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(54) **CONVERTIBLE FAN SYSTEM**

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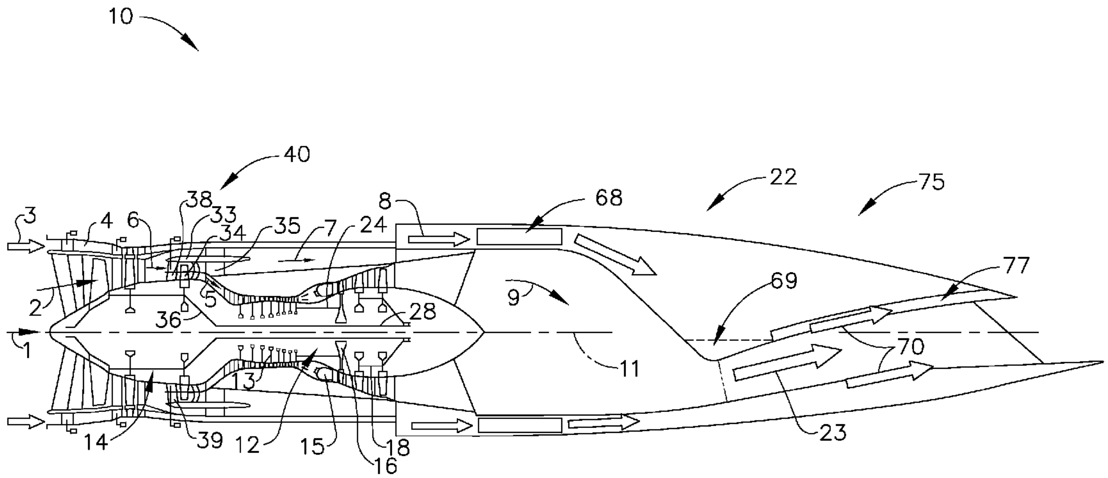
(57) **ABSTRACT**

A convertible fan system is disclosed having a fan rotor with a plurality of fan blades having an arcuate splitter that forms a portion of an inner flow passage and an outer flow passage wherein an inner portion of the fan blade pressurizes an inner flow in the inner flow passage and an outer portion of the fan blade pressurizes an outer flow in the outer flow passage and a vane system having an outer vane that is adapted to be able to vary the flow in the outer flow passage such that pressure ratio of the fan system can be varied.



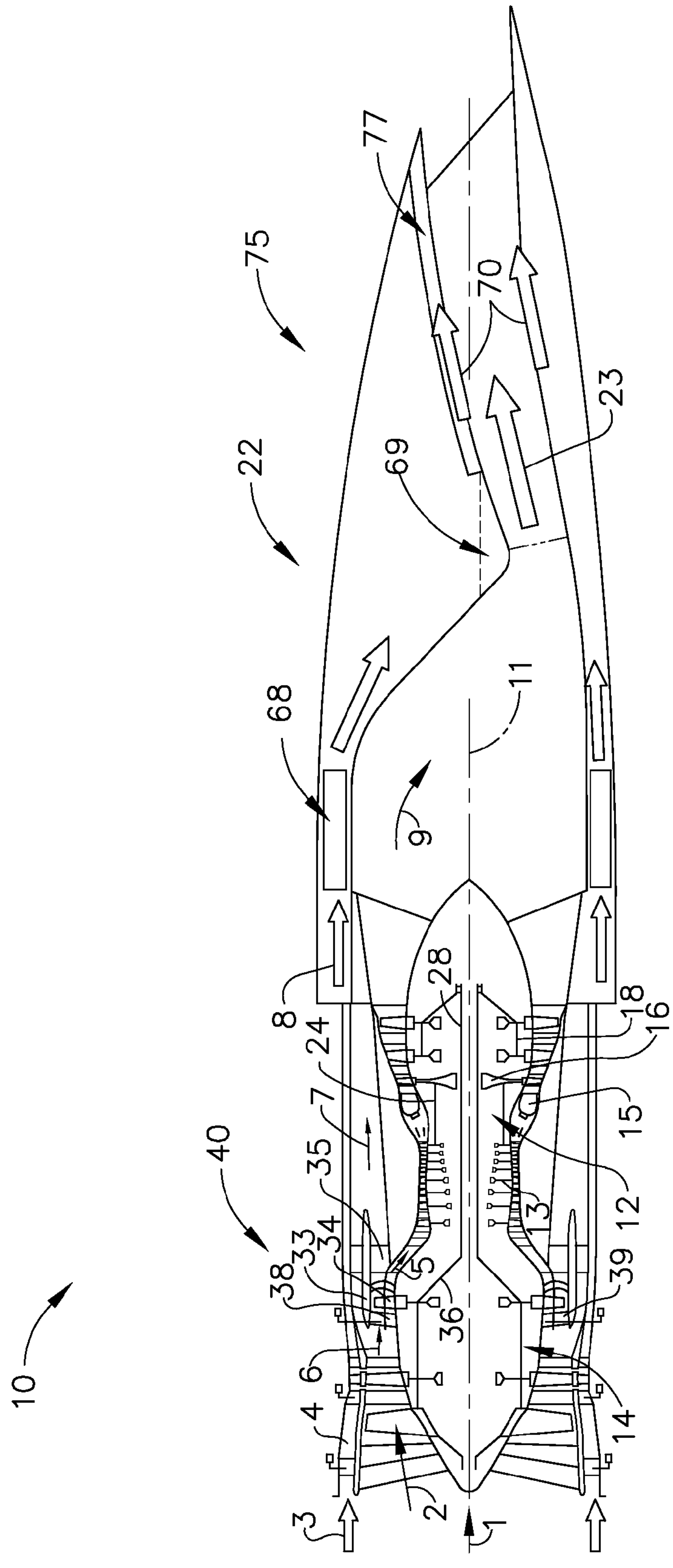

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FIG. 1

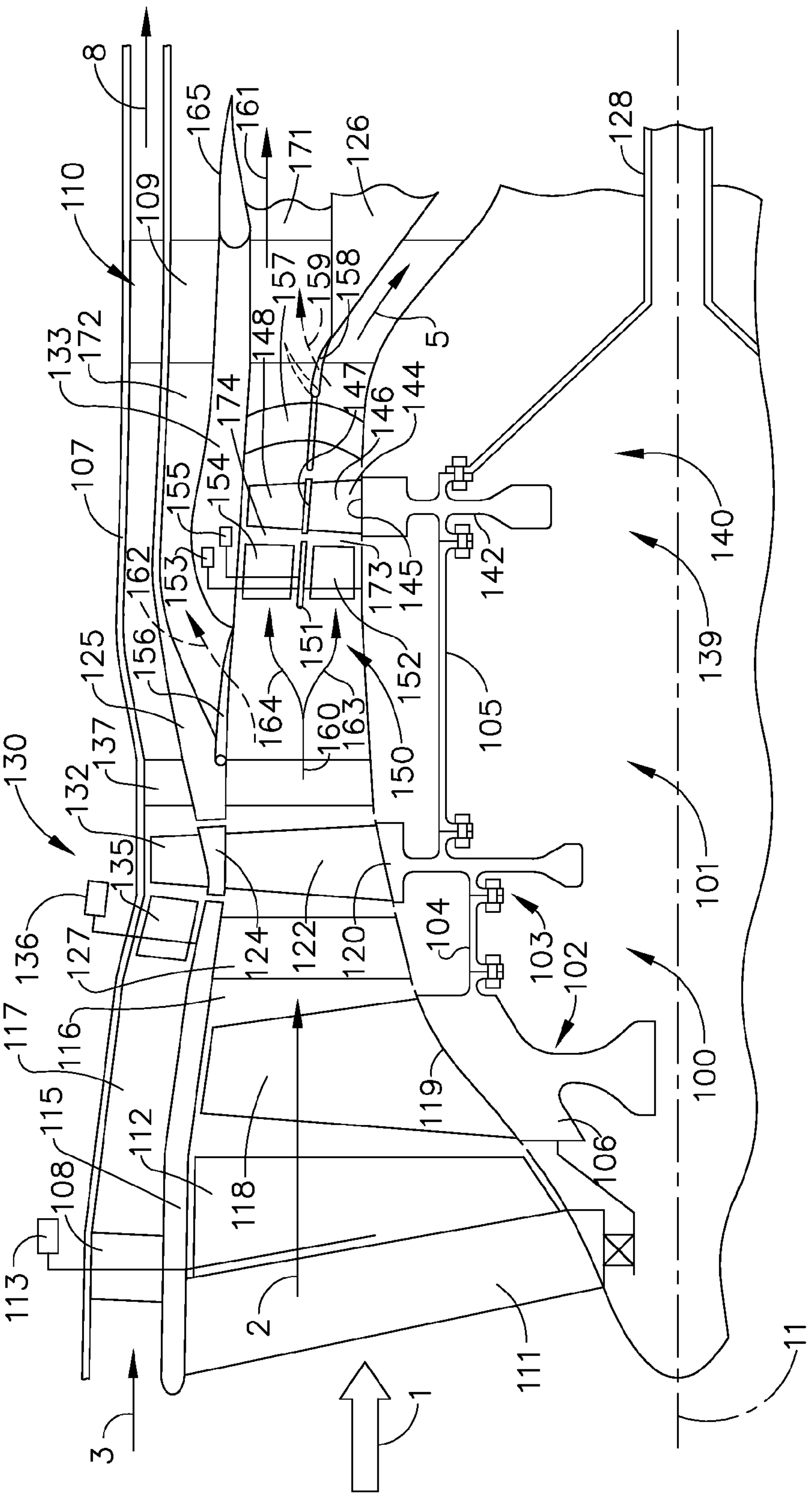

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FIG. 2

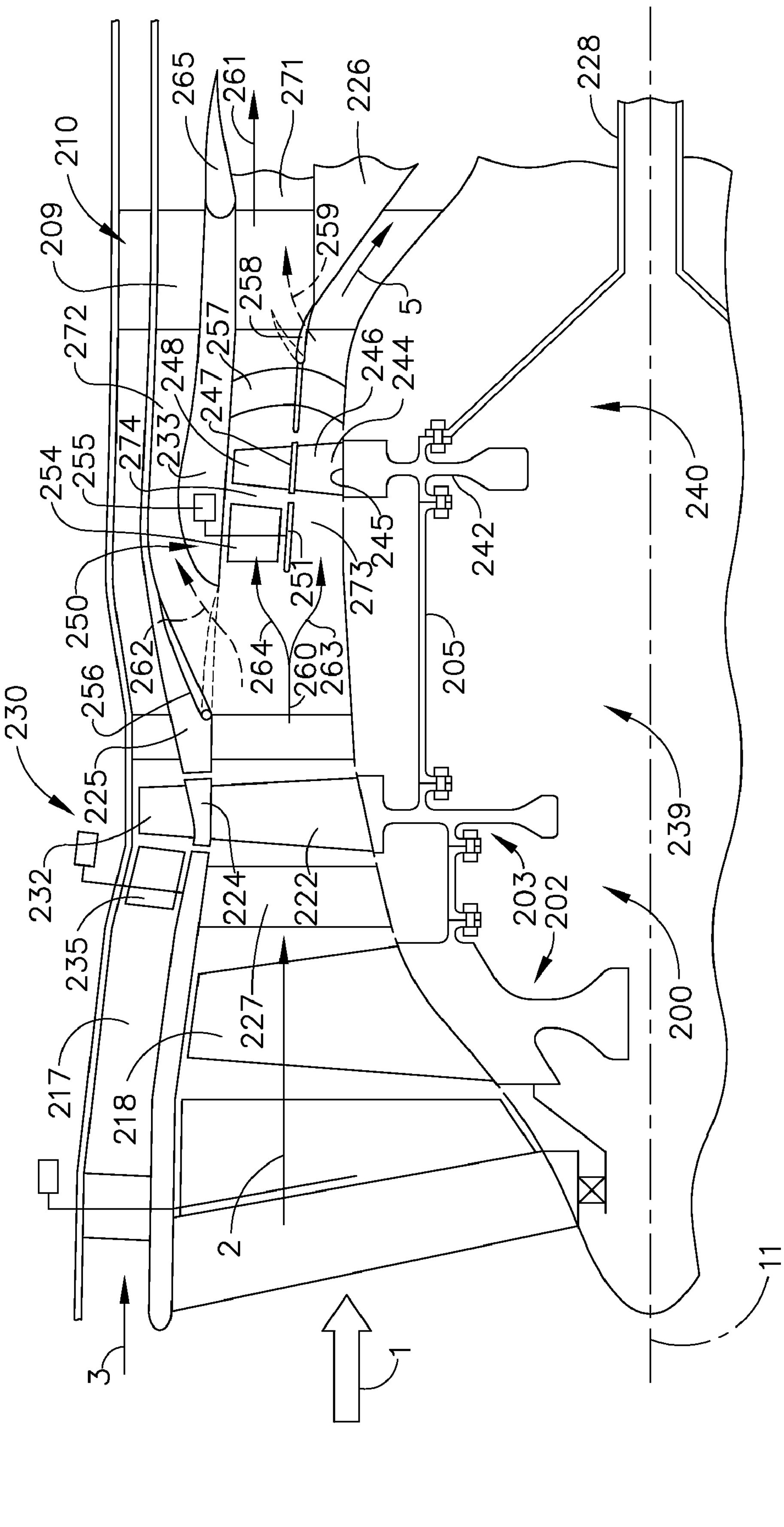
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FIG. 3

