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(54) **COMBUSTION SECTION WITH A PRIMARY COMBUSTOR AND A SET OF SECONDARY COMBUSTORS**

(57) A turbine engine (10) with a compressor section (12), a combustion section (14, 114, 214, 314) and a turbine section (16) in serial flow arrangement along an engine centerline (20, 320). The combustion section (14, 114, 214, 314) having a primary combustor liner (38, 138, 238, 338) including an inner liner (42, 142, 242, 342) and an outer liner (40, 140, 240, 340, 440, 540). A primary combustor (32, 132, 232, 332) having a primary combus-

tion chamber (46, 146, 246, 346) defined at least in part by the inner liner (42, 142, 242, 342), the outer liner (40, 140, 240, 340, 440, 540), and the dome wall (44, 144, 244, 344) and having a primary combustor height (H) and at least one mini combustor (34, 134, 234) with a secondary combustion chamber (54, 154, 254, 354) having a mini combustor height (H_M).

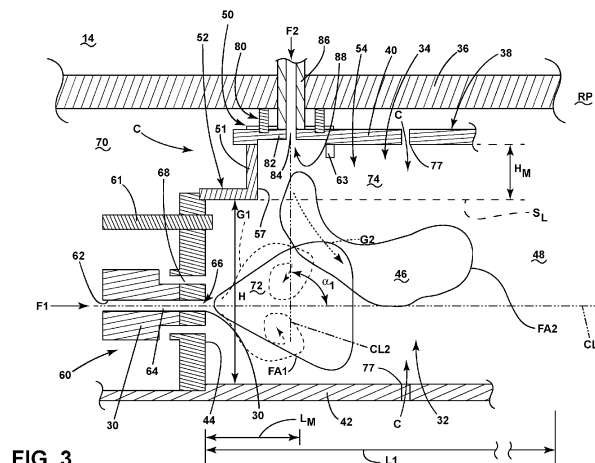


FIG. 3

Description

TECHNICAL FIELD

[0001] The present subject matter relates generally to a combustion section of a turbine engine, and more specifically to a combustion section with a primary combustor and a secondary combustor.

BACKGROUND

[0002] Turbine engines are driven by a flow of combustion gases passing through the engine to rotate a multitude of turbine blades, which, in turn, rotate a compressor to provide compressed air to the combustor for combustion. A combustor can be provided within the turbine engine and is fluidly coupled with a turbine into which the combusted gases flow.

[0003] The use of hydrocarbon fuels in the combustor of a turbine engine is known. Generally, air and fuel are fed to a combustion chamber, the air and fuel are mixed, and then the fuel is burned in the presence of the air to produce hot gas. The hot gas is then fed to a turbine where it cools and expands to produce power. By-products of the fuel combustion typically include environmentally unwanted by-products, such as nitrogen oxide and nitrogen dioxide (collectively called NO_x), carbon monoxide (CO), unburned hydrocarbons (UHC) (e.g., methane and volatile organic compounds that contribute to the formation of atmospheric ozone), and other oxides, including oxides of sulfur (e.g., SO_2 and SO_3).

[0004] Varieties of fuel for use in combustion turbine engines are being explored. Hydrogen or hydrogen mixed with another element or compound can be used for combustion, however hydrogen or a hydrogen mixed fuel can result in a higher flame temperature than traditional fuels. That is, hydrogen or a hydrogen mixed fuel typically has a wider flammable range and a faster burning velocity than traditional fuels such as petroleum-based fuels, or petroleum and synthetic fuel blends.

[0005] Standards stemming from air pollution concerns worldwide regulate the emission of NO_x , UHC, and CO generated as a result of the turbine engine operation. In particular, NO_x is formed within the combustor as a result of high combustor flame temperatures during operation. It is desirable to decrease NO_x emissions while still maintaining desirable efficiencies by regulating the temperature profile and or flame pattern within the combustor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the drawings:

FIG. 1 is a schematic of a turbine engine.
FIG. 2 depicts a cross-sectional view along line II-II of FIG. 1 of a combustion section of the turbine engine with a set of secondary combustors comprising an

annular mini combustor.

FIG. 3 depicts a cross-sectional view taken along line III-III of FIG. 2 of a primary combustor in the combustion section and a portion of the annular mini combustor.

FIG. 4 is a variation of the cross-sectional view of FIG. 3 according to an aspect of the disclosure herein.

FIG. 5 is another variation of the cross-sectional view of FIG. 3 according to another aspect of the disclosure herein.

FIG. 6 is a variation of the cross-sectional view of FIG. 2 according to an aspect of the disclosure herein.

FIG. 7 is a schematic of a portion of an outer liner of the combustion section from FIG. 6 as seen from line VII.

FIG. 8 is variation of the schematic of FIG. 7 for the outer liner of the combustion section.

FIG. 9 is variation of the schematic of FIG. 7 for the outer liner of the combustion section.

DETAILED DESCRIPTION

[0007] Aspects of the disclosure described herein are directed to a combustion section, and in particular a combustion section with a primary combustor and a secondary combustor. For purposes of illustration, the present disclosure will be described with respect to a turbine engine. It will be understood, however, that aspects of the disclosure described herein are not so limited and that a combustion section as described herein can be implemented in engines, including but not limited to turbojet, turboprop, turboshaft, and turbofan engines. Aspects of the disclosure discussed herein may have general applicability within non-aircraft engines having a combustor, such as other mobile applications and non-mobile industrial, commercial, and residential applications.

[0008] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any implementation described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other implementations. Additionally, unless specifically identified otherwise, all embodiments described herein should be considered exemplary.

[0009] As used herein, the terms "first", "second", and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components.

[0010] The terms "forward" and "aft" refer to relative positions within a gas turbine engine or vehicle, and refer to the normal operational attitude of the gas turbine engine or vehicle. For example, with regard to a gas turbine engine, forward refers to a position closer to an engine inlet and aft refers to a position closer to an engine nozzle or exhaust.

[0011] As used herein, the term "upstream" refers to a

direction that is opposite the fluid flow direction, and the term "downstream" refers to a direction that is in the same direction as the fluid flow. The term "fore" or "forward" means in front of something and "aft" or "rearward" means behind something. For example, when used in terms of fluid flow, fore/forward can mean upstream and aft/rearward can mean downstream.

[0012] The term "fluid" may be a gas or a liquid. The terms "fluidly couples" and "fluidly coupled" mean that a fluid is capable of making the connection between the areas specified.

[0013] Additionally, as used herein, the terms "radial" or "radially" refer to a direction away from a common center. For example, in the overall context of a turbine engine, radial refers to a direction along a ray extending between a center longitudinal axis of the engine and an outer engine circumference.

[0014] All directional references (e.g., radial, axial, proximal, distal, upper, lower, upward, downward, left, right, lateral, front, back, top, bottom, above, below, vertical, horizontal, clockwise, counterclockwise, upstream, downstream, forward, aft, etc.) may be used for identification purposes to aid the reader's understanding of the present disclosure, and do not create limitations, particularly as to the position, orientation, or use of aspects of the disclosure described herein. Connection references (e.g., attached, coupled, connected, and joined) may be used and are to be construed broadly and can include intermediate structural elements between a collection of elements and relative movement between elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and in fixed relation to one another. The exemplary drawings are for purposes of illustration only the dimensions, positions, order and relative sizes reflected in the drawings attached hereto can vary.

[0015] The singular forms "a", "an", and "the" include plural references unless the context clearly dictates otherwise. Furthermore, as used herein, the term "set" or a "set" of elements can be any number of elements, including only one.

[0016] Approximating language, as used herein throughout the specification and claims, is applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about", "approximately", "generally", and "substantially", are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or machines for constructing or manufacturing the components and/or systems. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or machines for constructing or manufacturing the components and/or

systems. For example, the approximating language may refer to being within a 1, 2, 4, 5, 10, 15, or 20 percent margin in either individual values, range(s) of values and/or endpoints defining range(s) of values. Here and throughout the specification and claims, range limitations are combined and interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

[0017] FIG. 1 is a schematic view of a turbine engine 10. As a non-limiting example, the turbine engine 10 can be used within an aircraft. The turbine engine 10 can include, at least, a compressor section 12, a combustion section 14, and a turbine section 16. A drive shaft 18 rotationally couples the compressor section 12 and the turbine section 16, such that rotation of one affects the rotation of the other, and defines a rotational axis or centerline 20 for the turbine engine 10.

[0018] The compressor section 12 can include a low-pressure (LP) compressor 22, and a high-pressure (HP) compressor 24 serially fluidly coupled to one another. The turbine section 16 can include an LP turbine 26, and an HP turbine 28 serially fluidly coupled to one another. The drive shaft 18 can operatively couple the LP compressor 22, the HP compressor 24, the LP turbine 26 and the HP turbine 28 together. Alternatively, the drive shaft 18 can include an LP drive shaft (not illustrated) and an HP drive shaft (not illustrated). The LP drive shaft can couple the LP compressor 22 to the LP turbine 26, and the HP drive shaft can couple the HP compressor 24 to the HP turbine 28. An LP spool can be defined as the combination of the LP compressor 22, the LP turbine 26, and the LP drive shaft such that the rotation of the LP turbine 26 can apply a driving force to the LP drive shaft, which in turn can rotate the LP compressor 22. An HP spool can be defined as the combination of the HP compressor 24, the HP turbine 28, and the HP drive shaft such that the rotation of the HP turbine 28 can apply a driving force to the HP drive shaft which in turn can rotate the HP compressor 24.

