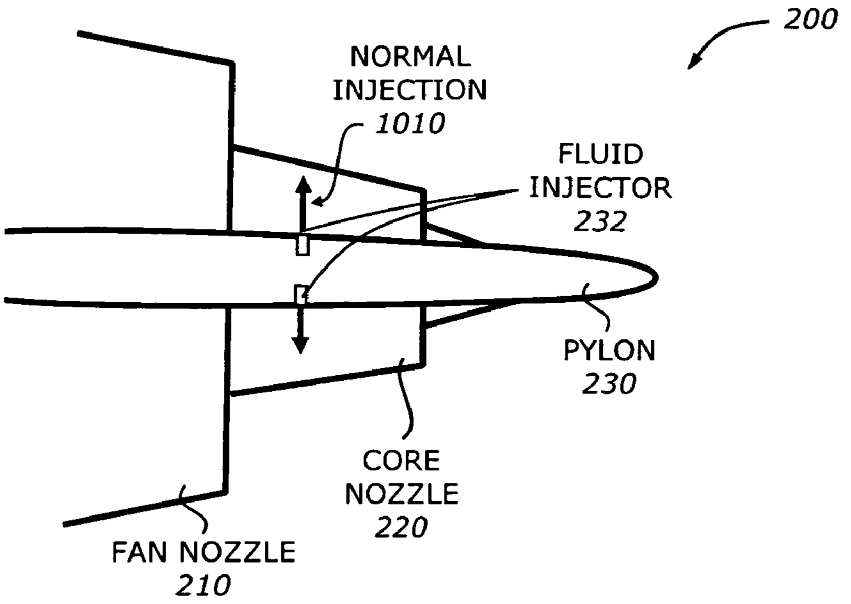


FIG. 10A

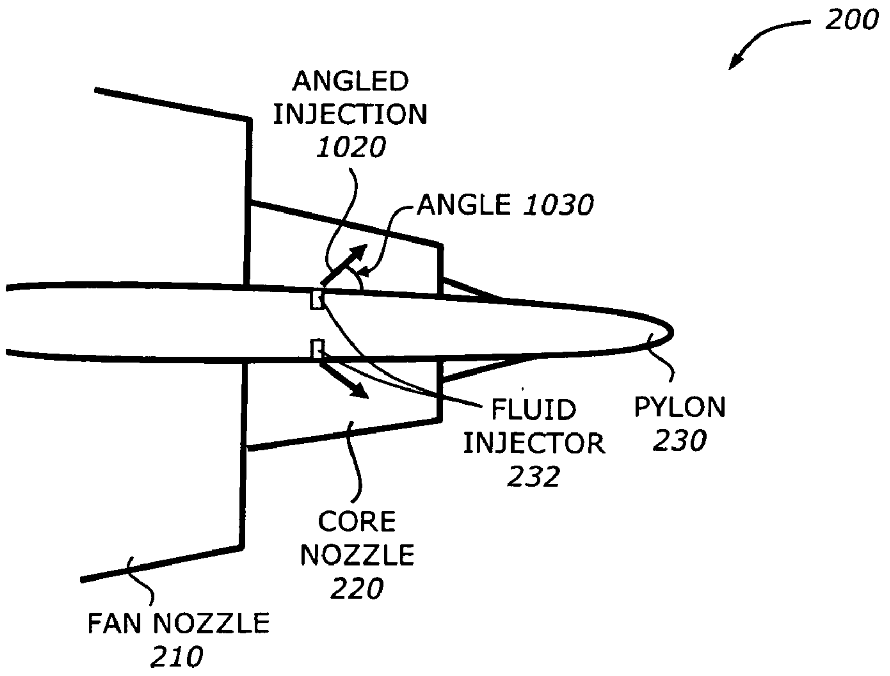


FIG. 10B

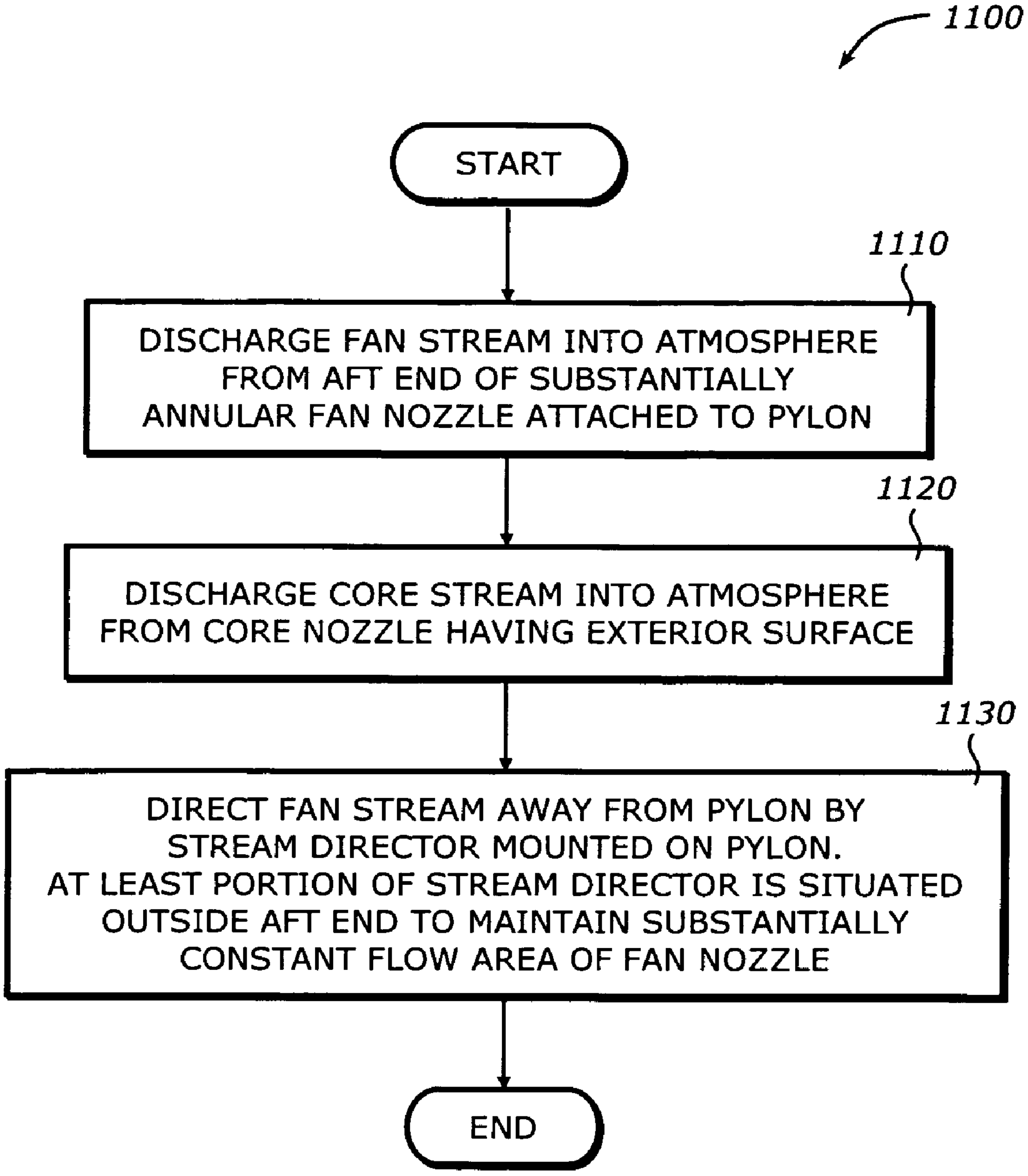

1100
START
1110
DISCHARGE FAN STREAM INTO ATMOSPHERE FROM AFT END OF SUBSTANTIALLY ANNULAR FAN NOZZLE ATTACHED TO PYLON
1120
DISCHARGE CORE STREAM INTO ATMOSPHERE FROM CORE NOZZLE HAVING EXTERIOR SURFACE
1130
DIRECT FAN STREAM AWAY FROM PYLON BY STREAM DIRECTOR MOUNTED ON PYLON. AT LEAST PORTION OF STREAM DIRECTOR IS SITUATED OUTSIDE AFT END TO MAINTAIN SUBSTANTIALLY CONSTANT FLOW AREA OF FAN NOZZLE
END

FIG. 11

# JET ENGINE NOISE SUPPRESSOR

This patent application is a continuation-in-part of the Patent application titled "Jet Engine Noise Suppressor", Ser. No. 10/393,173, filed on Mar. 20, 2003 now U.S. Pat. No. 7,293,401 which claims the benefit of the provisional application, titled "Jet Engine Noise Suppressor", filed on Mar. 20, 2002, Ser. No. 60/366,379.

This invention was made with Government support under Grant No. NAG-3-2345, awarded by the National Aeronautics & Space Administration. The Government has certain rights in this invention.

## BACKGROUND

### 1. Field of the Invention

Embodiments of the invention relate to jet engines, and more specifically, to jet engine noise suppression.

### 2. Description of Related Art

Aircraft noise has been a major problem in the aircraft industry. Among the sources of aircraft noise, jet engine noise is a dominant source. For commercial aircraft, the noise level becomes significant during both take-off and landing, causing concerns to local community near airports.

Current techniques to suppress jet engine noise have a number of drawbacks. Techniques relying on corrugated or fluted exhaust nozzles or additional passages connected to exhaust gas flow can only reduce some amount of noise at the expense of thrust loss and base drag increase. Other techniques do not provide satisfactory results or are not flexible to accommodate different engine operational modes in a typical aircraft flight route.

