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(54) **OIL SYSTEM BEARING COMPARTMENT ARCHITECTURE FOR GAS TURBINE ENGINE**

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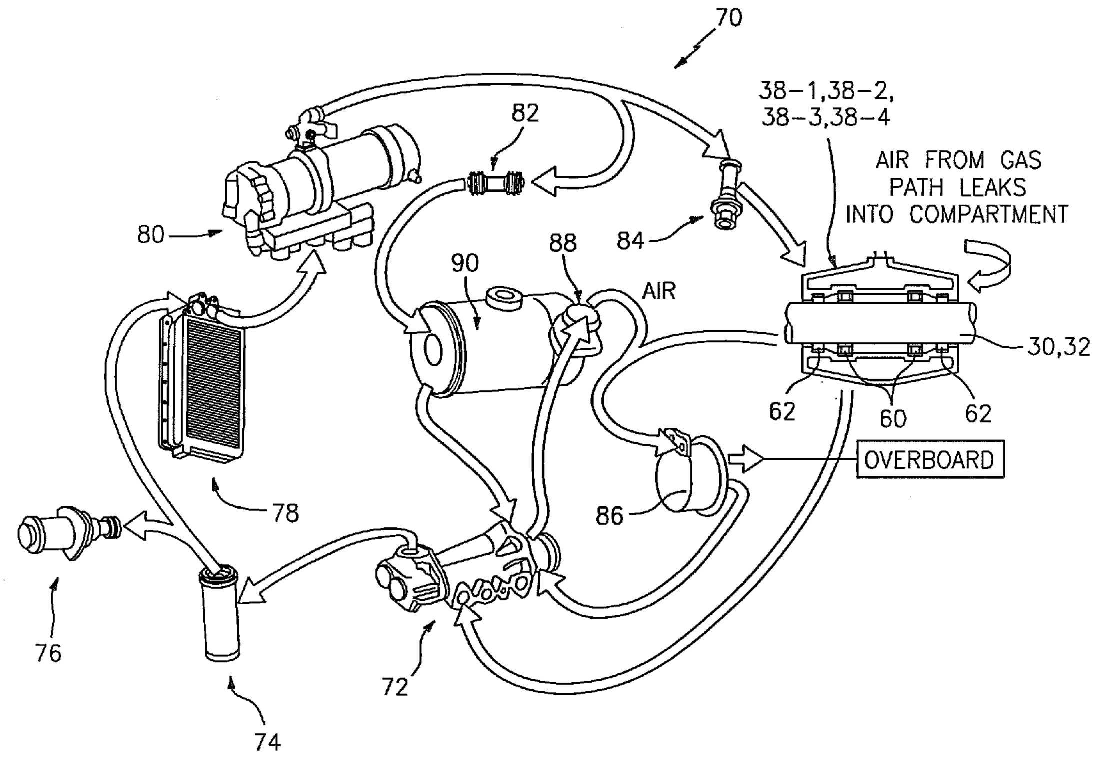
(57) **ABSTRACT**

A gas turbine engine with a geared architecture includes a multiple of bearing compartments and at least one carbon seal that seals at least one side of each of the multiple of bearing compartments.



