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(54) **Combustor liner**

(57) The present invention relates to a combustor liner (300) for a gas turbine, the combustor liner having a cylindrical shape and comprising two sections, wherein the upstream section (310) with respect to the hot gas flow during operation is ring shaped and comprises a rounded lip section (330) and a trailing section (340), and

wherein an inner radius (R1) of the trailing section (340) is increasing along a centerline of the liner in the direction of the hot gas flow during operation.

The invention also relates to a combustor (400) and a gas turbine comprising such combustor.

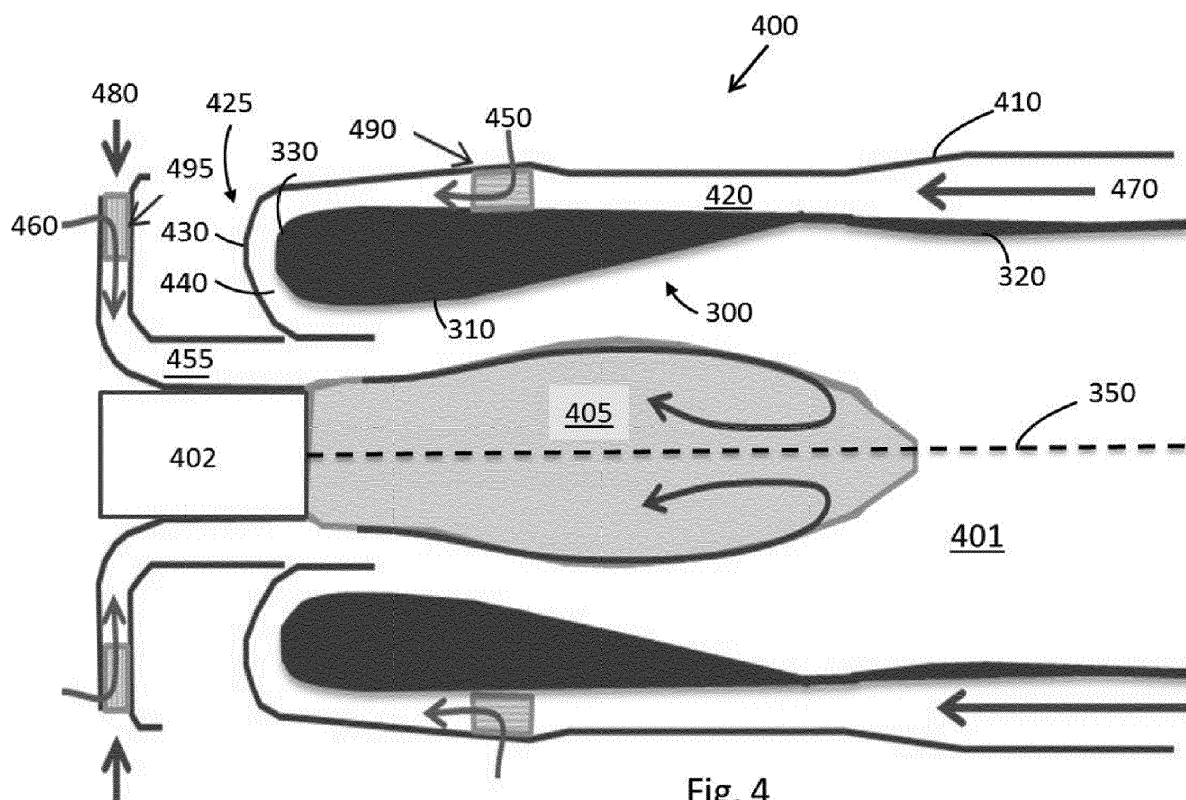


Fig. 4

Description

TECHNICAL FIELD

[0001] The present invention relates to gas turbine engines, and more particularly relates to a combustor liner for improving combustion performance.

BACKGROUND

[0002] In an effort to reduce the amount of pollutant emissions from gas-powered turbines, governmental agencies have enacted numerous regulations requiring reductions in the amount of oxides of nitrogen (NOx) and carbon monoxide (CO). Lower combustion emissions can often be attributed to a more efficient combustion process, with specific regard to fuel injector location and mixing effectiveness.

[0003] Early combustion systems utilized diffusion type nozzles, where fuel is mixed with air external to the fuel nozzle by diffusion, proximate the flame zone. Diffusion type nozzles have been known to produce high emissions due to the fact that the fuel and air burn stoichiometrically at high temperature to maintain adequate combustor stability and low combustion dynamics.

[0004] An enhancement in combustion technology is the utilization of premixing, such that the fuel and air mix prior to combustion to form a homogeneous mixture that burns at a lower temperature than a diffusion type flame and produces lower NOx emissions. Premixing fuel and air together before combustion allows for the fuel and air to form a more homogeneous mixture, which for a given combustor exit temperature will burn at lower peak emissions temperatures, resulting in lower emissions. Example of such a gas turbine flamesheet combustion system with reduced emissions and improved flame stability at multiple load conditions is disclosed in US patent application US2004/0211186A1

[0005] While the combustors of the prior art have improved emissions levels and ability to operate at reduced load settings, thermoacoustics of the flamesheet combustors could still lead to instability modes (such as pulsation), which could restrict the operation window. Additionally, aerodynamics of the burner can lead to flame attachment in the mixing zone under certain circumstances, causing flashback and overheating risk. Furthermore, current fuel staging strategies could cause asymmetrical heat load on the combustor liner, which could lead to creep problems.

[0006] Finally, measure which help against pulsation, as for example the staging of 1/3-2/3 groups in the main fuel supply can lead to asymmetrical liner heat loading, as well as to non-uniformities in the combustor exit temperature profile. The invention described below is intended to widen the operation window beyond the currently available range,

without sacrificing the low emission values.

[0007] What is intended is a system that can provide

further flame stability and low emissions benefits while also reducing thermoacoustic instabilities which can enlarge the operation window available of the current combustor designs.

SUMMARY OF THE INVENTION

[0008] It is one object of the present invention to modify the flamesheet combustor to obtain improved thermoacoustics characteristics, reduced flashback, better flame holding and increased operation window through aerodynamics and advanced fuel staging measures.

[0009] The above and other objects of the invention are achieved by a combustor liner for a gas turbine, the combustor liner having substantially cylindrical shape and comprising a first section and a second section wherein the first section is upstream of the second section with respect to the hot gas flow during operation, characterized in that the first section is ring shaped and comprises a rounded lip section and a trailing section, wherein an inner radius (R1) of the trailing section is increasing along a centerline of the liner in the direction of the hot gas flow during operation. According to one embodiment, the radius (R1) of the trailing section is increasing monotonically along the centerline of the combustion liner.

[0010] According to another embodiment, the length in the axial direction of the first section is in the range from 20 percent to 80 percent of the total length in the axial direction of the liner.

[0011] According to yet another embodiment, an angle (α) between the trailing section and an outer surface of the combustion liner is in the range of 5 to 15 degrees.

[0012] According to another embodiment, a radius of outer surface of the combustion liner is substantially constant.

[0013] According to yet another embodiment, a radius (R2) of the second part is substantially constant along the centerline of the liner.

[0014] According to another embodiment, the first section of the combustor liner is substantially hollow. An additional volume can be used for placement of at least one damper (preferably Helmholtz damper) and/or a means for a liquid fuel injection.