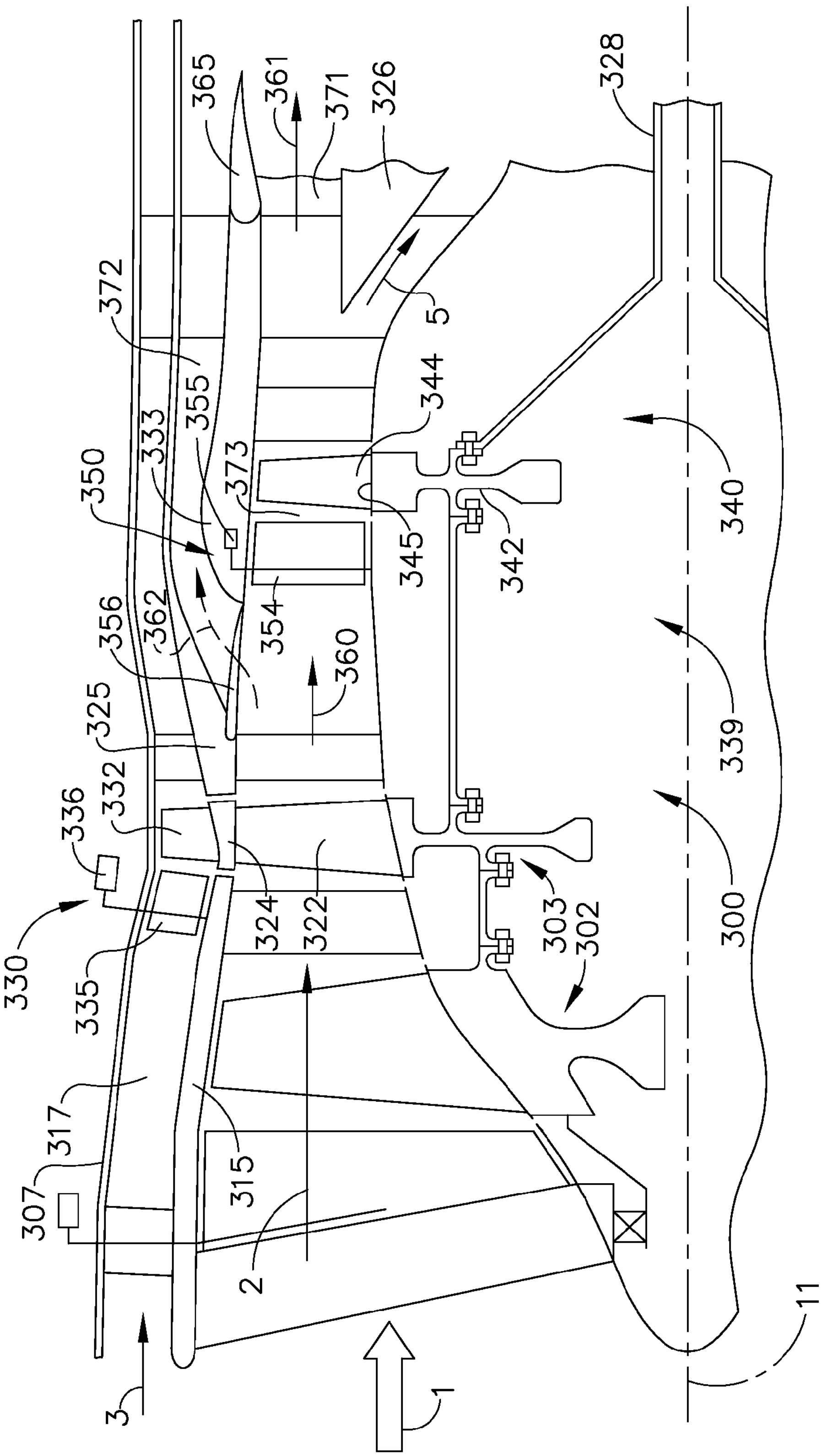
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FIG. 4

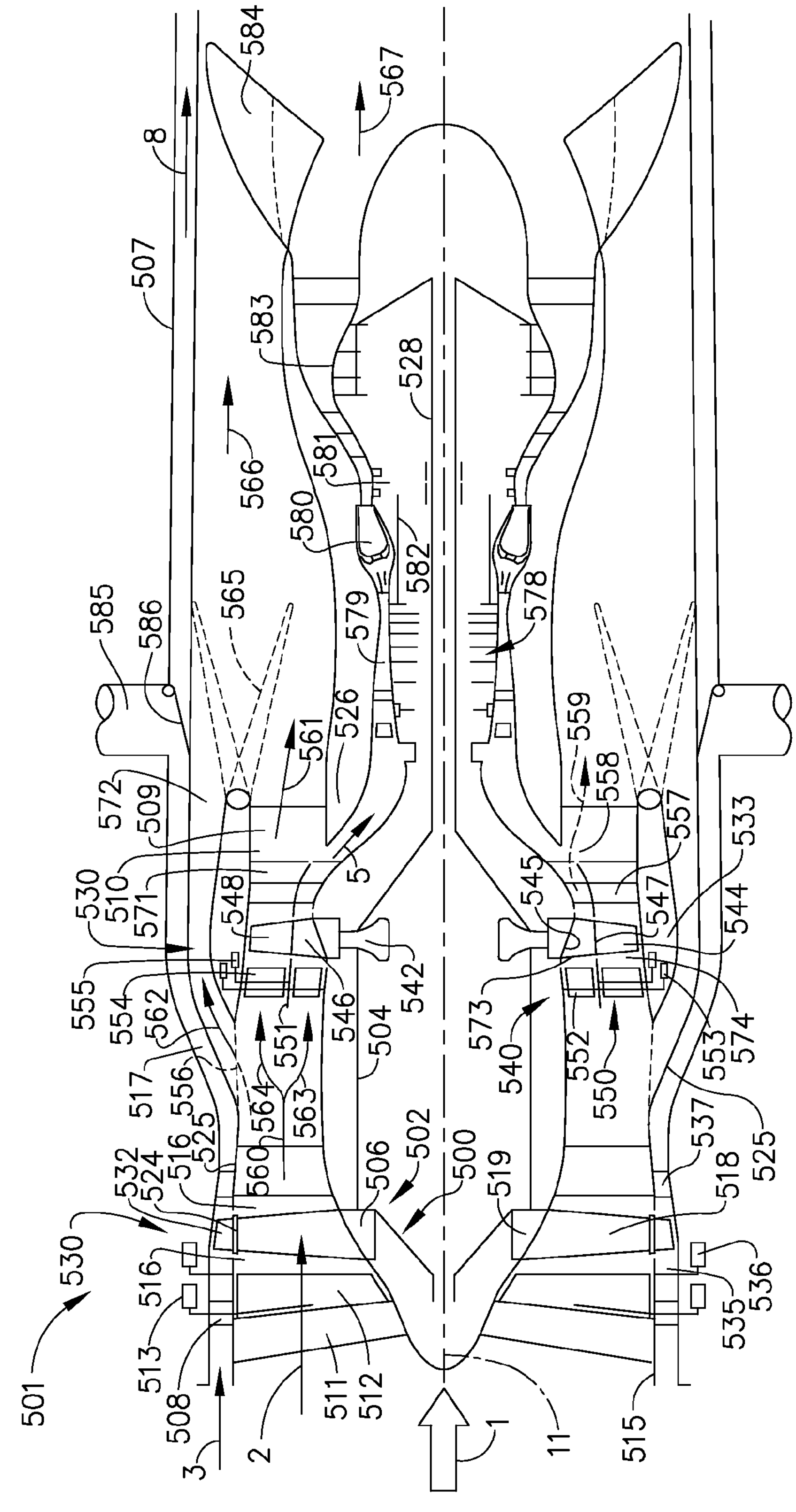
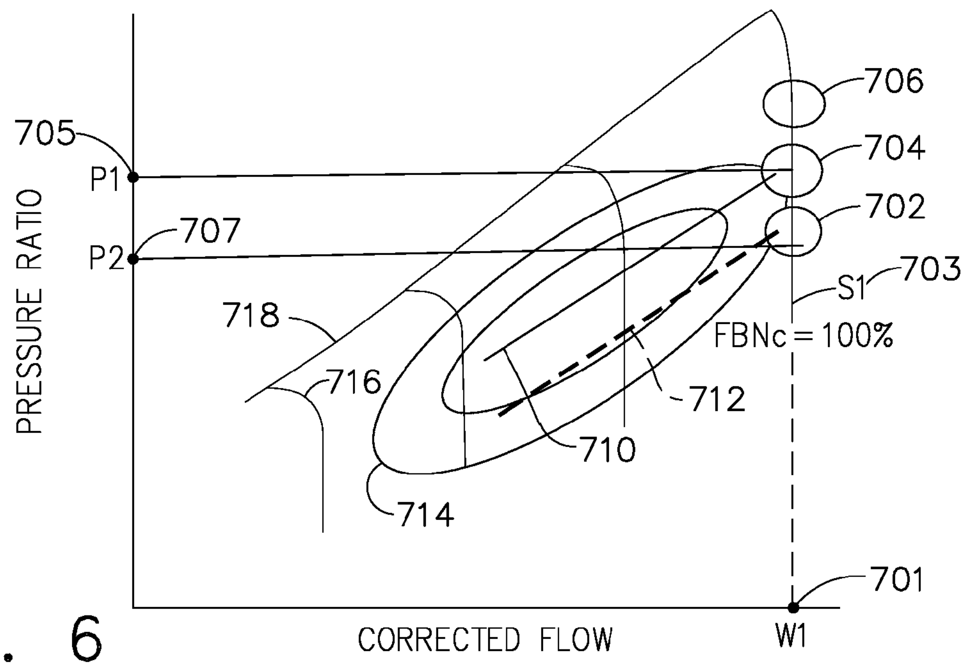


FIG. 5


706
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P1
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PRESSURE RATIO
P2
S1
703
718
FBNc=100%
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CORRECTED FLOW
W1

