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(54) **HIGH AND LOW SPOOL ACCESSORY GEARBOX DRIVE**

(71) Applicant: **United Technologies Corporation**, Farmington, CT (US)

(72) Inventors: **Gabriel L. Suciu**, Glastonbury, CT (US); **Hung Duong**, Unionville, CT (US); **Jonathan F. Zimmitti**, Glastonbury, CT (US); **William G. Sheridan**, Southington, CT (US); **Michael E. McCune**, Colchester, CT (US); **Brian Merry**, Andover, CT (US)

(73) Assignee: **United Technologies Corporation**, Farmington, CT (US)

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F02C 7/36	(2006.01)

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See application file for complete search history.

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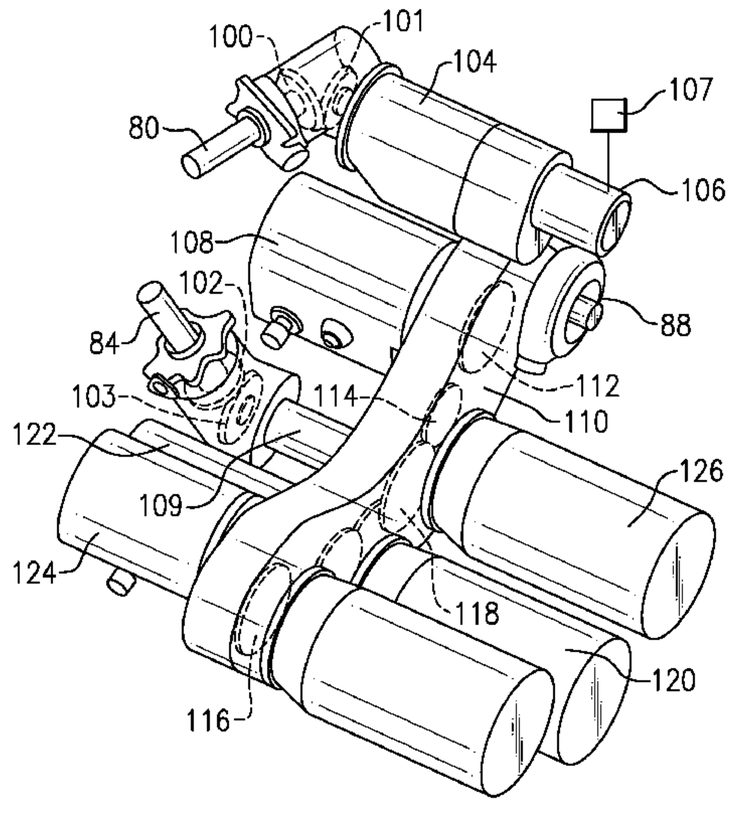
Primary Examiner — James A English

(74) *Attorney, Agent, or Firm* — Carlson, Gaskey & Olds, P.C.

(57) **ABSTRACT**

A gas turbine engine comprises a low speed spool and a high speed spool, with each of the spools including a turbine to drive a respective one of the spools. The high speed spool rotates at a higher speed than the low speed spool. A high speed power takeoff is driven to rotate by the high speed spool, and a low speed power takeoff is driven to rotate by the low speed spool. The high speed power takeoff drives a starter generator and a permanent magnet alternator. The low speed power takeoff drives a variable frequency generator.