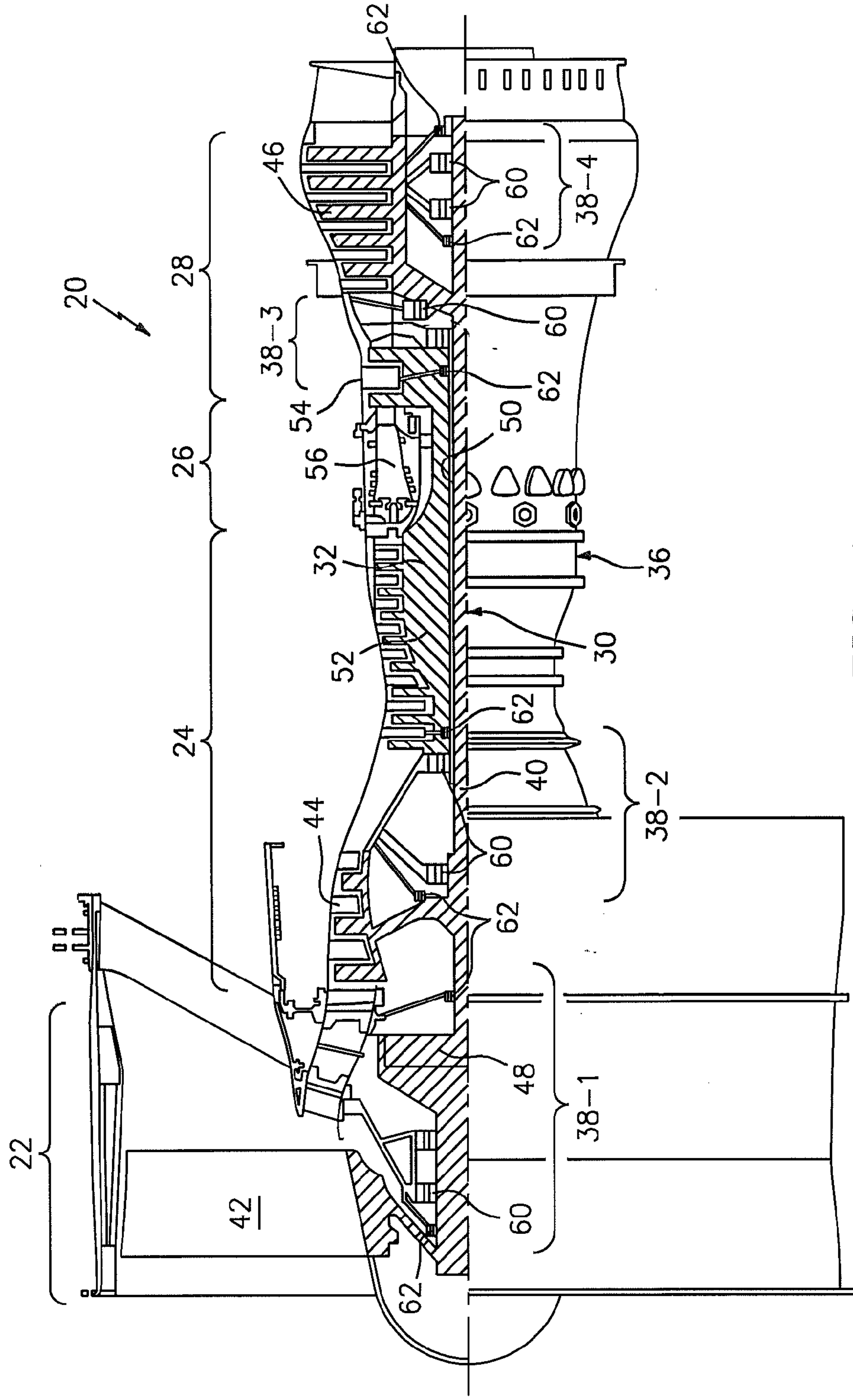

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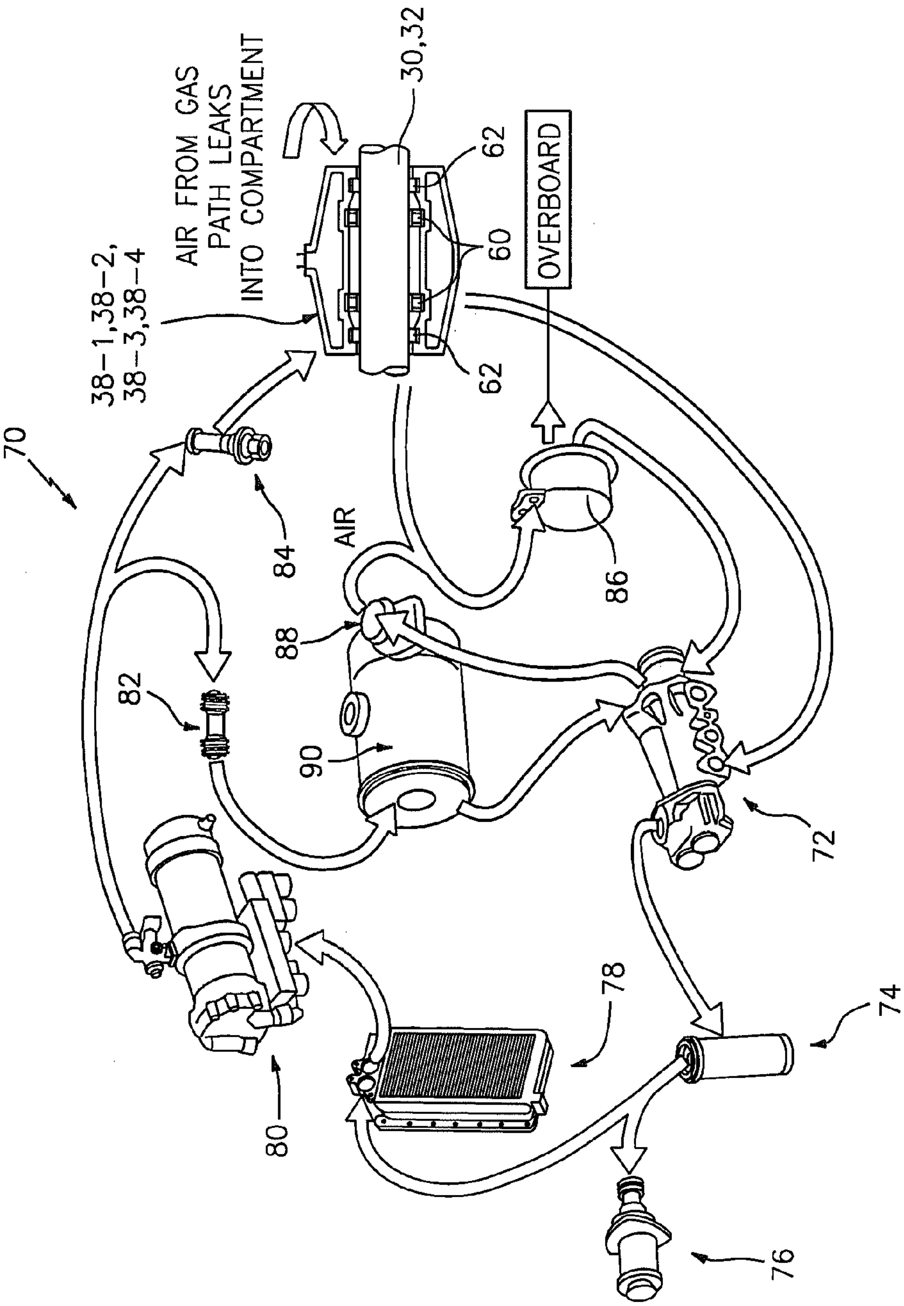
FIG. 1


