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(54) **FUEL INJECTION ASSEMBLY FOR GAS TURBINE ENGINE COMBUSTOR**

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(51) **Int. Cl.**[7] **F02C 1/00**; F02G 3/00
(52) **U.S. Cl.** **60/737**
(58) **Field of Search** 60/733, 746, 747, 60/740, 39.83, 742, 261, 738

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,854,127 A * 8/1989 Vinson et al. 60/748
5,444,982 A 8/1995 Heberling et al. 60/737
5,540,056 A 7/1996 Heberling et al. 60/737
5,577,386 A * 11/1996 Alary et al. 60/742
5,596,873 A 1/1997 Joshi et al. 60/738
5,619,855 A 4/1997 Burrus 60/736
5,791,148 A 8/1998 Burrus 60/752

FOREIGN PATENT DOCUMENTS

EP 0689007 A 12/1995
EP 841517 A2 8/1997

OTHER PUBLICATIONS

"HSCT Computer Model Takes Shape at NASA," pp. 68–76, by James Ott, Hampton, VA, in Aviation Week & Space Technology, Oct. 13, 1997.

* cited by examiner

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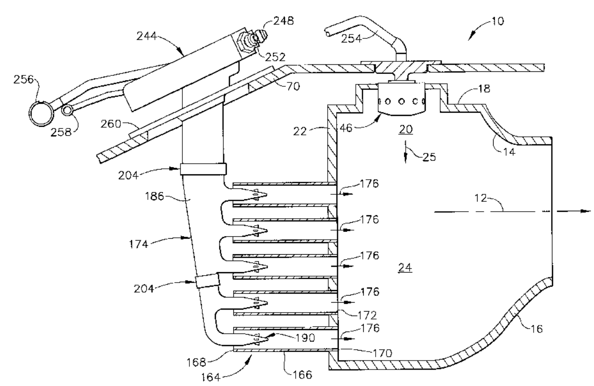
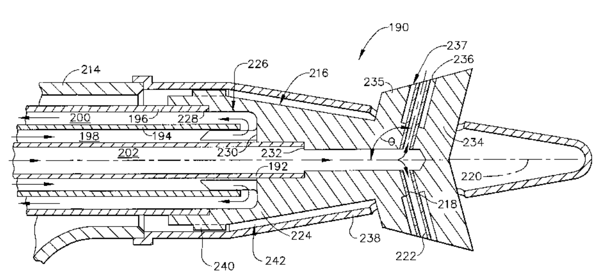
(57) **ABSTRACT**

A fuel injection assembly for a gas turbine engine combustor, including at least one fuel stem, a plurality of concentrically disposed tubes positioned within each fuel stem, wherein a cooling supply flow passage, a cooling return flow passage, and a tip fuel flow passage are defined thereby, and at least one fuel tip assembly connected to each fuel stem so as to be in flow communication with the flow passages, wherein an active cooling circuit for each fuel stem and fuel tip assembly is maintained by providing all active fuel through the cooling supply flow passage and the cooling return flow passage during each stage of combustor operation. The fuel flowing through the active cooling circuit is then collected so that a predetermined portion thereof is provided to the tip fuel flow passage for injection by the fuel tip assembly.