## SUMMARY OF THE INVENTION

An embodiment of the invention is a technique to suppress noise in a jet engine. A substantially annular fan nozzle is attached to a pylon and discharges a fan stream into atmosphere from an aft end thereof. A core nozzle discharges core stream into the atmosphere. The core nozzle has an exterior surface. A stream director is mounted on the pylon to direct the fan stream away from the pylon. At least a portion of the stream director is situated outside the aft end to maintain substantially constant flow area of the fan nozzle.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention may best be understood by referring to the following description and accompanying drawings that are used to illustrate embodiments of the invention. In the drawings:

FIG. **1** is a diagram illustrating a basic principle of noise suppression according to one embodiment of the invention.

FIG. **2**A is a diagram illustrating a side view of a noise suppression system according to one embodiment of the invention.

FIG. **2**B is a diagram illustrating a top view of a noise suppression system according to one embodiment of the invention.

FIG. **2**C is a diagram illustrating a rear view of a noise suppression system with a horizontal pylon according to one embodiment of the invention.

FIG. **3** is a diagram illustrating a stream director having flap forming a slant angle with air direction according to one embodiment of the invention.

FIG. **4** is a diagram illustrating a stream director having flap forming a gap with the surface of the core nozzle according to one embodiment of the invention.

FIG. **5**A is a diagram illustrating a side view of a stream director having flap with a trailing edge angled with the pylon surface according to one embodiment of the invention.

FIG. **5**B is a diagram illustrating a top view of a stream director having flap with a trailing edge angled with the pylon surface according to one embodiment of the invention.

FIG. **6** is a diagram illustrating a stream director with perforations according to one embodiment of the invention.

FIG. **7**A is a diagram illustrating a side view of a stream director with a triangular prism according to one embodiment of the invention.

FIG. **7**B is a diagram illustrating a top view of a stream director with a triangular prism according to one embodiment of the invention.

FIG. **8**A is a diagram illustrating a top view of a stream director with a triangular prism in activation mode according to one embodiment of the invention.

FIG. **8**B is a diagram illustrating a top view of a stream director with a triangular prism in de-activation mode according to one embodiment of the invention.

FIG. **9** is a diagram illustrating a stream director with injection ports according to one embodiment of the invention.

FIG. **10**A is a diagram illustrating a stream director with a normal fluid injection according to one embodiment of the invention.

FIG. **10**B is a diagram illustrating a stream director with an angled fluid injection according to one embodiment of the invention.

FIG. **11** is a flowchart illustrating a process to suppress noise according to one embodiment of the invention.

## DESCRIPTION

An embodiment of the invention is a technique to suppress noise in a jet engine. A substantially annular fan nozzle is attached to a pylon and discharges a fan stream into atmosphere from an aft end thereof. A core nozzle discharges core stream into the atmosphere. The core nozzle has an exterior surface. A stream director is mounted on the pylon to direct the fan stream away from the pylon. At least a portion of the stream director is situated outside the aft end to maintain substantially constant flow area of the fan nozzle.

In the following description, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known circuits, structures, and techniques have not been shown in order not to obscure the understanding of this description.

FIG. **1** is a diagram illustrating a basic principle of noise suppression according to one embodiment of the invention. The principle of noise suppression may be explained from a deactivation condition **150** and an activation condition **152**. In this illustrative example, there are two air streams exhausted from an aircraft engine: a primary stream **160** and a secondary stream **170**. The two streams may be discharged from two nozzles in a turbofan engine such as the fan and core nozzles.

The principle of noise suppression or reduction is based on a directional noise reduction method. In other words, noise is suppressed when the direction of the primary stream **160** or the secondary stream **170** is altered such that the slower secondary stream **170** is concentrated or forced adjacent to the faster primary stream **160** in the region where intense noise is generated and in a direction where noise reduction is desired. In a typical jet exhaust configuration at the exit of the jet engine, the primary stream **160** is a fast stream which forms around an axis **165** of primary stream, typically aligned with the center line of the engine core. The region around the end of the primary stream **160** is a region of intense noise production **185**. In this region, high-speed primary stream **160** is very turbulent and jet noise emission is the most significant. The secondary stream **170** is typically slower than the primary stream **160** and forms around the start of the primary stream **160**. The secondary stream **170** has an axis **175** of secondary stream. Suppose a stream director **180** is positioned at a location in the vicinity of the exit of the secondary nozzle and is substantially immersed in the secondary stream **170** exiting the nozzle.

In the deactivated mode **150**, the stream director **180** is at the retracted position where it is substantially aligned with the axis **165** of the primary stream **160** which is substantially coaxial with the axis **175** of the secondary stream **170**. In this condition, the primary and secondary streams **160** and **170** are substantially coaxial. In this configuration, the secondary stream **170** ends well upstream of the end of the primary stream **160** resulting in little or no noise suppression.