[0015] Apart from the combustor liner, the present application also relates to a combustor comprising the liner described above and a combustion zone delimited by the combustor liner. In a first embodiment, the combustor comprises a substantially cylindrical flow sleeve, wherein the combustion liner is located at least partially within the flow sleeve thereby forming a first passage between the flow sleeve and the combustion liner; a dome located forward of the flow sleeve and encompassing at least partially a first section of the combustion liner, the dome having a substantially rounded head end thereby forming a turning passage between the rounded lip section of the first section of combustion liner and the dome; and at least one pilot channel comprising a means for supplying a pilot fuel and a first swirling device. The turning passage

can for example have a cross section shaped like half annulus. The turning passage extends from the first passage into combustion zone and guides cooling air leaving the first passage around the upstream end of the first section of combustion liner into the combustion zone of the combustor.

[0016] According to another embodiment of the combustor, the first passage and/or the turning passage comprise a fuel injection means and a second swirling device. Preferably, the first swirling device and/or the second swirling device are axial or radial swirlers.

[0017] The present application also provides for a gas turbine comprising the combustor described above.

[0018] In addition, the present application also provides for a method for operating the gas turbine combustor. The method comprises: supplying a first flow of air into the pilot channel ;supplying a first stream of fuel into the pilot channel to mix with the first flow of air , and feeding the resulting first mixture into the combustion zone for providing pilot flame; supplying a second flow of air into the first passage ;supplying a second stream of fuel into the first passage or second passage to mix with the second flow of air , and feeding the resulting second mixture into the combustion zone for providing a main flame; wherein the first mixture and second mixture are guided along the inner wall of the liner and form a central recirculation zone in the center of the combustion zone.

[0019] Additional advantages and features of the present invention will be set forth in part in a description which follows, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned from practice of the invention. The instant invention will now be described with particular reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0020] Preferred embodiments of the invention are described in the following with reference to the drawings, which are for the purpose of illustrating the present preferred embodiments of the invention and not for the purpose of limiting the same. In the drawings,

Figure 1 shows a cross section view of a gas turbine combustion system of the prior art.

Figure 2 shows a cross section view of a gas turbine combustion system of the prior art schematically indicating recirculation zones.

Figure 3a shows a cross section view of a combustion liner in accordance with an embodiment of the present invention.

Figure 3b shows a cross section view of a combustion liner in accordance with an alternate embodiment of the present invention.

Figure 3c shows a cross section view of a combustion liner in accordance with another alternate embodiment of the present invention.

Figure 3d shows a cross section view of a combustor

tion liner in accordance with yet another alternate embodiment of the present invention.

Figure 4 shows a cross section view of a combustor in accordance with an embodiment of the present invention.

Figure 5 shows a cross section view of a combustor in accordance with an alternate embodiment of the present invention.

Figure 6 shows a cross section view of a combustor in accordance with another embodiment of the present invention.

Figure 7 shows a cross section view of a combustor in accordance with yet another embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0021] An example of a premixing flamesheet combustor 100 for a gas turbine of the prior art is shown in Fig. 1. The combustion system 100 includes a flow sleeve 102 containing a combustion liner 104. The combustion liner 104 has a constant radius along the centreline AA' of the combustor 100. A fuel injector 106 is secured to a casing 108 with the casing 108 encapsulating a radial mixer 110. Secured to the forward portion of the casing 108 are a cover 112 and pilot nozzle assembly 114. The combustor 100 is a type of reverse flow premixing combustor

[0022] Fig.2 shows cross section of a central portion of a flamesheet combustor 100 during an operation. The fuel is provided to the combustor 100 via fuel injection nozzles 106 (main fuel) and 114 (pilot fuel). The air is mixed with pilot fuel and main fuel respectively. The radial mixer 110 provides swirled air to the fuel-air mixture to improve flame stabilization. Use of the mixer 110 stabilizes the combustion process by developing a reverse flow inside the combustor 100. The reverse flow returns free radicals and heat upstream to the unburnt air-fuel mixture. In this way, two separate recirculation zones, a central recirculation zone 210 and an outer recirculation zone 220 are created as shown in Fig. 2. The flame is anchored in the central recirculation zone 210 at ignition and part-load conditions with the help of pilot fuel. At higher loads, the flame is transferred to outer recirculation zone 220 by increasing supply of main fuel.

[0023] Utilization of two competing recirculation zones (central 210, and outer 220) could lead to instability problems, especially when both pilot and main are comparable in equivalence ratios. Transition from pilot-stabilized flame to main-stabilized flame requires a carefully defined procedure to avoid high pulsations.

[0024] To overcome above mentioned problems, a combustion liner design is proposed according to the invention. Fig. 3a shows a cross section view of a combustion liner 300 for a gas turbine in accordance with an embodiment of the present invention. The combustor liner 300 has substantially cylindrical shape and comprises a first section 310 and a second section 320 wherein the

first section is upstream of the second section with respect to the hot gas flow during operation. The first section 310 is ring shaped and comprises a rounded lip section 330 and a trailing section 340. An inner radius (R1) of the trailing section 340 is increasing along a centerline 350 of the liner 300 in the direction of the hot gas flow during operation. In one embodiment of the present invention, the radius (R1) of the trailing section 340 is increasing monotonically along the centerline 350 of the liner 300. This means, for example, that the trailing section 340 can have at least one flat region with the constant radius (R1).

[0025] The length, in axial direction, of the first section 310 in respect to the total length, in axial direction, of the liner 300 can vary. In one preferred embodiment, the length of the first section 310 is in the range from 20 percent to 80 percent of the total length of the liner 300. As shown in Fig. 3a, there is an angle (α) between an outer surface 360 of the combustion liner 300 and the trailing section 340. The angle (α) can vary. In one preferred embodiment the angle (α) is in the range of 5 to 15 degrees.

[0026] In one preferred embodiment of the invention, the radius of the outer surface 360 of the combustion liner 300 is substantially constant along the centerline 350 of the liner 300. This means that the outer radius of the section 310 and the section 320 are substantially equal. In another embodiment according to the invention, a radius (R2) of the second section 320 is substantially constant along the centerline 350 of the liner 300. In addition, the radius (R1) and radius (R2) are equal at least at a point of connection between the first section 310 and the second section 320.

[0027] Fig 3b shows another embodiment of the combustor liner 300 according to the invention. Contrary from the first embodiment (Fig. 3a), where the trailing section radius (R1) is increasing smoothly towards second section, in this embodiment there is a sharp step-like increase in the radius (R1) of the trailing section 340. In one embodiment the step occurs after the radius (R1) already increased for at least 10 percent. Combustion liners from the prior art (such as shown in Fig.1) have substantially cylindrical shape with constant radius along liner's centreline.

[0028] Normally, they are made of thin metal sheets. Due to the low thickness of the walls, such liners have no possibilities to incorporate additional devices in the liner structures. One of the features of the combustor liners according to the invention is that the first section 310 of combustion liner 300 is substantially hollow, while the second section 320 is made of thin material, normally of sheet metal. The additional space inside the first section 310 can be advantageous comparing to liners from the prior art. In one embodiment according to the invention, this additional space inside the first section 310 can be used for placing a damper device. Fig. 3c shows the combustor liner 300 wherein the first section 310 comprises a Helmholtz damper 370. In general, Helmholtz

damper is designed according to an individually determined or predetermined damping requirement against the thermoacoustic oscillation frequencies occurring in the combustion chamber. The Helmholtz damper 370 comprises a damper volume, a neck 371 and a cooling channel 372.

