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(54) **Aerodynamic fuel nozzle**

(57) The present application and the resultant patent provide a combustor (100) for a turbine engine (10). The combustor (100) may include a number of fuel nozzles (110) with one or more of the fuel nozzles (110) including

a swirler assembly (130). The swirler assembly (130) may include a number of stages (140) with a number of fueled structures (245) and a number of unfueled structures (250).

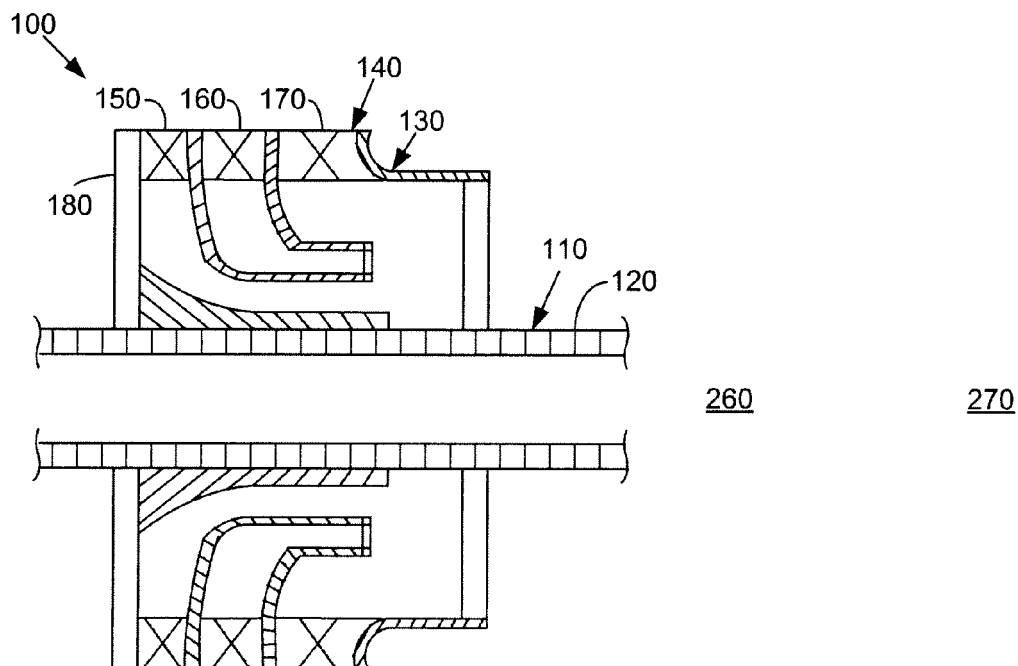


Fig. 4

Description

TECHNICAL FIELD

5 **[0001]** The present application relates generally to gas turbine engines and more particularly relates to an aerodynamic fuel nozzle with a triple stage swirler for late lean injection and turndown.

BACKGROUND OF THE INVENTION

10 **[0002]** Dry Low NO_x technology may be applied for emissions control with gaseous fuel combustion in industrial gas turbines using annular can combustion systems and the like. These known Dry Low NO_x combustion systems provide premixing of the fuel and the air for a generally uniform rate of combustion with relatively constant reaction zone temperatures. Through careful air management, these reaction zone temperatures may be optimized for very low production of nitrogen oxides ("NO_x"), carbon monoxide ("CO"), unburned hydrocarbons ("UHC"), and other types of undesirable emissions. Specifically, the modulation of a center premix fuel nozzle may expand the range of operation by allowing the fuel-air ratio and the corresponding reaction rates of the outer nozzles to remain relatively constant while varying the fuel input into the turbine.

15 **[0003]** Fuel staging allows for higher turbine inlet temperatures with a uniform heat release. Axially staged systems generally employ multiple planes of fuel injection along the combustor flow path. Even with advances in materials and heat transfer methods, however, current combustor designs are challenged to produce low nitrogen oxide emissions at full load conditions. Likewise, carbon monoxide emissions at part load conditions pose a challenge in reducing combustion firing temperatures. By firing only selected nozzles, the adjacent unfired nozzles may quench the reaction and produce carbon monoxide. The fired nozzle also may cause significant thermal stresses in the combustor liner so as to reduce component life time.

20 **[0004]** There is thus a desire for improved fuel nozzle and combustor designs and/or methods of staging fuel therein so as to lower peak fuel temperatures. Such improved designs should maintain adequate system output and efficiency with correspondingly low production of nitrogen oxides, carbon monoxide, and other types of emissions.