70
38-1,38-2,
38-3,38-4
AIR FROM GAS
PATH LEAKS
INTO COMPARTMENT
30,32
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OVERBOARD
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AIR
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72
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76

FIG. 2

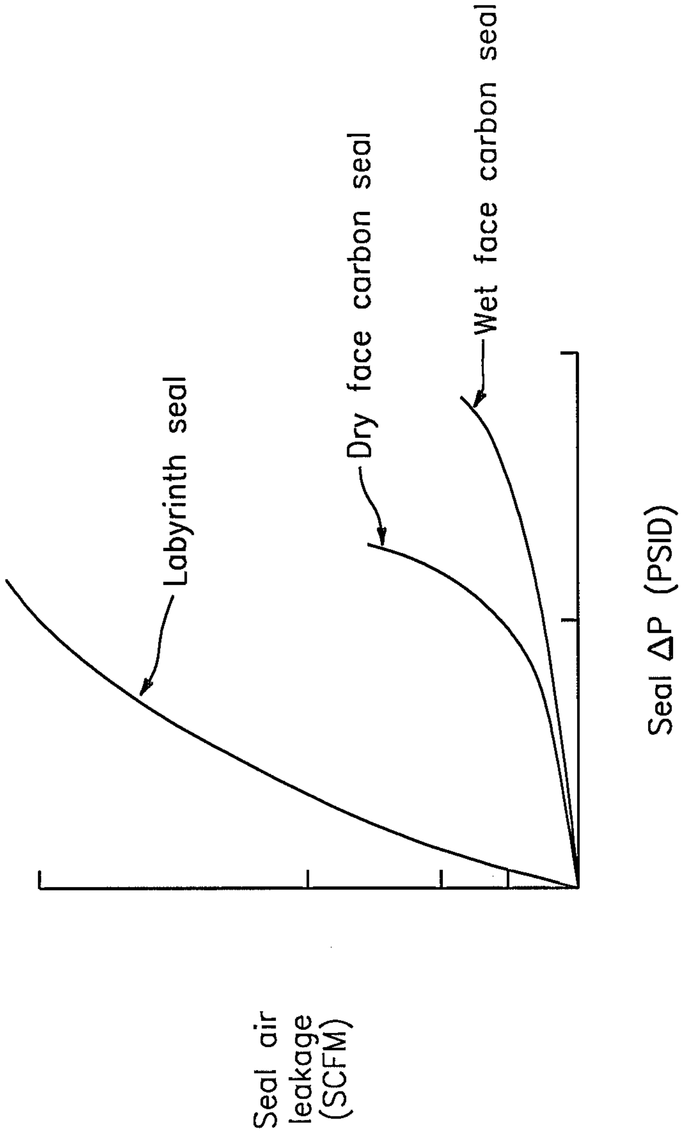
Labyrinth seal
Dry face carbon seal
Wet face carbon seal
Seal ΔP (PSID)
Seal air leakage (SCFM)