FIG. 6

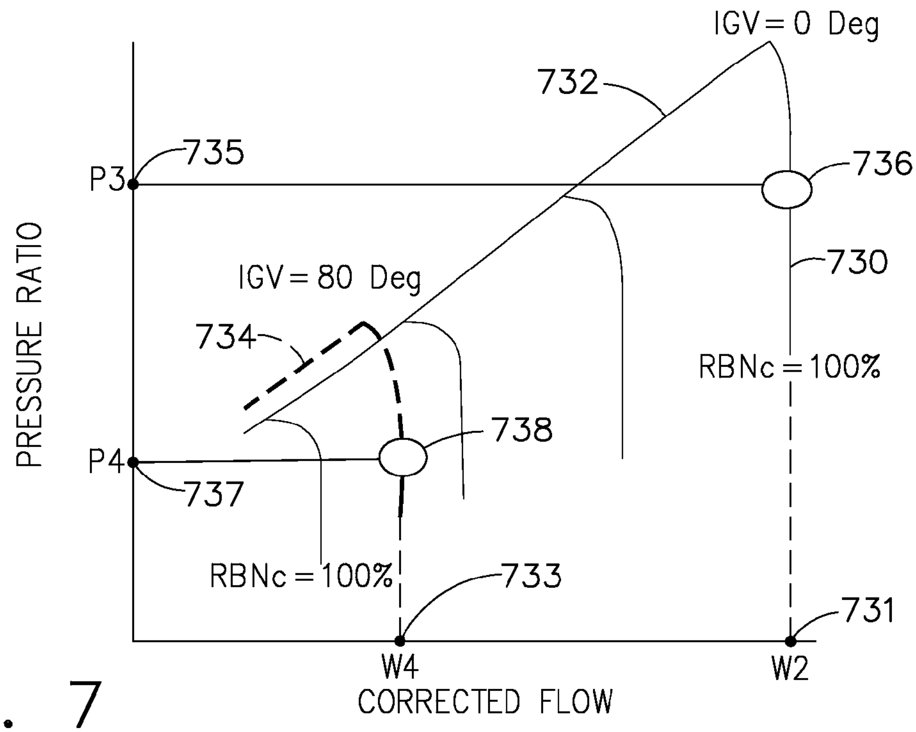
IGV=0 Deg
732
735
736
P3
730
IGV=80 Deg
734
RBNc=100%
PRESSURE RATIO
738
P4
737
RBNc=100%
733
731
W4
W2
CORRECTED FLOW

FIG. 7

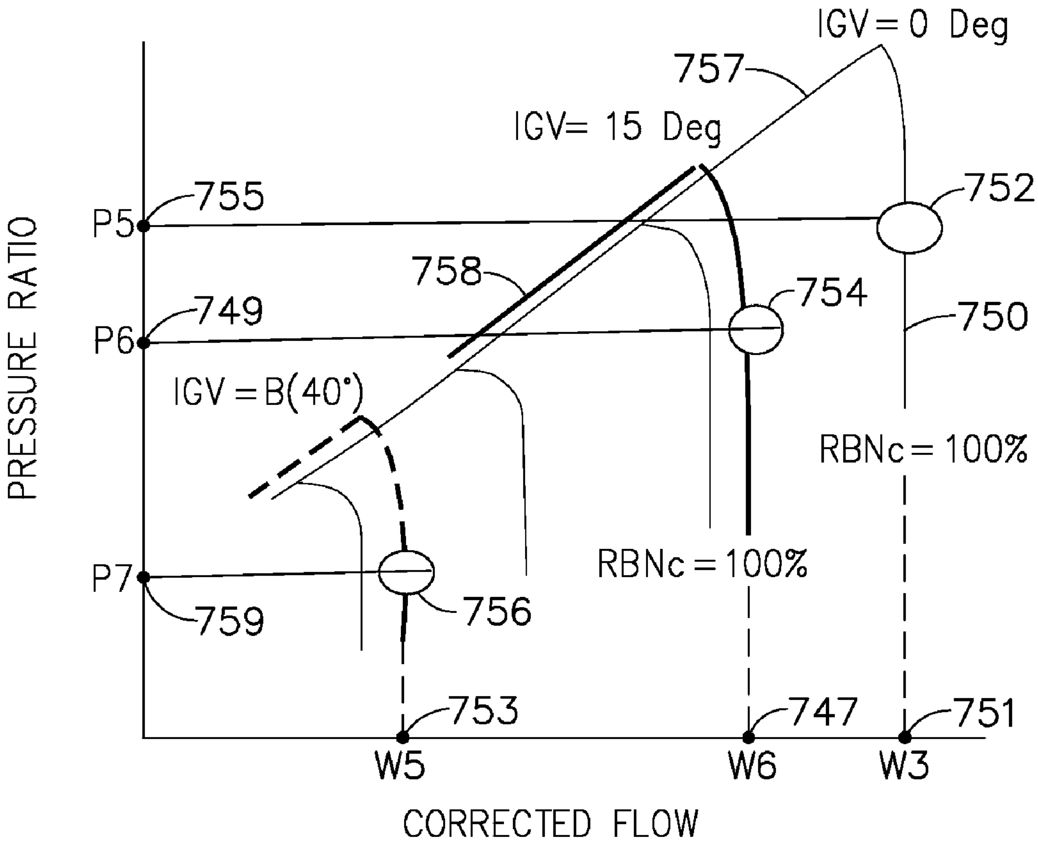
IGV = 0 Deg
757
IGV= 15 Deg
755
752
P5
758
754
749
750
P6
IGV = B(40°)
RBNc = 100%
PRESSURE RATIO
RBNc = 100%
P7
756
759
753
747
751
W5
W6
W3
CORRECTED FLOW

FIG. 8

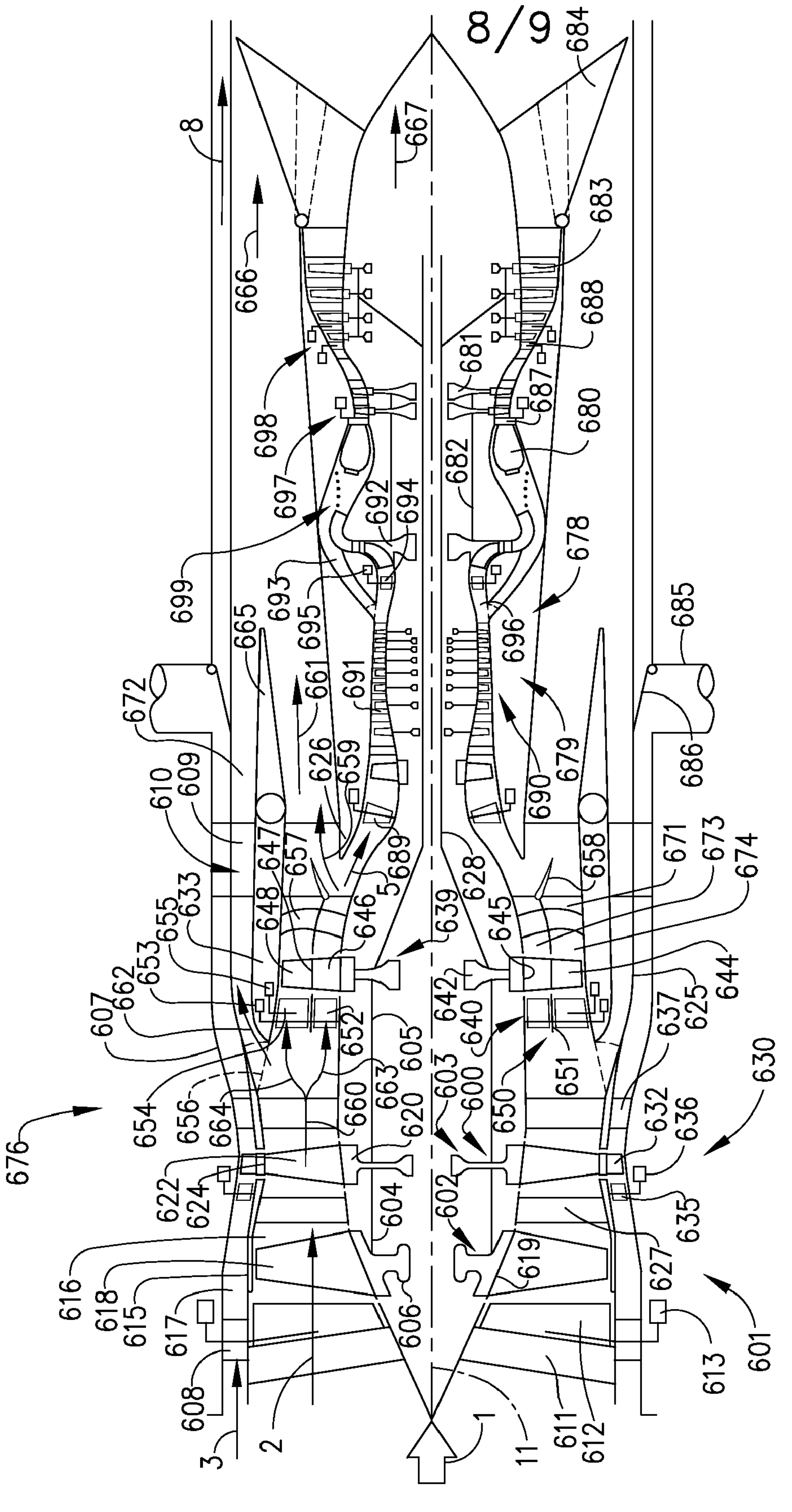
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FIG. 9

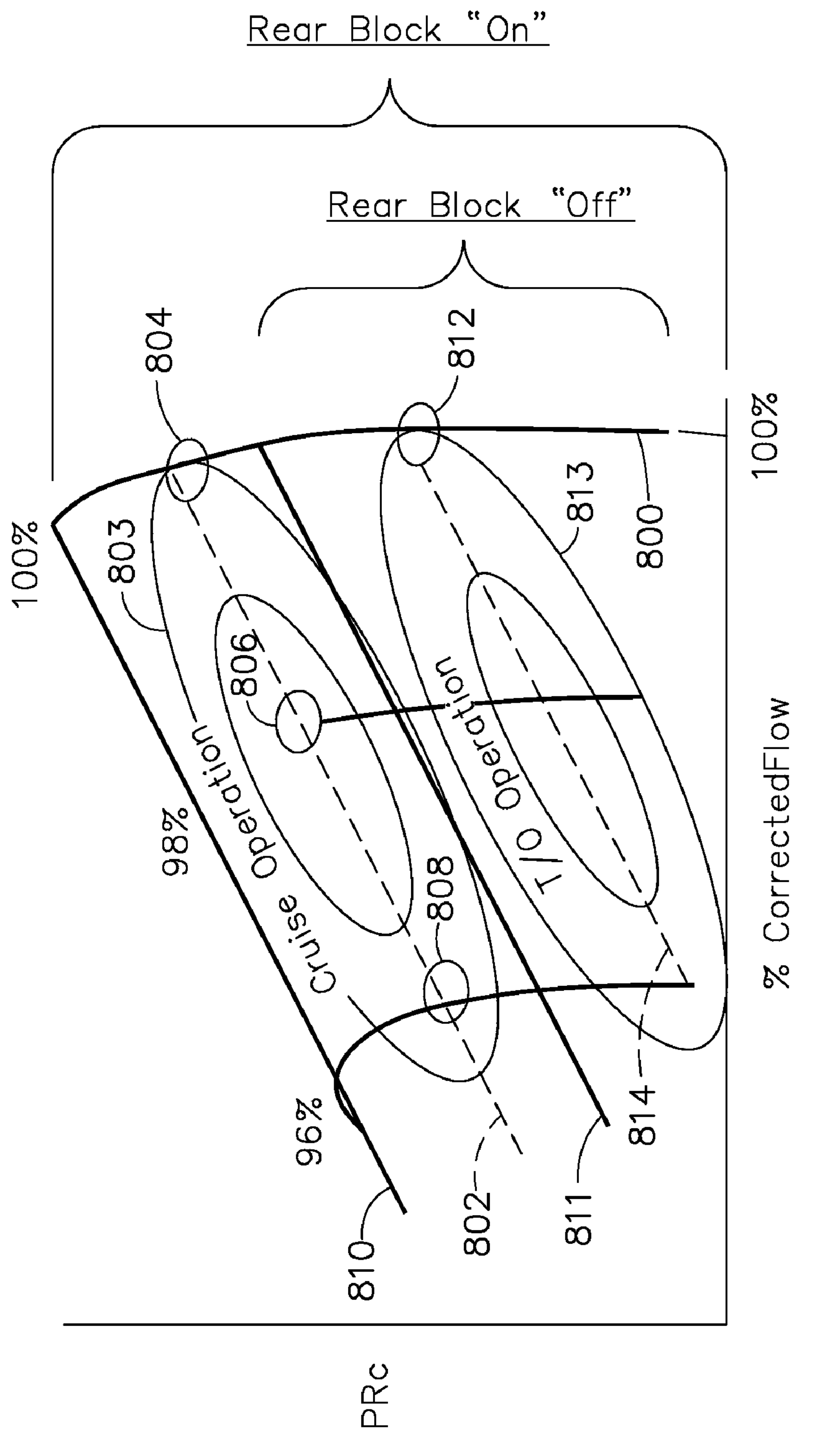
Rear Block "On"
Rear Block "Off"
804
812
100%
100%
803
813
800
806
Cruise Operation
T/O Operation
98%
808
% CorrectedFlow
96%
814
810
802
811
PRc

FIG. 10

CONVERTIBLE FAN SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application Ser. No. 61/246,075, filed Sep. 25, 2009, and to U.S. Provisional Application Ser. No. 61/263,107, filed Nov. 20, 2009, which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] This invention relates generally to jet propulsion engines, and more specifically to versatile engines having convertible fan systems capable of operating under variable flow conditions and pressure ratios.