SUMMARY OF THE INVENTION

25 **[0005]** The present invention resides in a combustor for a turbine engine including a number of fuel nozzles with one or more of the fuel nozzles including a swirler assembly. The swirler assembly includes a number of stages with a number of fueled structures and a number of unfueled structures.

30 **[0006]** The present invention further resides in a method of operating a combustor for late lean injection including the steps of providing a flow of air to a fuel nozzle, providing a flow of fuel through one or more fueled structures of a swirler assembly, swirling the flow of air and the flow of fuel through multiple stages of the swirler assembly, establishing a primary recirculation zone about the fuel nozzle for low emissions, and establishing a secondary recirculation zone downstream of the fuel nozzle for high temperatures.

35 **[0007]** These and other features and improvements of the present application and the resultant patent will become apparent to one of ordinary skill in the art upon review of the following detailed description when taken in conjunction with the several drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

40 **[0008]** Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a schematic view of a known gas turbine engine.

45 Fig. 2 is a schematic cross-sectional view of a known combustor.

Fig. 3 is a schematic front view of an end cover and fuel nozzle assembly of the combustor of Fig. 2.

50 Fig. 4 is a partial side cross-sectional view of a fuel nozzle with a swirler as may be described herein.

55 Fig. 5 is a partial side cross-sectional view of a fuel nozzle with an alternative embodiment of a swirler as may be described herein.

Fig. 6 is a front plan view of a radial embodiment of the swirler of the fuel nozzle of Fig. 4.

Fig. 7 is a schematic view of a block embodiment of the swirler of the fuel nozzle of Fig. 4.

Fig. 8 is a partial side view of the block embodiment of the swirler of Fig. 7.

DETAILED DESCRIPTION

[0009] Referring now to the drawings, in which like numerals refer to like elements throughout the several views, Fig. 1 shows a schematic view of a turbo-machine such as a gas turbine engine 10 as may be described herein. The gas turbine engine 10 may include a compressor 15. The compressor 15 compresses an incoming flow of air 20. The compressor 15 delivers the compressed flow of air 20 to a combustor 25. The combustor 25 mixes the compressed flow of air 20 with a compressed flow of fuel 30 and ignites the mixture to create a flow of combustion gases 35. Although only a single combustor 25 is shown, the gas turbine engine 10 may include any number of combustors 25. The flow of combustion gases 35 is delivered in turn to a turbine 40. The flow of combustion gases 35 drives the turbine 40 so as to produce mechanical work. The mechanical work produced in the turbine 40 drives the compressor 15 via a shaft 45 and an external load 50 such as an electrical generator and the like.

[0010] The gas turbine engine 10 may use natural gas, various types of syngas, and/or other types of fuels. The gas turbine engine 10 may be any one of a number of different gas turbine engines such as those offered by General Electric Company of Schenectady, New York and the like. The gas turbine engine 10 may have different configurations and may use other types of components. Other types of gas turbine engines also may be used herein. Multiple gas turbine engines, other types of turbines, and other types of power generation equipment also may be used herein together.

[0011] Figs. 2 and 3 show an example of a known combustor 25. Generally described, the combustor includes an outer casing 55. The outer casing 55 may be bolted to the turbine 40 or otherwise attached. One end of the outer casing 55 may be enclosed by an end cover 60. The end cover 60 receives supply tubes, manifolds, and associated valves for feeding gaseous fuel, liquid fuel, air, and water. The end cover 60 supports a number of outer fuel nozzles 65 that surround a center nozzle 70. Other components and other configurations may be used herein.

[0012] A combustion zone 75 may be positioned within the outer casing 55 downstream of the end cover 60 and the fuel nozzles 65, 70. The combustion zone 75 may be enclosed via a combustion liner 80. A flow sleeve 85 may surround the combustion liner 80 and define a flow path 90 therebetween. The flow of air 20 from the compressor 15 flows through the flow path 90, reverses direction about the end cover 60, and flows into the fuel nozzle 65, 70. A transition piece 95 may extend about the downstream end of the outer casing 55. The transition piece 95 may be in communication with the turbine 10 for directing the flow of combustion gases 35 thereto. Other components and other configurations may be used herein.