FIG. 3

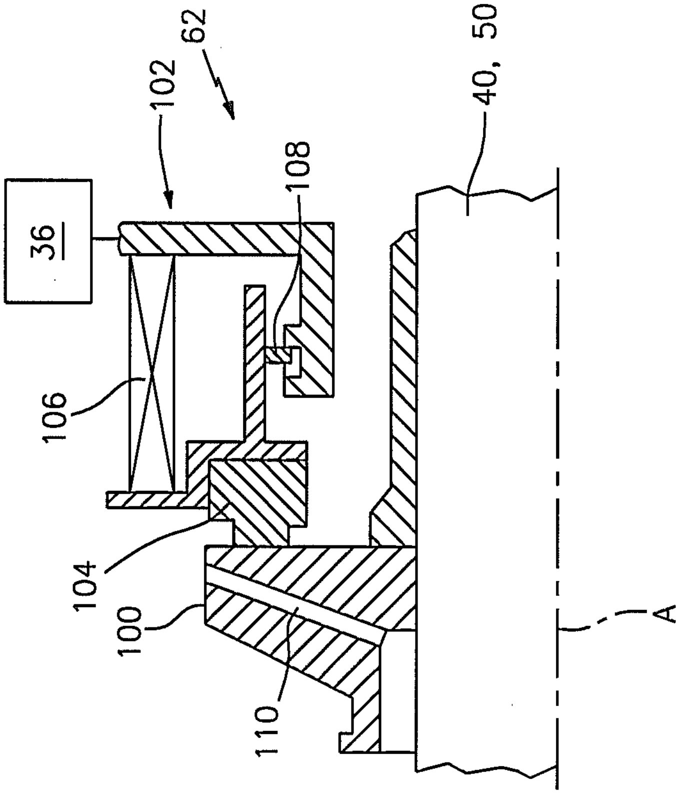

FIG. 4

OIL SYSTEM BEARING COMPARTMENT ARCHITECTURE FOR GAS TURBINE ENGINE

[0001] This application claims priority to U.S. Provisional Application No. 61/719,162 filed Oct. 26, 2012, which is hereby incorporated by reference.

BACKGROUND

[0002] The present disclosure relates to a gas turbine engine and, more particularly, to an oil system bearing compartment arrangement therefor.

[0003] Aircraft gas turbine engines include an oil system to supply oil to various components such as bearings that are typically contained within bearing compartments. All gas turbine engines ingest some air from the gas path in regular operation due to the pressure differential between the gas path and bearing compartments. Under certain conditions, the oil may be churned at a high velocity and thereby become aerated. If the oil is not quieted and deaerated, the oil may not be effectively scavenged. In a geared engine architecture, higher air pressures within bearing compartments that contain a gear system can reduce the efficiency of the gear system. Entrained air in the oil is removed through a deaerator to assure quality oil, however, removal of air may also result in some undesirable oil consumption. The oil must eventually be replaced during maintenance operations.

SUMMARY

[0004] A gas turbine engine with a geared architecture according to one disclosed non-limiting embodiment of the present disclosure includes a multiple of bearing compartments and at least one carbon seal which seals at least one side of each of the multiple of bearing compartments.

[0005] In a further embodiment of the foregoing embodiment, the multiple of bearing compartments include a front bearing compartment.

[0006] In a further embodiment of any of the foregoing embodiments, the multiple of bearing compartments include a mid bearing compartment.

[0007] In a further embodiment of any of the foregoing embodiments, the multiple of bearing compartments include a mid-turbine bearing compartment.

[0008] In a further embodiment of any of the foregoing embodiments, the multiple of bearing compartments include a rear bearing compartment.

[0009] In a further embodiment of any of the foregoing embodiments, each of the multiple of bearing compartments interface with an engine shaft.

[0010] In a further embodiment of any of the foregoing embodiments, the geared architecture is 98% efficient.

[0011] In a further embodiment of any of the foregoing embodiments, the multiple of bearing compartments include a front bearing compartment, a mid bearing compartment axially aft of the front bearing compartment, a mid-turbine bearing compartment axially aft of the mid bearing compartment, and a rear bearing compartment axially aft of the mid-turbine bearing compartment.

