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(54) **HOT GAS PATH DUCT FOR A COMBUSTOR OF A GAS TURBINE**

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F23R 3/46	(2006.01)
F23R 3/34	(2006.01)
F01D 9/02	(2006.01)

(52) **U.S. Cl.**

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CPC F23R 3/346; F23R 3/34; F23R 3/286; F23R 3/26; F01D 9/023

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,872,664	A *	3/1975	Lohmann	F23R 3/14 431/9
4,265,615	A *	5/1981	Lohmann	F23R 3/346 431/158
4,420,929	A *	12/1983	Jorgensen	B60C 9/08 60/733
5,069,029	A *	12/1991	Kuroda	F23R 3/346 60/733
5,380,154	A	1/1995	Norton	
5,450,725	A	9/1995	Takahara	
5,475,979	A *	12/1995	Oag	F23C 6/047 60/737
5,802,854	A	9/1998	Maeda	

(Continued)

FOREIGN PATENT DOCUMENTS

EP	0526058 A1	3/1993
EP	0578461 A1	12/1994
EP	1884297 A1	2/2008

OTHER PUBLICATIONS

Co-Pending U.S. Appl. No. 13/845,365, dated Mar. 18, 2013.

(Continued)

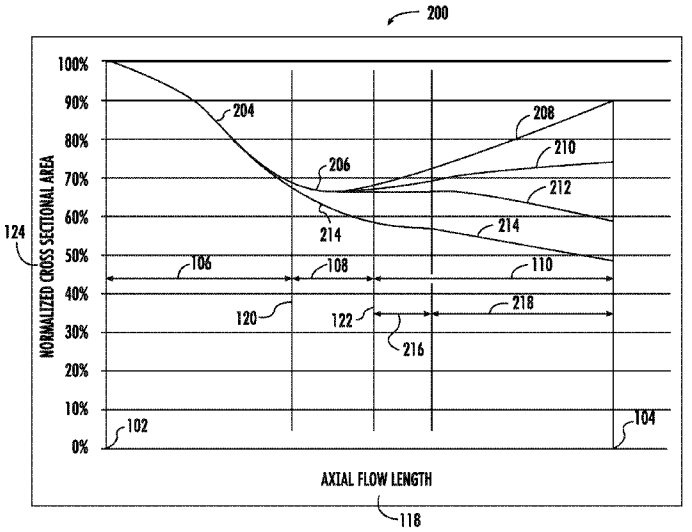
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(57) **ABSTRACT**

A hot gas path duct or unibody liner for a gas turbine includes a main body having a forward end and an aft end. The main body defines a cross-sectional flow area and an axial flow length that extends between the forward end and the aft end. The main body further defines a fuel injection portion disposed downstream from the forward end and upstream from the aft end. The cross-sectional flow area decreases along the axial flow length between the forward end and the fuel injection portion and increases along at least a portion of the axial flow length downstream from the fuel injection portion.

15 Claims, 7 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,047,550	A	4/2000	Beebe	
6,148,604	A *	11/2000	Salt	F01D 9/023 60/39.37
6,212,870	B1	4/2001	Thompson et al.	
6,374,594	B1	4/2002	Kraft et al.	
6,442,946	B1	9/2002	Kraft	
6,450,762	B1	9/2002	Munshi	
6,543,993	B2	4/2003	Burdgick et al.	
6,654,710	B1	11/2003	Keller	
6,875,009	B2	4/2005	Kayahara et al.	
6,896,509	B2	5/2005	Carroni et al.	
6,957,949	B2	10/2005	Hyde et al.	
7,082,766	B1	8/2006	Widener et al.	
7,743,612	B2	6/2010	Morenko	
8,096,131	B2	1/2012	Ziaei	
8,158,428	B1	4/2012	Krishna	
8,171,738	B2	5/2012	Fish et al.	
2002/0184893	A1	12/2002	Farmer	
2003/0039542	A1	2/2003	Cromer	
2005/0044855	A1	3/2005	Crawley	
2005/0241317	A1	11/2005	Martling	
2005/0268617	A1	12/2005	Amond	
2008/0282667	A1	11/2008	Intile	
2009/0071157	A1 *	3/2009	Cai	F23R 3/346 60/737
2009/0199561	A1 *	8/2009	Hessler	F23D 11/24 60/734
2010/0054928	A1	3/2010	Schiavo	
2010/0071377	A1	3/2010	Fox	
2010/0139283	A1	6/2010	Phillips et al.	
2010/0170216	A1	7/2010	Venkataraman	
2010/0174466	A1	7/2010	Davis, Jr. et al.	
2010/0263386	A1	10/2010	Edwards	
2011/0067402	A1	3/2011	Wiebe	
2011/0146284	A1	6/2011	Morimoto	
2011/0247314	A1	10/2011	Chila	
2011/0304104	A1	12/2011	McMahan	
2012/0186260	A1	7/2012	DiCintio et al.	
2012/0210729	A1	8/2012	Cihlar et al.	
2012/0304648	A1	12/2012	Byrne	
2014/0033728	A1 *	2/2014	Marmilic	F02C 7/141 60/772
2014/0260272	A1	9/2014	DiCintio	

OTHER PUBLICATIONS

Co-Pending U.S. Appl. No. 13/845,485, dated Mar. 18, 2013.
Co-Pending U.S. Appl. No. 13/845,565, dated Mar. 18, 2013.
Co-Pending U.S. Appl. No. 13/845,617, dated Mar. 18, 2013.
Co-Pending U.S. Appl. No. 13/845,661, dated Mar. 18, 2013.
Co-Pending U.S. Appl. No. 13/845,699, dated Mar. 18, 2013.
Co-Pending U.S. Appl. No. 13/845,384, dated Mar. 18, 2013.
Co-Pending U.S. Appl. No. 13/845,378, dated Mar. 18, 2013.