[0019] The compressor section 12 can include a plurality of axially spaced stages. Each stage includes a set of circumferentially-spaced rotating blades and a set of circumferentially-spaced stationary vanes. The compressor blades for a stage of the compressor section 12 can be mounted to a disk, which is mounted to the drive shaft 18. Each set of blades for a given stage can have its own disk. The vanes of the compressor section 12 can be mounted to a casing which can extend circumferentially about the turbine engine 10. It will be appreciated that the representation of the compressor section 12 is merely schematic and that there can be any number of stages. Further, it is contemplated, that there can be any other number of components within the compressor section 12.

[0020] Similar to the compressor section 12, the tur-

bine section 16 can include a plurality of axially spaced stages, with each stage having a set of circumferentially-spaced, rotating blades and a set of circumferentially-spaced, stationary vanes. The turbine blades for a stage of the turbine section 16 can be mounted to a disk which is mounted to the drive shaft 18. Each set of blades for a given stage can have its own disk. The vanes of the turbine section 16 can be mounted to the casing in a circumferential manner. It is noted that there can be any number of blades, vanes and turbine stages as the illustrated turbine section is merely a schematic representation. Further, it is contemplated, that there can be any other number of components within the turbine section 16.

[0021] The combustion section 14 can be provided serially between the compressor section 12 and the turbine section 16. The combustion section 14 can be fluidly coupled to at least a portion of the compressor section 12 and the turbine section 16 such that the combustion section 14 at least partially fluidly couples the compressor section 12 to the turbine section 16. As a non-limiting example, the combustion section 14 can be fluidly coupled to the HP compressor 24 at an upstream end of the combustion section 14 and to the HP turbine 28 at a downstream end of the combustion section 14.

[0022] During operation of the turbine engine 10, ambient or atmospheric air is drawn into the compressor section 12 via a fan (not illustrated) upstream of the compressor section 12, where the air is compressed defining a pressurized air. The pressurized air can then flow into the combustion section 14 where the pressurized air is mixed with fuel and ignited, thereby generating combustion gases. Some work is extracted from these combustion gases by the HP turbine 28, which drives the HP compressor 24. The combustion gases are discharged into the LP turbine 26, which extracts additional work to drive the LP compressor 22, and the exhaust gas is ultimately discharged from the turbine engine 10 via an exhaust section (not illustrated) downstream of the turbine section 16. The driving of the LP turbine 26 drives the LP spool to rotate the fan (not illustrated) and the LP compressor 22. The pressurized airflow and the combustion gases can together define a working airflow that flows through the fan, compressor section 12, combustion section 14, and turbine section 16 of the turbine engine 10.

[0023] FIG. 2 depicts a cross-sectional view of the combustion section 14 along line II-II of FIG. 1 defining a transverse plane (denoted "TP"). The combustion section 14 can include an annular arrangement of primary fuel injectors 30 disposed around the centerline 20 of the turbine engine 10. Each of the primary fuel injectors 30 are fluidly coupled to a primary combustor 32. It should be appreciated that the annular arrangement of fuel injectors can be one or multiple fuel injectors and one or more of the primary fuel injectors 30 can have different characteristics. The primary combustor 32 can have a can, can-annular, or annular arrangement depending on the

type of engine in which the primary combustor 32 is located. In a non-limiting example, an annular arrangement is illustrated and disposed within a casing 36. The primary combustor 32 is defined by a primary combustor liner 38 including an outer liner 40 and an inner liner 42 concentric with respect to each other and annular about the centerline 20. A dome wall 44 together with the primary combustor liner 38 define a primary combustion chamber 46 annular about the centerline 20. A compressed air passageway 70 can surround the primary combustor 32 and be at least partially defined by the casing 36.

[0024] The combustion section 14 further includes a set of secondary combustors 50 comprising an annular mini combustor 34. As used herein "mini" means that the component referenced with the term mini is smaller than the corresponding like component without the term mini (i.e., the annular mini combustor 34 is smaller than the primary combustor 32). The annular mini combustor 34 is defined by a secondary combustor liner 52 concentric with respect to the outer liner 40 and the inner liner 42 and annular about the centerline 20. The secondary combustor liner 52 together with the outer liner 40 defines at least a portion of a secondary combustion chamber 54 circumferentially arranged about the centerline 20. The annular mini combustor 34 is open to the primary combustor 32. More specifically, the secondary combustor liner 52 terminates at an end 57 axially downstream from the primary fuel injectors 30.

[0025] The primary combustor 32 produces primary exhaust gasses (denoted "G1") in the primary combustion chamber 46. The set of secondary combustors 50 produce secondary exhaust gasses (denoted "G2") in the secondary combustion chamber 54 that flow into the primary combustion chamber 46. The secondary exhaust gasses G2 circulate in the primary combustion chamber 46 starving O₂ levels and reducing temperatures in the primary combustion chamber 46. This results in a reduction of NO_x emissions.

[0026] FIG. 3 depicts a cross-sectional view taken along line III-III of FIG. 2 illustrating the combustion section 14 as viewed in a radial plane (denoted "RP"). It can more clearly be seen that annular mini combustor 34 is open to the primary combustor 32. The primary combustor 32 extends between the dome wall 44 and a primary combustor outlet 48 fluidly coupled to the turbine section 16 (FIG. 1). A dome assembly 60 includes the dome wall 44 and houses the primary fuel injector 30. The primary fuel injector 30 can be fluidly coupled to a fuel inlet 62 via a fuel passageway 64 that can be adapted to receive a primary flow of fuel (denoted "F1"). The primary fuel injector 30 can terminate in a fuel outlet also referred to herein as a dome inlet 66. In some implementations the primary fuel injector 30 can include a swirler 68 circumferentially arranged about the dome inlet 66. A primary igniter 61 is fluidly coupled to the primary combustion chamber 46. A backwall 51 extends radially from the end 57 to connect the secondary combustor liner 52 to the

outer liner 40. The secondary combustor liner 52 terminates in the end 57 located downstream from the dome inlet 66.

[0027] A primary set of dilution openings 77 can be located downstream from the annular mini combustor 34 in both the outer liner 40 and the inner liner 42. It is further contemplated that the set of dilution openings 77 is located at any location, including upstream from the annular mini combustor 34.

[0028] The annular mini combustor 34 includes at least one mini dome assembly 80 including a mini dome wall 82 and housing a mini fuel injector 84. The at least one mini dome assembly 80 can be multiple dome assemblies arranged circumferentially about the annular mini combustor 34. The mini fuel injector 84 can be fluidly coupled to a secondary fuel passageway 86 that can be adapted to receive a secondary flow of fuel (denoted "F2"). The mini fuel injector 84 terminates in a secondary fuel outlet also referred to herein as a mini dome inlet 88 open to the secondary combustion chamber 54. While illustrated as radially aligned, it is contemplated that the mini dome inlet 88 is circumferentially staggered with respect to the dome inlet 66. In some implementations the mini fuel injector 84 can include a swirler (not shown). It is further contemplated that the set of secondary combustors do not include a swirler, but can have non swirling air passages. A secondary igniter 63 is fluidly coupled to the secondary combustion chamber 54.

[0029] The dome inlet 66 defines a first centerline (denoted "CL1"). The mini dome inlet 88 defines a second centerline (denoted "CL2") extending toward the primary combustion chamber 46. The first centerline CL1 and the second centerline CL2 intersect to define a first primary combustor angle (denoted " α_1 ") in the radial plane RP. The first primary combustor angle α_1 can be 90° as illustrated. The mini dome inlet 88 can be angled as well, such that the first primary combustor angle α_1 ranges from 90° to 165° .

[0030] A primary combustor length (denoted "L1") is measured parallel to the first centerline CL1 between the dome wall 44 and the primary combustor outlet 48. A main combustion zone 72 is defined as the volume between the dome wall 44 and the second centerline CL2. A main combustion length (denoted " L_M ") is measured parallel to the first centerline CL1 from the dome wall 44 to the second centerline CL2. The main combustion length L_M is from 5% to 90% of the primary combustor length L1. The main combustion length L_M can be 5% to 70%, 5% to 50%, or 5% to 40% of the primary combustor length L1.

[0031] The primary combustion chamber 46 has a radial dimension extending from the inner liner 42 to the secondary combustor liner 52 and referred to herein as a primary combustor height (denoted "H"). The primary combustor height H can be measured proximate the dome wall 44. A separating line (denoted " S_L ") extends axially from the end 57 parallel to the first centerline CL1 at the primary combustor height H. The separating

line S_L separates the primary combustion chamber 46 from the secondary combustion chamber 54.

[0032] A mini combustor height (denoted " H_M ") is defined as a radial dimension extending from the secondary combustor liner 52 to the outer liner 40. The backwall 51 extends radially toward the mini dome inlet 88 an amount equal to the mini combustor height H_M . The mini combustor height H_M varies from $0.0H$ to $0.6H$. In other words, the mini combustor height H_M measurement is an amount up to and including 60% of the primary combustor height H.

[0033] The mini combustor height H_M is maintained between the separating line S_L and the outer liner 40 to define a mini combustion zone 74. The mini combustion zone 74 is spaced radially outward and axially downstream from the main combustion zone 72.

[0034] During operation, compressed air (denoted "C") can be provided to the combustion section 14 from the compressor section 12 (FIG. 1) via the compressed air passageway 70. The compressed air C can be split between the primary combustor 32 and the set of secondary combustors 50 such that the primary combustor 32 receives 60% to 90% of the compressed air C from the compressor section 12 while the set of secondary combustors 50 receives between 10% and 40%.

