US010385785B2

(12) **United States Patent**
MacFarlane et al.

(10) **Patent No.: US 10,385,785 B2**
(45) **Date of Patent: Aug. 20, 2019**

(54) **AIR INLET FOR A GAS TURBINE ENGINE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 199 days.

(21) Appl. No.: **15/651,289**

(22) Filed: **Jul. 17, 2017**

(65) **Prior Publication Data**

US 2019/0017442 A1 Jan. 17, 2019

(51) **Int. Cl.**

F02C 7/32	(2006.01)
F01D 9/04	(2006.01)
F01D 9/06	(2006.01)
F02C 3/04	(2006.01)
F02C 7/04	(2006.01)
F02C 7/06	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***F02C 7/32*** (2013.01); ***F01D 9/045*** (2013.01); ***F01D 9/065*** (2013.01); ***F01D 15/12*** (2013.01); ***F02C 3/04*** (2013.01); ***F02C 7/04*** (2013.01); ***F02C 7/06*** (2013.01); ***F02C 7/36*** (2013.01); *F05D 2220/323* (2013.01); *F05D 2240/12* (2013.01); *F05D 2240/60* (2013.01); *F05D 2260/40* (2013.01)

(58) **Field of Classification Search**

CPC F01D 9/045; F01D 9/065; F01D 15/12; F01D 1/06; F01D 1/08; F02C 7/32; F02C 3/04; F02C 7/04; F02C 7/36; F05D 2220/323; F05D 2240/12; F05D 2240/60; F05D 2260/40

See application file for complete search history.

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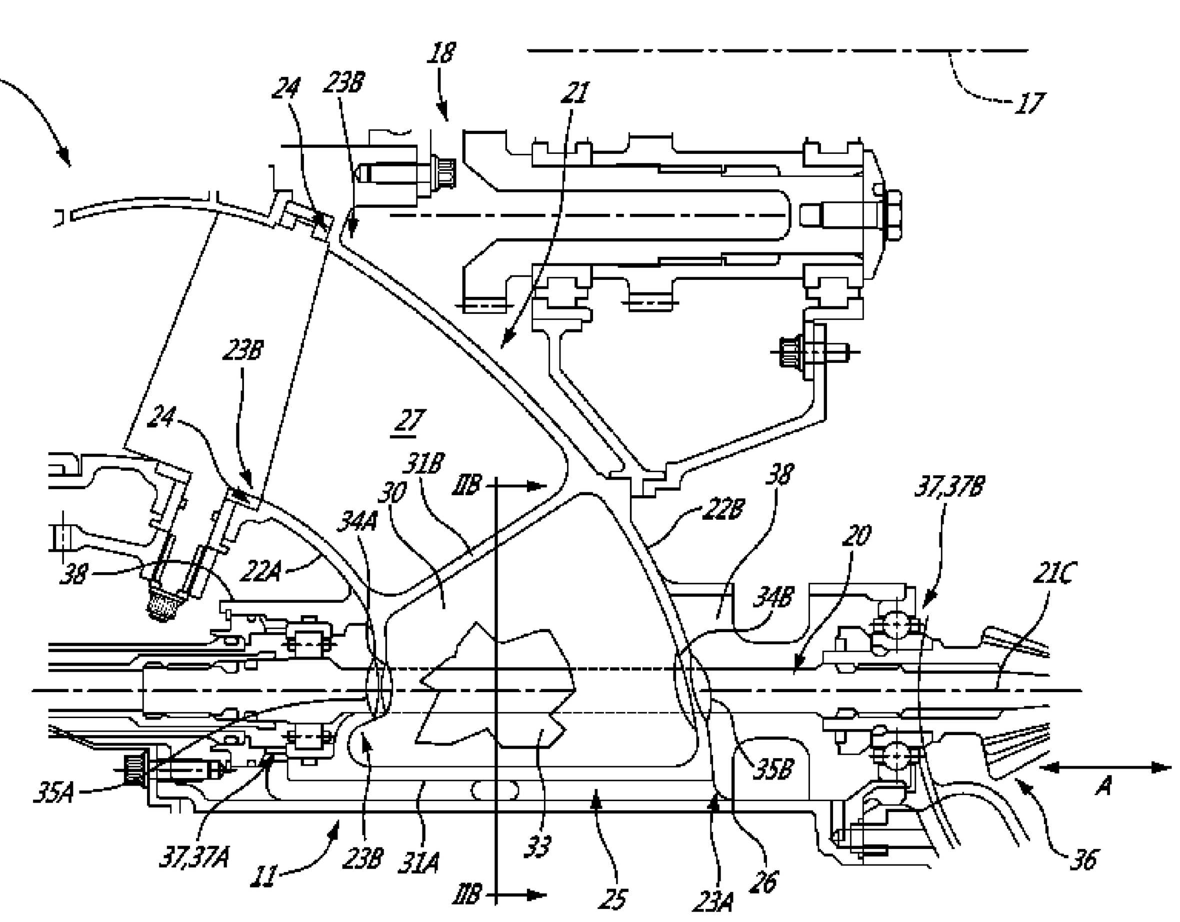
(57) **ABSTRACT**

A radial air inlet for a gas turbine engine. The air inlet has an inlet duct defined between two axially-spaced radially-extending annular walls and has a plurality of circumferentially-spaced axially-extending struts extending between the annular walls adjacent a radially-outer portion of the air inlet. At least one of the struts has an internal passage extending between a first opening in a forward end of the strut and a second opening in an aft end of the strut, the first and second openings being axially spaced apart. A transmission shaft extends through the internal passage of said strut.