[0029] In another embodiment according to the invention, shown in Fig. 3d, the space inside the first section 310 is used to incorporate the means for liquid fuel injection 380. The one example of such a means for liquid fuel injection is fuel nozzles.

[0030] The combustor liner 300 according to the present invention can be incorporated in a combustion system of a gas turbine. Fig. 4 shows a combustor 400 for a gas turbine according to the invention, comprising the combustor liner 300 and a combustion zone 401 delimited by the combustion liner 300. In one embodiment of the present invention, the combustor comprises a substantially cylindrical flow sleeve 410, wherein the combustion liner 300 is located at least partially within the flow sleeve 410. The flow sleeve 410 and the combustion liner 300 form a first passage 420. The combustor 400 further comprises a dome 425 located forward of the flow sleeve and encompassing at least partially a first section 310 of the combustion liner 300. The dome 425 has a substantially round head 430 thereby forming a turning passage 440 between the rounded lip section 330 of the first section 310 of combustion liner and the dome 425. In addition, the combustor comprises at least one pilot channel 455 comprising a means for supplying a pilot fuel 460 and a first swirling device 495. In one embodiment, the first passage 420 further comprises a main fuel injection means 450 and a second swirling device 490. In one embodiment, the combustor 400 comprises a bluff body 402 to stabilize a flame inside the combustion zone 401. The bluff body 402 could contain additional fuel nozzles.

[0031] During the operation of the combustion systems from prior art, outer and central recirculation zones are created (as shown in Fig.2). As shown in Fig.4, during the operation of the combustor 400, according to the invention, only the central recirculation zone 405 is created. The outer recirculation zone is not present due to the design of the combustor liner 300 according to the invention. Elimination of outer recirculation zone removes the problems of bi-stable flame. Flame is stabilized through the central recirculation zone. There is neither competition nor transfer from one zone to another.

[0032] The alternate embodiments of the combustion liner presented in Fig 3b, 3c, and 3d can also be incorporated in the combustor 400 according to invention.

[0033] Fig. 5 shows the combustor 400 comprising the combustor liner 300 with the Helmholtz damper 370. This embodiment offers additional acoustic damping possibilities for the combustor 400.

[0034] Fig. 6 shows the combustor liner 400 comprising the means for liquid fuel injection 380. This embodiment offers additional liquid fuel supply possibilities for

the combustor 400.

[0035] Fig. 7 shows another embodiment of the combustor according to the invention. In this embodiment, a radial staging means 710 are positioned in the turning passage 440, preferably downstream of the dome 425. In this configuration, the fuel injection and mixing can be separated in at least two radial stages. The radial staging means 710 comprises at least one and preferably two separated parts, an inner part and an outer part. Inner part comprises an inner main swirler 712 while the outer part comprises an outer swirler 711. The swirlers 711 and 712 are supplied with fuel from a fuel injector 721, which is preferably positioned downstream the turning passage 440. This staging configuration can prevent flame attachment problems completely and enable smooth loading of the combustor by increasing the fuel radially from inside to outside gradually.

[0036] The present invention also provides a method for operating the gas turbine combustor 400 according to the invention. The method comprises the steps: supplying a first flow of air 480 into the pilot channel 455; supplying a first stream of fuel into the pilot channel 455 to mix with the first flow of air 480, and feeding the resulting first mixture into the combustion zone 401 for providing pilot flame; supplying a second flow of air 470 into the first passage 420; supplying a second stream of fuel into the first passage 420 or turning passage 440 to mix with the second flow of air 470, and feeding the resulting second mixture into the combustion zone 401 for providing a main flame; wherein the first mixture and second mixture are guided along the inner wall of the liner and form a central recirculation zone 405 in the center of the combustion zone 401. The first flow of air 480 and the second flow of air 470 are normally supplied from a compressor plenum (not shown).

[0037] The main advantages of the present invention are improved stability due to single recirculation zone, thus elimination of competition between inner and outer recirculation zones and loading the combustor without any flame transfer from inside to outside. The flame is always anchored in the centre as the fuel added to outer layers as increased load.

[0038] Additional advantages of the present application, in addition to improved stability, are: reduced heat load to liner at part load due to cooler outer streams (liner loading is high only at peak loads); uniform heat load to liner, preventing creep and deformation; more uniform combustor exit temperature distribution; creation of additional volume for acoustic damping and dual-fuel injection (liquid fuel); elimination of flame-holding and flashback risk by moving the main premix injection downstream of bend.

[0039] It should be apparent that the foregoing relates only to the preferred embodiments of the present application and that 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.

List of designations

[0040]

5	100 Combustor
	102 Flow sleeve
	104 Combustion liner
	106 Fuel injection nozzles
	108 Casing
10	110 Radial mixer
	112 Cover
	114 Fuel injection nozzles
	210 Central recirculation zone
	220 Outer recirculation zone
15	300 Combustion liner
	310 First section of the combustion liner 300
	320 Second section of the combustion liner 300
	330 Rounded lip section of 310
	340 Trailing section of 310
20	350 Centerline of the combustion liner 300
	360 Outer surface of the liner 300
	370 Helmholtz damper
	371 Neck of 370
	372 Cooling channel of 370
25	380 Liquid fuel injection means
	400 Combustor
	401 Combustion zone
	402 Bluff body
	405 Central recirculation zone
30	410 Flow sleeve
	420 First passage
	425 Dome
	430 Head end of 425
	440 Turning passage
35	450 Fuel injection means
	455 Pilot channel
	460 Pilot fuel
	470 Second flow of air
	480 First flow of air
40	490 Second swirling device
	495 First swirling device
	710 Radial staging means
	711 Outer main swirler
	712 Inner main swirler
45	721 Main fuel injection
	R1 Inner radius of 340
	R2 Inner radius of 320
	α angle between 340 and 360

Claims

1. A combustor liner (300) for a gas turbine, the combustor liner (300) having substantially cylindrical shape and comprising a first section (310) and a second section (320) wherein the first section is upstream of the second section with respect to the hot gas flow during operation, **characterized in that** the