[0012] A gas turbine engine according to another disclosed non-limiting embodiment of the present disclosure includes a front bearing compartment bounded by a first and second carbon seal, a mid bearing compartment bounded by a first and second carbon seal, the mid bearing compartment axially aft of the front bearing compartment, a mid-turbine baring compartment bounded by a first and second carbon seal, the mid-turbine bearing compartment axially aft of the mid bearing compartment, and a rear bearing compartment bounded by a first and second carbon seal, the rear bearing compartment axially aft of the mid-turbine bearing compartment.

[0013] In a further embodiment of the foregoing embodiment, the front bearing compartment contains #1 and a #1.5 tapered bearing and a geared architecture which drives a fan at a lower speed than a low spool.

[0014] In a further embodiment of any of the foregoing embodiments, the mid-bearing compartment contains a #2 bearing that rotationally supports a forward end section of a low spool and a #3 bearing that rotationally supports a forward end section of a high spool.

[0015] In a further embodiment of any of the foregoing embodiments, the mid-turbine bearing compartment contains a #4 bearing that rotationally supports an aft end section of a high spool.

[0016] In a further embodiment of any of the foregoing embodiments, the rear bearing compartment contains a #5 bearing and a #6 bearing that rotationally supports an aft end section of a low spool.

[0017] In a further embodiment of any of the foregoing embodiments, further comprises an oil system in fluid communication with each of the front bearing compartment, the mid bearing compartment, the mid-turbine bearing compartment and the rear bearing compartment. In the alternative or additionally thereto, the foregoing embodiment includes the oil system includes a deoiler. In the alternative or additionally thereto, the foregoing embodiment includes the oil system includes a deaerator.

[0018] A method of reducing oil outflow from an oil system in communication with a geared architecture of a gas turbine engine having a multiple of bearing cavities, according to another disclosed non-limiting embodiment of the present disclosure includes bounding a multiple of bearing cavities with a multiple of carbon seals.

[0019] In a further embodiment of the foregoing embodiment, further comprises bounding each of the multiple of bearing cavities with a first and second carbon seal.

[0020] In a further embodiment of any of the foregoing embodiments, further comprises associating each of the multiple of bearing cavities with a spool of the gas turbine engine.

[0021] In a further embodiment of any of the foregoing embodiments, one of the bearing cavities contains a geared architecture which drives a fan at a rotational speed less than a low spool.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Various features will become apparent to those skilled in the art from the following detailed description of the disclosed non-limiting embodiment. The drawings that accompany the detailed description can be briefly described as follows:

[0023] FIG. **1** is a schematic cross-sectional view of a geared architecture gas turbine engine;

[0024] FIG. **2** is a schematic view of an oil system for the geared architecture gas turbine engine;

[0025] FIG. **3** is a graphical representation of seal air leakage in standard cubic feet of air per minute (SCFM) on the ordinate and differential pressure (deltaP) across the seal on the abscissa; and

[0026] FIG. **4** is an expanded cross-sectional view of a carbon seal according to one disclosed non-limiting embodiment.

DETAILED DESCRIPTION

[0027] FIG. **1** 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 architectures such as a low-bypass turbofan may include an augmentor section (not shown) among other systems or features. Although schematically illustrated as a turbofan in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with turbofans as the teachings may be applied to other types of turbine engines to include but not limited to a three-spool (plus fan) engine wherein an intermediate spool includes an intermediate pressure compressor (IPC) between a low pressure compressor and a high pressure compressor with an intermediate pressure turbine (IPT) between a high pressure turbine and a low pressure turbine as well as other engine architectures such as turbojets, turboshafts, open rotors and industrial gas turbines.

[0028] The fan section **22** drives air along a bypass flowpath and a core flowpath while the compressor section **24** drives air along the core flowpath for compression and communication into the combustor section **26** then expansion through the turbine section **28**. The engine **20** generally includes a low spool **30** and a high spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine case assembly **36** via several bearing compartments **38-1**, **38-2**, **38-3**, **38-4**. The low spool **30** generally includes an inner shaft **40** that interconnects a fan **42**, a low pressure compressor **44** ("LPC") and a low pressure turbine **46** ("LPT"). The inner shaft **40** drives the fan **42** through a geared architecture **48** to drive the fan **42** at a lower speed than the low spool **30**.

[0029] The high spool **32** includes an outer shaft **50** that interconnects a high pressure compressor **52** ("HPC") and high pressure turbine **54** ("HPT"). A combustor **56** is arranged between the HPC **52** and the HPT **54**. The inner shaft **40** and the outer shaft **50** are concentric and rotate about the engine central longitudinal axis A that is collinear with their longitudinal axes.