20 Claims, 3 Drawing Sheets



(51) **Int. Cl.**
F02C 7/36 (2006.01)
F01D 15/12 (2006.01)

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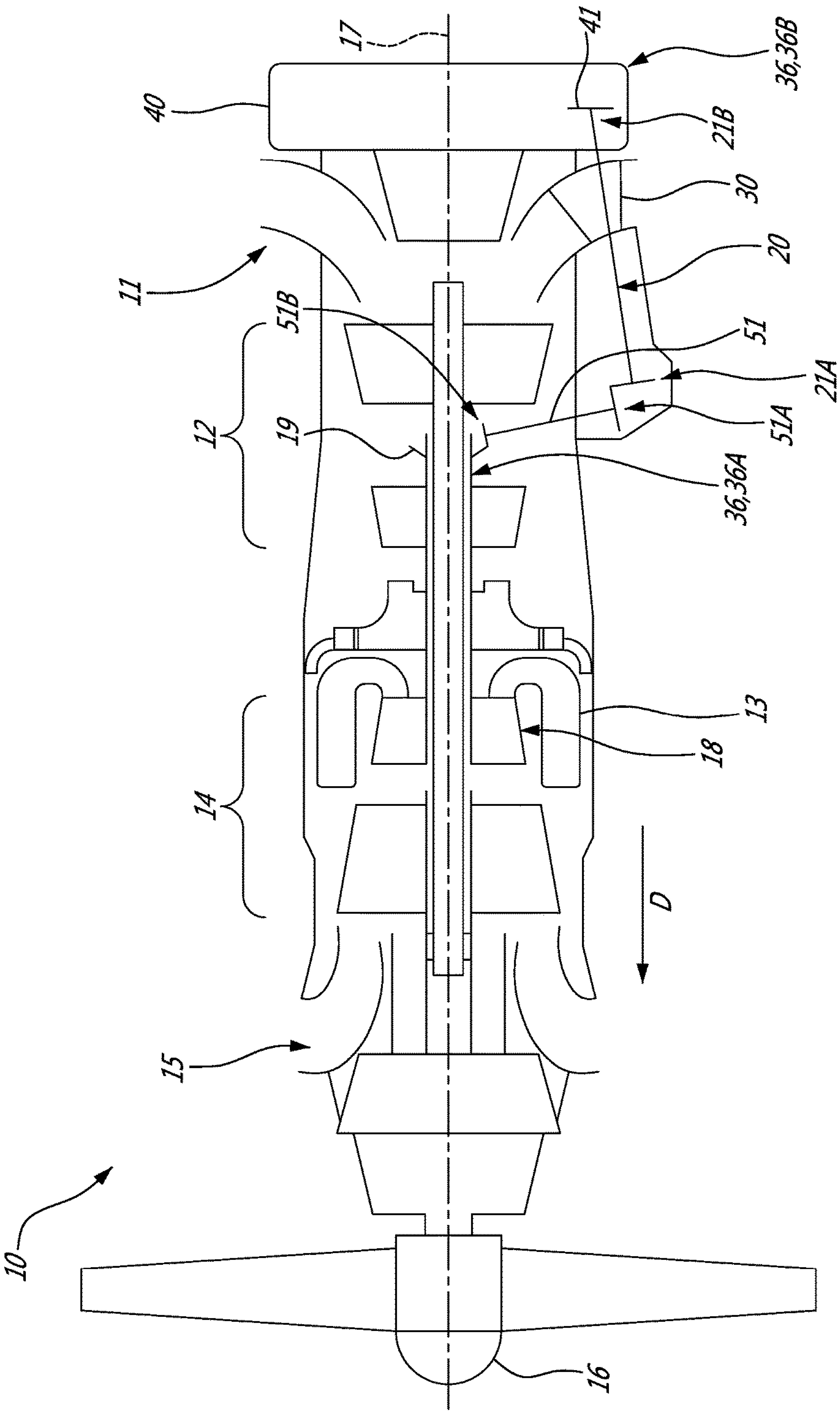
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FIG. 1