14 Claims, 2 Drawing Sheets



(52) **U.S. Cl.**
CPC .. *F05D 2220/764* (2013.01); *F05D 2220/768* (2013.01); *F05D 2270/023* (2013.01)

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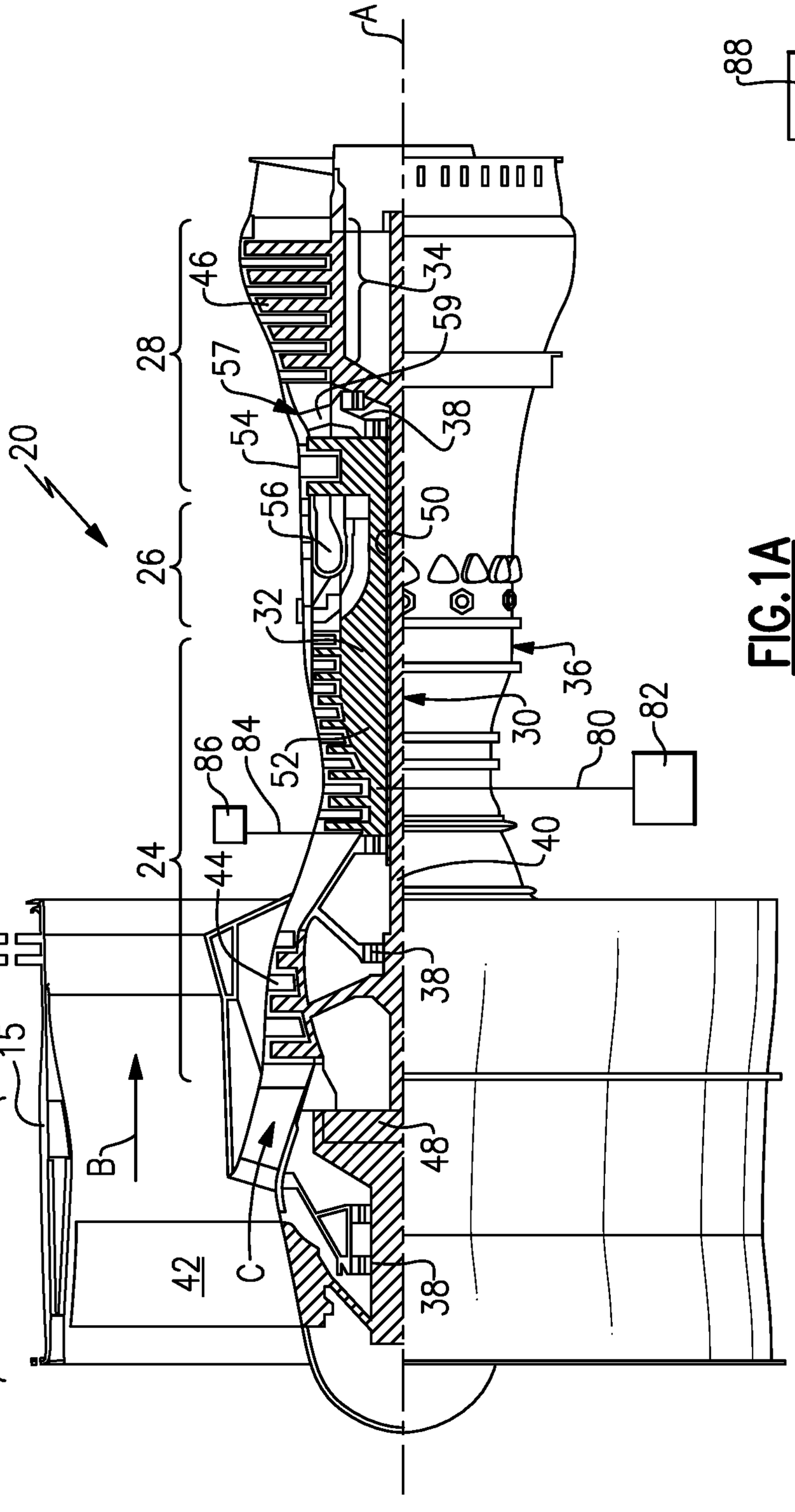