In the activation mode **152**, the stream director **180** is at the extended position. The stream director generates a force F which causes a deflection of the secondary stream **170** so that the axis of the secondary stream **175** is no longer aligned with the axis **165** of the primary stream **160**. The secondary stream **170** is deflected in the general direction where noise reduction is desired. In typical applications, this direction will be downward (towards the ground) and/or sideward. For the illustrative discussion that follows, the direction of noise reduction is taken to be downward. The force F induces a downward motion of the secondary flow so that the lower portion of the secondary flow is elongated. Moreover, the downward induction of secondary flow results in a layer of substantially unmixed flow around and downstream of the lower portion of the secondary stream **170**. The result is that a layer of potential or substantially unmixed flow covers the region of intense noise production **185**. In the vicinity of the region of intense noise production **185**, the high-speed primary stream **160** and the layer of substantially unmixed flow form an eccentric configuration. This eccentric configuration causes noise suppression at the downward and sideward directions. The eccentricity of the high-speed primary flow and substantially unmixed secondary flow depends on the on the angle of deflection of the axis **175** of the secondary stream **170** relative to the axis **165** of the primary stream **160**. Since the activation of the stream director **180** creates the force F that produces this deflection, the stream director **180** may be referred to as a force generator. FIG. **1** depicts a simplified version of this process wherein a unidirectional force F is shown. However, in general the force F may be a distributed force causing a distributed deformation of the secondary stream according to the range of directions in which noise suppression is desired.

Although the above discussion refers to two operating modes: the activation mode and the de-activation mode, the same principle may apply when the exhaust system operates only in the activation mode. In this situation, the stream director **190** may be fixed it its configuration or position.

FIG. **2**A is a diagram illustrating a side view of an exhaust system **200** according to one embodiment of the invention. The exhaust system **200** suppresses noise from an engine of an aircraft. The exhaust system **200** includes a substantially annular fan nozzle **210**, a core nozzle **220**, a mounting pylon **230**, and a stream director **240**.

The fan nozzle **210**, the core nozzle **220**, and the pylon **230** represent the well-known art of the exhaust of a separate-flow turbofan engine. The fan nozzle **210** and the core nozzle **220** are parts of a jet engine of an aircraft. The pylon **230** is a structural member that supports the engine on the wing or on the fuselage. For a wing-mounted engine, the pylon is substantially vertical. For a typical fuselage-mounted engine, the pylon is substantially horizontal. The pylon structure extends longitudinally from near the front of the engine to downstream of the core exhaust. The structure cuts through the fan nozzle **210** on the attachment side. Inside the fan nozzle **210**, the pylon leading edge is located substantially upstream of the fan nozzle exit.

The fan nozzle **210** is attached to the pylon **230**. It has an aft end **212**. The fan nozzle **210** discharges a fan stream **215** into atmosphere from the aft end **212**. The core nozzle **220** discharges a core stream **225** into the atmosphere. The core nozzle has an exterior surface **222**. In normal operation, the fan stream **215** and the core stream **225** are substantially coaxial.

The stream director **240** operates essentially in the same principle as the stream director **180** shown in FIG. **1**. It is attached or mounted on the pylon **230** to direct the fan stream **215** away from the pylon **230**. As discussed above, the deflection of the fan stream **215** creates an eccentric configuration at substantially the sideward and/or downward direction. This is shown in FIG. **2**A by illustrative streamlines of the fan stream **215** and core stream **225**. Each portion of the stream director **240**, on either side of the pylon **230**, creates a force that directs the fan flow away from the pylon **230**. Depending on the direction and distribution of this force, the movement of the fan stream **215** may be sideward and/or downward. The geometry of the exterior surface **222** may contribute to the downward motion of the fan stream **215** directed away from the pylon **230**. For example, if the exterior surface **222** has a convergent shape, it may impart a downward motion to the sideward-deflected flow. In reference to the general principle of operation approximated in FIG. **1**, the operation of the pylon-mounted deflector may be understood conceptually by considering only the lower halves of the deactivated **150** and activated **152** jet flows and by taking the direction of noise reduction to be the sideward direction. The resulting deformation of the air stream causes reduced velocity gradients, and ensuing reduction of the noise sources, in the general direction of the deformation. Additional noise reduction mechanisms may include refraction and convective Mach number reduction. At least a portion of the stream director **240** is situated outside the aft end **212** to maintain a substantially constant flow area of the fan nozzle **210**. The leading edge of the stream director member **232** may be as far as about five exit heights downstream of the aft end **212** of the fan nozzle. The exit height H is the distance between the external surface **222** of the core nozzle **220** and the inner surface of the fan nozzle **210** at the aft end of the fan nozzle **212**.

The stream director **240** includes a member **232**, an actuator **234**, and a controller **236**. The stream director **240** may operate in a fixed mode or a variable mode. In the fixed mode, the position and/or the orientation of the member **232** is fixed according to some optimal criteria. In this mode, the controller **236** and/or the activator **234** may not be needed and the stream director **240** may include only then member **232**. In the variable mode, the position and/or the movement of the member **232** is variable or changed, either manually or automatically, according to the desired level of noise suppression.

