



US 20170122219A1

(19) **United States**(12) **Patent Application Publication**
Hasel et al.(10) **Pub. No.: US 2017/0122219 A1**(43) **Pub. Date: May 4, 2017**(54) **GAS TURBINE ENGINE COMPRESSOR
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Diego, CA (US)(51) **Int. Cl.****F02C 7/36** (2006.01)**F02C 7/06** (2006.01)**F02K 3/06** (2006.01)**F02C 9/18** (2006.01)**F01D 21/00** (2006.01)**F01D 9/02** (2006.01)**F01D 25/24** (2006.01)**F02C 3/06** (2006.01)**F01D 5/06** (2006.01)(52) **U.S. Cl.**CPC **F02C 7/36** (2013.01); **F02C 3/06**(2013.01); **F02C 7/06** (2013.01); **F02K 3/06**(2013.01); **F01D 5/06** (2013.01); **F01D****21/003** (2013.01); **F01D 9/02** (2013.01);**F01D 25/24** (2013.01); **F02C 9/18** (2013.01);**F05D 2220/323** (2013.01); **F05D 2240/35**(2013.01); **F05D 2260/40311** (2013.01)(21) Appl. No.: **15/411,147**(22) Filed: **Jan. 20, 2017****Related U.S. Application Data**

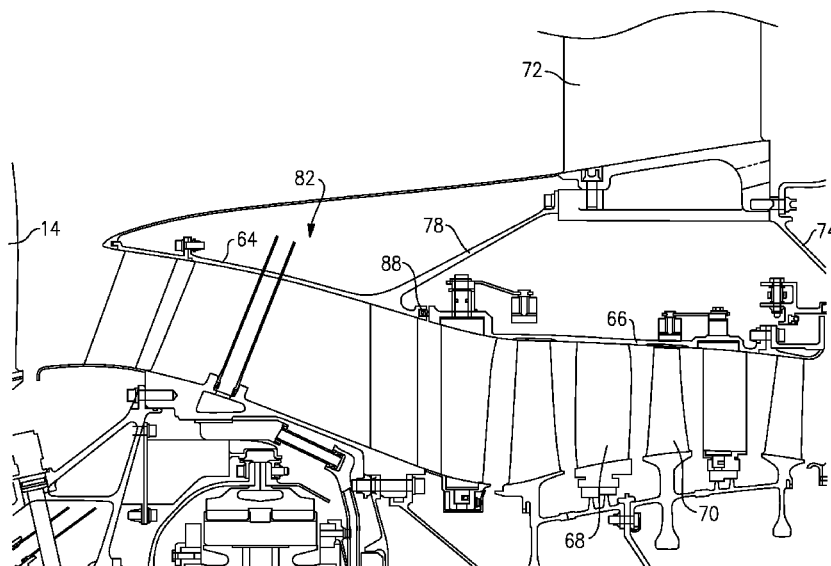
(63) Continuation of application No. 15/184,253, filed on Jun. 16, 2016, which is a continuation of application No. 14/179,640, filed on Feb. 13, 2014, now abandoned, which is a continuation-in-part of application No. 13/869,057, filed on Apr. 24, 2013, now Pat. No. 9,121,367, which is a continuation of application No. 13/590,273, filed on Aug. 21, 2012, now Pat. No. 8,449,247, which is a continuation of application No. 13/418,457, filed on Mar. 13, 2012, now Pat. No. 8,277,174, Continuation-in-part of application No. 13/337,354, filed on Dec. 27, 2011, now Pat. No. 8,337,147, which is a continuation-in-part of application No. 13/294,492, filed on Nov. 11, 2011, now Pat. No. 8,596,965, which is a continuation of application No. 11/858,988, filed on Sep. 21, 2007, now Pat. No. 8,075,261.

(60) Provisional application No. 61/604,646, filed on Feb. 29, 2012.

(57)

ABSTRACT

A gas turbine engine includes, among other things, a fan section, a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine, the bypass ratio being greater than 8 at cruise power. A gear arrangement drives the fan section. A guide vane includes a forward attachment, the forward attachment positioned aft of a plumbing connection area. A compressor section includes both a first compressor and a second compressor. A lubrication system and a compressed air system are in fluid communication with the gear arrangement. A turbine section drives the gear arrangement, and includes a low pressure turbine. An overall pressure ratio is provided by the combination of a pressure ratio across the first compressor and a pressure ratio across the second compressor, and greater than about 50, measured at sea level and at a static, full-rated takeoff power. The pressure ratio across the second compressor is greater than about 7.