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FIG.1A

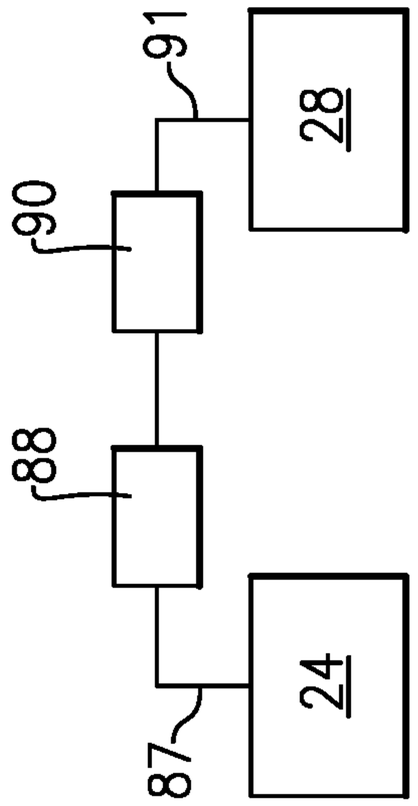

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FIG.1B

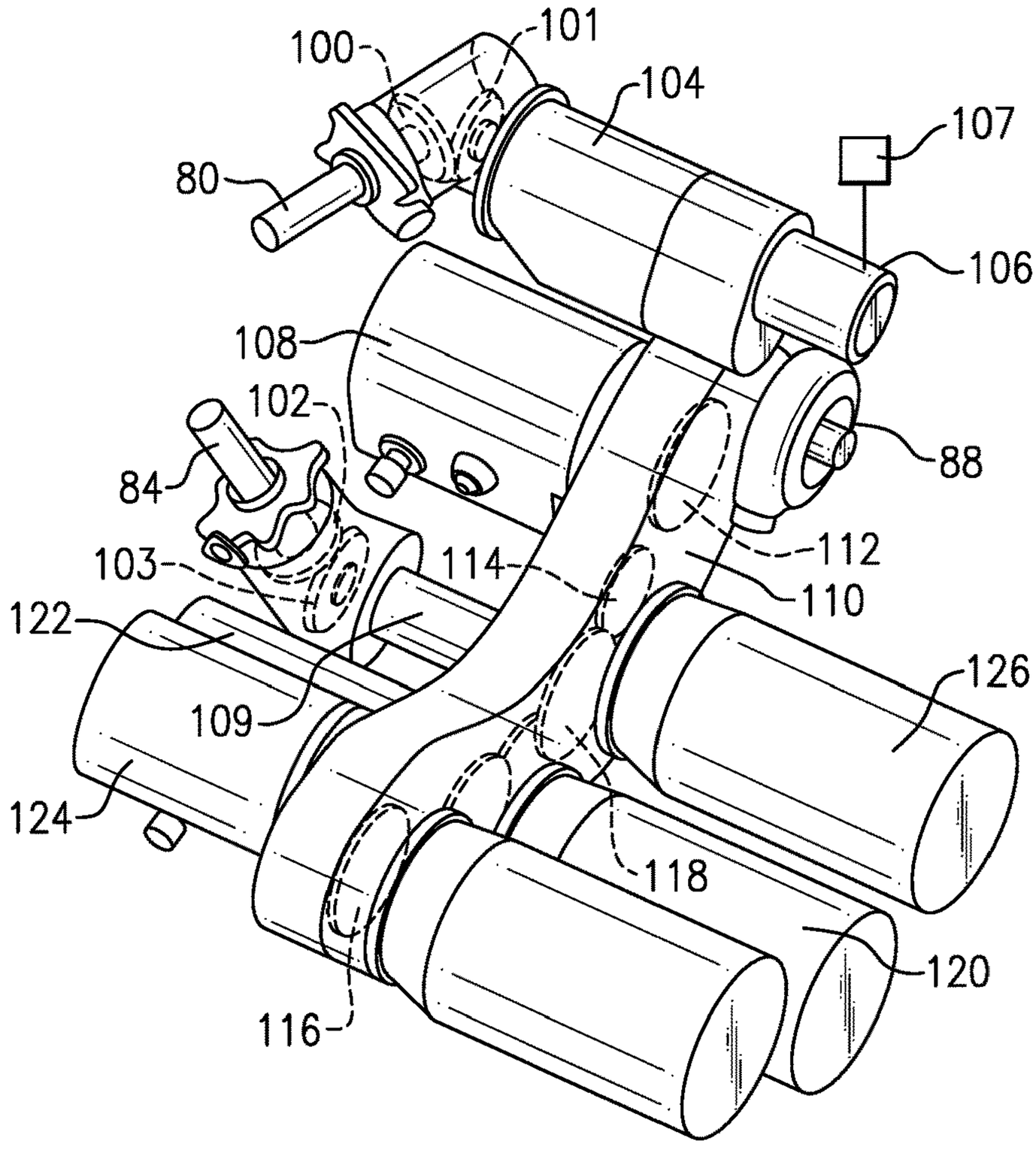

100
101
104
107
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FIG.2A

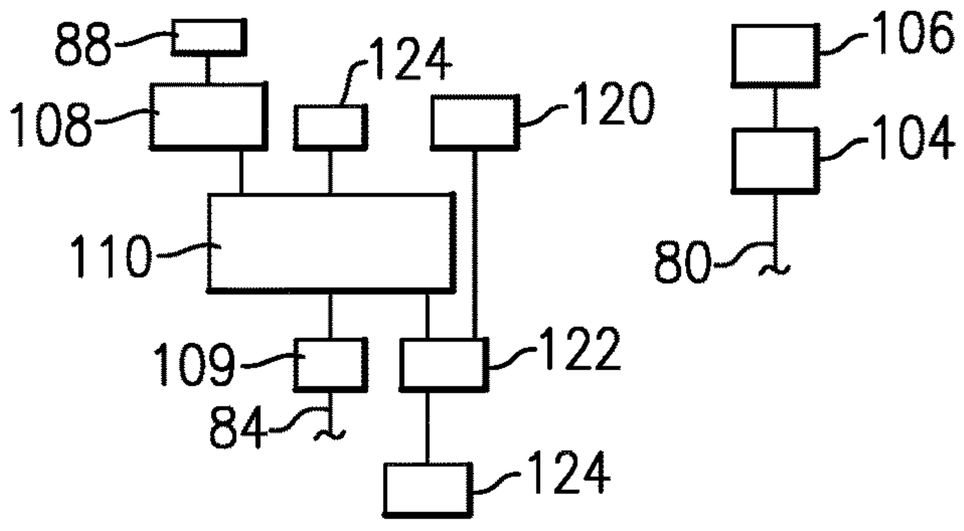

88
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FIG.2B

HIGH AND LOW SPOOL ACCESSORY GEARBOX DRIVE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/484,376 filed on Apr. 11, 2017.

BACKGROUND OF THE INVENTION

This application relates to an accessory gearbox drive for a gas turbine engine wherein a low spool drives a variable frequency generator along with other components.

Gas turbine engines are known and typically include a pair of spools.

A fan delivers air into a bypass duct as propulsion air and also delivers air into a core engine. Air passing into the core engine reaches a low pressure compressor and then passes to a high pressure compressor. The air compressed by the high pressure compressor is delivered into a combustor where it is mixed with fuel and ignited. Products of this combustion pass downstream over a high pressure turbine rotor.

The high pressure turbine rotor is driven to rotate and rotates the high pressure compressor. A low pressure turbine rotor is downstream of the high pressure turbine and is also driven to rotate. The low pressure turbine rotates with the low pressure compressor as a low speed spool. Further, the low pressure turbine may drive the fan rotor through a gear reduction.

A number of accessories, such as generators, starters, pumps, etc., are powered by accessory gearboxes which are driven to rotate with either the high or low pressure spool. Traditionally, the high pressure spool has driven most of these accessories.

