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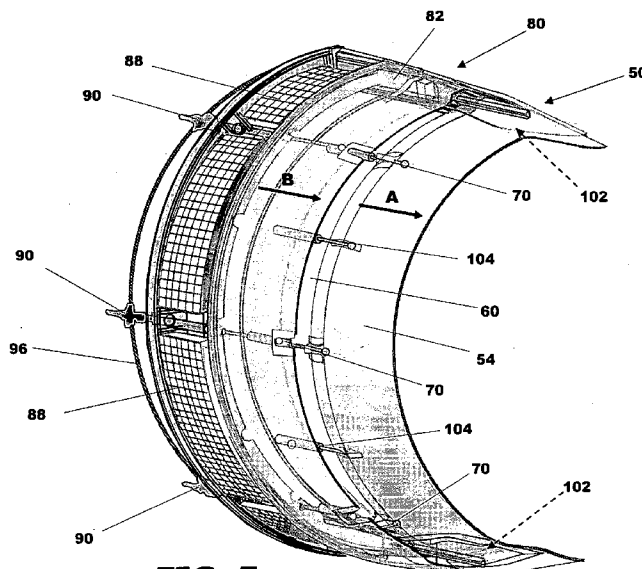


FIG. 5

(57) Abstract: The exit area of a nozzle assembly is varied by translating a ring assembly located at a rear of the engine nacelle. The ring may be axially translatable along the axis of the engine. As the ring translates, the trailing edge of the ring defines a variable nozzle exit area. Translation of the ring creates an upstream exit at a leading edge of the ring assembly. The upstream exit can be used to bleed or otherwise spill flow excess from the engine bypass duct. As the engine operates in various flight conditions, the ring can be translated to obtain lower fan pressure ratios and thereby increase the efficiency of the engine. Fairings partially enclose actuator components for reduced drag.

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VARIABLE AREA FAN NOZZLE WITH BYPASS FLOW

TECHNICAL FIELD

5 [001] The present invention generally relates to gas turbine aircraft engines, and in particular, to a translating trailing edge variable area nozzle assembly for a gas turbine aircraft engine for controlling the air flow exhausted from the engine for varying performance output.

BACKGROUND

10 [002] Typical aircraft turbofan jet engines include a fan that draws and directs a flow of air into and around an engine core and a nacelle. The nacelle surrounds the engine core and helps promote the laminar flow of air past the engine core. The flow of air that is directed into the engine core is initially passed through a compressor that increases the air flow pressure, and then through a combustor where the air is mixed with fuel and ignited.
15 The combustion of the fuel and air mixture causes a series of turbine blades at the rear of the engine core to rotate, and in turn to provide power to the fan. The high-pressure heated exhaust gases from the combustion of the fuel and air mixture are thereafter directed through an exhaust nozzle out of the rear of the engine.

20 [003] The flow of air that is directed around the engine core is called bypass flow and provides the main thrust for the aircraft. The bypass flow also is used to help slow an aircraft, when the flow is diverted by thrust reversers mounted in the nacelle structure that surrounds the engine core. The bypass flow may or may not be mixed with the engine core exhaust before exiting.

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[004] Several turbofan engine parameters are important to those of skill in the art in order to optimize design characteristics and performance. The bypass ratio (BPR) is the ratio

of air mass passing through the fan to that going through the core. Higher BPR engines can be more efficient and quieter. In general, a higher BPR results in lower average exhaust velocities and less jet noise at equivalent thrust rating of a lower BPR engine. Also, the exit area and mass flow rates and pressures define the fan pressure ratio (FPR).

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[005] Turbofan engine operation parameters and characteristics can further be reflected in a turbofan engine's operating map. Operation maps can be created in various ways, such as on turbine rig test results or predicted by applicable computer programs as is known in the art. Typical turbine operation maps can show relationships between pressure ratios (e.g., FPR) on the y-axis and corrected mass flows on the x-axis. The operation line(s) on the turbofan operation map reflects the line or ranges in which the relationship between FPRs and correct mass flow values result in maximum thrust and minimum fuel consumption. For example, it is known that altering the engine's characteristics that lower the operating line can increase fuel efficiency and reduce noise emissions from the engine since more thrust is produced with less fuel being injected into the combustors, and the stoichiometry of the engine is increased. The resulting reduction of FPRs, however, can reach a practical limit as a low FPR can cause engine fan stall, blade flutter or compressor surge under certain operating conditions, with insufficient bypass flow possibly causing engine malfunction.

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[006] A solution to optimizing the operating line at all flight conditions, for those engines that draw significant benefit from such an optimization, includes varying the exit nozzle area during operation. Variable area nozzles for aircraft jet engines are known to help aircraft obtain lower FPR by favorably reconfiguring engine cycle characteristics. Such variable area nozzles generally have included a series of flow deflectors or fins (often called "turkey feathers") that can flair outwardly or pivot inwardly to increase or decrease the size of the nozzle opening and accordingly expand or constrict the flow of the exhaust air upon exit. Unfortunately, the expansion of such turkey feathers may cause undesirable leakage and can adversely interact with the outside air flow passing over the engine, which can create undesirable drag, noise, and a reduction in thrust due to the overboard leakage, leading to

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greater fuel consumption. In addition, prior variable area nozzle systems typically have been heavy, expensive and somewhat complex in their structure and operation, generally requiring the coordinated movement of multiple components that employ complicated drive mechanisms.

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[007] Accordingly, it can be seen that a need exists for a variable area nozzle assembly for an aircraft turbine engine that promotes a cost effective, simple and efficient operation for control of engine output to match desired flight conditions.

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SUMMARY

[008] According to one embodiment of the invention, the exit area of a nozzle assembly is varied by translating, or moving fore and aft, a ring assembly located at the rear of the engine nacelle. The ring may be axially translatable, for example, along the axis of the engine. As the ring translates, the trailing edge of the ring defines a variable nozzle exit area.

15 Translation of the ring creates an upstream exit at a leading edge of the ring assembly to bleed or otherwise spill excess flow from the engine bypass duct. As the engine operates in various flight conditions, the ring can be translated to optimize on-demand the engine operating line, resulting in lower fan pressure ratios and thereby increase the efficiency of the engine.

20 [009] The foregoing and other features, aspects, and advantages of the invention will become more apparent upon review of the detailed description of the preferred embodiments set forth below when taken in conjunction with the accompanying drawing figures, which are briefly described as follows.

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DESCRIPTION OF THE DRAWINGS

[0010] According to common practice, the various features of the drawings discussed below are not necessarily drawn to scale. Dimensions of various features and elements in the

drawings may be expanded or reduced to more clearly illustrate the embodiments of the invention.

5 [0011] **FIG. 1** illustrates an aircraft engine having a trailing edge variable area nozzle assembly according to a first embodiment of the invention.

[0012] **FIG. 2** is a partially schematic section view of the aircraft engine according to the first embodiment.

10 [0013] **FIG. 3** is an end view of the nozzle end of the engine according to the first embodiment.

[0014] **FIG. 4** is a partially schematic section view of the variable area nozzle assembly portion according to the first embodiment.

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[0015] **FIG. 5** is another partially schematic section view of the variable area nozzle assembly according to the first embodiment.

20 [0016] **FIG. 6** is a partially schematic, exploded section view of the variable area nozzle assembly according to the first embodiment.

[0017] **FIG. 7** is a partially schematic isolated view of a guide structure of the variable area nozzle assembly according to the first embodiment.

25 [0018] **FIG. 8** is a partially schematic section view of the variable area nozzle assembly according to the first embodiment.

[0019] **FIG. 9A** is a partial exploded view of a variable area nozzle assembly according to a second embodiment of the invention.

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[0020] FIG. 9B is another partial exploded view of the variable area nozzle assembly according to the second embodiment.

[0021] FIG. 10 is another partial exploded view of the variable area nozzle assembly
5 according to the second embodiment.

[0022] FIG. 11 is another partial exploded view of the variable area nozzle assembly according to the second embodiment.

10 [0023] FIG. 12 is another partial exploded view of the variable area nozzle assembly according to the second embodiment.

[0024] FIG. 13 is a partial exploded view of a variable area nozzle assembly according to a third embodiment of the invention.

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[0025] FIG. 14 is an isolated view of a guide structure of the variable area nozzle assembly according to the third embodiment.

[0026] FIG. 15 is schematic illustration of an actuation system for the variable area
20 nozzle assembly according to the third embodiment.

[0027] FIG. 16 is an isolated view of a stabilizer of the variable area nozzle assembly according to the third embodiment.

25 [0028] FIG. 17 is a section view of the variable area nozzle assembly according to the third embodiment.

[0029] FIG. 18 is another section view of the variable area nozzle assembly according to the third embodiment.

[0030] **FIG. 19** is another section view of the variable area nozzle assembly according to the third embodiment.

[0031] **FIG. 20** is another section view of the variable area nozzle assembly according to the third embodiment.

[0032] **FIG. 21** is a partial exploded view of a variable area nozzle assembly according to a fourth embodiment of the invention.

10 [0033] **FIG. 22** is an isolated view of a guide structure of the variable area nozzle assembly according to the fourth embodiment.

[0034] **FIG. 23** is a section view of the variable area nozzle assembly according to the fourth embodiment.

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[0035] **FIG. 24** is another section view of the variable area nozzle assembly according to the fourth embodiment.

[0036] **FIG. 25** is another section view of the variable area nozzle assembly according to the fourth embodiment.

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[0037] **FIG. 26** is another section view of the variable area nozzle assembly according to the fourth embodiment.

25 [0038] **FIG. 27** is a partial exploded view of an actuator for a variable area nozzle assembly according to a fifth embodiment of the invention.

[0039] **FIG. 28** is schematic illustration of an actuation system for the variable area nozzle assembly according to the fifth embodiment.

[0040] FIGS. 29A-29C illustrate the actuator according to the fifth embodiment of the invention in various modes of operation.

[0041] FIG. 30 is a section view of the variable area nozzle assembly according to the
5 fifth embodiment.

[0042] FIG. 31 is another section view of the variable area nozzle assembly according to the fifth embodiment.

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DETAILED DESCRIPTION

[0043] FIGS. 1-8 show a variable area nozzle assembly according to a first embodiment of this invention.

[0044] Referring to FIGS. 1 and 2, the engine 10 includes a trailing edge variable area fan nozzle (VAFN) assembly 12 having a translating ring assembly 50 that may be adjusted, for example, as the engine 10 operates under varying flight conditions. As stated, such an adjustment can cause a shift in the engine's operating line. The translating ring assembly 50 is translated (i.e., moved fore and aft) to vary the nozzle exit area in order to optimize engine operation and to adjust an amount of engine bypass flow spilled through an upstream exit of the nozzle assembly 12. By bleeding or spilling off excess fan flow through the upstream exit of the nozzle assembly 12, lower fan pressure ratios for the same amount of delivered mass flow can be obtained, thereby increasing stall margins and avoiding engine malfunction and shutdown. For the purposes of illustration, the exemplary variable area fan nozzle assembly 12 of the present invention is shown in the context of a gas turbine jet aircraft engine. The engine 10 may be mounted to a wing or fuselage of an aircraft, for example, by a pylon or other, similar support (not illustrated).
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[0045] The engine 10 includes an engine core 16 and a nacelle 18. The engine core 16 is housed in a core cowl 19. As shown in FIG. 2, a fan 20 is mounted adjacent to an

upstream end of the nacelle **18**, and includes a series of fan blades **22** that are rotated about the engine centerline C_L during engine operation so as to draw a flow of air into an inlet end **26** of the engine **10**. An annular bypass duct **24** is defined between the engine core **16** and the nacelle **18**. The air flow drawn into the engine **10** is accelerated by the rotating fan blades **22**.

5 A portion of the air flow is directed into and through a compressor (not illustrated) within the engine core **16**. The air flow through the engine core **16** is initially passed through the compressor to increase the air flow pressure, after which the pressurized air is passed through a combustor (not shown), where it is mixed with fuel and ignited. The combustion of the fuel and air mixture within the combustor causes the air to expand which in turn drives a series of

10 turbines at the rear of the engine, indicated generally at **38**, to rotate and in turn to provide power to the fan **20**.

[0046] The bypass flow accelerated by the rotating fan blades **22** passes through the bypass duct **24**, past stators **40**, and out through the nozzle assembly **12**. The bypass flow

15 provides the main engine thrust. The high pressure heated exhaust gases from the combustion of the fuel and air mixture are directed through the nozzle assembly **12** out of the rear of the engine core **16**.

[0047] The translating ring assembly **50** can be a ring-like annular airfoil structure

20 mounted at the trailing end of a thrust reverser **80**, adjacent to and circumscribing the engine core cowl **19**. The area between the trailing edge of the ring assembly **50** and the core cowl **19** defines the nozzle exit area **52** for the nozzle assembly **12**. As shown in **FIGS. 1** and **3**, the ring assembly **50** can comprise an arcuate first ring section **54** and an arcuate second ring section **56**, each ring section **54**, **56** being axially translatable in the direction of the

25 bidirectional arrow **58**. Translation of the ring assembly **50** effects a desired size of an upstream exit **60** and varies the outlet geometric and exit area **52** of the nozzle **12** outlet for the engine bypass flow. The ring assembly **50** can be translated, for example, by a plurality of ring actuators **70**.

[0048] The thrust reverser **80** may be adjacent to and forward of the translating ring assembly **50** to block and redirect the bypass flow in the bypass duct **24** into a thrust reversing vector. In **FIG. 1**, the thrust reverser **80** and the translating ring assembly **50** are in stowed or closed positions. The thrust reverser **80** can comprise an arcuate first sleeve or cowl section **82** and an opposed arcuate second sleeve or cowl section **84** (shown in **FIG. 3**). The thrust reverser sleeve sections **82, 84** can be axially translatable in the direction of the bidirectional arrow **86** by a plurality of sleeve actuators **90**. The thrust reverser sleeve sections **82, 84** are translatable over a series of cascade vanes **88**. The cascade vanes **88** are indicated by dashed lead lines in **FIG 1** because they are not visible when the thrust reverser **80** is in the stowed position. Axial translation of the sleeve sections **82, 84** in the fore and aft directions allows the bypass air flow to be passed through the cascade vanes **88** to generate a thrust-reversing vector.

[0049] **FIG. 3** is a partial section view of the aft end of the engine **10**, and illustrates the arrangement of the ring and sleeve actuators **70, 90**, respectively, around the periphery of the engine **10**. As shown in **FIG. 1**, and more clearly in **FIG. 3**, the sleeve half section **82** and the ring half-section **54** cooperate to generally define an approximately 180 degree sector of the combined thrust reverser and translating ring structure. Likewise, sleeve half section **84** and ring half section **56** cooperate to generally define an opposed approximately 180 degree sector of the thrust reverser and translating ring structure. Together, these approximate 180 degree sectors cooperate to define the entire approximate 360 degree thrust reverser-translating ring structure.

[0050] In the embodiment shown in **FIGS. 1-3**, each thrust reverser sleeve half-section **82, 84** of the thrust reverser **80** can be translatable by one or more (three are shown) peripherally spaced sleeve actuators **90** fixedly mounted in the nacelle **18**. In the embodiment shown, three actuators **90** are used for each sleeve half-section **82, 84**. Each half-section **54, 56** of the translating ring assembly **50** similarly can be translated by one or more (three are shown) peripherally spaced ring actuators **70**. Ring actuators **70** can be mounted on an adjacent thrust reverser sleeve section **82, 84**, respectively. The ring actuators **70** could be

powered by, for example, electricity, mechanical, pneumatics, hydraulics, or other means, with appropriate power cables and conduits (not shown) passing via pre-defined passages between or above the thrust reverser cascade boxes or pivot doors. The number and arrangement of ring and sleeve actuators **70, 90** may be varied, for example, according to the thrust reverser and ring assembly configuration, and according to other factors. The ring sections **54, 56** may be mounted in, for example, upper and lower guide structures **102** located at each end of corresponding sleeve sections **82, 84**, respectively. **FIG. 7** is an isolated view of a guide structure **102**. Guide tubes **104** may be mounted in the nacelle **18** and may extend into the ring sections **54, 56** to stabilize the sections **54, 56** against undesirable translation and/or vibration. Guide tubes may alternatively be mounted in the thrust reverser **80**.

[0051] The translating ring assembly **50** may be a continuous (e.g., one-piece) or, as shown in **FIG. 3**, a continuing (e.g., split or multi-section) generally annular ring having an airfoil cross section. The upstream exit **60** (formed when the ring assembly **50** moves in the aft direction away from the sleeve sections **82, 84**) therefore can have the form of a generally annular gap extending around the perimeter of the rear of the nacelle **18**. Other outlet shapes can also be used, e.g., oval, etc. The generally annular gap between the ring sections **54, 56** and the sleeve sections **82, 84** can be continuous, for example, or interrupted at one or more locations, such as, for example, at points of bifurcation or other separation of the ring assembly **50**. The bypass duct **24** may also be interrupted at one or more locations.

[0052] The translating ring assembly **50** and surrounding structure are described below with reference to **FIGS. 4-7**. In **FIGS. 4-7**, elements that are obscured or partially obscured due to intervening elements are indicated by dashed lead lines.

[0053] **FIG. 4** is a partial view of the mounting structure for a first ring section **54** of the translating ring assembly **50** and the corresponding, adjacent first sleeve section **82** of the thrust reverser **80**. The second ring section **56** of the translating ring assembly **50** and the second sleeve section **84** of the thrust reverser **80**, which are shown in **FIGS. 1 and 3**, can be mounted in a similar manner. In **FIG. 4**, the thrust reverser **80** is in a stowed position,

covering the cascade vanes **88**. The translating ring assembly **50** is in an open or deployed position so that an upstream exit **60** is defined between the first ring section **54** and the first sleeve section **84**. The rearward axial translation of the first ring section **54** to the deployed position is indicated by the arrow **A**. The ring actuators **70** can extend from the sleeve section **82**, across the upstream exit **60**, and connect to a fore end of the ring section **54**. The guide tubes **104** can also extend from the sleeve section **82**, across the upstream exit **60**, and connect to the fore end of the ring section **54**. A sleeve actuation cable **96** can connect to each sleeve actuator **90** for power and to provide simultaneous actuation of each actuator **90**.

10 [0054] **FIG. 5** shows the thrust reverser **80** in a deployed position and the translating ring assembly **50** in the open position. The rearward axial translation of the first sleeve section **82** from the position shown in **FIG. 4** to the deployed position is indicated by the arrow **B**. Rearward translation of the sleeve section **82** exposes the cascade vanes **88** during operation of the thrust reverser **80**. The ring section **54** can also be translated rearwardly during operation of the thrust reverser **80**, as shown in this embodiment. Translation of the ring section **54** at the same time that the thrust reverser **80** is deployed, may be optional because the bypass flow is rerouted through the cascade vanes **88**.

[0055] **FIG. 6** is a partial, exploded view with the first sleeve section **82** and its corresponding first ring section **54**, illustrated separate from the surrounding mounting structure.