17 Claims, 5 Drawing Sheets





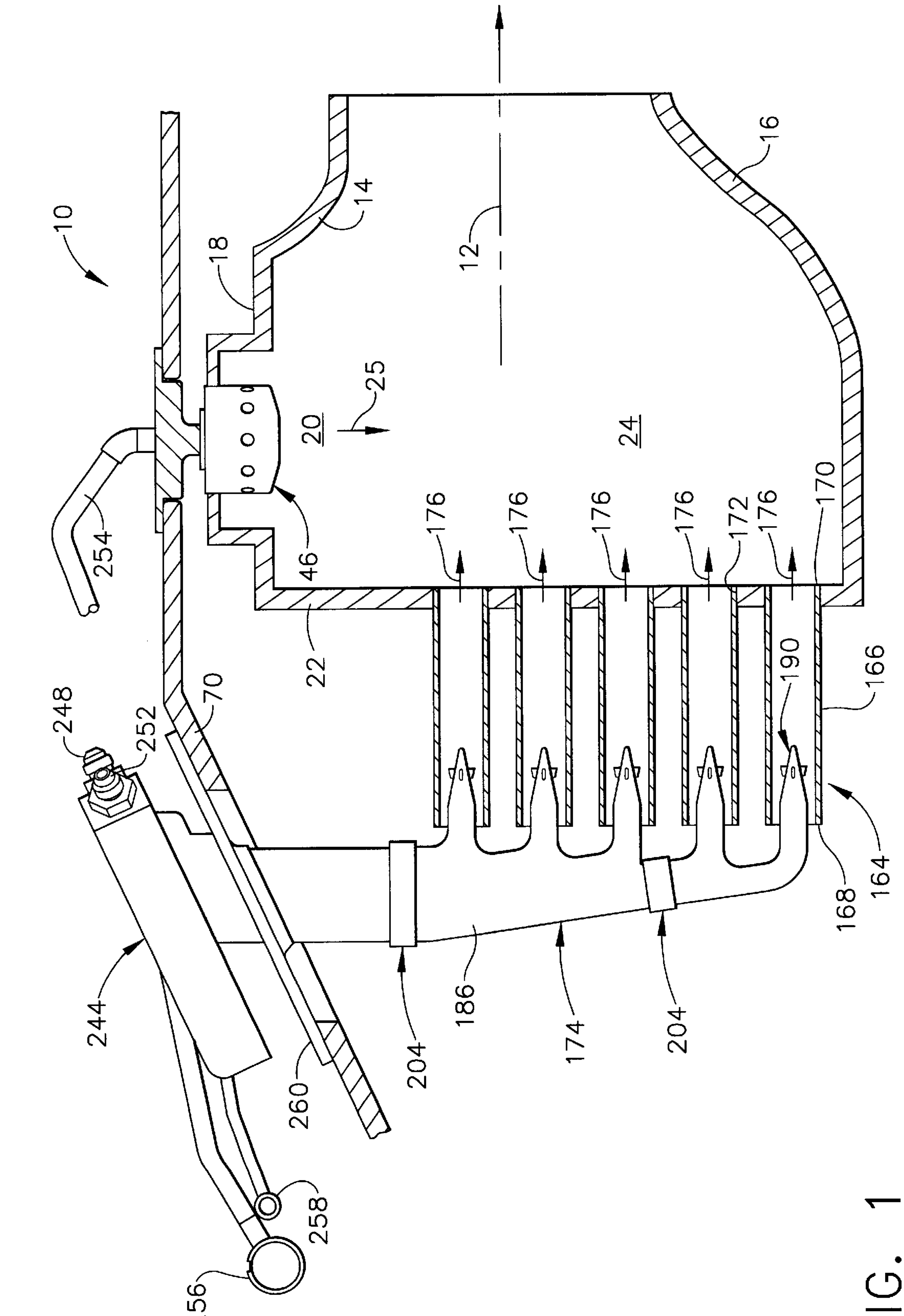

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