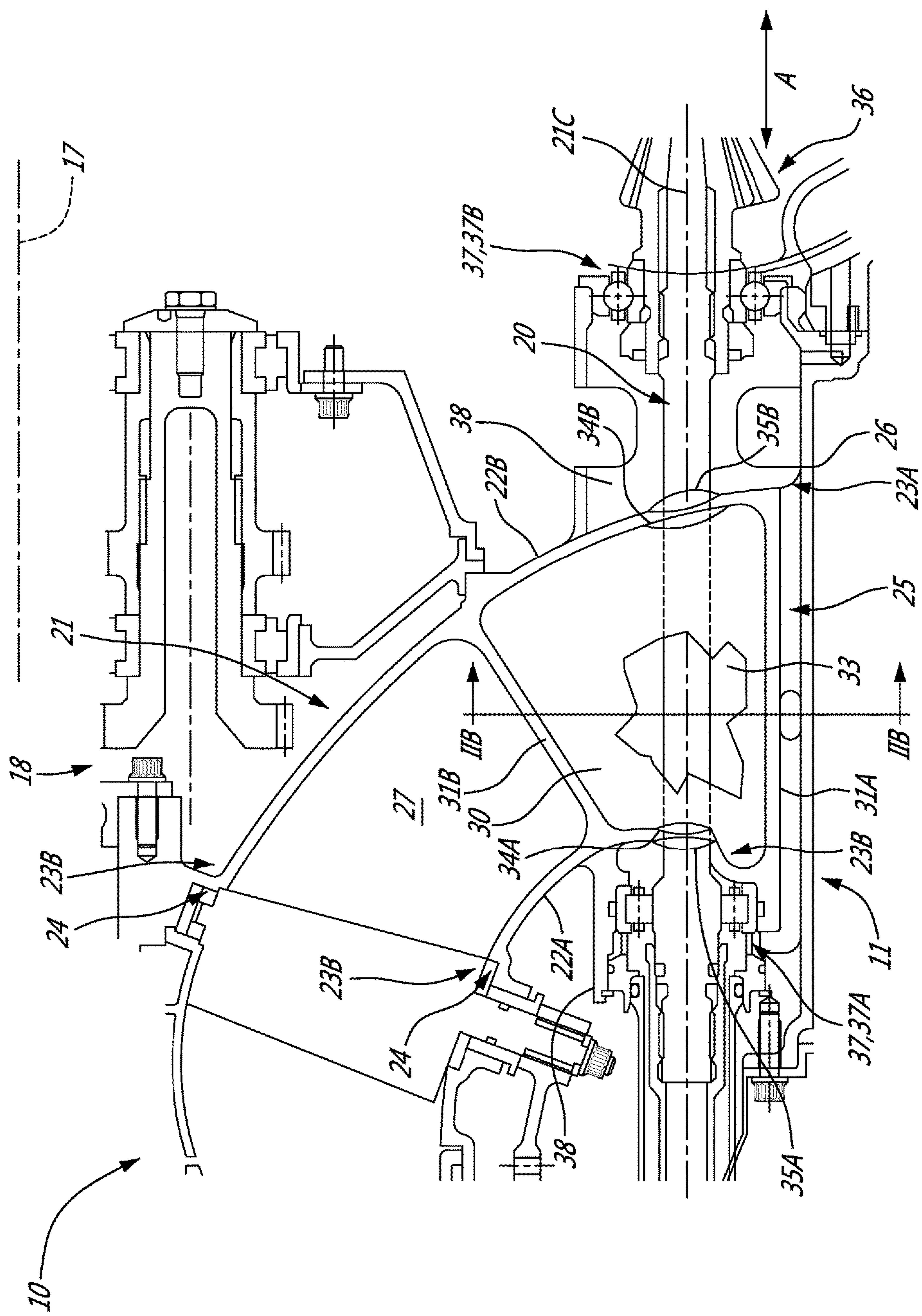
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FIG. 2A