[0013] The combustor 25 may be late lean injection compatible. A late lean injection compatible combustor may be any combustor with either an exit temperatures that exceeds about 2,500 degrees Fahrenheit (about 1,371 degrees Celsius) or handles fuels with components that are more reactive than, for example, methane with a hot side residence time greater than about 10 milliseconds. Examples of late lean injection compatible combustors include a DLN-1 ("Dry-Low NO_x") combustor, a DLN-2 combustor, and a DLN-2.6 combustor offered by General Electric Company of Schenectady, New York. Other types of late lean injection compatible combustors may be used herein. Such late lean injection compatible combustors may have a number of fuel injectors (not shown) positioned about the transition piece 95 or otherwise for fuel staging and the like. These downstream fuel injectors, however, may increase the overall complexity of the combustor 25. Other components and other configurations may be used herein.

[0014] Fig. 4 shows an example of a portion of a combustor 100 as may be described herein. The combustor 100 includes a number of fuel nozzles 110. Any number of the fuel nozzles 110 may be used. In this example, at least a center nozzle 120 may include a swirler assembly 130. The swirler assembly 130 may be a swirler with three stages 140. The three stages 140 thus include a first stage 150, a second stage 160, and a third stage 170. Any number of stages 140 may be used herein. The stages 140 may be positioned in an axial direction 180 as is shown in Fig. 4, in a circumferential direction 190 as shown in Fig. 5, or in combinations thereof. The outer swirler may have a swirl number $S_3 > 0.6$ and the inner swirlers may have a swirl number $S_2 > S_3$ and a swirl number $S_1 > S_3$. The swirl number characterizes combustor recirculation with a swirl number greater than 0.6 indicating good recirculation. Other components and other configurations may be used herein.

[0015] The stages 140 of the swirler assembly 130 may take many different forms. For example, the swirlers 130 may include a number of radial vanes 200 as is shown in Fig. 6, a number of blocks 210 as shown in Fig. 7, and/or combinations thereof. Other shapes also may be used herein. In the block embodiment of Fig. 7, a number of fixed blocks 220 and a number of movable blocks 230 may be used so as to provide a variable swirler. In either embodiment, a number of injection ports 240 may be used as are shown in Fig. 8 for a fueled structure 245. The injection ports 240 may be positioned in radial, axial, and/or circumferential directions. For example, three (3) different directions may be used in

the vane 200 of Fig. 7. The vanes 200 and blocks 210 also may be unfueled structures 250. Other configurations and other components may be used herein.

[0016] Combinations of the vanes 200 and the blocks 210 may be used together. Specifically, different types of swirlers with different types of vanes 200, blocks 210, or other shapes may be used herein. The following chart shows several examples of differing embodiments of the swirler assemblies 130:

Embodiment	Swirler 1	Swirler 2	Swirler 3
1	Radial Vane, Fueled	Radial Vane, Fueled	Block Vane, Unfueled
2	Radial Vane, Fueled	Block Vane, Fueled	Block Vane, Unfueled
3	Radial Vane, Fueled	Radial Vane, Fueled	Radial Vane, Unfueled
4	Radial Vane, Fueled	Radial Vane, Unfueled	Radial Vane, Fueled
5	Block Vane, Fueled	Block Vane, Fueled	Block Vane, Fueled

[0017] The examples shown herein are not exclusive. As one can appreciate, any number of different combinations of vanes 200 and blocks 210 being fueled or unfueled may be used herein.

[0018] The fuel nozzle 110 thus creates a primary recirculation zone 260 near the nozzle 120 and a secondary recirculation zone 270 downstream. With late lean injection operations, the primary recirculation zone 260 operates near the flammability limits (about $\Phi = 2.5$ or about $\Phi = 0.4$) and the combustion products travel downstream without forming significant nitrogen oxides or other emissions. In the secondary recirculation zone 270, the core and tertiary air mix at overall lean conditions and raise the overall temperature of the hot combustion gases so as to reduce fuel staging by aerodynamic means.

[0019] For high turndown, the primary recirculation zone 260 may be fired at moderately lean temperatures (about $\Phi = 0.5$ to 0.6). This may accomplish good fuel burnout and maintain low emissions. Further downstream, the inner products mix with the tertiary stream in the secondary recirculation zone 270 so as to bring the mixture to overall lean conditions. The fuel nozzle 110 thus is able to form turndown while maintaining low carbon monoxide in the presence of unfired nozzles.