FIG. 1

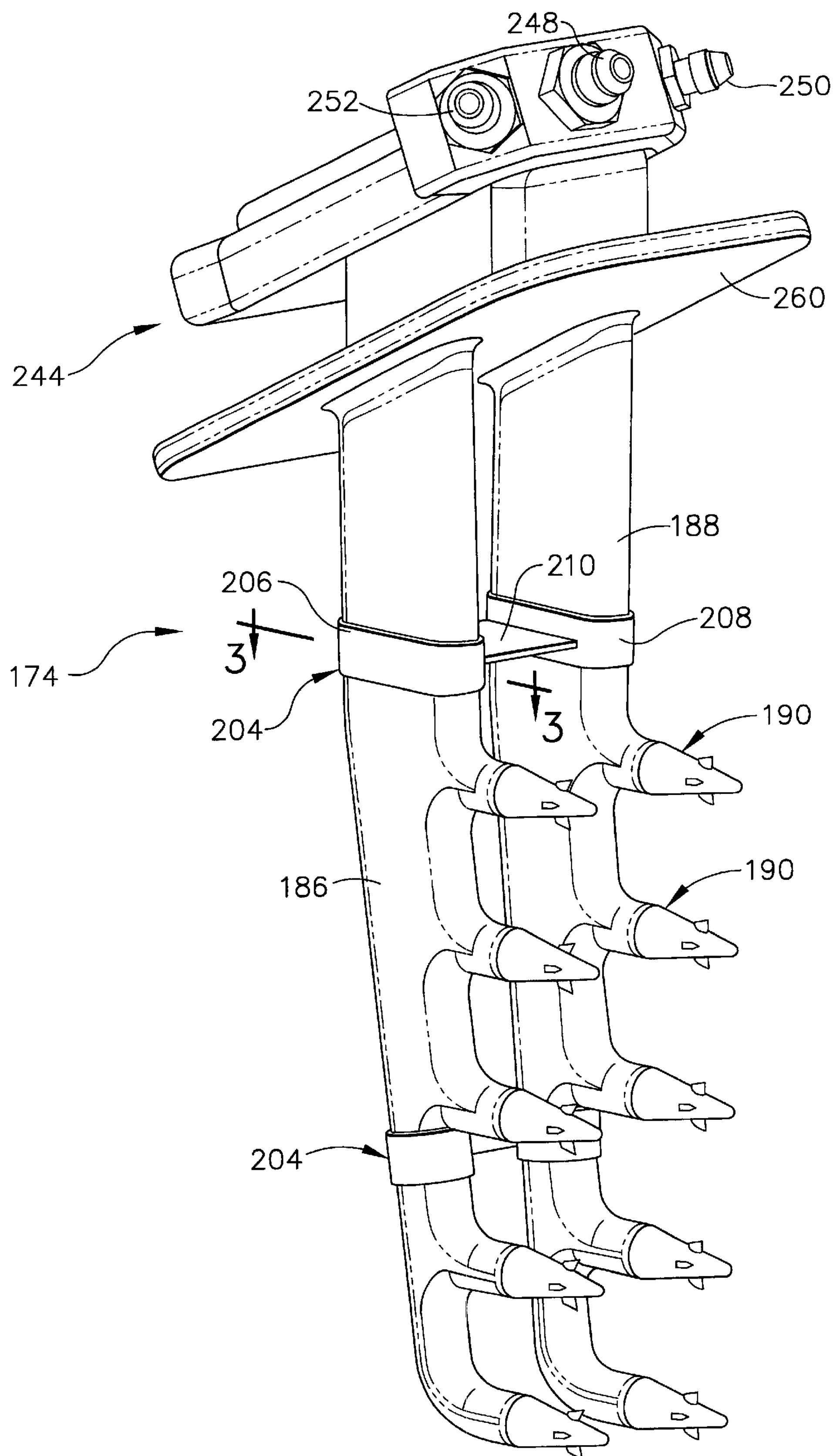

FIG. 2

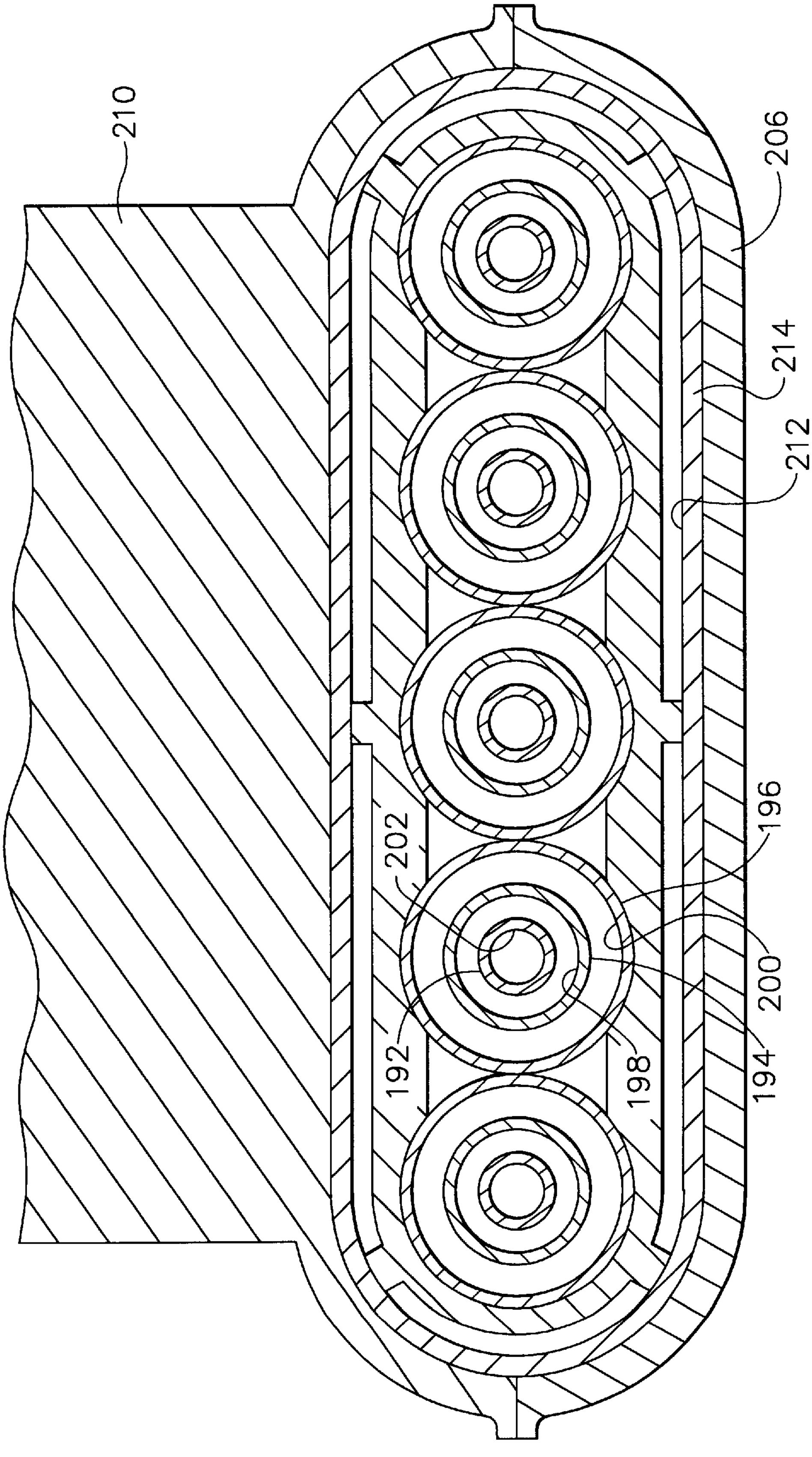