[0030] Core airflow is compressed by the LPC **44** then the HPC **52**, mixed with the fuel and burned in the combustor section **56**, then expanded over the HPT **54** and the LPT **46**. The HPT **54** and the LPT **46** drive the respective low spool **30** and high spool **32** in response to the expansion.

[0031] In one non-limiting example, the gas turbine engine **20** is a high-bypass geared architecture engine in which the bypass ratio is greater than about six (6:1). The geared architecture **48** can include an epicyclic gear train, such as a planetary gear system, star gear system or other gear system. The example epicyclic gear train has a gear reduction ratio of greater than about 2.3, and in another example is greater than about 2.5 with a gear system efficiency greater than approximately 98%. The geared turbofan enables operation of the low spool **30** at higher speeds which can increase the operational efficiency of the low pressure compressor **44** and low pressure turbine **46** and render increased pressure in a fewer number of stages.

[0032] A pressure ratio associated with the LPT **46** is pressure measured prior to the inlet of the LPT **46** as related to the pressure at the outlet of the LPT **46** prior to an exhaust nozzle of the gas turbine engine **20**. In one non-limiting embodiment, the bypass ratio of the gas turbine engine **20** 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). It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present disclosure is applicable to other gas turbine engines including direct drive turbofans.

[0033] In one non-limiting embodiment, a significant amount of thrust is provided by the bypass flow due to the high bypass ratio. The fan section **22** of the gas turbine engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet. This flight condition, with the gas turbine engine **20** at its best fuel consumption, is also known as bucket cruise Thrust Specific Fuel Consumption (TSFC). TSFC is an industry standard parameter of fuel consumption per unit of thrust.

[0034] Fan Pressure Ratio is the pressure ratio across a blade of the fan section **22** without the use of a Fan Exit Guide Vane system. The low Fan Pressure Ratio according to one non-limiting embodiment of the example gas turbine engine **20** is less than 1.45. Low Corrected Fan Tip Speed is the actual fan tip speed divided by an industry standard temperature correction of $(\text{"T"}/518.7)^{0.5}$. in which "T" represents the ambient temperature in degrees Rankine. The Low Corrected Fan Tip Speed according to one non-limiting embodiment of the example gas turbine engine **20** is less than about 1150 fps (351 m/s).

[0035] The bearing compartments **38-1**, **38-2**, **38-3**, **38-4** in the disclosed non-limiting embodiment are defined herein as a front bearing compartment **38-1**, a mid-bearing compartment **38-2** axially aft of the front bearing compartment **38-1**, a mid-turbine bearing compartment **38-3** axially aft of the mid-bearing compartment **38-2** and a rear bearing compartment **38-4** axially aft of the mid-turbine bearing compartment **38-3**.

[0036] Each of the bearing compartments **38-1**, **38-2**, **38-3**, **38-4** include one or more bearings **60** (illustrated schematically) and one or more—typically two (2)—carbon seals **62** (illustrated schematically). In another disclosed non-limiting embodiment, only one carbon seal may be located on one side of the bearing compartment **38-1**, **38-2**, **38-3**, **38-4** subject to greatest air leakage—the lower air leakage side could use a labyrinth type seal.

[0037] Various types of carbon seals **62** may be used herewith and the carbon seals **62** contemplated herein include, but are not limited to face contact seals. The bearings **60** and carbon seals **62** respectively support and interface with the shafts **40**, **50** of the respective low spool **30** and high spool **32**. The carbon seals **62** operate to seal a "wet" zone from a "dry" zone. In other words, regions or volumes that contain oil may be referred to as a "wet" zone and an oil-free region may be referred to as a "dry" zone. So, for example, the interior of each bearing compartment **38-1**, **38-2**, **38-3**, **38-4** may be referred to as a wet zone that ultimately communicates with an oil sump (not shown) of an oil system (FIG. **2**) while the region external thereto may be referred to as a dry zone. That is, the bearings **60** support the low spool **30** and the high spool **32** and the carbon seals **62** separate the "wet" zone from the "dry" zone to define the boundaries of each bearing compartment **38-1**, **38-2**, **38-3**, **38-4**.