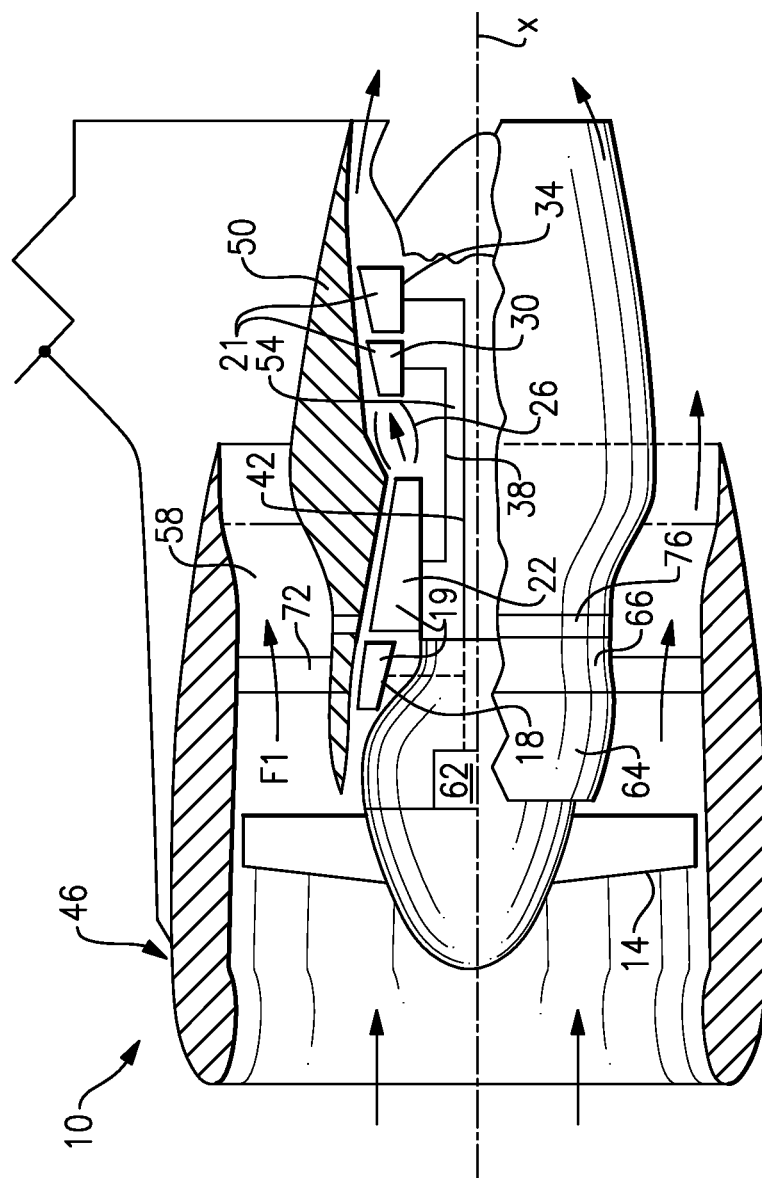


FIG. 1

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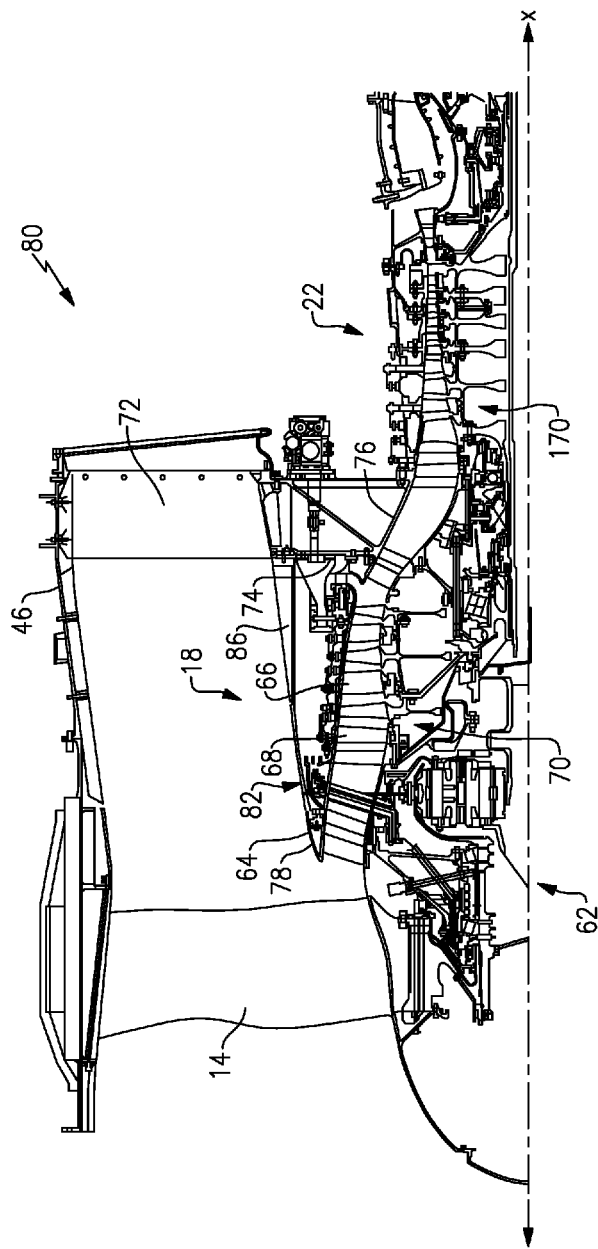