- first section (310) is ring shaped and comprises a rounded lip section (330) and a trailing section (340), wherein an inner radius (R1) of the trailing section (340) is increasing along a centerline (350) of the liner (300) in the direction of the hot gas flow during operation. 5
2. The combustor liner (300) of claim 1, wherein the inner radius (R1) of the trailing section (340) is increasing monotonically along the centerline (350) of the liner (300). 10
3. The combustor liner (300) of claims 1 or 2, wherein the length in axial direction of the first section (310) is in the range from 20 percent to 80 percent of the total length in axial direction of the liner (300). 15
4. The combustor liner (300) of any of the preceding claims, wherein an angle (α) between the trailing section (340) and an outer surface (360) of the combustion liner (300) is in the range of 5 to 15 degrees. 20
5. The combustor liner (300) of any of the preceding claims, wherein a radius of an outer surface (360) of the combustion liner (300) is substantially constant along the centerline (350) of the liner (300). 25
6. The combustor liner (300) of any of the preceding claims, wherein a radius (R2) of the second section (320) is substantially constant along the centerline (350) of the liner (300). 30
7. The combustor liner (300) of any of the preceding claims, wherein the first section (310) is substantially hollow. 35
8. The combustor liner (300) of any of the preceding claims, wherein the first section (310) comprises a damper device (370), preferably the damper device is Helmholtz damper. 40
9. The combustor liner (300) of any of the preceding claims, wherein the first section (310) comprises means for a liquid fuel injection (380). 45
10. A combustor (400) for a gas turbine **characterized in that** it comprises the combustor liner (300) according to any of the preceding claims and a combustion zone (401) delimited by the combustion liner (300). 50
11. The combustor (400) of claim 10 further comprising:
- a substantially cylindrical flow sleeve (410), wherein the combustion liner (300) is located at least partially within the flow sleeve (410) thereby forming a first passage (420) between the flow sleeve (410) and the combustion liner (300); 55
- a dome (425) located forward of the flow sleeve and encompassing at least partly a first section (310) of the combustion liner (300), the dome (425) having a substantially rounded head end (430) thereby forming a turning passage (440) between the rounded lip section (330) of the first section (310) of combustion liner and the dome (425);
- at least one pilot channel (455) comprising a means for supplying a pilot fuel (460) and a first swirling device (495);
12. The combustor (400) of claim 11 wherein the first passage (420) and/or the turning passage (440) comprise a fuel injection means (450, 721) and a second swirling device (490, 711, 712);
13. The combustor (400) of claim 11 or 12 wherein the first swirling device (495) and/or the second swirling device (490, 711, 712) are axial or radial swirlers.
14. A gas turbine comprising the combustor according to any of claims 9 to 13.
15. A method for operating the gas turbine combustor (400) according to any of claims 10 to 13, the method comprising:
- supplying a first flow of air (480) into the pilot channel (455);
- supplying a first stream of fuel into the pilot channel (455) to mix with the first flow of air (480), and feeding the resulting first mixture into the combustion zone (401) for providing pilot flame;
- supplying a second flow of air (470) into the first passage (420);
- supplying a second stream of fuel into the first passage (420) or turning passage (440) to mix with the second flow of air (470), and feeding the resulting second mixture into the combustion zone (401) for providing a main flame;
- wherein the first mixture and second mixture are guided along the inner wall of the liner (300) and form a central recirculation zone (405) in the center of the combustion zone (401).