[0035] Compressed air C can be fed into the primary fuel injector 30 and mixed with the primary flow of fuel F1 to define a primary fuel/air mixture (denoted "FA1"). The primary fuel injector 30 along with the primary igniter 61 define a primary burn system having a primary flame. The primary fuel injector 30 can dispense a primary fuel/air mixture FA1 that is premixed or partially premixed. Further the flow of fuel F1 can be a diffusion fuel free of an air mixture prior to entering the primary combustion chamber 46.

[0036] The primary burn system can be a rich burn system or a lean burn system. A rich burn combustion system includes a fuel/air ratio above the stoichiometric fuel/air ratio whereas a lean burn combustion system includes a fuel/air ratio below the stoichiometric fuel/air ratio. A rich burn system for the primary combustor 32 will create a higher temperature within the primary combustion chamber 46 providing flame stability to the overall combustion system. When combined with a lean burn system for the set of secondary combustors 50, NO_x is reduced from the secondary combustion chamber 54.

[0037] Similarly, the primary combustor 32 can be a lean burn system for lower NO_x from the primary combustion chamber 46 with the set of secondary combustors 50 having a rich burn system for providing flame stability to the primary combustor 32 and the entire combustion system.

[0038] Compressed air C can be fed into the mini fuel injector 84 and mixed with the secondary flow of fuel F2 to define a secondary fuel/air mixture (denoted "FA2"). The mini fuel injector 84 along with the secondary igniter 63 can define a mini burn system including a secondary flame that can be premixed, partially premixed, or diffu-

sion. The mini burn system can be a rich burn system or a lean burn system. Fuel provided to the primary fuel injectors 30 and the mini fuel injectors 84 can include jet fuel natural gas or a more reacting fuel like H_2 and blends of H_2 . In some implementations, the turbine engine 10 can be started on conventional fuel using the set of secondary combustors 50 where the secondary exhaust gasses G2 (FIG. 2) are propagated towards the primary combustion chamber 46 which can be fueled using conventional fuel or H_2 fuel.

[0039] Further, both the primary combustor 32 and the set of secondary combustors 50 can be a rich burn system or a lean burn system. With both having lean burn systems, the NOx emissions are greatly reduced. However, at least one or more of the primary fuel injectors 30 or mini fuel injectors 84 will need to be fuel rich to provide flame stability. Likewise, both the primary combustor 32 and the set of secondary combustors 50 can have rich burn systems where lowering NOx in this system is achieved by staging fuel and starvation of O_2 in the primary combustor 32 from product released from the set of secondary combustors 50 that produces lower NOx.

[0040] When the secondary exhaust gasses G2 are directed towards the primary combustion chamber 46, the primary exhaust gasses G1 (FIG. 2) and the secondary exhaust gasses G2 mix which reduces O_2 levels in the primary combustion chamber 46 that reduces NOx emissions. Fuel staging between the primary combustion chamber 46 and the secondary combustion chamber 54 reduces the fuel/air ratio in these stages of the combustion section 14 which contributes to a further reduction in temperature and NOx emissions. In comparison a single staged combustor will have relatively higher fuel/air ratios and higher temperatures which leads to higher NOx emissions.

[0041] The main combustion zone 72 can have a combustion residence time that ranges from 2ms to 8ms, inclusive of endpoints. The mini combustion zone 74 can have a combustion residence time that ranges from 0.1ms to 2ms, inclusive of endpoints. The total combustion residence time for the combustion section 14 can range from 2ms to 10ms, inclusive of endpoints.

[0042] The primary combustor 32 can have an equivalence ratio from 0.5 to 2, inclusive of endpoints. The annular mini combustor 34 can have an equivalence ratio from 0.4 to 2, inclusive of endpoints.

[0043] FIG. 4 depicts a cross-sectional view of another embodiment of a combustion section 114 as viewed in a radial plane (denoted "RP"). The combustion section 114 is similar to the combustion section 14 of FIG. 3; therefore, like parts will be identified with like numerals increased by 100, with it being understood that the description of the like parts of the combustion section 14 applies to the combustion section 114, except where noted.

[0044] A primary combustor 132 is provided within a casing 136 and extends between a dome wall 144 and a primary combustor outlet 148 fluidly connected to the

turbine section 16 (FIG. 1). An outer liner 140 is spaced radially from an inner liner 142 to define a primary combustion chamber 146 of the primary combustor 132. A dome assembly 160 includes the dome wall 144 and houses a primary fuel injector 130. The primary fuel injector 130 can be fluidly coupled to a fuel inlet 162 via a fuel passageway 164 that can be adapted to receive a primary flow of fuel (denoted "F1"). The primary fuel injector 130 can terminate in a fuel outlet also referred to herein as a dome inlet 166. In some implementations the primary fuel injector 130 can include a swirler 168 circumferentially arranged about the dome inlet 166. A primary igniter 161 is fluidly coupled to the primary combustion chamber 146. At least one opening 157 extends through the outer liner 140 and is located downstream from the dome inlet 66.

[0045] A set of dilution openings 177 can be located downstream from the at least one opening 157 in the inner liner 142. It is further contemplated that a primary combustor liner 138 can include any number of dilution openings 177 at any location including upstream from the at least one opening 157 and also within the outer liner 140.

[0046] The combustion section 114 further includes a set of secondary combustors 150 comprising at least one annular mini combustor 134. The at least one mini combustor 134 includes a secondary combustor liner 152 defining a secondary combustion chamber 154. The at least one mini combustor 134 includes a mini dome assembly 180 including a mini dome wall 182 and housing a mini fuel injector 184. The mini fuel injector 184 can be fluidly coupled to a secondary fuel passageway 186 that can be adapted to receive a secondary flow of fuel (denoted "F2"). The mini fuel injector 184 terminates in a secondary fuel outlet also referred to herein as a mini dome inlet 188 open to the secondary combustion chamber 154. The secondary combustion chamber 154 is fluidly coupled to the primary combustion chamber 146 at the at least one opening 157 to define a secondary combustor outlet 158. In some implementations the mini fuel injector 184 can include a low swirl number swirler 189, i.e., with a number less than 1 and having a low tangential velocity, circumferentially arranged about the mini dome inlet 188. It is further contemplated that the at least one mini combustor 134 does not include a swirler, but can have non swirling air passages. A secondary igniter 163 is fluidly coupled to the secondary combustion chamber 154.

[0047] It is contemplated that the at least one mini combustor 134 includes a gradually converging body 176. The gradually converging body 176 is defined as a portion of the at least one mini combustor 134 where a first cross-sectional area (denoted "CA1") proximate the mini dome inlet 188 is greater than a second cross-sectional area (denoted "CA2") proximate the secondary combustor outlet 158.

[0048] A secondary set of dilution openings 178 can be provided in the secondary combustor liner 152 for con-

necting a compressed air passageway 170 and the secondary combustion chamber 154. By way of non-limiting example, when the primary combustor 132 is a rich burn system, the secondary set of dilution openings 178 are at an aft location of the at least one mini combustor 134 for trimming a combustor exit temperature profile and pattern factor associated with the at least one mini combustor 134 and primary combustor 132.

[0049] The outer liner 140 defines a primary combustor height H of the primary combustor 132 proximate the dome wall 144 and measured radially between the inner liner 142 and the outer liner 140.

[0050] A mini combustor height H_M is defined as a radial dimension extending from the outer liner 140 to the mini dome wall 182. The mini combustor height H_M varies from $0.0H$ to $0.6H$. In other words, the mini combustor height H_M measurement is an amount up to and including 60% of the primary combustor height H .

[0051] The secondary combustor liner 152 defines a mini combustion zone 174. The mini combustion zone 174 is radially and axially spaced away from a main combustion zone 172.

[0052] The dome inlet 166 defines a first centerline CL1. The mini dome inlet 188 defines a second centerline CL2 extending toward the secondary combustor outlet 158. The secondary combustor outlet 158 intersects the second centerline CL2 to define a geometric center 190 of the secondary combustor outlet 158. The first centerline CL1 and the second centerline CL2 intersect to define a second primary combustor angle (denoted " α_2 ") in the radial plane RP. The at least one mini combustor 134 can be angled toward the primary combustor outlet 148 such that the second primary combustor angle α_2 is greater than 90° . The at least one mini combustor 134, when angled toward the primary combustor outlet 148, has a second primary combustor angle α_2 that can vary from 90° to 165° .

[0053] The process of directing the secondary exhaust gasses G2 from the at least one mini combustor 34 into the primary combustion chamber 46 at the second primary combustor angle α_2 improves turbulence levels. Further the gradually converging body 176 accelerates the secondary fuel/air mixture FA2 exiting the secondary combustor outlet 158 into the primary combustion chamber 146, this further improves turbulence levels. Turbulence helps to thoroughly mix the primary and secondary exhaust gasses G1, G2 which improves a uniform temperature distribution, again resulting in a reduction in NO_x .

[0054] FIG. 5 depicts a cross-sectional view of yet another embodiment of a combustion section 214 as viewed in a radial plane (denoted "RP"). The combustion section 214 is similar to the combustion section 114 of FIG. 4; therefore, like parts will be identified with like numerals increased by 100, with it being understood that the description of the like parts of the combustion section 114 applies to the combustion section 214, except where noted.

[0055] A primary combustor 232 extends between a dome wall 244 and a primary combustor outlet 248 fluidly connected to the turbine section 16 (FIG. 1). An outer liner 240 is spaced radially from an inner liner 242, together defining a primary combustor liner 238. The primary combustor liner 238 defining at least a portion of a primary combustion chamber 246 of the primary combustor 232. A dome assembly 260 includes the dome wall 244 and houses a primary fuel injector 230. The primary fuel injector 230 can be fluidly coupled to a fuel inlet 262 via a fuel passageway 264 that can be adapted to receive a primary flow of fuel (denoted "F1"). The primary fuel injector 230 can terminate in a fuel outlet also referred to herein as a dome inlet 266 and located in a dome assembly 260. In some implementations the primary fuel injector 230 can include a swirler 268 circumferentially arranged about the dome inlet 266. A primary igniter 261 is fluidly coupled to the primary combustion chamber 246. At least one opening 257 extends through the outer liner 240 and is located downstream from the dome inlet 266.