FIG. 2
Prior Art

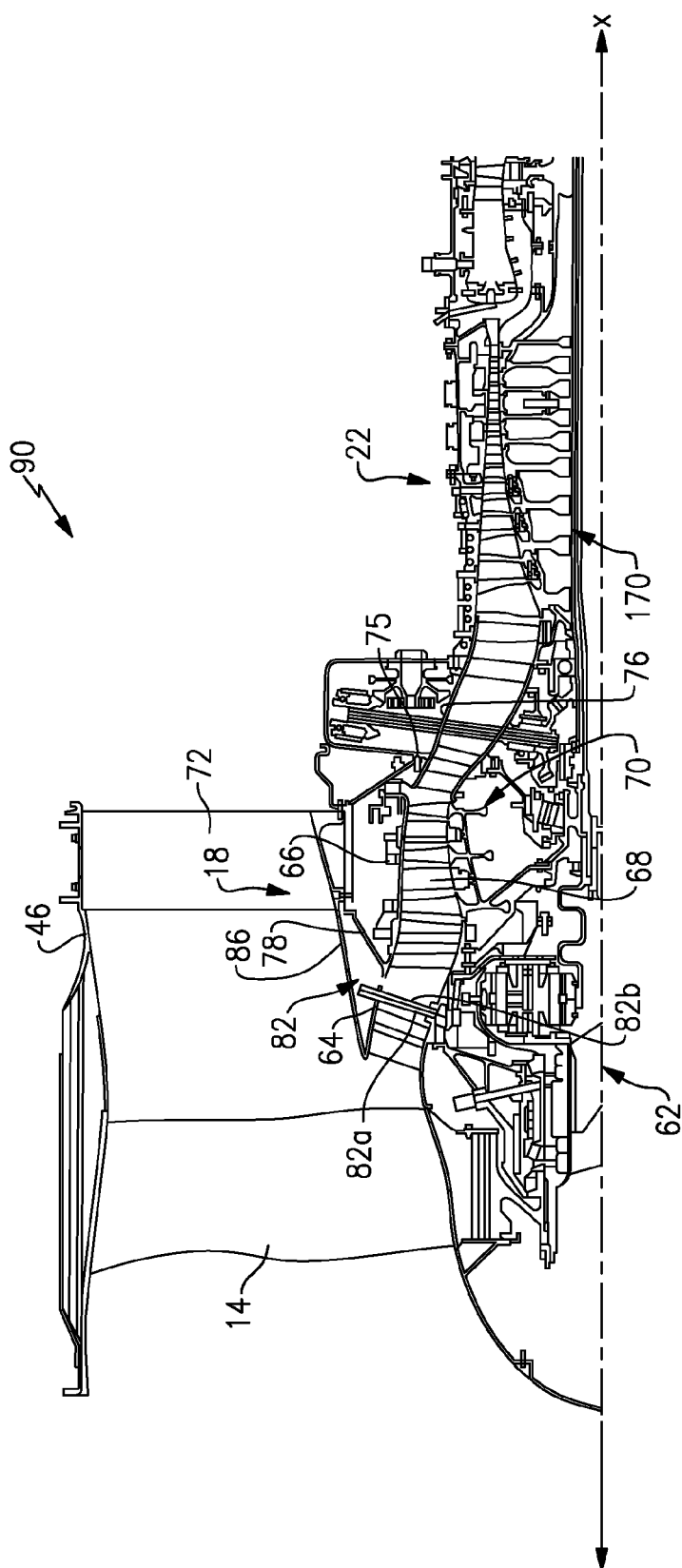


FIG. 3

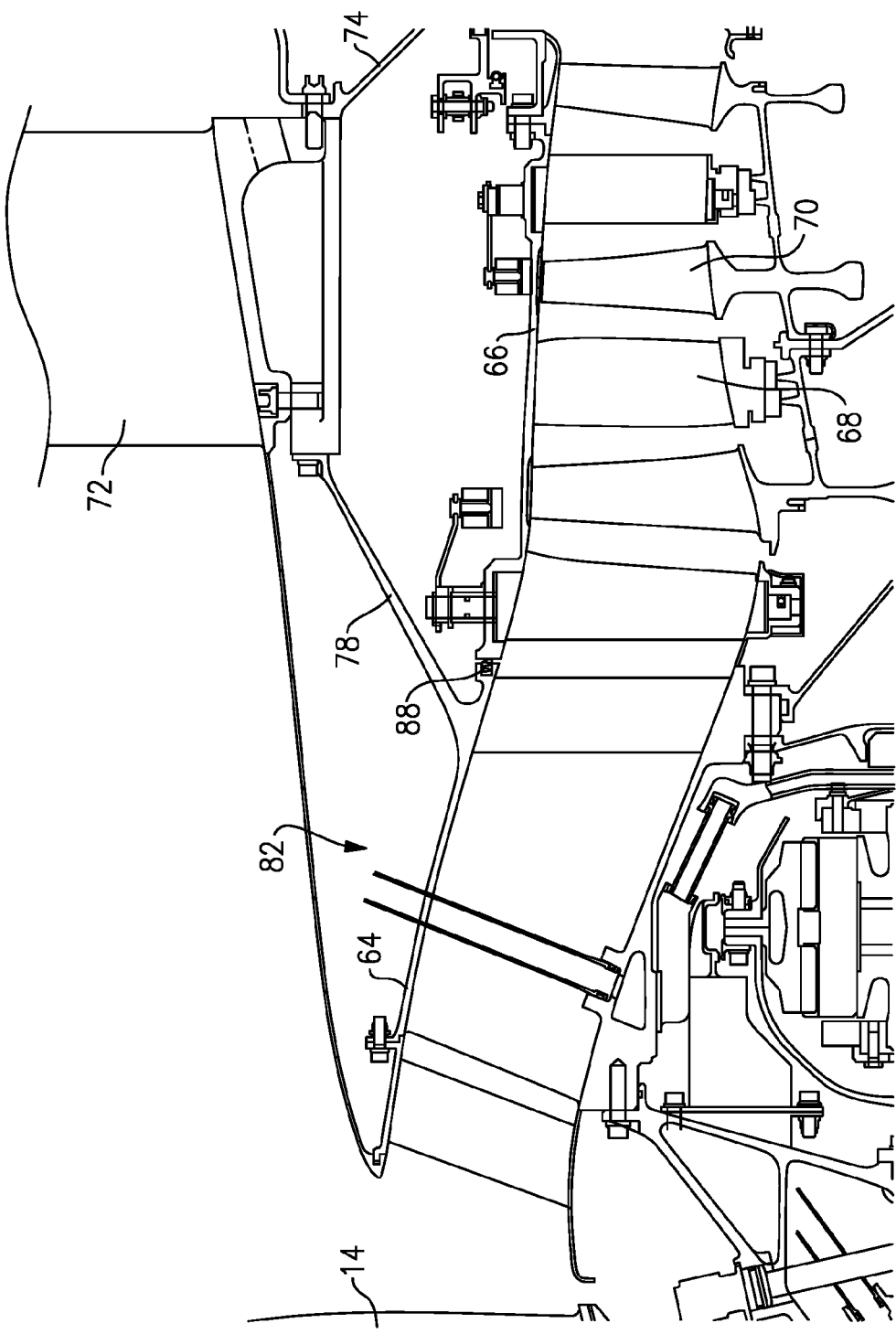


FIG. 4

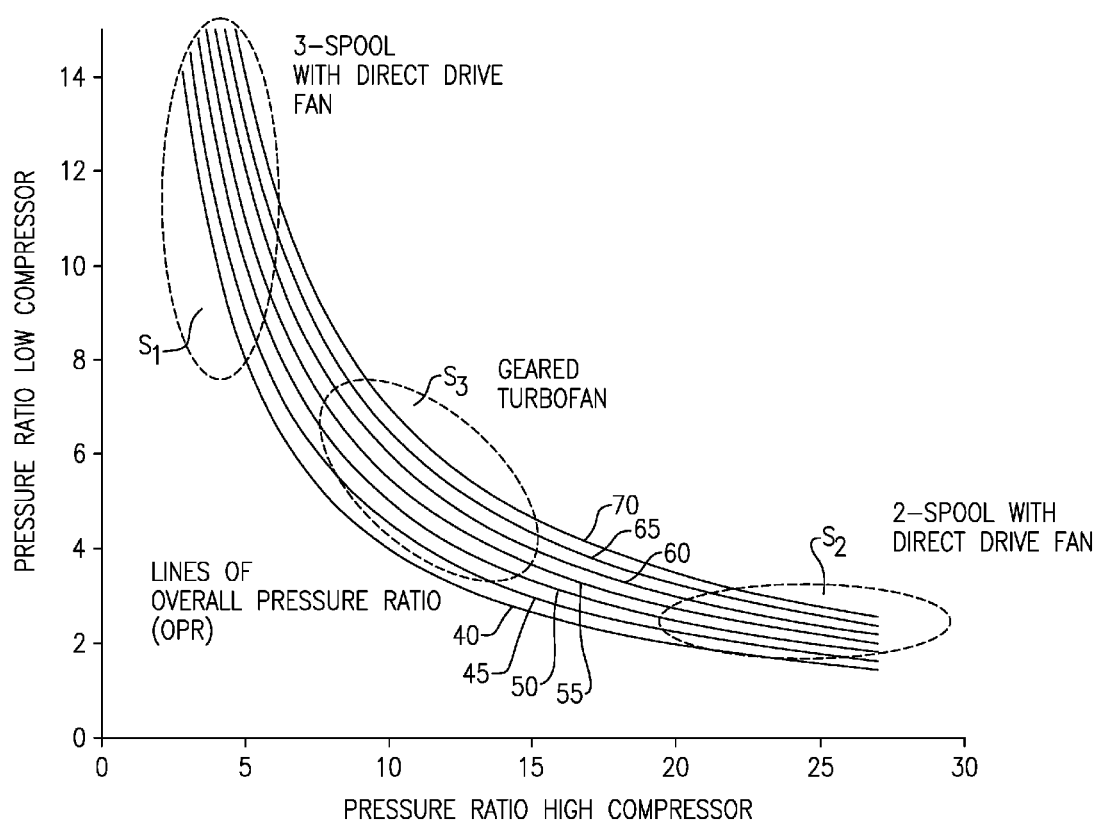


FIG.5

GAS TURBINE ENGINE COMPRESSOR ARRANGEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. application Ser. No. 15/184,253, filed Jun. 16, 2016, which is a continuation of U.S. application Ser. No. 14/179,640, filed Feb. 13, 2014, which is a continuation-in-part of U.S. application Ser. No. 13/869,057, filed Apr. 24, 2013 (now U.S. Pat. No. 9,121,367), which is a continuation of U.S. application Ser. No. 13/590,273, filed Aug. 21, 2012, which is a continuation of U.S. application Ser. No. 13/418,457, filed Mar. 13, 2012 (now U.S. Pat. No. 8,277,174), which claims priority to U.S. Provisional Application 61/604,646, filed Feb. 29, 2012, and is a continuation-in-part of U.S. patent application Ser. No. 13/337,354, filed on Dec. 27, 2011 (now U.S. Pat. No. 8,337,147), and entitled "Gas Turbine Engine Compressor Arrangement," which was a continuation-in-part of U.S. patent application Ser. No. 13/294,492 filed on Nov. 11, 2011, and entitled "Gas Turbine Engine Compressor Case Mounting Arrangement," which was a continuation of U.S. patent application Ser. No. 11/858,988 filed on Sep. 21, 2007 (now U.S. Pat. No. 8,075,261), and entitled "Gas Turbine Engine Compressor Case Mounting Arrangement."

BACKGROUND

[0002] The present invention relates generally to a gas turbine engine.

[0003] Gas turbine engines are known, and typically include a compressor for compressing air and delivering it downstream into a combustion section. A fan may move air to the compressor. The compressed air is mixed with fuel and combusted in the combustion section. The products of this combustion are then delivered downstream over turbine rotors, which are driven to rotate and provide power to the engine.

[0004] The compressor includes rotors moving within a compressor case to compress air. Maintaining close tolerances between the rotors and the interior of the compressor case facilitates air compression.

[0005] Gas turbine engines may include an inlet case for guiding air into a compressor case. The inlet case is mounted adjacent the fan section. Movement of the fan section, such as during in-flight maneuvers, may move the inlet case. Some prior gas turbine engine designs support a front portion of the compressor with the inlet case while an intermediate case structure supports a rear portion of the compressor. In such an arrangement, movement of the fan section may cause at least the front portion of the compressor to move relative to other portions of the compressor.

[0006] Disadvantageously, relative movement between portions of the compressor may vary rotor tip and other clearances within the compressor, which can decrease the compression efficiency. Further, supporting the compressor with the inlet case may complicate access to some plumbing connections near the inlet case.