[0003] Many current and most future aircraft need efficient installed propulsion system performance capabilities at diverse flight conditions and over widely varying power settings for a variety of missions. Current turbofan engines are limited in their capabilities to supply this type of mission adaptive performance, in great part due to the fundamental operating characteristics of their existing fan systems which have limited flexibility in efficiently reducing fan pressure ratio while maintaining high levels of fan flow. In the art, current turbofan engines use fan rotor speed reduction, sometimes coupled with a variable throat exhaust nozzle system, to reduce both fan pressure ratio and airflow as the engine is throttled back during part-power operation. This lack of operational flexibility limits the possibility of fully optimizing part power uninstalled specific fuel consumption levels. Further, the limitations in the current fan systems severely restrict making major improvements in spillage and nozzle closure drag losses that cause large increases in part-power installed specific fuel consumption levels.

[0004] Future mixed mission morphing aircraft as well as more conventional mixed mission capable military systems that have a high value of take-off thrust/take-off gross weight, i.e., a thrust loading in the 0.8-1.2 category, present many challenges to the propulsion system. They need efficient propulsion operation at diverse flight speeds, altitudes, and particularly at low power settings where conventional engines operate at inefficient off-design conditions both in terms of uninstalled performance and, to an even greater degree, fully installed performance that includes the impact of spillage drag losses associated with both subsonic and supersonic inlets.

[0005] When defining a conventional engine cycle and configuration for a mixed mission application, compromises have to be made in the selection of fan pressure ratio, bypass ratio, and overall pressure ratio to allow a reasonably sized engine to operate effectively at both subsonic and supersonic flight conditions. In particular, the fan pressure ratio and related bypass ratio selection needed to obtain a reasonably sized engine capable of developing the thrusts needed for combat maneuvers and supersonic operation are non-optimum for efficient low power subsonic flight. Basic uninstalled subsonic engine performance is compromised and fully installed performance suffers even more due to the inlet/engine flow mismatch that occurs at reduced power settings.

[0006] In the art, the core concepts used in convertible engines are quite complex, having multiple cores with complex ducting and valving needs. Current conventionally bladed core in engines cannot maintain constant or near constant operating pressure ratios as core flow is reduced. Current conventionally bladed fan rotors do not have the flexibility in efficiently reducing fan pressure ratio while maintaining high levels of fan flow. This lack of operational flexibility limits the possibility of fully optimizing part power uninstalled specific fuel consumption levels. This severely limits the potential Specific Fuel Consumption (SFC) advantage offered by known variable bypass convertible engine concepts.

[0007] Accordingly, it would be desirable to have an engine having a convertible fan system that allows thrust effective overall fan pressure ratio to be efficiently reduced while maintaining constant or near-constant total inlet flow during part-power engine operation, such as, for example, when the thrust is lowered to match aircraft drag during cruise operation. It would be desirable to have methods of operating convertible fans under conditions of variable flow and pressure ratio settings while providing the SFC advantages over various flight regimes. It would be desirable to have convertible fan engines having adaptive cores that combine the advantages of convertible fan engines and lower SFC at various power settings.

BRIEF DESCRIPTION OF THE INVENTION

[0008] The above-mentioned need or needs may be met by exemplary embodiments disclosed herein which provide a convertible fan system having a fan rotor with a plurality of fan blades having an arcuate splitter that forms a portion of an inner flow passage and an outer flow passage wherein an inner portion of the fan blade pressurizes an inner flow in the inner flow passage and an outer portion of the fan blade pressurizes an outer flow in the outer flow passage and a vane system having an outer vane that is adapted to be able to vary the flow in the outer flow passage such that pressure ratio of the fan system can be varied.

[0009] In one aspect of the invention, the convertible fan system has an outer bypass passage and an inner bypass passage. In another aspect of the invention, the convertible fan system has a bypass door that is adapted to control a core bypass flow. In another aspect of the invention, the convertible fan system has a blocker door that is adapted to prevent a reverse flow in the outer bypass passage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the concluding part of the specification. The invention, however, may be best understood by reference to the following description taken in conjunction with the accompanying drawing figures in which:

[0011] FIG. **1** is a schematic cross-sectional view of a versatile gas turbine engine according to an exemplary embodiment of the present invention.

[0012] FIG. **2** is a schematic cross-sectional view of a convertible fan system according to an exemplary embodiment of the present invention.

[0013] FIG. **3** is a schematic cross-sectional view of a convertible fan system according to another exemplary embodiment of the present invention.

[0014] FIG. **4** is a schematic cross-sectional view of a convertible fan system according to another exemplary embodiment of the present invention.

[0015] FIG. **5** is a schematic cross-sectional view of a versatile gas turbine engine according to another exemplary embodiment of the present invention.

[0016] FIG. **6** is an example of the fan operating characteristics of the front block of the convertible fan system shown in FIGS. **2**, **5** and **9**.

[0017] FIG. **7** is an example of the fan operating characteristics of outer portion of the aft fan of the convertible fan system shown in FIGS. **2**, **5** and **9**.

[0018] FIG. **8** is an example of the fan operating characteristics of inner portion of the aft fan of the convertible fan system shown in FIGS. **2**, **5** and **9**.

[0019] FIG. **9** is a schematic cross-sectional view of an exemplary versatile gas turbine engine having an adaptive core according to another exemplary embodiment of the present invention.

[0020] FIG. **10** is an example of the operating characteristics of the compressor of the exemplary versatile gas turbine engine shown in FIG. **9**.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Referring to the drawings wherein identical reference numerals denote the same elements throughout the various views, FIG. **1** is a schematic cross-sectional view of an adaptive, versatile gas turbine engine **10** according to an exemplary embodiment of the present invention. The gas turbine engine **10** has a fan **14**, a core **12** comprising a compressor **13** driven by a high-pressure turbine (HPT) **16** shaft **24**. The fan **14** comprises a convertible fan system **40** having a longitudinal axis **11** and is driven by a low-pressure turbine (LPT) **18** shaft **28**. The HPT **16** and LPT **18** are driven by the hot combustion gases from a combustor **15**. In some applications, the engine **10** may optionally have an outer flow passage **4** that receives an outer flow stream **3** and an outer fan system as described subsequently herein. The inlet air flow stream **1** enters the front of the engine **10**. The fan flow stream **2** is pressurized by the fan **14** and splits into one or more bypass flow streams **6** and a core flow stream **5**. The one or more bypass flow streams **6** bypass the core **12** of the engine and enter the exhaust system **22**. The core flow stream **5** enters the core **12** of the engine and is further compressed by the compressor **13** before entering the combustor **15**. The core bypass flows and the exhaust from the LPT are mixed to form the inner exhaust stream **9** which is further expanded in the variable throat area exhaust system **22** forming the main engine exhaust flow stream **23**.

[0022] As shown in FIGS. **1-5** and **9** and described herein in various exemplary embodiments, the engine **10** comprises a convertible fan system, such as, for example, item **40** in FIG. **1**, that is coaxial with the engine centerline axis **11** and located inside a convertible fan casing **33** that is supported by known frame structures, such as struts **35**. The convertible fan system **40** shown in FIG. **1** comprises a plurality of convertible fan blades **34** and one or more sets of variable vanes **38**, **39** to control the air flow and pressure ratio as described subsequently. In the exemplary embodiment shown in FIG. **1**, the convertible fan rotor is driven by a convertible fan shaft **36** that is coupled to the LPT shaft **28**.

[0023] When an outer flow passage **4** is present, the outer flow stream **4** may be further pressurized by an outer fan system and form an outer exhaust stream **8**. The outer fan is alternatively referred to herein by the term "FLADE™" which is an acronym for "Fan tip on BLADE". The term FLADE™, as used herein, is characterized by an outer fan coupled to a radially inner fan. The FLADE™ discharges the FLADE™ air stream **8** into an outer fan duct which is generally co-annular with and circumscribes an inner fan duct. In some exemplary embodiments of the invention disclosed herein, a heat exchanger system **68** (see FIG. **1** for example) is provided wherein the heat exchanger system is capable of cooling the engine cooling air using the air stream **8**. In some embodiments, the heat exchanger system **68** may also be used to collect and recover aircraft system waste heat energy. Further, in the exemplary embodiments of the invention disclosed herein, a variable throat area **69** (see FIG. **1**, for example) is provided in the engine exhaust system **22** wherein the main exhaust nozzle throat area can be varied as necessary, such as for example, by opening the throat area when the engine thrust is reduced.

[0024] FIG. **2** is a schematic cross-sectional view of a convertible fan system ("CF") **140** according to a preferred embodiment of the present invention. FIGS. **5** and **9** show exemplary embodiments of gas turbine engines **576**, **676** having convertible fan systems, such as, for example, shown in FIG. **2**. As shown in FIGS. **2**, **5** and **9** the convertible fan system **140**, **540**, **640** comprises a convertible (CF) fan rotor **142**, **542**, **642** (alternatively referred to herein as "aft fan rotor") having a plurality of CF fan blades **144**, **544**, **644** (alternatively referred to herein as "aft fan blade") radially extending from a hub **145**, **545**, **645** and arranged circumferentially around a longitudinal axis **11**. Each CF fan blade **144**, **544**, **644** has an arcuate shroud **147**, **547**, **647** (alternatively referred to herein as "arcuate splitter") located radially outward from the hub. In the assembled state of the CF fan rotor **142**, **542**, **642** the arcuate shroud of a CF Fan blade **144**, **544**, **644** abuts the arcuate shrouds of the circumferentially adjacent CF fan blades **144**, **544**, **644** to form an annular splitter in the CF fan rotor **142**, **542**, **642**. In alternative embodiments of the present invention, the CF fan rotor **142**, **542**, **642** may be manufactured as a single part (alternatively known as a "BLISK") using known BLISK manufacturing methods. In other alternative embodiments, one or more of the forward fan stages may be manufactured as a BLISK. Although the fan blades and rotors shown herein are sometimes described as assemblies of parts, a fan system using BLISKS with the features described herein are within the scope of the present invention. The CF fan rotor **142**, **542**, **642** is located radially within a CF fan casing **133**, **533**, **633** that circumferentially surrounds the CF fan rotor **142**, **542**, **642** with a small clearance between the casing **133**, **533**, **633** and the CF fan blade tips. In the assembled state, the arcuate shrouds **147**, **547**, **647** form a portion of an inner flow passage **173**, **573**, **673** between the annular splitter and the hub of the CF fan rotor **142**, **542**, **642**, and an outer flow passage **174**, **574**, **674** between the annular splitter and the casing **133**, **533**, **633**. During operation of the CF fan system **140**, **540**, **640**, the inner portion **146**, **546**, **646** of the CF fan blade **144**, **544**, **644** pressurizes an inner flow **163**, **563**, **663** in the inner flow passage **173**, **573**, **673** and the outer portion **148**, **548**, **648** of the fan blade **144**, **544**, **644** pressurizes an outer flow **164**, **564**, **664** in the outer flow passage **174**, **574**, **674**.