However, this reduces the overall efficiency of the engine. Thus, it has been proposed to drive at least some accessories off the low speed spool.

SUMMARY OF THE INVENTION

In a featured embodiment, a gas turbine engine comprises a low speed spool and a high speed spool, with each of the spools including a turbine to drive a respective one of the spools. The high speed spool rotates at a higher speed than the low speed spool. A high speed power takeoff is driven to rotate by the high speed spool, and a low speed power takeoff is driven to rotate by the low speed spool. The high speed power takeoff drives a starter generator and a permanent magnet alternator. The low speed power takeoff drives a variable frequency generator.

In another embodiment according to the previous embodiment, a first transmission is driven by the low speed or power takeoff, and the first transmission drives the variable frequency generator at a plurality of speeds.

In another embodiment according to any of the previous embodiments, the first transmission also drives a hydraulic pump at one of a plurality of distinct speeds relative to an input speed from the low speed power takeoff.

In another embodiment according to any of the previous embodiments, a controller controls the first transmission to achieve a desired input speed for the variable frequency generator.

In another embodiment according to any of the previous embodiments, the controller also controls the first transmission to drive a hydraulic pump at a desired speed.

In another embodiment according to any of the previous embodiments, the low speed power takeoff also drives an oil pump.

In another embodiment according to any of the previous embodiments, cooling air is tapped from a location in a compressor section which is upstream of a most downstream location in the compressor section and the tapped air is passed through a heat exchanger and through a cooling air compressor.

In another embodiment according to any of the previous embodiments, the low speed spool power takeoff drives the cooling air compressor.

In another embodiment according to any of the previous embodiments, a second transmission is driven by the low power takeoff to drive the cooling air compressor at a desired speed.

In another embodiment according to any of the previous embodiments, the second transmission is a three-speed transmission.

In another embodiment according to any of the previous embodiments, the controller controls the second transmission to achieve a desired speed for the cooling air compressor.

In another embodiment according to any of the previous embodiments, cooling air is tapped from a location in a compressor section which is upstream of a most downstream location in the compressor section and the tapped air is passed through a heat exchanger and through a cooling air compressor.

In another embodiment according to any of the previous embodiments, the low speed spool power takeoff drives the cooling air compressor.

In another embodiment according to any of the previous embodiments, a second transmission is driven by the low power takeoff to drive the cooling air compressor at a desired speed.

In another embodiment according to any of the previous embodiments, the second transmission is a three-speed transmission.

In another embodiment according to any of the previous embodiments, the controller controls the second transmission to achieve a desired speed for the cooling air compressor.

In another embodiment according to any of the previous embodiments, the controller controls the first transmission to achieve a desired input speed tor the variable frequency generator.

In another embodiment according to any of the previous embodiments, the controller also controls the first transmission to drive a hydraulic pump at a desired speed.

In another embodiment according to any of the previous embodiments, cooling air is tapped from a location in a compressor section which is upstream of a most downstream location in the compressor section and the tapped air is passed through a heat exchanger and through a cooling air compressor.

In another embodiment according to any of the previous embodiments, a second transmission is driven by the low power takeoff to drive the cooling air compressor at a desired speed.

These and other features may be best understood from the following drawings and specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A schematically shows a gas turbine engine.

FIG. **1**B shows an optional feature for delivering cooling air to a turbine section.

FIG. **2**A shows an accessory drive arrangement.

FIG. **2**B schematically shows the arrangement of FIG. **2**A.

DETAILED DESCRIPTION

FIG. **1**A schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section **22** drives air along a bypass flow path B in a bypass duct defined within a nacelle **15**, while the compressor section **24** drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.

The exemplary engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided, and the location of bearing systems **38** may be varied as appropriate to the application.