[0007] It would be desirable to reduce relative movement between portions of the compressor and to simplify accessing plumbing connection in a gas turbine engine.

[0008] Traditionally, a fan and low pressure compressor have been driven in one of two manners. First, one type of

known gas turbine engine utilizes three turbine sections, with one driving a high pressure compressor, a second turbine rotor driving the low pressure compressor, and a third turbine rotor driving the fan. Another typical arrangement utilizes a low pressure turbine section to drive both the low pressure compressor and the fan.

[0009] Recently it has been proposed to incorporate a gear reduction to drive the fan such that a low pressure turbine can drive both the low pressure compressor and the fan, but at different speeds.

SUMMARY

[0010] A gas turbine engine according to an example of the present disclosure includes a fan section, a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine. The bypass ratio is greater than 8 at cruise power. A gear arrangement that drives the fan section defines a gear reduction ratio of greater than 2.3:1. A lubrication system and a compressed air system are in fluid communication with the gear arrangement. A compressor section includes both a low pressure compressor and a high pressure compressor. A guide vane includes a forward attachment, the forward attachment positioned aft of a plumbing connection area. A turbine section drives the gear arrangement. The turbine section includes a low pressure turbine with an inlet, an outlet, and a low pressure turbine pressure ratio greater than 5:1. The low pressure turbine pressure ratio is a ratio of a pressure measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle. An overall pressure ratio is provided by the combination of a pressure ratio across the low pressure compressor and a pressure ratio across the high pressure compressor, and is greater than about 50, measured at sea level and at a static, full-rated takeoff power. The pressure ratio across the high pressure compressor is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

[0011] In a further embodiment of any of the foregoing embodiments, the plumbing connection area is removable with the gear arrangement.

[0012] A further embodiment of any of the foregoing embodiments includes a low fan pressure ratio of less than about 1.45 measured across a fan blade alone. The bypass ratio is greater than 10.

[0013] In a further embodiment of any of the foregoing embodiments, the turbine section further comprises a two stage high pressure turbine.

[0014] In a further embodiment of any of the foregoing embodiments, the low pressure turbine is a four stage turbine.

[0015] In a further embodiment of any of the foregoing embodiments, the low pressure compressor is a three stage compressor.

[0016] In a further embodiment of any of the foregoing embodiments, the high pressure compressor is a nine stage compressor.

[0017] In a further embodiment of any of the foregoing embodiments, the low fan pressure ratio is less than 1.45.

[0018] In a further embodiment of any of the foregoing embodiments, the gear arrangement is a planetary gear system with a sun gear, a ring gear, and a plurality of orbiting planet gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear.

[0019] In a further embodiment of any of the foregoing embodiments, the pressure ratio across the low pressure compressor is less than 6, measured at sea level and at a static, full-rated takeoff power.

[0020] In a further embodiment of any of the foregoing embodiments, the plumbing connection area is removable with the gear arrangement.

[0021] A further embodiment of any of the foregoing embodiments includes a low fan pressure ratio of less than about 1.35 measured across a fan blade alone. The bypass ratio is greater than 10. The turbine section includes a two stage high pressure turbine, and the pressure ratio across the low pressure compressor is less than about 6, measured at sea level and at a static, full-rated takeoff power.

[0022] A gas turbine engine according to an example of the present disclosure includes a fan section, a low fan pressure ratio of less than about 1.45 measured across a fan blade alone, a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine. The bypass ratio is greater than about 8 at cruise power. A gear arrangement that drives the fan section has a gear system with a sun gear, a ring gear, and a plurality of intermediate gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear. A compressor section includes both a first compressor section and a second compressor section. A plumbing connection area provides access to at least one of compressed air from a compressed air system, or oil from a lubrication system. A guide vane has a forward attachment. The forward attachment is positioned aft of the plumbing connection area. A turbine section drives the gear arrangement. The turbine section includes a four stage first turbine. An overall pressure ratio is provided by the combination of a pressure ratio across the first compressor section and a pressure ratio across the second compressor section, and is greater than about 40, measured at sea level and at a static, full-rated takeoff power. The pressure ratio across the second compressor section is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

[0023] In a further embodiment of any of the foregoing embodiments, the turbine section further has a two stage second turbine. The second turbine is upstream of the first turbine.

[0024] In a further embodiment of any of the foregoing embodiments, the bypass ratio is greater than 10. The first turbine comprises an inlet, an outlet, and a pressure ratio greater than 5:1. The pressure ratio is a ratio of a pressure measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle.

[0025] In a further embodiment of any of the foregoing embodiments, the lubrication system and the compressed air system are in fluid communication with the gear arrangement.

[0026] In a further embodiment of any of the foregoing embodiments, the plumbing connection area provides access to the both the compressed air system and the lubrication system.

[0027] In a further embodiment of any of the foregoing embodiments, the gear arrangement is a planetary gear system. The overall pressure ratio is greater than 50, measured at sea level and at a static, full-rated takeoff power.

[0028] A gas turbine engine according to an example of the present disclosure includes a core engine, a bypass

passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine. The bypass ratio is greater than or equal to about 8 at cruise power. A gear arrangement that drives a fan section defines a gear reduction ratio of greater than about 2.3:1. A lubrication system and a compressed air system are in fluid communication with the gear arrangement. A compressor section includes both a low pressure compressor and a high pressure compressor. A plumbing connection area provides access to at least one of compressed air from the compressed air system, or oil from the lubrication system. A guide vane has a forward attachment. The forward attachment is positioned aft of the plumbing connection area. A turbine section that drives the gear arrangement includes a four stage low pressure turbine, an inlet, an outlet, and a low pressure turbine pressure ratio greater than 5:1. The low pressure turbine pressure ratio is a ratio of a pressure measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle. An overall pressure ratio is provided by the combination of a pressure ratio across the low pressure compressor and a pressure ratio across the high pressure compressor, and is greater than about 40, measured at sea level and at a static, full-rated takeoff power. The pressure ratio across the high pressure compressor is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

[0029] A further embodiment of any of the foregoing embodiments includes a low fan pressure ratio of less than about 1.45 measured across a fan blade alone. The bypass ratio is greater than 10.

[0030] In a further embodiment of any of the foregoing embodiments, the low fan pressure ratio is less than 1.45.

[0031] In a further embodiment of any of the foregoing embodiments, the pressure ratio across the low pressure compressor is less than 6, measured at sea level and at a static, full-rated takeoff power.

[0032] In a further embodiment of any of the foregoing embodiments, the gear arrangement is a planetary gear system with a sun gear, a ring gear, and a plurality of orbiting planet gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear. The turbine section includes a two stage high pressure turbine.

[0033] In a further embodiment of any of the foregoing embodiments, the fan pressure ratio is less than 1.35, and the gear arrangement is positioned between the fan section on one side and the low pressure compressor on another side.

[0034] A gas turbine engine according to an example of the present disclosure includes a fan section, a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine, wherein the bypass ratio is greater than about 8 at cruise power. A gear arrangement drives the fan section. A lubrication system and a compressed air system are in fluid communication with the gear arrangement. A compressor section has both a low pressure compressor and a high pressure compressor. A guide vane has a forward attachment. The forward attachment is positioned aft of a plumbing connection area. A turbine section drives the gear arrangement, and has a low pressure turbine with an inlet, an outlet, and a low pressure turbine pressure ratio greater than 5:1. The low pressure turbine pressure ratio is a ratio of a pressure measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle. The turbine section further includes a two

stage high pressure turbine. An overall pressure ratio is provided by the combination of a pressure ratio across the low pressure compressor and a pressure ratio across the high pressure compressor, and is greater than about 40, measured at sea level and at a static, full-rated takeoff power. The pressure ratio across the high pressure compressor is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

[0035] A further embodiment of any of the foregoing embodiments includes a low fan pressure ratio of less than about 1.45 measured across a fan blade alone. The bypass ratio is greater than 10.