[0025] The exemplary convertible fan systems **140**, **540**, **640** shown in FIGS. **2**, **5** and **9** comprise a vane system **150**, **550**, **650** located axially forward from the convertible fan rotor **142**, **542**, **642**. The exemplary vane system **150**, **550**, **650** shown in FIGS. **2**, **5** and **9** has a plurality of outer vanes **154**, **554**, **654** that are arranged circumferentially around the longitudinal axis **11** and are located axially forward from the outer portions **148**, **548**, **648** of the fan blades **144**, **544**, **644**. The outer vanes **154**, **554**, **654** are suitably supported by a static structure, such as for example, the CF fan casing **133**, **533**, **633** using known methods. The exemplary convertible fan system **140**, **540**, **640** shown in FIGS. **2**, **5** and **9** comprises a static annular flow splitter **151**, **551**, **651** that splits the incoming CF flow stream **160**, **560**, **660** into a radially outer flow **164**, **564**, **664** and a radially inner flow **163**, **563**, **663**. The static annular flow splitter **151**, **551**, **651** is located axially forward from the CF fan rotor **142**, **542**, **642**. The static CF flow splitter **151**, **551**, **651** is located radially corresponding to the radial location of the arcuate splitters **144**, **544**, **644** on the CF blades **144**, **544**, **644** such that the outer vanes **154**, **554**, **654** direct the CF fan outer flow **164**, **564**, **664** into the CF fan blade outer portion **148**, **548**, **648**. The outer vanes **154**, **554**, **654** are variable vanes such that they can vary the volume and direction of the flow entering the CF fan blade **144**, **544**, **644** and the outer flow passage **174**, **574**, **674** such that fan tip pressure ratio of the fan system **140**, **540**, **640** can be varied. The variable outer vanes **154**, **554**, **654** are actuated by known methods to vary the stagger angle of the outer vanes between about zero degree (open) and about 90 degrees (closed) using known outer vane actuators **155**, **555**, **655**.

[0026] The exemplary vane system **150**, **550**, **650** shown in FIGS. **2**, **5** and **9** also comprises a plurality of radially inner vanes **152**, **552**, **652** that are arranged circumferentially around the longitudinal axis **11** and are located axially forward from the inner portions **146**, **546**, **646** of the fan blades **144**, **544**, **644**. The inner vanes **152**, **662**, **652** are suitably supported by a static structure, such as for example, the annular splitter **151**, **551**, **651** and the CF fan casing **133**, **533**, **633** using known methods. The inner vanes **152**, **552**, **652** direct the CF fan inner flow **163**, **563**, **663** into the CF fan blade inner portion **146**, **546**, **646**. The inner vanes **152**, **552**, **652** are variable vanes such that they can vary the volume and direction of the flow entering the CF fan blade **144**, **544**, **644** and the inner flow passage **173**, **573**, **673** such that fan hub pressure ratio of the fan system **140**, **540**, **640** can be varied. The variable inner vanes **152**, **552**, **652** are actuated by known methods to vary the stagger angle of the inner vanes between about zero degree (open) and about 40 to 50 degrees (partially closed) using known inner vane actuators **153**, **553**, **653**. In some applications, the inner vanes **152**, **552**, **652** are optionally used during starting and low power operation to maintain an adequate level of CF fan hub stall margin for the inner portions **146**, **546**, **646** of the CF fan blades **144**, **544**, **644**.

[0027] During operation of the CF fan system **140**, **540**, **640** the outer flow stream **164**, **564**, **664** that is pressurized by the outer portion **148**, **548**, **648** of the CF fan blade **144**, **544**, **644** is directed by a circumferential array of CF fan outlet guide vanes (OGV) **157**, **557**, **657** to enter an inner bypass passage **171**, **571**, **671**. The inner flow stream **163**, **563**, **663** that is pressurized by the inner portion **146**, **546**, **646** of the CF fan blade **144**, **544**, **644** is directed by a circumferential array of CF fan outlet guide vanes to enter an inner passage and forms a core flow stream **5** that enters the engine core. In one aspect of the present invention, the convertible fan system **140**, **540**, **640** optionally comprises a hub bleed system having a bypass bleed door **158**, **558**, **658** that can be selectively be opened using known methods such that a portion of the core flow **5**, shown as core bypass flow **159**, **559**, **659** in FIGS. **2**, **5** and **9** can be blown into the inner bypass passage **171**, **571**, **671**. In some applications, the hub bleed system using the bypass door **158**, **558**, **658** is optionally used during starting and low power operation to maintain an adequate level of CF fan hub stall margin for the inner portions **146**, **546**, **646** of the CF fan blades **144**, **544**, **644**.

[0028] The exemplary convertible fan system **140** further comprises an outer bypass passage **172**. **572**, **672** formed between an annular aft inner casing **125**, **525**, **625** and an annular outer casing **107**, **507**, **607**. An annular outer bypass flow **162**, **562**, **662** flows through the outer bypass passage **172**, **572**, **672**. The outer bypass flow **162**, **562**, **662** and the inner bypass flow **161**, **561**, **661** in the inner bypass passage **171**, **571**, **671** mix down-stream from the convertible fan system **140**, **540**, **640**. An optional variable mixer **165**, **565**, **665** suitably shaped using known aerodynamic design methods is used at the aft end of the inner casing **133**, **533**, **633** to enhance the mixing of the outer bypass flow **162**, **562**, **662** and the inner bypass flow **161**, **561**, **661** and achieve a suitable static pressure balance, and to maintain adequate level of CF fan stall margin for the outer portions **148**, **548**, **648** of the CF fan blades **144**, **544**, **644**. The exemplary convertible fan system **140**, **540**, **640** comprises a blocker door **156**, **556**, **656** located near the inlet portion of the outer bypass passage **172**, **572**, **672** such that it is controllably opened or closed using known actuation methods to control the amount of outer bypass flow **162**, **562**, **662**. The blocker door **156**, **556**, **656** is modulated to close as necessary to prevent a reversal of flow in the outer bypass passage **172**, **572**, **672** that may be caused by a higher pressure down-stream from the CF fan rotor **142**, **542**, **642**. The blocker door **156**, **556**, **656** is suitably supported by a static structure such as the aft inner casing **125**, **525**, **625** or frames.

[0029] FIG. **2** shows a multi-stage fan system **101** having a forward fan system **100** and an aft fan system **139**. The aft fan system **139** shown is a convertible fan system **140**, described previously herein. The forward fan system **101** comprises a first fan stage **102** and a second fan stage **103**. In alternate embodiments of the present invention, the forward fan system **100** may comprise only one stage, such as, for example, shown in FIG. **5**. As shown in FIG. **2**, the first fan stage **102** comprises a first stage fan rotor **106** having a plurality of first stage fan blades **118** radially extending from a hub **119** and arranged circumferentially around the longitudinal axis **11**. A circumferential array of fan inlet guide vanes **111** (Fan IGV) is located axially forward from the first fan stage **102**. The fan IGVs **111** may have a variable vane **112** portion that is actuated by an actuator **113** of a known type. The first stage fan blades **118** are located inside an annular forward inner casing **115** that forms a portion of the fan inner flow path **116**. The inner casing **115** is suitably supported by a static structure, such as, for example, struts **108**. In one embodiment, shown in FIG. **2**, a circumferential array of vanes **127** is located axially aft from the first stage fan rotor **106** to reorient the fan flow stream **2** after it is pressurized by the first stage fan blades **118**.

[0030] A second fan stage **103** is located axially aft from the first fan stage **102** and coupled by a suitable means, such as a drive shaft **104**. As shown in FIG. **2**, the second fan stage **103** comprises a second stage fan rotor **120** having a plurality of second stage fan blades **122** arranged circumferentially around the longitudinal axis **11**. In the exemplary embodiment shown in FIG. **2**, the second stage fan blades **122** are coupled to an arcuate platform **124** located at the tip of the blades **122**. The arcuate platform **124** may be suitably formed by assembling a circumferential array of abutting platform segments supported by the fan blades **122**. In alternative embodiments, one or more of the other forward fan stages may have arcuate platforms (see, for example, FIG. **5**) as described above.

[0031] As shown in FIG. **2**, the convertible fan system **140** comprises an outer fan system **130** having a circumferential row of outer fan blades **132** (FLADES™ blades) supported by the arcuate platform **124** and driven by the second fan stage **103**. The outer fan system **130** is located in an outer flow path **117** that is formed between an outer casing **107** and an inner casing **115**, the arcuate platform **124** and aft inner casing **125**. The outer fan system **130** comprises a circumferential row of outer fan inlet guide vanes **135** located upstream and having a variable stagger angle geometry operated by known actuators **136**. A circumferential row of outer fan outlet guide vanes (OGVs) **137** are located down stream from the outer fan blades **132**. During operation, the outer fan blades **132** pressurize an outer flow stream **3** and form a pressurized outer exhaust stream **8** (alternatively referred to herein as a FLADES™ stream. The pressurized outer exhaust stream **8** may be used for a variety of purposes such as, for example, cooling the engine exhaust nozzle system, for thermal management, or for wing blowing. A heat exchanger system, such as, for example, shown as item **68** in FIG. **1**, can be used for cooling and/or thermal management.

[0032] FIG. **3** shows a schematic cross-sectional view of a convertible fan system **240** according to another exemplary embodiment of the present invention. The convertible fan system **240** comprises a convertible fan rotor **242** having convertible fan blades **244** with arcuate shrouds **247** that form an inner portion **246** and an outer portion **248**. The exemplary convertible fan system **240** further comprise a vane system **250** located axially forward from the convertible fan rotor **242**. The exemplary vane system **250** shown in FIG. **3**, has a plurality of outer vanes **254** that are arranged circumferentially around the longitudinal axis **11** and are located axially forward from the outer portions **248** of the fan blades **244**. A static annular flow splitter **250** is provided (see FIG. **3**) that splits the incoming CF flow stream **260** into a radially outer flow **264** and a radially inner flow **263**. The static annular flow splitter **251** is located axially forward from the CF fan rotor **242**. The static CF flow splitter **251** is located radially corresponding to the radial location of the arcuate splitters on the CF blades **244** such that the outer vanes **254** direct the CF fan outer flow **264** into the CF fan blade outer portion **248**. The outer vanes **250** are variable vanes having variable stagger angles such that they can vary the volume and direction of the flow entering the CF fan blade **244** and the outer flow passage **274** such that fan tip pressure ratio of the fan system **240** can be varied. The variable outer vanes **254** are actuated by known methods using known outer vane actuators **255**. Unlike the exemplary embodiment shown in FIG. **2**, the exemplary embodiment shown in FIG. **3** does not have a variable vane system to direct the flow **263** to the inner portion of the fan blades **246**. Control and optimization of the core flow **5** is accomplished by operating a bypass door **258** to create and control a core bypass flow **259** (hub bleed flow). Operation of the bypass door **258** facilitates the improvement of the fan hub stall margin during starting and low-power operation. The other features, their construction and their functions shown in FIG. **3** are substantially as described previously herein with respect to the embodiment shown and described in FIG. **2**, with corresponding item numbers.

