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(54) **CANTED FUEL INJECTOR ASSEMBLY FOR A TURBINE ENGINE**

(57) An assembly for a gas turbine engine includes a combustor and a fuel injector assembly (62). The combustor includes a combustion chamber (58) that extends axially along and circumferentially about an axial centerline (22). The fuel injector assembly (62) is configured to direct fuel and air into the combustion chamber (58). The fuel injector assembly (62) includes a fuel injector nozzle (122) and an air swirler structure (66). The fuel injector nozzle (122) projects into and is coupled with the air swirler structure (66). The centerline axis (72) of the fuel injector nozzle (122) and/or the air swirler structure (66) is angularly offset from the axial centerline (22) by an offset angle (144) in a circumferential direction about the axial centerline (22).

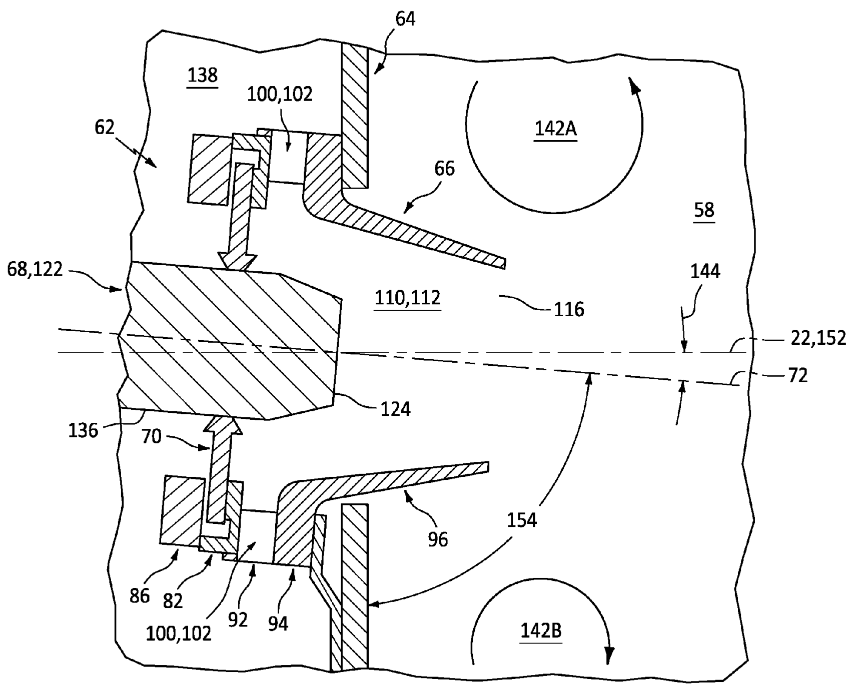

FIG. 6

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Description

BACKGROUND OF THE INVENTION

1. Technical Field

[0001] This invention relates generally to a gas turbine engine and, more particularly, to a fuel injector assembly for the gas turbine engine.

2. Background Information

[0002] Various types and configurations of fuel injector assemblies are known in the art. Some of these known fuel injector assemblies include an air swirler mated with a fuel injector nozzle. While these known fuel injector assemblies have various advantages, there is still room in the art for improvement.

SUMMARY OF THE INVENTION

[0003] According to an aspect of the present invention, an assembly is provided for a gas turbine engine. This turbine engine assembly includes a combustor and a fuel injector assembly. The combustor includes a combustion chamber that extends axially along and circumferentially about an axial centerline. The fuel injector assembly is configured to direct fuel and air into the combustion chamber. The fuel injector assembly includes a fuel injector nozzle and an air swirler structure. The fuel injector nozzle projects into and is coupled with the air swirler structure. The centerline axis of at least one of the fuel injector nozzle or the air swirler structure is angularly offset from the axial centerline by an offset angle in a circumferential direction about the axial centerline.

[0004] According to another aspect of the present invention, another assembly is provided for a gas turbine engine. This turbine engine assembly includes a combustor and a fuel injector assembly. The combustor includes a combustion chamber. The fuel injector assembly is configured to direct fuel and air into the combustion chamber. The fuel injector assembly includes a fuel injector nozzle and an air swirler structure. The fuel injector nozzle projects into and coupled with the air swirler structure. A centerline axis of at least one of the fuel injector nozzle or the air swirler structure is angularly offset from a reference plane by an offset angle. The reference plane is parallel with and projects radially out from an axial centerline of the combustor.

[0005] According to still another aspect of the present invention, another assembly is provided for a gas turbine engine. This turbine engine assembly includes a combustor and a fuel injector assembly. The combustor includes a combustion chamber. The fuel injector assembly is configured to direct fuel and air into the combustion chamber. The fuel injector assembly includes a fuel injector nozzle and an air swirler structure. The fuel injector nozzle projects into and is coupled with the air swirler structure. A centerline axis of at least one of the fuel injector nozzle or the air swirler structure is angularly offset from a reference plane by an offset angle. The reference plane is tangent to a circular reference line that extends circumferentially about an axial centerline of the combustor.

[0006] The following optional features may be applied individually, or in any combination, to any of the above aspects of the invention.

[0007] The offset angle may be greater than zero degrees and less than twenty degrees.

[0008] A reference plane may be parallel with and project radially out from the axial centerline. The centerline axis may be angularly offset from the reference plane by the offset angle.

[0009] A reference line may extend circumferentially about the axial centerline. The centerline axis may be angularly offset from the axial centerline by the offset angle in a reference plane tangent to the reference line.

[0010] The offset angle may be between two degrees and five degrees.

[0011] The offset angle may be between five degrees and ten degrees.

[0012] The offset angle may be between ten degrees and fifteen degrees.

[0013] The centerline axis may also be angularly offset from the axial centerline in a radial direction out from the axial centerline.

[0014] The combustion chamber may be an annular combustion chamber.

[0015] The combustor may include an inner wall, an outer wall and a bulkhead connected to and extending radially between the inner wall and the outer wall. The combustion chamber may extend radially between the inner wall and the outer wall. The combustion chamber may extend axially along the axial centerline to the bulkhead.

[0016] The centerline axis may be angularly offset from the bulkhead by a second offset angle in the circumferential direction about the axial centerline. The second offset angle may be equal to ninety degrees minus the offset angle.

[0017] The centerline axis may be perpendicular to the bulkhead in a reference plane including the axial centerline.

[0018] The centerline axis may bisect the combustion chamber radially between the inner wall and the outer wall in a reference plane including the axial centerline.

[0019] The fuel injector assembly may also include a nozzle guide coupling the fuel injector nozzle to the air swirler structure. The nozzle guide may be configured to engage and move along a surface of the fuel injector nozzle.

[0020] The air swirler structure may include an inner bore and an air swirler passage. The inner bore may extend along the centerline axis through the air swirler structure. The air swirler passage may extend into the air swirler structure, towards the centerline axis, to the inner bore.

The fuel injector nozzle may project along the centerline axis into the inner bore.

[0021] The air swirler structure may include one or more radial air swirlers.

[0022] The assembly may also include a second fuel injector assembly configured to direct additional fuel and air into the combustion chamber. The second fuel injector assembly may include a second fuel injector nozzle and a second air swirler structure. The second fuel injector nozzle may project into and may be coupled with the second air swirler structure. A second centerline axis of at least one of the second fuel injector nozzle or the second air swirler structure may be angularly offset from the axial centerline by a second offset angle in the circumferential direction about the axial centerline.

[0023] The second offset angle may be equal to the offset angle.

[0024] The present invention may include any one or more of the individual features disclosed above and/or below alone or in any combination thereof.

[0025] The foregoing features and the operation of the invention will become more apparent in light of the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

FIG. 1 is a side cutaway illustration of a geared turbine engine.

FIG. 2 is a partial side sectional illustration of a combustor with a fuel injector assembly.

FIG. 3 is a partial side sectional illustration of the fuel injector assembly.

FIG. 4 is a cross-sectional illustration of a radial air swirler.

FIGS. 5A-C are partial schematic illustrations of a fuel injector nozzle injecting fuel along various trajectories.

FIG. 6 is a partial sectional illustration at an interface between the combustor and the fuel injector assembly.

FIG. 7 is a schematic illustration of the combustor with multiple fuel injector assemblies.

FIG. 8 is a partial side sectional illustration of the fuel injector assembly configured with multiple air swirlers.