[0036] In a further embodiment of any of the foregoing embodiments, the low fan pressure ratio is less than 1.45.

[0037] In a further embodiment of any of the foregoing embodiments, the overall pressure ratio is greater than 50, measured at sea level and at a static, full-rated takeoff power.

[0038] In a further embodiment of any of the foregoing embodiments, the low fan pressure ratio is less than 1.35, and the low pressure turbine is a four stage turbine.

[0039] In a further embodiment of any of the foregoing embodiments, the gear arrangement is a planetary gear system with a sun gear, a ring gear, and a plurality of orbiting planet gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear.

[0040] A gas turbine engine, according to an exemplary aspect of the present disclosure includes, among other things, a fan section including a fan and a gear arrangement configured to drive the fan section. A compressor section includes both a first compressor and a second compressor. A turbine section is configured to drive the compressor section and the gear arrangement. An overall pressure ratio is provided by the combination of a pressure ratio across the first compressor and a pressure ratio across the second compressor and is greater than or equal to about 35. The pressure ratio across the first compressor is greater than or equal to about 7. A pressure ratio across the fan section is less than or equal to about 1.50. The fan is configured to deliver a portion of air into the compressor section, and a portion of air into a bypass duct.

[0041] In a further non-limiting embodiment of the foregoing gas turbine engine, the first compressor is upstream of the second compressor.

[0042] In a further non-limiting embodiment of either of the foregoing gas turbine engines, the first compressor is downstream of the second compressor.

[0043] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the pressure ratio across the fan section is less than or equal to about 1.45.

[0044] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the overall pressure ratio is above or equal to about 50.

[0045] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the geared arrangement defines a gear reduction ratio greater than or equal to about 2.3.

[0046] In a further non-limiting embodiment of any of the foregoing gas turbine engines, a bypass ratio, which is defined as a volume of air passing to the bypass duct compared to a volume of air passing into the compressor section, is greater than or equal to about 8.

[0047] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the turbine section includes a

fan drive turbine configured to drive the fan section, a pressure ratio across the fan drive turbine being greater than or equal to about 5.

[0048] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the fan section includes a plurality of fan blades and a fan blade tip speed of each of the fan blades is less than about 1150 ft/second.

[0049] A gas turbine engine, according to an exemplary aspect of the present disclosure includes, among other things, a fan section including a fan, and a gear arrangement configured to drive the fan section. A compressor section includes both a first compressor and a second compressor. A turbine section is configured to drive the compressor section and the gear arrangement. An overall pressure ratio is provided by the combination of a pressure ratio across the first compressor and a pressure ratio across the second compressor and is greater than or equal to about 35. The pressure ratio across the first compressor is less than or equal to about 8. A pressure ratio across the fan section is less than or equal to about 1.50. The fan is configured to deliver a portion of air into the compressor section, and a portion of air into a bypass duct.

[0050] In a further non-limiting embodiment of the foregoing gas turbine engine, the first compressor is upstream of the second compressor.

[0051] In a further non-limiting embodiment of either of the foregoing gas turbine engines, the first compressor is downstream of the second compressor.

[0052] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the pressure ratio across the fan section is less than or equal to about 1.45.

[0053] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the overall pressure ratio is above or equal to about 50.

[0054] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the pressure ratio across the second compressor is greater than or equal to about 7.

[0055] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the pressure ratio across the first compressor is between about 3 and about 8, and the pressure ratio across the second compressor is between about 7 and about 15.

[0056] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the geared arrangement defines a gear reduction ratio greater than or equal to about 2.3.

[0057] In a further non-limiting embodiment of any of the foregoing gas turbine engines, a bypass ratio, which is defined as a volume of air passing to the bypass duct compared to a volume of air passing into the compressor section, being greater than or equal to about 8.

[0058] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the turbine section includes a fan drive turbine configured to drive the fan section, a pressure ratio across the fan drive turbine being greater than or equal to about 5.

[0059] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the fan section includes a plurality of fan blades and a fan blade tip speed of each of the fan blades is less than about 1150 ft/second.

[0060] A gas turbine engine, according to an exemplary aspect of the present disclosure includes, among other things, a fan section including a fan, and a gear arrangement configured to drive the fan section. A compressor section

includes both a first compressor and a second compressor. A turbine section is configured to drive the compressor section and the gear arrangement. An overall pressure ratio is provided by the combination of a pressure ratio across the first compressor and a pressure ratio across the second compressor, the pressure ratio across the first compressor being less than about 8, and the pressure ratio across the second compressor being greater than or equal to about 7. A pressure ratio across the fan section is less than or equal to about 1.50. The fan is configured to deliver a portion of air into the compressor section, and a portion of air into a bypass duct.

[0061] In a further non-limiting embodiment of the foregoing gas turbine engine, the first compressor is upstream of the second compressor.

[0062] In a further non-limiting embodiment of the foregoing gas turbine engine, the first compressor is downstream of the second compressor.

[0063] In a further non-limiting embodiment of the foregoing gas turbine engine, the pressure ratio across the fan section is less than or equal to about 1.45.

[0064] In a further non-limiting embodiment of the foregoing gas turbine engine, the overall pressure ratio is greater than or equal to about 35.

[0065] In a further non-limiting embodiment of the foregoing gas turbine engine, the geared arrangement defines a gear reduction ratio greater than or equal to about 2.3.

[0066] In a further non-limiting embodiment of the foregoing gas turbine engine, a bypass ratio, which is defined as a volume of air passing to the bypass duct compared to a volume of air passing into the compressor section, being greater than or equal to about 8.

[0067] In a further non-limiting embodiment of the foregoing gas turbine engine, the turbine section includes a fan drive turbine configured to drive the fan section, a pressure ratio across the fan drive turbine being greater than or equal to about 5.

[0068] An arrangement for a gas turbine engine, according to an exemplary aspect of the present disclosure includes, among other things, a fan section having a central axis, a compressor case for housing a compressor, and an inlet case for guiding air to the compressor, the compressor case positioned axially further from the fan section than the inlet case. A support member extends between the fan section and the compressor case wherein the support member restricts movement of the compressor case relative to the inlet case. The compressor case includes a front compressor case portion and a rear compressor case portion, the rear compressor case portion being axially further from the inlet case than the front compressor case portion. The support member extends between the fan section and the front compressor case portion, and the inlet case is removable from the gas turbofan engine separately from the compressor case. The compressor case includes a first compressor section and a second compressor section. A turbine section drives at least one of the first and second compressor sections, and a gear arrangement is driven by the turbine section such that the gear arrangement drives the fan section. A plumbing connection area is positioned upstream of the support member to be utilized for maintenance and repair.

[0069] The various features and advantages of this invention will become apparent to those skilled in the art from the

following detailed description of an embodiment. The drawings that accompany the detailed description can be briefly described as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0070] FIG. 1 illustrates a schematic sectional view of an embodiment of a gas turbine engine.

[0071] FIG. 2 illustrates a sectional view of a prior art compressor case mounting arrangement. Notably, some aspects are not prior art.

[0072] FIG. 3 illustrates a sectional view of an example compressor case mounting arrangement of an embodiment of the current invention.

[0073] FIG. 4 illustrates a close up sectional view of the intersection between an inlet case and a low pressure compressor case in the embodiment of FIG. 3.