[0056] **FIG. 7** is a partial section isolated view taken through one of the guide structures **102**. Referring generally to **FIGS. 3** and **6** and particularly to **FIG. 7**, in the guide structure **102**, a beam **106** can be fixedly attached to a transverse bulkhead **110** that extends 180 degrees and can include axially (e.g., parallel to the centerline of the engine **10**) extending guide tracks **108** attached thereto. The bulkhead **110** may be integral with or otherwise fixedly mounted to the engine nacelle **18** (**FIG. 1**). The thrust reverser sleeve section **82** can be connected to axially extending track bars **114** (**FIG. 7**) that are slidably received within the guide tracks **108** of the fixed beam **106**. The thrust reverser sleeve section

82 is thereby slidably mounted with respect to the nacelle **18**. The thrust reverser sleeve section **82** can also include an axially extending track guide **116** in which a translating ring track bar **120** is slidably received. The translating ring track bar **120** can be connected to the first ring section **54**, and the ring section **54** axially translates as the track bar **120** slides within the track guide **116**. The ring section **54** is thereby slidably mounted with respect to the sleeve section **82** of the thrust reverser **80**. The translating sleeve section **82** and the track bar **120** can be powered through conventional means, such as mechanical, electric, hydraulic or pneumatic or other equivalent means.

10 [0057] **FIG. 8** illustrates one method of operating the ring section **54** to achieve flow diversion in accordance with this invention. For example, the size of the upstream exit **60** and the nozzle exit area **52** can be varied in order to achieve differing engine operating parameters. In this capacity, the upstream exit **60** essentially acts as a “bleed” exit that spills airflow traveling through the bypass duct **24**. **FIG. 8** shows a partial section of a downstream portion of the nozzle assembly **12** illustrating a portion of the bypass air flow, indicated by the curved arrows, being bled through the annular upstream exit **60** in one mode of operation of the nozzle assembly **12**. In **FIG. 8**, the first ring section **54** of the ring **50** and the first sleeve section **82** of the thrust reverser **80** are shown in section, along with associated ring and sleeve actuators **70, 90**, respectively, used for axial translation of the sections **54, 82**. The second ring section **56** may be similarly constructed and arranged with respect to the second sleeve section **84**. The thrust reverser **80** can include blocker doors **134** that are operatively coupled to the first sleeve section **82** and are pivotable in the direction of the curved arrow **136** thereby to block and redirect the bypass flow into a thrust reversing vector.

25 [0058] Still referring to **FIG. 8**, a high pressure seal **130** may be disposed between the sections **82, 54**, at the trailing edge of the translating sleeve section **82**. In certain modes of operation, when the sections **82, 54** are drawn together, the seal **130** can operate to substantially seal any gap between the sections **82, 54** and thereby close the upstream exit **60**.

[0059] As previously discussed, the ring and sleeve actuators **90**, **70** can be, for example, mechanical, hydraulic, pneumatic or electric actuators. In the illustrated embodiment, the ring actuator **70** is a constant opening air spring damper with hydraulic closing override, and the sleeve actuator **90** is an electric actuator.

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[0060] **FIGS. 9A-12** illustrate a variable area nozzle assembly **212** according to a second embodiment of the invention. The nozzle assembly **212** may be mounted to a nacelle as generally illustrated in **FIG. 1**, however with no intervening thrust reverser. Therefore, elements within the embodiment shown in **FIG. 9A-12** that are analogous to elements in **FIGS. 1-8** use a similar reference numbering system, but are preceded by a “**2**” or “**3**.”

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[0061] **FIGS. 9A** and **9B** are partial cutaway illustrations of the variable area nozzle assembly **212** according to the second embodiment of the invention. In the cutaway illustrations, an outer duct structural liner **214** of the nacelle is visible. The nozzle assembly **212** includes a translating ring assembly (removed for ease of illustration and not shown in **FIGS. 9A** and **9B**) comprised of two ring sections, of which one ring section **254** is illustrated in **FIGS. 9A** and **9B**. In **FIG. 9A**, the ring section **254** is in the closed (i.e., axially fore) position, and **FIG. 9B** illustrates the ring section **254** in the open or deployed (i.e., axially aft) position.

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[0062] The ring section **254** can be mounted at the aft end of an engine. Peripherally spaced translating ring actuators **270** may be mounted to a bulkhead **310** that is fixedly mounted to the nacelle. Guide tubes **304** may also be fixedly mounted to the bulkhead **310** at one end, and received in the ring section **254** at their opposite ends. The translating ring actuators **270** can act in unison to translate the ring section **254** in the direction of the bidirectional arrow **258**. Referring to **FIG. 9B**, actuator shafts **272** of the ring actuators **270** can pass through a blister fairing **320** located fore of the ring section **254**. Upstream fairings **324** may be provided at the points where the actuator shafts **272** pass through the blister fairing **320** in order to reduce drag induced by the actuators **270**. Similarly, downstream

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fairings 328 may be provided at the points where the actuator shafts 272 are received in the ring section 254.

[0063] The ends of the ring section 254 can terminate at beaver tail split fairings 330. As shown in FIGS. 10 and 11, each end of the blister fairing 320 can include an upstream portion 332 of a beaver tail split fairing 330, and a downstream portion 334 of the fairing 330 can be connected to and translatable with the translating ring section 254. Translation of the translating ring section 254 in the direction of the bidirectional arrow 258 can create an upstream exit 260 between the translating ring section 254 and the blister fairing 320. The aft edge of the blister fairing 320 can include a bullnose section 255 (FIG. 11) to also aid in improving air flow out of upstream exit 260 and minimize flow disruption caused by linkages supporting the actuator shafts 272. FIG. 12 is a partial, isolated view of the upstream and downstream fairings 324, 328 of the beaver tail split fairing 330.

[0064] The fairings 320, 324, 328, 330 of the aforesaid described embodiment can be selectively used in conjunction with other embodiments described herein. By way of non-limiting example, fairings analogous to fairings 324, 328 could be used in conjunction with the translating sleeve actuators 90, spaced ring actuators 70, or other actuators disclosed herein.

[0065] FIGS. 13-20 illustrate a variable area nozzle assembly 412 according to a third embodiment of the invention. The nozzle assembly 412 includes a translating ring assembly 450 and may be mounted to a nacelle 18 as generally illustrated in FIG. 1. Referring to FIGS. 13 and 14, the translating ring assembly 450 according to the third embodiment can be comprised of two ring sections, of which a first ring section 454 is illustrated in FIG. 13. The second ring section 456, illustrated schematically in FIG. 15, may be a mirror image of the ring section 454.

[0066] In FIG. 13, the translating ring section 454 is in the closed or non-deployed position, with no upstream exit defined between the ring section 454 and the thrust reverser

sleeve section 482. The translating ring assembly 450 is mounted aft of a thrust reverser 460 comprising two translating sleeve sections, of which a first sleeve section 462 is illustrated in FIG. 13. The first sleeve section 462 of the thrust reverser 460 can be translated by one or more actuators 464. The ring section 454 can be operated by an actuation system including ring actuators 470 located at each end of the first translating ring section 454. Stabilizer assemblies 480 connecting the first ring section 454 to the first sleeve section 462 can be spaced along the periphery of the nozzle assembly 412 to reduce undesirable translation and/or vibration (e.g., flutter) of the ring section 454. Analogous stabilizer assemblies can be added to other embodiments shown herein where additional stabilization is desired.

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[0067] Still referring to FIG. 13, a motor or drive mechanism 482 governs the motion of the ring actuators 470. The drive mechanism 482 is connected to a splined coupling 484 by transmission shafting 485 and a gear box 486. The splined coupling 484 terminates at the aft end of the sleeve section 462 at a gear box 488, which is coupled to flexible cable shafting 490. The flexible shafting 490 is connected to the actuators 470 at each end of the translating ring section 454. The drive mechanism 482 is thereby coupled to the ring actuators 470 to effect translation of the ring section 454.

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[0068] The translating ring section 454 may be mounted in, for example, upper and lower guide structures 500 located at each end of the ring section 454. Each translating ring actuator 470 can be operably coupled with a guide structure 500, as discussed below with reference to FIG. 14.

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[0069] FIG. 14 is a partial view of a guide 500 and associated actuator 470 at one end of the ring section 454. The thrust reverser sleeve section 462 forward of the ring section 454 can be connected to an axially extending beam 502 of the guide 500. The ring section 454 is mounted to a track bar 503 that is slidably mounted on the beam 502. The ring section 454 is thereby slidably mounted with respect to the sleeve section 462. The guide 500 includes a slider 504 that receives a screw shaft 506. The screw shaft 506 can be coupled to a gear box 508 that converts rotary movement of the flexible actuator cable 490 to rotary movement of

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the screw shaft **506**. Rotation of the screw shaft **506** within the slider **504** translates the track **503** along the beam **502**, which can be used to effect translation of the ring section **454** in the direction of the bidirectional arrow **458**. The aforesaid described actuator system could be used in each of the actuator embodiments discussed elsewhere herein.

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[0070] **FIG. 15** is a schematic view of an actuation and control system that may be used to actuate translation of the translating ring assembly **450** illustrated in **FIGS. 13** and **14**. Referring specifically to **FIG. 15** and also to **FIGS. 13** and **14**, the drive unit **482** can include a motor **516** coupled to a gear box **520**. Rotational motion provided by the motor **516** is sequentially transmitted through the gear box **520**, the transmission shafting **485**, the gear boxes **486**, the splined couplings **484**, the actuator cable **490**, and ultimately to the ring actuators **470** through the gear boxes **488** to provide axial translation of the ring sections **454**, **456**.

15 [0071] Referring to **FIG. 15**, the motor **516** can be coupled to a host controller unit **526**, which is coupled to a full authority digital engine controller (FADEC) **540**. The FADEC **540** can thereby control actuation of the ring sections **454**, **456** of the translating ring assembly **450**. The FADEC **540** can also control actuation of a thrust reverser. Linear variable differential transformers **550** can be coupled to the ring sections **454**, **456** to provide position feedback to the FADEC **540**.

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[0072] **FIG. 16** is an isolated view of a stabilizer assembly **480**. The stabilizer assembly **480** can include an aft portion **580** fixedly mounted to the translating ring section **454**, and a guide portion **582** fixed to the translating sleeve **482** of the thrust reverser **480**. The aft portion **580** can be axially slidable within the guide portion **582** with relatively low clearance to minimize unwanted translation and/or vibration (e.g., flutter) of the ring section **454**.

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[0073] **FIG. 17** is a sectional partial view of a downstream portion of the nozzle assembly **412**, taken along a longitudinal section that passes through a stabilizer assembly

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480. The translating ring section 454 in FIG. 17 is translatable in the direction of the bidirectional arrow 458 to create an upstream exit forward of the section 454, as discussed above with reference to the embodiment illustrated in FIG. 8. Blocker doors 586 are operatively coupled to the first sleeve section 462 and pivotable in the direction of the curved arrow 588 thereby to block and redirect the bypass flow through cascade vanes 590 to produce a thrust reversing vector.

[0074] FIG. 18 is a sectional partial view of a downstream portion of the nozzle assembly 412, taken along a longitudinal section that passes through a translating ring actuator 470 at one end of the translating ring section 454.

[0075] FIG. 19 is a sectional partial view of a downstream portion of the nozzle assembly 412, taken along a longitudinal section that passes through an actuator 464 of the thrust reverser 460.

[0076] FIG. 20 is a sectional partial view of a downstream portion of the nozzle assembly 412, taken along a longitudinal section that passes through a splined coupling 484.

[0077] FIGS. 21-26 illustrate a variable area nozzle assembly 612 according to a fourth embodiment of the invention. The nozzle assembly 612 may be mounted to a nacelle as generally illustrated in FIG. 1.

[0078] FIG. 21 is a partially exploded, cutaway illustration of the variable area nozzle assembly 612, which has a translating ring assembly 650 at an aft end of the nozzle assembly. FIG. 22 is an isolated view of an actuator of the translating ring assembly 650. Translation of the translating ring assembly 650 can be effected by an actuation system such as, for example, the actuation system illustrated in FIG. 15. Referring to FIGS. 21 and 22, the translating ring assembly 650 can be comprised of two ring sections, of which a first ring section 654 is illustrated in FIG. 21. The second ring section (not illustrated) may be a mirror image of the ring section 654.

[0079] In FIG. 21, the first translating ring section 654 is in the closed position, with no upstream exit defined forward of the first section 654. The ring assembly 650 is mounted aft of a thrust reverser 660 comprising two translating sleeve sections, of which a first sleeve section 662 is illustrated in FIG. 21. The translating sleeve section 662 of the thrust reverser 660 can be translated by one or more actuators 664. The ring section 654 can be operated by an actuation system including actuators 670 located at each end of the ring section 654. Stabilizer assemblies 680 connecting the ring section 654 to the sleeve section 662 can be spaced along the periphery of the nozzle assembly 612 to reduce undesirable translation and/or vibration (e.g., flutter) of the ring section 654.

[0080] Still referring to FIG. 21, a motor or drive mechanism 682 governs the motion of the ring actuators 670. The drive mechanism 682 is connected to a splined coupling 684 by transmission shafting 685 and a gear box 686. The splined coupling 684 terminates at the aft end of the sleeve section 662 at a gear box 688, which is coupled to flexible cable shafting 690. The flexible cable shafting 690 is connected to the ring actuators 670 at each end of the translating ring section 654. The drive mechanism 682 is thereby coupled to the ring actuators 670 to effect translation of the ring section 654. The ring section 654 may be translatably mounted in, for example, upper and lower guide structures 700 located at each end of the ring section 654. Each actuator 670 can be operably coupled with a guide structure 700, as discussed below with reference to FIG. 22.

[0081] FIG. 22 is a partial view of a guide 700 and associated actuator 670 at one end of the ring section 654. The translating sleeve section 662 forward of the ring section 654 can be connected to an axially extending beam 702 of the guide 700. The ring section 654 is mounted to a track bar 703 that is slidably mounted on the beam 702. The first translating ring section 654 is thereby slidably mounted with respect to the first thrust reverser sleeve section 662. The ring actuator 670 is coupled at one end to a gear box 708 and at its opposite end to the track bar 703. The gear box 708 utilizes rotational motion of the flexible cable 690

to cause the actuator **670** to translate the ring section **654** in the direction of the bidirectional arrow **658**.

[0082] **FIG. 23** is a sectional partial view of a downstream portion of the nozzle assembly **612**, taken along a longitudinal section that passes through one of the stabilizer assemblies **680**. The translating ring section **654** illustrated in **FIG. 23** is translatable in the direction of the bidirectional arrow **658** to create an upstream exit forward of the section **654**, as discussed above with reference to the embodiment illustrated in **FIG. 8**. The thrust reverser **660** can include blocker doors **786** that are operatively coupled to the first sleeve section **662** and are pivotable in the direction of the curved arrow **788** thereby to block and redirect the bypass flow through variable depth cascade vanes **790** to produce a thrust reversing vector.

[0083] **FIG. 24** is a sectional partial view of a downstream portion of the nozzle assembly **612**, taken along a longitudinal section that passes through an actuator **670** at one end of the translating ring section **654**.

[0084] **FIG. 25** is a sectional partial view of a downstream portion of the nozzle assembly **612**, taken along a longitudinal section that passes through an actuator **664** of the thrust reverser **660**.

[0085] **FIG. 26** is a sectional partial view of a downstream portion of the nozzle assembly **612**, taken along a longitudinal section that passes through a splined coupling **684**.

[0086] **FIGS. 27-31** illustrate an actuator **870** for translating ring sections **854**, **856** of a translating ring assembly **650** (illustrated schematically in **FIG. 28**) according to a fifth embodiment of the invention. Each translating ring section **854**, **856** can include an actuator **870** at each end of the ring section. In **FIG. 27**, an actuator **870** is shown in a cutaway section of a portion of a variable area nozzle assembly **812**. The variable area nozzle assembly **812** includes a thrust reverser **860** located forward of the translating ring assembly **650**. The

movable cowl or sleeve of the thrust reverser **860** is present but not shown in **FIG. 27** for ease of illustration so that that cascade vanes **990** of the thrust reverser are visible. The translating ring assembly **650** and thrust reverser **860** of the nozzle assembly **812** can be, for example, generally similar in structure to those of the variable area nozzle assemblies **412**, **612** discussed above. In **FIG. 27**, the thrust reverser **860** is in the stowed or non-deployed position.

[0087] Referring to **FIG. 27**, the translating ring actuator **870** can include a bearing **886** that can be fixedly mounted forward of the thrust reverser **860**. In the embodiment shown, the bearing **886** is coupled to an extensible shaft **888**. The shaft **888** is coupled to a spline bush gimbal **890**, which is coupled to a sliding spline **894**. The sliding spline **894** is fixed to a track bar **903**, which can be fixed to one end of the translating ring section **854** (**FIG. 28**). The track bar **903** is slidably mounted on a beam **702** that is fixed to a section of the thrust reverser **860**. The first translating ring section **854** is thereby slidably mounted with respect to the thrust reverser **860**. The bearing **886** at each end of the translating ring section **854** is coupled to transmission shafting **885**. Rotation of the transmission shafting **885** effects translation of the ring section **854**.

[0088] **FIG. 28** is a schematic view of an actuation and control system that may be used with the translating ring assembly **850**. Referring specifically to **FIG. 28** and also to **FIG. 27**, a drive unit **882** can include a motor **916** coupled to a gear box **920**. Rotation provided by the motor **916** is transmitted through the gear box **920** to the transmission shafting **885**. The rotational motion from the transmission shafting **885** is utilized by the actuators **870** at each end of the ring sections **854**, **856** to translate the ring sections.

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[0089] The motor **916** can be coupled to a host controller unit **926**, which is coupled to a full authority digital engine controller (FADEC) **940**. The FADEC **940** can thereby control actuation of the translating ring sections **854**, **856** of the translating ring assembly **850**. The FADEC **940** can also control actuation of a thrust reverser. Linear variable differential

transformers 950 can be coupled to the ring sections 854, 856 to provide position feedback information to the FADEC 940.

[0090] FIGS. 29A-29C illustrate an actuator 870 in three operational modes. In FIG. 5 29A, the actuator 890 is fully retracted, corresponding to an operating condition in which the translating ring assembly 850 and the thrust reverser 860 are stowed. In FIG. 29B, the actuator 890 is in a deployed state in which the translating ring assembly 850 is deployed and the thrust reverser 860 is stowed. FIG. 29C illustrates the actuator 890 where the thrust reverser 860 is deployed.

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[0091] FIG. 30 is a sectional partial view of a downstream portion of the nozzle assembly 812, taken along a longitudinal section that passes through an actuator 870 at one end of the translating ring section 854. The translating ring section 854 is in a stowed position in FIG. 30.

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[0092] FIG. 31 is a sectional partial view of a downstream portion of the nozzle assembly 812, taken along a longitudinal section that passes through an actuator 870 at one end of the translating ring section 854. The translating ring section 854 is in a deployed position in FIG. 31.

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[0093] It will be understood by those skilled in the art that while the foregoing has been described with reference to preferred embodiments and features, various modifications, variations, changes and additions can be made thereto without departing from the spirit and scope of the invention. The optional elements in each of the embodiments may be employed 25 with all possible combinations of other disclosed elements to form additional embodiments.