[0020] The nozzle 110 thus enables increased combustion firing temperatures without increasing nitrogen oxides by effectively implementing late lean injection performance without significant hardware changes. The nozzle 110 also enables high combustion turndown without producing significant levels of carbon monoxide. The nozzle 110 may be used in conjunction with existing nozzles that may remain unfired without impacting on the low carbon monoxide performance.

[0021] The use of the swirler assembly 130 with a center nozzle 120 thus provides fuel staging so as to create a downstream aero-staged flame. Fuel staging herein thus may be maximized. Moreover, such fuel staging may dampen combustion dynamics.

[0022] It should be apparent that the foregoing relates only to certain embodiments of the present application and the resultant patent. Numerous changes and modifications may be made herein by one of ordinary skill in the art without departing from the general spirit and scope of the invention as defined by the following claims and the equivalents thereof.

Claims

1. A combustor (100) for a turbine engine (10), comprising:

a plurality of fuel nozzles (110); and

one or more of the plurality of fuel nozzles (110) comprising a swirler assembly (130);

wherein the swirler assembly (130) comprises a plurality of stages (140); and

wherein the plurality of stages (140) comprises a plurality of fueled structures (245) and a plurality of unfueled structures (250).

2. The combustor (100) of claim 1, wherein the plurality of fuel nozzles (110) comprises a central fuel nozzle (120).

3. The combustor (100) of claim 1 or 2, wherein the plurality of stages (140) comprises a first stage (150), a second stage (160), and a third stage (170).

4. The combustor (100) of any of claims 1, 2 or 3, wherein the plurality of stages (140) extend in an axial direction (180).

5. The combustor (100) of any of claims 1 to 4, wherein the plurality of stages (140) extend in a circumferential direction (190).
- 5 6. The combustor (100) of any preceding claim, wherein the plurality of stages (140) comprises one of a plurality of radial vanes (200) or a plurality of blocks (210).
7. The combustor (100) of claim 6, wherein the plurality of stages (140) comprises a plurality of blocks (210) and wherein the plurality of blocks (210) comprises a plurality of fixed blocks (220) and a plurality of movable blocks (230).
- 10 8. The combustor (100) of any preceding claim, wherein the plurality of fueled structures (245) comprises one of a plurality of radial vanes (200), a plurality of moveable blocks (210) or a plurality of radial vanes (200) and a plurality of blocks (210).
- 15 9. The combustor (100) of any of claims 1 to 7, wherein the plurality of fueled structures (245) comprises a plurality of injection ports (240).
10. The combustor (100) of claim 9, wherein the plurality of injection ports (240) comprises an axial direction (180) and/or a circumferential direction (190).
- 20 11. The combustor (100) of any preceding claim, further comprising a primary recirculation zone (260) about the plurality of fuel nozzles (110) and a secondary recirculation zone (270) downstream of the plurality of fuel nozzles (110).
12. A method of operating a combustor (100) for late lean injection, comprising:
 - 25 providing a flow of air (20) to a fuel nozzle (110);
 - providing a flow of fuel (30) through one or more fueled structures (245) of a swirler assembly (130);
 - swirling the flow of air (20) and the flow of fuel (30) through multiple stages (140) of the swirler assembly (130);
 - establishing a primary recirculation zone (260) about the fuel nozzle (110) for low emissions; and
 - 30 establishing a secondary recirculation zone (270) downstream of the fuel nozzle (110) for high temperatures.
13. The method of claim 12, wherein the step of establishing a primary recirculation zone (260) comprises combusting the flow of fuel (30) and the flow of air (20) near a flammability limit.
14. The method of claim 12 or 13, wherein the step of establishing a primary recirculation zone (260) comprises com-
busting the flow of fuel (30) and the flow of air (20) without forming nitrogen oxides.
- 35 15. The method of any of claims 12 to 14, wherein the step of establishing a secondary recirculation zone (270) comprises lean mixing of the flow of fuel (30) and the flow of air (20).