[0038] In the disclosed, non-limiting embodiment, the front bearing compartment **38-1** contains a #1 tapered bearing **60**, a #1.5 tapered bearing **60** and the geared architecture **48**. The #1 tapered bearing **60** and the #1.5 tapered bearing **60** rotationally support the fan **42**. In the disclosed, non-limiting embodiment, the mid-bearing compartment **38-2** contains a #2 bearing **60** and a #3 bearing **60**. The #2 bearing **60** rotationally supports a forward end section of the low spool **30** and the #3 bearing **60** rotationally supports a forward end section of the high spool **32**. The mid-turbine bearing compartment **38-3** contains a #4 bearing **60** that rotationally supports the aft end section of the high spool **32**. In the disclosed, non-limiting embodiment, the rear bearing compartment **38-4** contains a #5 bearing **60** and a #6 bearing **60** that rotationally support an aft end section of the low spool **30**. Although particular bearing compartments and bearing arrangements are illustrated in the disclosed non-limiting embodiment, other bearing compartments and bearing arrangements in other engine architectures such as three-spool architectures will also benefit herefrom.

[0039] With reference to FIG. **2**, an oil system **70** provides oil under pressure to lubricate and cool moving components of the engine **20**, such as, for example but not limited to, the geared architecture **48** and the bearings **60**. The oil system **70** generally includes a pump **72**, a main filter **74**, a pressure relief valve **76**, an air-oil cooler **78**, a fuel-oil cooler **80**, an oil pressure trim orifice **82**, an oil strainer **84**, a deoiler **86**, a deareator **88** and a tank **90**. The oil system **70** is but a simplified schematic illustration and that other additional or alternative components and subsystems may be included in the oil system **70**.

[0040] In operation, the pump **72** communicates oil to the main filter **74** then filtered oil proceeds to the air-oil cooler **78** and/or the fuel-oil cooler **80** to be cooled. Should the main filter **74** become clogged, the pressure relief valve **76** indicates the clog. The oil pressure trim orifice **82** then regulates the oil flow and returns any oil overage to the oil tank **90**. The oil strainer **84** strains any debris before the oil is communicated to the bearing compartment **38-1**, **38-2**, **38-3**, **38-4** to lubricate, for example, the bearings **60**.

[0041] Oil is then scavenged from the bearing compartment **38-1**, **38-2**, **38-3**, **38-4** by the pump **72** through the deoiler **86** for return to the tank **90**. Air is separated from the scavenge oil from the pump **72** by the deaerator **88** at the tank **90**. Vent air from the bearing compartment **38-1**, **38-2**, **38-3**, **38-4** and air from the deaerator **88** is communicated directly to the deoiler **86** where the air is removed from the oil and rejected overboard. The oil cycle is then repeated.

[0042] Geared architecture engines are architected to minimize oil flow, heat rejection and air entrained in the oil as well as oil outflow from the oil system in regular operation. In particular, gear systems operate more efficiently with less air flow into the bearing compartment because the additional air creates windage and churning within the rotating gears and bearings. This additional loss in gear system efficiency reduces the overall efficiency of the engine, increasing the amount of fuel needed to complete a specified mission. All gas turbine engines, however, ingest some air from the gas path due to the pressure differential between the gas path and the bearing compartments. Geared architecture engines typically utilize an oil system that has an oil flow circulation that may be approximately twice that of a traditional direct drive turbofan, e.g., 45 gallons per minute versus 25 gallons per minute from a 35 quart oil tank vs. a 28 quart system. As such, oil ingestion may be amplified. Minimization of entrained air in the oil will thereby facilitate reduced consumption of oil, the minimization of maintenance requirements and longer mission potential.

[0043] Complete utilization of carbons seals **62** significantly reduces the air leakage (FIG. **3**) into each bearing compartment **38-1**, **38-2**, **38-3**, **38-4** as compared to labyrinth seals that are typically utilized to seal bearing compartments of conventional direct drive turbofan engines. It should be understood that all carbon seals form a seal with a smooth carbon surface rubbing against a smooth metal surface and that various carbon seal types and structures may be utilized herewith.

[0044] With reference to FIG. **4**, an illustrated embodiment of the carbon seal **62** includes a seal race **100**, a fixed segment **102**, a carbon element **104**, a preload **106** and a secondary seal **108**. The seal race **100** may be mounted to the shaft **40**, **50** for rotation therewith. The seal race **100** may also include cooling passages **110** (one shown) to receive and direct cooling oil toward the carbon element **104**. The fixed segment **102** is mounted to the case assembly **36** to support and preload the carbon element **104** into contact with the seal race **100** by the preload **106** such as spring compression, centrifugal force, and air pressure. The secondary seal **108** may include, for example, a piston ring, O-ring type, C-ring type, or other interface. The piston ring may be manufactured of a metal alloy while the O-ring type and the C-ring type may be elastomeric and may include non-metallic materials to provide an effective seal.