What is claimed:

1. A nacelle for a turbofan engine comprising:
 - (a) a stationary forward nacelle portion (18);
 - (b) a thrust reverser (80) comprising:
 - (i) an array of cascade vanes (88) disposed aft of the forward nacelle portion (18);
 - (ii) a thrust reverser sleeve (82, 84) disposed aft of the forward nacelle portion, the thrust reverser sleeve (82, 84) being selectively movable between a stowed position and a deployed position, wherein in the stowed position the thrust reverser sleeve (82, 84) substantially covers the cascade vanes (88), and in the deployed position, at least a portion of the cascade vanes (88) are not covered by the thrust reverser sleeve;
 - (iii) a plurality of thrust reverser sleeve actuators (90) configured to selectively move the thrust reverser sleeve (82, 84) between the stowed position and the deployed position;
 - (c) a fan nozzle sleeve (50) disposed aft of the thrust reverser sleeve (82, 84) and being selectively movable between a forward position and one or more extended positions, wherein an upstream bypass flow exit (60) is formed between the fan nozzle sleeve (50) and the thrust reverser sleeve (82, 84) when the fan nozzle sleeve (50) is in the extended position; and
 - (d) a plurality of fan nozzle sleeve actuators (70) extending from the stationary forward nacelle portion to the fan nozzle sleeve are configured to selectively move the fan nozzle sleeve (50) between the forward position and the extended position, the fan nozzle sleeve actuators (70) being separate from and spaced apart from the thrust reverser sleeve actuators (90).

2. A nacelle according to claim 1 wherein the fan nozzle sleeve (50) comprises a first fan nozzle sleeve segment (54) disposed on a first side of the engine (10), and a second fan nozzle sleeve segment (56) disposed on an opposed second side of the engine (10).

3. A nacelle according to claim 1 further comprising a transverse bulkhead (110) on the forward nacelle portion, wherein the thrust reverser sleeve and the fan nozzle sleeve are movably connected to the transverse bulkhead.

4. A nacelle according to claim 3 further comprising:
 - (a) a beam attached to the transverse bulkhead, the beam having at least a first guide track;
 - (b) a first track bar attached to the thrust reverser sleeve, the first track bar being slidably engaged in the beam guide track;
 - (c) a second guide track attached to the thrust reverser sleeve; and
 - (d) a second track bar attached to the fan nozzle sleeve, the second track bar being slidably engaged in the second guide track.

5. A nacelle according to claim 4 wherein sliding movement of the first or second track bars is powered by at least one mechanical, electrical, hydraulic or pneumatic device.

6. A nacelle for a turbofan aircraft engine (10) comprising:
 - (a) a stationary forward nacelle portion (18) having an inlet end and an opposed rear end;
 - (b) a thrust reverser (80) comprising:
 - (i) a cascade array (88) disposed aft of the rear end of the stationary forward nacelle portion;
 - (ii) a translating thrust reverser sleeve (82, 84) having a front edge and a trailing edge, the thrust reverser sleeve (82, 84) being movably disposed aft of the rear end of the stationary forward nacelle portion (18), the thrust reverser sleeve (82, 84) being movable between a stowed position in which the front edge is proximate to the rear end of the stationary forward nacelle portion (18) and the thrust reverser sleeve (82, 84) substantially covers the cascade array (88), and a deployed position in which

the thrust reverser sleeve (82, 84) is disposed substantially aft of the cascade array (88) and the cascade array (88) is substantially uncovered; and

(iii) at least one thrust reverser actuator (90) extending from the stationary forward nacelle portion (18) to the thrust reverser sleeve (82, 84), and being operable to selectively move the thrust reverser sleeve (82, 84) between the stowed position and the deployed position;

(c) a translating fan nozzle sleeve (50) having a forward edge, the fan nozzle sleeve (50) being movably disposed aft of the translating thrust reverser sleeve (82, 84), the fan nozzle sleeve (50) being movable between a forward position in which the forward edge is proximate to the trailing edge of the thrust reverser sleeve (82, 84), and an extended position in which an upstream bypass flow exit (60) is disposed between the forward edge of the fan nozzle sleeve (50) and the trailing edge of the thrust reverser sleeve (82, 84); and

(d) at least one fan nozzle actuator (70) separate from and spaced apart from the thrust reverser actuator (90), the fan nozzle actuator (70) being configured to selectively move the fan nozzle sleeve (50) between the forward position and the extended position.

7. A nacelle according to claim 6 wherein the translating thrust reverser sleeve (82, 84) comprises a first arcuate thrust reverser sleeve portion (82) and a second arcuate thrust reverser sleeve portion (84), wherein at least one thrust reverser actuator (90) is operable to selectively move the first thrust reverser sleeve portion (82) between the stowed position and the deployed position, and wherein at least one thrust reverser actuator (90) is operable to selectively move the second thrust reverser sleeve portion (84) between the stowed position and the deployed position.

8. A nacelle according to claim 6 wherein the translating fan nozzle sleeve (50) comprises a first arcuate fan nozzle sleeve portion (54) having a first end and a second end, and a second arcuate fan nozzle sleeve portion (56) having a third end and a fourth end, wherein at least one fan nozzle actuator (70) is operable to selectively move the first fan nozzle sleeve portion (54) between the forward position and the extended position, and

wherein at least one fan nozzle actuator (70) is operable to selectively move the second thrust reverser sleeve portion (56) between the forward position and the extended position.

9. A nacelle according to claim 8 further comprising a transverse bulkhead (110), wherein the first end of the first arcuate fan nozzle sleeve portion (54) and the third end of the second arcuate fan nozzle sleeve portion (56) are slidably connected an upper portion of the transverse bulkhead (110), and wherein the second end of the first arcuate fan nozzle sleeve portion (54) and the fourth end of the second arcuate fan nozzle sleeve portion (56) are slidably connected to a lower portion of the transverse bulkhead (110).

10. A nacelle according to claim 9 wherein each of the first, second, third and fourth ends of the respective first and second fan nozzle sleeve portions (54, 56) is movably connected to the transverse bulkhead (110) by a guide mechanism (102) comprising:

- (a) a beam (106) attached to and rearwardly extending from the transverse bulkhead (110);
- (b) a first guide track (108) attached to the beam (106);
- (c) a first track bar (114) attached to the thrust reverser sleeve (82, 84) and slidably engaged with the first guide track (108);
- (d) at least a second guide track (116) attached to the thrust reverser sleeve (82, 84); and
- (e) a second track bar (120) slidably engaged with the second guide track (116), the second track bar (120) being connected to an end of a respective fan nozzle sleeve portion (54, 56).

11. A nacelle according to claim 10 wherein sliding movement of the first or second track bars (114, 120) is powered by at least one mechanical, electrical, hydraulic or pneumatic device.

12. A nacelle according to claim 6 further comprising a plurality of spaced extendable guide tubes (104) axially extending between the thrust reverser sleeve (82, 84) and the fan

nozzle sleeve (50), the guide tubes (104) being configured to permit longitudinal translating movement of the fan nozzle sleeve (50), and to inhibit movement of the fan nozzle sleeve (50) in directions that are transverse to the direction of the longitudinal translating movement of the fan nozzle sleeve (50).

13. A nacelle according to claim 6 wherein the fan nozzle actuator (70) is operable to move the fan nozzle sleeve (50) such that the forward edge of the fan nozzle sleeve is a selected distance from the trailing edge of the thrust reverser sleeve (82, 84) when the fan nozzle sleeve (50) is in the extended position, whereby a width of the upstream bypass flow exit (60) can be selectively varied.

14. A nacelle according to claim 6 further comprising a seal (130) disposed between the forward edge of the fan nozzle sleeve (50) and the trailing edge of the thrust reverser sleeve (82, 84), the seal (130) being configured to substantially block airflow between the forward edge of the fan nozzle sleeve (50) and the trailing edge of the thrust reverser sleeve (82, 84) when the fan nozzle sleeve (50) is in the forward position.

15. A nacelle for a turbofan aircraft engine, the nacelle comprising:

(a) a stationary forward nacelle portion (18) having an inlet end and an opposed aft end;

(b) a translating fan nozzle sleeve (254, 256) having a forward edge, the fan nozzle sleeve (254, 256) being movably disposed aft of the forward nacelle portion (18), the fan nozzle sleeve (254, 256) being movable between a forward position, in which the forward edge is proximate to the aft end of the forward nacelle portion (18) with no cascade-type thrust reverser disposed therebetween, and one or more extended positions in which an upstream bypass flow exit (260) is disposed between the forward edge of the fan nozzle sleeve (254, 256) and the aft end of the forward nacelle portion (18); and

(c) at least one fan nozzle actuator (270) extending from the stationary forward nacelle portion (18) to the fan nozzle sleeve (254, 256), the fan nozzle actuator (270) being

operable to selectively move the fan nozzle sleeve (254, 256) between the forward position and the extended position.

16. A nacelle according to claim 15 wherein the translating fan nozzle sleeve (254, 256) comprises a first arcuate fan nozzle sleeve portion (254) having a first end and a second end, and a second arcuate fan nozzle sleeve portion (256) having a third end and a fourth end, wherein at least one fan nozzle actuator (270) is operable to selectively move the first fan nozzle sleeve portion (254) to one or more positions between the forward position and the extended position, and wherein at least one fan nozzle actuator (270) is operable to selectively move the second fan nozzle sleeve portion (256) to one or more positions between the forward position and the extended position.

17. A nacelle according to claim 16 further comprising a transverse bulkhead (310), wherein the first end of the first arcuate fan nozzle sleeve portion (254) and the third end of the second arcuate fan nozzle sleeve portion (256) are slidably attached to an upper portion of the transverse bulkhead (310), and wherein the second end of the first arcuate fan nozzle sleeve portion (254) and the fourth end of the second arcuate fan nozzle sleeve portion (256) are slidably attached to a lower portion of the transverse bulkhead (310).

18. A nacelle according to claim 17 wherein each of the first, second, third and fourth ends of the respective first and second fan nozzle sleeve portions (254, 256) is movably connected to the transverse bulkhead (310) by a guide mechanism (102) comprising:

- (a) a beam (106) attached to and rearwardly extending from the transverse bulkhead (310);
- (b) at least one guide track (108) attached to the beam (106);
- (c) at least one track bar (114) slidably engaged with the guide track (108), and connected to an end of a respective fan nozzle sleeve portion (254, 256).

19. A nacelle according to claim 15 further comprising a plurality of spaced extendable guide tubes (304) axially extending between the forward nacelle portion and the fan nozzle

sleeve (254, 256), the guide tubes (304) being configured to permit longitudinal translating movement of the fan nozzle sleeve (254, 256), and to inhibit movement of the fan nozzle sleeve (254, 256) in directions that are transverse to the direction of the longitudinal translating movement of the fan nozzle sleeve (254, 256) .

20. A nacelle according to claim 15 wherein the fan nozzle actuator (270) is operable to move the fan nozzle sleeve (254, 256) such that the forward edge of the fan nozzle sleeve (254, 256) is a selected distance from the trailing edge of the forward nacelle portion (18) when the fan nozzle sleeve (254, 256) is in the extended position, thereby permitting a width of the upstream bypass flow exit (260) to be selectively varied.

21. A nacelle according to claim 15 further comprising a blister fairing (320) extending along the aft end of the forward nacelle portion (18), the blister fairing (320) at least partially overlapping the forward edge of the translating fan nozzle sleeve (254, 256) when the fan nozzle sleeve (254, 256) is in the forward position.

22. A nacelle according to claim 21 wherein a portion of the fan nozzle actuator (270) extends through an actuator opening in the blister fairing (320) to the fan nozzle sleeve (254, 256), and further comprising an upstream fairing (324) on the blister fairing (320) at least partially shrouding the actuator opening, and a downstream fairing (328) at least partially shrouding the portion of the fan nozzle actuator (270).

23. A nacelle according to claim 17 wherein an upstream portion (332) of a split beavertail fairing (330) on the forward stationary nacelle portion (18) at least partially shrouds a forward portion of a beam (106) rearwardly extending from the transverse bulkhead (310), and wherein a downstream portion (334) of the split beavertail fairing (330) on the fan nozzle sleeve (254, 256) at least partially shrouds an aft portion of the beam (106), wherein the upstream and downstream portions (332, 334) of the split beavertail fairing (330) combine to form a substantially continuous contoured external surface when the translating fan nozzle sleeve (254, 256) is in the forward position.

24. A nacelle for a turbofan aircraft engine comprising:
- (a) a stationary forward nacelle portion (18) having an inlet end and an opposed rear end;
 - (b) a thrust reverser comprising:
 - (i) a cascade array (590) disposed aft of the rear end of the stationary forward nacelle portion (18);
 - (ii) a translating thrust reverser sleeve (460) comprising first and second thrust reverser sleeve segments (462, 464) each having a front edge and a trailing edge, the thrust reverser sleeve segments (462, 464) being movably disposed aft of the rear end of the stationary forward nacelle portion (18), each thrust reverser sleeve segment (462, 464) being movable between a stowed position in which its front edge is proximate to the rear end of the stationary forward nacelle portion (18) and the thrust reverser sleeve segment (462, 464) substantially covers a portion of the cascade array (590), and a deployed position in which the thrust reverser sleeve segment (462, 464) is disposed substantially aft of the cascade array (590) and does not cover a substantial portion of the cascade array (590); and
 - (iii) a plurality of thrust reverser actuators (464) operable to selectively move the thrust reverser sleeve segments (462, 464) between their stowed positions and their deployed positions;
 - (c) a translating fan nozzle sleeve (450) comprising first and second fan nozzle sleeve segments (454, 456) each having a forward edge, an upper end and a lower end, and being movably disposed aft of the translating thrust reverser sleeve (460), each fan nozzle sleeve segment (454, 456) being movable between a forward position in which the forward edge is proximate to the trailing edge of one of the thrust reverser sleeve segments (462, 464), and an extended position in which an upstream bypass flow exit is disposed between the forward edge of the fan nozzle sleeve segment (454, 456) and the trailing edge of one of the thrust reverser sleeve segments (462, 464); and
 - (d) a plurality of fan nozzle sleeve actuators (470) that are separate from the thrust reverser actuators (464), at least one fan nozzle actuator (470) being located proximate to the

upper end of each fan nozzle sleeve segment (454, 456) and at least one other fan nozzle actuator (470) being located proximate to the lower end of each fan nozzle sleeve segment (454, 456), the fan nozzle actuators (470) being operable to selectively move the fan nozzle sleeve segments (454, 456) between their forward position and their extended position.

25. A nacelle according to claim 24 wherein the fan nozzle actuators (470) extend from the thrust reverser sleeve (460) to the fan nozzle sleeve (450).

26. A nacelle according to claim 24 wherein the fan nozzle actuators (470) extend from the forward nacelle portion (18) to the fan nozzle sleeve (450).

27. A nacelle according to claim 24 further comprising at least a first stabilizer (480) disposed between the first thrust reverser sleeve segment (462) and the first fan nozzle sleeve segment (454), and at least a second stabilizer disposed between the second thrust reverser sleeve segment (464) and the second fan nozzle sleeve segment (456), the first and second stabilizers (480) being configured to permit translational movement between the thrust reverser sleeve segments (462, 464) and the fan nozzle sleeve segments (454, 456), and to substantially inhibit movement of the first and second fan nozzle sleeve segments (454, 456) in a direction that is non-parallel to the translational movement between the thrust reverser sleeve segments (462, 464) and the fan nozzle sleeve segments (454, 456).

28. A nacelle according to claim 24 further comprising:

- (a) a fan nozzle sleeve drive mechanism (482);
- (b) a forward gear box (486) operably connected (485) to the fan nozzle sleeve drive mechanism (482), the forward gear box (486) being located forward of the translating thrust reverser sleeve (462);
- (c) an aft gear box (488) positioned proximate to the front edge of the first fan nozzle sleeve segment (454);
- (d) a splined coupling (484) rotatably connecting the forward gear box (486) to the aft gear box (488), the splined coupling (484) being axially extendable; and

(e) at least one actuator cable (490) operably connecting at least a portion of the plurality of fan nozzle actuators (470) to the aft gear box (488);

(f) whereby the fan nozzle sleeve drive mechanism (482) is operably coupled to at least a portion of the plurality of fan nozzle actuators (470) and is capable of effecting translation of the first fan nozzle sleeve segment (454) between its forward and extended positions.

29. A nacelle according to claim 24 further comprising an upper guide structure (500) slidably supporting the upper ends of the first and second fan nozzle sleeve segments (454, 456), and a lower guide structure (500) slidably supporting the lower ends of the first and second fan nozzle sleeve segments (454, 456).

30. A nacelle according to claim 29 wherein the upper and lower guide structures (500) each comprise a beam (502) that extends aft of the first and second translating thrust reverser sleeves (462), and a track bar (503) connected to one of the first and second fan nozzle sleeve segments (454, 456), the track bar (503) being slidably engaged with the beam (500).

31. A nacelle according to claim 30 further comprising a slider (504) attached to the track bar (503), and a screw shaft (506) engaged with the slider (504) and extending between the slider (504) and an actuator gear box (508).

32. A nacelle according to claim 28 wherein the fan nozzle sleeve drive mechanism (482) comprises a motor (516) coupled to a motor gear box (520), the motor gear box (520) being operably connected (485) to the forward gear box (486), wherein selective rotation of the motor (516) causes rotation of the forward gear box (486) and actuation of the plurality of fan nozzle sleeve actuators (470).

33. A nacelle according to claim 32 further comprising at least one controller (526/540) coupled to the motor (516), the controller (526/540) being configured to selectively control translation of the fan nozzle sleeve segments (454).

34. A nacelle according to claim 24 wherein the cascade array comprises a plurality of substantially parallel longitudinally spaced vanes (790) having variable depths.

35. A nacelle according to claim 34, wherein the depths of the vanes (790) progressively decrease from a deepest forward-most vane to a shallowest aft-most vane.

36. A nacelle according to claim 29 wherein the fan nozzle sleeve actuators (670) are positioned proximate to the upper and lower guide structures (700).