* cited by examiner

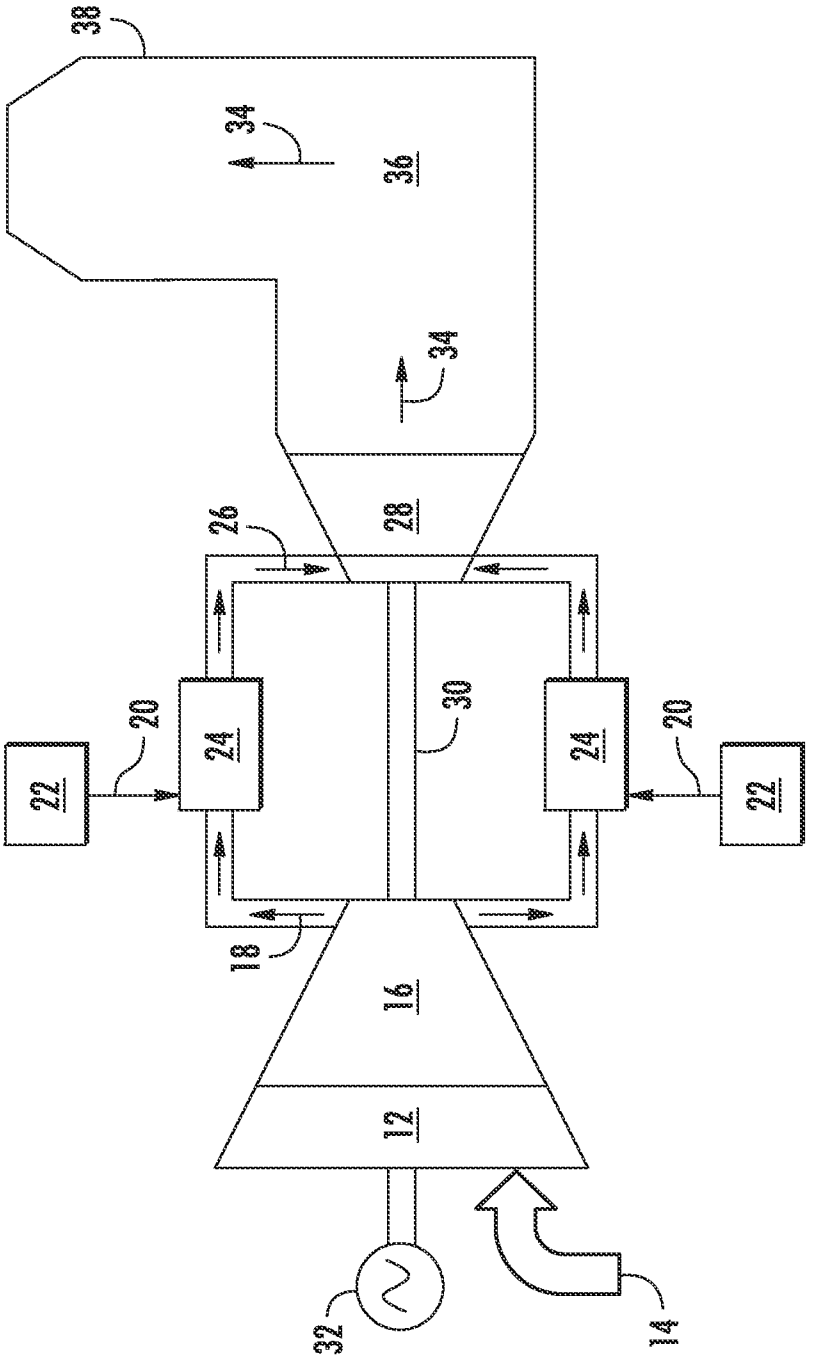


FIG. 1
PRIOR ART

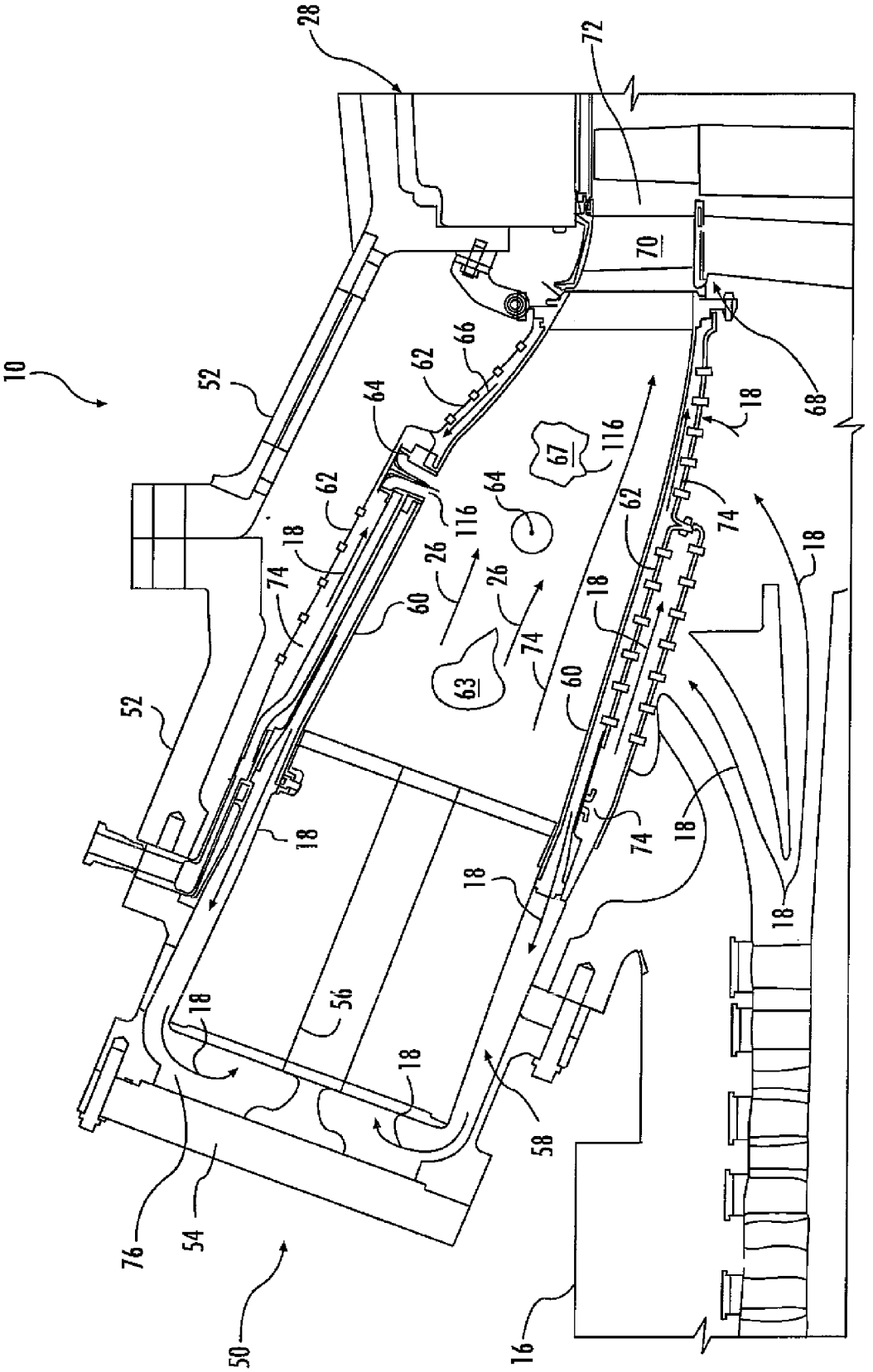


FIG. 2

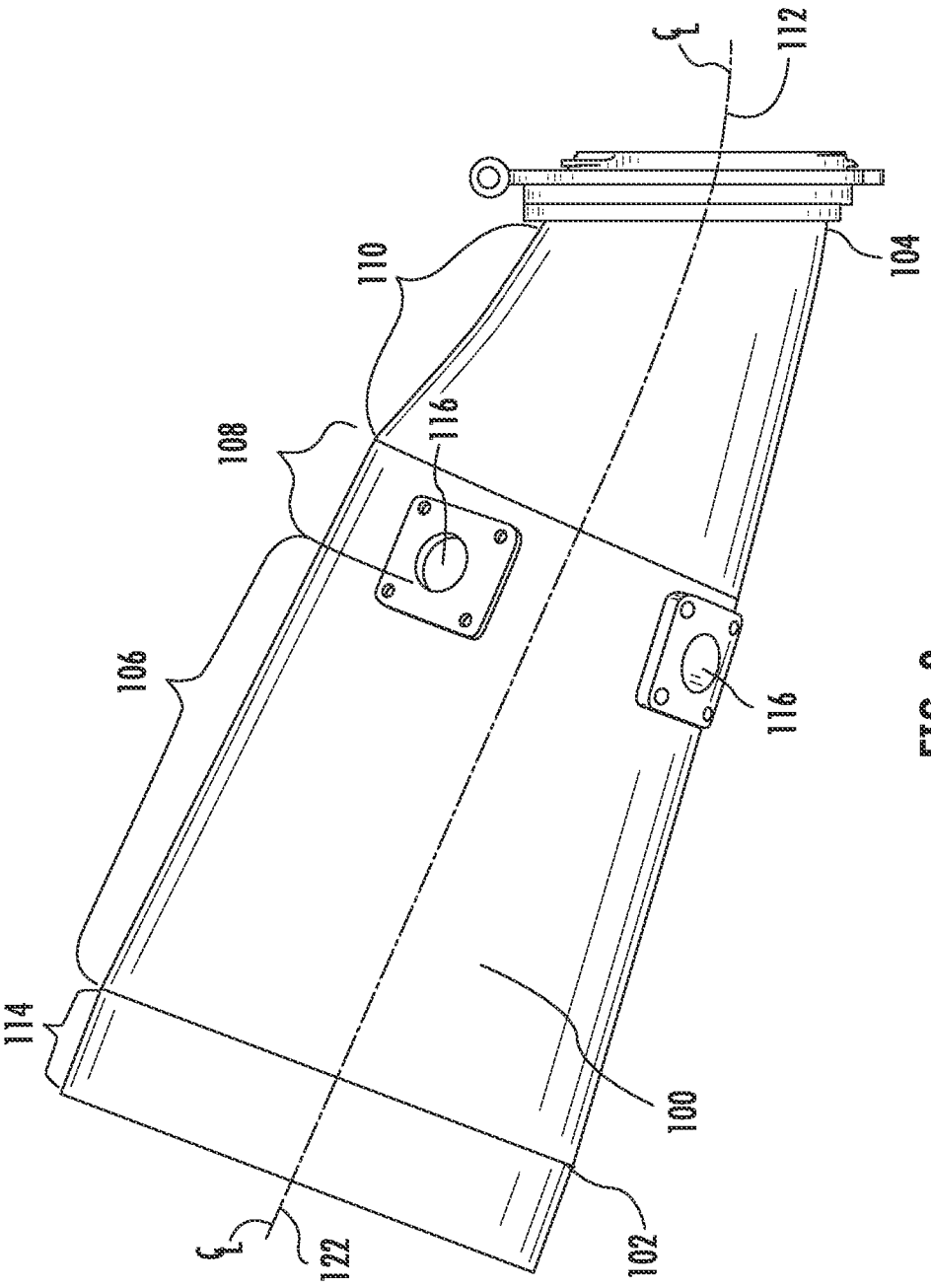


FIG. 3

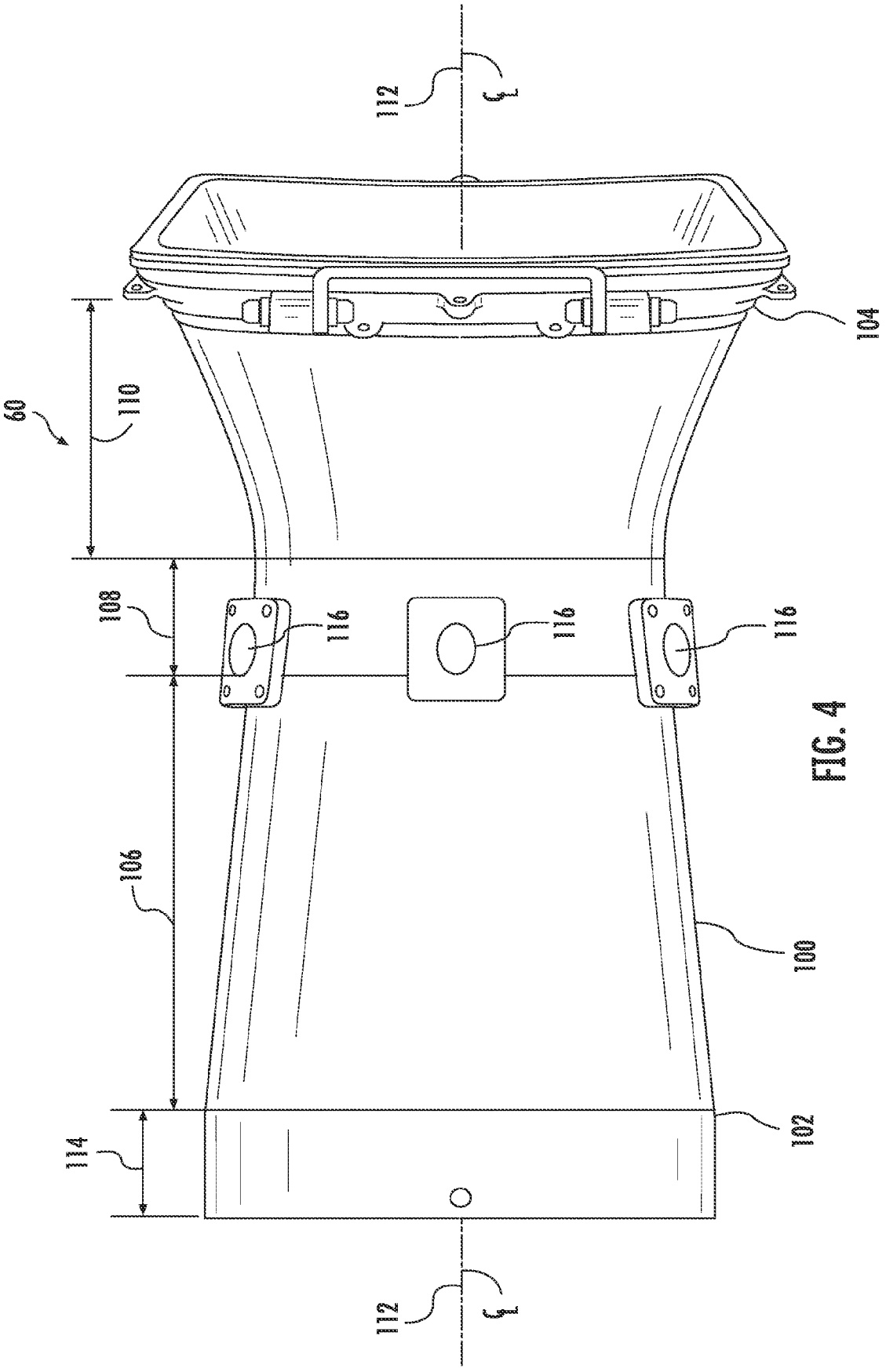


FIG. 4

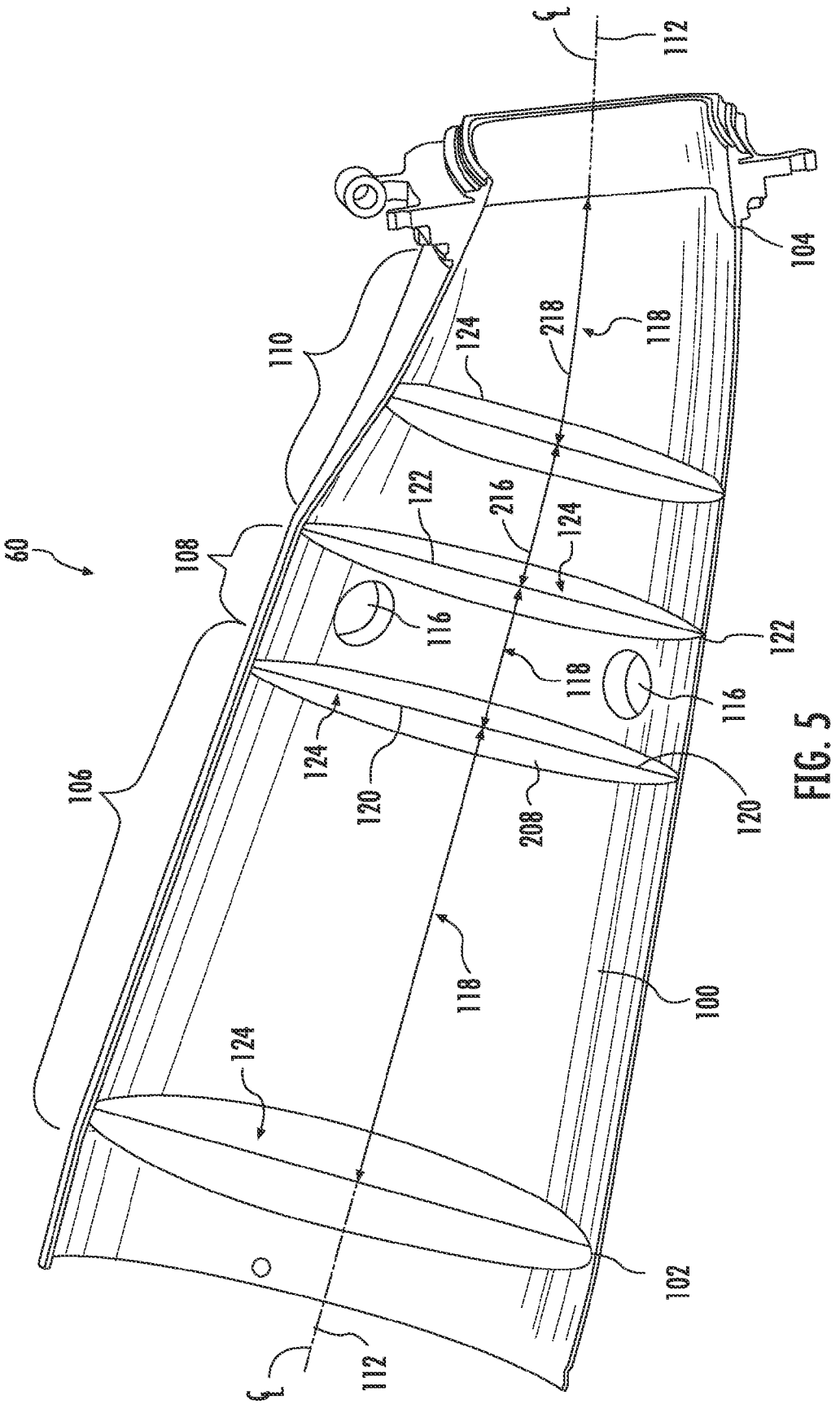


FIG. 5

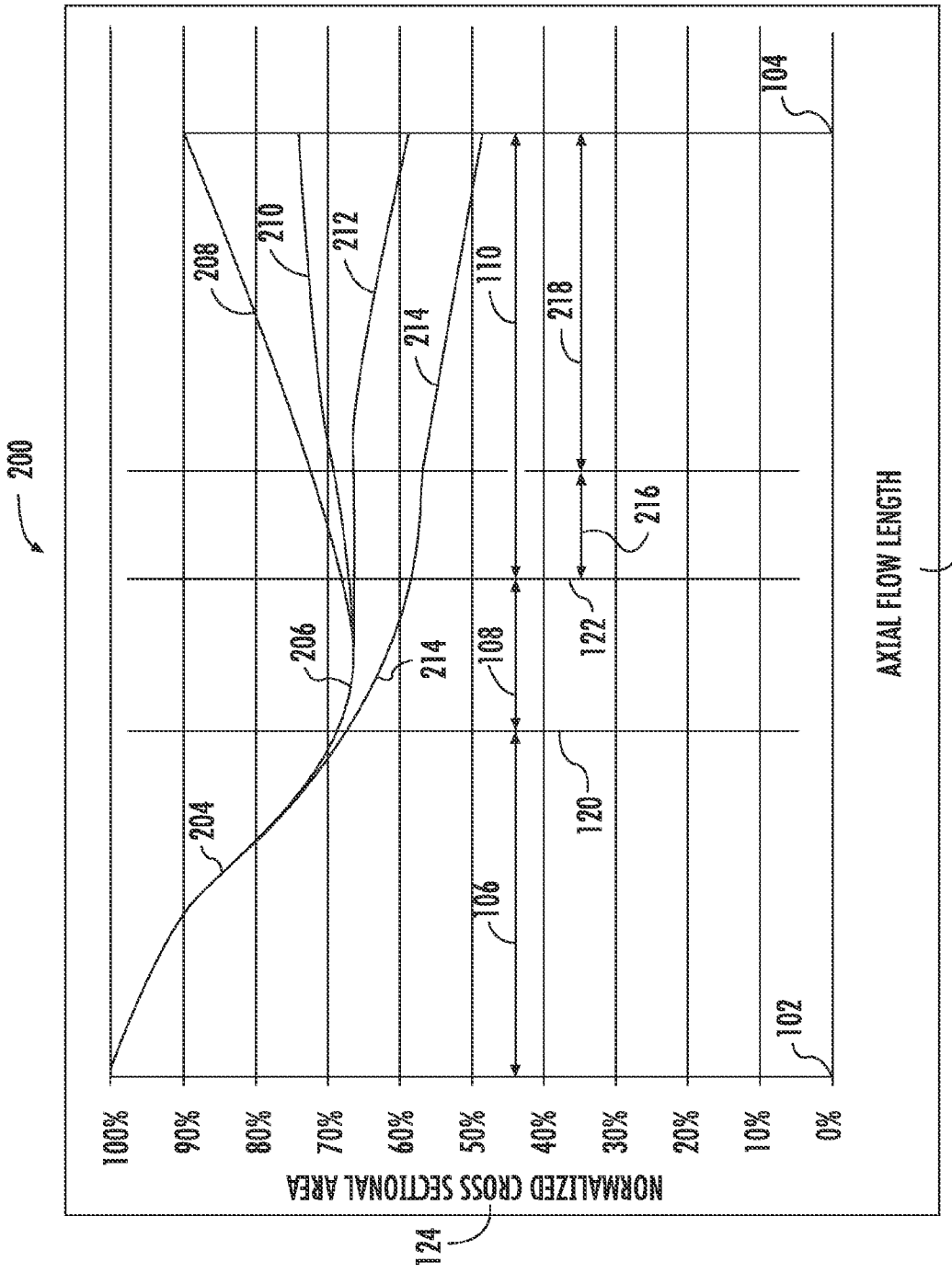

200
NORMALIZED CROSS SECTIONAL AREA
124
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
AXIAL FLOW LENGTH
118
102
104
204
206
208
210
212
214
106
108
110
120
122
216
218

FIG. 6

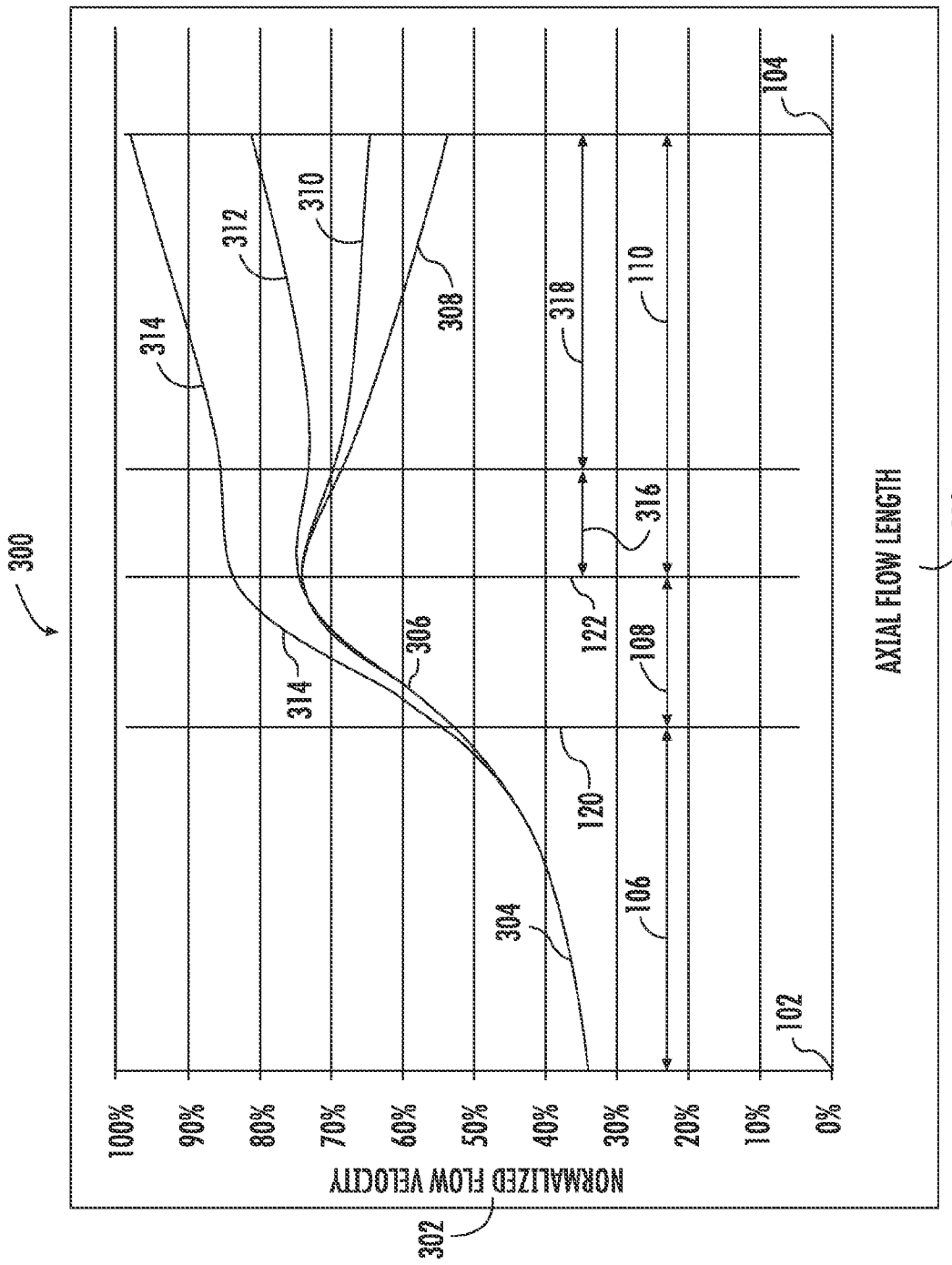

300
302
NORMALIZED FLOW VELOCITY
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
AXIAL FLOW LENGTH
118
102
104
106
108
110
120
122