[0056] A set of dilution openings 277 can be located upstream from a mini dome inlet 288 in the outer liner 240 and also within the inner liner 242. It is further contemplated that the primary combustor liner 238 can include any number of dilution openings at any location including downstream from the mini dome inlet 288 in the outer liner 240 and also within the inner liner 242.

[0057] The combustion section 214 further includes a set of secondary combustors 250 comprising at least one mini combustor 234. The at least one mini combustor 234 includes a secondary combustor liner 252 defining a secondary combustion chamber 254. The at least one mini combustor 234 includes a mini dome assembly 280 including a mini dome wall 282 and housing a mini fuel injector 284. The mini fuel injector 284 can be fluidly coupled to a secondary fuel passageway 286 that can be adapted to receive a secondary flow of fuel (denoted "F2"). The mini fuel injector 284 terminates in a secondary fuel outlet also referred to herein as a mini dome inlet 288 open to the secondary combustion chamber 254. In some implementations the mini fuel injector 284 can include a low swirl number swirler 289, i.e., with a number less than 1 and having a low tangential velocity, circumferentially arranged about the mini dome inlet 288. It is further contemplated that the at least one mini combustor 234 does not include a swirler, but can have non-swirling air passages. A secondary igniter 263 is fluidly coupled to the secondary combustion chamber 254. The secondary igniter 263 is fluidly coupled to the secondary combustion chamber 254.

[0058] The dome inlet 266 defines a first centerline CL1. The mini dome inlet 288 can define a second centerline CL2 extending toward a secondary combustor outlet 258. The secondary combustor outlet 258 intersects the second centerline CL2 to define a geometric center 290 of the secondary combustor outlet 258. The at least one mini combustor 234 can have a constant area cross-

section along the second centerline CL2 between the mini dome inlet 288 and the secondary combustor outlet 258.

[0059] A secondary set of dilution openings 278 can be provided in the secondary combustor liner 252 for connecting a compressed air passageway 270 and the secondary combustion chamber 254. By way of non-limiting example, when the primary combustor 232 is a rich burn system, the secondary set of dilution openings 278 are at an aft location of the at least one mini combustor 234 for trimming a combustor exit temperature profile and pattern factor associated with the at least one mini combustor 234 and primary combustor 232.

[0060] The secondary combustor liner 252 defines a mini combustion zone 274. The mini combustion zone 274 is radially and axially spaced away from a main combustion zone 272.

[0061] The secondary combustor outlet 258 intersects the second centerline CL2 to define the geometric center 290 of the secondary combustor outlet 258. The first centerline CL1 and the second centerline CL2 intersect to define a third primary combustor angle (denoted " α_3 ") in the radial plane RP. The at least one mini combustor 234 can be orthogonally oriented with the primary combustor 232 such that the third primary combustor angle α_3 is 90°.

[0062] FIG. 6 depicts a cross-sectional view of a combustion section 314. The combustion section 314 is a variation of the combustion section 14 from FIG. 2; therefore, like parts will be identified with like numerals increased by 300, with it being understood that the description of the like parts of the combustion section 14 applies to the combustion section 314, except where noted.

[0063] The combustion section 314 can include an annular arrangement of primary fuel injectors 330 disposed around a centerline 320 of the turbine engine 10. Each of the primary fuel injectors 330 are fluidly coupled to a primary combustor 332. It should be appreciated that the annular arrangement of fuel injectors can be one or multiple fuel injectors and one or more of the primary fuel injectors 330 can have different characteristics. The primary combustor 332 can have a can, can-annular, or annular arrangement depending on the type of engine in which the primary combustor 332 is located. In a non-limiting example, an annular arrangement is illustrated and disposed within a casing 336. The primary combustor 332 is defined by a primary combustor liner 338 including an outer liner 340 and an inner liner 342 concentric with respect to each other and annular about the centerline 320. A dome wall 344 together with the primary combustor liner 338 define a primary combustion chamber 346 annular about the centerline 320.

[0064] The combustion section 314 further includes a set of secondary combustors 350 comprising a circumferential arrangement of multiple discrete mini combustors 334. Each discrete mini combustor 334 in the set of secondary combustors 350 is defined by a secondary combustor liner 352 extending generally perpendicular

from the primary combustor liner 338. The secondary combustor liner 352 defines at least a portion of a secondary combustion chamber 354 circumferentially spaced about the centerline 320. The set of secondary combustors 350 is fluidly coupled to the primary combustor 332 by at least one opening 357 extending through the outer liner 340. More specifically, the secondary combustion chamber 354 terminates at the at least one opening 357 to define a secondary combustor outlet 358. In a non-limiting example, each secondary combustion chamber 354 in the set of secondary combustors 350 is radially aligned with the primary fuel injectors 330.

[0065] The primary combustor 332 produces primary exhaust gasses (denoted "G1") in the primary combustion chamber 346. The set of secondary combustors 350 produce secondary exhaust gasses (denoted "G2") in the secondary combustion chamber 354 that flow into the primary combustion chamber 346. The secondary exhaust gasses G2 circulate in the primary combustion chamber 346 starving O₂ levels and reducing temperatures in the primary combustion chamber 346. This results in a reduction of NO_x emissions.

[0066] It should be understood that any of the multiple discrete mini combustors 334 can include a gradually converging body 176 as previously described herein with respect to FIG. 4. Further, any of the multiple discrete mini combustors 334 can have a constant area cross-section throughout as illustrated in FIG. 5. It is further contemplated that any combination of converging and constant area cross-section combustor bodies is contemplated.

[0067] FIG. 7 is a schematic of a portion of the outer liner 340 as seen from line VII-VII in FIG. 6. An axial direction (denoted "AD") extends parallel to the engine centerline 20 (FIG. 1), a radial direction (denoted "RD") extends into the page and perpendicular to the axial direction AD, and a circumferential direction (denoted "CD") is perpendicular to both the radial and axial directions RD, AD. The circumferential direction CD circumscribes the engine centerline and extends up and down the page when oriented in two dimensions as illustrated.

[0068] The at least one opening 357 is multiple openings 357a, 357b, 357c. Each opening 357a, 357b, 357c defining the secondary combustor outlet 358 corresponding with each of the mini combustors 334 (FIG. 6) in the set of secondary combustors 350 (FIG. 6). In one aspect, the multiple openings 357a, 357b, 357c are located at the same axial location and aligned along the circumferential direction CD.

[0069] FIG. 8 is a schematic of variation of the portion of the outer liner 340 from FIG. 7 according to another aspect of the disclosure herein. At least one opening 457 is multiple openings 457a, 457b, 457c located within an outer liner 440 each defining a secondary combustor outlet 458. The multiple openings 457a, 457b, 457c are axially spaced from each other in the axial direction AD and unaligned in the circumferential direction CD. A first opening 457a is axially spaced from a second opening 457b a first amount (denoted "S1"). A third opening 457c

is axially spaced from the second opening 457b a second amount (denoted "S2"). The second opening 457b can be located downstream from the first opening 457a and the third opening 457c. The third opening 457c can be located downstream from the first opening 457a and upstream from the second opening 457b.

[0070] FIG. 9 is a schematic of variation of the portion of the outer liner 340 from FIG. 7 according to yet another aspect of the disclosure herein. At least one opening 557 is multiple openings 557a, 557b, 557c located within an outer liner 540 each defining a secondary combustor outlet 558. In one aspect, the multiple openings 557a, 557b, 557c are aligned along the circumferential direction CD and angled with respect to the axial direction AD. An axial orientation angle (denoted " β ") is an amount the at least one opening 557 is turned from the axial direction AD toward the circumferential direction CD.

[0071] The orientation and location of the multiple discrete mini combustors 334 can embody any of the variations including a combination of the variations illustrated in FIG. 7, FIG. 8, and FIG. 9. The orientation and location can be tuned to achieve sufficient mixing between the two exhaust gasses G1, G2.

[0072] A method for controlling nitrogen oxides present within the combustion sections 14, 114, 214, 314 described herein includes generating the primary exhaust gasses G1 in the primary combustion chambers 46, 146, 246, 346 and generating secondary exhaust gasses G2 in the set of secondary combustors 50, 150, 250, 350 including the secondary combustion chambers 54, 154, 254, 354. The method further includes injecting the secondary exhaust gasses G2 into the main combustion zones 72, 172, 272 of the primary combustion chambers 46, 146, 246.

[0073] The method can further include enhancing mixing of the primary and secondary exhaust gasses G1, G2 by injecting the secondary exhaust gasses G2 at the first, second, or third primary combustor angles α_1 , α_2 , α_3 described herein. Further, the method can include accelerating the flow of the primary fuel/air mixture FA1 and resulting primary exhaust gasses G1 by introducing the secondary fuel/air mixture FA2 via the multiple discrete mini combustors 334. Accelerating the flow of the primary fuel/air mixture FA1 and resulting primary exhaust gasses G1 can also be done by utilizing the annular mini combustor 34 arranged about the primary combustor 32. Further, the proximity of the set of secondary combustors 50 accelerates the primary exhaust gasses G1 as is illustrated in FIG. 3.