[0074] FIG. 5 graphically shows a split in the compression ratios between the low pressure and high pressure compressor sections in a gas turbine engine embodiment.

DETAILED DESCRIPTION

[0075] FIG. 1 schematically illustrates an example gas turbine engine 10 including (in serial flow communication) a fan section 14, a compressor section 19 that includes a low pressure (or first) compressor section 18 and a high pressure (or second) compressor section 22, a combustor 26, and a turbine section 21 that includes a high pressure (or second) turbine section 30 and a low pressure (or first) turbine section 34. The gas turbine engine 10 is circumferentially disposed about an engine centerline X. During operation, air is pulled into the gas turbine engine 10 by the fan section 14, pressurized by the compressors 18, 22 mixed with fuel, and burned in the combustor 26. Hot combustion gases generated within the combustor 26 flow through high and low pressure turbines 30, 34, which extract energy from the hot combustion gases. As used herein, a “high pressure” compressor or turbine experiences a higher pressure than a corresponding “low pressure” compressor or turbine.

[0076] In a two-spool design, the high pressure turbine 30 utilizes the extracted energy from the hot combustion gases to power the high pressure compressor 22 through a high speed shaft 38, and a low pressure turbine 34 utilizes the energy extracted from the hot combustion gases to power the low pressure compressor 18 and the fan section 14 through a low speed shaft 42. However, the invention is not limited to the two-spool gas turbine architecture described and may be used with other architectures such as a single-spool axial design, a three-spool axial design and other architectures. That is, there are various types of gas turbine engines, many of which could benefit from the examples disclosed herein, which are not limited to the design shown.

[0077] The example gas turbine engine 10 is in the form of a high bypass ratio turbine engine mounted within a nacelle or fan casing 46, which surrounds an engine casing 50 housing a core engine 54. A significant amount of air pressurized by the fan section 14 bypasses the core engine 54 for the generation of propulsion thrust. The airflow entering the fan section 14 may bypass the core engine 54 via a fan bypass passage 58 extending between the fan casing 46 and the engine casing 50 for receiving and communicating a discharge airflow F1. The high bypass flow arrangement provides a significant amount of thrust for powering an aircraft.

[0078] The gas turbine engine 10 may include a geartrain 62 for controlling the speed of the rotating fan section 14. The geartrain 62 can be any known gear system, such as a planetary gear system with orbiting planet gears, a planetary system with non-orbiting planet gears or other type of gear system. The low speed shaft 42 may drive the geartrain 62. In the disclosed example, the geartrain 62 has a constant gear ratio. It should be understood, however, that the above parameters are only exemplary of a contemplated geared gas turbine engine 10. That is, aspects of the invention are applicable to traditional turbine engines as well as other engine architectures.

[0079] The engine 10 in one example is a high-bypass geared aircraft engine. In a further example, the engine 10 bypass ratio is greater than about six (6), with an example embodiment being greater than ten (10), the geared architecture 62 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 34 has a pressure ratio that is greater than or equal to about 5. In one example, the geared architecture 62 includes a sun gear, a ring gear, and intermediate gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear. The intermediate gears are star gears grounded against rotation about the axis X. The sun gear is supported by the low speed shaft 38, and the ring gear is interconnected to the fan 14.

[0080] In one disclosed embodiment, the engine 10 bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor 18, and the low pressure turbine 34 has a pressure ratio that is greater than or equal to about 5:1. Low pressure turbine 34 pressure ratio is pressure measured prior to inlet of low pressure turbine 34 as related to the pressure at the outlet of the low pressure turbine 34 prior to an exhaust nozzle. The geared architecture 62 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, and more specifically greater than about 2.6:1. 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 turbfans.

[0081] A significant amount of thrust is provided by a bypass flow through the bypass passage 58 due to the high bypass ratio. The fan section 14 of the engine 10 is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet. The flight condition of 0.8 Mach and 35,000 ft, with the engine at its best fuel consumption—also known as “bucket cruise Thrust Specific Fuel Consumption (‘TSFC’)”—is the industry standard parameter of lbf 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 $[(T_{\text{ambient deg R}}/518.7)^{0.5}]$. The “Low corrected fan tip speed” as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second. The above parameters for the engine 20 are intended to be exemplary.

[0082] As shown in FIG. 2, the example engine casing 50 generally includes at least an inlet case portion 64, a low pressure compressor case portion 66, and an intermediate case portion 76. The inlet case 64 guides air to the low pressure compressor case 66. The low pressure compressor case 66 in an example prior art gas turbine engine 80 supports a plurality of compressor stator vanes 68. Notably, the low pressure compressor section 18, and the high pressure compressor section 22, and the arrangement of the low rotor 70 and high rotor 170, respectively, are not part of the prior art. The low rotor 70 rotates about the central axis X, and, with the compressor stator vanes 68, help compress air moving through the low pressure compressor case 66. Downstream of the low pressure compressor the air passes into the high pressure compressor section 22, and is further compressed by its rotor 170. The mounting of the compressor as shown in FIG. 2 is prior art, however, the structure of the low pressure compressor section 18 and high pressure compressor section 22, and the rotors 70 and 170 were not part of the prior art.

[0083] A plurality of guide vanes 72 secure the intermediate case 76 to the fan casing 46. Formerly, the guide vanes 72 each included at least a rear attachment 74 and a forward attachment 78. The rear attachment 74 connects to an intermediate case 76 while the forward attachment 78 connects to the inlet case 64. The lower pressure compressor case 66 was thus supported through the intermediate case 76 and the inlet case 64.

[0084] In the prior art, a plumbing connection area 82 is positioned between the rear attachment 74 and the forward attachment 78. The plumbing connection area 82 includes connections used for maintenance and repair of the gas turbine engine 80, such as compressed air attachments, oil attachments, etc. The forward attachment 78 extends to the inlet case 64 from at least one of the guide vanes 72 and covers portions of the plumbing connection area 82. A fan stream splitter 86, a type of cover, typically attaches to the forward attachment 78 to shield the plumbing connection area 82.

[0085] Referring now to an example of the present invention shown in FIG. 3, in the turbine engine 90, the forward attachment 78 attaches to a front portion of the low pressure compressor case 66. In this example, the forward attachment 78 extends from the guide vane 72 to support the low pressure compressor case 66. Together, the forward attachment 78 and guide vane 72 act as a support member for the low pressure compressor case 66. The plumbing connection area 82 (which includes connections used for maintenance and repair of the gas turbine engine 90, such as compressed air attachments, oil attachments, etc) is positioned upstream of the forward attachment 78 facilitating access to the plumbing connection area 82. In contrast, the plumbing connection area of prior art embodiments was typically positioned between the rear attachment and the forward attachment and the forward attachment typically extended to the inlet case from at least one of the guide vanes, thereby covering portions of the plumbing connection area, which complicated access thereto; this complicated structure was further complicated by a fan stream splitter, a type of cover, that typically was attached to the forward attachment to shield the plumbing connection area.

[0086] In the embodiment shown in FIG. 3, an operator may directly access the plumbing connection area 82 after removing the fan stream splitter 86. The plumbing connec-

tion area **82** typically provides access to a lubrication system **82a**, a compressed air system **82b**, or both. The lubrication system **82a** and compressed air system **82b** are typically in fluid communication with the geartrain **62**.