DETAILED DESCRIPTION

[0027] FIG. 1 is a side cutaway illustration of a geared gas turbine engine 20. This gas turbine engine 20 extends along an axial centerline 22 between an upstream airflow inlet 24 and a downstream airflow exhaust 26. The gas turbine engine 20 includes a fan section 28, a compressor section 29, a combustor section 30 and a turbine section 31. The compressor section 29 includes a low pressure compressor (LPC) section 29A and a high pressure compressor (HPC) section 29B. The turbine section 31 includes a high pressure turbine (HPT) section 31A and a low pressure turbine (LPT) section 31B.

[0028] The engine sections 28-31B are arranged sequentially along the axial centerline 22 within an engine housing 34. This engine housing 34 includes an inner case 36 (e.g., a core case) and an outer case 38 (e.g., a fan case). The inner case 36 may house one or more of the engine sections 29A, 29B, 30, 31A and 31B; e.g., a core of the gas turbine engine 20. The outer case 38 may house at least the fan section 28.

[0029] Each of the engine sections 28, 29A, 29B, 31A and 31B includes a respective bladed rotor 40-44. Each of these bladed rotors 40-44 includes a plurality of rotor blades arranged circumferentially around and connected to one or more respective rotor disks and/or hubs. The rotor blades, for example, may be formed integral with or mechanically fastened, welded, brazed, adhered and/or otherwise attached to the respective rotor disk(s) and/or the respective hub(s).

[0030] The fan rotor 40 is connected to a geartrain 46, for example, through a fan shaft 48. The geartrain 46 and the LPC rotor 41 are connected to and driven by the LPT rotor 44 through a low speed shaft 49. The HPC rotor 42 is connected to and driven by the HPT rotor 43 through a high speed shaft 50. The engine shafts 48-50 are rotatably supported by a plurality of bearings 52; e.g., rolling element and/or thrust bearings. Each of these bearings 52 is connected to the engine housing 34 by at least one stationary structure such as, for example, an annular support strut.

[0031] During engine operation, air enters the gas turbine engine 20 through the airflow inlet 24. This air is directed through the fan section 28 and into a core flowpath 54 and a bypass flowpath 56. The core flowpath 54 extends sequentially through the engine sections 29A-31B; e.g., the engine core. The air within the core flowpath 54 may be referred to as "core air". The bypass flowpath 56 extends through a bypass duct, and bypasses the engine core. The air within the bypass flowpath 56 may be referred to as "bypass air".

[0032] The core air is compressed by the LPC rotor 41 and the HPC rotor 42 and directed into a (e.g., annular) combustion chamber 58 of a (e.g., annular) combustor 60 in the combustor section 30. Fuel is injected into the combustion chamber 58 and mixed with the compressed core air to provide a fuel-air mixture. This fuel-air mixture is ignited and combustion products thereof flow through and sequentially cause the HPT rotor 43 and the LPT rotor 44 to rotate. The rotation of the HPT rotor 43 and the LPT rotor 44 respectively drive rotation of the HPC rotor 42 and the LPC rotor 41 and, thus, compression of the air received from an inlet to the core flowpath 54. The rotation of the LPT rotor 44 also drives rotation of the fan rotor 40, which propels the bypass air through and out of the bypass flowpath 56. The propulsion of the bypass air may account for a majority of thrust generated by the gas turbine engine 20.

[0033] Referring to FIG. 2, the combustor section 30 includes a plurality of fuel injector assemblies 62 (one visible in FIG. 2) arranged circumferentially about the axial centerline 22 in a circular array. The fuel injector assemblies 62 are mounted to a (e.g., annular) bulkhead 64 of the combustor 60. The fuel injector assemblies 62 are configured to direct a mixture of the fuel and the compressed core air into the combustion chamber 58 for combustion. Each fuel injector assembly 62 of FIG. 2 includes an air swirler structure 66 and a fuel injector 68. The fuel injector assembly 62 also includes a nozzle guide 70 (e.g., a guide plate, a slider, a nozzle mount, etc.) coupling the fuel injector 68 to the air swirler structure 66.

[0034] Referring to FIG. 3, the air swirler structure 66 extends circumferentially around a longitudinal centerline axis 72 (e.g., a centerline of the air swirler structure 66) providing the air swirler structure 66 with a full-hoop body. The air swirler structure 66 extends longitudinally along the centerline axis 72 from an upstream end 74 of the air swirler structure 66 to a downstream end 76 of the air swirler structure 66. The air swirler structure 66 of FIG. 3 includes a base section 78 and a swirler section 80.

[0035] The base section 78 is disposed at (e.g., on, adjacent or proximate) the structure upstream end 74. This base section 78 may be configured as or otherwise include a first swirler wall 82; e.g., an annular upstream swirler wall. The base section 78 may also be configured to form a receptacle 84 (e.g., a slot, a channel, etc.) for receiving the nozzle guide 70 at the structure upstream end 74. The base section 78 of FIG. 3, for example, also includes a mounting plate 86 abutted longitudinally against and attached (e.g., mechanically fastened and/or bonded) to the first swirler wall 82. The receptacle 84 is formed at an inner periphery of the base section 78, longitudinally between a (e.g., annular) back surface 88 of the first swirler wall 82 and a (e.g., annular) back surface 90 of the mounting plate 86.

[0036] The swirler section 80 includes an outer air swirler 92 and a second swirler wall 94; e.g., an annular downstream swirler wall. The swirler section 80 of FIG. 3 also includes a swirler guide wall 96; e.g., a tubular funnel wall.

[0037] The air swirler 92 may be configured as a radial air swirler. The air swirler 92 of FIG. 3, for example, is arranged longitudinally between and is connected to the first swirler wall 82 and the second swirler wall 94. The air swirler 92 of FIG. 4 includes a plurality of air swirler vanes 98. Each of these air swirler vanes 98 of FIG. 3 extends longitudinally along the centerline axis 72 between and is connected to the first swirler wall 82 and the second swirler wall 94. The air swirler vanes 98 of FIG. 4 are arranged circumferentially about the centerline axis 72 in a circular array. Each of the air swirler vanes 98 is circumferentially separated from each circumferentially neighboring (e.g., adjacent) air swirler vane 98 by a respective air swirler channel 100; e.g., an air gap. Each air swirler channel 100 extends circumferentially between and to a respective circumferentially neighboring pair of the air swirler vanes 98. Each air swirler channel 100 of FIG. 3 extends longitudinally along the centerline axis 72 between and to the first swirler wall 82 and the second swirler wall 94. With this arrangement of FIGS. 3 and 4, the air swirler channels 100 collectively form an air swirler passage 102 radially (relative to the centerline axis 72) through the air swirler 92, longitudinally between the swirler walls 82 and 94. The air swirler vanes 98 / the air swirler channels 100 are configured such that air passing through and out of the air swirler passage 102 is directed in a first circumferential direction (e.g., a clockwise direction, or alternatively a counterclockwise direction) about the centerline axis 72. In other words, the air swirler vanes 98 / the air swirler channels 100 are operable to circumferentially swirl the air passing through the air swirler 92 in the first circumferential direction.

[0038] Referring to FIG. 3, the swirler guide wall 96 is disposed at the structure downstream end 76. The swirler guide wall 96 of FIG. 3, for example, is connected to (and cantilevered from) the second swirler wall 94 at an inner end of the air swirler 92. This swirler guide wall 96 projects out from the second swirler wall 94 and extends longitudinally along the centerline axis 72 to a (e.g., downstream) distal end 104 of the swirler guide wall 96 at the structure downstream end 76. As the swirler guide wall 96 extends longitudinally towards (e.g., to) the structure downstream end 76, the swirler guide wall 96 may (e.g., continuously or incrementally) radially taper inwards towards the centerline axis 72. The swirler guide wall 96 may thereby have a tubular frustoconical geometry with frustoconical inner and/or outer surfaces 106 and 108.

[0039] The air swirler structure 66 of FIG. 3 is further configured with a swirler inner passage 110. This inner passage 110 is formed by an inner bore 112 of the air swirler structure 66, which inner bore 112 extend longitudinally along the centerline axis 72 (e.g., generally axially along the axial centerline 22 of FIG. 2) through the air swirler structure 66 between and to the structure upstream end 74 and the structure downstream end 76. An outer peripheral boundary of an upstream portion of the inner passage 110 may be formed by and radially within the base section 78 and its first swirler wall 82. An outer peripheral boundary of a downstream portion of the inner passage 110 may be formed by and radially within the swirler section 80 and its swirler guide wall 96. The inner passage 110 of FIG. 3 extends longitudinally within the air swirler structure 66 from (or about) a side 114 of the nozzle guide 70, which engages (e.g., abuts against, contacts, etc.) the first swirler wall 82, to an inner swirler outlet 116 (e.g., an outlet orifice) at the structure downstream end 76.