[0074] Benefits associated with the set of secondary combustors in combination with the primary combustor and methods described herein are to reduce NO_x emissions even in a severe cycle with a higher operating air pressure, higher temperature, higher fuel/air ratio and with heated fuel. Typically, higher fuel/air ratio within a combustion system leads to a higher flame temperature which results in higher NO_x . By having two combustion chambers within the combustion system, fuel can be split

between these chambers thereby reducing the fuel/air ratio in each chamber and in turn achieving lower temperature and hence lower NO_x emission. By directing product of combustion from a secondary combustion into a primary combustion chamber, O_2 levels in the primary combustion chamber can be reduced, further reducing NO_x emission. The combustions section herein can operate with 100% H_2 fuel.

[0075] While described with respect to a turbine engine, it should be appreciated that the combustor as described herein can be for any engine having a combustor that emits NO_x . It should be appreciated that application of aspects of the disclosure discussed herein are applicable to engines with propeller sections or fan and booster sections along with turbojets and turbo engines as well.

[0076] To the extent not already described, the different features and structures of the various embodiments can be used in combination, or in substitution with each other as desired. That one feature is not illustrated in all of the embodiments is not meant to be construed that it cannot be so illustrated, but is done for brevity of description. Thus, the various features of the different embodiments can be mixed and matched as desired to form new embodiments, whether or not the new embodiments are expressly described. All combinations or permutations of features described herein are covered by this disclosure.

[0077] This written description uses examples to describe aspects of the disclosure described herein, including the best mode, and also to enable any person skilled in the art to practice aspects of the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of aspects of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

[0078] Further aspects are provided by the subject matter of the following clauses:

[0079] A combustion section for a turbine engine, the combustion section comprising a primary combustor liner including an inner liner and an outer liner; a dome wall extending from the inner liner toward the outer liner; a dome inlet located in the dome wall and defining a first centerline; a primary combustor having a primary combustion chamber defined at least in part by the inner liner, the outer liner, and the dome wall, the primary combustion chamber having a primary combustor height; and at least one mini combustor having a secondary combustion chamber and a mini dome inlet, the secondary combustion chamber fluidly coupled to the primary combustion chamber and having a mini combustor height; wherein the mini combustor height is less than the primary combustor height.

[0080] The combustion section of any preceding clause, wherein the mini combustor height ranges from 0% to 60% of the primary combustor height.

[0081] The combustion section of any preceding clause, wherein the at least one mini combustor is an annular mini combustor.

[0082] The combustion section of any preceding clause, further comprising a secondary combustor liner extending axially from the dome wall and terminating in a backwall, the backwall extending radially toward the mini dome inlet an amount equal to the mini combustor height.

[0083] The combustion section of any preceding clause, wherein the outer liner and the backwall together define at least a portion of the secondary combustion chamber.

[0084] The combustion section of any preceding clause, wherein the primary combustor height is a radial dimension extending between the secondary combustor liner and the inner liner.

[0085] The combustion section of any preceding clause, further comprising at least one opening extending through the outer liner and located downstream from the dome inlet.

[0086] The combustion section of any preceding clause, wherein the secondary combustion chamber is fluidly coupled to the primary combustion chamber at the at least one opening.

[0087] The combustions section of any preceding clause, wherein the primary combustion chamber is annular about an engine centerline of the turbine engine.

[0088] The combustion section of any preceding clause, wherein the at least one mini combustor is an annular mini combustor.

[0089] The combustion section of any preceding clause, wherein the at least one mini combustor is multiple discrete mini combustors circumferentially arranged about the engine centerline and the at least one opening is multiple openings corresponding with the multiple discrete mini combustors.

[0090] The combustion section of any preceding clause, wherein the multiple openings are located at the same axial location and aligned in a circumferential direction.

[0091] The combustion section of any preceding clause, wherein at least one opening in the multiple openings is angled with respect to an axial direction.

[0092] The combustion section of any preceding clause, wherein the multiple openings are axially spaced from each other in an axial direction and unaligned in a circumferential direction.

[0093] The combustion section of any preceding clause, wherein the dome inlet defines a first centerline and the mini dome inlet defines a second centerline and the first centerline and the second centerline intersect to define a primary combustor angle in a radial plane.

[0094] The combustion section of any preceding clause, wherein the primary combustor angle varies from 90° to 165°.

[0095] The combustion section of any preceding clause, wherein the dome inlet defines a first centerline and the mini dome inlet defines a second centerline and a primary combustor length is measured parallel to the first centerline between the dome wall and a primary combustor outlet and a main combustion length is measured parallel to the first centerline from the dome wall to the second centerline, wherein the main combustion length is from 5% to 90% of the primary combustor length.

[0096] The combustion section of any preceding clause, wherein the primary combustor angle is 90°.

[0097] The combustion section of any preceding clause, wherein the primary combustor angle varies from 90° to 165°.

[0098] The combustion section of any preceding clause, further comprising a set of dilution openings in the primary combustor liner.

[0099] The combustion section of any preceding clause, wherein the set of dilution openings are located in the outer liner.

[0100] The combustion section of any preceding clause, wherein the set of dilution openings are located in the inner liner.

[0101] The combustion section of any preceding clause, wherein the set of dilution openings are located upstream of the at least one mini combustor.

[0102] The combustion section of any preceding clause, wherein the set of dilution openings are located downstream of the at least one mini combustor.

[0103] The combustion section of any preceding clause, further comprising a set of dilution openings in the mini combustor liner.

[0104] The combustion section of any preceding clause, wherein the dome inlet defines a first centerline and the mini dome inlet defines a second centerline and a primary combustor length is measured parallel to the first centerline between the dome wall and a primary combustor outlet and a main combustion length is measured parallel to the first centerline from the dome wall to the second centerline, wherein the main combustion length is from 5% to 90% of the primary combustor length.

[0105] A turbine engine comprising a compressor section, a combustion section, and a turbine section in serial flow arrangement along an engine centerline, the combustion section comprising a primary combustor liner including an inner liner and an outer liner; a dome wall extending from the inner liner toward the outer liner; a dome inlet located in the dome wall and defining a first centerline; a primary combustor having a primary combustion chamber defined at least in part by the inner liner, the outer liner, and the dome wall, the primary combustion chamber having a primary combustor height; and at least one mini combustor having a secondary combustion chamber and a mini dome inlet, the secondary combustion chamber fluidly coupled to the primary combustion chamber and having a mini combustor height; wherein the mini combustor height ranges from 0% to 60% of the primary combustor height.

[0106] The turbine engine of any preceding clause, wherein the at least one mini combustor is an annular mini combustor.

[0107] The turbine engine of any preceding clause, wherein the at least one mini combustor is multiple discrete mini combustors.

[0108] The combustion section of any preceding clause, further comprising a set of dilution openings in the primary combustor liner.

[0109] The combustion section of any preceding clause, wherein the set of dilution openings are located in the outer liner.

[0110] The combustion section of any preceding clause, wherein the set of dilution openings are located in the inner liner.

[0111] The combustion section of any preceding clause, wherein the set of dilution openings are located upstream of the at least one mini combustor.

[0112] The combustion section of any preceding clause, wherein the set of dilution openings are located downstream of the at least one mini combustor.

[0113] The combustion section of any preceding clause, further comprising a set of dilution openings in the mini combustor liner.

[0114] A method for controlling nitrogen oxides present within a combustion section comprising generating primary exhaust gasses in primary combustion chambers and generating secondary exhaust gasses in a set of secondary combustors including a set of secondary combustion chambers.

[0115] The method of any preceding clause further comprising injecting the secondary exhaust gasses into a main combustion zone of the primary combustion chambers.

[0116] The method any preceding clause further comprising enhancing mixing of the primary and secondary exhaust gasses by injecting the secondary exhaust gasses at a first, second, or third primary angle.

[0117] The method of any preceding clause further comprising accelerating a flow of a primary fuel/air mixture and resulting primary exhaust gasses by introducing a secondary fuel/air mixture via a discrete mini combustor.

[0118] The method of any preceding clause further comprising accelerating a flow of a primary fuel/air mixture and resulting primary exhaust gasses by utilizing an annular mini combustor arranged about the primary combustor.

[0119] The method of any preceding clause further comprising accelerating a flow of a primary fuel/air mixture and resulting primary exhaust gasses by locating the set of secondary combustors in close proximity to the primary combustion chamber.

Claims

1. A combustion section (14, 114, 214, 314) for a tur-

bine engine (10), the combustion section (14, 114, 214, 314) comprising:

a primary combustor liner (38, 138, 238, 338) including an inner liner (42, 142, 242, 342) and an outer liner (40, 140, 240, 340, 440, 540);
a dome wall (44, 144, 244, 344) extending from the inner liner (42, 142, 242, 342) toward the outer liner (40, 140, 240, 340, 440, 540);
a dome inlet (66, 166, 266) located in the dome wall (44, 144, 244, 344) and defining a first centerline (20, 320);

a primary combustor (32, 132, 232, 332) having a primary combustion chamber (46, 146, 246, 346) defined at least in part by the inner liner (42, 142, 242, 342), the outer liner (40, 140, 240, 340, 440, 540), and the dome wall (44, 144, 244, 344), the primary combustion chamber (46, 146, 246, 346) having a primary combustor height (H); and

at least one mini combustor (34, 134, 234) having a secondary combustion chamber (54, 154, 254, 354) and a mini dome inlet (88, 188, 288), the secondary combustion chamber (54, 154, 254, 354) fluidly coupled to the primary combustion chamber (46, 146, 246, 346) and having a mini combustor height (H_M);

wherein the mini combustor height (H_M) is less than the primary combustor height (H).