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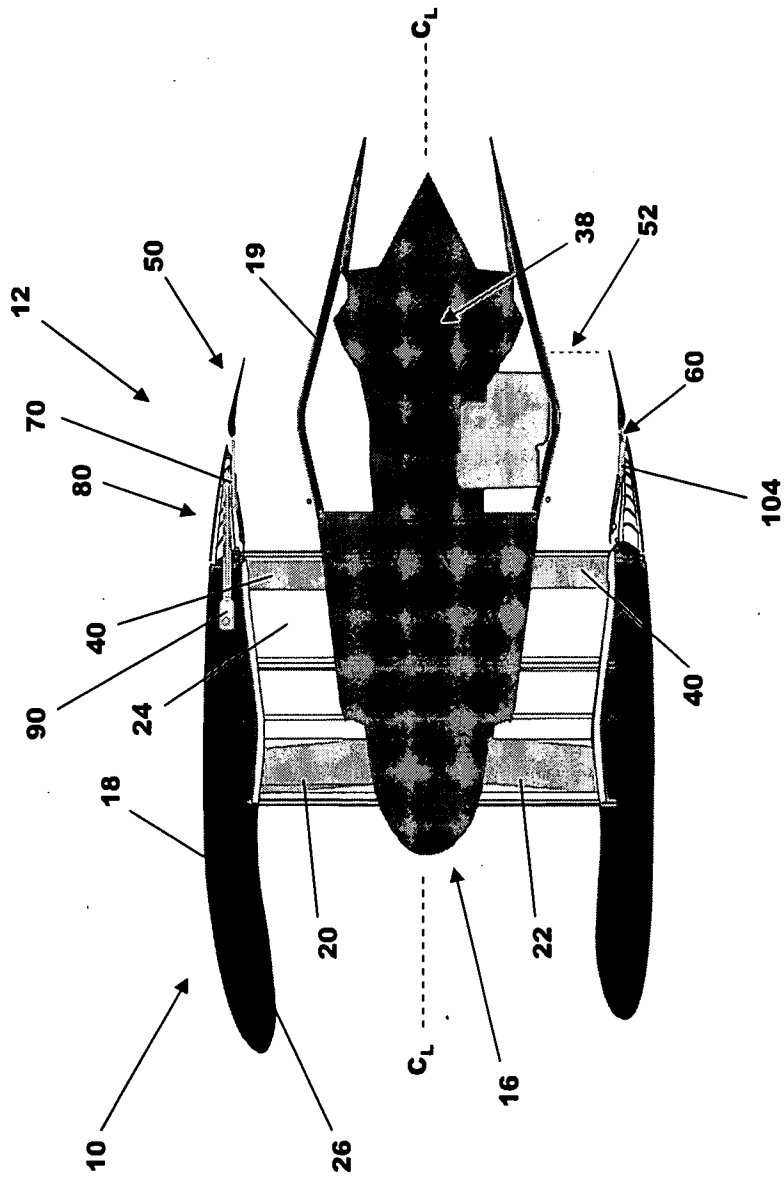
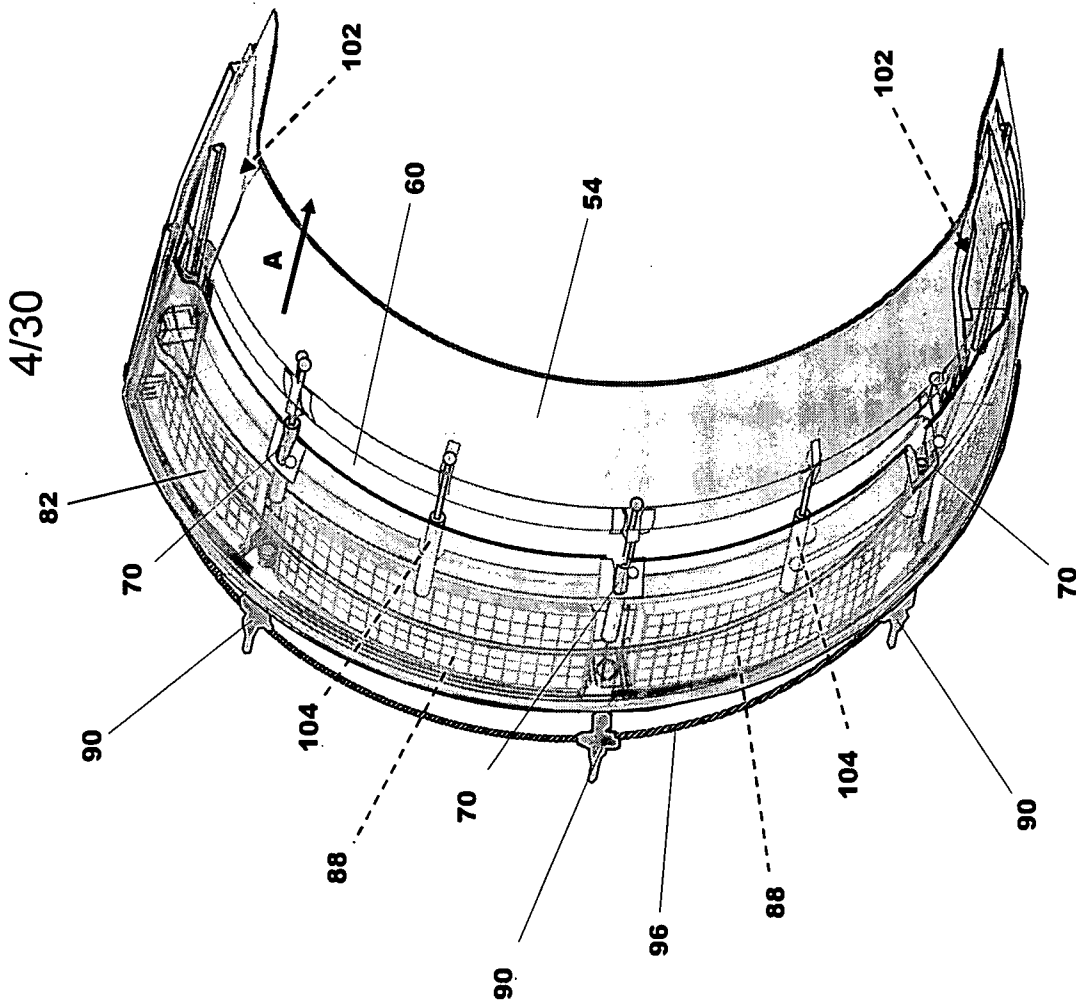


FIG. 2



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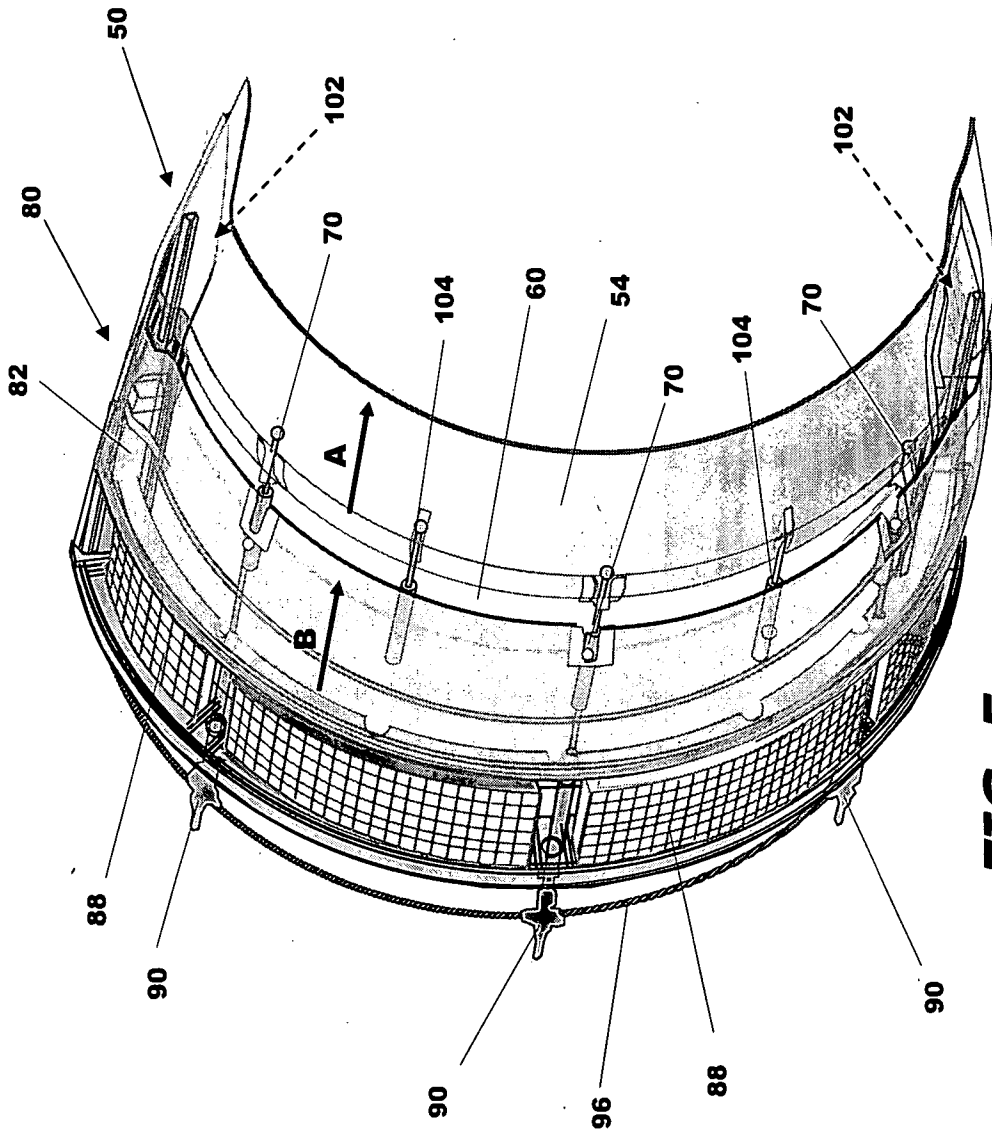
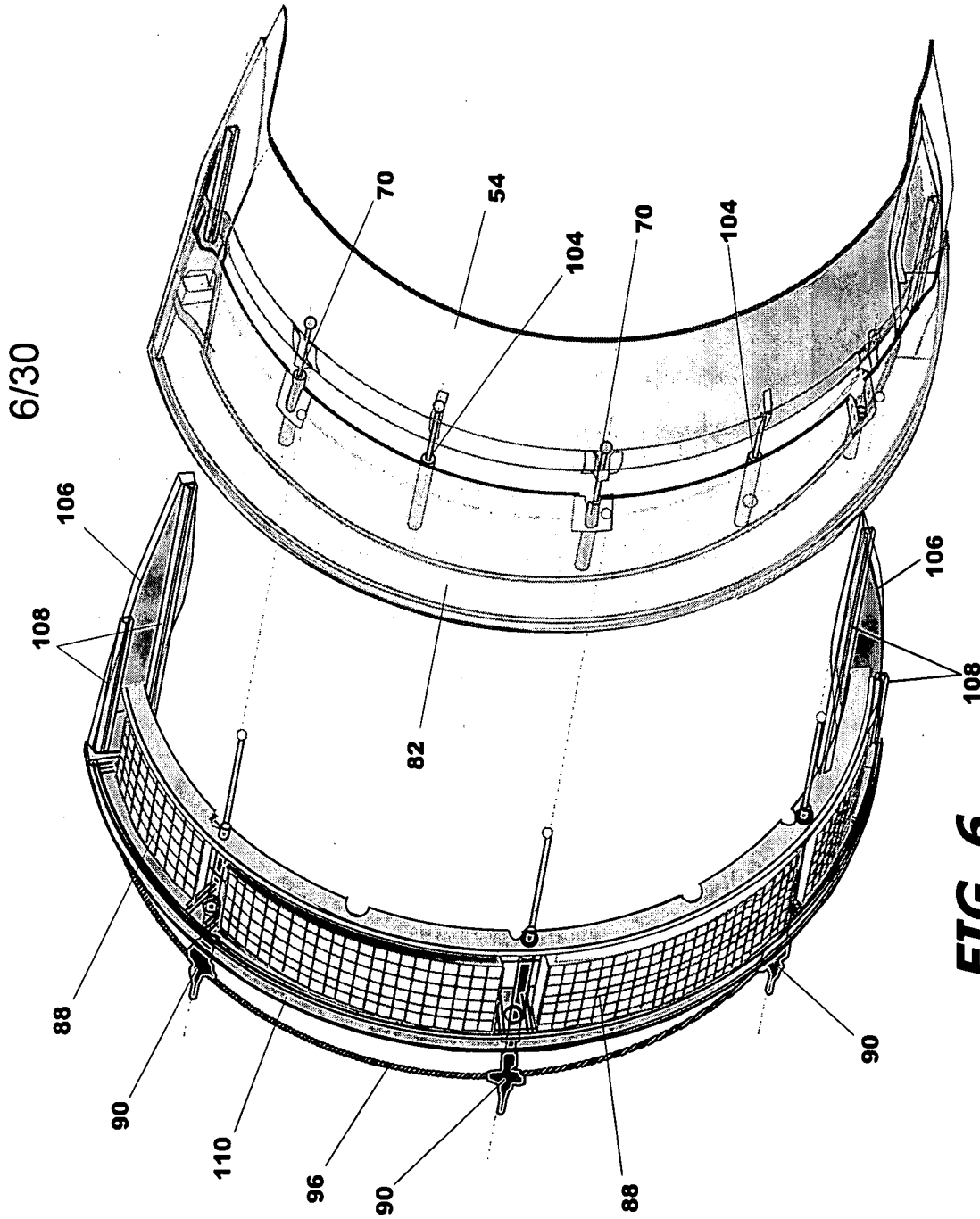


FIG. 5



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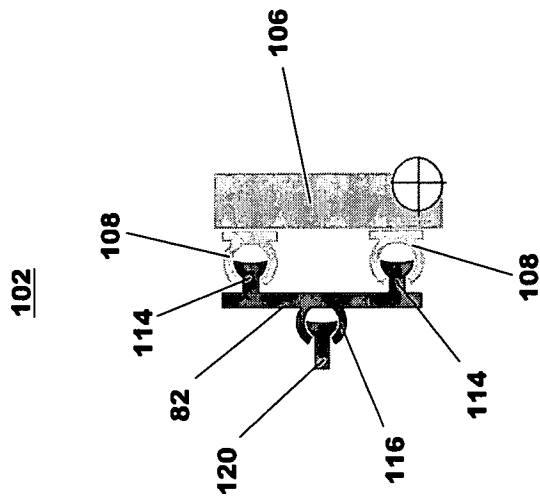


FIG. 7

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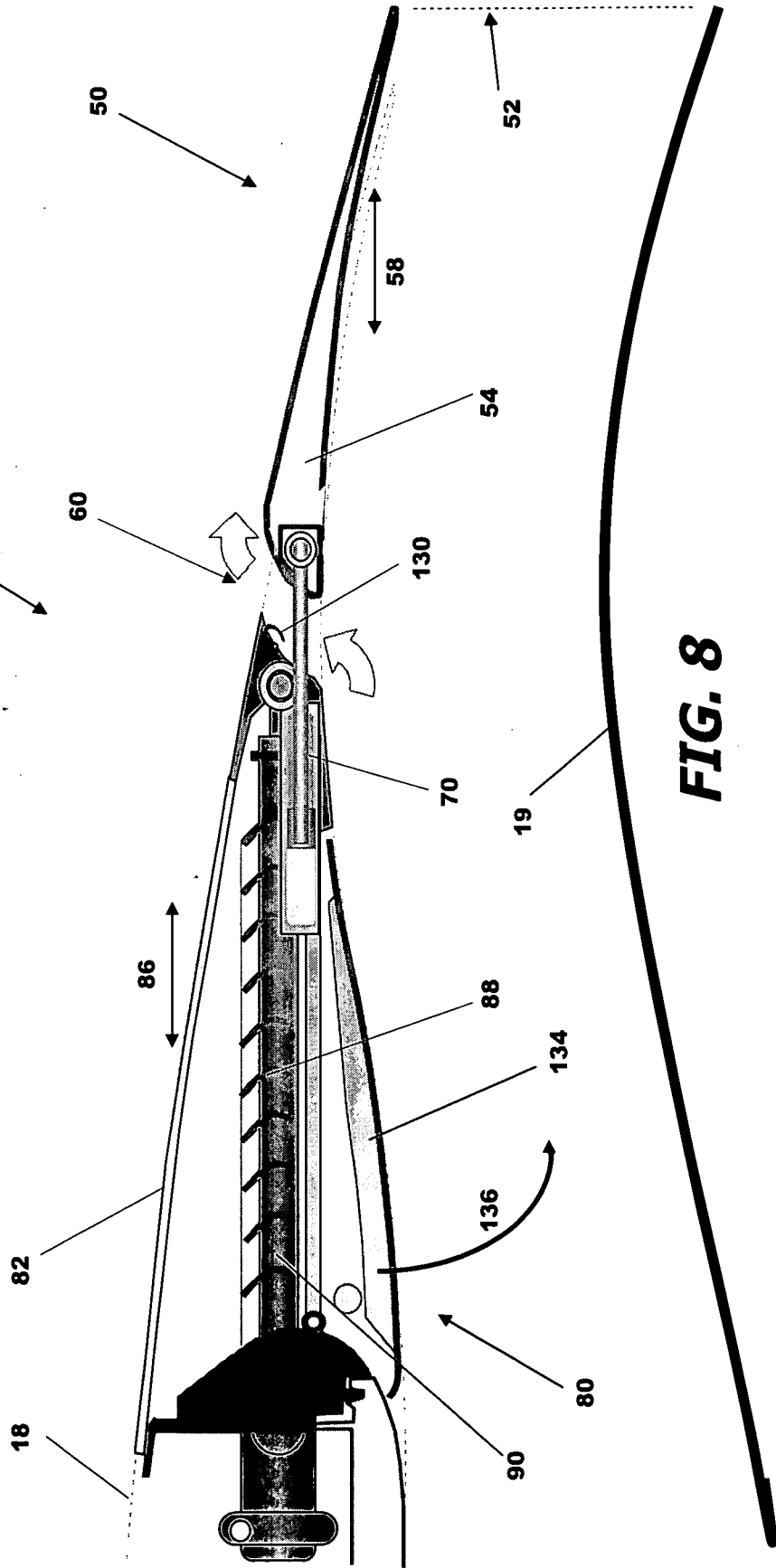


FIG. 8

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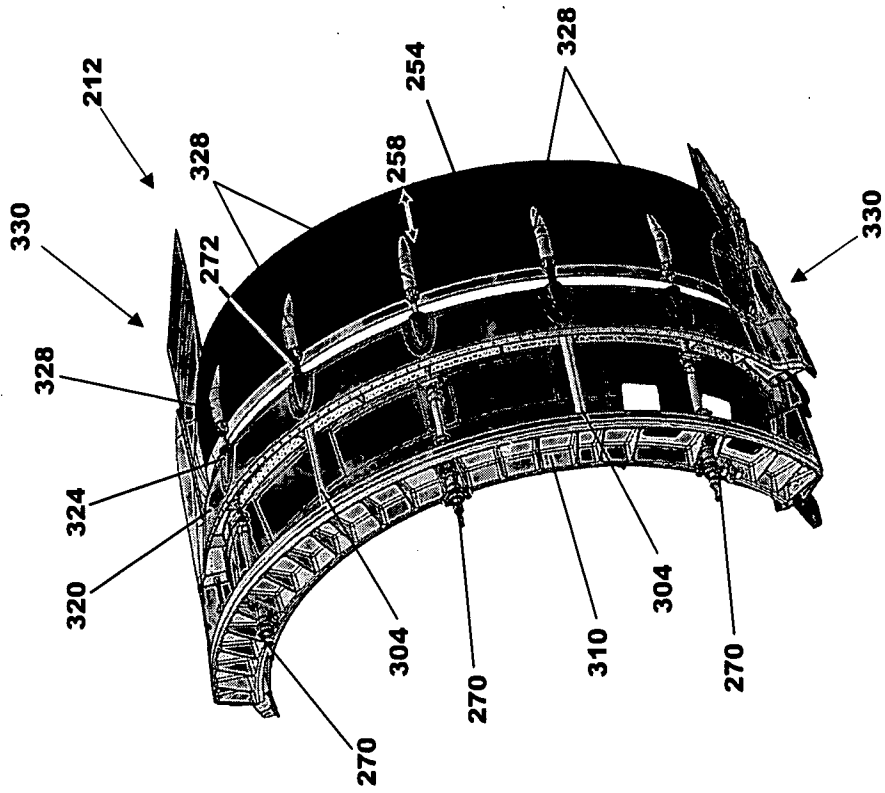