The low speed spool **30** generally includes an inner shaft **40** that interconnects a fan **42**, a first (or low) pressure compressor **44** and a first (or low) pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive the fan **42** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **50** that interconnects a second (or high) pressure compressor **52** and a second (or high) pressure turbine **54**. A combustor **56** is arranged in exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. A mid-turbine frame **57** of the engine static structure **36** is arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The mid-turbine frame **57** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.

The core airflow is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded over the high pressure turbine **54** and low pressure turbine **46**. The mid-turbine frame **57** includes airfoils **59** which are in the core airflow path C. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of combustor section **26** or even aft of turbine section **28**, and fan section **22** may be positioned forward or aft of the location of gear system **48**.

The engine **20** in one example is a high-bypass geared aircraft engine. In a further example, the engine **20** bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture **48** is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine **46** has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine **20** bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor **44**, and the low pressure turbine **46** has a pressure ratio that is greater than about five 5:1. Low pressure turbine **46** pressure ratio is pressure measured prior to inlet of low pressure turbine **46** as related to the pressure at the outlet of the low pressure turbine **46** prior to an exhaust nozzle. The geared architecture **48** may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section **22** of the engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet (10,668 meters). The flight condition of 0.8 Mach and 35,000 ft (10,668 meters), with the engine at its best fuel consumption—also known as "bucket cruise Thrust Specific Fuel Consumption ('TSFC')"—is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. "Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane ("FEGV") system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(\text{Tram}\ ^\circ\ \text{R})/(518.7^\circ\ \text{R})]^{0.5}$. The "Low corrected fan tip speed" as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second (350.5 meters/second).

FIG. **1**A also shows a power takeoff or power shaft **80** being driven to rotate with the high speed spool **32** and driving accessory gears **82**. At the same time, a second power takeoff or power shaft **84** rotates with the low speed spool **30** and drives additional accessories shown schematically at **86**.

FIG. **1**B shows an optional feature. A tap **87** taps cooling air from a location in the compressor section **24** which is upstream of a downstream most point in the compressor section. Tapping the air from this more upstream location increases the efficiency of the engine compared to tapping the highly compressed air downstream of the last stage of the high pressure compressor **52**. However, this tapped air is not at a sufficiently high pressure to necessarily enter the turbine section **28** for cooling. Thus, a cooling air compressor **88** is provided to increase the pressure of the air from tap **87**. Downstream of the compressor **88**, the air passes through a heat exchanger **90** where it is cooled by air such as the bypass air B. Downstream of the heat exchanger **90**, the air passes into a line **91** and moves to cool components in the turbine section **28**. Such systems have been generally proposed.

FIG. **2**A shows an arrangement for driving a number of accessories. As shown in FIG. **2**A, the shaft **80** drives a bevel gear **100** which drives a second bevel gear **101** which rotates to drive accessories, as will be explained below.

The shaft **84** drives a gear **102** to drive a gear **103** which is associated with the shaft for driving accessories driven by the low speed shaft **84**.

As shown, the shaft driven by gear **101** includes a starter generator **104** and a permanent magnet alternator **106**. These components are necessary for initially starting the gas turbine engine. The permanent magnet alternator is necessary to start or "fire up" a controller **107** for the engine, which is shown schematically. The starter generator **104** begins rotation of the engine at start-up, as is known.

By minimizing the number of components driven by the high speed driven shaft **80**, the efficiency of the overall engine is increased.

The gear **103** drives a shaft **109** drive a gearbox **110**, which drives a number of components through a plurality of gears **112**, **114**, **116**, **118**. The gears allow the various accessories to be driven by the shaft **84** to rotate at different speeds.

As shown, the cooling air compressor **88** may be driven by the shaft **84**. In the disclosed embodiment, the gear **112** drives a transmission **108**, which actually drives the compressor **88** at a desired speed. The use of the transmission **108** allows the speed of the compressor **88** to be kept closer to a constant value than it might otherwise see from the input at shaft **84**. That is, it is known that the input from the high speed spool **80** will be closer to constant than would be the input speed to the shaft **84**. The use of the transmission, which may be a three-speed transmission **108**, allows the ultimate speed of the compressor **88** to be kept closer to a desired constant value.