2. The combustion section (14, 114, 214, 314) of claim 1, wherein the mini combustor height (H_M) ranges from 0% to 60% of the primary combustor height (H).

3. The combustion section (14, 114, 214, 314) of claim 2, wherein the at least one mini combustor (34, 134, 234) is an annular mini combustor (34).

4. The combustion section (14, 114, 214, 314) of any preceding claim, further comprising a secondary combustor liner (52, 152, 252, 352) extending axially from the dome wall (44, 144, 244, 344) and terminating in a backwall (51), the backwall (51) extending radially toward the mini dome inlet (88, 188, 288) an amount equal to the mini combustor height (H_M).

5. The combustion section (14, 114, 214, 314) of claim 4, wherein the outer liner (40, 140, 240, 340, 440, 540) and the backwall (51) together define at least a portion of the secondary combustion chamber (54, 154, 254, 354).

6. The combustion section (14, 114, 214, 314) of any preceding claim, wherein the primary combustor height (H) is a radial dimension extending between the secondary combustor liner (52, 152, 252, 352) and the inner liner (42, 142, 242, 342).

7. The combustion section (14, 114, 214, 314) of claim 2, further comprising at least one opening (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c) extending through the outer liner (40, 140, 240, 340, 440, 540) and located downstream from the dome inlet (66, 166, 266). 5
8. The combustion section (14, 114, 214, 314) of claim 7, wherein the secondary combustion chamber (54, 154, 254, 354) is fluidly coupled to the primary combustion chamber (46, 146, 246, 346) at the least one opening (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c). 10
9. The combustion section of claim 8, wherein the primary combustion chamber (46, 146, 246, 346) is annular about an engine centerline (20, 320) of the turbine engine (10). 15
10. The combustion section (14, 114, 214, 314) of claim 9, wherein the at least one mini combustor (34, 134, 234) is an annular mini combustor (34). 20
11. The combustion section (14, 114, 214, 314) of claim 9, wherein the at least one mini combustor (34, 134, 234) (134, 234) is multiple discrete mini combustor (334) circumferentially arranged about the engine centerline centerline (20, 320) and the at least one opening (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c) is multiple openings (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c) corresponding with the multiple discrete mini combustors (334). 25
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12. The combustion section (14, 114, 214, 314) of claim 11, wherein the multiple openings (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c) are located at the same axial location and aligned in a circumferential direction (CD). 40
13. The combustion section (14, 114, 214, 314) of claim 12, wherein at least one opening (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c) in the multiple openings (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c) is angled with respect to an axial direction (AD). 45
14. The combustion section (14, 114, 214, 314) of claim 11, wherein the multiple openings (157, 257, 357, 357a, 357b, 357c, 457, 457a, 457b, 457c, 557, 557a, 557b, 557c) are axially spaced from each other in an axial direction (AD) and unaligned in a circumferential direction (CD). 50
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15. The combustion section of claim 11, wherein the dome inlet (66, 166, 266) defines a first centerline (20, 320) and the mini dome inlet (88, 188, 288) defines a second centerline (CL2) and the first centerline (CL1) and the second centerline (CL2) intersect to define a primary combustor angle in (α_1 , α_2 , α_3) a radial plane (RP).