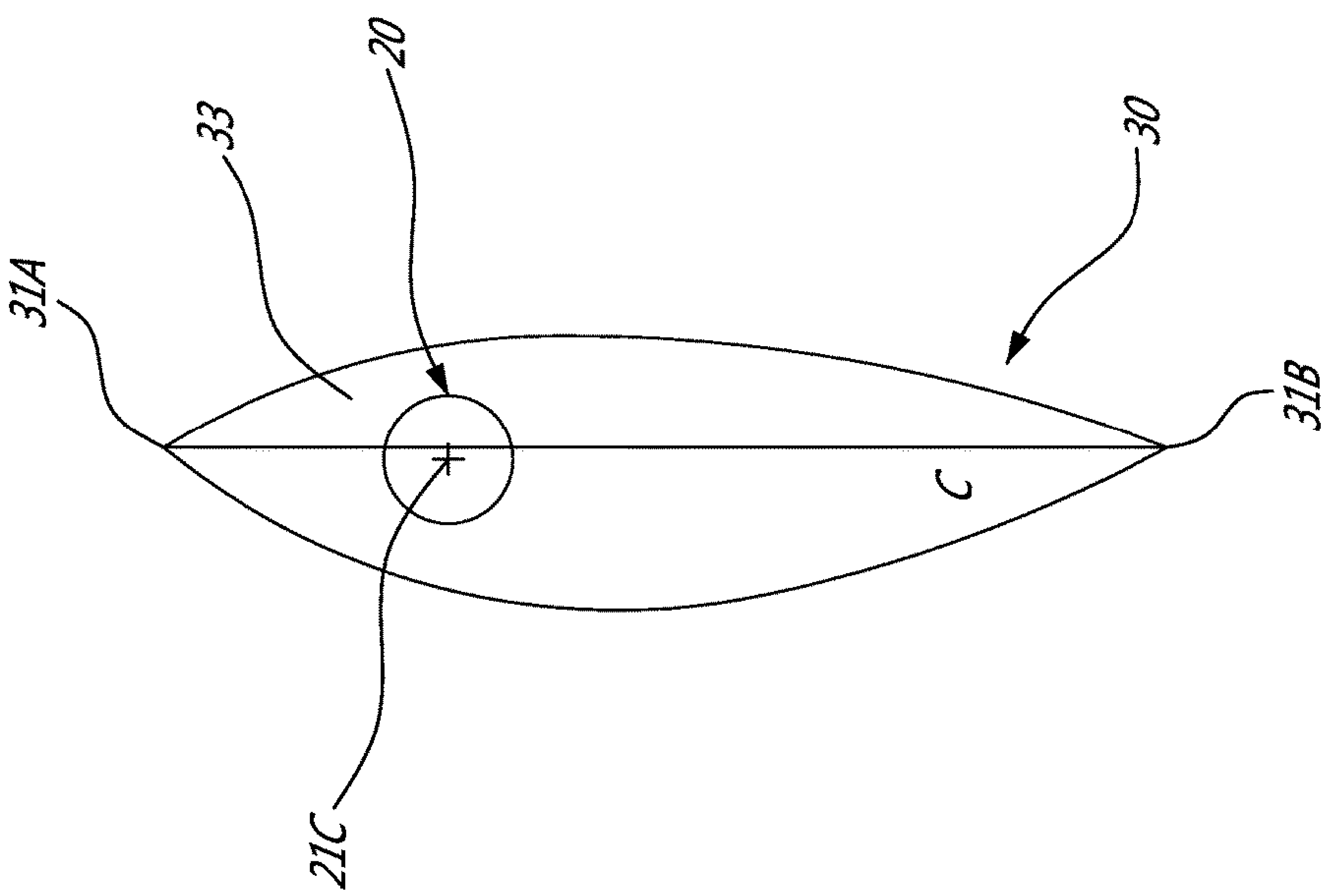

Fig-2B

AIR INLET FOR A GAS TURBINE ENGINE

TECHNICAL FIELD

The application relates generally to gas turbine engines and, more particularly, to air inlets for gas turbine engines.

BACKGROUND

Power is sometimes taken from one or more of the central shafts of the turbomachinery of a gas turbine engine to drive other components of the engine. This arrangement can include the central shaft of the engine being engaged to another drive shaft that drives a gearbox of the engine.

SUMMARY

In one aspect, there is provided a gas turbine engine, comprising: a compressor section and a turbine section drivingly engaged with a drive shaft, the drive shaft being rotatable about a center axis of the gas turbine engine; a radial air inlet in fluid communication with the compressor section, the radial air inlet having an inlet duct defined between two axially-spaced radially-extending annular walls and having a plurality of circumferentially-spaced axially-extending struts extending between the annular walls adjacent a radially-outer portion of the air inlet, at least one of the struts having an internal passage extending between a first opening in a forward end of the strut and a second opening in an aft end of the strut, the first and second openings being axially spaced apart; and a transmission shaft extending through the internal passage of said strut.

In another aspect, there is provided a drive system for a gas turbine engine, comprising: an inlet duct having two annular walls disposed about a center axis, each wall extending between an outer portion and an inner portion, the inner portion being radially closer to the center axis than the outer portion, the walls being axially spaced apart and defining an annular air passage between the walls; a plurality of struts being circumferentially spaced-apart within the inlet duct, each strut extending between the annular walls and through the annular air passage, one of the struts having an internal passage extending between a first opening in a forward end of the strut and a second opening in an aft end of the strut, the first and second openings being axially spaced apart; and a transmission shaft extending through the internal passage and the first and second openings of said strut.

In a further aspect, there is provided a method of operating a gas turbine engine, comprising: drawing air from a radially-outer portion of a radial air inlet of the engine to a radially-inner portion of the air inlet, the air inlet having circumferentially spaced-apart struts; and driving a rotatable load of the engine with a transmission shaft extending across the air inlet and through one of the struts.

DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying figures in which:

FIG. **1** is a schematic cross-sectional view of a gas turbine engine, according to an embodiment of the present disclosure; and

FIG. **2**A is an enlarged cross-sectional view of an air inlet of the gas turbine engine of FIG. **1**; and

FIG. **2**B is a cross-sectional view of the air inlet of FIG. **2**A taken along the line IIB-IIB in FIG. **2**A.

DETAILED DESCRIPTION

FIG. **1** illustrates a gas turbine engine **10** of a type preferably provided for use in subsonic flight, generally comprising in serial flow communication an air inlet **11**, a compressor section **12** for pressurizing the air from the air inlet **11**, a combustor **13** in which the compressed air is mixed with fuel and ignited for generating an annular stream of hot combustion gases, a turbine section **14** for extracting energy from the combustion gases, and an exhaust outlet **15** through which the combustion gases exit the gas turbine engine **10**. The gas turbine engine **10** includes a propeller **16** which provides thrust for flight and taxiing. The gas turbine engine **10** has a longitudinal center axis **17**. A drive shaft **19** mechanically couples the turbine section **14** and the compressor section **12**, and extends between them. The drive shaft **19** is coaxial with the center axis **17** of the gas turbine engine **10** and rotatable about the center axis **17**. The drive shaft **19** allows the turbine section **14** to drive the compressor section **12** during operation of the gas turbine engine **10**. In the depicted embodiment, the air inlet **11** is positioned aft of the compressor section **12**.