[0040] Referring to FIG. 2, the air swirler structure 66 may be mated with the combustor bulkhead 64. The swirler guide wall 96, for example, may project axially into or through a respective port in the combustor bulkhead 64. The air swirler structure 66 may also be mounted to the combustor bulkhead 64. For example, the swirler section

80 (e.g., the second swirler wall 94 and/or the swirler guide wall 96 of FIG. 3) may be bonded (e.g., brazed or welded) and/or otherwise connected to the combustor bulkhead 64 and, more particularly, a shell 118 of the combustor bulkhead 64. However, various other techniques are known in the art for mounting an air swirler structure to a combustor bulkhead (or various other combustor components), and the present disclosure is not limited to any particular ones thereof.

[0041] The fuel injector 68 of FIG. 2 includes a fuel injector stem 120 and a fuel injector nozzle 122. The injector stem 120 is configured to support and route the fuel to the injector nozzle 122. The injector nozzle 122 is cantilevered from the injector stem 120. The injector nozzle 122 projects along the centerline axis 72 (e.g., a centerline of the injector nozzle 122) partially into the inner bore 112 of the air swirler structure 66. A tip 124 of the injector nozzle 122 is thereby disposed within the inner passage 110. Here, the nozzle tip 124 is longitudinally spaced from the inner swirler outlet 116 by a longitudinal distance along the centerline axis 72.

[0042] Referring to FIG. 3, the nozzle guide 70 includes a nozzle guide base 126 (e.g., an annular plate) and a nozzle guide foot 128 (e.g., a bearing and/or slide member). The nozzle guide 70 extends radially between and to an inner end 130 of the nozzle guide 70 and an outer end 132 of the nozzle guide 70. The nozzle guide 70 and each of its members 126 and 128 extends circumferentially about (e.g., completely around) the centerline axis 72. The nozzle guide 70 may thereby be configured with a full-hoop annular body.

[0043] The guide base 126 projects radially outward (e.g., away from the centerline axis 72) from the guide foot 128 to the guide outer end 132; e.g., a radial outer distal end of the guide base 126. The guide base 126 extends longitudinally along the centerline axis 72 between and to opposing axial sides 114 and 134 of the guide base 126. The guide base 126 of FIG. 3 is disposed radially outboard of and circumscribes the guide foot 128. The guide foot 128 is disposed at the guide inner end 130.

[0044] The nozzle guide 70 is configured to couple the injector nozzle 122 to the air swirler structure 66 and, thus, the bulkhead 64 (see FIG. 2). The nozzle guide 70 and its guide base 126, for example, may project radially into the receptacle 84, where the nozzle guide 70 and its guide base 126 may be (e.g., loosely) captured longitudinally between the first swirler wall 82 and the mounting plate 86. This capturing of the nozzle guide 70 between the first swirler wall 82 and the mounting plate 86 may facilitate the nozzle guide 70 and its guide base 126 to radially float (e.g., shift) within the receptacle 84. The nozzle guide 70 and its guide base 126, for example, may longitudinally abut against, but slide (e.g., radially) along the first swirler wall 82 and/or the mounting plate 86. This floating may in turn accommodate (e.g., slight) radial shifting between the air swirler structure 66 and the fuel injector 68 and its injector nozzle 122 during gas turbine engine operation.

[0045] The injector nozzle 122 is mated with the nozzle guide 70. The injector nozzle 122, for example, projects axially through an inner bore of the guide foot 128. The guide foot 128 thereby extends axially along and circumscribes the injector nozzle 122. The guide foot 128 is configured to radially engage (e.g., contact) an outer cylindrical bearing surface 136 (e.g., a land surface) of the injector nozzle 122. The guide foot 128 is further configured to move (e.g., slide, translate, etc.) axially along the injector nozzle 122 and its bearing surface 136. This relative movement between the guide foot 128 and the injector nozzle 122 and its bearing surface 136 may in turn accommodate (e.g., slight) axial shifting between the air swirler structure 66 and the fuel injector 68 and its injector nozzle 122 during gas turbine engine operation.

[0046] During operation of the fuel injector assembly 62 of FIG. 3, the compressed core air received from a diffuser plenum 138 surrounding the combustor 60 (see also FIG. 2) is directed into the air swirler passage 102. This air flows radially through the air swirler passage 102, along the first swirler wall 82 and the second swirler wall 94, and is directed into the inner passage 110; e.g., a portion of the inner bore 112 downstream of the nozzle guide 70. As the air passes through the air swirler 92 and the air swirler passage 102, the stream of air is swirled in the first circumferential direction (see FIG. 4). The air stream directed through the air swirler 92 into the inner passage 110 is therefore (or otherwise includes) swirled air. This swirled air is then directed longitudinally through the inner passage 110 along the centerline axis 72 (e.g., generally axially along the axial centerline 22 of FIG. 2) and is discharged from the air swirler structure 66 through the inner swirler outlet 116 into the combustion chamber 58.

[0047] The fuel is also injected into the combustion chamber 58 by the fuel injector 62 and its injector nozzle 122. More particularly, the fuel is directed out of one or more nozzle orifices (e.g., nozzle outlets) in the injector nozzle 122 into the inner passage 110 for mixing with the swirled air within the inner passage 110 and/or within the combustion chamber 58. The fuel injected by the injector nozzle 122 may be a hydrocarbon fuel such as kerosene or jet fuel and/or a non-hydrocarbon fuel such as hydrogen fuel (e.g., H_2 gas).

[0048] Referring to FIG. 5A, the fuel may be directed out of the injector nozzle 122 in a substantially radial direction (e.g., see line 140A) from one or more of the fuel nozzle orifice(s). Referring to FIG. 5B, the fuel may alternatively (or also) be directed out of the injector nozzle 122 in a substantially longitudinal direction (e.g., see line 140B) from one or more of the fuel nozzle orifice(s). Referring to FIG. 5C, the fuel may alternatively (or also) be directed out of the injector nozzle 122 in a canted (e.g., longitudinal and radial; diagonal) direction (e.g., see line 140C) from one or more of the fuel nozzle orifice(s). The present disclosure, however, is not limited to the foregoing exemplary injector nozzle configurations.

[0049] Referring to FIG. 6, the swirled air and the fuel (e.g., the fuel-air mixture) are injected into the combustion chamber 58 from the respective fuel injector assembly 62 along a trajectory. This trajectory extends longitudinally along the centerline axis 72 of the respective fuel injector assembly components 66 and/or 122. Recirculation zones 142A and 142B (generally referred to as "142") may form within the combustion chamber 58 (e.g., adjacent the bulkhead 64) to opposing circumferential sides (e.g., relative to the axial centerline 22) of the air and fuel injected from the respective fuel injector assembly 62. These recirculation zones 142 may affect downstream mixing and/or flow characteristics of the combustion products within the combustion chamber 58. In an effort to promote increased (e.g., circumferential) uniformity in pattern factor of the combustion products exiting the combustion chamber 58, each fuel injector assembly 62 is canted (e.g., angled) in a circumferential (e.g., clockwise or counterclockwise) direction about the axial centerline 22. Such asymmetry of each fuel injector assembly 62 may tailor characteristics of the recirculation zones 142; e.g., provide asymmetric recirculation zones. This tailoring of the recirculation zones 142 may: (A) reduce formation of a bi-stable head-end flow field within each sector of the combustion chamber 58; (B) facilitate a more consistent head-end flow field in each sector of the combustion chamber 58; and/or (C) promote intersector mixing. The tailoring of the recirculation zones 142 may thereby promote a more consistent downstream interaction and mixing with quench air (e.g., dilution air) and/or mitigate generation of local hot spots. Reducing hot spots may facilitate increased combustor section and/or turbine section component life. Reducing hot spots may also facilitate a reduction in cooling requirements for combustor section and/or turbine section components.