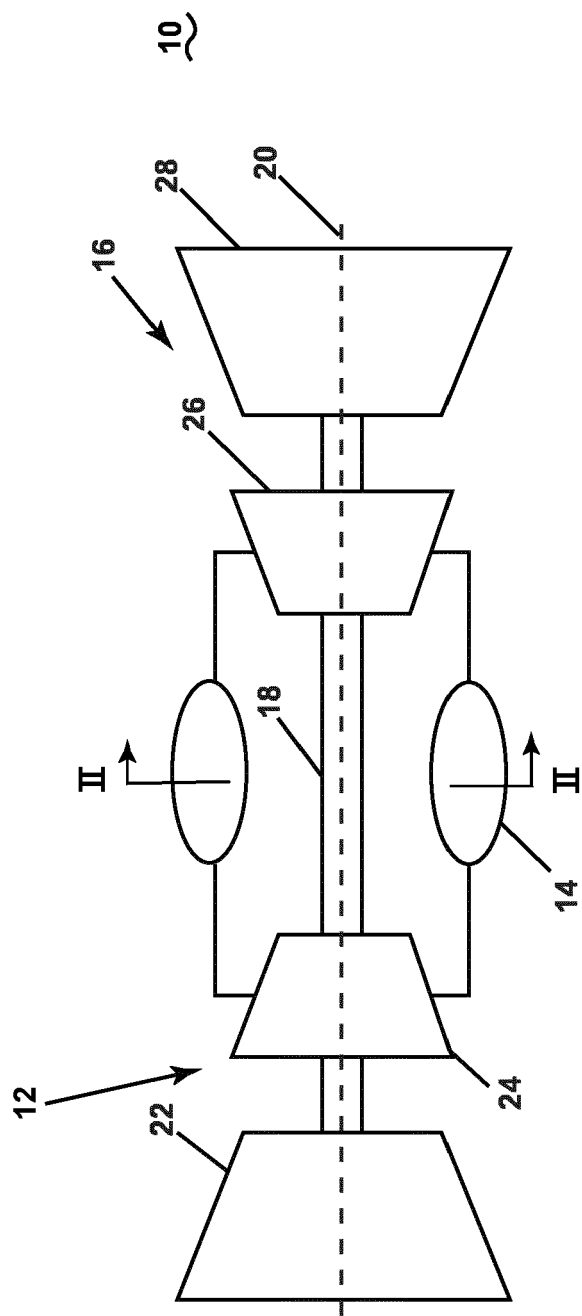


FIG. 1

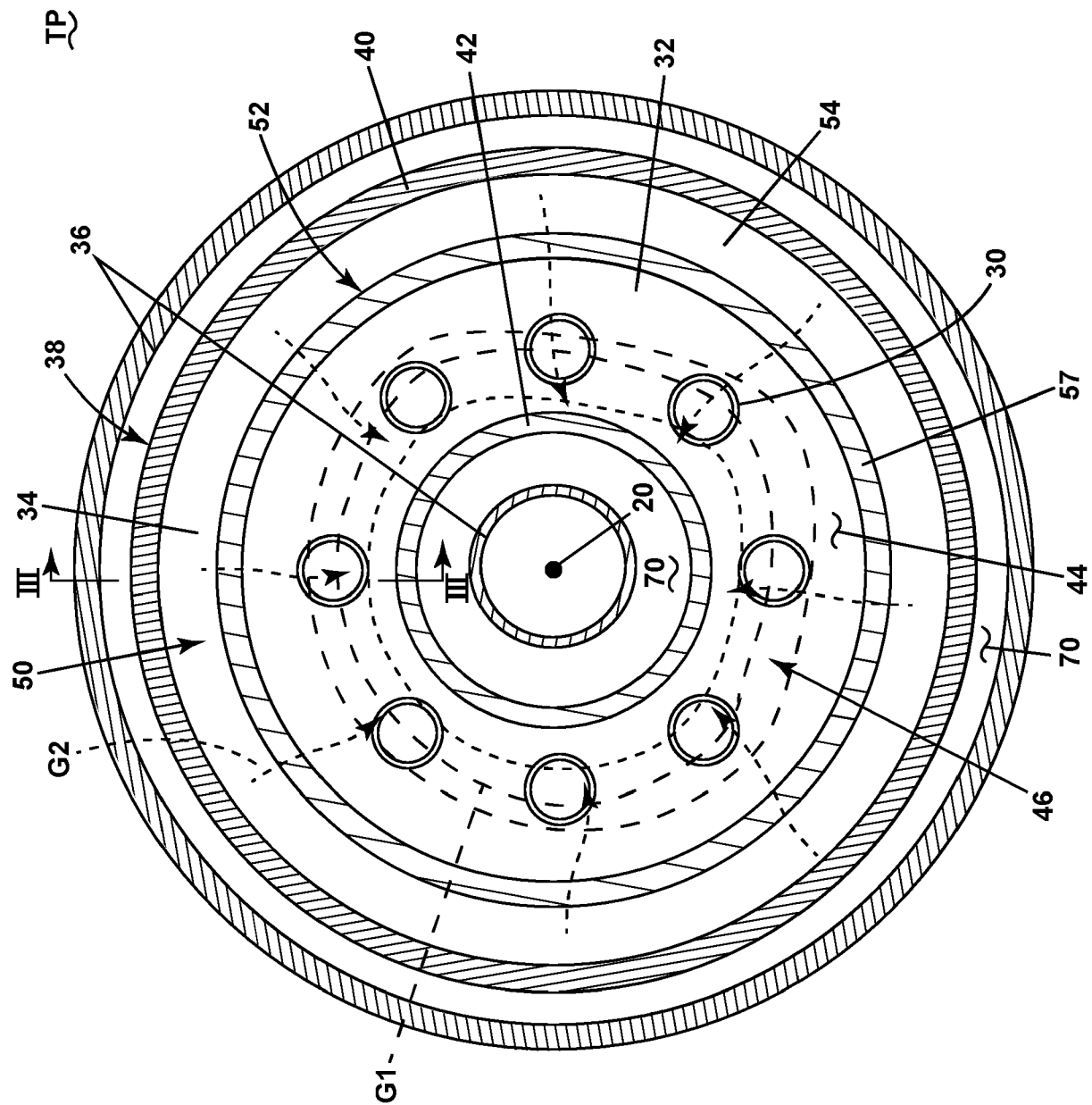
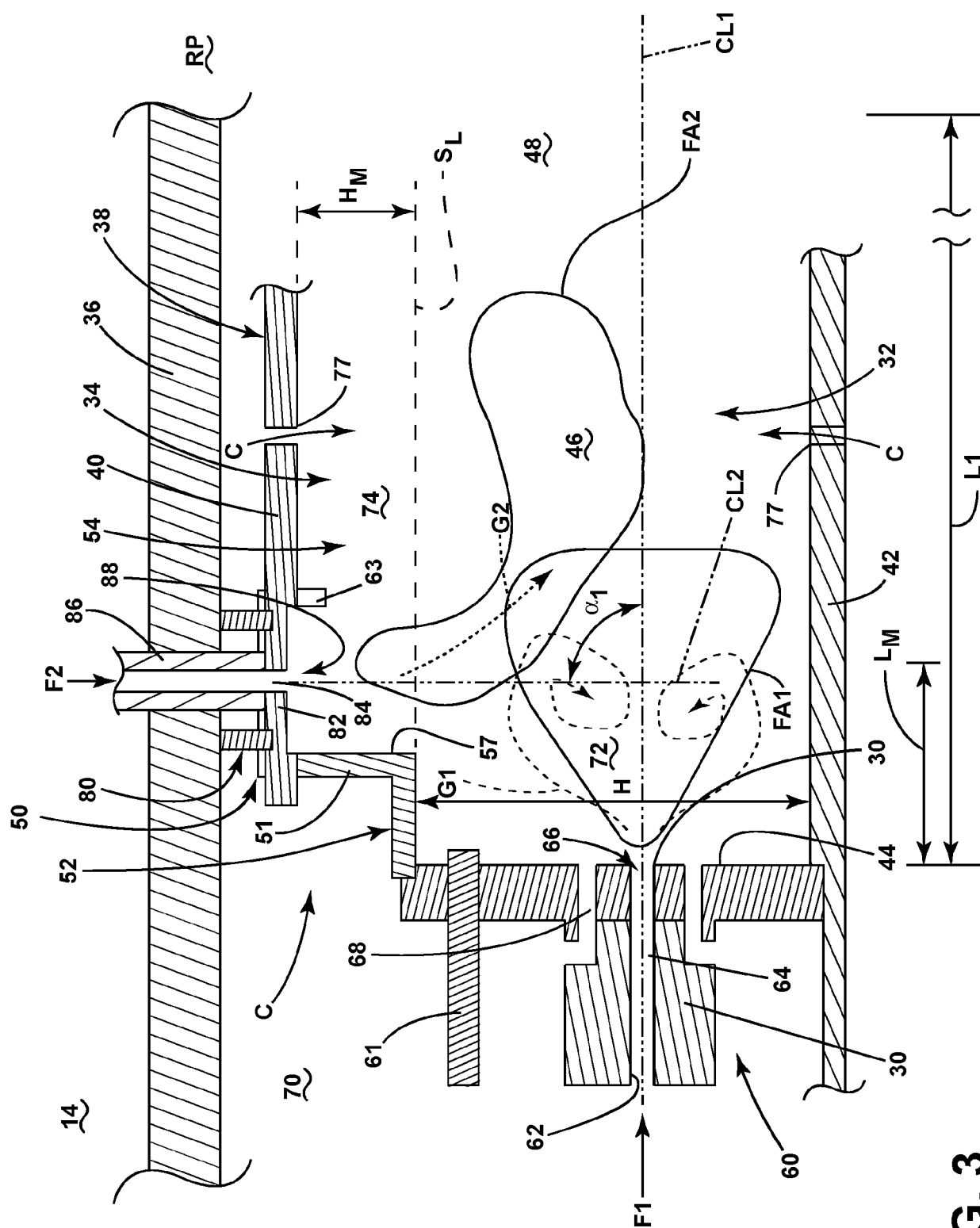
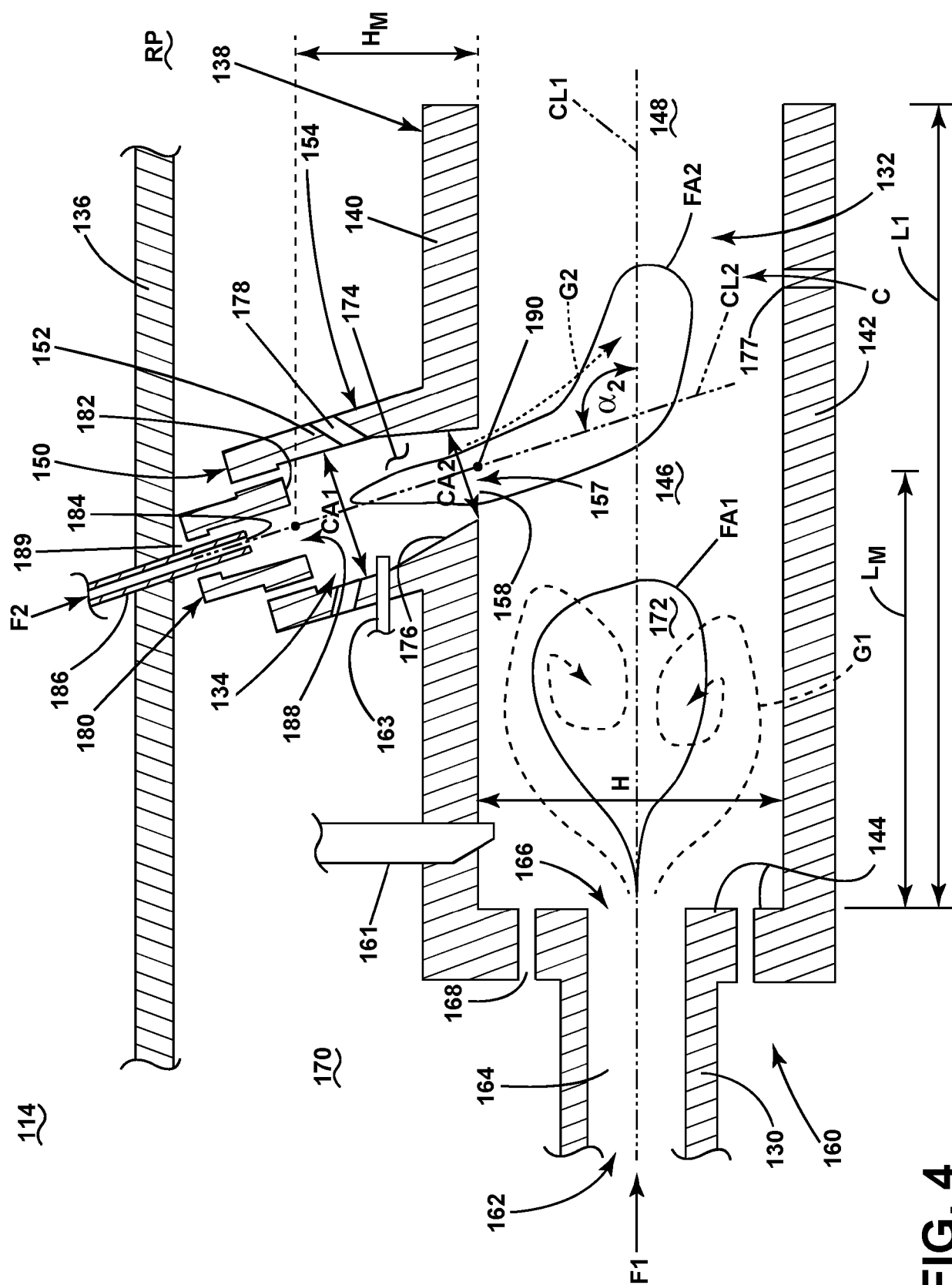
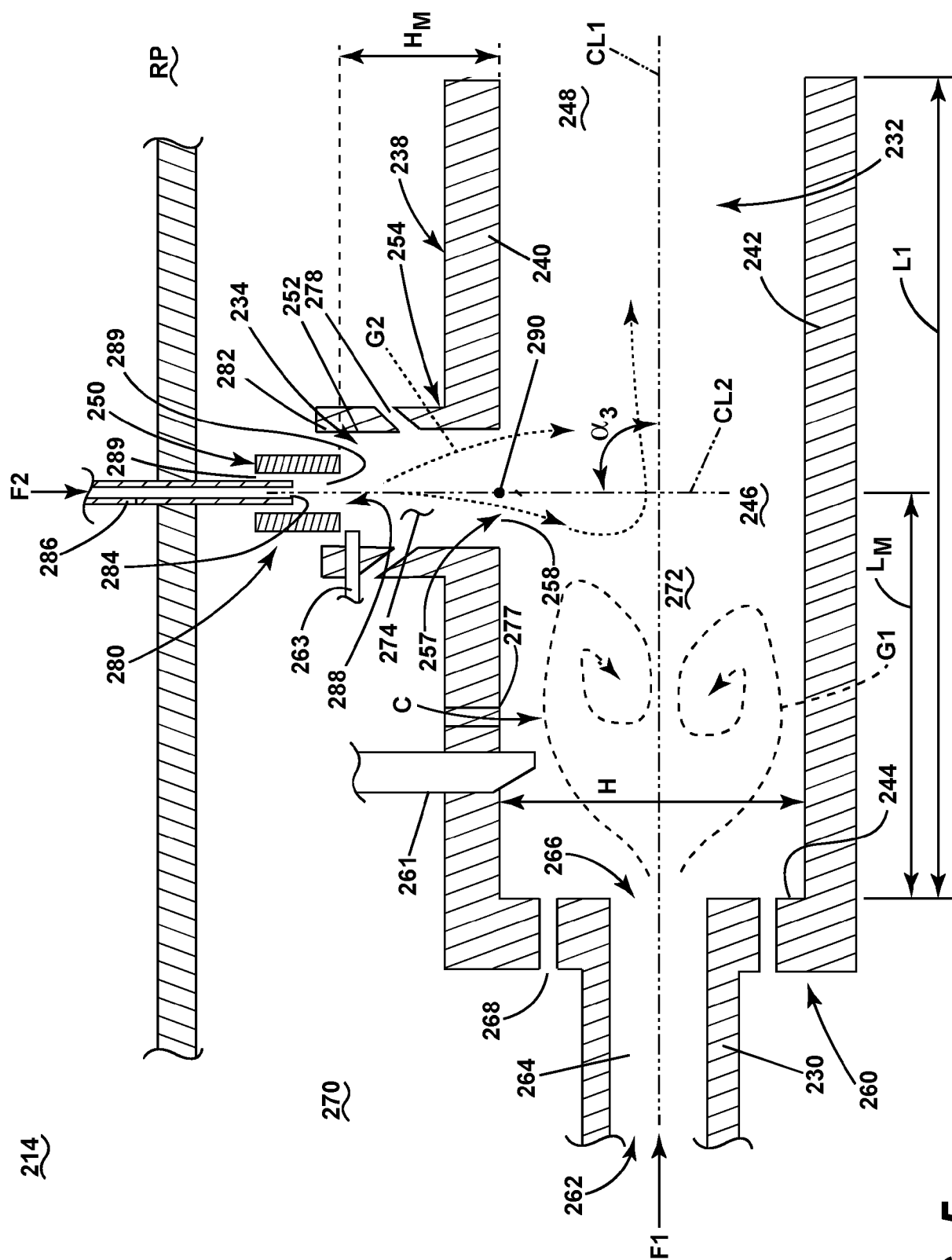