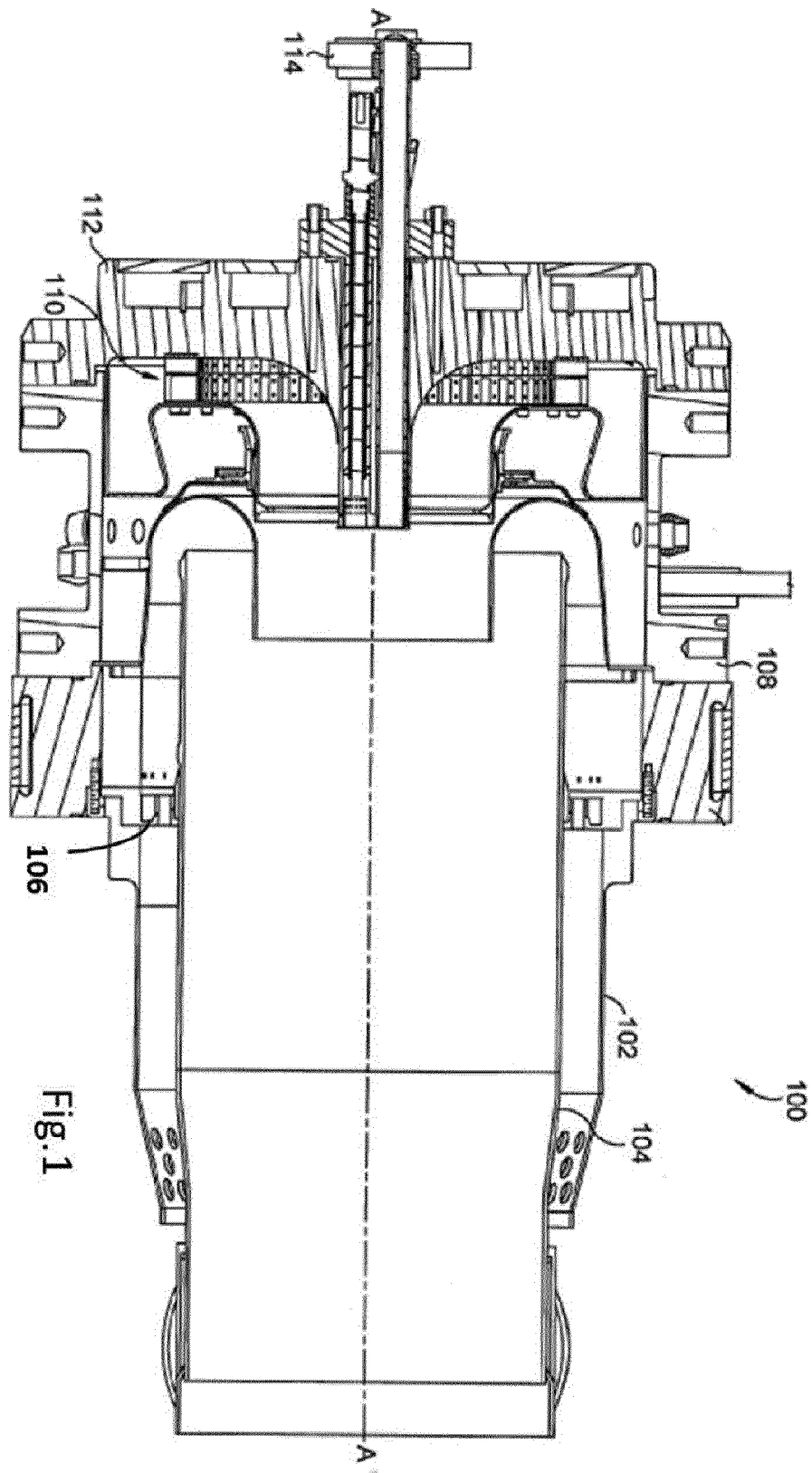


Fig. 1

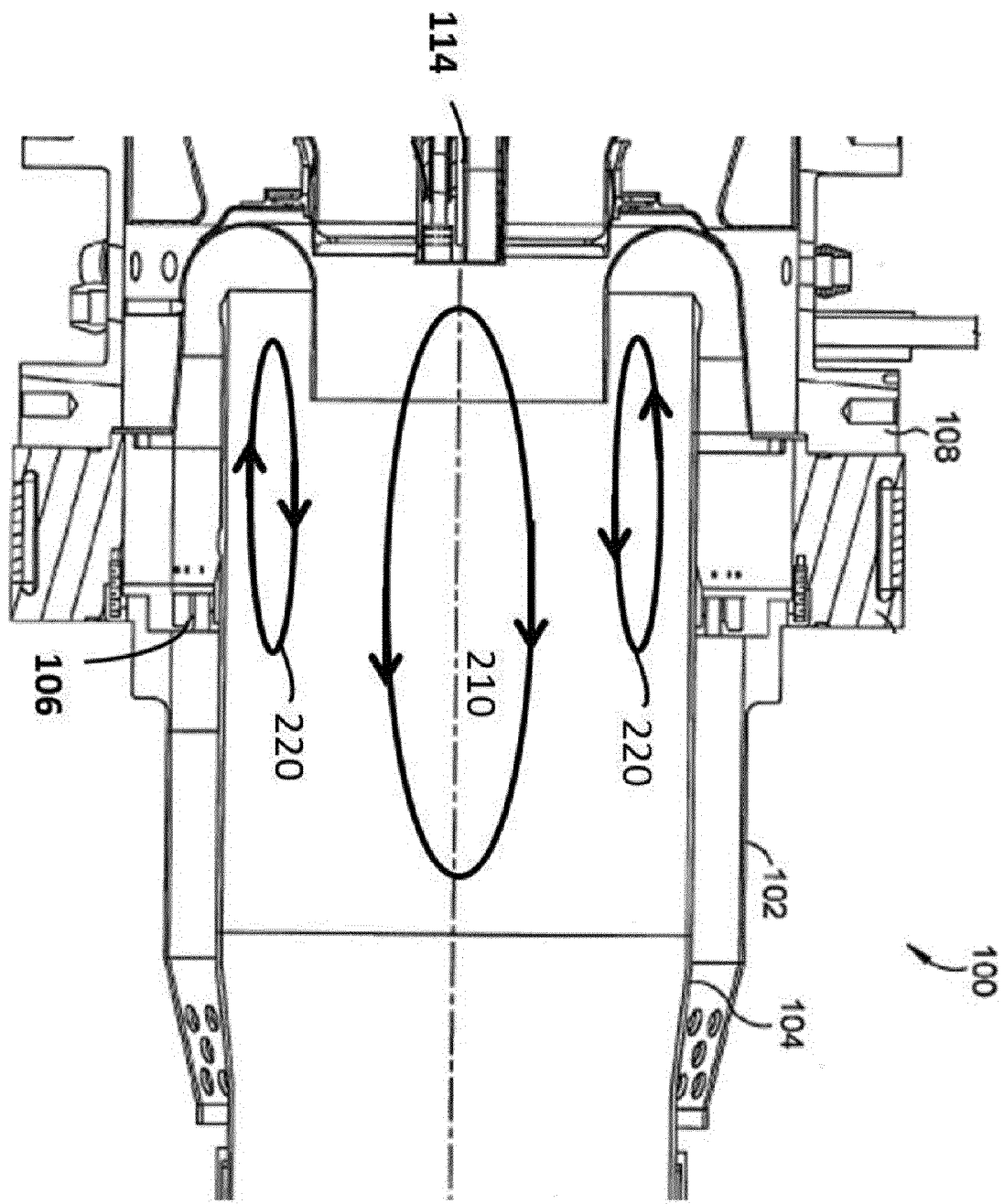


Fig. 2

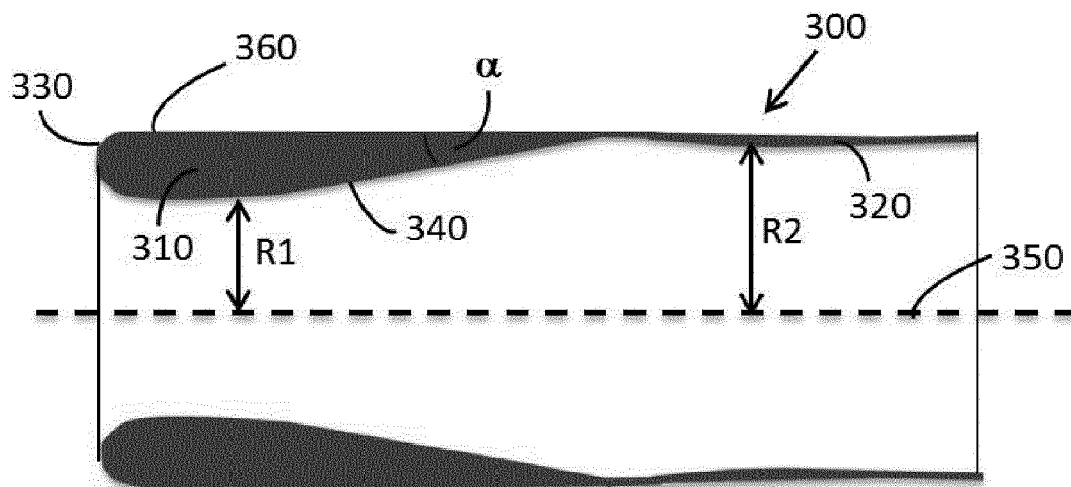