FIG. 9B

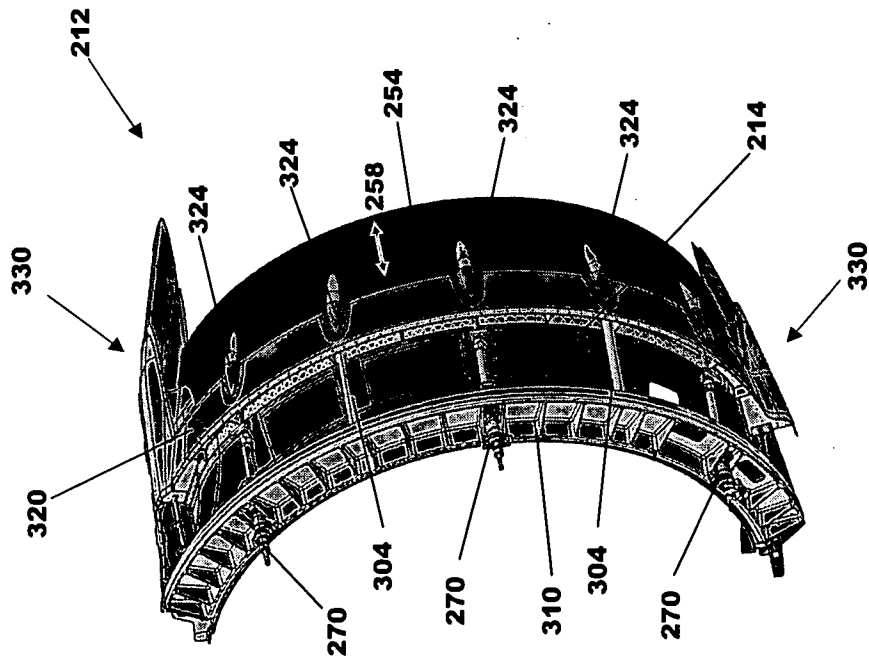


FIG. 9A

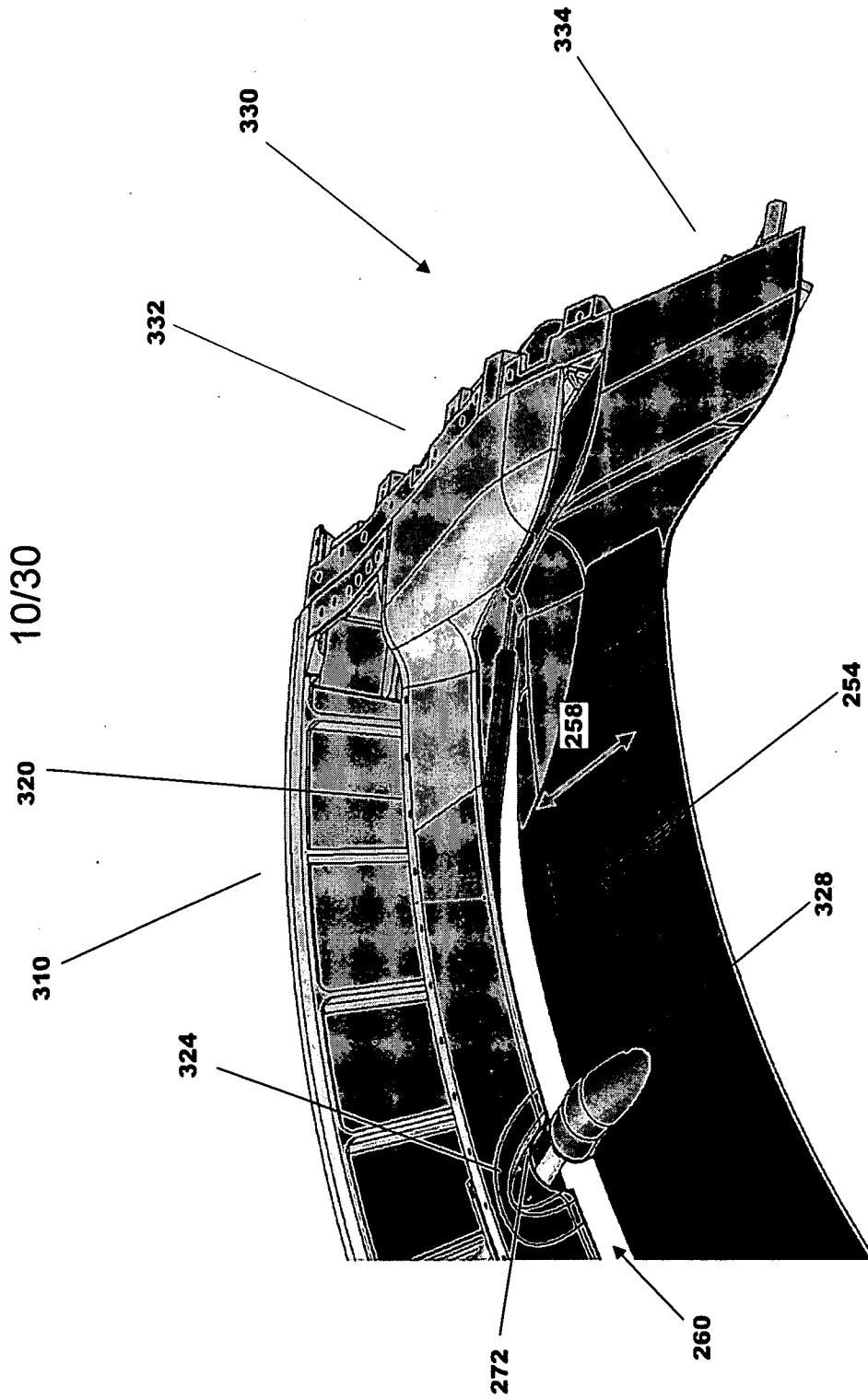


FIG. 10

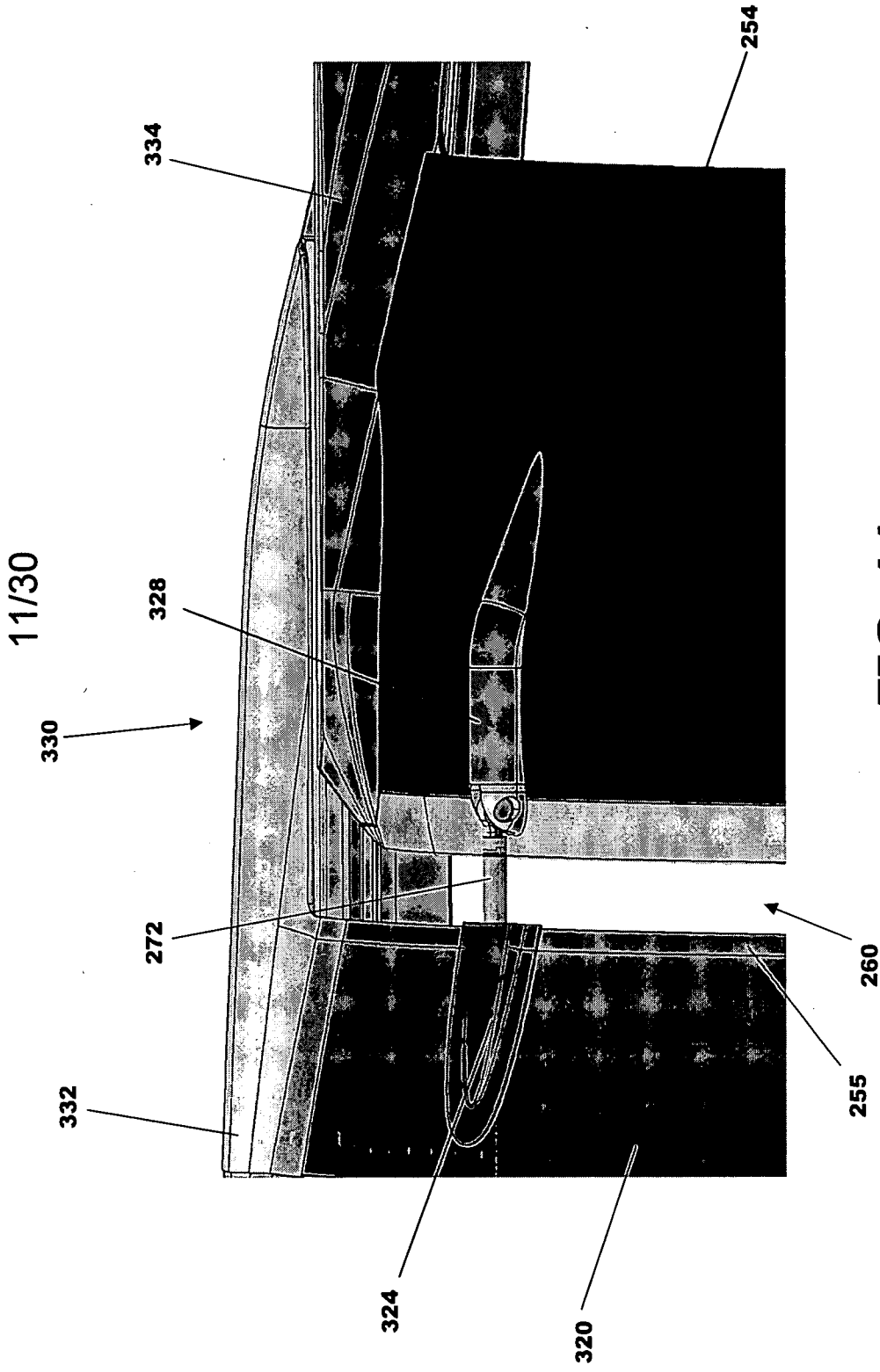


FIG. 11

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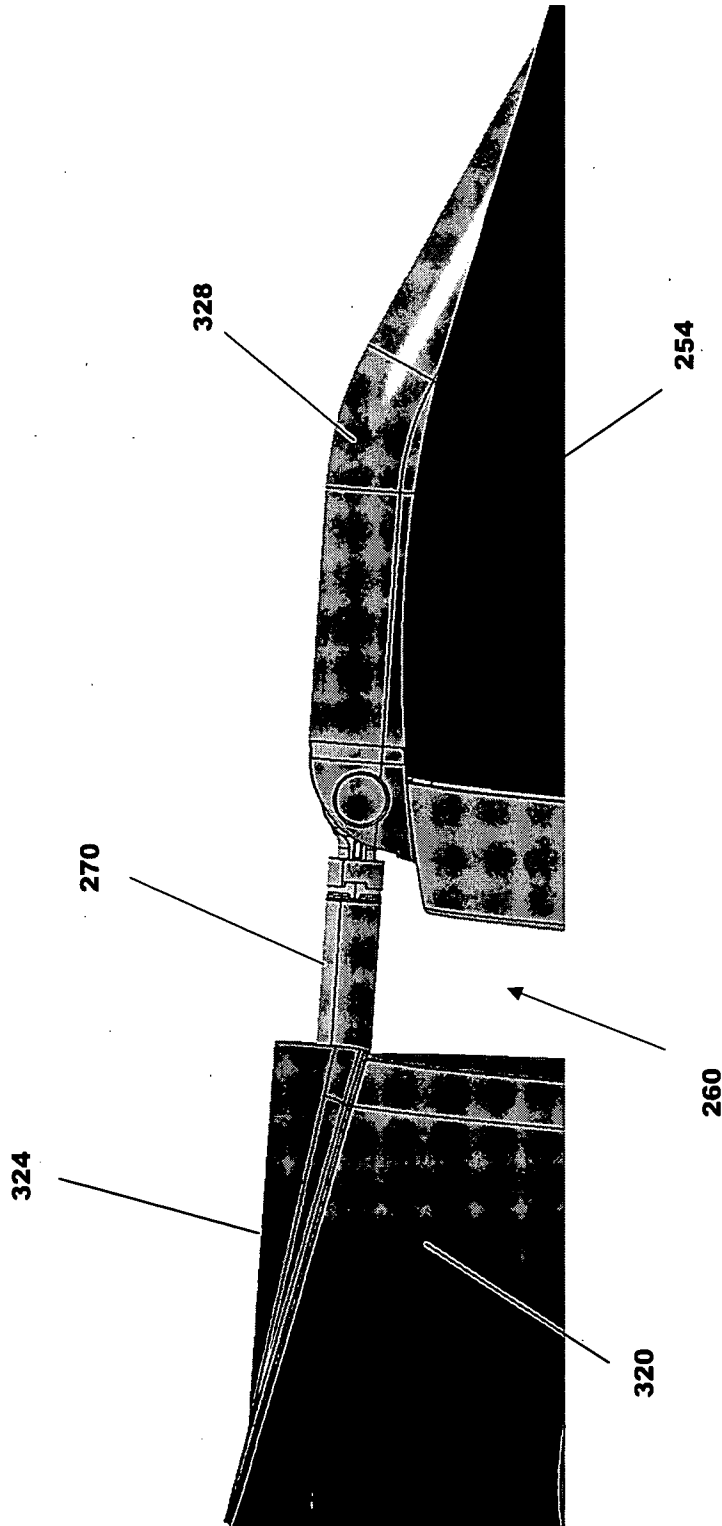
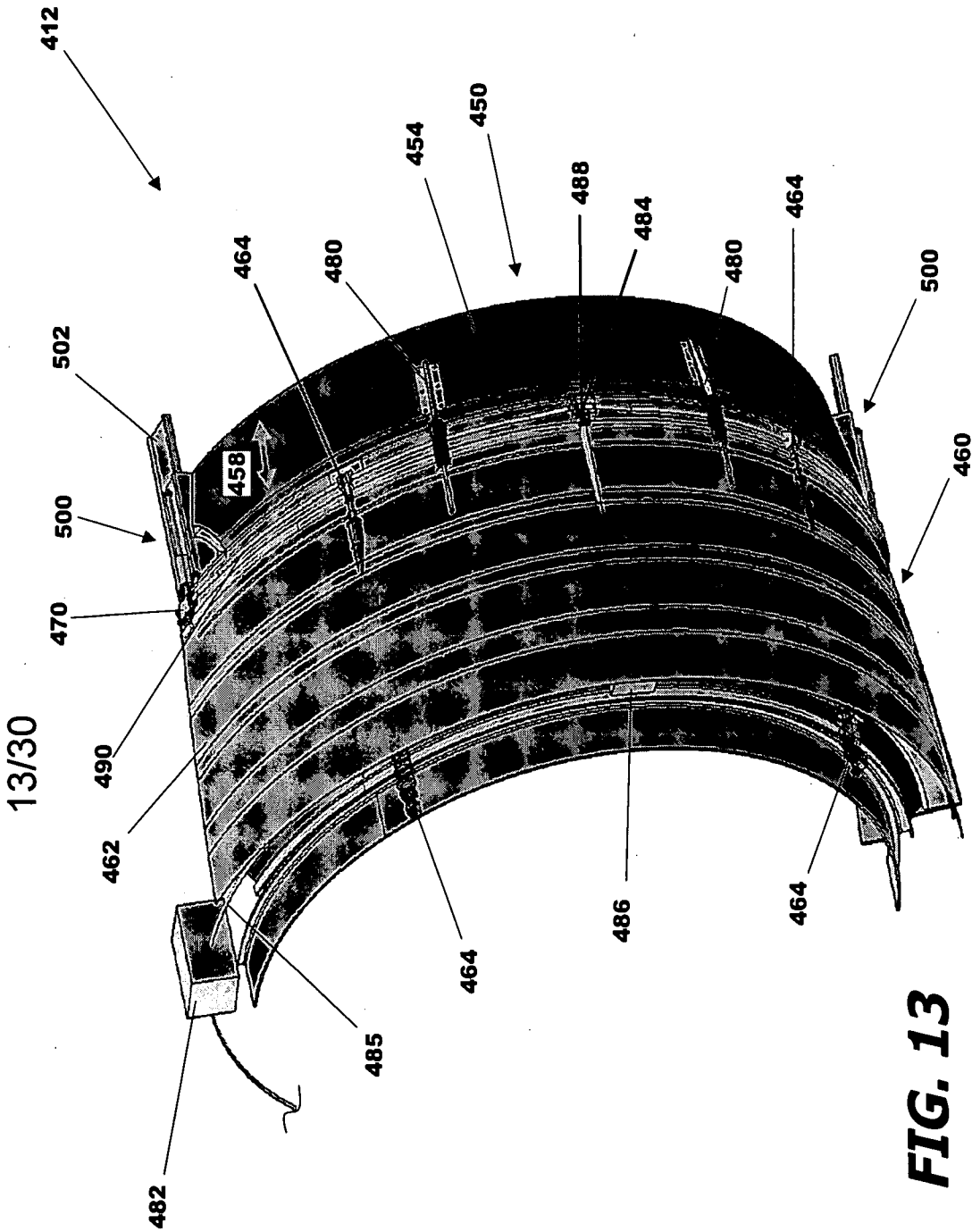


FIG. 12



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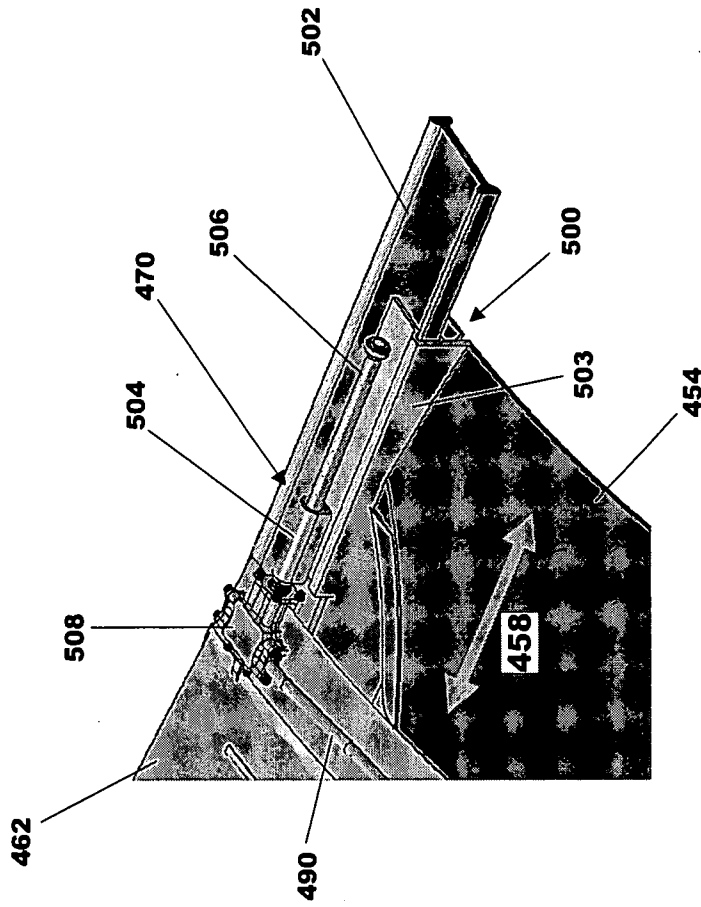