FIG. 3

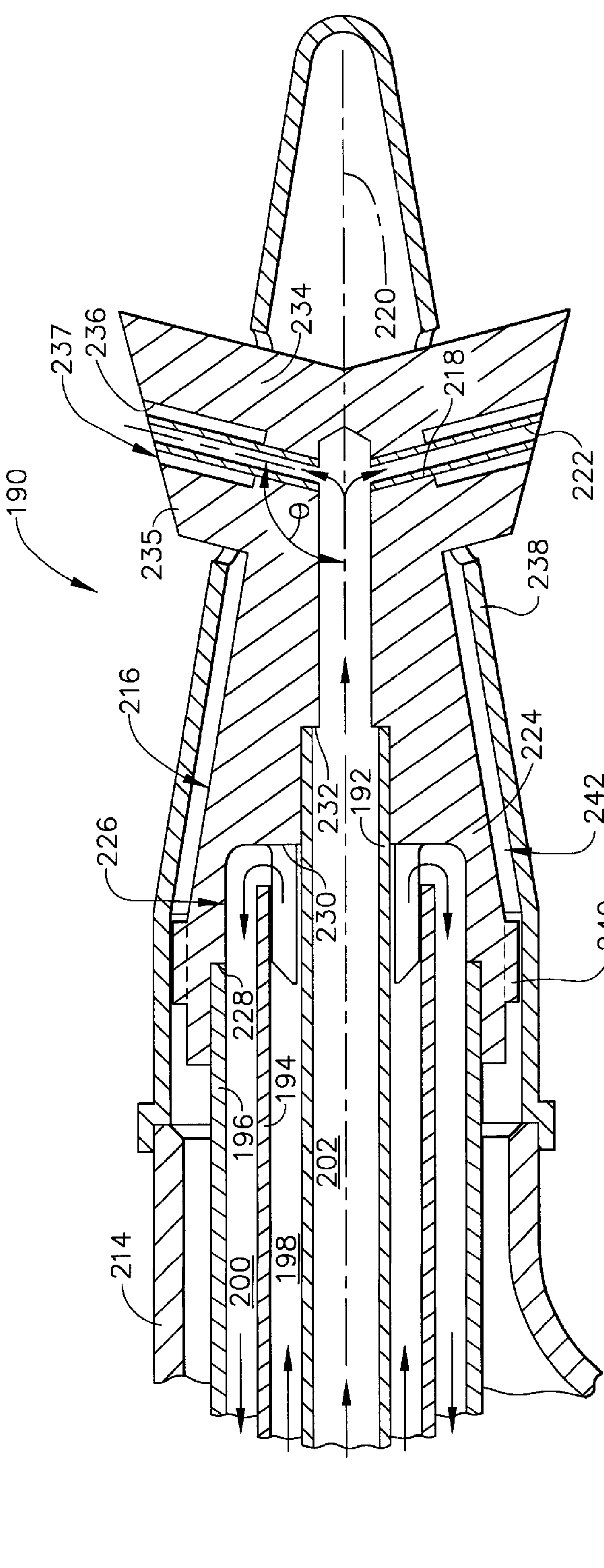
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FIG. 4