[0033] FIG. **4** shows a schematic cross-sectional view of a convertible fan system **340** according to another exemplary embodiment of the present invention. The convertible fan system **340** comprises an aft fan rotor **342** having a circumferential row of aft fan blades **344**. The exemplary fan system **340** further comprises a vane system **350** located axially forward from the aft fan rotor **342**. The exemplary vane system **350** shown in FIG. **4**, has a plurality of vanes **354** that are arranged circumferentially around the longitudinal axis **11** and are located axially forward from the fan blades **344**. In the exemplary embodiment shown in FIG. **4**, the static annular flow splitter **251** and the arcuate shrouds **247** such as shown in FIG. **3** are eliminated. The incoming CF flow stream **360** is pressurized by the aft fan rotor blades **344** and is discharged towards a splitter **326** that is located axially aft from the aft fan rotor **342**. The splitter **326** splits the pressurized flow discharged from the aft fan rotor **342** into a radially outer flow **361** and a radially inner core flow **5**. The vane system **350** directs the aft fan in-flow **360** to the fan blades **344**. The vanes **354** are variable vanes having variable stagger angles such that they can vary the volume and direction of the flow entering the aft fan blade **344** such that overall fan pressure ratio of the fan system **340** can be varied. The variable vanes **354** are actuated by known methods using known actuators **355**. Unlike the exemplary embodiment shown in FIG. **3**, the exemplary embodiment shown in FIG. **4** has a variable vane system **350** that directs the flow **360** to substantially the entire span of the fan blades **344**. Control and optimization of the core flow **5** may be accomplished by operating an optional bypass door (not shown in FIG. **4**). As shown in FIG. **4**, the fan system **340** comprises an outer fan system **330** having a circumferential row of outer fan blades **332** (FLADES™ blades) supported and driven by the second fan stage **303**. The outer fan system **330** is located in an outer flow path **317** that is formed between an outer casing **307** and an inner casing **315**, the arcuate platform **324** and aft inner casing **325**. The outer fan system **330** comprises a circumferential row of outer fan inlet guide vanes **335** located upstream and having a variable stagger angle geometry operated by known actuators **336**. The use of the FLADE™ system **330**, **332** shown in FIG. **4**, although not directly controlling the aft fan tip and hub operating pressure levels independently, affords operational flexibilities for the fan system **340**. The other features, their construction and their functions shown in FIG. **4** are substantially as described previously herein with respect to the embodiment shown and described in FIG. **3**, with corresponding item numbers.

[0034] FIG. **5** is a schematic cross-sectional view of an adaptive, versatile gas turbine engine **576** according to an exemplary embodiment of the present invention incorporating a convertible fan system **540**. FIG. **9** shows, in schematic cross-sectional view, another exemplary embodiment of an adaptive, versatile gas turbine engine **676** incorporating a convertible fan system **640** and an adaptive core **678** according to another exemplary embodiment of the present invention. As shown in FIGS. **5** and **9**, the gas turbine engine **576**, **676** comprises a multi stage fan system **501**, **601** having an axially forward ("FWD") fan system **500**, **600** and an aft ("AFT") fan system **540**, **640**, alternatively referred to herein as a convertible fan system, that is located axially aft from the FWD fan system. Although the FWD fan system **500** in the exemplary embodiment shown in FIG. **5** is shown comprising a single front stage fan rotor **506**, the present invention is not thus limited. Multistage FWD fan systems can be also used. For example, the FWD fan system **600** shown in the exemplary embodiment in FIG. **9** is a multi stage FWD fan system having a first stage fan rotor **606** and a second stage fan rotor **620**. In the exemplary embodiments shown in FIGS. **5** and **9**, the gas turbine engine comprises an AFT fan system **540**, **640** (convertible fan) having an aft fan rotor **542**, **642** (alternatively referred to herein as a convertible fan rotor or CF fan rotor) that is located axially aft from the front stage fan rotor **506**, **606**. A core **578**, **678** comprising a compressor **579**, **679** is coupled to, and driven by, a high-pressure turbine **581**, **681** (HPT). The aft fan rotor **542**, **642** is driven by a low-pressure turbine **583**, **683** (LPT) using an LPT shaft **528**, **628**. The FWD fan system is also driven by the LPT, as shown in FIGS. **5** and **9**. Alternatively, the FWD fan system **500**, **600** may be driven by another separate LPT (not shown).

[0035] The exemplary convertible fan systems **540**, **640** are substantially similar in construction and function to the exemplary convertible fan system shown in FIG. **2** and described in detail previously herein. The convertible fan features, their construction and their functions are substantially as described previously herein with respect to the embodiment shown and described in FIG. **2**, with corresponding item numbers. The aft fan rotor **542**, **642** has a row of aft fan blades **544**, **644** (alternatively referred to herein as convertible fan blades or CF fan blades) arranged circumferentially around the engine axis **11**. An arcuate splitter **547**, **647** (alternatively referred to herein as an arcuate shroud) is located on the fan blades **544**, **644**. In the assembled state of the aft fan rotor, the arcuate shrouds **547**, **647** form a portion of an inner flow passage **573**, **673** and an outer flow passage **574**, **674**. During the operation of the engine, an inner portion **546**, **646** of the aft fan blade **544**, **644** pressurizes an inner flow **563**, **663** in the inner flow passage **573**, **673** to have a hub pressure ratio. An outer portion **548**, **648** of the aft fan blade **544**, **644** pressurizes an outer flow **564**, **664** in the outer flow passage **574**, **674** to have a tip pressure ratio. In one aspect of the present invention, the fan tip pressure ratio and fan hub pressure ratio in the aft fan system **540**, **640** can be changed, even while the air flow **2** (see FIGS. **5** and **9**) into the front stage fan rotor **506**, **606** is held substantially constant. In another aspect of the present invention, the gas turbine engine **576**, **676** comprises an annular inner bypass passage **571**, **671** around the engine axis **11** that is adapted to flow an inner bypass flow **561**, **661** from the fan system **501**, **601**. The gas turbine engine **576**, **676** further comprises an annular outer bypass passage **572**, **672** around the engine axis **11** that is adapted to flow an outer bypass flow **562**, **662** from the fan system **501**, **601**. The outer flow **564**, **664** pressurized by aft fan rotor **542**, **642** flows into the inner bypass passage **571**, **671**. At least a portion of the inner flow **563**, **663** pressurized by the inner portion **546**, **646** of the fan blade **544**, **644** forms a core flow **5** into the compressor **579**, **679**. A core bypass door **558**, **658** may be provided (see FIGS. **5**, **9**) adapted to control a core bypass flow **559**, **659**. A blocker door **556**, **656** may also be used as shown in FIGS. **5** and **9** that is adapted to prevent a reverse flow in the outer bypass passage **572**, **672** as described previously herein.

[0036] In one aspect of the present invention, engine **576**, **676** has a static annular splitter **551**, **651** located axially forward from the aft fan rotor **542**, **642** wherein a flow stream **560**, **660** into the aft fan rotor **542**, **642** is bifurcated to form the inner flow **563**, **663** in the inner flow passage **573**, **673** and the outer flow **564**, **664** in the outer flow passage **574**, **674**. In another aspect of the present invention, the gas turbine engine **576**, **676** as shown in FIGS. **5** and **9** has a vane system **550**, **650** located axially forward from the aft fan rotor **542**, **642**. The vane system **550**, **650** is constructed using known methods such that it can vary the flow in inner flow passage **573**, **673** and in the outer flow passage **574**, **674** such that overall pressure ratio of the fan system **501**, **601** can be varied as needed during engine operation. The vane system **550**, **650** has an outer vane **554**, **654** located radially outward from the splitter **551**, **651**. In order to vary the flow rates and directions into the aft fan rotor, a portion of the outer vane **554**, **654** may be movable by an actuator **555**, **655** to vary the vane stagger angles. Known variable vane actuators may be used for this purpose. In one embodiment (shown in FIGS. **5** and **9**) the vane system **501**, **601** further comprises an inner vane **552**, **652** located radially inboard from the splitter **551**, **651**, and may be movable by known actuators **553**, **653**. The method of operating the engine **576**, **676** using these features is described subsequently herein.

[0037] In one aspect of the present invention, the gas turbine engine **576**, **676** has a forward mixer **565**, **665** (alternatively referred to herein as a Variable Area Bypass Injector or "VABI") located downstream from the aft fan rotor **542**, **642**. The fwd VABI is adapted using known methods of construction to enhance the mixing of the inner bypass flow **561**, **661** and the outer bypass flow **562**, **662** to form a mixed bypass flow **566**, **666**. The inner bypass flow and outer bypass flow may have different pressure levels and flow rates. Their mixing is done by the fwd VABI in order to minimize mixing pressure losses down-stream from the fan system. The gas turbine engine **576**, **676** may also have a rear mixer **584**, **684** (rear VABI) located down-stream from the low-pressure turbine **583**, **683** to enhance the mixing of the core stream **567**, **667** (hot exhaust stream) from the low-pressure turbine **583**, **683** and the mixed bypass flow **566**, **666** that is relatively cooler. Known VABI systems can be used. In alternative embodiments of the present invention, the fwd VABI mixer **565**, **665** and/or the rear VABI mixer **584**, **684** may be of a variable type or fixed type. When variable, they are scheduled to satisfy certain operating limits of the engine **576**, **676** and to minimize mixing losses (i.e. maximize performance). When they are fixed, they serve to enhance the flow mixing process for improved performance. In some applications, the gas turbine engines **576**, **676** may also have a circumferential row of variable inlet guide vanes **511**, **611** (IGVs) located axially forward from the front fan stage fan rotor **506**, **606**. The IGVs, operated using known actuators, can be used to control the flow of air **2** to the front stage fan rotor **506**, **606**.

[0038] In another aspect of the present invention, the gas turbine engine **576**, **676** has a front stage fan rotor **506**, **620** having a circumferential row of fan blades **518**, **622** arranged circumferentially around the engine axis **11** that support and drive a an outer fan **530**, **630** (alternatively referred to herein as a FLADE™ fan). FIG. **5** shows an outer fan system **530** having a circumferential row of outer fan blades **532** (FLADE™ blades) that are located radially outward from the front stage fan rotor **506**. In the embodiment shown in FIG. **9**, the outer fan system **630** has a circumferential row of outer fan blades **632** supported and driven by the second stage fan rotor **620**. The FLADE™ blades **532**, **632** are adapted to rotate with the fan blades **518**, **622** to pressurize an outer flow stream **3** in an outer flow path **517**, **617**. The outer fan system **530**, **630** may further comprise a plurality of outer fan inlet guide vanes **532**, **635** that are adapted to control the outer flow stream **3** in the outer flow path **517**, **617**. In one embodiment (see FIGS. **5** and **9**) the gas turbine engine **576**, **676** comprises an air bleed conduit **585**, **685** and air bleed door **586**, **686** that is adapted to remove at least a portion of the flow **8** in the outer flow path **517** as needed for uses such as wing blowing. In an exemplary embodiment, the flow stream **8** is used for cooling portions of the engine **576** such as, for example, an exhaust nozzle (see FIG. **1**).

[0039] The various figures and descriptions provided herein show convertible fan systems and adaptive engines that provide operational flexibilities that conventional fan systems and engines cannot provide. As disclosed herein, the convertible fan systems, and engines having such fan systems, can provide further advantages using the disclosed outer fan systems such as the FLADE™ systems in a front fan rotor coupled to the unique rear fan rotor having an annular splitter through the rotor as shown herein. Unlike conventional fan systems, use of a convertible fan system as disclosed herein permits different tip and hub design fan pressure ratio levels. Further, use of additional systems and features shown herein, such as the tip inlet guide vanes (IGV) **154**, **254**, **554**, **654** having variable geometry, bypass doors **158**, **258**, **558**, **658** short outer bypass passages (ducts) **172**, **272**, **572**, **672**, front variable area by-pass injector ("VABI") **165**, **265**, **365**, **565**, **665** systems, rear VABI **584**, **684** systems permit the tip pressure ratio and flow in the convertible fan rotor **142**, **242**, **342**, **542**, **642** to be significantly reduced during part-power (i.e., reduced from maximum power/thrust) engine operations. Unlike conventional gas turbine engines, main fan flow **2** in the front stages of the forward fan system **100**, **200**, **300**, **500**, **600** can be maintained at constant or near-constant design flow levels even when the engine thrust is reduced into the 50-60% levels for part-power operations. This is made possible by the use of the convertible engine features described herein, since the effective fan pressure ratio level in the by-pass duct **171**, **271**, **371**, **571**, **671** (and at the static pressure balance plane near the front VABI **165**, **265**, **365**, **565**, **665**) can be reduced, thereby allowing the core **578**, **678** of the convertible engine **576**, **676** to be throttled back to reduce the core stream **567**, **667** exit pressure and temperature. As described herein, the FLADE™ stream **3** pressure and flow can be adjusted using the FLADE™ variable IGV system **135**, **136**, **235**, **236**, **335**, **336**, **535**, **536** to further optimize the total operating airflow and overall thrust effective fan system pressure levels for minimizing both uninstalled and installed specific fuel consumption (SFC) levels.