FIG. 14

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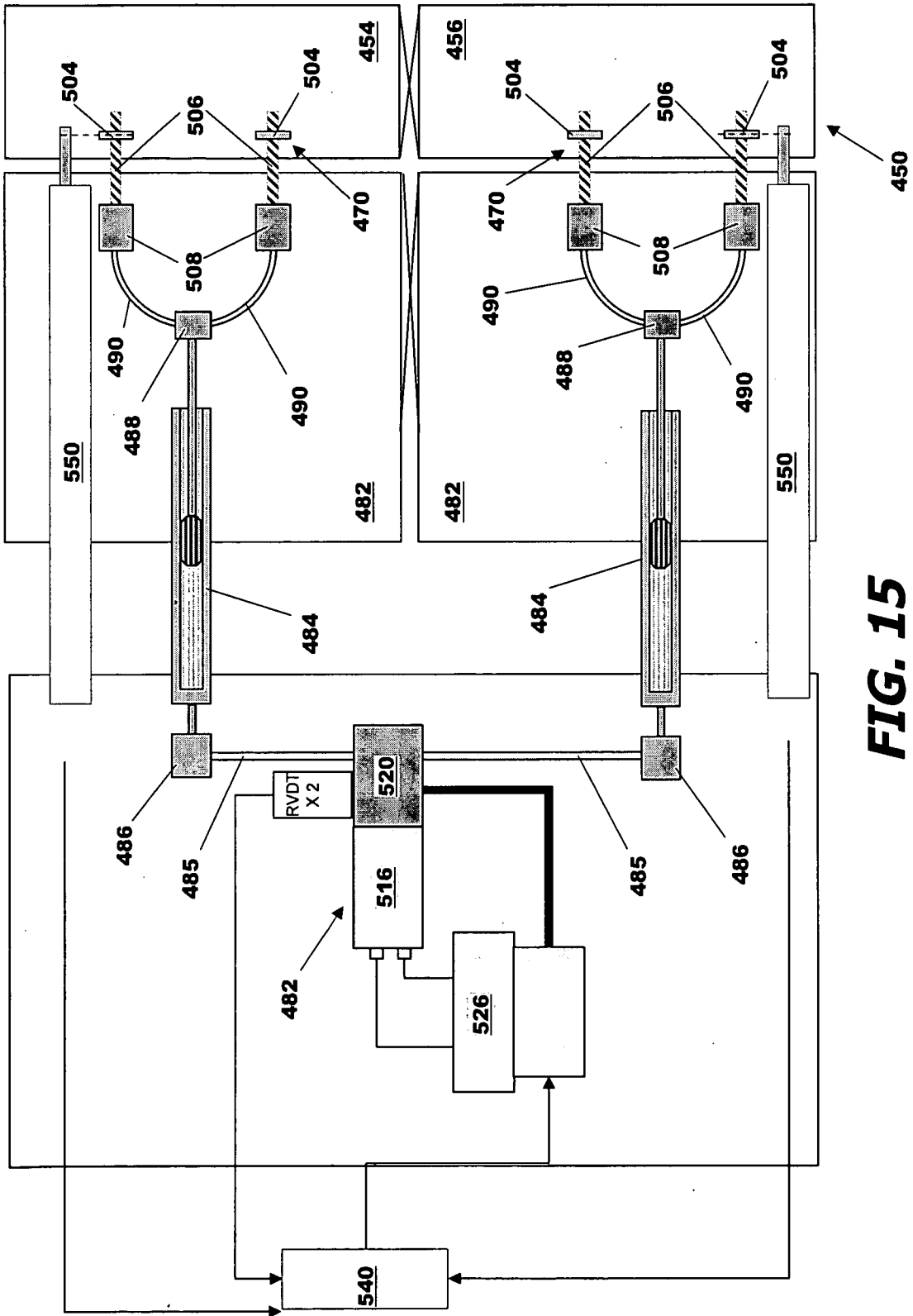


FIG. 15

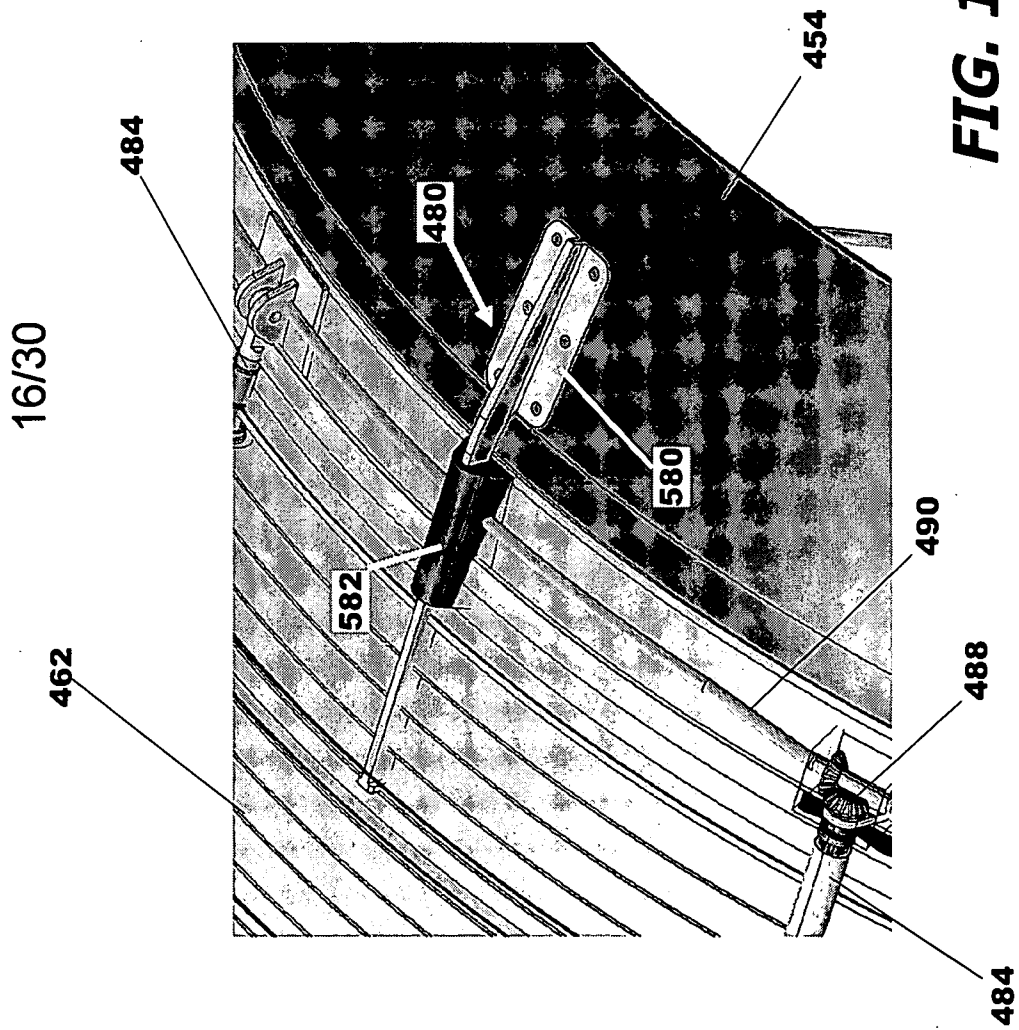


FIG. 16

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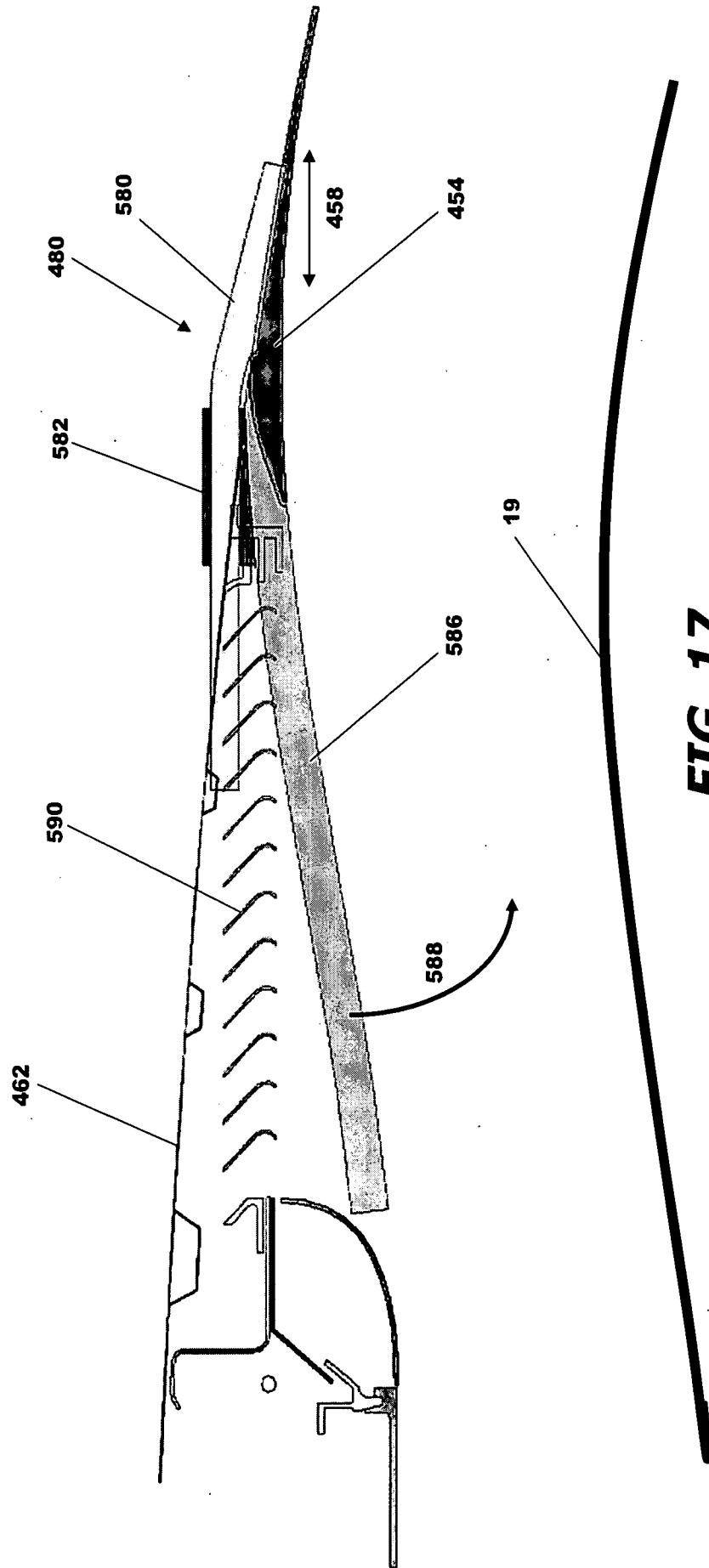


FIG. 17

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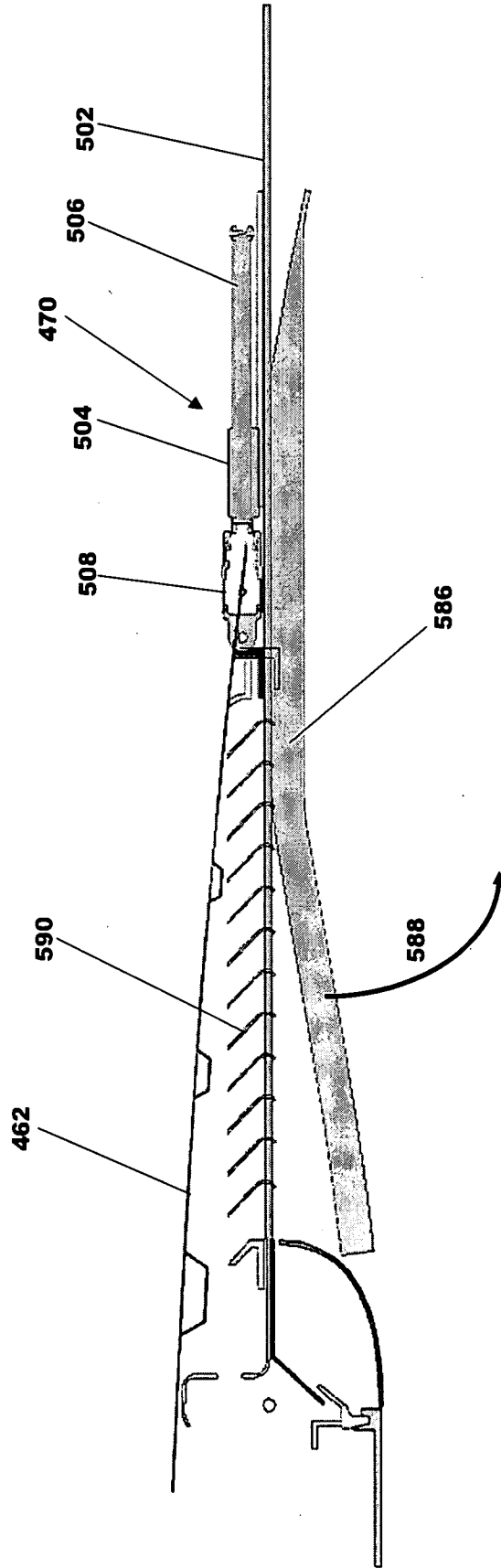


FIG. 18

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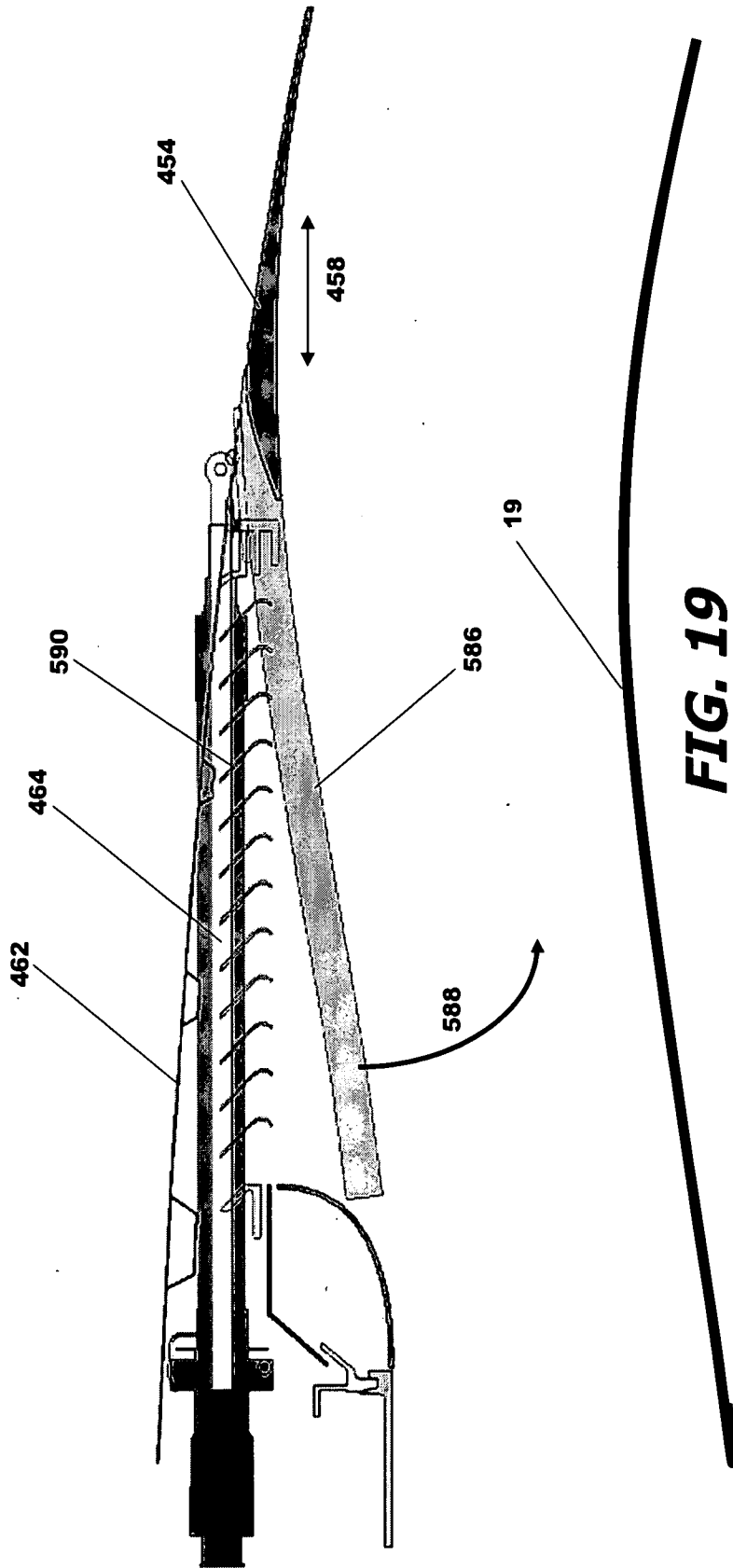