The gas turbine engine **10** (sometimes referred to herein simply as "engine **10**") has a central core **18** through which gases flow and which includes some of the turbomachinery of the engine **10**. The engine **10** is a "reverse-flow" engine **10** because gases flow through the core **18** from the air inlet **11** at a rear portion, to the exhaust outlet **15** at a front portion. This is in contrast to "through-flow" gas turbine engines in which gases flow through the core of the engine from a front portion to a rear portion. The direction of the flow of gases through the core **18** of the engine **10** disclosed herein can be better appreciated by considering that the gases flow through the core **18** in the same direction D as the one along which the engine **10** travels during flight. Stated differently, gases flow through the engine **10** from a rear end towards the propeller **16**. In the embodiment of FIG. **1**, the engine **10** has multiple spools which perform compression to pressurize the air received through the air inlet **11**, and which extract energy from the combustion gases before they exit the core **18** via the exhaust outlet **15**. The spools and this engine architecture are described in greater detail in U.S. patent application Ser. No. 15/266,321 filed on Sept. 15, 2016, the entire contents of which are hereby incorporated by reference.

It will thus be appreciated that the expressions "forward" and "aft" used herein refer to the relative disposition of components of the engine **10**, in correspondence to the "forward" and "aft" directions of the engine **10** and aircraft including the engine **10** as defined with respect to the direction of travel. In the embodiment shown, a component of the engine **10** that is "forward" of another component is arranged within the engine **10** such that it is located closer to the propeller **16**. Similarly, a component of the engine **10** that is "aft" of another component is arranged within the engine **10** such that it is further away from the propeller **16**.

Still referring to FIG. **1**, a rotatable transmission shaft **20** of the engine **10** extends across the air inlet **11**. As described in greater detail below, the transmission shaft **20** extends through one of the structural supports, or struts **30**, of the air inlet **11**. The transmission shaft **20** transmits a rotational drive force to a rotatable load **36** of the engine **10**. The transmission shaft **20** also transmits a rotational drive force from the rotatable load **36**. The rotatable load **36** can therefore be any suitable component, or any combination of suitable components, that is capable of receiving or conveying a rotational drive to/from the transmission shaft **20**.

In the depicted embodiment, the transmission shaft **20** transmits a rotational force to a first rotatable load **36**A located on one side of the air inlet **11**, and transmits a rotational force to a second rotatable load **36**B located on the other side of the air inlet **11**. The two sides of the air inlet **11** are axially spaced apart along the center axis **17**. In the depicted embodiment, the transmission shaft can also receive the rotational force from either one of the first and second rotatable loads **36**A,**36**B. The transmission shaft **20** is mechanically coupled at a first end **21**A of the transmission shaft **20** to the first rotatable load **36**A, and mechanically coupled at an opposite second end **21**B to the second rotatable load **36**B of the engine **10**. By "mechanically coupled", it is understood that the transmission shaft **20** can be, at either one of its ends **21**A,**21**B, directly engaged to the rotatable load **36**, or indirectly engaged to the rotatable load **36** via another rotating component.

In FIG. **1**, the first rotatable load **36**A includes the drive shaft **19** of the engine **10**, and the second rotatable load **36**A includes an accessory gearbox **40** of the engine **10**. The accessory gearbox **40** (sometimes referred to herein simply as "AGB **40**") receives a rotational output from the transmission shaft **20** and in turn drives accessories (e.g. fuel pump, starter-generator, oil pump, scavenge pump, etc.) that contribute to the functionality of the engine **10**. The AGB **40** can be designed with side-facing accessories, top-facing accessories, or rear-facing accessories depending on the installation needs. In the depicted embodiment, the first and second rotatable loads **36**A,**36**B are axially-spaced apart on opposite sides of the air inlet **11**. More particularly, the drive shaft **19** is forward of the air inlet **11** and the AGB **40** is aft of the air inlet **11**. In the depicted embodiment, the air inlet **11** therefore separates the drive shaft **19** from the AGB **40**, and prevents the direct transmission of rotational force between the drive shaft **19** and the AGB **40**. In such an engine architecture, the transmission shaft **20** helps to transfer rotational force between the drive shaft **19** and the AGB **40**.

The engine **10** also has a tower shaft **51** that has a first geared end **51**A and a second geared end **51**B. The first end **51**A of the tower shaft **51** is mechanically coupled to the transmission shaft **20**, and the second end **51**B of the tower shaft **51** is mechanically coupled to the drive shaft **19**. The second end **51**B of the tower shaft **51** meshes with the drive shaft **19** at a location that is forward of a low pressure compressor and aft of a high pressure compressor of the compressor section **12**. The second end **21**B of the transmission shaft **20** is directly engaged to an input gear **41** of the AGB **40**. The tower shaft **51**, in conjunction with the transmission shaft **20**, mechanically couples and links the compressor section **12** to the AGB **40**.