[0050] To circumferentially cant the fuel injector assembly 62, the centerline axis 72 of the air swirler structure 66 and/or the injector nozzle 122 may be angularly offset from the axial centerline 22 by a first offset angle 144 in a circumferential direction about the axial centerline 22. This first offset angle 144 may be viewed from / measured in a tangential reference plane; e.g., plane of FIG. 6. Referring to FIG. 7, the tangential reference plane may be a plane 146 that is tangent to a (e.g., circular or arcuate) reference line 148 extending circumferentially about the axial centerline 22 at a location 150 circumferentially aligned with the respective centerline axis 72. Referring to FIG. 6, the first offset angle 144 may also or alternatively be measured between the respective centerline axis 72 and a radial reference plane; e.g., plane of FIG. 2. The radial reference plane may be a plane 152 that is parallel with (e.g., includes) and projects radially out from the axial centerline 22.

[0051] The first offset angle 144 of FIG. 6 is a (e.g., relatively small, slight) non-zero acute angle. The first offset angle 144, for example, may be greater than zero degrees (0°) and less than or equal to twenty degrees (20°). More particularly, the first offset angle 144 may be between two degrees (2°) and five degrees (5°), between five degrees (5°) and ten degrees (10°), or between ten degrees (10°) and fifteen degrees (15). In general, the first offset angle 144 may be selected to be large enough to tailor the recirculation zones 142 as described above. However, the first offset angle 144 may be selected to be small enough to avoid or minimize bulk combustion products swirl about the axial centerline 22 within the combustion chamber 58.

[0052] By circumferentially canting the fuel injector assembly 62 of FIG. 6, the centerline axis 72 may also be angularly offset from the bulkhead 64 by a second offset angle 154 in the circumferential direction about the axial centerline 22. This second offset angle 154 is greater than the first offset angle 144. The second offset angle 154 may be equal to ninety degrees (90°) minus the first offset angle 144. For example, where the first offset angle 144 is between two and fifteen degrees (2-15°), the second offset angle 154 may be between seventy-five and eighty-eight degrees (75-88°). The present disclosure, however, is not limited to such an exemplary relationship.

[0053] Referring to FIG. 2, when viewed / measured in the radial reference plane, the centerline axis 72 may be perpendicular to the bulkhead 64. Alternatively, the centerline axis 72 may be (e.g., slightly) angularly offset from the bulkhead 64 in a radial outward direction or a radial inward direction relative to the axial centerline 22.

[0054] When viewed / measured in the radial reference plane of FIG. 2, the centerline axis 72 may radially bisect the combustion chamber 58 between an inner wall 156 and an outer wall 158 of the combustor 60. For example, an inner distance 160 from the centerline axis 72 to the inner wall 156 may be equal to an outer distance 162 from the centerline axis 72 to the outer wall 158 as the centerline axis 72 extends away from the bulkhead 64 through a portion or an entirety of the combustion chamber 58. Each distance 160, 162 may be measured along a line perpendicular to the centerline axis 72. However, in other embodiments, a ratio between the inner distance 160 and the outer distance 162 may change (e.g., increase, decrease or fluctuate) as the centerline axis 72 extends away from the bulkhead 64 through a portion or the entirety of the combustion chamber 58.

[0055] When viewed / measured in the radial reference plane of FIG. 2, the centerline axis 72 may be angularly offset from the axial centerline 22 in a radial direction out from (or in towards) the axial centerline 22. However, in other embodiments, the centerline axis 72 may be parallel with the axial centerline 22.

[0056] In some embodiments, referring to FIG. 3, the air swirler structure 66 may be configured with a single air swirler. In other embodiments, referring to FIG. 8, the air swirler may alternatively be one of a plurality of air swirlers 92A-C (generally referred to as "92"). In the embodiment of FIG. 8, the first air swirler 92A and the second air swirler 92B are each configured to direct (counter or co) swirled air radially into the inner bore 112 and its inner passage 110. The second air swirler 92B may be configured similar to the first air swirler 92A, except positioned axially downstream of the first air swirler 92A. The first air swirler 92A, for example, may be arranged axially between (a) the nozzle guide 70 / the first swirler wall 82 and (b) the second air swirler 92B. The first air swirler 92A may also be axially aligned with (e.g., axially overlap) the injector nozzle 122; e.g., axially arranged between (a) the nozzle guide 70 / the first swirler wall 82 and (b) the nozzle tip 124. The third air swirler 92C, on the other hand, may be configured to direct swirled air into an outer swirler passage 164 (e.g., an annulus within the air swirler structure 66) that circumscribes and extends along the swirler guide wall 96. This third air swirler 92C may swirl a third stream of air in the first circumferential direction (e.g., a common direction as the first air swirler 92A and/or the second air swirler 92B), or in the second circumferential direction about the centerline axis 72 that is opposite the first circumferential direction. The present disclosure, however, is not limited to such an exemplary multi-air swirler configuration. For example, in other embodiments, the air swirler structure 66 may also or alternatively include one or more other radial and/or axial flow air swirlers. In still other embodiments, the second air swirler 92B or the third air swirler 92C may be omitted to provided, for example, a dual air swirler arrangement.

[0057] The fuel injector assembly(ies) 62 may be included in various turbine engines other than the one described above. The fuel injector assembly(ies) 62, for example, may be included in a geared turbine engine where a geartrain connects one or more shafts to one or more rotors in a fan section, a compressor section and/or any other engine section. Alternatively, the fuel injector assembly(ies) 62 may be included in a direct drive turbine engine configured without a geartrain. The fuel injector assembly(ies) 62 may be included in a turbine engine configured with a single spool, with two spools (e.g., see FIG. 1), or with more than two spools. The turbine engine may be configured as a turbofan engine, a turbojet engine, a turboprop engine, a turboshaft engine, a propfan engine, a pusher fan engine or any other type of turbine engine. The turbine engine may alternatively be configured as an auxiliary power unit (APU) or an industrial gas turbine engine. The present disclosure therefore is not limited to any particular types or configurations of turbine engines.

[0058] While various embodiments of the present disclosure have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the invention. For example, the present invention as described herein includes several aspects and embodiments that include particular features. Although these features may be described individually, it is within the scope of the present invention that some or all of these features may be combined with any one of the aspects and remain within the scope of the invention. Accordingly, the present disclosure is not to be restricted except in light of the attached claims and their equivalents.

Claims

1. An assembly for a gas turbine engine (20), comprising:

   a combustor (60) comprising a combustion chamber (58) that extends axially along and circumferentially about an axial centerline (22); and

   a fuel injector assembly (62) configured to direct fuel and air into the combustion chamber (58), the fuel injector assembly (62) including a fuel injector nozzle (122) and an air swirler structure (66), the fuel injector nozzle (122) projecting into and coupled with the air swirler structure (66), and a centerline axis (72) of the fuel injector nozzle (122) and/or the air swirler structure (66) angularly offset from the axial centerline (22) by an offset angle (144) in a circumferential direction about the axial centerline (22).

2. The assembly of claim 1, wherein:

   a first reference plane (152) is parallel with and projects radially out from the axial centerline (22); and

   the centerline axis (72) is angularly offset from the first reference plane (152) by the offset angle (144).

3. The assembly of claim 1 or 2, wherein:

   a reference line (148) extends circumferentially about the axial centerline (22); and

   the centerline axis (72) is angularly offset from the axial centerline (22) by the offset angle (144) in a second reference plane (146) tangent to the reference line (148).

4. The assembly of any preceding claim, wherein:

   the offset angle (144) is between two degrees and five degrees;

   the offset angle (144) is between five degrees and ten degrees; or

   the offset angle (144) is between ten degrees and fifteen degrees.

5. The assembly of any preceding claim, wherein the centerline axis (72) is further angularly offset from the axial centerline (22) in a radial direction out from the axial centerline (22).

6. The assembly of any preceding claim, wherein:

   the combustion chamber (58) is an annular combustion chamber (58); and/or

   the air swirler structure (66) includes one or more radial air swirlers (92).

7. The assembly of any preceding claim, wherein:

the combustor (60) includes an inner wall (156), an outer wall (158) and a bulkhead (64) connected to and extending radially between the inner wall (156) and the outer wall (158);
the combustion chamber (58) extends radially between the inner wall (156) and the outer wall (158); and
the combustion chamber (58) extends axially along the axial centerline (22) to the bulkhead (64),

optionally wherein:

the centerline axis (72) is angularly offset from the bulkhead (64) by a second offset angle (154) in the circumferential direction about the axial centerline (22); and
the second offset angle (154) is equal to ninety degrees minus the offset angle (144).

8. The assembly of claim 7, wherein the centerline axis (72) is perpendicular to the bulkhead (64) in a or the first reference plane (152) including the axial centerline (22).