[0045] The reduction of air leakage due to utilization of carbon seals **62** in all the bearing compartments **38-1**, **38-2**, **38-3**, **38-4** reduces air entrainment in the oil such that oil tank dwell time is concomitantly reduced to facilitate usage of a relatively small deoiler **86**, deareator **88** and tank **90**. Reduced airflow in bearing compartments that house the gear system such as the front bearing compartment **38-1** improves gear system efficiency. Even though the geared architecture turbofan engine may have oil flow requirements greater than that of a conventional direct drive turbofan, complete usage of carbon seals **62** facilitate a significant weight, cost and complexity savings. Furthermore, a quart of oil weighs approximately 2 lbs. (907 g), so a size reduction of the oil system components facilitates further weight savings.

[0046] It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. The foregoing description is exemplary rather than defined by the limitations within Various non-limiting embodiments are disclosed herein, however, one of ordinary skill in the art would recognize that various modifications and variations in light of the above teachings will fall within the scope of the appended claims. It is therefore to be understood that within the scope of the appended claims, the disclosure may be practiced other than as specifically described. For that reason the appended claims should be studied to determine true scope and content.

What is claimed is:

1. A gas turbine engine with a geared architecture, comprising:

a multiple of bearing compartments; and

at least one carbon seal which seals at least one side of each of said multiple of bearing compartments.

2. The gas turbine engine as recited in claim **1**, wherein said multiple of bearing compartments include a front bearing compartment.

3. The gas turbine engine as recited in claim **1**, wherein said multiple of bearing compartments include a mid bearing compartment.

4. The gas turbine engine as recited in claim **1**, wherein said multiple of bearing compartments include a mid-turbine bearing compartment.

5. The gas turbine engine as recited in claim **1**, wherein said multiple of bearing compartments include a rear bearing compartment.

6. The gas turbine engine as recited in claim **1**, wherein each of said multiple of bearing compartments interface with an engine shaft.

7. The gas turbine engine as recited in claim **1**, wherein said geared architecture is 98% efficient.

8. The gas turbine engine as recited in claim **1**, wherein said multiple of bearing compartments include:

a front bearing compartment;

a mid bearing compartment axially aft of said front bearing compartment;

a mid-turbine bearing compartment axially aft of said mid bearing compartment; and

a rear bearing compartment axially aft of said mid-turbine bearing compartment.

9. A gas turbine engine, comprising:

a front bearing compartment bounded by a first and second carbon seal;

a mid bearing compartment bounded by a first and second carbon seal, said mid bearing compartment axially aft of said front bearing compartment;

a mid-turbine bearing compartment bounded by a first and second carbon seal, said mid-turbine bearing compartment axially aft of said mid bearing compartment; and

a rear bearing compartment bounded by a first and second carbon seal, said rear bearing compartment axially aft of said mid-turbine bearing compartment.

10. The gas turbine engine as recited in claim **9**, wherein said front bearing compartment contains #1 and a #1.5 tapered bearing and a geared architecture which drives a fan at a lower speed than a low spool.

11. The gas turbine engine as recited in claim **9**, wherein said mid-bearing compartment contains a #2 bearing that rotationally supports a forward end section of a low spool and a #3 bearing that rotationally supports a forward end section of a high spool.

12. The gas turbine engine as recited in claim **9**, wherein said mid-turbine bearing compartment contains a #4 bearing that rotationally supports an aft end section of a high spool.

13. The gas turbine engine as recited in claim **9**, wherein said rear bearing compartment contains a #5 bearing and a #6 bearing that rotationally supports an aft end section of a low spool.

14. The gas turbine engine as recited in claim **9**, further comprising an oil system in fluid communication with each of said front bearing compartment, said mid bearing compartment, said mid-turbine bearing compartment and said rear bearing compartment.

15. The gas turbine engine as recited in claim **14**, wherein said oil system includes a deoiler.

16. The gas turbine engine as recited in claim **14**, wherein said oil system includes a deaerator.

17. A method of reducing oil outflow from an oil system in communication with a geared architecture of a gas turbine engine having a multiple of bearing cavities, comprising:

bounding a multiple of bearing cavities with a multiple of carbon seals.

18. The method as recited in claim **14**, further comprising:

bounding each of the multiple of bearing cavities with a first and second carbon seal.

19. The method as recited in claim **14**, further comprising:

associating each of the multiple of bearing cavities with a spool of the gas turbine engine.

20. The method as recited in claim **14**, wherein one of said bearing cavities contains a geared architecture which drives a fan at a rotational speed less than a low spool.

* * * * *