304
306
308
310
312
314
314
316
318

FIG. 7

HOT GAS PATH DUCT FOR A COMBUSTOR OF A GAS TURBINE

FIELD OF THE INVENTION

The present invention generally involves a hot gas duct for a combustor of a gas turbine. More specifically, the invention relates to a unibody liner for the combustor.

BACKGROUND OF THE INVENTION

A combustion portion of a can annular gas turbine generally includes a plurality of combustors that are arranged in an annular array around a compressor discharge casing. Pressurized air flows from a compressor to the compressor discharge casing and is routed to each combustor. Fuel is mixed with the pressurized air in each combustor to form a combustible mixture within a primary combustion zone of the combustor. The combustible mixture is burned to produce hot combustion gases having a high pressure and high velocity. The combustion gases are routed towards an inlet of a turbine of the gas turbine through a hot gas path that is at least partially defined by one or more hot gas path ducts such as a combustion liner and/or a transition duct. Thermal and kinetic energy is transferred from the combustion gases to the turbine to cause the turbine to rotate, thereby producing mechanical work. For example, the turbine may be coupled to a shaft that drives a generator to produce electricity.

The hot combustion gases flowing through the ducts) subjects those components to high temperatures and thermal stresses. Hot spots or areas of high thermal stress have been shown to develop within certain areas of the duct due in part to separation of the combustion gases from an inner or hot side surface of the duct. There are certain respective cross sectional flow areas of a duct between a forward or inlet end and an aft or outlet end of the duct. Typically, the cross sectional flow area of the duct will converge or decrease continuously between the forward end and the aft end. Traditionally, this was done to prevent separation between the hot combustion gases and the inner surface of the duct, thereby reducing the thermal stresses within the duct.