9. The assembly of claim 7 or 8, wherein the centerline axis (72) bisects the combustion chamber (58) radially between the inner wall (156) and the outer wall (158) in a or the first reference plane (152) including the axial centerline (22).

10. The assembly of any preceding claim, wherein:

the fuel injector assembly (62) further includes a nozzle guide (70) coupling the fuel injector nozzle (122) to the air swirler structure (66); and
the nozzle guide (70) is configured to engage and move along a surface of the fuel injector nozzle (122).

11. The assembly of any preceding claim, wherein:

the air swirler structure (66) includes an inner bore (112) and an air swirler passage (110);
the inner bore (112) extends along the centerline axis (72) through the air swirler structure (66);
the air swirler passage (110) extends into the air swirler structure (66), towards the centerline axis (72), to the inner bore (112); and
the fuel injector nozzle (122) projects along the centerline axis (72) into the inner bore (112).

12. The assembly of any preceding claim, further comprising:

a second fuel injector assembly (62) configured to direct additional fuel and air into the combustion chamber (58), the second fuel injector assembly (62) including a second fuel injector nozzle (122) and a second air swirler structure (66), the second fuel injector nozzle (122) projecting into and coupled with the second air swirler structure (66); and
a second centerline axis (72) of the second fuel injector nozzle (122) and/or the second air swirler structure (66), angularly offset from the axial centerline (22) by a or the second offset angle (154) in the circumferential direction about the axial centerline (22).

13. The assembly of claim 12, wherein the second offset angle (154) is equal to the offset angle (144).

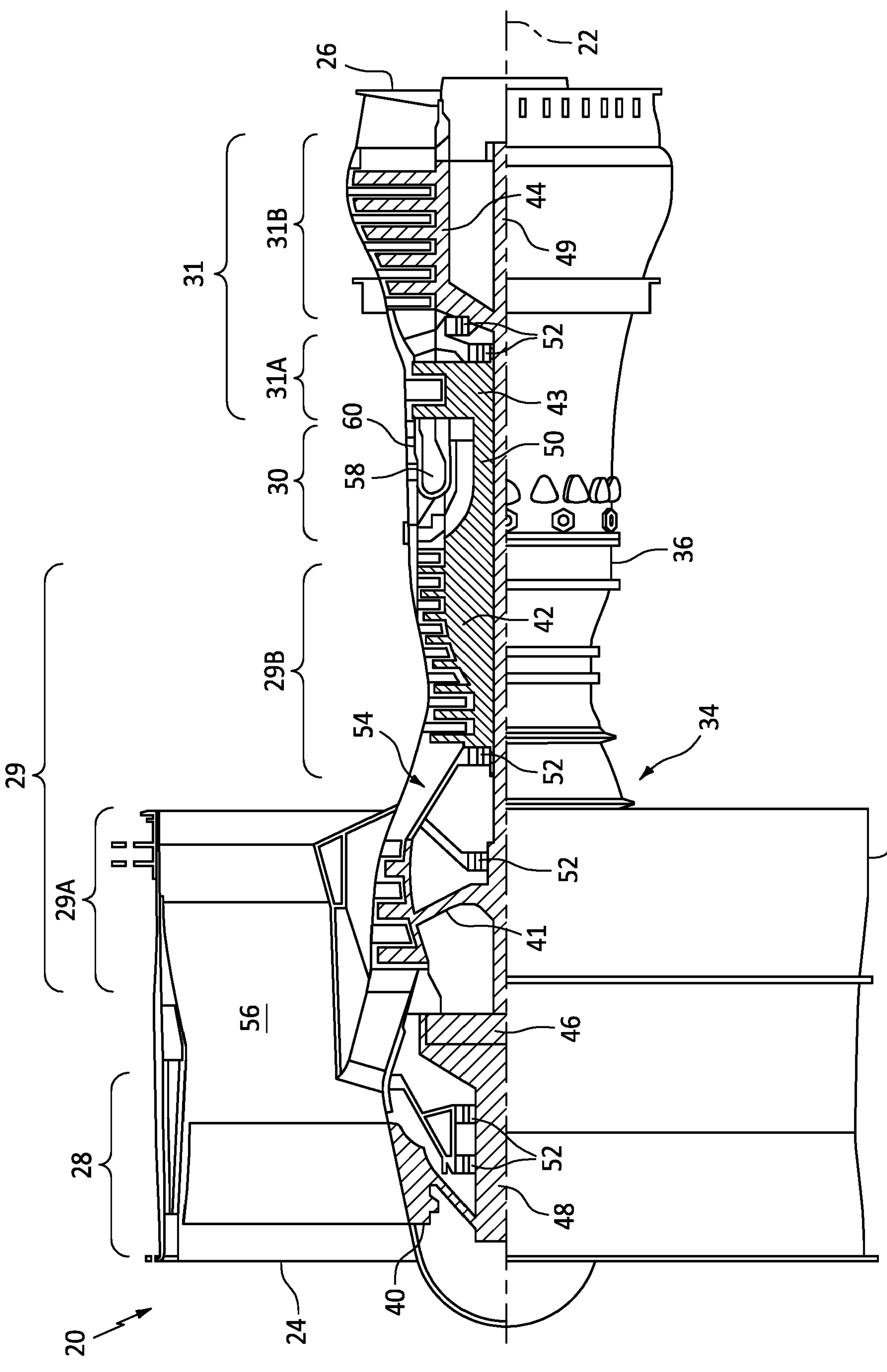
14. An assembly for a gas turbine engine (20), comprising:

a combustor (60) comprising a combustion chamber (58); and
a fuel injector assembly (62) configured to direct fuel and air into the combustion chamber (58), the fuel injector assembly (62) including a fuel injector nozzle (122) and an air swirler structure (66), the fuel injector nozzle (122) projecting into and coupled with the air swirler structure (66), a centerline axis (72) of the fuel injector nozzle (122) and/or the air swirler structure (66) angularly offset from a reference plane (152) by an offset angle (144), and the reference plane (152) parallel with and projecting radially out from an axial centerline (22) of the combustor (60),

optionally wherein the offset angle (144) is greater than zero degrees and less than twenty degrees.

15. An assembly for a gas turbine engine (20), comprising:

a combustor (60) comprising a combustion chamber (58); and
a fuel injector assembly (62) configured to direct fuel and air into the combustion chamber (58), the fuel injector assembly (62) including a fuel injector nozzle (122) and an air swirler structure (66), the fuel injector nozzle (122) projecting into and coupled with the air swirler structure (66), a centerline axis (72) of at least one of the fuel injector nozzle (122) or the air swirler structure (66) angularly offset from a reference plane (146) by an offset angle (144), and the reference plane (146) tangent to a circular reference line (148) that extends circumferentially about an axial centerline (22) of the combustor (60).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31A
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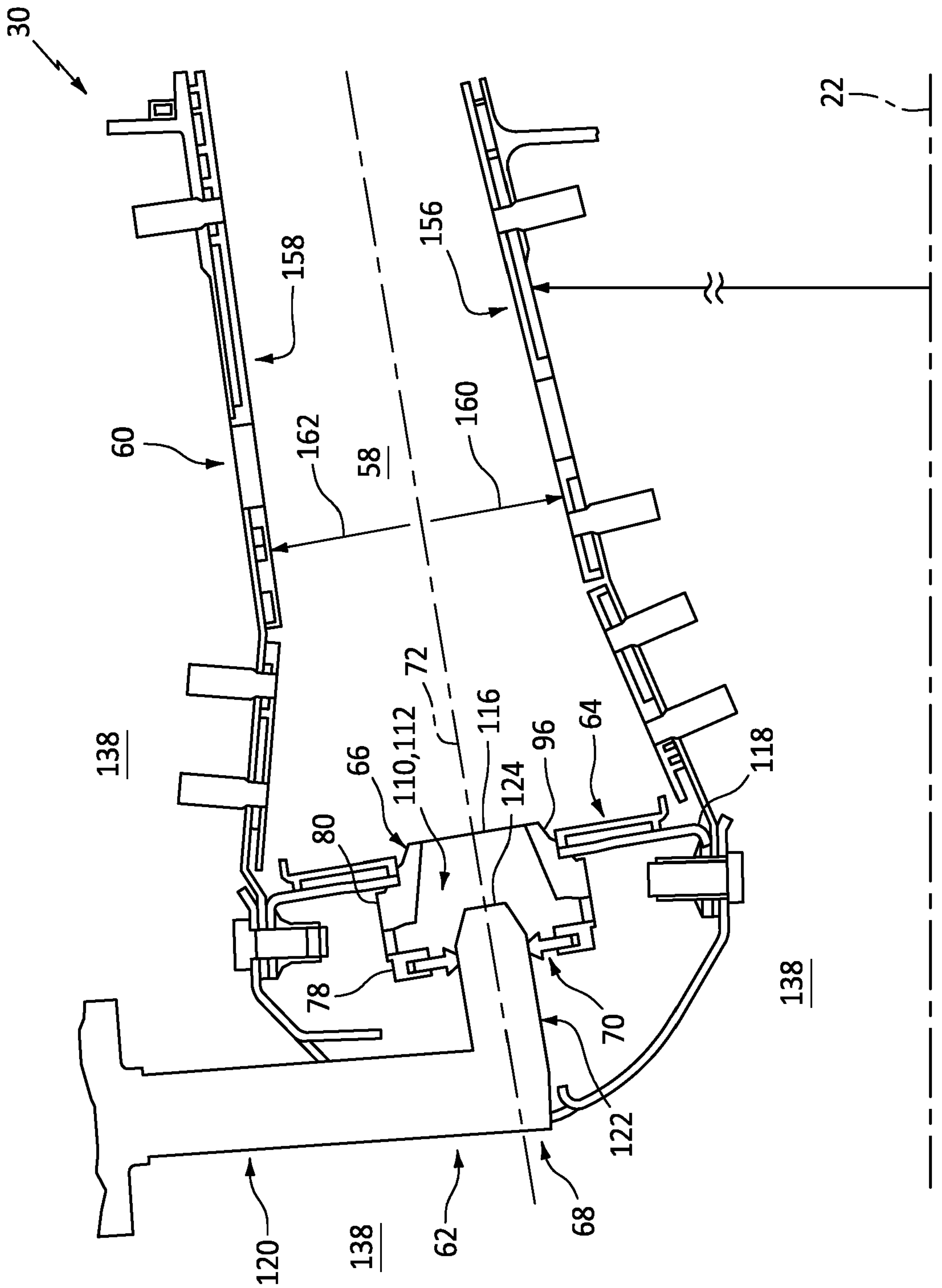
FIG. 1