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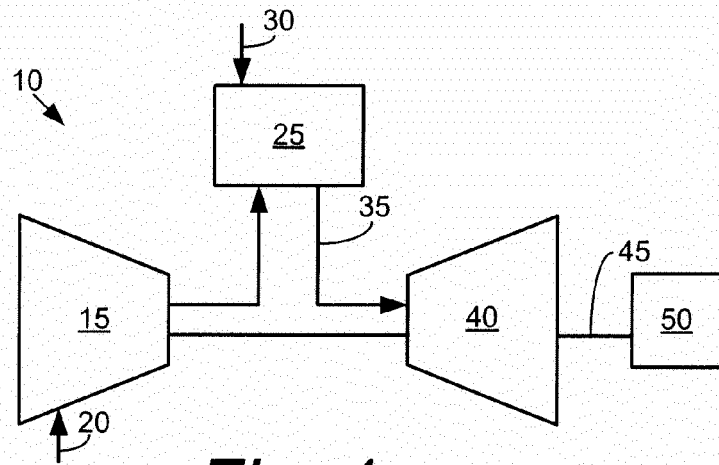


Fig. 1

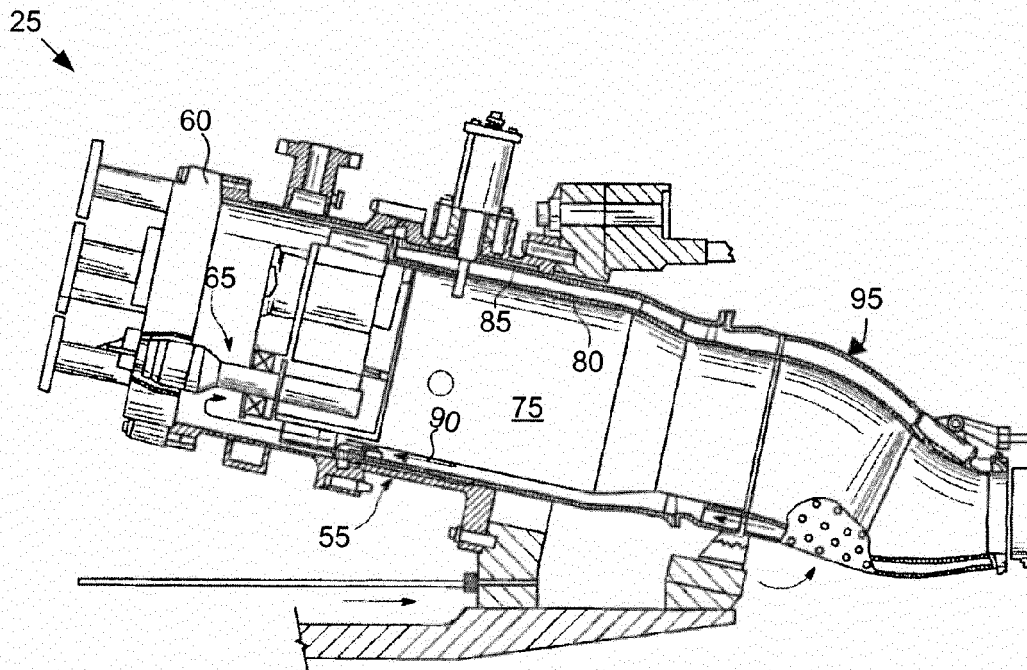


Fig. 2

Fig. 3

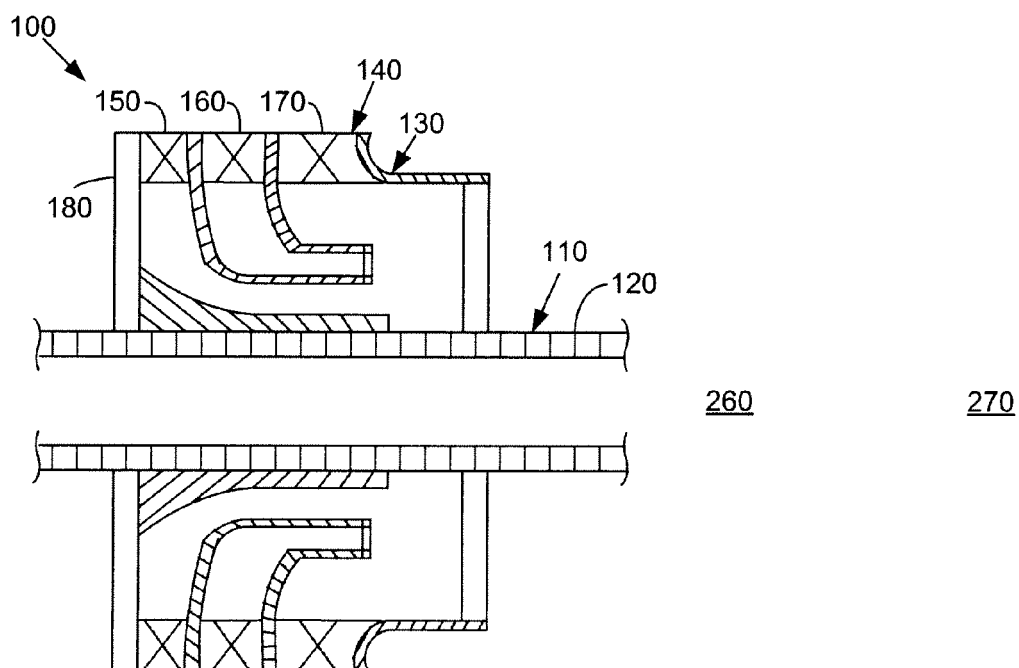
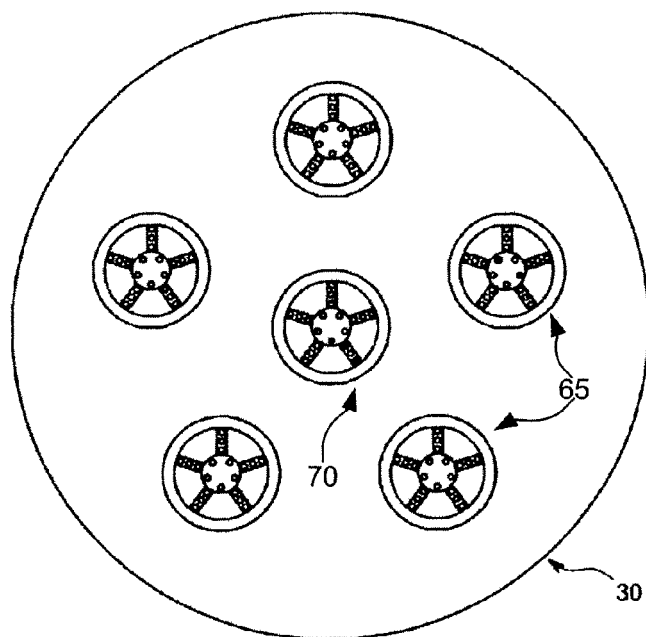