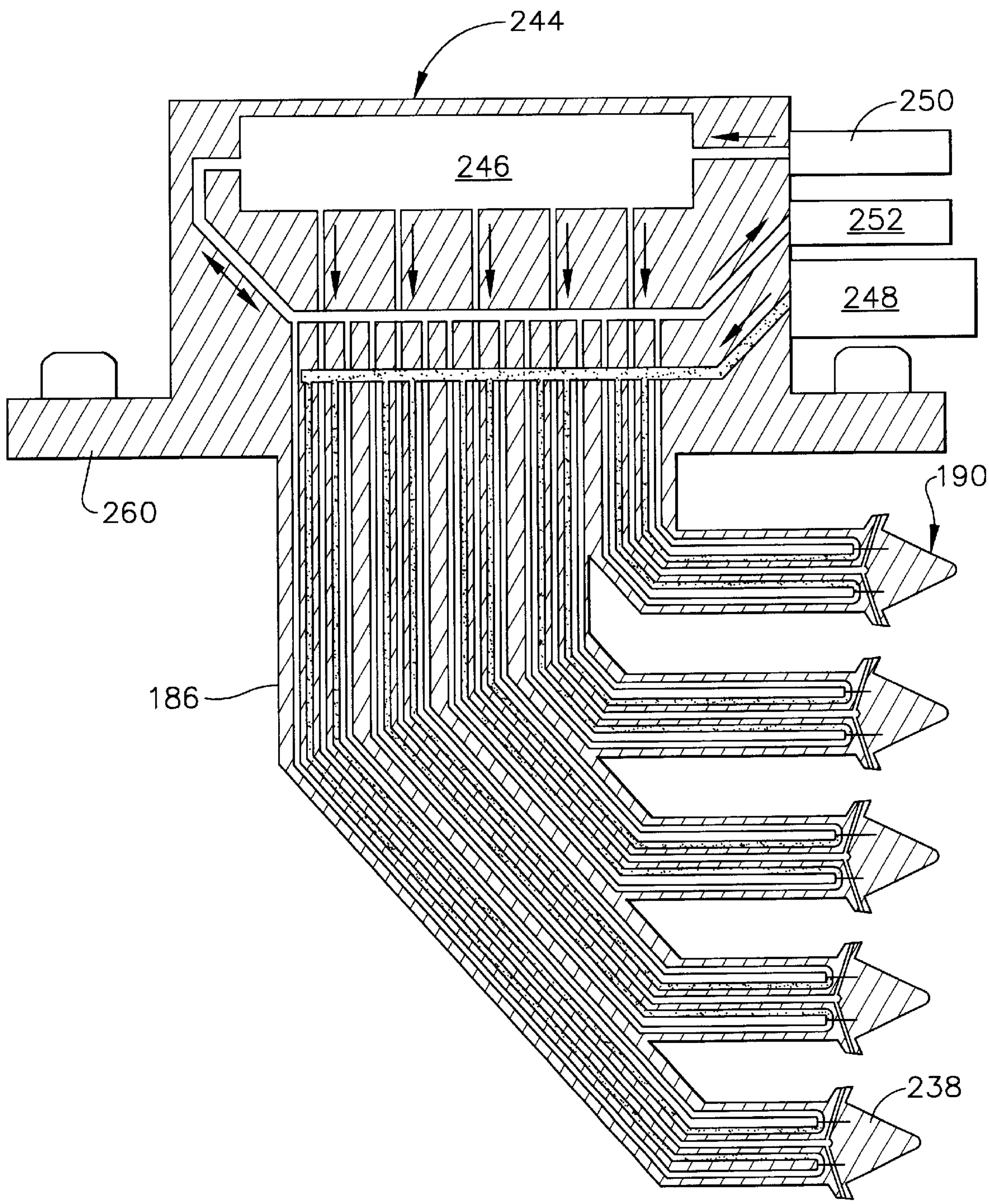

FIG. 5

FUEL INJECTION ASSEMBLY FOR GAS TURBINE ENGINE COMBUSTOR

Benefit of Provisional Application No. 60/103,651, filed on Oct. 9, 1998, is hereby claimed.

This invention was made with Government support under contract number NAS3-27235 awarded by NASA. The U.S. Government may have rights in this invention.

BACKGROUND OF THE INVENTION

The present invention relates generally to combustors in gas turbine engines and, in particular, to a fuel injection assembly for a gas turbine engine combustor having mixing tubes which are widely dispersed throughout the main combustor dome region.

It will be appreciated that emissions are a primary concern in the operation of gas turbine engines, particularly with respect to the impact on the ozone layer by nitrous oxides (NOx), carbon monoxide (CO), and hydrocarbons. In the case of supersonic commercial transport aircraft flying at high altitudes, current subsonic aircraft technology is not applicable given the detrimental effects on the stratospheric ozone. Accordingly, new fuel injection and mixing techniques have been and continue to be developed in order to provide ultra-low NOx at all engine operating conditions.

In response to such emissions concerns, a new combustor has been developed and is discussed in a parent application entitled "Multi-Stage Radial Axial Gas Turbine Engine Combustor," which is filed concurrently herewith by the assignee of the present invention, has Ser. No. 09/398,577, and is hereby incorporated by reference. It will be seen therein that a key component found to provide extremely low levels of NOx at moderate to high power conditions for aircraft engines was the use of a series of simple mixing tubes as the main fuel injection source. A related patent application entitled "Fuel Flow Control System," owned by the assignee of the present invention and having Ser. No. 09/366,510, describes how a control system determines which mixing tubes are to be supplied with fuel in greater detail and is hereby incorporated by reference.