In addition, a variable frequency generator **120** is driven by a transmission **122**, which may also be a three-speed transmission. Here again, the transmission **122** keeps the speed of the variable frequency generator **120** closer to constant such that the output of the generator will be more readily useable.

In addition, a hydraulic pump **124** is provided for supplying hydraulic fluid across the engine. Hydraulic pump **124** may also be driven by the three-speed transmission **122**.

In addition, an oil pump **126** is driven by the input shaft **109** and may be driven through the several gears in the gearbox **110** to achieve a desired speed.

FIG. **2**B schematically shows the drive inputs into the several components. As shown, the shaft **80** drives the starter generator **104** and permanent magnet alternator **106** on a common shaft.

The drive shaft **109** is driven by shaft **84**, and drives a plurality of gears in a gearbox **110** to drive a three-speed transmission **122** to drive a variable frequency generator **120**.

Similarly, the gearbox **110** drives a three-speed transmission **108** to ultimately drive the cooling air compressor **88**.

The controller **107** may also control the three-speed transmissions **108** and **122** to achieve desired speeds for the cooling compressor **88**, variable frequency generator **120** and pump **124**. A worker of ordinary skill in the art would recognize how to control the transmissions **108** and **122** to achieve this goal. Also, as mentioned, the transmission **122** controls the speed of the hydraulic pump **124**. Further, the shaft **109** also drives the pump **126**.

Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

The invention claimed is:

1. A gas turbine engine comprising:

a low speed spool and a high speed spool, with each of said spools including a turbine to drive a respective one of said spools;

said high speed spool rotating at a higher speed than said low speed spool;

a high speed power takeoff driven to rotate by said high speed spool, and a low speed power takeoff driven to rotate by said low speed spool;

said high speed power takeoff driving a starter generator and a permanent magnet alternator;

said low speed power takeoff driving a variable frequency generator;

wherein a first transmission is driven by said low speed power takeoff, and said first transmission driving said variable frequency generator at a plurality of speeds; and

wherein a controller controls said first transmission to achieve a desired input speed for said variable frequency generator.

2. The gas turbine engine as set forth in claim **1**, wherein said first transmission also driving a hydraulic pump at one of a plurality of distinct speeds relative to an input speed from said low speed power takeoff.

3. The gas turbine engine as set forth in claim **2**, wherein said controller also controls said first transmission to drive a hydraulic pump at a desired speed.

4. The gas turbine engine as set forth in claim **3**, wherein said low speed power takeoff also driving an oil pump.

5. The gas turbine engine as set forth in claim **1**, wherein said low speed spool driving a fan rotor through a gear reduction.

6. The gas turbine engine as set forth in claim **5**, wherein said first transmission also driving a hydraulic pump at one of a plurality of distinct speeds relative to an input speed from said low speed power takeoff.

7. The gas turbine engine as set forth in claim **6**, wherein said controller also controls said first transmission to drive a hydraulic pump at a desired speed.

8. The gas turbine engine as set forth in claim **7**, wherein said low speed power takeoff also driving an oil pump.

9. The gas turbine engine as set forth in claim **8**, wherein a gear ratio of said gear reduction is greater than 2.3.

10. The gas turbine engine as set forth in claim **5**, wherein said controller also controls said first transmission to drive a hydraulic pump at a desired speed.

11. The gas turbine engine as set forth in claim **5**, wherein a gear ratio of said gear reduction is greater than 2.3.

12. The gas turbine engine as set forth in claim **5**, wherein said low speed power takeoff also driving an oil pump.

13. The gas turbine engine as set forth in claim **1**, wherein said low speed power takeoff also driving an oil pump.

14. The gas turbine engine as set forth in claim **1**, wherein said control is provided with power at start up by said permanent magnet alternator.

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