Although this design is generally effective for reducing hot spots within a hot gas path duct of a combustor having a single combustion zone, it is less effective for a combustor that includes a secondary combustion zone that is downstream from the primary combustion zone such as a combustor that incorporates late lean fuel injection technology. In particular, a combustor that incorporates late lean fuel injection technology requires additional pressurized air to be injected in to the hot gas path downstream from the primary combustion zone to support combustion in the secondary combustion zone. Injection of the pressurized air results in increased mass flow within the duct at and downstream from the injection point which results in increased velocity of the combustion gases, thereby resulting in increased heat transfer coefficients on the inner or hot side of the duct. Therefore, an improved hot gas path duct or liner for routing the hot combustion gases from the combustor to the inlet of the turbine that incorporates late lean fuel injection would be useful.

BRIEF DESCRIPTION OF THE INVENTION

Aspects and advantages of the invention are set forth below in the following description, or may be obvious from the description, or may be learned through practice of the invention.

One embodiment of the present invention is a unibody liner for a gas turbine includes a main body having a forward end and an aft end. The main body defines a cross-sectional flow area and an axial flow length that extends between the forward end and the aft end. The main body further defines a fuel injection portion disposed downstream from the forward end and upstream from the aft end. The cross-sectional flow area decreases along the axial flow length between the forward end and the fuel injection portion and increases along at least a portion of the axial flow length downstream from the fuel injection portion.

Another embodiment of the present invention is a combustor for a gas turbine. The combustor generally includes an end cover coupled to an outer casing, a fuel nozzle that extends downstream from the end cover, a cap assembly that at least partially surrounds the fuel nozzle and a unibody liner that extends downstream from the cap assembly. The unibody liner includes a main body having a forward end and an aft end. The main body defines a cross-sectional flow area and an axial flow length that is defined between the forward end and the aft end. The main body further defines a fuel injection portion disposed downstream from the forward end and upstream from the aft end. The cross-sectional flow area decreases along the axial flow length between the forward end and the fuel injection portion and increases along at least a portion of the axial flow length downstream from the fuel injection portion.

The present invention may also include a gas turbine. The gas turbine generally includes a compressor, a combustor downstream from the compressor and a turbine having an inlet disposed downstream from the combustor. The combustor generally includes an end cover, a fuel nozzle that extends downstream from the end cover and a unibody liner that defines a flow path between the combustor and the inlet of the turbine. The unibody liner comprises a main body having an upstream end and a downstream end and defines a cross-sectional flow area. An axial flow length extends between the upstream end and the downstream end along an axial centerline of the unibody liner. A conical portion extends downstream from the forward end, a fuel injection portion extends downstream from the conical portion and a transitional portion extends downstream from the fuel injection portion. The cross-sectional flow area decreases along the axial flow length from the upstream end to the fuel injection portion and increases along at least a portion of the axial flow length downstream from the fuel injection portion.

Those of ordinary skill in the art will better appreciate the features and aspects of such embodiments, and others, upon review of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof to one skilled in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

FIG. **1** is a functional block diagram of an exemplary gas turbine within the scope of the present invention;

FIG. **2** is a cross-section side view of a portion of an exemplary gas turbine having an exemplary combustor according to various embodiments of the present invention;

FIG. **3** is a side view of an unibody liner as may incorporate at least one embodiment of the present disclosure;

FIG. **4** is a top view of the unibody liner as shown in FIG. **3**;

FIG. **5** is a cross-section perspective view of the unibody liner as shown in FIG. **3**, according to at least one embodiment of the present disclosure;

FIG. **6** is a normalized graphical illustration of cross-sectional flow area of the unibody liner with respect to axial flow length across a conical portion, a fuel injection portion and a transition portion of the unibody liner according to various embodiments of the present invention; and

FIG. **7** is a normalized graphical illustration of flow velocity through the unibody liner with respect to axial flow length as related to the cross-sectional flow area as shown in FIG. **6**, according to various embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention. 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. The terms "upstream" and "downstream" refer to the relative direction with respect to fluid flow in a fluid pathway. For example, "upstream" refers to the direction from which the fluid flows, and "downstream" refers to the direction to which the fluid flows. The term "radially" refers to the relative direction that is substantially perpendicular to an axial centerline of a particular component, and the term "axially" refers to the relative direction that is substantially parallel to an axial centerline of a particular component.

Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that modifications and variations can be made in the present invention without departing from the scope or spirit thereof. For instance, features illustrated or described as part of one embodiment may be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents. Although exemplary embodiments of the present invention will be described generally in the context of a combustor incorporated into a gas turbine for purposes of illustration, one of ordinary skill in the art will readily appreciate that embodiments of the present invention may be applied to any combustor incorporated into any turbomachine and is not limited to a gas turbine combustor unless specifically recited in the claims.

Referring now to the drawings, wherein identical numerals indicate the same elements throughout the figures, FIG. **1** provides a functional block diagram of an exemplary gas turbine **10** that may incorporate various embodiments of the present invention. As shown, the gas turbine **10** generally includes an inlet section **12** that may include a series of filters, cooling coils, moisture separators, and/or other devices to purify and otherwise condition a working fluid (e.g., air) **14** entering the gas turbine **10**. The working fluid **14** flows to a compressor section where a compressor **16** progressively imparts kinetic energy to the working fluid **14** to produce a compressed working fluid **18** at a highly energized state.

The compressed working fluid **18** is mixed with a fuel **20** from a fuel supply **22** to form a combustible mixture within one or more combustors **24**. The combustible mixture is burned to produce combustion gases **26** having a high temperature and pressure. The combustion gases **26** flow through a turbine **28** of a turbine section to produce work. For example, the turbine **28** may be connected to a shaft **30** so that rotation of the turbine **28** drives the compressor **16** to produce the compressed working fluid **18**. Alternately or in addition, the shaft **30** may connect the turbine **28** to a generator **32** for producing electricity. Exhaust gases **34** from the turbine **28** flow through an exhaust section **36** that connects the turbine **28** to an exhaust stack **38** downstream from the turbine **28**. The exhaust section **36** may include, for example, a heat recovery steam generator (not shown) for cleaning and extracting additional heat from the exhaust gases **34** prior to release to the environment.

FIG. **2** provides a cross sectional side view of a portion of an exemplary gas turbine **10** including an exemplary combustor **50** that may encompass various embodiments of the present disclosure. As shown, the combustor **50** is at least partially surrounded by an outer casing **52** such as a compressor discharge casing and/or a turbine casing. The outer casing **52** is in fluid communication with the compressor **16**. An end cover **54** is coupled to the casing **52** at one end of the combustor **50**. The combustor **50** generally includes at least one axially extending fuel nozzle **56** that extends downstream from the end cover **54** and an annular cap assembly **58** that extends radially and axially within the outer casing **52** downstream from the end cover **54**.