During operation of the engine **10**, the drive shaft **19** transmits a rotational drive to the tower shaft **51** which in turn drives the transmission shaft **20** to thereby drive the input gear **41** and the accessories of the AGB **40**. During some operating modes of the engine **10**, for example engine start, a starter-generator accessory of the AGB **40** drives the input gear **41** of the AGB **40**, which in turn transmits a rotational drive to the transmission shaft **20**, which then transmits the rotational drive to the tower shaft **51** and thus to the drive shaft **19** of the engine **10**.

Referring to FIG. **2**A, the air inlet **11** is a radial air inlet **11** because, during operation of the engine **10**, air is drawn into the engine via the air inlet **11** along a substantially radial direction. The air inlet **11** is therefore the first point of entry of air into the core **18** of the engine **10**.

The air inlet **11** has an inlet duct **21** along which air flows as it drawn into the engine **10**. The inlet duct **21** is defined by two radially-extending annular walls **22**A,**22**B. Each wall **22**A,**22**B is shown as being an integral body. In an alternate embodiment, one or both of the walls **22**A,**22**B is made up of wall segments. Each annular wall **22**A,**22**B extends between a radially-outer portion **23**A and a radially-inner portion **23**B. The radially-inner portion **23**B is a portion of each wall **22**A,**22**B that is radially inward (i.e. closer to the center axis **17** of the engine **10**) than the radially-outer portion **23**A. Each wall **22**A,**22**B therefore extends from an outer surface or portion of the engine **10** radially inwards toward the core **18**. The walls **22**A,**22**B in the depicted embodiment also have portions extending in an axial direction as well. The radially-inner portions **23**B of each wall **22**A,**22**B have trailing ends **24** which, in the frame of reference of the engine **10**, are defined by both axial and radial direction vectors. An air opening **25** is defined at the radially-outer portions **23**A of the walls **22**A,**22**B. The air opening **25** is circumferential because it spans a portion or all of the circumference of the inlet duct **21**. The air opening **25** extends through an outermost surface **26** of the engine **10**. The outermost surface **26** may be located in an engine covering, such as a nacelle or casing. The air opening **25** may be provided with a screen, filter, or mesh to prevent the ingress of foreign objects into the engine **10**.

The walls **22**A,**22**B are axially spaced apart from one another. In the depicted embodiment, the wall **22**B is aft of the wall **22**A in a direction along the center axis **17**. The axial offset between the annular walls **22**A,**22**B defines an inner volume of the inlet duct **21** through which air is conveyed toward the compressor section **12**. The spaced-apart walls **22**A,**22**B therefore define an annular air passage **27** between them. The air passage **27** is an annular volume that extends radially inwardly at the radially-outer portions **23**A and which has both axial and radial direction vectors at the radially-inner portion **23**B of the walls **22**A,**22**B.

Multiple air inlet struts **30** are located within the inlet duct **21**. Each strut **30** is part of the fixed structure of the engine **10**. Each strut **30** is a stationary component that helps to prevent ingress into the engine **10** of large foreign objects, and helps to provide structure to the air inlet **11**. The struts **30** are circumferentially spaced-apart from one another within the inlet duct **21**. Each strut **30** extends between the annular walls **22**A,**22**B and through the annular air passage **27**. Each strut **30** is attached to the annular walls **22**A,**22**B. In the depicted embodiment, each strut **30** is integral with the walls **22**A,**22**B. In an alternate embodiment, one or more of the struts **30** can be removably mounted to the walls **22**A,**22**B. Each of the struts **30** in the depicted embodiment is a radial air inlet strut **30** because it extends radially inwardly. Stated differently, each strut has a radial span defined between a radially-outer edge **31**A near the radially-outer portions **23**A of the walls **22**A,**22**B, and a radially-inner edge **31**B near the radially-inner portions **23**B of the walls **22**A,**22**B. The inner edge **31**B is radially closer to the center axis **17** than the outer edge **31**A. The position of the edges **31**A,**31**B of the strut **30** relative to the engine may vary, and what remains constant is that the edge **31**B is radially inward of the edge **31**A. In the embodiment of FIG. **2**A, each strut **30** also has an axial span defined between the annular walls **22**A,**22**B of the inlet duct **21**.

Referring to FIGS. **2**A and **2**B, one or more of the struts **30** is shaped like an airfoil. The airfoil shape of the strut **30** helps to guide the flow of air through the air inlet **11**. Each airfoil-shaped strut **30** includes the radially-outer edge **31**A which forms the leading edge of the strut **30**, and the radially-inner edge **31**B forms the trailing edge of the strut **30**. The trailing edge **31**B is radially closer to the center axis **17** than the leading edge **31**A. The chord C of the strut **30** is therefore defined along a line extending between the leading and trailing edges **31**A,**31**B. The chord C therefore extends in a substantially radial direction. By "substantially radial", it is understood that in the frame of reference of the engine **10**, the magnitude of the radial direction vector of the chord C is much greater than the magnitude of the axial direction vector of the chord C.