Fig. 3a

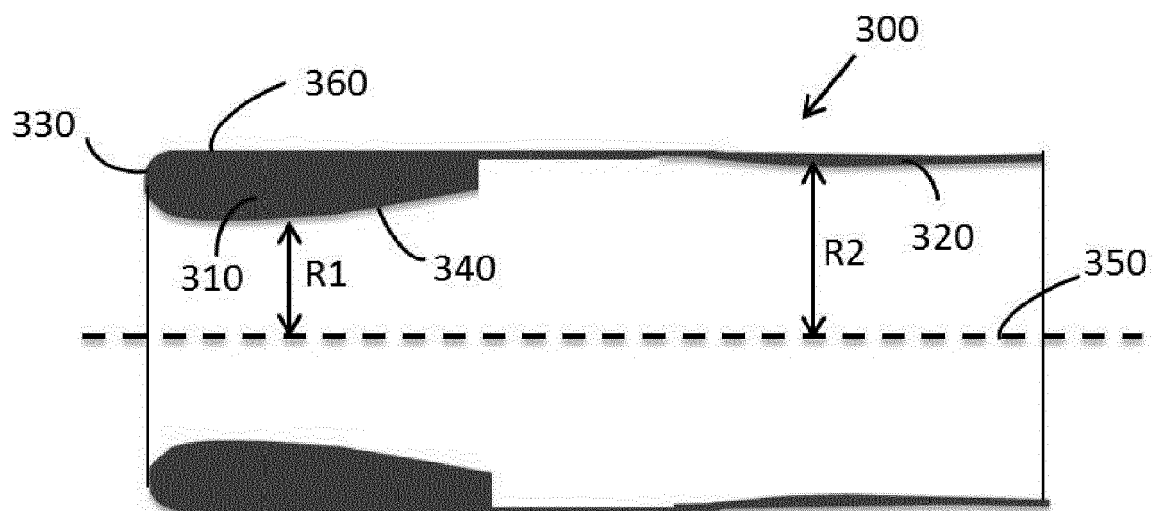
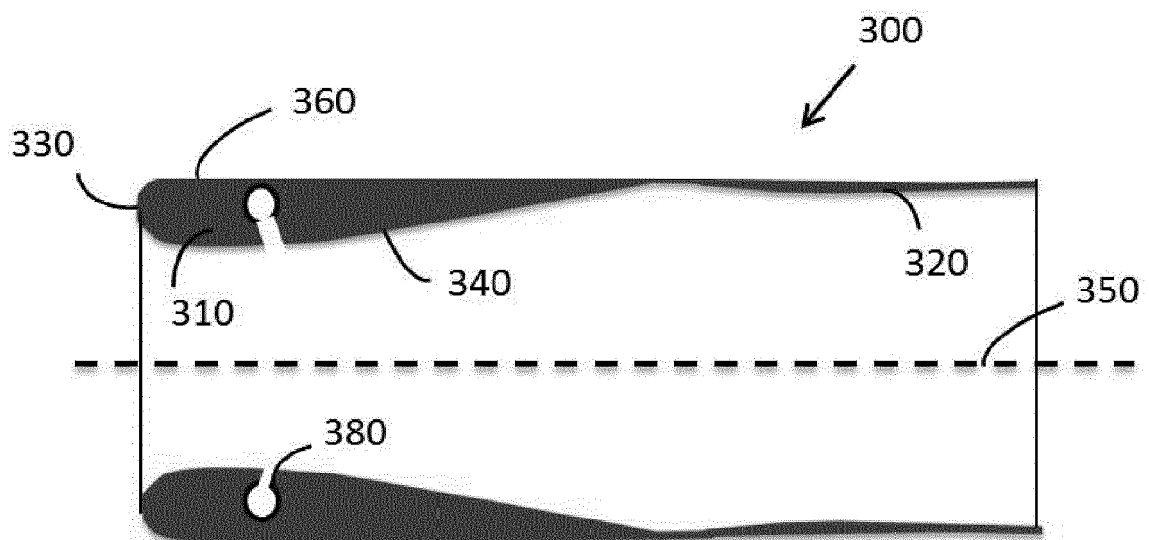
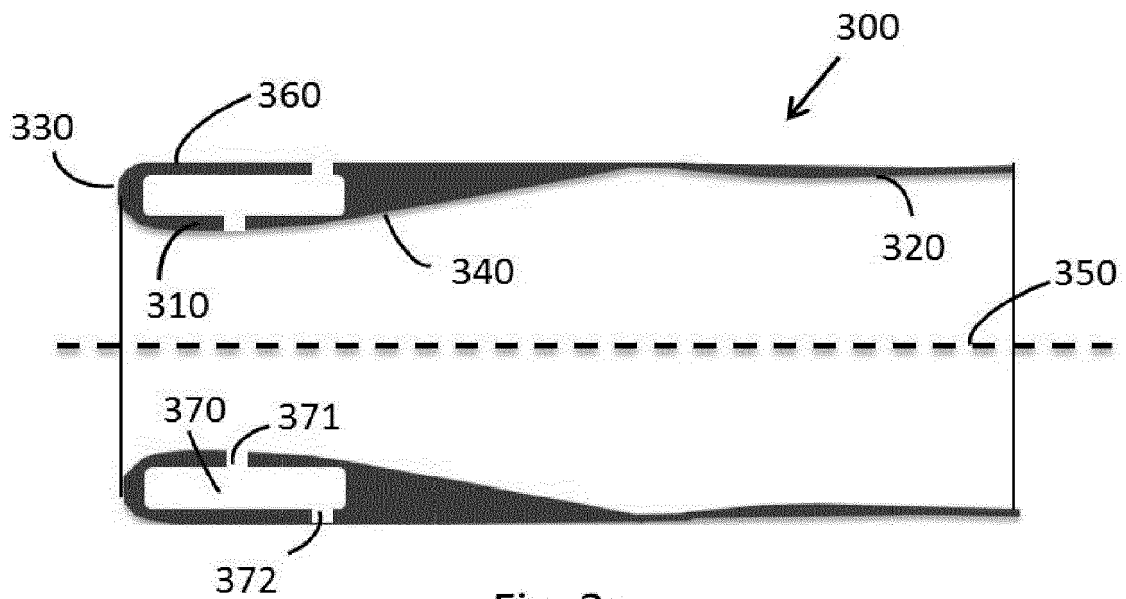