FIG. 19

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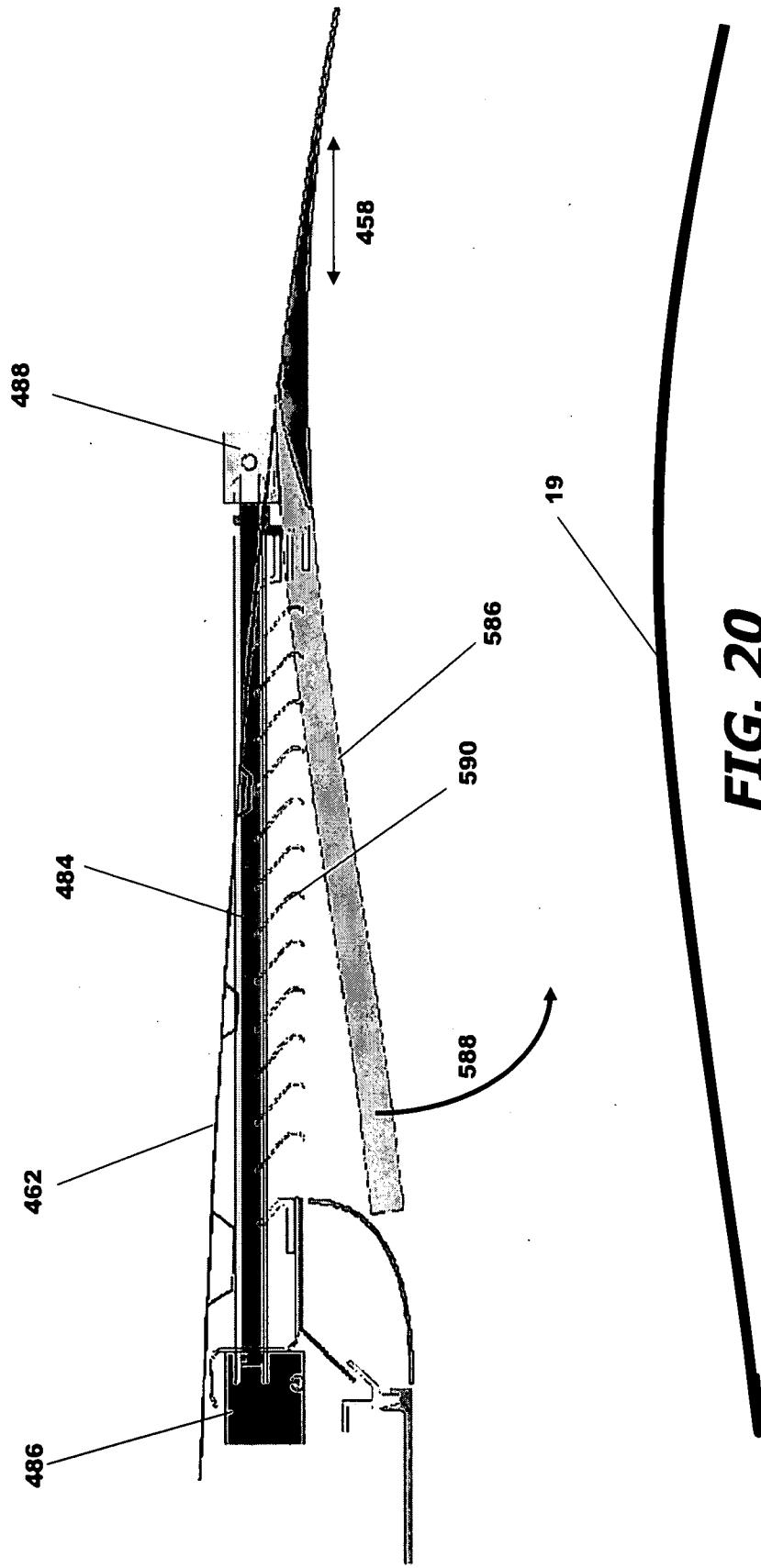


FIG. 20

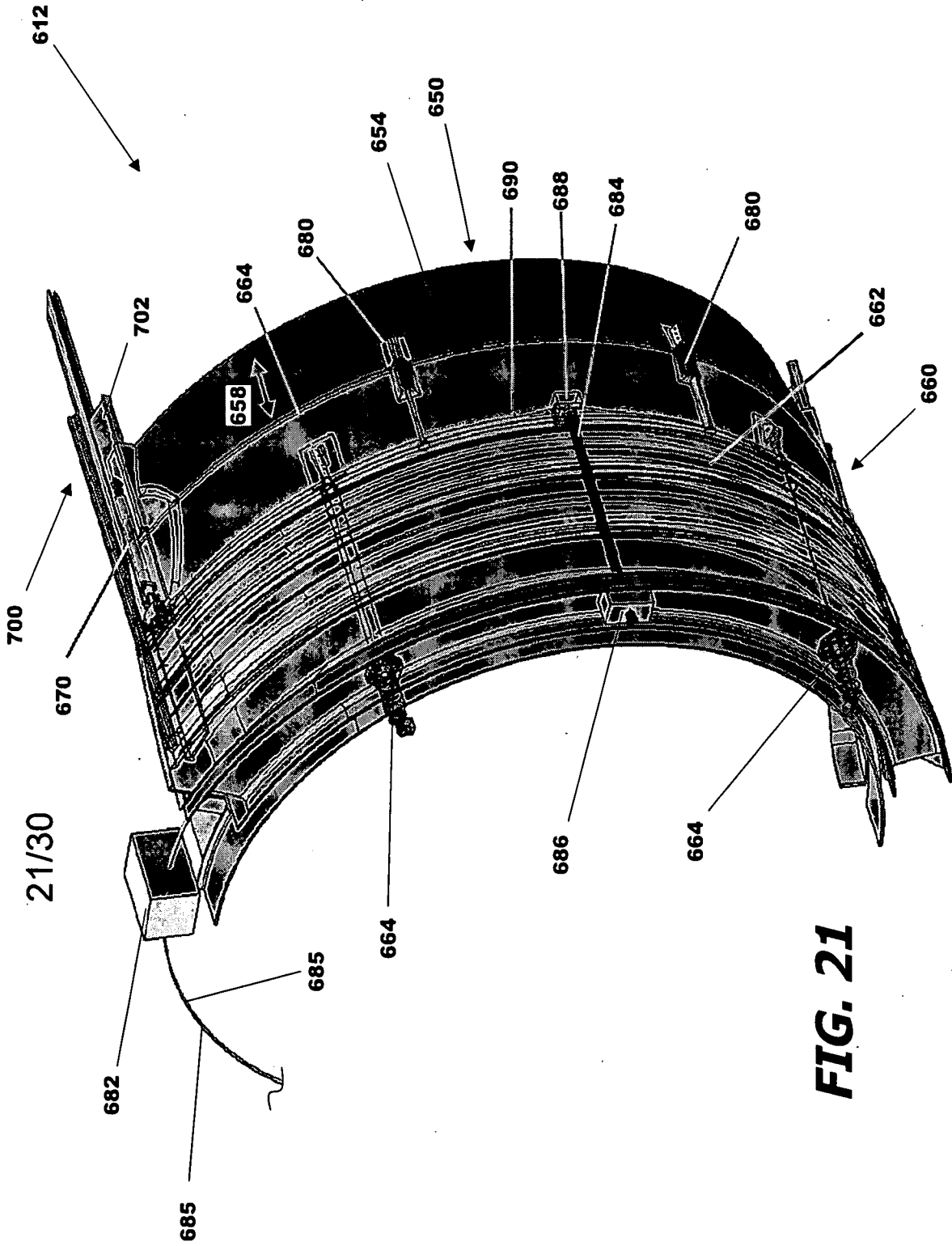


FIG. 21

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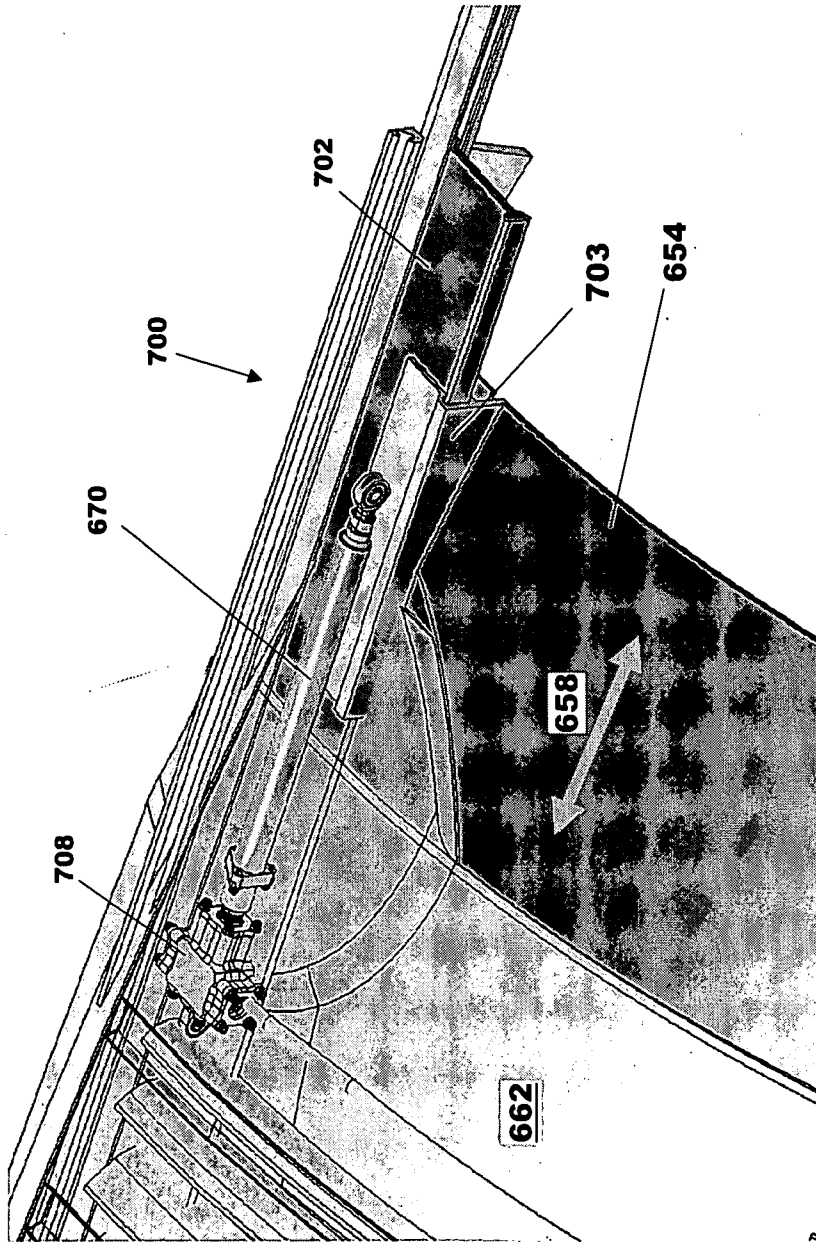


FIG. 22

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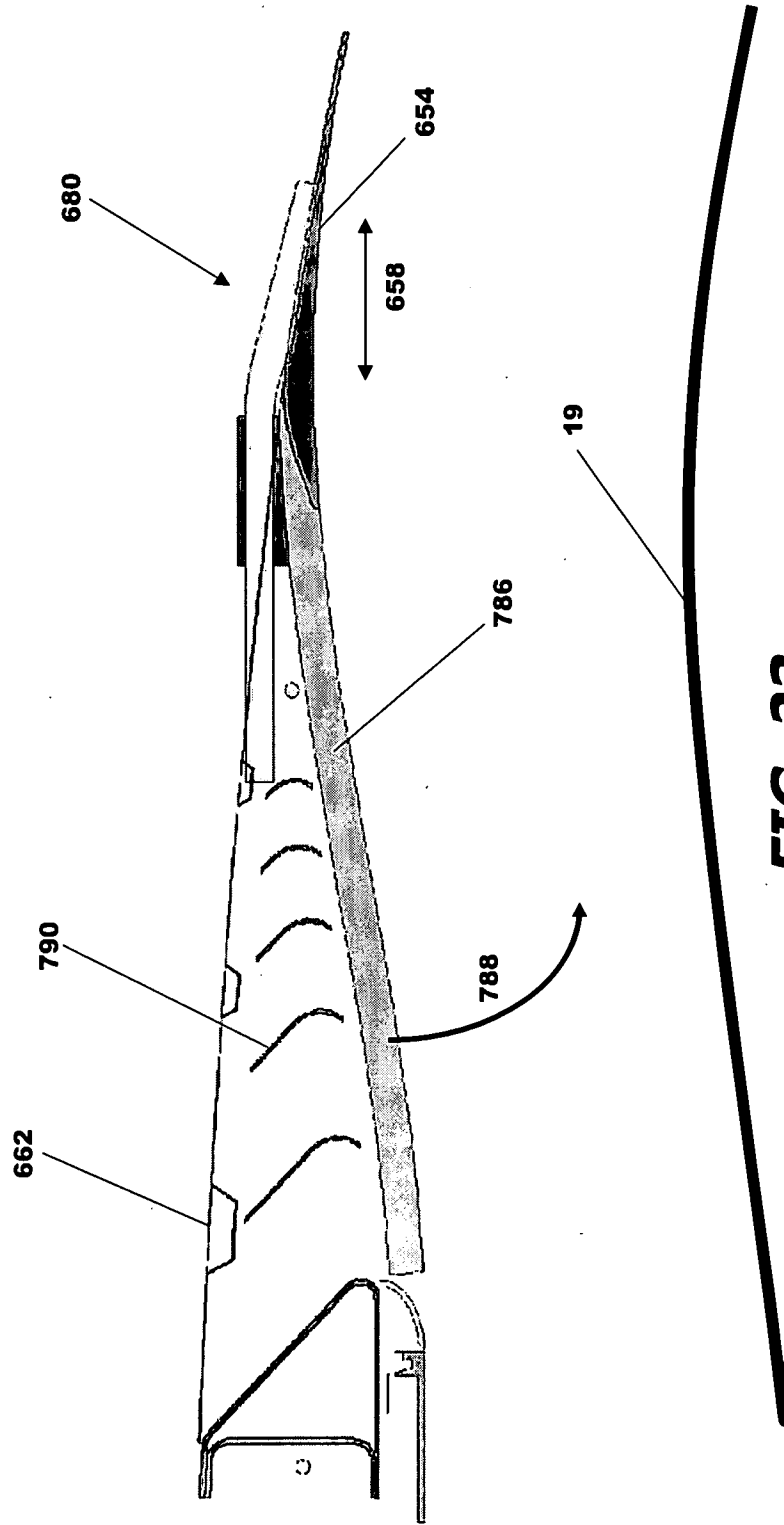


FIG. 23

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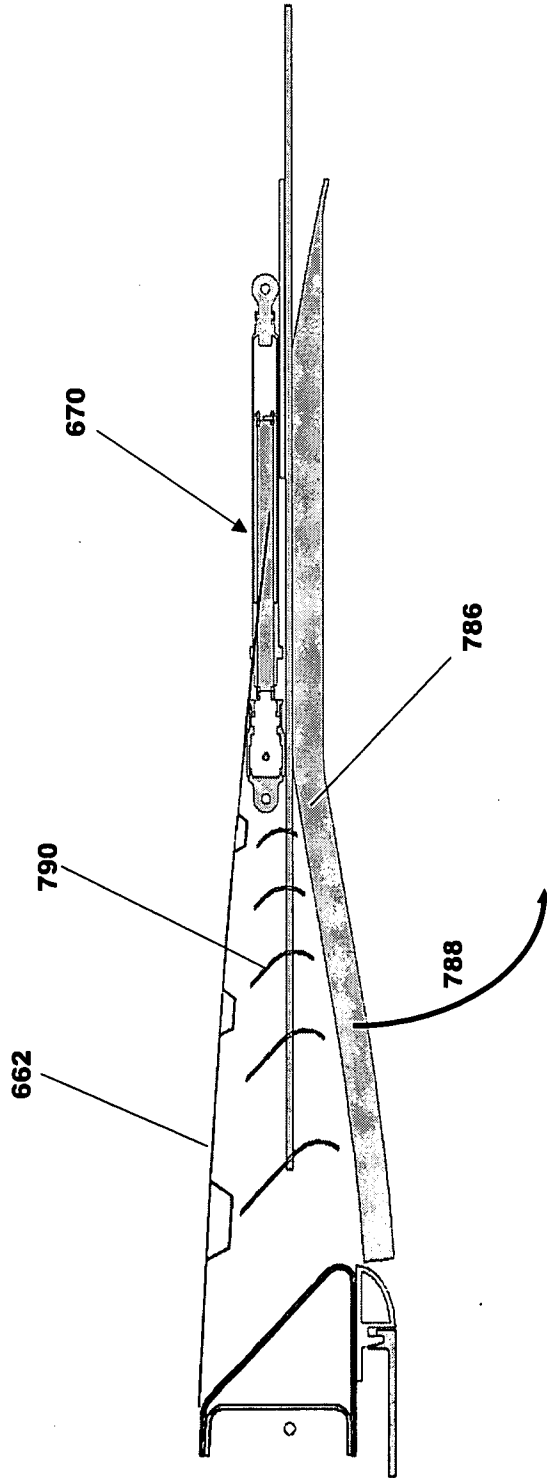


FIG. 24

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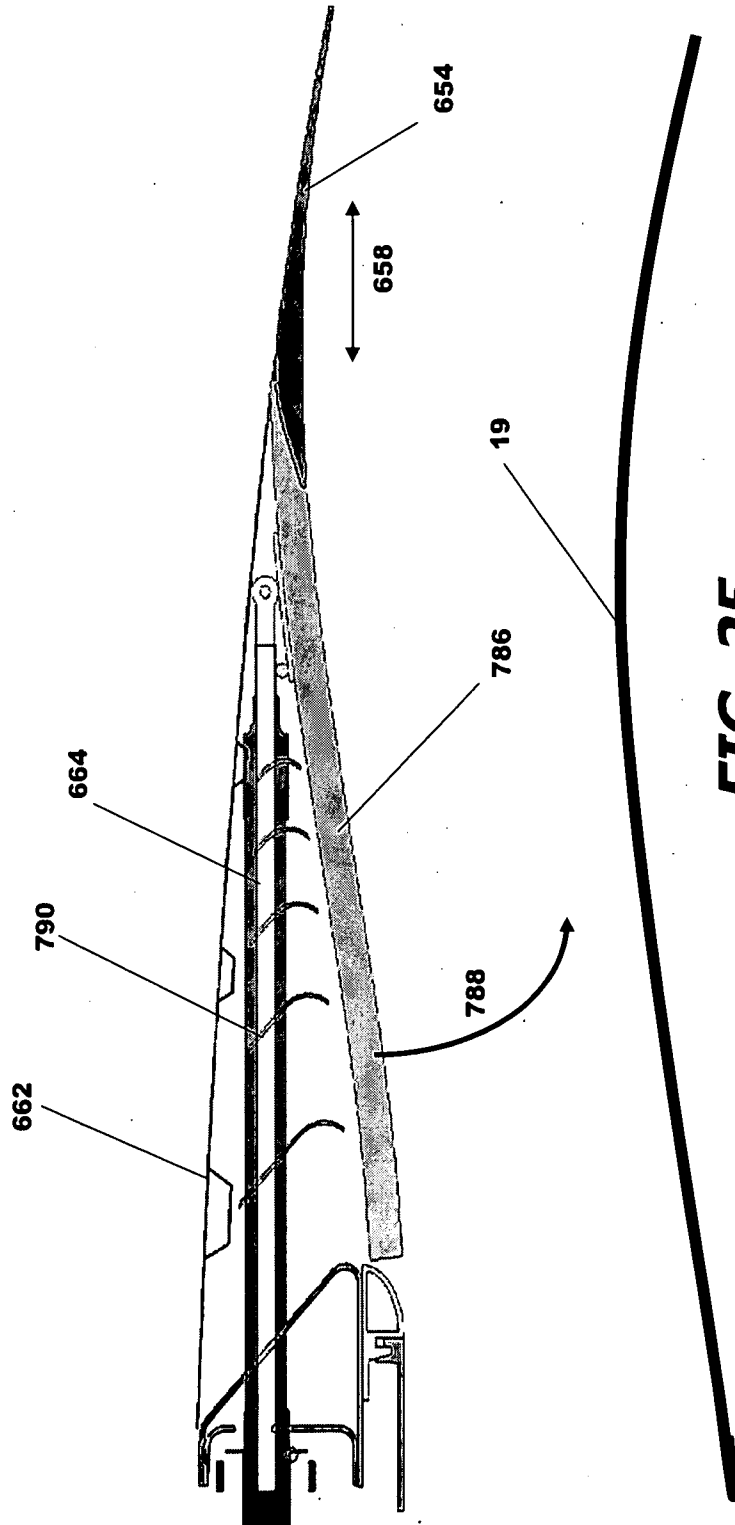