[0040] FIGS. **6**, **7** and **8** illustrate how the variable tip and hub IGV's of the preferred embodiment shown in FIG. **2**, and implemented in the exemplary engines shown FIGS. **5** and **9**, are used to adjust both the overall fan pressure ratio and pressure ratios of both the fan tip and fan hub. The front block fan stages **102**, **103** could be held at constant flow even though the engine power and/or thrust is lowered to 40-50% of maximum level. Although a two-stage front block fan is shown in FIG. **3**, some fan system designs might only have one single stage front fan **506**, such as, for example, shown in FIG. **5**. The tip IGV **154**, **254**, **554**, **654** (alternatively referred to herein as the outer vane) of the CF Fan system **140**, **240**, **540**, **640** is closed to reduce the overall tip pressure ratio when the engine thrust is reduced at constant fan flow. The FLADE™ outer fan section flow **3** and operating pressure ratio are independent of the main fan system **140**, **240**, **540**, **640** and can be adjusted as needed by proper scheduling of its IGV **135**, **235**, **335**, **535**, **635**.

[0041] The independently variable hub IGV of the last stage can be used to optimize the core stream flow **5** at all engine power/thrust settings, and in some applications, may even eliminate the need for a hub bleed system. It can also be sized/scheduled to help control the front block operating line during transition from single bypass mode (i.e., max fan tip pressure) to double bypass mode (i.e., min fan tip pressure), with the main front fan flow being held constant. Smooth transition from a single bypass to double bypass is made possible by proper scheduling of the variable IGVs, the bypass door, blocker door, the front VABI, and the aft VABI. It may be possible to have this scheduling system to be self-actuating using a pressure regulated bypass door system.

[0042] An exemplary gas turbine engine **576** having an exemplary embodiment of a convertible fan system is shown in FIG. **5**. A method of operating a gas turbine engine according to an exemplary of the present invention is described as follows, in reference to FIGS. **6**, **7** and **8**. In the method, a first operating power level is selected. This power is level may correspond, for example, to a maximum power level. This power level may also correspond to the maximum thrust level of the engine. The expressions "maximum power level" and "maximum thrust level" are used herein interchangeably and have the same meaning for the purposes of explanation of the invention. FIG. **6** is an example of the fan operating characteristics of the front block fan system, such as item **502** in FIG. **5**. A flow of air **2** is directed to a front fan stage **502** located near the front of the engine **576**. Referring to FIG. **6**, the mass flow rate corresponding to the selected maximum power level is shown as "W**1**" **701**. The fan speed corresponding to the selected maximum power level is shown as "S**1**" **703** and front fan stage **502** pressure ratio corresponding to the selected maximum power level is shown as "P**1**" **705**. In an exemplary embodiment of the present invention, "W**1**" is the 100% corrected flow of the front stage fan **502**, "S**1**" is the 100% corrected speed of the front fan stage **502** and the front stage fan **502** pressure ratio "P**1**" is about 2.9.

[0043] A portion **564** of the flow **560** from the front fan stage **502** (see FIG. **5**) is directed to an aft fan rotor **542** that is located axially aft from the front fan stage **502**. FIG. **7** is an example of the fan operating characteristics of outer portion of the aft fan rotor **542** of the convertible fan system. The portion **564** of the air flow is pressurized by the aft fan rotor **542** is to a first tip pressure ratio "P**3**" **735** when the corrected flow rate is "W**2**" **731** (see FIG. **7**). In an exemplary embodiment, "W**2**" is the 100% corrected flow of the aft fan outer portion **548** and the outer portion **548** pressure ratio "P**3**" is about 1.48 and the corresponding aft fan rotor **542** corrected speed is about 100%. The result of the combined pressurization by the forward fan system and the aft fan is to generate a first overall fan pressure ratio "A" in the engine. For the exemplary embodiment described above, "A" is about 4.3 (=2.9*1.48). The portion **563** of the air flow is pressurized by aft fan hub **546** to a first hub pressure ratio "P**5**" **755** when the corrected flow rate is "W**3**" **751** (see FIG. **8**). In an exemplary embodiment "W**3**" is the 100% corrected flow for the aft fan hub portion **546** and the inner portion **546** pressure ratio "P**5**" is about 1.48 and corresponding aft fan rotor **542** corrected speed is about 100%. The result of the combined pressurization by the forward fan system and the aft fan is to generate a first overall fan hub pressure ratio "AA" in the engine. For the exemplary embodiment described above, "AA" is about 4.3 (2.9 *1.48).

[0044] A portion **563** of the air flow from the front fan stage **502** (see FIG. **5**) is pressurized and discharged to an inner bypass passage **571** (see FIG. **5**). Another portion of this pressurized flow is directed to a compressor **579** to form a core flow **5**. When the bleed door **558** is opened, a portion **559**

of the flow **563** enters the inner bypass duct **571**, reducing the amount of the core flow **5**. The core flow **5** flows towards a compressor **579** in a core inlet passage and is compressed using the compressor **579** prior to combustion in a combustor **580**.

[0045] The method of operating the engine further comprises the step of selecting a second operating power level that is lower than the first operating power level. The corresponding fan maps at this lower power/thrust setting is shown as broken lines in FIGS. **6-8**. At this lower power/thrust setting, the flow rate in the front fan stage **502** is held substantially constant at about "W1" and corrected speed (see FIG. **6**) and the front fan stage pressure is lowered to "P2". In the example used herein, P2 has a value of about 2.5. Further, the flow in the aft fan rotor **542** outer portion **548** is reduced, such as, for example, by closing a variable inlet guide vane **554**. The reduced flow rate in the outer portion **548** is denoted by "W4" **733** corresponding to the lower power/thrust level (See FIG. **7**). The flow in the outer portion **548** of the aft fan rotor **542** is pressurized to a second tip pressure ratio "P4" **737** (See FIG. **7**). This generates a second overall pressure ratio "B" (at the lower power/thrust level) that is substantially lower than the first overall fan pressure ratio "A" (at the higher power/thrust setting), even while holding the flow rate "W1" in the front fan stage **502** substantially constant. In the exemplary embodiment described above, the pressure ratio "P4" is about 1.05 and the overall pressure ratio "B" is about 2.63 (=2.5*1.05). The lower power/thrust setting of the engine is usually chosen as the portion of the engine operating cycle which is used most, such as the cruise portion, and the pressure ratios and transition operating process are chosen so as to minimize the specific fuel consumption at the lower power setting.

[0046] In the exemplary embodiments shown herein, the step of reducing the flow in the aft fan rotor **542** is performed by partially closing a variable inlet guide vane **554** that is actuated by a known actuator **555**. When the flow in the outer portion of the aft fan rotor is reduced, a blocker door **556** is opened at least partially such that a portion **562** of the flow from the front fan stage **502** is flown into an outer bypass passage **572**. The opening of the blocker door **556** is determined, at least partially, by the available stability margin of the front fan **502**. A mixer **565** that located down stream from the aft fan **542** is engaged such that the inner bypass flow **561** and the outer bypass flow **562** achieve a substantial pressure balance when they mix downstream from the aft fan rotor **542**. In some operating conditions, the method described herein further comprises the step of opening a bypass door **558** and establishing a core bypass flow **559** to control the core flow **5** to better match the core compressor characteristics.

[0047] In an exemplary embodiment of the present invention, the method further comprises the step of pressurizing a portion **563** of the flow from the front fan stage **502** in an inner portion **546** of the aft fan rotor **542** to a first hub pressure ratio P6 at the first operating power level (maximum power/thrust setting in the example). See FIG. **8**. The core flow **5** can be controlled by operating a variable inlet guide vane (IGV) **552** upstream from the inner portion **546** of the aft fan rotor **542**. In the example described herein, "P6" has a value of about 1.38, and the IGV is closed by about 15 degrees. For lower power settings, the IGV **552** may be closed to a suitable degree (for example 40 to 50 degree) as necessary to match the compressor **579** requirements. In some applications, such as the exemplary embodiment shown in FIG. **5**, the flow of air **2** to the front fan stage **502** is controlled by operating a variable inlet guide vane **511** located axially forward from the front fan stage **502** using a known actuator **513**.

[0048] In some applications, such as the exemplary embodiment shown in FIG. **5**, an outer flow stream **3** through in an outer flow passage **517** is compressed using an outer fan **532** located on a front fan stage rotor **506**. These outer fans are alternatively known as FLADES™, as described previously herein. Controlling of the outer flow stream **3** is performed by operating a variable inlet guide vane **535** located upstream from the outer fan **532** using known actuators **536**.

[0049] In another exemplary method of operating the gas turbine engine shown in FIG. **5**, to aid in the transition from a high power/thrust setting to a lower power/thrust setting, where the front fan stage **502** pressure ratio is lowered to a level "P2" from a higher level "P1" (see FIG. **6**) the pressure ratio of the front fan stage is allowed to rise to a higher level than "P1" (see operating point marked by item number **706**). This occurs just before the blocker door **556** is opened (thereby flowing a portion of the flow **562** from the front fan stage **502** into an outer bypass passage **572**). To maintain front fan stage and aft fan stage flow continuity, the convertible fan outer inlet guide vanes **554** begin to close to start the process of reducing the overall fan tip pressure ratio while maintaining a substantially constant fan flow in the front fan stage **552**. During this transition, the convertible fan inner guide vanes **552** may be opened (see item **736** in FIG. **7**) to allow more core flow **5** to optimize the operation of the engine system **576**. The core flow **5** may further be fine-tuned by opening a bypass door **558** thereby establishing a core bypass flow **559**. In the exemplary embodiment of the engine system **576** shown in FIG. **5**, a variable throat area (not shown in FIG. **5**, but substantially similar to item **69** shown in FIG. **1**) is provided in the engine exhaust system wherein the main exhaust nozzle throat area can be varied as necessary, such as for example, by opening the throat area when the engine thrust is reduced.

[0050] FIG. **9** shows a schematic cross-sectional view of an exemplary versatile gas turbine engine **676** having an adaptive core **678** according to an exemplary embodiment of the present invention. The exemplary versatile gas turbine engine **676** comprises a convertible fan system **640** adapted to have a variable fan pressure ratio while an air flow into the convertible fan system **640** remains substantially constant. The exemplary versatile gas turbine engine **676** shown in FIG. **9** further comprises an adaptive core **678** having a compressor **679** capable of maintaining a substantially constant core pressure ratio while a core airflow flow **5** rate is varied to enable efficient engine operation under a variety of flight conditions. The convertible fan system, such as item **640** in FIG. **9**, and its operation have been described previously herein. It comprises an annular inner bypass passage **671** around an engine axis **11** that is adapted to flow an inner bypass flow **661** from the convertible fan system **640** and an annular outer bypass passage **672** around the engine axis **11** that is adapted to flow an outer bypass flow **662** from the convertible fan system **640**. The exemplary convertible fan system **640** has a front stage fan rotor **622** and an aft fan rotor **642** that is located axially aft from the front stage fan rotor **622** and has a row of aft fan blades **644** arranged circumferentially around an engine axis **11**. The aft fan rotor **642** has an arcuate splitter **647** on the fan blades **644** that form a portion of an inner flow passage **673** and an outer flow passage **674**. An inner portion **646** of the aft fan blade **644** pressurizes an inner flow **663** in the inner flow passage **673** to have a hub pressure ratio. An outer portion **648** of the aft fan blade **644** pressurizes an outer flow **664** in the outer flow passage **673** to have a tip pressure ratio. The convertible fan system **640** has a vane system **650** located axially forward from the aft fan rotor **642**. The vane system **650** has variable vanes that are adapted to be able to vary the flow in the aft fan blades **644** such that overall pressure ratio of the fan system **640** can be varied as needed to attain flexible and efficient engine operation for a variety of flight power/thrust conditions. Use of the convertible fan system **640** enables the engine **676** to have a variable fan pressure ratio while an air flow **2** into the convertible fan system **640** remains substantially constant. The outer flow **664** pressurized by aft fan rotor **642** flows into an annular inner bypass passage **671**. A portion of the inner flow **663** pressurized by the inner portion **646** of the fan blade **644** forms a core flow **5** that flows into the compressor **679**. The exemplary engine **676** has a core bypass door **658** (see FIG. **9**) that is adapted to control a core bypass flow **659**. A blocker door **656** may be used in the outer bypass passage **672** to control the outer bypass flow **662** and to prevent a reverse flow in the outer bypass passage **672** when the down-stream pressure is high.