Still referring to FIGS. **2**A and **2**B, one or more of the struts **30** is at least partially hollow. The surfaces of the strut **30** define an inner cavity or passage **33** within the strut **30**. The inner passage **33** is a volume delimited by the surfaces of the strut **30**. The strut **30** also has openings at opposed axial ends. More particularly, the strut **30** has an opening **34**A at forward end of the strut **30**, and an opening **34**B at an opposite aft end of the strut **30**. The first and second openings **34**A,**34**B are spaced apart along the center axis **17**. In FIG. **2**A, each of the walls **22**A,**22**B has an opening **35** aligned with the first and second openings **34**A,**34**B. More particularly, the wall **22**A has an opening **35**A aligned with the first opening **34**A in the strut **30**, and the wall **22**B has an opening **35**B aligned with the second opening **34**B. In an alternate embodiment, there is only one opening for each of the walls **22**A,**22**B of the inlet duct **21**. The first and second openings **34**A,**34**B define a through passage extending from one end of the strut **30** to the other. In the depicted embodiment, the first and second openings **34**A,**34**B are aligned along a substantially axial direction A. By "substantially axial", it is understood that in the frame of reference of the engine **10**, the axial direction vector is predominant. Stated differently, the magnitude of the axial direction vector, which is parallel to the center axis **17** of the engine **10**, is much greater than the magnitude of the radial direction vector. In an alternate embodiment, the first and second openings **34**A,**34**B are aligned in another direction that has a more important radial direction vector, and which is consequently not the substantially axial direction A.

Still referring to FIGS. **2**A and **2**B, the rotatable transmission shaft **20** of the engine **10** extends through the inner passage **33** of the strut **30** and through the first and second openings **34**A,**34**B. The transmission shaft **20** is shown in FIG. **2**A through a cut-away portion of the strut **30**. Some or all of the transmission shaft **20** is disposed within the strut **30** and extends through the openings **34**A,**34**B of the strut **30**. In the depicted embodiment where the first and second openings **34**A,**34**B are aligned along the substantially axial direction A, the transmission shaft **20** also extends through the strut **30** in the substantially axial direction A. Stated differently, a shaft axis **21**C of the transmission shaft **20** has, in the frame of reference of the engine **10**, an axial direction vector which is parallel to the center axis **17** of the engine **10** and which is predominant. Stated differently, the axial direction vector of the shaft axis **21**C has a magnitude that is much greater than the magnitude of the radial direction vector of the shaft axis **21**C. In FIG. **2**B, the shaft axis **21**C is normal to the plane of the illustrated cross-section.

The rotatable transmission shaft **20** therefore extends across the radial air inlet **11** by extending through the interior of the radial strut **30** in the air inlet duct **21**. By being housed within the strut **30**, the transmission shaft **20** is shielded from the flow of air through the air inlet **11**, which helps to minimize losses. A drive system is thus formed by the transmission shaft **20** extending through one of the inlet radial struts **30** of the gas turbine engine **10**, and facilitates the transfer of power through the radial inlet strut **30**.

The transmission shaft **20** is rotationally supported by bearings **37**. In the embodiment of FIG. **2**A, the transmission shaft **20** is supported by first and second bearings **37**A,**37**B. Each bearing **37**A,**37**B is located outside the inlet duct **21**. More particularly, the first bearing **37**A is disposed on a side of one of the annular walls **22**A outside the inlet duct **21** adjacent to the strut **30**. The second bearing **37**B is disposed on a side of the other annular wall **22**B outside the inlet duct **21** adjacent to the strut **30**. The bearings **37**A,**37**B are, in the depicted embodiment, provided as close as possible to the inlet duct **21**. The first and second bearings **37**A,**37**B are axially offset from one another along the center axis **17**. The bearings **37**A,**37**B are aligned along the substantially axial direction A. The first and second bearings **37**A,**37**B are located at the same radial distance from the center axis **17** of the engine **10**. Each bearing **37**A,**37**B is mounted to one of the walls **22**A,**22**B of the inlet duct **21**. More particularly, a bracket **38** mounts each bearing **37**A,**37**B to a corresponding wall **22**A,**22**B of the inlet duct **21**. In an alternate embodiment, each bearing **37**A,**37**B is mounted directly to the strut **30**. In the depicted embodiment, none of the bearings **37**A,**37**B are provided in the strut **30**. In an alternate embodiment, one or more of the bearings **37** is provided within the inner passage **33** of the strut **30**. An example of such a bearing **37** includes a journal bearing.

Providing the bearings **37**A,**37**B on either side of the strut **30** helps the transmission shaft **20** sizing criteria to be focused on power rather than rotor dynamics. This may contribute to lowering the outside diameter (OD) of the transmission shaft **20**, thereby helping to minimize the size of the strut **30** required to house the transmission shaft **20**, and thus minimize any losses associated with the strut **30**.

Referring to FIGS. **2**A and **2**B, there is also disclosed a method of operating the engine **10**. The method includes drawing air into the air inlet **11** from a radially-outer portion to a radially-inner portion of the air inlet **11**. The air inlet **11** has circumferentially spaced-apart struts **30**. The method also includes driving one or more rotatable loads **36** of the engine **10** with the transmission shaft **20**. The transmission shaft **20** extends across the air inlet **20** and through one of the struts **30**.