The member **232** may be attached to either side of the pylon **230** to cause the fan stream **215** to deflect away from the pylon **230**. The member **232** may have a fixed or variable position on the pylon **230**.

At a cross-plane downstream of the location of the stream director **240**, the velocity profile without stream director is largely symmetric (e.g., concentric or coaxial) around the axis of the nozzle. When the stream director **240** is activated, the velocity profile becomes deformed and asymmetric (e.g., non-concentric or eccentric), with reduced gradients in the general direction where noise reduction is desired. In most civilian applications, the general direction of the deformation, and of the resulting noise suppression, is downward and to the sideline. In a wing-mounted engine with vertical pylon, the stream director **240** may be applied symmetrically on both sides of the pylon **230** to cause deformation of the fan stream **215** in the sideline and downward directions. In a fuselage-mounted engine with a horizontal pylon, the stream director **240** may be applied to only the bottom side of the pylon **230** to cause a downward deformation of the fan stream **215**.

In all embodiments, the stream director **240** is located substantially or totally outside the exit of the fan duct. This allows a substantially constant flow area of the fan nozzle **210** and thus prevents alterations to the engine cycle that would have resulted from significant changes in the flow area. Moreover, the placement of the stream director **240** on the pylon **230** and substantially outside the fan nozzle **210** means that this noise suppression system requires changes only to the pylon **230** and that the nozzles **210** and/or **220** may not require any modifications.

The actuator **234** is coupled to the member **232** to activate the member **232** when the member **232** has the variable or adjustable position. When activated, the member **232** directs the fan stream **215** away from the pylon **230**. The controller **236** is coupled to the actuator **234** to control the actuator **234** to activate or de-activate the member **232**. The controller **236** may be located on the engine **130** or at a distance from the engine **130** such as in the frame of the wing **120**, the pylon **230**, or any other suitable location. The controller **112** receives control signals either from the flight crew (e.g., pilot, flight engineer), from a prescribed control sequence, or from an automatic sensing instrument. The prescribed control sequence may be such as to maximize noise reduction at each monitoring/certification point or to maximize the cumulative noise reduction at all monitoring/certification points; such monitoring/certification points include the sideline, takeoff/cutback, and approach monitors. The controller **112** generates control signals to the actuator **234** to activate or deactivate the stream director **240**. The actuator **234** may activate the member **232** using at least one of pneumatic, hydraulic, mechanical, electrical, and electromagnetic action or a valve. The action controls the movement of the stream director **232** into two positions: a retracted position and an extended position. The actuator **234** and/or the stream director **232** may be fabricated, in part or in full, using a shape-memory alloy that is activated by electricity or by the temperature of the fan flow. Any alloy that possesses the shape-memory property, i.e., the ability to remember the original shapes, may be used. Examples of shape-memory alloys include nickel-titanium, copper-aluminum, copper-zinc-aluminum, and iron-manganese-silicon alloys. Use of a shape-memory alloy activated by the temperature of the fan air would enable autonomous operation of the stream director **232** thus obviating the use of the controller **236**.

The retracted position of the member **232** corresponds to a deactivated condition or to the position of the member **232** where the fan stream **215** is not directed away from the pylon. The extended position of the member **232** corresponds to an activated condition or to the position of the member **232** that directs fan stream away from the pylon **230**. The activated position may be prescribed to optimally provide noise reduction monitored at a particular monitoring station and may not necessarily correspond to the full deployment of the member **232**. Intermediate positions may be defined to allow a gradual movement of the member **232**. The member **232** may be a flap, prism, or a fluid injector. When the member **232** is a fluid injector, the term retracted position corresponds to a closed position where the fluid injector stops or reduces injecting the fluid, and the term extended position corresponds to an open position where the fluid injector injects or increases injecting the fluid.

FIG. **2**B is a diagram illustrating a top view of the noise suppression system **200** according to one embodiment of the invention.

The member **232** may include at least one flap on either side of the pylon **230**. The flap **232** makes an acute angle with the direction of the fan stream **215** and directs the fan stream **215** away from the pylon **230**. This angle may range from zero to 60 degrees. The flap length may range from 1.0 to 4.0 exit heights H, and the flap height may range from 0.75 to 2.0 exit heights H. The flap **232** may include a rigid plate or a flexible plate. The plate may be straight or curved. For a rigid plate, the flap **232** may be hinged at its leading edge. For a flexible plate, the flap may be cantilevered around its leading edge. Further, for a flexible plate, the actuator **234** may be arranged to impart longitudinal and/or transverse curvature to the flap surface. As discussed above, activation of the flap **232** may include pneumatic, hydraulic, or mechanical actuation. Further, the actuator **234** or the flap member **232** may be fabricated, in part or in full, by a shape-memory alloy that is activated by electricity or by the temperature of the fan flow. Two flaps, one on either side of the pylon, may be used. Alternatively, only one flap may be used. The angle of the flap **232** with the pylon **230** is controlled by the actuator **234**. In the deactivated position, the flap **232** may be flush with the surface of the pylon **230** to eliminate aerodynamic disturbances. This can be accomplished by the surface of the pylon **230** having a recess where the flap **232** is stored; alternatively, the skin of the pylon **230** may be used to form the flap **232**.