FIG. 2







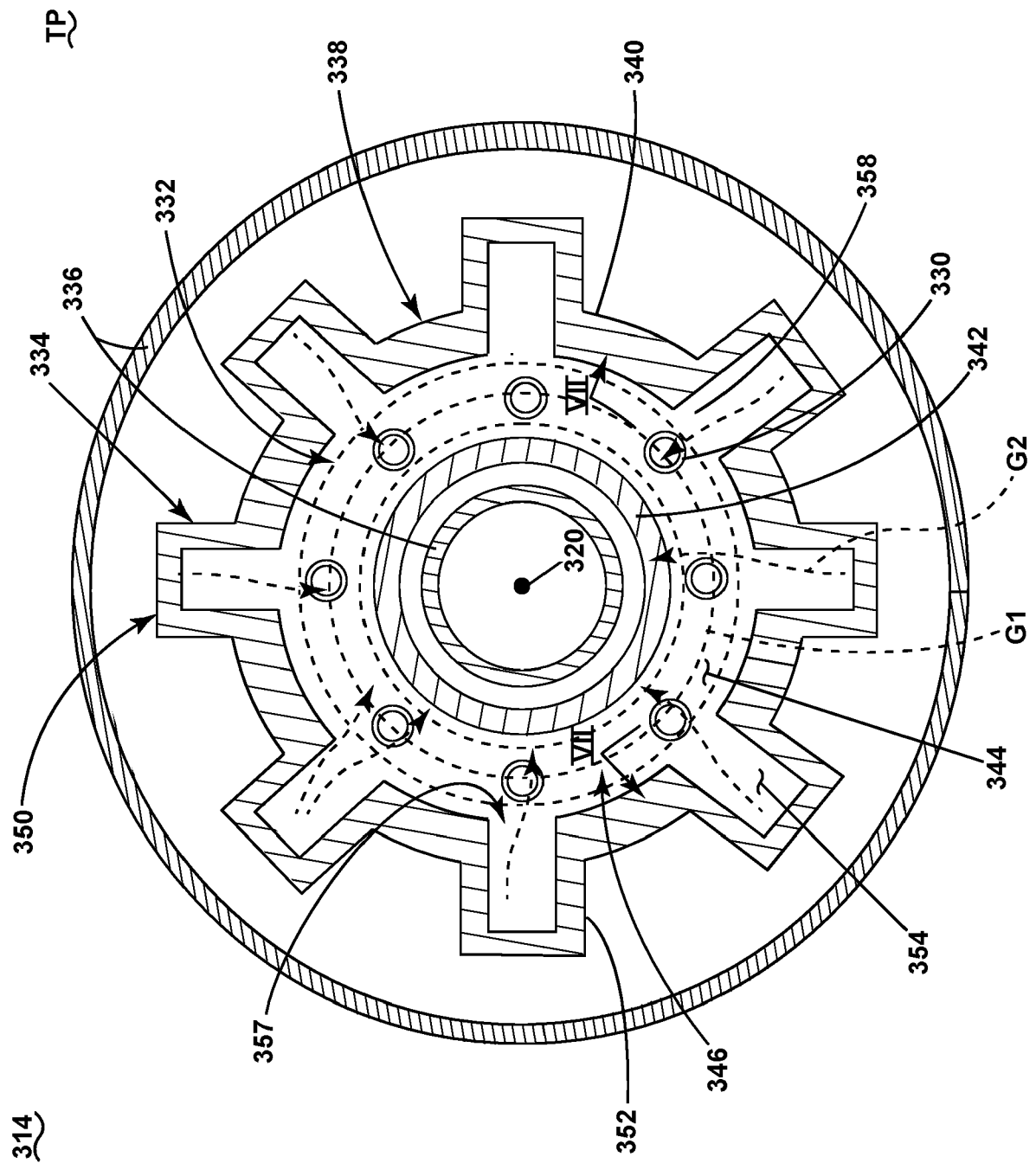


FIG. 6

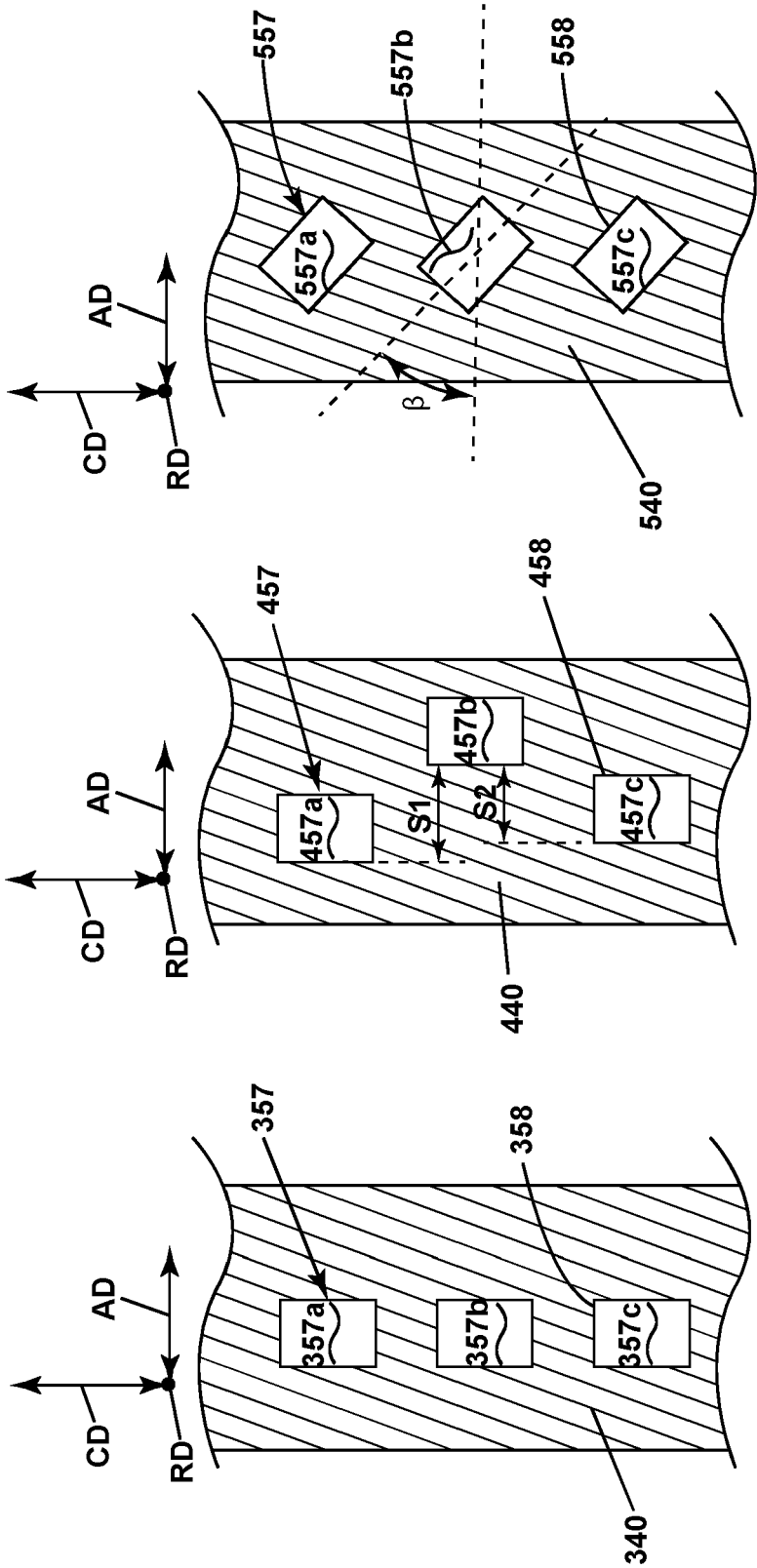


FIG. 7

FIG. 8

FIG. 9