[0087] Maintenance and repair of the geartrain **62** may require removing the geartrain **62** from the engine **90**. Positioning the plumbing connection area **82** ahead of the forward attachment **78** simplifies maintenance and removal of the geartrain **62** from other portions of the engine **90**. Draining oil from the geartrain **62** prior to removal may take place through the plumbing connection area **82** for example. The plumbing connection area **82** is typically removed with the geartrain **62**. Thus, the arrangement may permit removing the geartrain **62** on wing or removing the inlet case **64** from the gas turbine engine **90** separately from the low pressure compressor case **66**. This reduces the amount of time needed to prepare an engine for continued revenue service, saving an operator both time and money.

[0088] Connecting the forward attachment **78** to the low pressure compressor case **66** helps maintain the position of the rotor **70** relative to the interior of the low pressure compressor case **66** during fan rotation, even if the fan section **14** moves. In this example, the intermediate case **76** supports a rear portion of the low pressure compressor case **66** near a compressed air bleed valve **75**.

[0089] As shown in FIG. 4, a seal **88**, such as a “W” seal, may restrict fluid movement between the inlet case **64** and the low pressure compressor case **66**. In this example, the seal **88** forms the general boundary between the inlet case **64** and the low pressure compressor case **66**, while still allowing some amount of movement between the cases.

[0090] FIG. 5 shows a novel worksplit that has been invented to improve the fuel burn efficiency of a geared turbofan architecture with a fan **14** connected to the low compressor **18** through a speed reduction device such as a gearbox **62**. Since a gear reduction **62** is incorporated between the fan **14** and the low pressure compressor **18**, the speeds of the low pressure compressor can be increased relative to a traditional two spool direct drive arrangement. This provides freedom in splitting the amount of compression between the low pressure section **18** and the high pressure section **22** that can be uniquely exploited to improve fuel burn efficiency on the geared turbofan architecture described in FIGS. 1 and 2. This resulting worksplit is distinctly different from historical two and three spool direct drive architectures as shown in FIG. 5.

[0091] Notably, while the gear train **62** is shown axially adjacent to the fan **14**, it could be located far downstream, and even aft of the low turbine section **34**. As is known, the gear illustrated at **62** in FIGS. 2 and 3 could result in the fan **14** rotating in the same, or the opposite direction of the compressor rotors **70** and **170**.

[0092] It is known in prior art that an overall pressure ratio (when measured at sea level and at a static, full-rated takeoff power) of at least 35:1 is desirable, and that an overall pressure ratio of greater than about 40:1 and even about 50:1 is more desirable. That is, after accounting for the fan **14** pressure rise in front of the low pressure compressor **18**, the pressure of the air entering the low compressor section **18** should be compressed as much or over 35 times by the time it reaches the outlet of the high compressor section **22**. This pressure rise through the low and high compressors will be referred to as the gas generator pressure ratio.

[0093] FIG. 5 shows the way that this high pressure ratio has been achieved in the two prior art engine types versus the Applicant’s engine’s configuration.

[0094] Area S_1 shows the typical operation of three spool arrangements discussed the Background Section. The pressure ratio of the low compressor (i.e., the pressure at the exit of the low pressure compressor divided by the pressure at the inlet of the low pressure compressor) is above 8, and up to potentially 15. That is, if a pressure of 1 were to enter the low pressure compressor, it would be compressed between 8 to 15 times.

[0095] As can be further seen, the high pressure compressor ratio (i.e., the pressure at the exit of the high pressure compressor divided by the pressure at the inlet of the high pressure compressor) in this arrangement need only compress a very low pressure ratio, and as low as 5 to achieve a combined gas generator pressure ratio of above 35. For example, if the low pressure compressor ratio is 10 and the high pressure compressor ratio is 3.5, the combined overall pressure ratio (“OPR”) would be $(10)(3.5)=35$. In addition, the three spool design requires complex arrangements to support the three concentric spools.

[0096] Another prior art arrangement is shown at area S_2 . Area S_2 depicts the typical pressure ratio split in a typical two spool design with a direct drive fan. As can be seen, due to the connection of the fan directly to the low pressure compressor, there is little freedom in the speed of the low pressure compressor. Thus, the low pressure compressor can only do a small amount of the overall compression. As shown, it is typically below 4 times. On the other hand, the high pressure compressor must provide an amount of compression typically more than 20 times to reach an OPR of 40 (or 50).

[0097] The S_2 area results in undesirably high stress on the high pressure compressor, which, in turn, yields challenges in the mounting of the high pressure spool. In other words, the direct drive system that defines the S_2 area presents an undesirable amount of stress, and an undesirable amount of engineering required to properly mount the high pressure spool to provide such high pressure ratios.

[0098] Applicant’s current low compressor/high compressor pressure split is shown at area S_3 . The fan is driven at a speed distinct from the low pressure compressor, and a higher compression ratio can be achieved at the low pressure compressor section than was the case at area S_2 . Thus, as shown, the pressure ratio across the low pressure compressor may be between 4 and 8. This allows the amount of compression to be performed by the high pressure compressor to only need to be between 8 times and 15 times.

[0099] The area S_3 is an enabling design feature that allows the geared turbofan architecture shown in FIGS. 1 and 2 to achieve a very high gas generator OPR while avoiding the complexities of historical three spool and two spool direct drive architectures. The area S_3 is an improvement over both areas S_1 and S_2 . As an example, a 3-4% fuel efficiency is achieved at area S_3 compared to area S_1 . A fuel savings of 4-5% is achieved at area S_3 , compared to area S_2 .

[0100] In fact, in comparison to a gas turbine engine provided with a gear drive, but operating in the pressure ratios of area S_2 , there is still a 2% fuel burn savings at the S_3 area.

[0101] As such, the area S_3 reduces fuel burn, and provides engineering simplicity by more favorably distributing work between the hotter high pressure spools and colder low pressure spools.

[0102] Stated another way, the present invention provides a combination of a low pressure compressor and a high pressure compressor which together provides an OPR of greater than about 35 and, in some embodiments greater than about 40, in some embodiments greater than about 50, and in some embodiments up to about 70. This high OPR is accomplished by a beneficial combination of a pressure ratio across the low pressure compressor of between about 4 and about 8 coupled with an additional pressure ratio across the high pressure ratio compressor of between about 8 and about 15.

[0103] Improved fuel consumption can be further achieved wherein the fan may be low pressure, and have a pressure ratio less than or equal to about 1.50, more specifically less than or equal to about 1.45, and even more specifically less than or equal to about 1.35. A bypass ratio, defined as the volume of air passing into bypass passage 58 compared to the volume of air in the core air flow is greater than or equal to about 8 at cruise power. The low pressure compressor may have a pressure ratio less than or equal to 8, more narrowly between 3 to 8, and even more narrowly 4 to 6, and be powered by a 4 or 5-stage low pressure turbine. In some embodiments, the first or low pressure compressor may have a pressure ratio greater than or equal to 7. The second or high compressor rotor may have a nominal pressure ratio greater than or equal to 7, more narrowly between 7 to 15, and even more narrowly 8 to 10, and may be powered by a 2-stage high pressure turbine. A gas turbine engine operating with these operational parameters provides benefits compared to the prior art.

[0104] 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.