30
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156
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162
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72
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122
120
138
62
68

FIG. 2

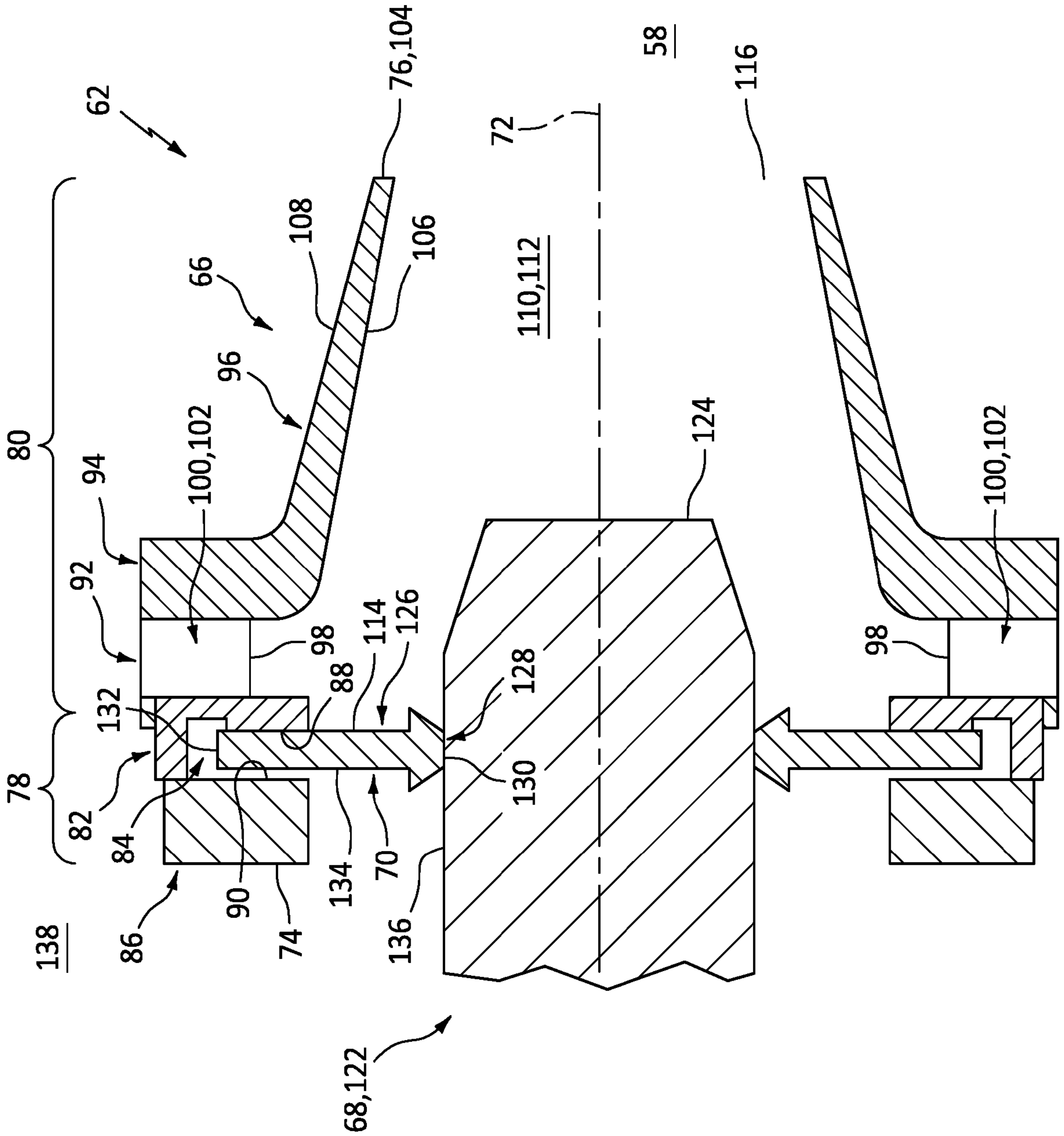
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FIG. 3