In particular embodiments, a hot gas path duct or unibody liner **60**, herein referred to as the "unibody **60**", extends downstream from the cap assembly **58**. One or more annular sleeves **62** that at least partially surround at least a portion of the unibody **60**. In particular embodiments, the combustor further includes one or more radially extending fuel injectors **64** that extend through the unibody **60** downstream from the at least one axially extending fuel nozzle **56**. In particular embodiments, the axially extending fuel nozzles **56** extend at least partially through the cap assembly **58** to provide a combustible mixture of the fuel **20** (FIG. **1**) and the compressed working fluid **18** to a primary combustion zone **63** that is downstream from the fuel nozzle **56**.

In particular embodiments, the one or more annular sleeves **62** may define one or more fluid flow passage(s) **66** for routing the compressed working fluid **18** across an outer surface of the unibody **60**. In addition, the sleeve(s) **62** may route at least a portion of the compressed working fluid **18** to the one or more radially extending fuel injectors **64** to combine with fuel for combustion in a secondary combustion zone **67** that is downstream from the primary combustion zone **72**. The unibody **60** generally terminates at a point that is adjacent to a first stage **68** of stationary nozzles **70**. The first stage **68** of the stationary nozzles **70** at least partially defines an inlet **72** to the turbine **28**. The unibody **60** at least partially defines a hot gas path **74** for routing the combustion gases **26** from the primary combustion zone **63** and the secondary combustion zone **67** to the inlet **72** of the turbine **28** during operation of the gas turbine **10**.

In operation, the compressed working fluid **18** flows from the compressor **16** and is routed through the fluid flow passage(s) **66**. A portion of the compressed working fluid **18** is routed to a head end **76** of the combustor **50** where it reverses direction and is directed through the axially extending fuel nozzle(s) **56**. The compressed working fluid **18** is mixed with fuel to form a first combustible mixture that is injected into the primary combustion zone **63**. The first combustible mixture is burned to produce the combustion gases **26**. A second portion of the compressed working fluid **18** may be routed through the radially extending fuel injectors **64** where it is

mixed with fuel to form a second combustible mixture. The second combustible mixture is injected through the unibody **60** and into the hot gas path **74**. The second combustible mixture at least partially mixes with the combustion gases **26** and is burned in the secondary combustion zone **67**. In the alternative, the compressed working fluid **18** may be fed into the hot gas path **74** through the liner **60** without adding additional fuel.

FIG. **3** provides a side view of the unibody **60** as shown in FIG. **2**, according to at least one embodiment of the present disclosure. FIG. **4** provides a top view of the unibody liner as shown in FIG. **3**. As shown in FIGS. **3** and **4**, the unibody **60** generally includes a main body **100** having a generally annular shape. The main body **100** includes a forward end **102**, an aft end **104**, a generally conical portion **106**, a fuel injection portion **108** and a transition portion **110**. The conical portion **106** extends between the forward end **102** and the fuel injection portion **108**, and the transition portion **110** extends downstream from the fuel injection portion **108** and terminates generally adjacent to the aft end **104**. The fuel injection portion **108** generally extends across the secondary combustion zone **67** (FIG. **2**). The unibody **60** may be generally cast as a singular component or may be formed from individual components which are connected so as to form a continuous hot gas path.

The conical portion **106** generally has a substantially circular cross section with respect to a plane that is perpendicular to an axial centerline **112** of the main body **100**. The fuel injection portion **108** may have a substantially circular cross section and/or a substantially non-circular cross section with respect to a plane that is perpendicular to the axial centerline **112**. As shown in FIG. **4**, the transition portion **110** may have a substantially non-circular cross section with respect to a plane that is perpendicular to the axial centerline **114**. In alternate embodiments, as shown in FIGS. **3** and **4**, the main body **100** may further include a support portion **114** that extends upstream from the forward end **102**.

In particular embodiments, the main body **100** at least partially defines one or more fuel injector openings **116** disposed downstream from the forward end **102** and upstream from the aft end **104**. The fuel injector openings **116** are disposed within the fuel injection portion **108** of the main body **100**. The fuel injector openings **116** provide for fluid communication through the main body **100** and into the hot gas path **74** (FIG. **2**). In particular embodiments, as shown in FIG. **2**, each of the fuel injectors **64** extends at least partially through a corresponding fuel injector opening **116**.

FIG. **5** provides a cross section perspective view of the unibody **60** as shown in FIG. **3**, according to at least one embodiment of the present disclosure. As shown in FIG. **5**, an axial flow length **118** is defined along the axial centerline **112**. The axial flow length **118** extends through the main body **100** between the forward end **102** and the aft end **104**. In particular embodiments, the fuel injection openings **116** generally define an intersection point **120** along the axial flow length **118** where the conical portion **106** and the fuel injection portion **108** intersect. The intersection point **120** may be defined adjacent to or upstream from the fuel injection openings **116**. Another intersection point **122** is generally defined along the axial flow length **118** where the fuel injection portion **108** and the transition portion **110** intersect. This intersection point **122** is generally defined at a position along the axial flow length **118** where the main body **100** transitions from a substantially circular cross section to a substantially non-circular cross section downstream from the fuel injector openings **116**.

The intersection points **120** and **122** are generally defined within a plane that is substantially perpendicular to the axial centerline **112**. The intersection points **120** and **122** may shift upstream or downstream from the shown positions shown in FIGS. **3**, **4** and **5** depending on such factors as the diameter of the unibody **60**, a desired or required mass flow rate through the unibody **60**, operating temperatures within the unibody **60**, thermal profile of the unibody **60** and/or positioning of the fuel injector openings **116**.

As shown in FIG. **5**, the main body **100** defines a cross-sectional flow area **124**. The cross sectional flow area **124** is generally defined with respect to a plane that extends perpendicular to the axial centerline **112**. The cross-sectional flow area **124** may increase, decrease, or remain constant along any portion of the axial flow length **118**. The size of the cross-sectional flow area **124** of the unibody **60** generally affects a flow velocity of the combustion gases **26** flowing through the unibody liner **60** and/or the hot gas path **74**.

FIG. **6** provides a normalized graphical illustration **200** of cross-sectional flow area **124** with respect to axial flow length **118** across the conical portion **106**, the fuel injection portion **108** and the transition portion **110** of the unibody **60**. As illustrated by line **204**, the cross-sectional flow area **124** generally decreases along the axial flow length **118** from a maximum cross-sectional flow area **124** at the forward end **102** to a smaller cross-sectional flow area **124** at the intersection point **120** between the conical portion **106** and the fuel injection portion **108** of the main body **100**. It should be appreciated that line **204** also illustrates a cross-sectional area of a traditional liner (not shown).

In particular embodiments, as illustrated by line **206**, the cross-sectional flow area **124** may increase, remain constant and/or may decrease along the axial flow length **118** across the fuel injection portion **108**. In particular embodiments, as illustrated by lines **208**, **210** and **212**, the cross-sectional flow area **124** increases along at least a portion of the axial flow length **118** that is defined downstream from the intersection point **122**. In contrast, as illustrated by line **214**, the cross-sectional flow area of the traditional liner continues to decrease through the fuel injection portion **108** and the transition portion **110**.