We claim:

1. A gas turbine engine comprising:

a fan section;

a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine, wherein the bypass ratio is greater than 8 at cruise power;

a gear arrangement that drives the fan section, the gear arrangement defining a gear reduction ratio of greater than 2.3:1;

a lubrication system and a compressed air system in fluid communication with the gear arrangement;

a compressor section, comprising both a low pressure compressor and a high pressure compressor;

a guide vane comprising a forward attachment, the forward attachment positioned aft of a plumbing connection area; and

a turbine section that drives the gear arrangement, the turbine section including a low pressure turbine with an inlet, an outlet, and a low pressure turbine pressure ratio greater than 5:1, wherein the low pressure turbine

pressure ratio is a ratio of a pressure measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle;

wherein an overall pressure ratio is:

provided by the combination of a pressure ratio across the low pressure compressor and a pressure ratio across the high pressure compressor; and

greater than about 50, measured at sea level and at a static, full-rated takeoff power; and

wherein the pressure ratio across the high pressure compressor is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

2. The gas turbine engine of claim 1, wherein the plumbing connection area is removable with the gear arrangement.

3. The gas turbine engine of claim 1, further comprising a low fan pressure ratio of less than about 1.45 measured across a fan blade alone, and wherein the bypass ratio is greater than 10.

4. The gas turbine engine of claim 3, wherein the turbine section further comprises a two stage high pressure turbine.

5. The gas turbine engine of claim 4, wherein the low pressure turbine is a four stage turbine.

6. The gas turbine engine of claim 5, wherein the low pressure compressor is a three stage compressor.

7. The gas turbine engine of claim 6, wherein the high pressure compressor is a nine stage compressor.

8. The gas turbine engine of claim 5, wherein the low fan pressure ratio is less than 1.45.

9. The gas turbine engine of claim 8, wherein the gear arrangement is a planetary gear system with a sun gear, a ring gear, and a plurality of orbiting planet gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear.

10. The gas turbine engine of claim 9, wherein the pressure ratio across the low pressure compressor is less than 6, measured at sea level and at a static, full-rated takeoff power.

11. The gas turbine engine of claim 5, wherein the plumbing connection area is removable with the gear arrangement.

12. The gas turbine engine of claim 1, further comprising a low fan pressure ratio of less than about 1.35 measured across a fan blade alone, and wherein the bypass ratio is greater than 10, the turbine section includes a two stage high pressure turbine, and the pressure ratio across the low pressure compressor is less than about 6, measured at sea level and at a static, full-rated takeoff power.

13. A gas turbine engine comprising:

a fan section;

a low fan pressure ratio of less than about 1.45 measured across a fan blade alone;

a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine, wherein the bypass ratio is greater than about 8 at cruise power;

a gear arrangement that drives the fan section, the gear arrangement having a gear system with a sun gear, a ring gear, and a plurality of intermediate gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear;

- a compressor section, comprising both a first compressor section and a second compressor section;
- a plumbing connection area that provides access to at least one of compressed air from a compressed air system, or oil from a lubrication system;
- a guide vane having a forward attachment, the forward attachment positioned aft of the plumbing connection area; and
- a turbine section that drives the gear arrangement, the turbine section including a four stage first turbine;

wherein an overall pressure ratio is:

provided by the combination of a pressure ratio across the first compressor section and a pressure ratio across the second compressor section; and
greater than about 40, measured at sea level and at a static, full-rated takeoff power; and

wherein the pressure ratio across the second compressor section is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

14. The gas turbine engine of claim **13**, wherein the turbine section further has a two stage second turbine, the second turbine upstream of the first turbine.

15. The gas turbine engine of claim **14**, wherein:

the bypass ratio is greater than 10; and

the first turbine comprises an inlet, an outlet, and a pressure ratio greater than 5:1, wherein the pressure ratio is a ratio of a pressure measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle.

16. The gas turbine engine of claim **15**, wherein the lubrication system and the compressed air system are in fluid communication with the gear arrangement.

17. The gas turbine engine of claim **16**, wherein the plumbing connection area provides access to the both the compressed air system and the lubrication system.

18. The gas turbine engine of claim **17**, wherein:

the gear arrangement is a planetary gear system; and
the overall pressure ratio is greater than 50, measured at sea level and at a static, full-rated takeoff power.

19. A gas turbine engine comprising:

a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine, wherein the bypass ratio is greater than or equal to about 8 at cruise power;

a gear arrangement that drives a fan section, the gear arrangement defining a gear reduction ratio of greater than about 2.3:1;

a lubrication system and a compressed air system in fluid communication with the gear arrangement;

a compressor section, comprising both a low pressure compressor and a high pressure compressor;

a plumbing connection area that provides access to at least one of compressed air from the compressed air system, or oil from the lubrication system;

a guide vane having a forward attachment, the forward attachment positioned aft of the plumbing connection area; and

a turbine section that drives the gear arrangement, the turbine section including a four stage low pressure turbine, an inlet, an outlet, and a low pressure turbine pressure ratio greater than 5:1, wherein the low pressure turbine pressure ratio is a ratio of a pressure

measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle; and

wherein an overall pressure ratio is:

provided by the combination of a pressure ratio across the low pressure compressor and a pressure ratio across the high pressure compressor; and

greater than about 40, measured at sea level and at a static, full-rated takeoff power; and

wherein the pressure ratio across the high pressure compressor is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

20. The gas turbine engine of claim **19**, further comprising a low fan pressure ratio of less than about 1.45 measured across a fan blade alone, and wherein the bypass ratio is greater than 10.

21. The gas turbine engine of claim **20**, wherein the low fan pressure ratio is less than 1.45.

22. The gas turbine engine of claim **21**, wherein the pressure ratio across the low pressure compressor is less than 6, measured at sea level and at a static, full-rated takeoff power.

23. The gas turbine engine of claim **22**, wherein:

the gear arrangement is a planetary gear system with a sun gear, a ring gear, and a plurality of orbiting planet gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear; and

the turbine section includes a two stage high pressure turbine.

24. The gas turbine engine of claim **23**, wherein the fan pressure ratio is less than 1.35, and the gear arrangement is positioned between the fan section on one side and the low pressure compressor on another side.

25. A gas turbine engine comprising:

a fan section;

a core engine, a bypass passage, and a bypass ratio defined as the volume of air passing into the bypass passage compared to the volume of air passing into the core engine, wherein the bypass ratio is greater than about 8 at cruise power;

a gear arrangement that drives the fan section;

a lubrication system and a compressed air system in fluid communication with the gear arrangement;

a compressor section, comprising both a low pressure compressor and a high pressure compressor;

a plumbing connection area;

a guide vane having a forward attachment, the forward attachment positioned aft of the plumbing connection area; and

a turbine section that drives the gear arrangement, the turbine section having a low pressure turbine with an inlet, an outlet, and a low pressure turbine pressure ratio greater than 5:1, wherein the low pressure turbine pressure ratio is a ratio of a pressure measured prior to the inlet as related to a pressure at the outlet prior to any exhaust nozzle, and wherein the turbine section further includes a two stage high pressure turbine;

wherein an overall pressure ratio is:

provided by the combination of a pressure ratio across the low pressure compressor and a pressure ratio across the high pressure compressor; and

greater than about 40, measured at sea level and at a static, full-rated takeoff power; and

wherein the pressure ratio across the high pressure compressor is greater than about 7, measured at sea level and at a static, full-rated takeoff power.

26. The gas turbine engine of claim **25**, further comprising a low fan pressure ratio of less than about 1.45 measured across a fan blade alone, and wherein the bypass ratio is greater than 10.

27. The gas turbine engine of claim **26**, wherein the low fan pressure ratio is less than 1.45.

28. The gas turbine engine of claim **27**, wherein the overall pressure ratio is greater than 50, measured at sea level and at a static, full-rated takeoff power.

29. The gas turbine engine of claim **28**, wherein the low fan pressure ratio is less than 1.35, and the low pressure turbine is a four stage turbine.

30. The gas turbine engine of claim **29**, wherein the gear arrangement is a planetary gear system with a sun gear, a ring gear, and a plurality of orbiting planet gears arranged circumferentially about the sun gear and intermeshing with the sun gear and the ring gear.

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