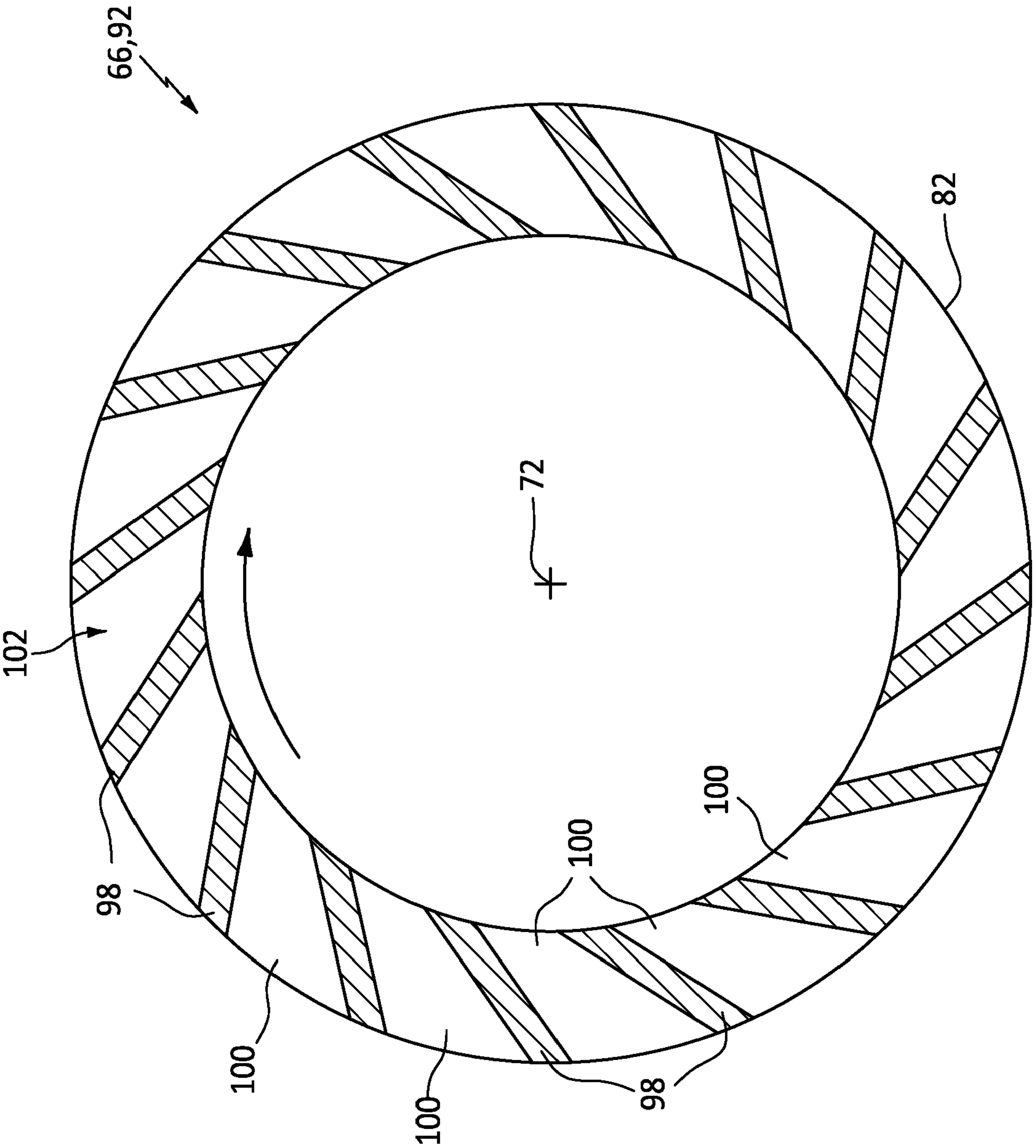


FIG. 4

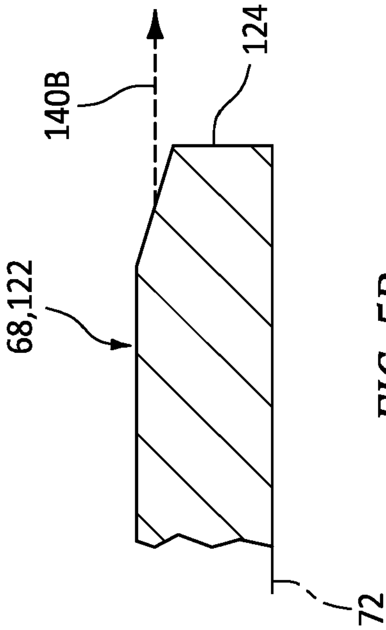


FIG. 5B

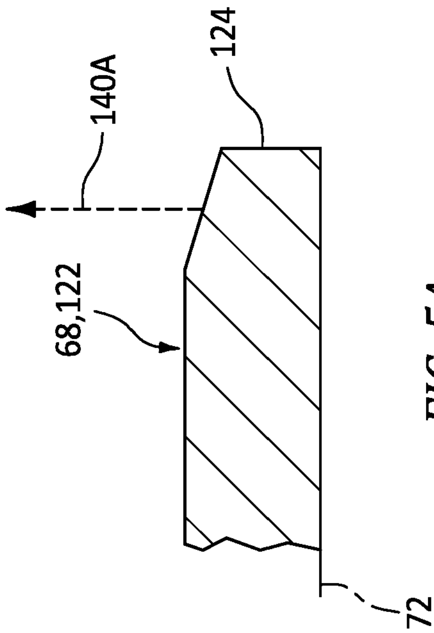


FIG. 5A

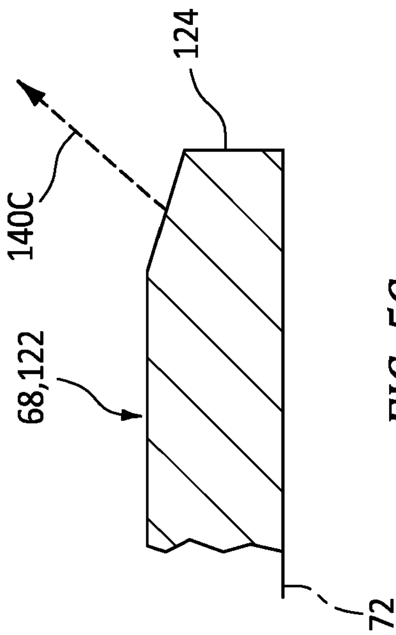
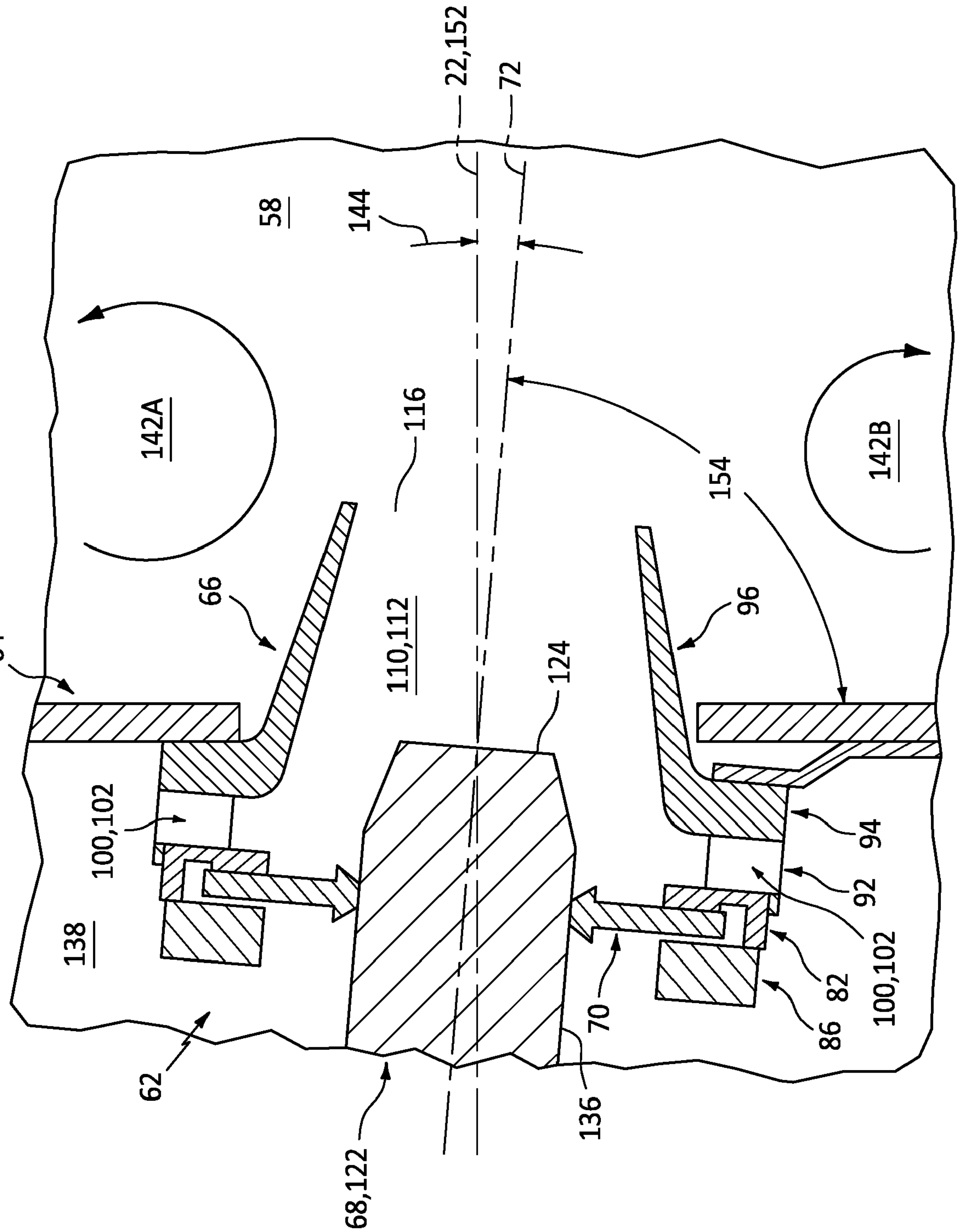


FIG. 5C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92
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62
136
68,122