In one embodiment, as illustrated by line **208**, the cross-sectional flow area **124** increases continuously downstream from the intersection point **122** between the fuel injection portion and the aft end **104**. In another embodiment, the cross-sectional flow area **124** increases continuously along a first portion **216** of the axial flow length **118** that is defined downstream from the intersection point **122** at a first rate of increase, and then increases at a second rate of increase along a second portion **218** of the axial flow length that is defined downstream from the first portion. In another embodiment, the cross-sectional flow area **124** increases continuously along the first portion **216** of the axial flow length **118** that is defined downstream from the intersection point **122** and then decreases along the second portion **218** of the axial flow length **118** that is defined downstream from the first portion **216**.

FIG. **7** provides a normalized graphical illustration **300** of flow velocity **302** of the combustion gases **26** (FIG. **2**) through the unibody **60** including the traditional transition liner or duct with respect to axial flow length **118** through the conical portion **106**, the fuel injection portion **108** and the transition portion **110** of the unibody **60** and traditional liner or duct. As shown in FIGS. **6** and **7**, line **304** correlates to line **204**, line **306** correlates to line **206**, line **308** correlates to line **208**, line **310** correlates to line **210**, line **312** correlates to line **212** (FIG. **6**), line **314** correlates to line **214** (FIG. **6**), line **316** correlates

to line **216** (FIG. **6**) and line **318** correlates to line **218** (FIG. **6**), line **308** correlates to line **208** (FIG. **6**).

As shown in FIGS. **6** and **7**, and illustrated in lines **204** and **304**, the flow velocity of the combustion gases **26** (FIG. **2**) increase as the cross-sectional flow area **124** decreases along the axial flow length **118** through the conical portion **106**. As illustrated by lines **206**, **214** and **306** and **314**, the flow velocity will increase at a much higher rate along the axial flow length **118** within the fuel injection portion **108** due to additional mass flow of the second combustible mixture and/or the compressed air through the unibody **60** and into the hot gas path **74**.

The increased flow velocity generally results in increased heat transfer coefficients at the transition portion which results in hot spots or areas of high thermal stress on an inner surface of the unibody **60** and/or the traditional liner or duct. In the various embodiments of the present invention, as shown in FIG. **6** by lines **208**, **210**, **212**, an increase in the cross-sectional flow area **124** at or downstream from the fuel injection portion **108** will result in a decrease in the flow velocity **302** of the combustion gases **26** (FIG. **2**) as shown in FIG. **7** by lines **310**, **312** and **314**. By maintaining or reducing the flow velocity **302** through the unibody **60** at or downstream from the fuel injection portion **108**, heat transfer coefficients are significantly reduced, thereby improving the durability and overall performance of the combustor.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention 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 include 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 language of the claims.

What is claimed is:

1. A unibody liner, comprising:

a. a main body having a forward end and an aft end, the main body defining a cross-sectional flow area and an axial flow length that is defined between the forward end and the aft end, the main body further defining a fuel injection portion disposed downstream from the forward end and upstream from the aft end; and

b. wherein the cross-sectional flow area decreases along the axial flow length between the forward end and the fuel injection portion and increases along at least a portion of the axial flow length downstream from the fuel injection portion and wherein the cross-sectional flow area increases continuously along the axial flow length downstream from the fuel injection portion to the aft end.

2. The unibody liner as in claim **1**, wherein the cross-sectional flow area increases along a first portion of the axial flow length that is defined downstream from the fuel injection portion and decreases along a second portion of the axial flow length that is defined downstream from the first portion.

3. The unibody liner as in claim **1**, wherein the cross-sectional flow area is substantially constant along the axial flow length across the fuel injection portion.

4. The unibody liner as in claim **1**, wherein the cross-sectional flow area decreases in a downstream direction along the axial flow length across the fuel injection portion.

5. The unibody liner as in claim **1**, wherein the cross-sectional flow area increases in a downstream direction along the axial flow length across the fuel injection portion.

6. The unibody liner as in claim **1**, further comprising a conical portion that extends between the forward end and the fuel injection portion and a transitional portion that extends downstream from the fuel injection portion and terminates at the aft end.

7. A combustor for a gas turbine, comprising:

a. an end cover coupled to an outer casing;

b. a fuel nozzle that extends downstream from the end cover;

c. a cap assembly that at least partially surrounds the fuel nozzle; and

d. a unibody liner that extends downstream from the cap assembly, the unibody liner comprising:

i. a main body having a forward end and an aft end, the main body defining a cross-sectional flow area and an axial flow length that is defined between the forward end and the aft end, the main body further defining a fuel injection portion disposed downstream from the forward end and upstream from the aft end; and

ii. wherein the cross-sectional flow area decreases along the axial flow length between the forward end and the fuel injection portion and increases along at least a portion of the axial flow length downstream from the fuel injection portion and wherein the cross-sectional flow area increases continuously along the axial flow length downstream from the fuel injection portion to the aft end.

8. The combustor as in claim **7**, wherein the cross-sectional flow area is substantially constant along the axial flow length across the fuel injection portion.

9. The combustor as in claim **7**, wherein the cross-sectional flow area decreases in a downstream direction along the axial flow length across the fuel injection portion.

10. The combustor as in claim **7**, wherein the cross-sectional flow area increases in a downstream direction along the axial flow length across the fuel injection portion.

11. The combustor as in claim **7**, wherein the unibody liner further comprises a conical portion that extends between the forward end and the fuel injection portion and a transitional portion that extends downstream from the fuel injection portion and terminates at the aft end.

12. A gas turbine comprising:

a. a compressor;

b. a combustor downstream from the compressor;

c. a turbine having an inlet disposed downstream from the combustor; and

d. wherein the combustor includes an end cover, a fuel nozzle that extends downstream from the end cover and a unibody liner that defines a flow path between the combustor and the inlet of the turbine, the unibody liner comprising:

i. a main body having an upstream end and a downstream end, the main body defining a cross-sectional flow area;

ii. an axial flow length that extends between the upstream end and the downstream end along an axial centerline of the unibody liner;

iii. a conical portion that extends downstream from the forward end, a fuel injection portion that extends downstream from the conical portion and a transitional portion that extends downstream from the fuel injection portion; and

iv. wherein the cross-sectional flow area decreases along the axial flow length from the upstream end to the fuel

injection portion and increases along at least a portion of the axial flow length downstream from the fuel injection portion and wherein the cross-sectional flow area increases continuously along the axial flow length between the fuel injection portion and the downstream end of the main body.

13. The gas turbine as in claim **12**, wherein the fuel injection portion has a substantially constant cross-sectional flow area along the axial flow length.

14. The gas turbine as in claim **12**, wherein the fuel injection portion has a decreasing cross-sectional flow area.

15. The gas turbine as in claim **12**, wherein the fuel injection portion has an increasing cross-sectional flow area.

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