Still, fuel must be transported from a fuel supply controlled by the system in the '510 patent application into the mixing tubes disclosed in the combustor of the '577 patent application. It will be appreciated that the mixing tubes are preferably arranged in a plurality of rows and columns. Because the mixing tubes are widely dispersed throughout the main combustor dome region, significant weight, thermal management and structural integrity challenges are presented. As is typical for all flight quality engine hardware, the fuel injection assembly must be as light as possible to minimize engine weight. The thermal management challenge for the fuel injection assembly stems from the extensive fuel-wetted surface area thereof immersed within the high temperature compressor discharge environment, which increases the potential for coke residues to form a partial or full blockage in the fuel passages.

Naturally, the injector tips of the fuel injection assembly must be accurately maintained in position throughout all engine power settings to obtain acceptable system emissions performance. Because the injection sites are widely dispersed, however, maintaining structural integrity of the fuel injection assembly in the hostile dynamic environment of the compressor discharge region, which contains high intensity broadband acoustic excitation, is a particular challenge. Thus, the fuel injection assembly must incorporate sufficient rigidity and damping capability to survive and function in the lightest weight configuration possible.

In light of the foregoing, it would be desirable for a fuel injection assembly to be developed which can provide fuel to a plurality of mixing tubes which are widely dispersed in a gas turbine engine combustor. It would also be desirable for such fuel injection assembly to include continuous active cooling for the fuel stem and injector tip whether fuel is injected into such mixing tubes or not. Further, it would be desirable for the fuel injection assembly to reflect a concern for weight, airflow blockage to the combustor dome region, and ease of removal for maintenance.

BRIEF SUMMARY OF THE INVENTION

In an exemplary embodiment of the invention, a fuel injection assembly for a gas turbine engine combustor is disclosed as including at least one fuel stem, a plurality of concentrically disposed tubes positioned within each fuel stem, wherein a cooling supply flow passage, a cooling return flow passage, and a tip fuel flow passage are defined thereby, and at least one fuel tip assembly connected to each fuel stem so as to be in flow communication with the flow passages, wherein an active cooling circuit for each fuel stem and fuel tip assembly is maintained by providing all active fuel through the cooling supply flow passage and the cooling return flow passage during each stage of combustor operation. The fuel flowing through the active cooling circuit is then collected so that a predetermined portion thereof is provided to the tip fuel flow passage for injection by the fuel tip assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic longitudinal cross-sectional view of a gas turbine engine combustor including a fuel injection assembly in accordance with the present invention;

FIG. **2** is a perspective view of the fuel injection assembly depicted in FIG. **1**;

FIG. **3** is a partial cross-sectional view of the fuel injection assembly depicted in FIGS. **1** and **2** taken along line **3**—**3** of FIG. **2**;

FIG. **4** is a partial longitudinal cross-sectional view of the injector tip portion of the fuel injector assembly depicted in FIGS. **1**–**3**; and,

FIG. **5** is a schematic longitudinal cross-sectional view of the fuel injector assembly depicted in FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings in detail, wherein identical numerals indicate the same elements throughout the figures, FIG. **1** depicts a multi-stage radial axial (MRA) gas turbine engine combustor identified generally by reference numeral **10**. It will be understood that combustor **10** is in accordance with a combustor disclosed in a patent application entitled "Multi-Stage Radial Axial Gas Turbine Engine Combustor," having Ser. No. 09/398,577, which is file concurrently herewith and hereby incorporated by reference. As seen therein, combustor **10** has a longitudinal axis **12** extending therethrough and includes an outer liner **14**, an inner liner **16**, a first or pilot dome **18** positioned immediately upstream of outer liner **14** to form a first combustion zone **20** radially oriented to longitudinal axis **12**, and a dome plate **22** which is connected to first dome **18** at an outer portion and to inner liner **16** at an inner portion. In this way, a second or main combustion zone **24** is defined by dome plate **22**, outer liner **14** and inner liner **16** which is located substantially perpendicular to first combustion zone **20**. Of course, it will be appreciated that first dome **18** is positioned axially downstream of dome plate **22** as indicated by a radial axis **25** extending through first dome **18**.