Fig. 3b



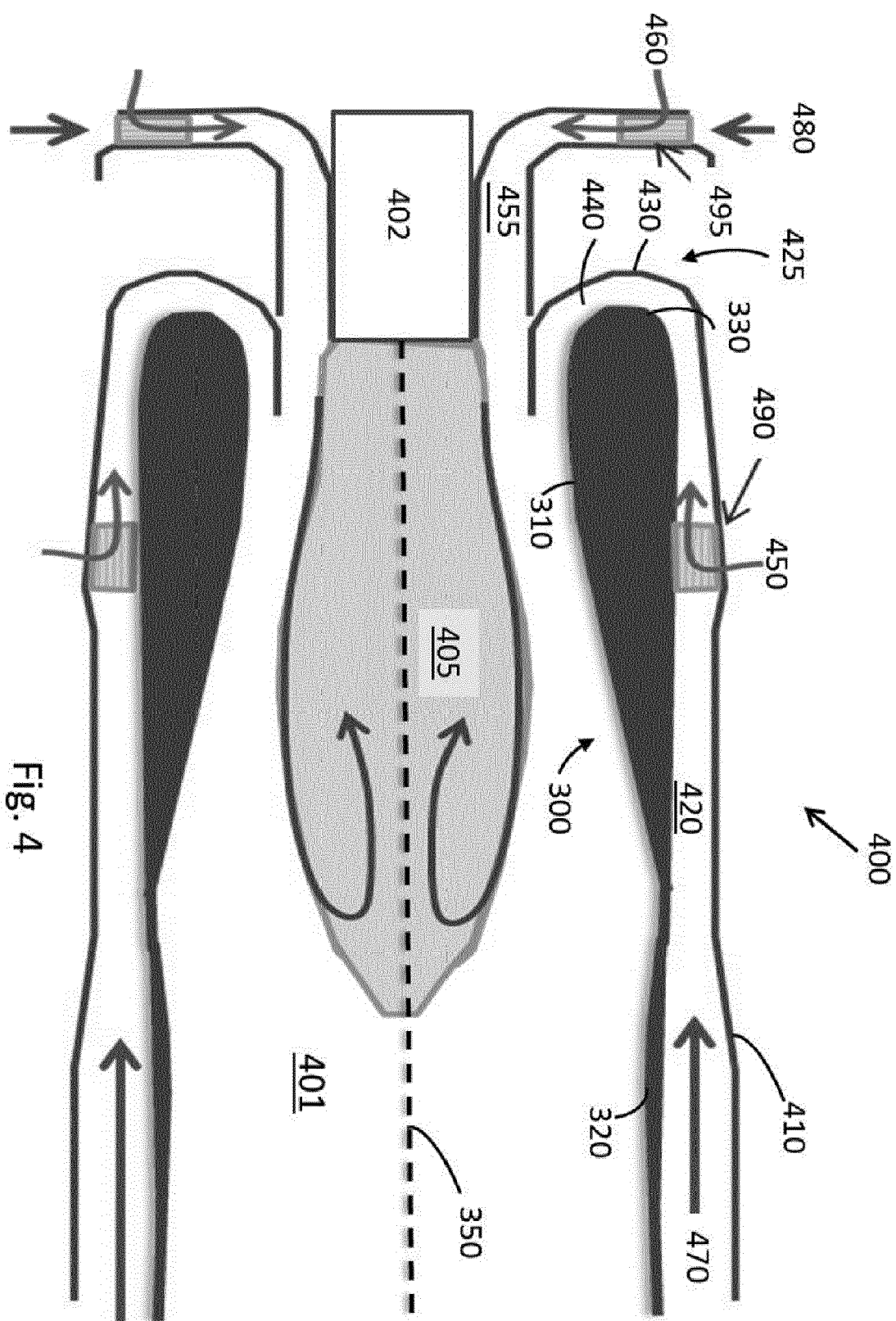


Fig. 4

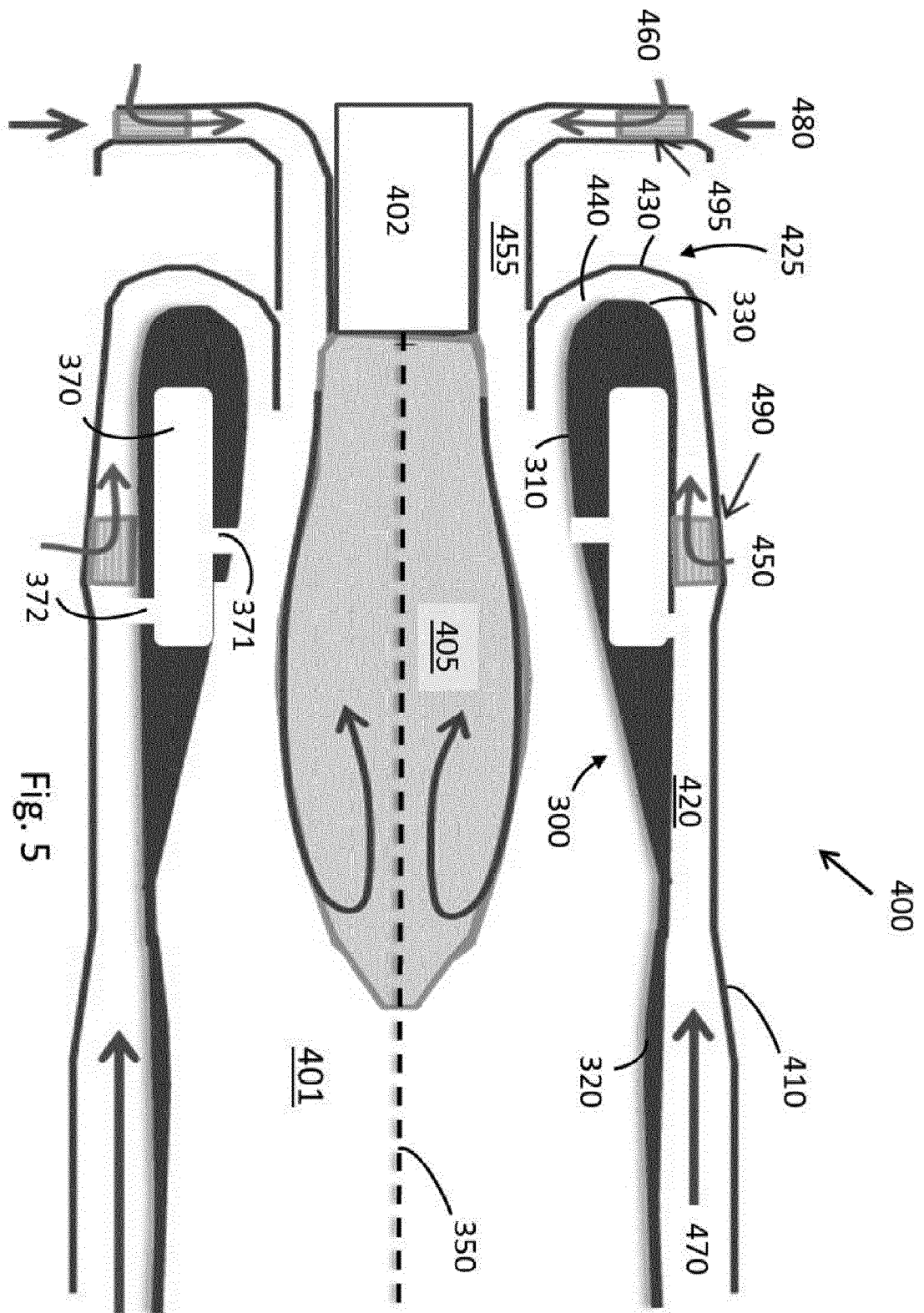


Fig. 5

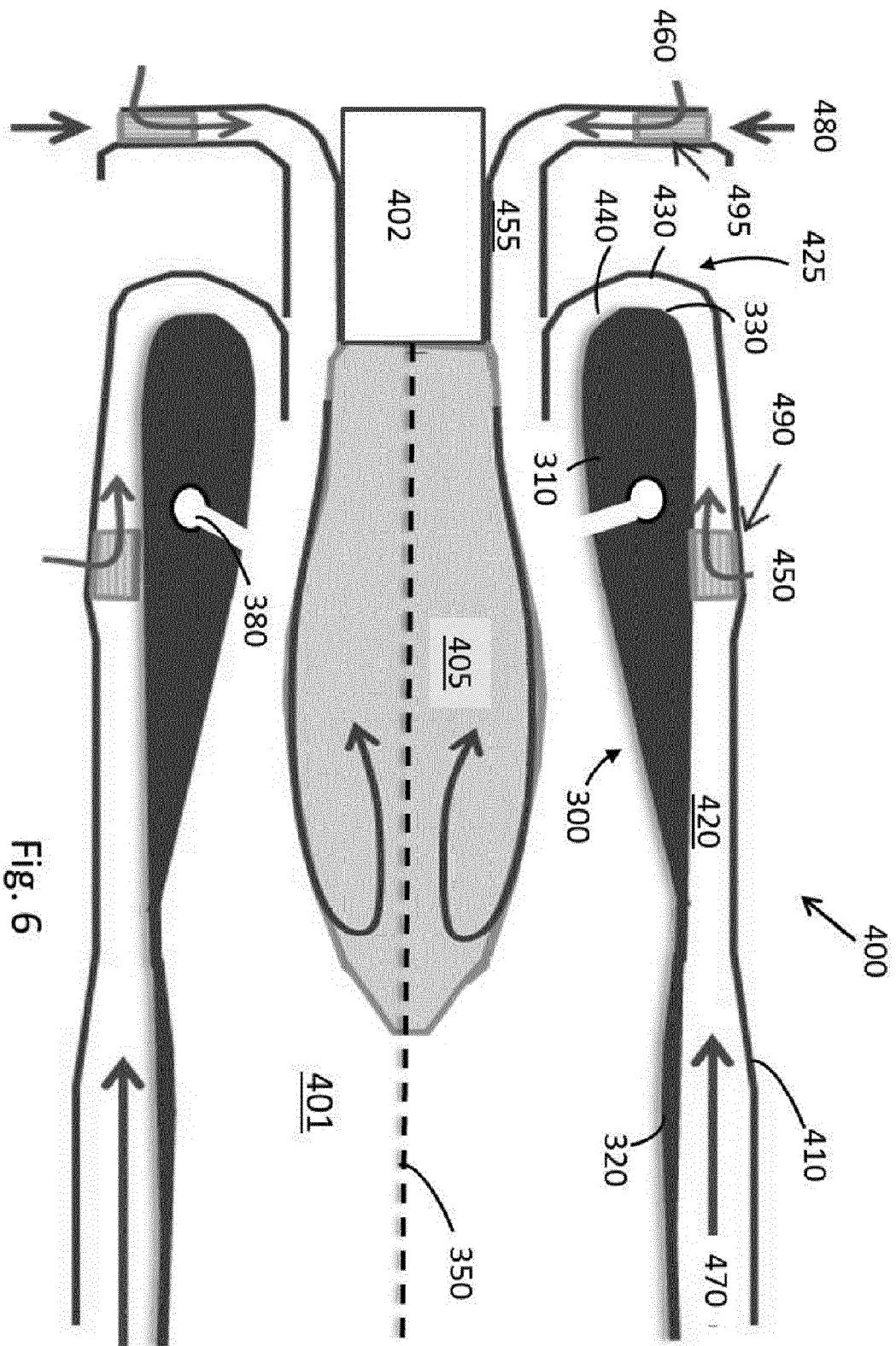


Fig. 6

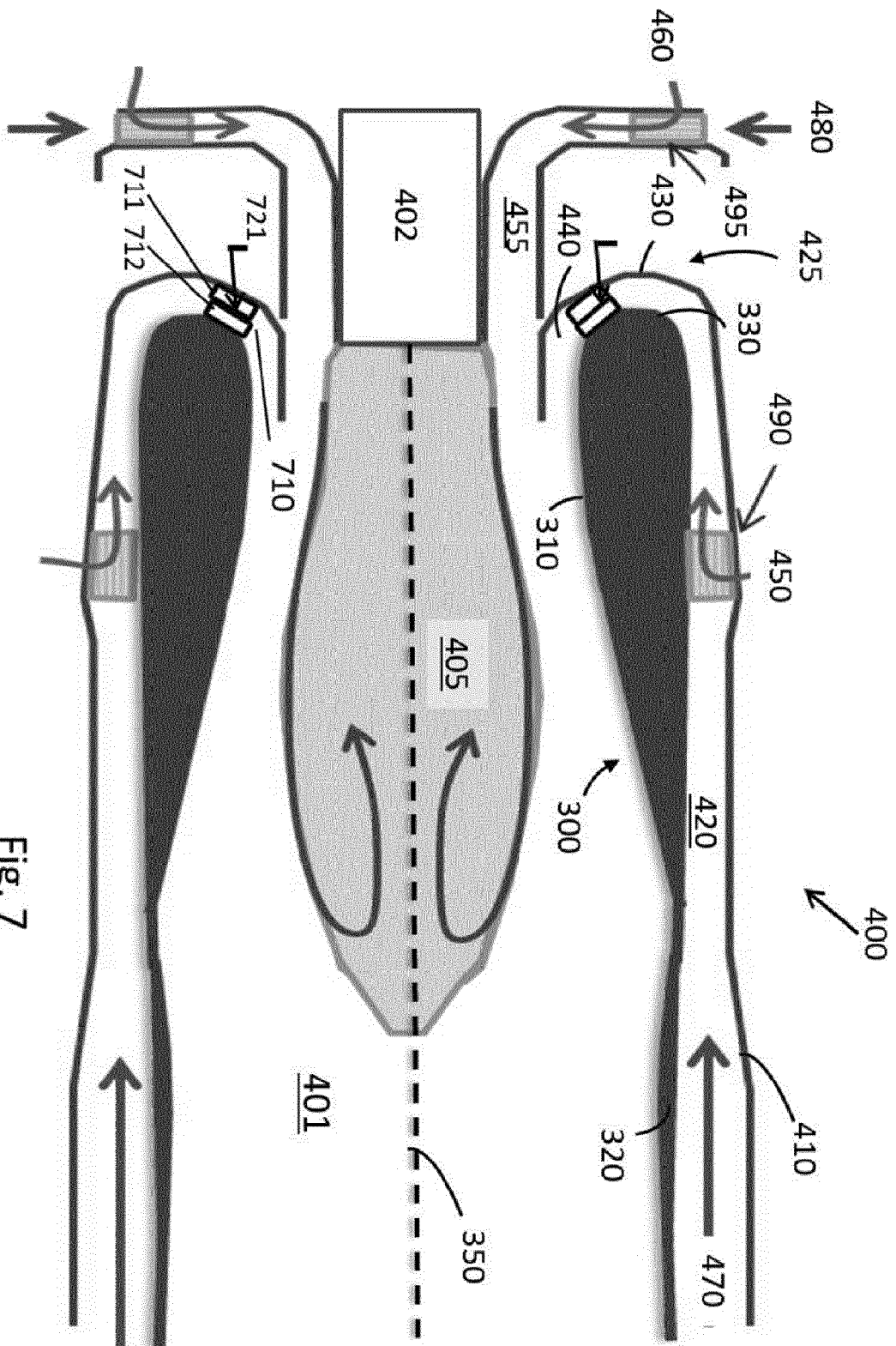


Fig. 7



EUROPEAN SEARCH REPORT

 Application Number
 EP 14 19 4791

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 3 751 911 A (DE TARTAGLIA P) 14 August 1973 (1973-08-14)	1,2,4-6, 10,14	INV. F23R3/44
Y	* Title; figure 1 * * column 1, line 3 - line 5 * * column 2, line 3 - line 37 *	11,13	F23R3/54
X	EP 2 657 608 A2 (GEN ELECTRIC [US]) 30 October 2013 (2013-10-30)	1-4,6,7, 10,14	
Y	* paragraph [0001]; figures 1-3 *	11,13	
A	* paragraph [0014] - paragraph [0016] * * paragraph [0019] - paragraph [0021] *	12,15	
X	EP 2 570 729 A2 (GEN ELECTRIC [US]) 20 March 2013 (2013-03-20)	1-4,6,9, 10,14	
Y	* paragraph [0001]; figures 1,2 *		
A	* paragraphs [0012], [0013], [0015] - [0020] *		
A	EP 2 362 147 A1 (ALSTOM TECHNOLOGY LTD [CH]) 31 August 2011 (2011-08-31)	8	TECHNICAL FIELDS SEARCHED (IPC)
A	* paragraphs [0001], [0020] - [0027] *		F23R