Fig. 4

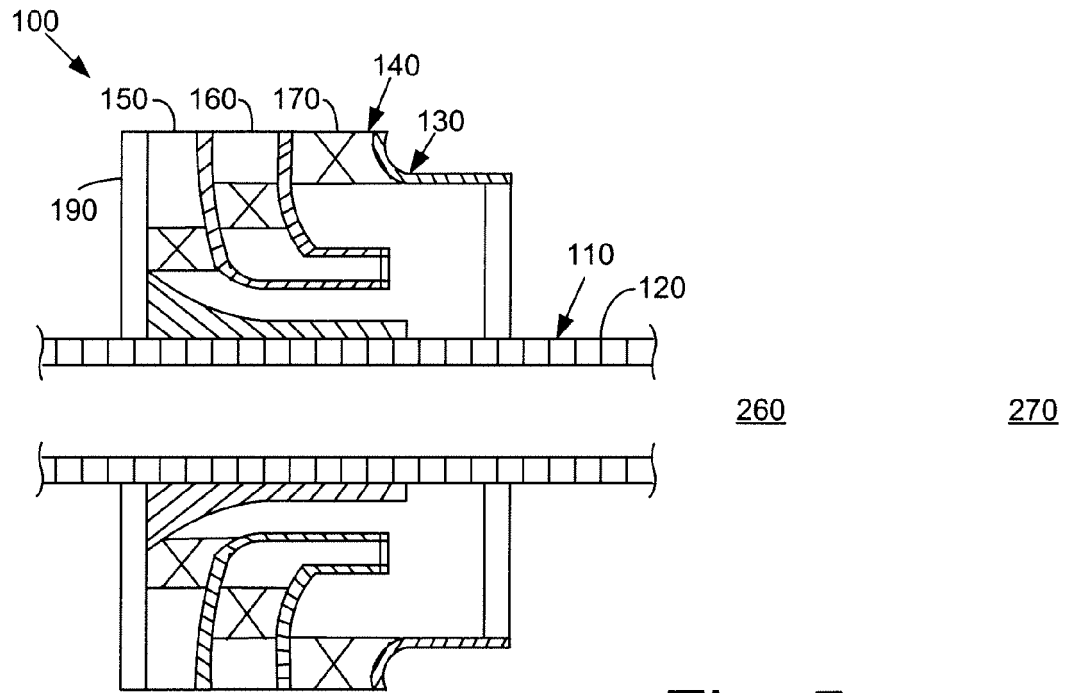


Fig. 5

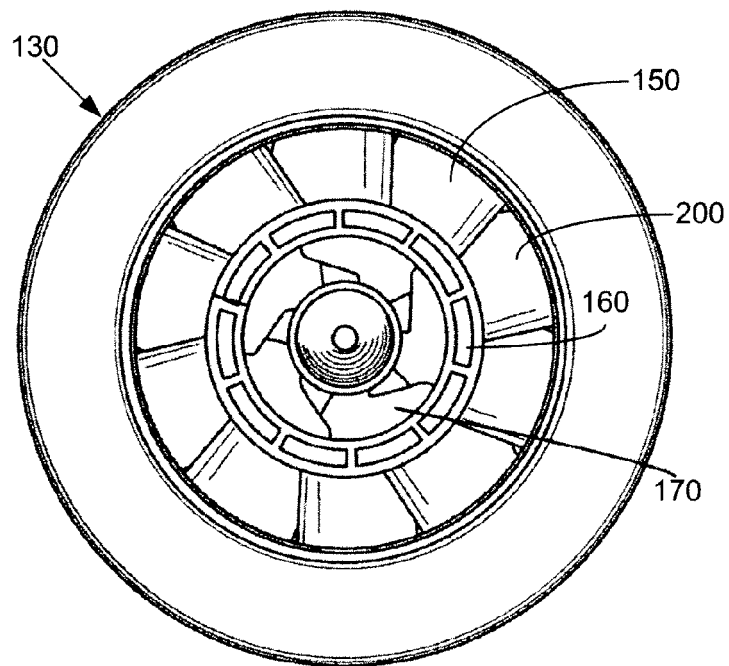


Fig. 6

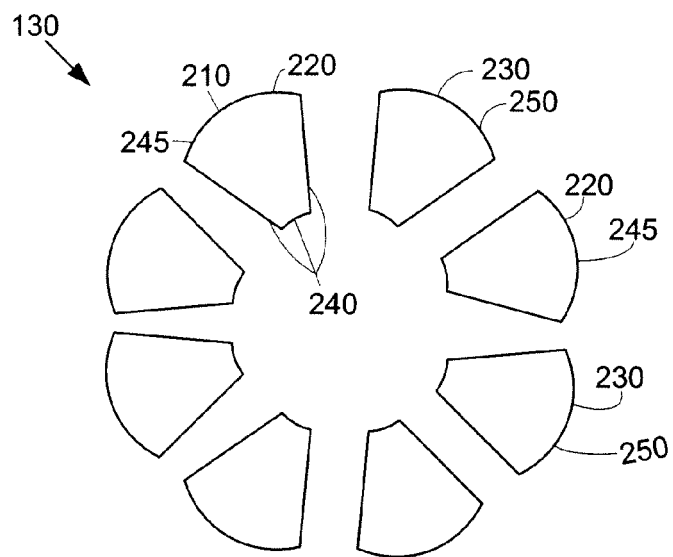


Fig. 7

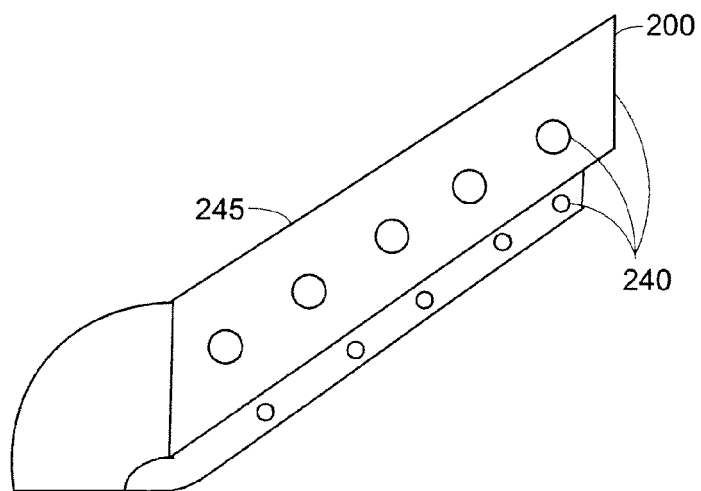


Fig. 8