As indicated in the '577 patent application, a mixture of fuel and air is provided axially through dome plate **22** into second combustion zone **24** only during moderate and high operation levels. This is preferably accomplished by a plurality of fuel air mixers **164** positioned upstream of dome plate **22**. It will be appreciated from FIG. **1** that a plurality of substantially linear tubes **166** are spaced radially and circumferentially around dome plate **22** so as to be arranged in rows and columns, respectively. Each tube **166** has an upstream end **168** and a downstream end **170**, wherein downstream end **170** is positioned in alignment with an opening **172** in dome plate **22** and a fuel injection assembly **174** in accordance with the present invention is positioned so as to provide fuel to tube upstream end **168**. In this way, flexibility is built into combustor **10** whereby designated rows and/or columns of fuel air mixers may be provided fuel. It will be appreciated that the fuel air mixtures flowing into second combustion zone **24**, represented by arrows **176**, are substantially parallel to longitudinal axis **12** and unswirled. Of course, fuel injection assemblies **174** are in flow communication with a fuel supply as will be discussed in greater detail hereinafter.

In operation, combustor **10** of the present invention has a multi-stage function in which first dome **18** acts as a pilot. Accordingly, fuel is supplied to first dome **18** during all phases of combustor operation. It is noted that this is particularly important during low power conditions (e.g., idle cycles and landing-takeoff operations), as fuel is not provided to fuel air mixers **164** during such time. For moderate to high power conditions, fuel is provided to at least some of fuel air mixers **164** so that fuel air mixture **176** is injected into second combustion zone **24**. Since combustor **10** involves multiple stages of operation, has a radially oriented dome **18**, and an axial dome plate **22**, it is known as a multi-stage radial axial (MRA) combustor.

With respect to the fuel injection assemblies **174**, it will be seen from FIG. **2** that at least one fuel stem, and preferably a pair of fuel stems **186** and **188**, are provided which extend substantially radially with respect to longitudinal axis **12**. At least one fuel tip assembly **190** is connected to fuel stems **186** and **188** for injecting fuel into a corresponding mixing tube **166**, with the number of fuel tip assemblies, as well as the spacing therebetween, being dependent upon the arrangement of mixing tubes **166**. Each fuel stem **186** and **188** includes a plurality of concentrically disposed tubes therein known as tip supply tube **192**, insulating tube **194**, and outer tube **196**. Such tubes define a cooling supply flow passage **198**, a cooling return flow passage **200**, and a tip fuel flow passage **202** (see FIGS. **3–5**). It will be noted that cooling supply flow passage **198** is preferably the middle annulus of the triple-concentric tube configuration in order to present the coolest fuel to tip assembly **190** and maximize cooling in this region. Moreover, utilizing cooling return passage **200** as the outer annulus assists in reducing heat transfer to the fuel on the return trip by raising the bulk temperature of the cooling fluid therein. This also has the effect of providing cooling to fuel stems **186** and **188** after cooling of fuel tip assemblies **190** has taken place. Thus, it will be understood that tip fuel flow passage **202** is the innermost passage of the triple-concentric tube configuration which supplies fuel to fuel tip assemblies **190** for injection into mixing tubes **166**.

As best seen in FIG. **5**, each fuel tip assembly **190** preferably has an independent set of concentrically disposed tubes **192**, **194** and **196** associated therewith (to form a so-called "tube bundle" in fuel stems **186** and **188**) so that fuel is supplied to each fuel tip assembly **190** or not based on the level of combustor operation desired. It will be remembered that fuel air mixers **164** of only designated rows or columns, for example, may have fuel supplied thereto. One example of how this is accomplished is disclosed in the '510 patent application incorporated hereinabove by reference. While provision of fuel through tip fuel passage **202** for each set of concentrically disposed tubes does not occur under all circumstances, it is preferred for fuel to be continuously circulated through all cooling supply and cooling return flow passages **198** and **200**, respectively. In this way, an active cooling circuit is provided for each fuel stem **186/188** and fuel tip assembly **190** during all stages of combustor operation, thereby assisting in the prevention of fuel being coked (and potential blockage in all flow passages stemming therefrom).

As stated above, it is preferred that a pair of fuel stems **186** and **188** be coupled together so as to reduce airflow blockage in the combustor dome region and facilitate maintenance removal or replacement of fuel injection assemblies **174** from the combustor casing. Additionally, it has been found that the paired configuration is a more structurally rigid and dynamically stable design. A preferred manner of coupling fuel stems **186** and **188** is by means of one or more cross brace assemblies **204** depicted in FIG. **2**. It will be seen that each cross brace assembly **204** includes a first portion **206** wrapped around a first fuel stem **186**, a second portion **208** wrapped around a second fuel stem **188**, and a third portion **210** connecting first and second portions **206** and **208**, respectively. While third portion **210** is shown as a straight beam, it will be appreciated that this may have any design to accommodate a change in stiffness and/or damping as required. It is further noted that such cross brace assemblies **204** preferably serve as the locations of the bundling feature for the set of concentric tubes.