FIG. **2**C is a diagram illustrating a rear view of the noise suppression system **200** with a horizontal pylon according to one embodiment of the invention.

The pylon **230** attached the fan nozzle **210** and/or the core nozzle **220** to a fuselage **120** in a horizontal plane. In this configuration, the stream director **240** is typically attached to the bottom surface of the pylon **230**.

FIG. **3** is a diagram illustrating a stream director having flap forming a slant angle with the direction of the fan stream according to one embodiment of the invention.

The stream director **240** includes a flap member **232** placed at a slant angle **310** relative to the direction of the fan stream **215**. The slant angle may be fixed or controlled by the actuator **234**. For a vertical pylon **230**, the slant angle **310** may control the amount of the fan stream **215** that is directed downward. The slant angle **310** may range from zero to 45 degrees. A large slant angle **310** result in a large movement of air deflected downward.

FIG. **4** is a diagram illustrating a stream director having flap forming a gap with the surface of the core nozzle according to one embodiment of the invention.

The stream director **240** includes of a flap member **232** that has a gap **410** between the bottom edge of the flap **232** and the surface of the core nozzle **220**. The gap allows some fan air of the fan stream **215** on the top of the core nozzle **220** thus preventing generation of steep velocity gradients on the top of the jet exiting the core nozzle **220** that may cause an increase in upward-generated noise. The height of the gap **410**, as a fraction of an exit height H of the annular fan nozzle **210**, may be the result of optimization but is expected to range approximately from 10% to 50% of the exit height H. In applications where a good seal is desired between the bottom edge of the flap **232** and the surface of the core nozzle **220**, the gap **410** may be zero.

FIGS. **5**A and **5**B are diagrams illustrating a side view and a top view, respectively, of a stream director having flap with a trailing edge angled with the pylon surface according to one embodiment of the invention.

The stream director **240** includes of a flap member **232** that has a trailing edge **510** and a leading edge **520**. The trailing edge **510** of the flap member **232** forms an angle **530** with the surface of the pylon **230**. Such arrangement may be achieved by using a flexible plate that has a twist so that the leading edge **520** of the flap **232** is aligned with the surface of the pylon **230** and the trailing edge of the flap **232** forms the angle **530** with the surface of the pylon **230**. The angle **530** of the trailing edge **510** may control the amount of air that is deflected downward. The angle **530** may range from zero to 45 degrees.

FIG. **6** is a diagram illustrating a stream director with perforations according to one embodiment of the invention.

The stream director **240** includes a flap member **232** with perforations. The perforations may reduce aerodynamic buffet that could occur when the flap **232** is deployed at significant angles. Additionally, the perforations allow some fan air through the flap **232** thus preventing generation of steep velocity gradients on the top of the jet exiting the core nozzle that could cause increase in upward-generated noise. The perforations may be circular, elliptical, or of other suitable shape. The percent of open area of the perforated flap **232** will be the result of optimization but is expected to range approximately from 20% to 70% of the total area of the flap **232**.

FIGS. **7**A and **7**B are diagrams illustrating a side view and a top view, respectively, of a stream director with a triangular prism according to one embodiment of the invention.

The stream director **240** includes a member **232** having the shape of a triangular prism. The fore joining face of the prism **232** makes an acute angle with direction of the fan stream. The angle of the aft joining face may be determined by optimization that minimizes the drag of the prism **232**. The prism **232** may be hollow and devoid of base faces. Similar to the flap configurations shown in FIGS. **3**, **4**, **5**A, **5**B, **6**A, and **6**B, the prism **232** may make a slant angle, leave a gap between its lower edge and the surface of the core nozzle **220**, have a twisted front joining surface, and/or have perforations.

FIG. **8**A is a diagram illustrating a top view of a stream director with a triangular prism in activation mode according to one embodiment of the invention.

The stream director **240** includes a member **232** having the shape of a triangular prism. The prism **232** may be hollow and devoid of base surfaces. The joint of fore and aft surfaces may be hinged at a hinge **810**. The hinge **810** allows for the prism **232** to change shape.

FIG. **8**B is a diagram illustrating a top view of a stream director with a triangular prism in de-activation mode according to one embodiment of the invention.

The hinge **810** allows for unfolding of the surface of the prism **232** onto the surface of the pylon **230** when the prism **232** is deactivated. In the de-activation mode, the surface of the prism **232** may be substantially flat resting on the surface of the pylon **230**.

FIG. **9** is a diagram illustrating a stream director with injection ports according to one embodiment of the invention.