FIG. 25

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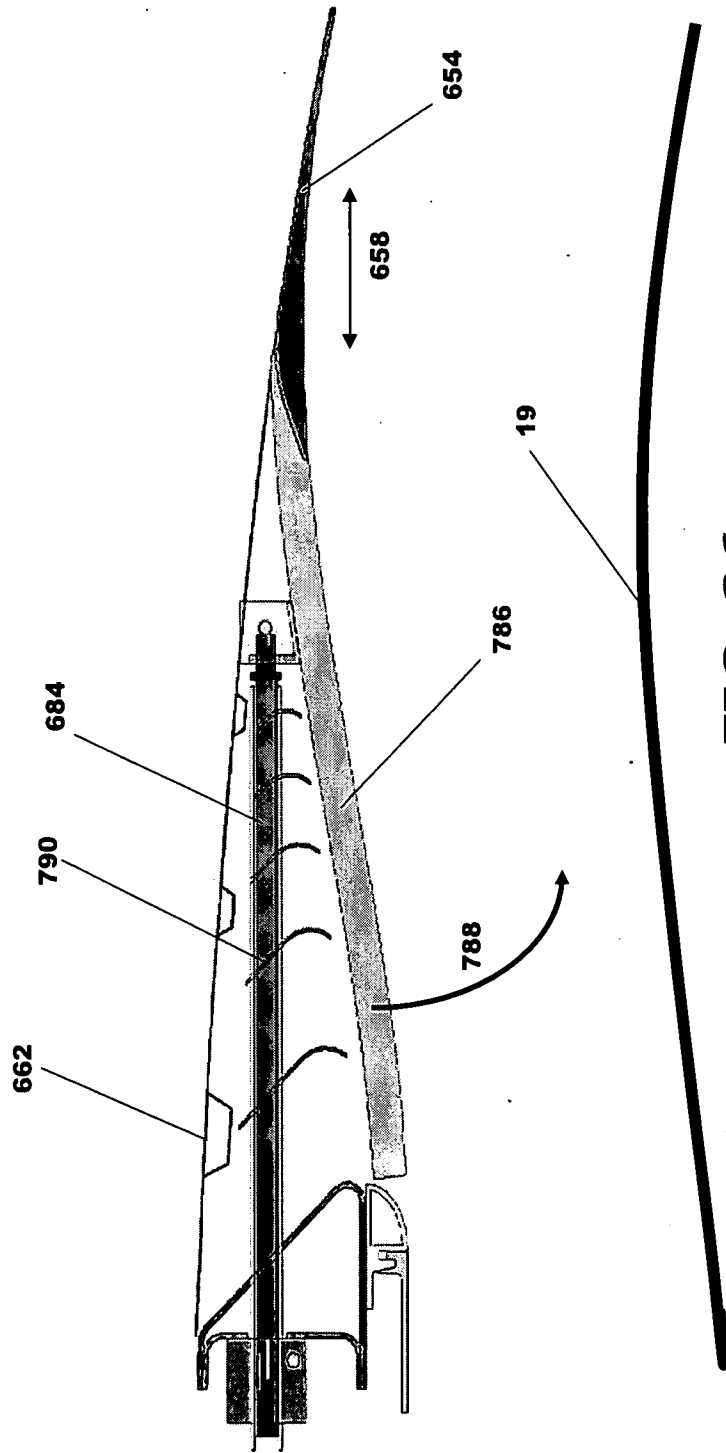


FIG. 26

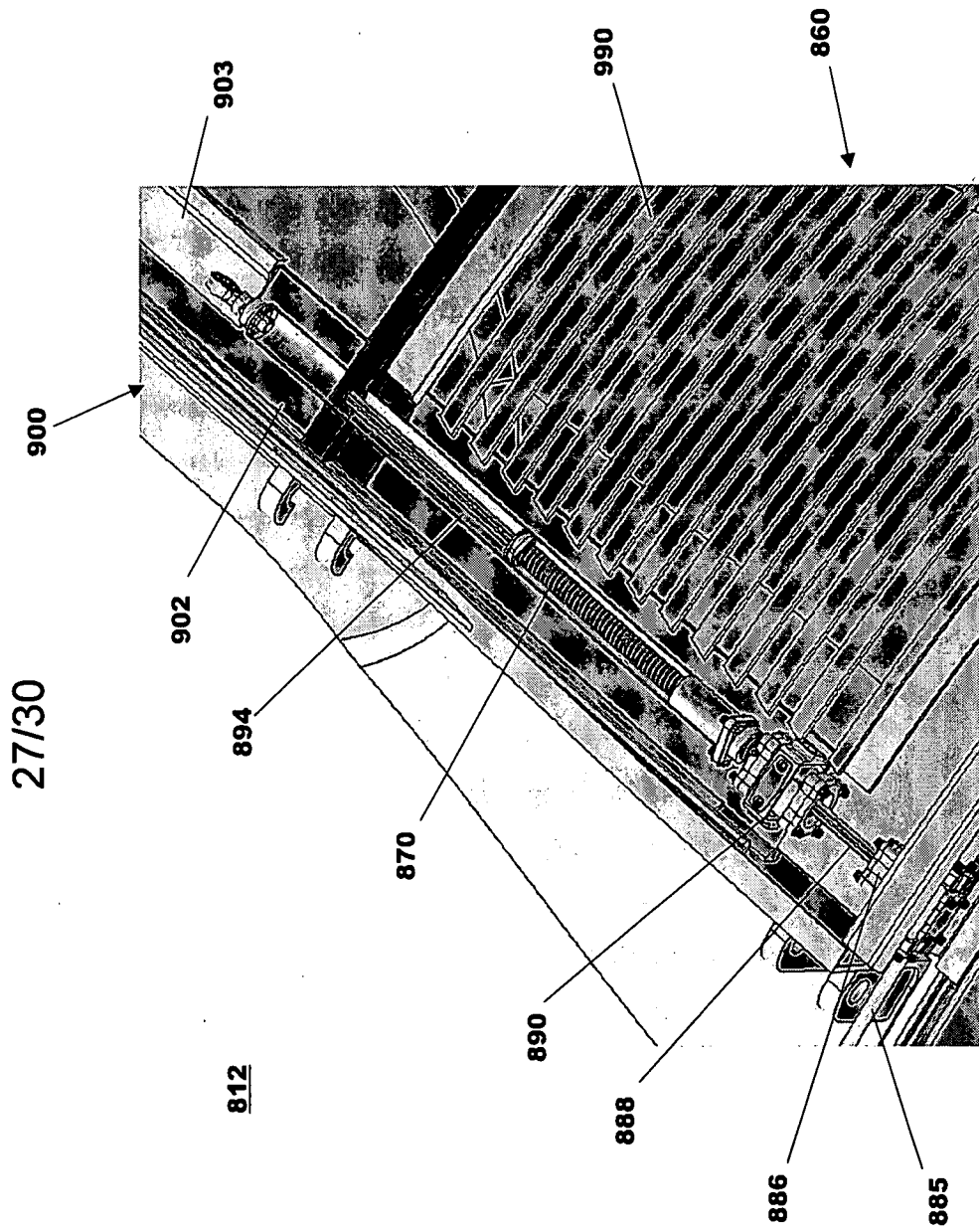


FIG. 27

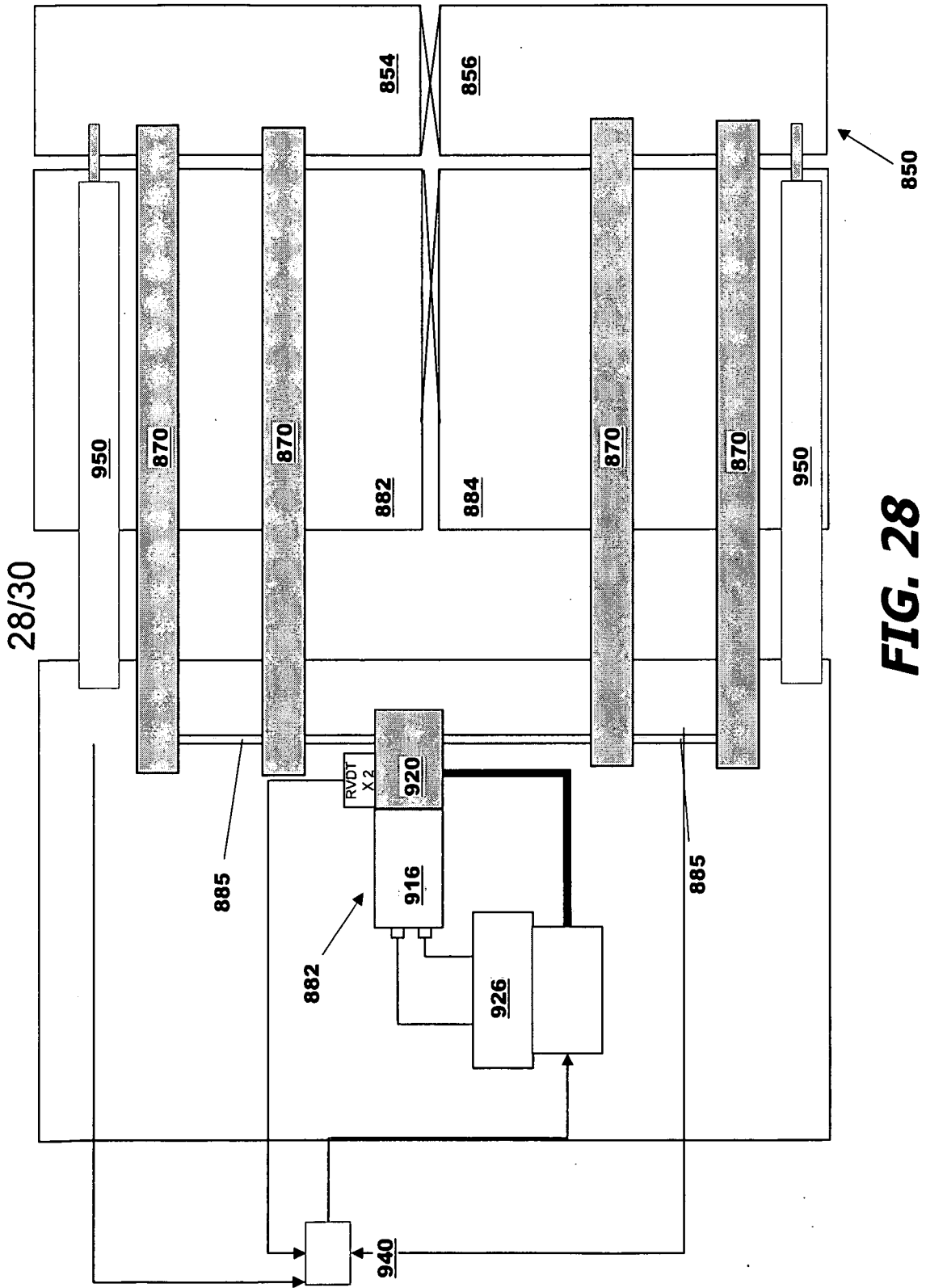


FIG. 28

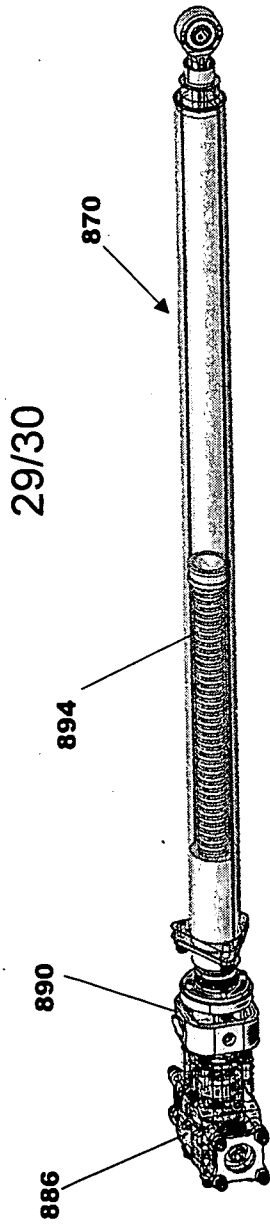


FIG. 29A

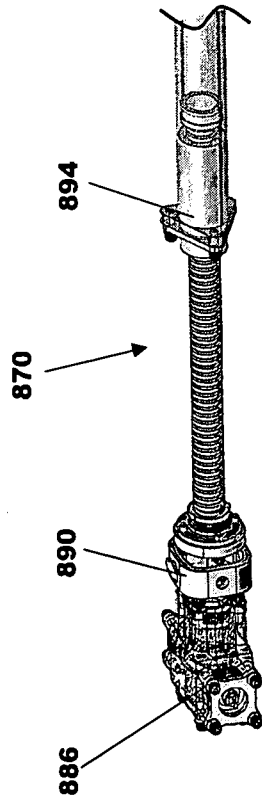


FIG. 29B

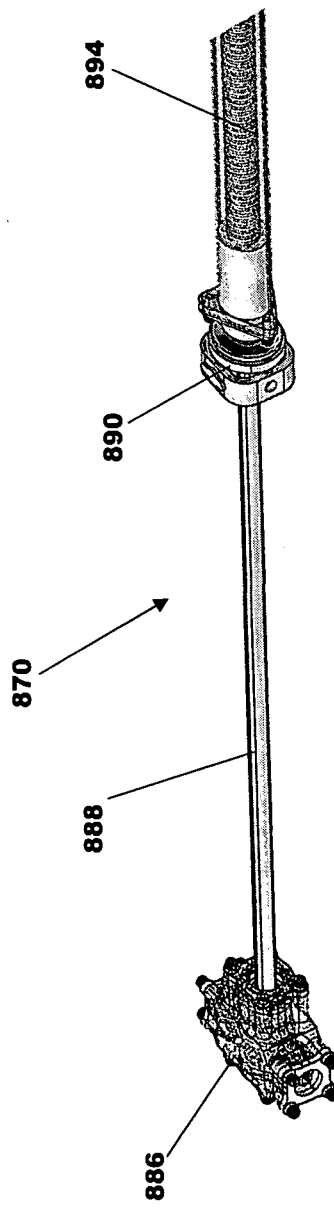


FIG. 29C

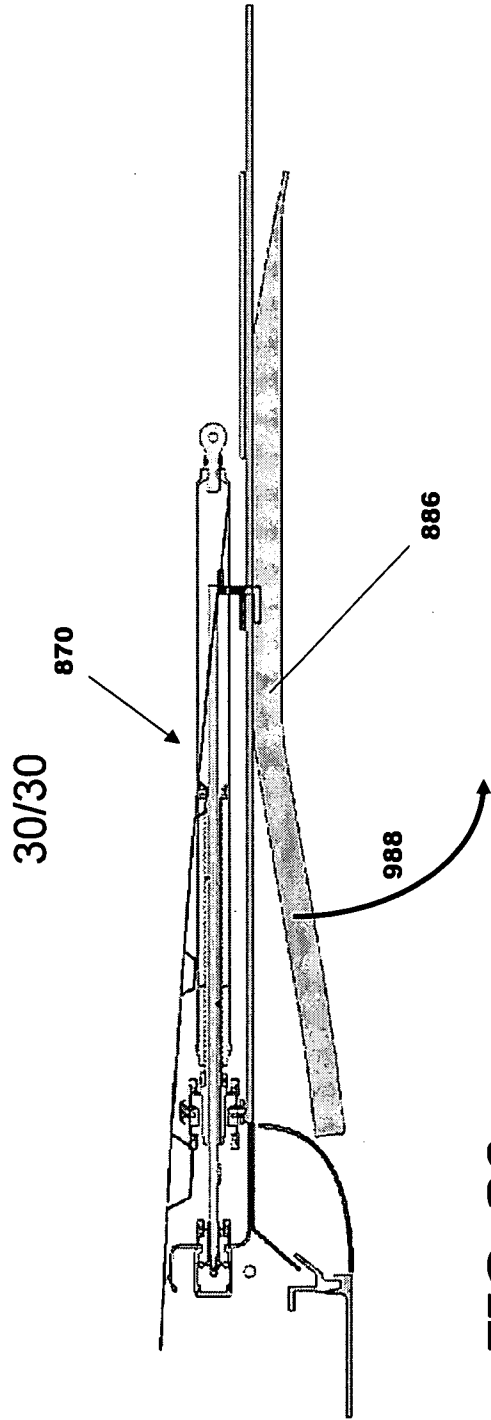


FIG. 30

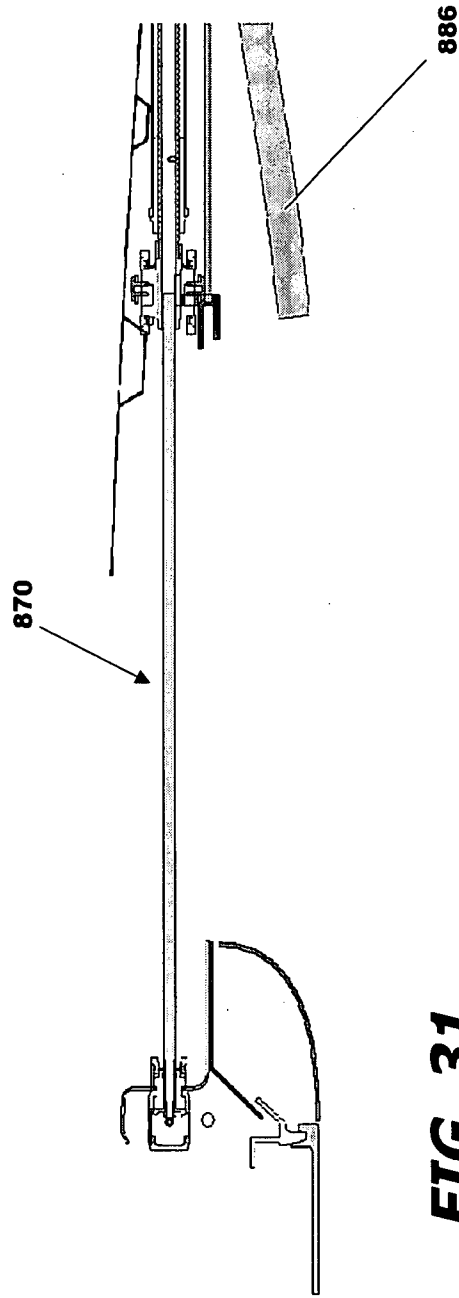


FIG. 31