[0051] FIG. **9** shows an exemplary adaptive core **678** in the versatile adaptive engine **676** according to an exemplary embodiment of the present invention. The exemplary adaptive core **678** has a front-block compressor **691** and a rear-block compressor **692** coupled to a turbine **681** that drives the compressors. In FIG. **9**, the front-block compressor **691** is shown as a multi-stage axial-flow compressor and the rear-block compressor **692** is shown as a centrifugal compressor. Alternatively, the rear-block compressor **692** may also be an axial flow compressor. The use of a two-block compressor system in the adaptive core **678** as shown in FIG. **9** gives the compressor system the versatile ability to both adjust core pressure at constant flow to control maximum compressor discharge temperature and pressure levels, and also to maintain a substantially constant core compressor pressure ratio while the core airflow **5** flow rate into the compressor is lowered, such as for example, at low power or low thrust operation of the engine **676**. This is shown in the compressor operating map shown in FIG. **10** and explained subsequently herein. The flow control into the front-block of the two-block compressor shown in FIG. **9** is accomplished by operating a front-block inlet guide vane **689** capable of varying the flow into the front-block compressor **691**. The flow control into the rear-block of the two-block compressor is accomplished by operating a rear-block inlet guide vane **694** capable of varying the flow into the rear-block compressor **692**. The adaptive core **678** has a rear-block bypass passage **693** that can receive a flow from an annular inter-block passage **696** when the rear-block IGV **694** is partially or fully closed. The annular inter-block passage **696** is located between the front-block compressor **691** and the rear-block compressor **692**. A variable area combustor diffuser system **699** may be used to help in transitioning between "rear-block on" and "rear-block off" modes of engine operation. The exemplary gas turbine engine **672** may optionally have a variable high-pressure turbine nozzle system **697**, and/or a variable low-pressure turbine nozzle system **698** as schematically shown in FIG. **9**. The variable turbine nozzles **697**, **698** may be operated by known means to attain turbine flow-function matching during operation of the engine **676**. The exemplary gas turbine engine according **676** further comprises a forward mixer **665** (alternatively known as a "fwd VABI") that is adapted to enhance mixing of an inner bypass flow **661** and an outer bypass flow **662** to form a mixed bypass flow **666** (see FIG. **9**). A rear mixer **684** (alternatively known as a "rear VABI") located down-stream from a low pressure turbine **683** may be used to enhance mixing of a mixed bypass flow **666** and the hot exhaust from the low pressure turbine **683**. Variable Area Bypass Injectors ("VABI") are known in the art. In the exemplary embodiment of the engine system **676** shown in FIG. **9**, a variable throat area (not shown in FIG. **9**, but substantially similar to item **69** shown in FIG. **1**) is provided in the engine exhaust system wherein the main exhaust nozzle throat area can be varied as necessary, such as for example, by opening the throat area when the engine thrust is reduced.

[0052] The exemplary versatile gas turbine engine **676** optionally comprises, as shown in FIG. **9**, an outer fan system **630**. The outer fan system **630** comprises a circumferential row of outer fan blades **632** (alternatively referred to herein as FLADES™ blades) that are located radially outward from a front stage fan rotor **620**. The outer fan blades **632** are carried by a front stage fan rotor, such as, for example, the second stage fan rotor **620** in FIG. **9**. The outer fan blades **632** rotate with the front stage fan rotor **620** to pressurize an outer flow stream **3** in an outer flow path **617**. The pressurized outer flow stream **8** may be used for a variety of purposes. For example, the exemplary gas turbine engine shown in FIG. **9** has an air bleed conduit **685** that is adapted to remove at least a portion of the flow **8** in the outer flow path **517** for use outside the engine, such as, for example, wing blowing. A portion of the flow **8** in the outer flow path **617** may be used to cool a portion of the engine **676**, such as the exhaust nozzle, as shown schematically, for example, in FIG. **1**.

[0053] FIG. **10** shows how to use the exemplary engine shown in FIG. **9** for different flight conditions on an operating map of the two-block adaptive compressor **690** such as, for example, shown in FIG. **9**. Two operating maps are shown in FIG. **10**, one with the "Rear Block Off" and one with the "Rear Block On". The rear-block compressor **692** is "OFF" when the flow into the rear-block compressor **692** is substantially cut off (except for a small purge flow) by closing the rear-block variable inlet guide vane (IGV) **694** using known actuators **695**. Item numbers **800** represent the speed lines (% speed, such as 100%, 98% 96% shown in FIG. **10**). The operating line with the "Rear Block Off" (such as, for example, during Take-Off operation of the engine **676**) is shown as item **814** and the corresponding stall line is shown as item **811**. Item numbers **813**, **803** etc. represent contours of constant efficiency. The pressure ratio of the adaptive core **678** with the "Rear Block Off" is shown as item **812** at a 100% speed, and may, for example, represent the design pressure ratio for the front-block compressor. During another mode of operation of the versatile adaptive engine **676**, such as for example, cruise-operation, the flow may be reduced, for example, from operating point item **812** to operating point item **808**. The operating line with the "Rear Block On" (such as, for example, during Cruise operation of the engine **676**) is shown as item **802** and the corresponding stall line is shown as item **810**. The "Rear Block On" is accomplished by opening the rear block IGV **694** to allow some of the flow from the front-block compressor **691** into the rear-block compressor **692** flow. By turning the "Rear Block On", the pressure ratio (see item **808**) of the adaptive core **678** may be maintained at substantially same level as before (see item **812**), even when the corrected flow is reduced (see items **812** and **808**) for low power/thrust conditions. Alternatively, for other engine operating regimes, the engine may be operated to achieve a higher pressure ratio, such as from item **812** to item **804**, with the core flow and corrected speed (item **800**) substantially constant.

[0054] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A convertible fan system comprising:

a convertible fan rotor having a plurality of fan blades radially extending from a hub and arranged circumferentially around a longitudinal axis, each blade having an arcuate splitter located radially outward from the hub wherein the arcuate splitter forms a portion of an inner flow passage and an outer flow passage wherein an inner portion of the fan blade pressurizes an inner flow in the inner flow passage and an outer portion of the fan blade pressurizes an outer flow in the outer flow passage; and

a vane system located axially forward from the convertible fan rotor that is adapted to be able to vary the flow in inner flow passage and the outer flow passage such that pressure ratio of the fan system can be varied.

2. A convertible fan system according to claim **1** further comprising a forward fan stage coupled to the convertible fan rotor and located axially forward from it.

3. A convertible fan system according to claim **1** further comprising a splitter located axially forward from the convertible fan rotor wherein a flow stream into the convertible fan rotor is bifurcated to form the inner flow in the inner flow passage and the outer flow in the outer flow passage.

4. A convertible fan system according to claim **3** wherein the vane system comprises an outer vane located radially outward from the splitter.

5. A convertible fan system according to claim **4** wherein a portion of the outer vane is movable by an actuator.

6. A convertible fan system according to claim **3** wherein the vane system comprises an inner vane located radially inboard from the splitter.

7. A convertible fan system according to claim **6** wherein a portion of the inner vane is movable by an actuator.

8. A convertible fan system according to claim **3** further comprising an outlet guide vane located down stream from the convertible fan rotor.

9. A convertible fan system according to claim **3** wherein at least a portion of the inner flow pressurized by the inner portion of the fan blade forms a core flow.

10. A convertible fan system according to claim **3** further comprising a bypass door that is adapted to control a core bypass flow.

11. A convertible fan system according to claim **2** further comprising an outer bypass passage and an inner bypass passage.

12. A convertible fan system according to claim **11** wherein the outer bypass passage is adapted to flow at least a portion of the flow pressurized by the forward fan stage.

13. A convertible fan system according to claim **12** further comprising a blocker door that is adapted to prevent a reverse flow in the outer bypass passage.

14. A convertible fan system according to claim **11** further comprising a mixer located downstream from the convertible fan rotor that is adapted to enhance mixing of the inner bypass flow and the outer bypass flow.

15. A convertible fan system according to claim **2** wherein the forward fan stage comprises an outer fan system having a plurality of outer fan blades that are located radially outward from a plurality of fan blades and adapted to rotate with the fan blades to pressurize an outer flow stream in an outer flow path.

16. A convertible fan system according to claim **15** wherein the outer fan system further comprises a plurality of outer fan inlet guide vanes that are adapted to control the outer flow stream in the outer flow path.

17. A convertible fan system comprising:

a convertible fan rotor having a plurality of fan blades radially extending from a hub and arranged circumferentially around a longitudinal axis, each blade having an arcuate splitter located radially outward from the hub wherein the arcuate splitter forms a portion of an inner flow passage and an outer flow passage wherein an inner portion of the fan blade pressurizes an inner flow in the inner flow passage and an outer portion of the fan blade pressurizes an outer flow in the outer flow passage;

a vane system located axially forward from the convertible fan rotor comprising an outer vane located radially outward from a splitter located axially forward from the fan rotor and is adapted to be able to vary the flow in the outer flow passage such that pressure ratio of the fan system can be varied.

18. A convertible fan system according to claim **17** wherein a portion of the outer vane is movable by an actuator.

19. A convertible fan system according to claim **17** further comprising a bypass door that is adapted to control a core bypass flow.

20. A convertible fan system according to claim **17** further comprising an outer bypass passage and an inner bypass passage.

21. A convertible fan system according to claim **20** further comprising a blocker door that is adapted to prevent a reverse flow in the outer bypass passage.

22. A convertible fan system according to claim **17** further comprising a forward fan stage having an outer fan system comprising a plurality of outer fan blades that are located radially outward from a plurality of fan blades and adapted to rotate with the fan blades to pressurize an outer flow stream in an outer flow path.

23. A convertible fan system according to claim **22** wherein the outer fan system further comprises a plurality of outer fan inlet guide vanes that are adapted to control the outer flow stream in the outer flow path.

24. A convertible fan system comprising:

a convertible fan rotor having a plurality of fan blades radially extending from a hub and arranged circumferentially around a longitudinal axis, the fan blade adapted to pressurize a flow in an inner flow passage;

an inner bypass passage and an outer bypass passage located radially outward from the inner bypass passage;

a vane system located axially forward from the convertible fan rotor comprising a vane adapted to be able to vary the flow in the convertible fan rotor such that pressure ratio of the fan system can be varied.

25. A convertible fan system according to claim **24** further comprising a forward fan stage coupled to the convertible fan rotor and located axially forward from it.

26. A convertible fan system according to claim **25** wherein the forward fan stage comprises an outer fan system having a plurality of outer fan blades that are located radially outward from a plurality of fan blades and adapted to rotate with the fan blades to pressurize an outer flow stream in an outer flow path.

27. A convertible fan system according to claim **26** wherein the outer fan system further comprises a plurality of outer fan inlet guide vanes that are adapted to control the outer flow stream in the outer flow path.

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