FIG. 6

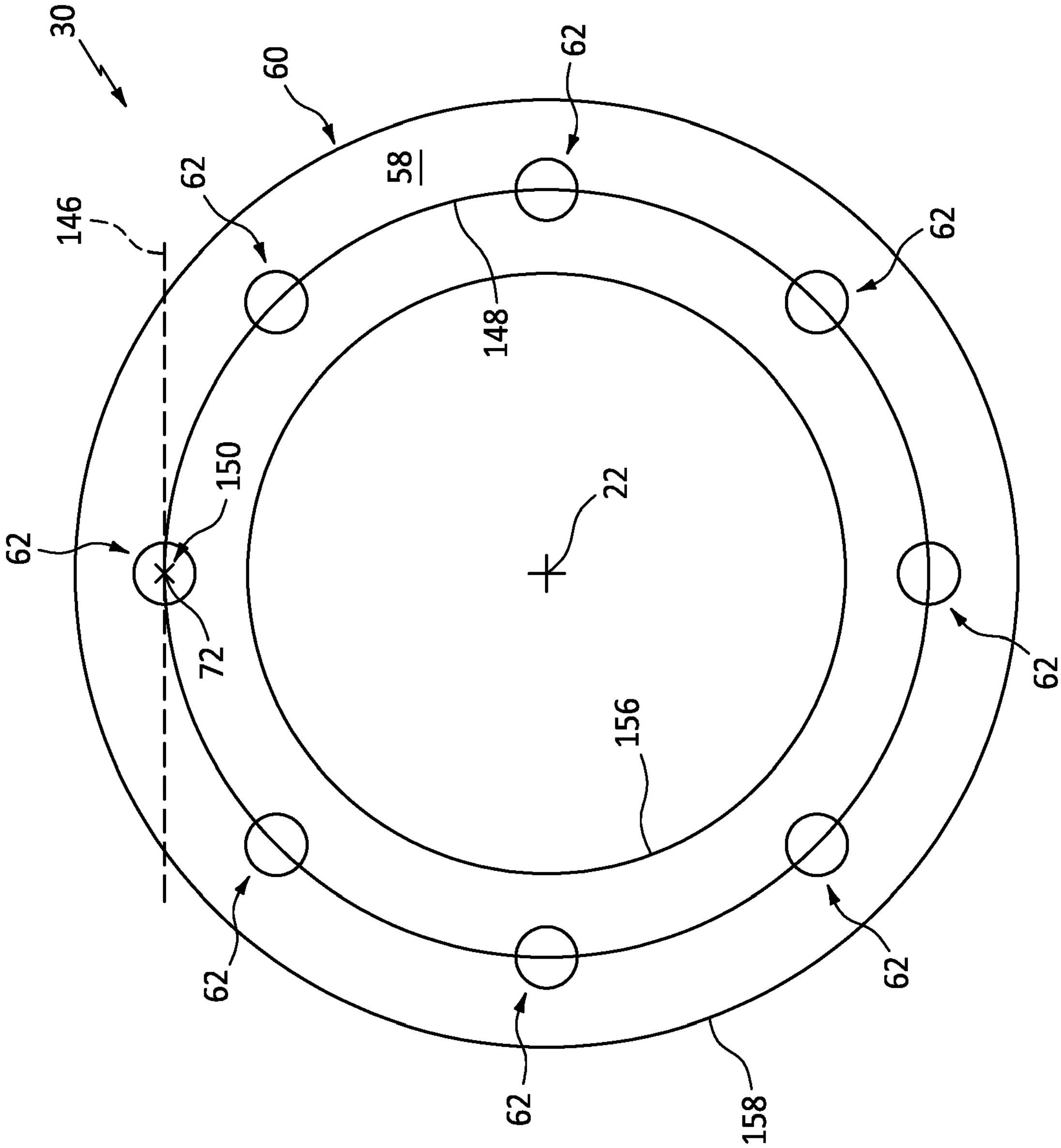

FIG. 7

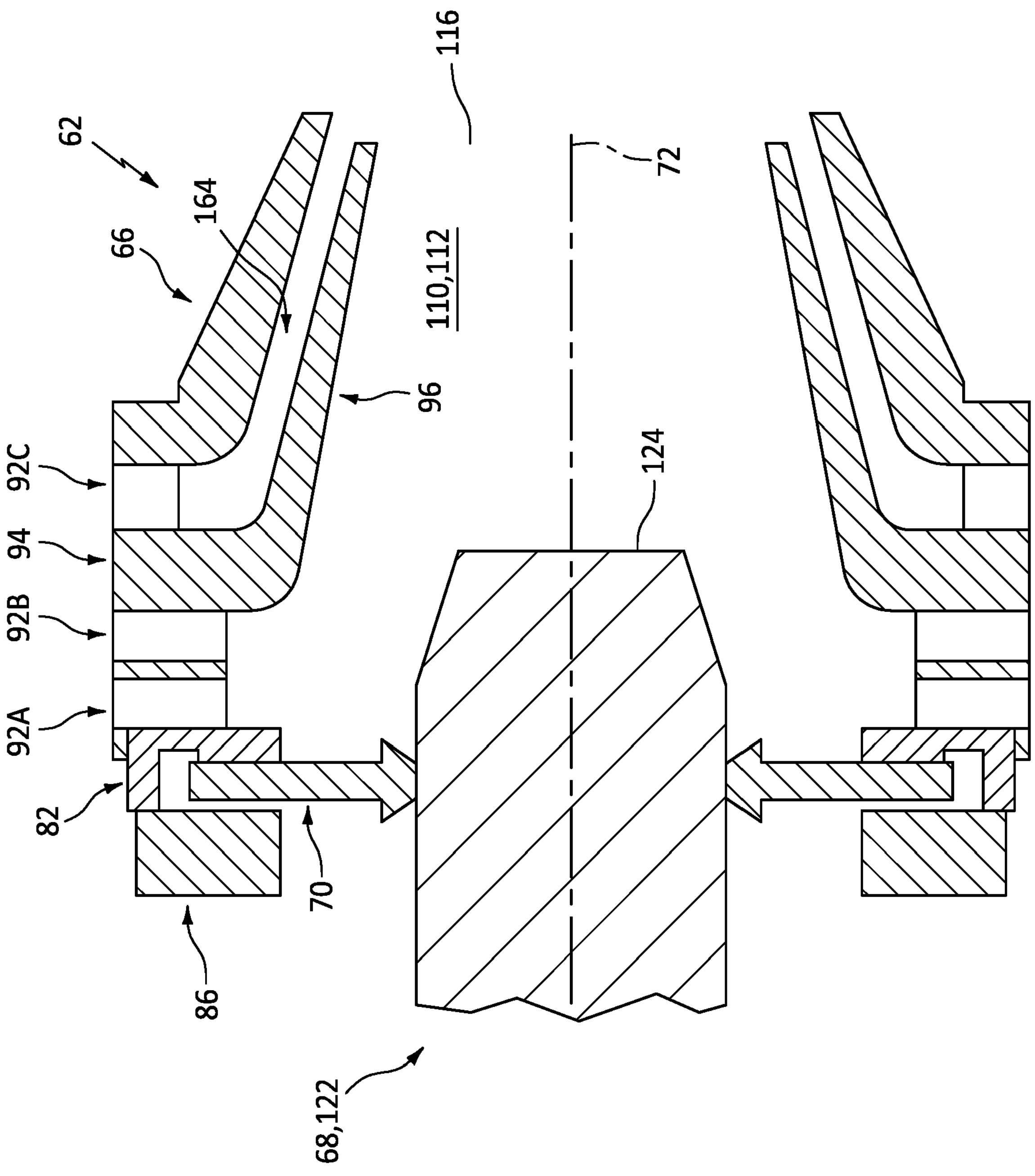

FIG. 8

EUROPEAN SEARCH REPORT

Application Number
EP 24 16 1845

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2007/012048 A1 (BURET MICHEL R [FR] ET AL) 18 January 2007 (2007-01-18) * paragraph [0058] - paragraph [0064]; figures 7,8 *	1-3,6-9, 11-15 4,10	INV. F23R3/14 F23R3/28 F23R3/50
Y	US 2019/113235 A1 (JOHNSON ARTHUR WESLEY [US] ET AL) 18 April 2019 (2019-04-18) * paragraph [0078]; figures 4-6 *	4	
Y	US 11 378 275 B2 (UNITED TECHNOLOGIES CORP [US]; RAYTHEON TECH CORP [US]) 5 July 2022 (2022-07-05) * column 8, line 3 - line 10; figure 7 *	10	
X	US 2019/107284 A1 (SEO JAEWON [KR]) 11 April 2019 (2019-04-11) * paragraph [0045] - paragraph [0049]; figures 3,4 * * paragraph [0076] - paragraph [0081]; figures 10,11 *	1-3,5, 11-15	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	20 June 2024	Mootz, Frank

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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& : member of the same patent family, corresponding document

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20-06-2024

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82