The stream director **240** includes member **232** having injection ports through which a fluid is injected. A single port or a multitude of ports may be used. The ports may be arranged in a vertical pattern, or other patterns depending on the desired displacement of the fan stream and the mechanical structure of the pylon **230**. The ports may include circular holes, elliptical holes, slots, or any other suitable orifice. The injection would be activated during noise-sensitive segments of flight and deactivated otherwise. The injection fluid may be air from a compressor stage of the engine, air from a fan stage of the engine, or a compressed gas or liquid stored onboard the aircraft. The injection may be controlled by pressure regulators and by on/off valve. The typical injection mass flow rate may be a small fraction (e.g., in the order of 10% or less) of the mass flow rate of the air flowing through the engine compressor.

FIGS. **10**A and **10**B are diagrams illustrating a stream director with a normal and angled, respectively, fluid injection according to one embodiment of the invention.

The injection **1010** may be normal, or substantially perpendicular, to the direction of the fan stream **215**.

The injection **1020** may be at an angle acute to the direction of the fan stream. The injection angle would be the result of optimization that includes the parameters of displacement of the fan stream away of the pylon **230** and the forward thrust of the injectors. The acute angle may be from 20 degrees to less than 90 degrees.

FIG. **11** is a flowchart illustrating a process **1100** to suppress noise according to one embodiment of the invention.

Upon START, the process **1100** discharges a fan stream into atmosphere from an aft end of a substantially annular fan nozzle attached to a pylon (Block **1110**). Next, the process **1100** discharges a core stream into the atmosphere from a core nozzle having an exterior surface (Block **1120**).

Then, the process **1100** directs the fan stream away from the pylon by a stream director mounted on the pylon (Block **1130**). At least a portion of the stream director is position or situated outside the aft end to maintain substantially constant flow area of the fan nozzle. This may be performed by causing the fan stream to deflect away from the pylon by a member of the stream director that is attached to either side of the pylon. The member may have a fixed or variable position on the pylon. The member may be a flap, a prism, or a fluid injector as described above.

While the invention has been described in terms of several embodiments, those of ordinary skill in the art will recognize that the invention is not limited to the embodiments described, but can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of limiting.

What is claimed is:

**1**. A turbofan exhaust system comprising:

a substantially annular fan nozzle attached to a pylon and discharging fan stream into atmosphere from an aft end thereof;

a core nozzle to discharge core stream into the atmosphere, the core nozzle having an exterior surface; and

a stream director mounted on the pylon substantially external to the fan nozzle directing the fan stream away from the pylon, at least a portion of the stream director situated outside the aft end to maintain substantially constant flow area of the fan nozzle.

**2**. The turbofan exhaust system of claim **1** wherein the stream director comprises:

a member attached to either side of the pylon to cause the fan stream to deflect away from the pylon, the member having a fixed or variable position on the pylon.

**3**. The turbofan exhaust system of claim **2** wherein the stream director further comprises:

an actuator coupled to the member to activate the member having the variable position, the activated member directing the fan stream away from the pylon; and

a controller coupled to the actuator to control the actuator to activate or de-activate the member.

**4**. The turbofan exhaust system of claim **3** wherein the actuator activates the member using at least one of pneumatic, hydraulic, mechanical, electrical, and electromagnetic action.

**5**. The turbofan exhaust system of claim **2** wherein the member comprises a flap forming an acute angle with a pylon surface or direction of the fan air when activated, the flap being flush with the pylon surface when de-activated.

**6**. The turbofan exhaust system of claim **2** wherein the member comprises a flap forming a slant angle relative to direction of the fan stream.

**7**. The turbofan exhaust system of claim **2** wherein the member comprises a flap forming a gap with respect of the exterior surface of the core nozzle.

**8**. The turbofan exhaust system of claim **2** wherein the member comprises a flap having a trailing edge and a leading edge, the leading edge being aligned with surface of the pylon and the trailing edge forming an acute angle with the surface of the pylon.

**9**. The turbofan exhaust system of claim **2** wherein the member comprises a flap having a perforated surface.

**10**. The turbofan exhaust system of claim **2** wherein the member comprises a triangular prism having a fore joining face making an acute angle with direction of the fan stream.

**11**. The turbofan exhaust system of claim **10** wherein the prism is hollow or hollow and devoid of base faces.

**12**. The turbofan exhaust system of claim **2** wherein the member comprises a fluid injector.

**13**. The turbofan exhaust system of claim **12** wherein the fluid injector comprises at least one injection port on surface of the pylon, the injection port injecting air from a compressor stage or a fan stage of a turbofan.

**14**. The turbofan exhaust system of claim **12** wherein the fluid injector injects a fluid at an angle normal or acute to direction of the fan stream.

**15**. The turbofan exhaust system of claim **2** wherein the member or the actuator is fabricated by a shape-memory alloy and is activated by an electric excitation or temperature of the fan stream.