A	DE 10 60 667 B (STROEMUNGSMASCH ANST) 2 July 1959 (1959-07-02)	1-4,6,7, 10,14	
	* the whole document *		
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 April 2015	Examiner Hauck, Gunther
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 14 19 4791

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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ORM P0459

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3751911 A	14-08-1973	DE 2018641 B1	14-10-1971
		FR 2086180 A1	31-12-1971
		GB 1347697 A	27-02-1974
		JP S4946665 B1	11-12-1974
		SE 368258 B	24-06-1974
		US 3751911 A	14-08-1973

EP 2657608 A2	30-10-2013	CN 103375811 A	30-10-2013
		EP 2657608 A2	30-10-2013
		JP 2013231575 A	14-11-2013
		RU 2013108310 A	10-09-2014
		US 2013283802 A1	31-10-2013

EP 2570729 A2	20-03-2013	CN 102997281 A	27-03-2013
		EP 2570729 A2	20-03-2013
		US 2013061598 A1	14-03-2013

EP 2362147 A1	31-08-2011	EP 2362147 A1	31-08-2011
		JP 5683317 B2	11-03-2015
		JP 2011169582 A	01-09-2011
		US 2011203250 A1	25-08-2011

DE 1060667 B	02-07-1959	NONE	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20040211186 A1 [0004]