The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departing from the scope of the invention disclosed. For example, although the engine **10** is shown as being a turboprop, it will be appreciated that the engine **10** can have suitable (through-flow from front to rear) by-pass ducting and be used as a turbofan as well. Still other modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

The invention claimed is:

1. A gas turbine engine, comprising:

a compressor section and a turbine section drivingly engaged with a drive shaft, the drive shaft being rotatable about a center axis of the gas turbine engine;

a radial air inlet in fluid communication with the compressor section, the radial air inlet having an inlet duct defined between two axially-spaced radially-extending annular walls and having a plurality of circumferentially-spaced axially-extending struts extending between the annular walls adjacent a radially-outer portion of the air inlet, at least one of the struts having an internal passage extending between a first opening in a forward end of the strut and a second opening in an aft end of the strut, the first and second openings being axially spaced apart; and

a transmission shaft extending through the internal passage of said strut.

2. The gas turbine engine as defined in claim **1**, wherein the first and second openings in said strut are aligned along a substantially axial direction, the transmission shaft extending through the openings in the substantially axial direction.

3. The gas turbine engine as defined in claim **1**, wherein the transmission shaft is mechanically coupled at a first end to a first rotatable load of the gas turbine engine disposed on one side of the inlet duct, and mechanically coupled at a second end to a second rotatable load disposed on another side of the inlet duct, the first load includes the drive shaft and the second rotatable load includes an accessory gearbox of the gas turbine engine, the drive shaft being disposed forward of the radial air inlet, and the accessory gearbox being disposed aft of the radial air inlet.

4. The gas turbine engine as defined in claim **3**, wherein the first rotatable load includes a tower shaft mechanically coupled at a first end to the first end of the transmission shaft, a second end of the tower shaft being mechanically coupled to the drive shaft.

5. The gas turbine engine as defined in claim **1**, further comprising first and second bearings supporting the transmission shaft, the first bearing disposed on a side of one of the annular walls outside the inlet duct adjacent to said strut, and the second bearing disposed on a side of the other annular wall outside the inlet duct adjacent to said strut.

6. The gas turbine engine as defined in claim **5**, wherein the first and second bearings are aligned along a substantially axial direction.

7. The gas turbine engine as defined in claim **1**, wherein the inlet duct includes an air opening being defined between the annular walls at the radially outer portion of the air inlet, the air opening extending through an outermost surface of the engine.

8. The gas turbine engine as defined in claim **1**, wherein at least one of the struts has an airfoil shape.

9. The gas turbine engine as defined in claim **8**, wherein said strut having the airfoil shape includes a leading edge and a trailing edge, the trailing edge being radially closer to the center axis than the leading edge, a chord of said strut extending in a substantially radial direction between the leading and trailing edges.

10. The gas turbine engine as defined in claim **1**, wherein each strut has an axial span defined between the annular walls of the inlet duct, and a radial span defined between an outer edge and an inner edge, the inner edge being radially closer to the center axis than the outer edge.

11. A drive system for a gas turbine engine, comprising:

an inlet duct having two annular walls disposed about a center axis, each wall extending between an outer portion and an inner portion, the inner portion being radially closer to the center axis than the outer portion, the walls being axially spaced apart and defining an annular air passage between the walls;

a plurality of struts being circumferentially spaced-apart within the inlet duct, each strut extending between the annular walls and through the annular air passage, one of the struts having an internal passage extending between a first opening in a forward end of the strut and a second opening in an aft end of the strut, the first and second openings being axially spaced apart; and

a transmission shaft extending through the internal passage and the first and second openings of said strut.

12. The drive system as defined in claim **11**, wherein the first and second openings in said strut are aligned along a substantially axial direction, the transmission shaft extending through the openings in the substantially axial direction.

13. The drive system as defined in claim **11**, wherein at least one of the struts has an airfoil shape.

14. The drive system as defined in claim **13**, wherein said strut having the airfoil shape includes a leading edge and a trailing edge, the trailing edge being radially closer to the center axis than the leading edge, a chord of said strut extending in a substantially radial direction between the leading and trailing edges.

15. The drive system as defined in claim **11**, wherein each strut has an axial span defined between the annular walls of the inlet duct, and a radial span defined between an outer edge and an inner edge, the inner edge being radially closer to the center axis than the outer edge.

16. A method of operating a gas turbine engine, comprising:

drawing air from a radially-outer portion of a radial air inlet of the engine to a radially-inner portion of the radial air inlet, the radial air inlet having circumferentially spaced-apart struts; and

driving a rotatable load of the engine with a transmission shaft extending across the radial air inlet and through one of the struts.

17. The method as defined in claim **16**, wherein driving the rotatable load includes driving the rotatable load with the transmission shaft being oriented in a substantially axial direction.

18. The method as defined in claim **16**, further comprising supporting the transmission shaft at each of axially-opposed sides of the radial air inlet.

19. The method as defined in claim **16**, wherein driving the rotatable load includes driving an accessory gearbox of the engine with the transmission shaft.

20. The method as defined in claim **19**, wherein driving the accessory gearbox includes driving a tower shaft of the engine with a drive shaft of the engine, and driving the transmission shaft with the tower shaft.

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