**16**. A method comprising:

discharging fan stream into atmosphere from an aft end of a substantially annular fan nozzle attached to a pylon;

discharging core stream into the atmosphere from a core nozzle having an exterior surface; and

directing the fan stream away from the pylon by a stream director mounted on the pylon substantially external to the fan nozzle, at least a portion of the stream director being situated outside the aft end to maintain substantially constant flow area of the fan nozzle.

**17**. The method of claim **16** wherein directing the fan stream comprises:

causing the fan stream to deflect away from the pylon by a member of the stream director that is attached to either side of the pylon, the member having a fixed or variable position on the pylon.

**18**. The method of claim **17** wherein directing the fan stream further comprises:

activating the member having the variable position by an actuator, the activated member directing the fan stream away from the pylon; and

controlling the actuator to activate or de-activate the member.

**19**. The method of claim **18** wherein activating comprises activating the member using at least one of pneumatic, hydraulic, mechanical, electrical, and electromagnetic action.

**20**. The method of claim **18** wherein activating the member comprises activating a flap forming an acute angle with a pylon surface or direction of the fan air when activated, the flap being flush with the pylon surface when de-activated.

**21**. The method of claim **18** wherein activating the member comprises activating a flap forming a slant angle relative to direction of the fan stream.

**22**. The method of claim **18** wherein activating the member comprises activating a flap forming a gap with respect of the exterior surface of the core nozzle.

**23**. The method of claim **18** wherein activating the member comprises activating a flap having a trailing edge and a leading edge, the leading edge being aligned with surface of the pylon and the trailing edge forming an acute angle with the surface of the pylon.

**24**. The method of claim **18** wherein activating the member comprises activating a flap having a perforated surface.

**25**. The method of claim **18** wherein activating the member comprises activating a triangular prism having a fore joining face making an acute angle with direction of the fan stream.

**26**. The method of claim **25** wherein the prism is hollow or hollow and devoid of base faces.

**27**. The method of claim **18** wherein activating the member comprises activating a fluid injector.

**28**. The method of claim **27** wherein the fluid injector comprises at least one injection port on surface of the pylon, the injection port injecting air from a compressor stage or a fan stage of a turbofan.

**29**. The method of claim **27** wherein activating the fluid injector comprises injecting a fluid at an angle normal or acute to direction of the fan stream.

**30**. The method of claim **18** wherein the member or the actuator is fabricated by a shape-memory alloy and is activated by an electric excitation or temperature of the fan stream.

**31**. A system comprising:

a pylon;

a jet engine attached to the pylon, comprising:

a substantially annular fan nozzle to discharge fan stream into atmosphere from an aft end thereof; and

a core nozzle to discharge core stream into the atmosphere, the core nozzle having an exterior surface, and

a stream director mounted on the pylon substantially external to the fan nozzle directing the fan stream away from the pylon, at least a portion of the stream director situated outside the aft end to maintain substantially constant flow area of the fan nozzle.

**32**. The system of claim **31** wherein the stream director comprises:

a member attached to either side of the pylon to cause the fan stream to deflect away from the pylon, the member having a fixed or variable position on the pylon.

**33**. The system of claim **32** wherein the stream director further comprises:

an actuator coupled to the member to activate the member having the variable position, the activated member directing the fan stream away from the pylon; and

a controller coupled to the actuator to control the actuator to activate or de-activate the member.

**34**. The system of claim **33** wherein the actuator activates the member using at least one of pneumatic, hydraulic, mechanical, electrical, and electromagnetic action.

**35**. The system of claim **32** wherein the member comprises a flap forming an acute angle with a pylon surface or direction of the fan air when activated, the flap being flush with the pylon surface when de-activated.

**36**. The system of claim **32** wherein the member comprises a flap forming a slant angle relative to direction of the fan stream.

**37**. The system of claim **32** wherein the member comprises a flap forming a gap with respect of the exterior surface of the core nozzle.

**38**. The system of claim **32** wherein the member comprises a flap having a trailing edge and a leading edge, the leading edge being aligned with surface of the pylon and the trailing edge forming an acute angle with the surface of the pylon.

**39**. The system of claim **32** wherein the member comprises a flap having a perforated surface.

**40**. The system of claim **32** wherein the member comprises a triangular prism having a fore joining face making an acute angle with direction of the fan stream.

**41**. The system of claim **40** wherein the prism is hollow or hollow and devoid of base faces.

**42**. The system of claim **32** wherein the member comprises a fluid injector.

**43**. The system of claim **42** wherein the fluid injector comprises at least one injection port on surface of the pylon, the injection port injecting air from a compressor stage or a fan stage of a turbofan.

**44**. The system of claim **42** wherein the fluid injector injects a fluid at an angle normal or acute to direction of the fan stream.

**45**. The system of claim **32** wherein the member or the actuator is fabricated by a shape-memory alloy and is activated by an electric excitation or temperature of the fan stream.

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