In conjunction with each cross brace assembly **204**, a lugged spacer member **212** is preferably positioned between the bundle of concentrically disposed tubes and a heat shield **214** (see FIG. **3**) preferably wrapped around the tube bundle for thermal protection. Not only does lugged spacer member **212** secure each tube bundle together, but it also transmits structural loads to cross brace assembly **204** while minimizing contact with heat shield **214**. Thus, lugged spacer member **212** serves to reduce the heat transfer between the relatively cool tubes and the hot heat shield **214** and therefore the cooling burden on the active cooling system.

It will further be appreciated that concentric tubes **192**, **194** and **196** are conventional straight tubes which are assembled together and mechanically formed into the final configuration using conventional manufacturing processes. Nevertheless, because fuel stems **186** and **188** include certain non-linear portions where tubes **192**, **194** and **196** are bent (i.e., where fuel stems **186** and **188** are configured to connect to tip assemblies **190** so as to be in substantially parallel relation to longitudinal axis **12**), a small gauge wire or other similar means is wrapped around each set of tubes at such location to avoid contact between the tubes and minimize restriction of flow passages **198**, **200** and **202**. The wire is able to accomplish this function by maintaining a minimum gap between the tubes in this non-linear region as they are bent.

With regard to each fuel tip assembly **190**, it will be seen in FIG. **4** that a fuel injector tip body **216** is included having a plurality of injection passages **218** formed therein which are in flow communication with tip fuel flow passage **202**.

Injection passages **218** generally extend radially with respect to an axis **220** through tip fuel flow passage **202** and optimally are oriented at an obtuse angle θ with respect to axis **220** so as to inject fuel in mixing tube **166** at a slight downstream orientation. Insulated fuel injection tubes **222** are preferably positioned in each injection passage **218** in order to thermally isolate the injected fuel flow from tip body **216**.

It will be noted that tip body **216** is substantially frustoconical in shape and has a cavity **226** formed in a first end **224** thereof that is configured to receive concentric tubes **192**, **194** and **196**. More specifically, cavity **226** includes a first step **228** which is connected to outer tube **196**, a second step **230** which is spaced from the end of insulating tube **194** so that cooling supply flow passage **198** is in flow communication with cooling return flow passage **200**, and a third step **232** which is connected to tip supply tube **192**.

A second end **234** of tip body **216** located downstream of first end **224**, while generally conforming with the frustoconical shape of tip body **216**, further includes a plurality of local aerodynamically-shaped extensions **235** which extend radially outward from the surface of tip body **216** with respect to axis **220**. Extensions **235** are circumferentially spaced about tip body second end **234** and include injection passages **218** formed therein. In order to also accommodate insulated mixing tubes **222**, it will be appreciated that each extension **235** has a cavity **236** incorporated therein. In this way, fuel is better introduced into the air stream of mixing tube **166** while providing additional thermal protections to insulated mixing tribes **222** by means of an air gap **237**.

Fuel tip assembly **190** further includes a heat shield **238** which encircles tip body **216** in a substantially conical design and is welded or otherwise attached to heat shield **214** so as to provide continuous thermal protection thereto. It will also be seen that heat shield **238** provides an aerodynamic faring to reduce separation of airflow at tip body **216** and encourage proper mixing of the fuel and air after discharge into mixing tube **166**. Offset lugs **240** are provided to set an air gap **242** between heat shield **238** and tip body **216**, as well as enhance mechanical rigidity of tip assembly **190** while minimizing contact between heat shield **238** and tip body **216**.

Fuel injection assembly **174** is coupled at the end opposite fuel tip assemblies **190** to a valve body **244** (see FIGS. **1**, **2** and **5**, where a cover to valve body **244** has been removed for clarity). Valve body **244** houses a multi-stage servo valve **246** and includes a first connection **248** for a main manifold inlet, a second connection **250** for a staging manifold inlet, and a third connection **252** with a pilot fuel supply tube **254**. It will be appreciated that first and second connections **248** and **250**, respectively, are in fluid communication with a main fuel manifold **256** and a staging signal manifold **258**. Valve body **244** also preferably includes a flange portion **260** incorporated therewith by which fuel injection assembly **174** is connected to combustor casing **70** by means of bolts or other mechanical connecting means. Fuel stems **186** and **188** are attached to valve body **244** by means of brazing or other similar attachment.

In operation, it will be seen that metered fuel flow (including both the pilot and main injector flow) is utilized to circulate cooling flow through fuel stems **186** and **188** and the fuel tip assemblies **190**. The fuel flow enters valve body **244** through main manifold inlet connection **248** and is distributed to all fuel stems **186, 188** through the middle annulus (i.e., cooling supply flow passage **198**) of each triple concentric tube configuration. This cooling flow may be distributed equally to all fuel stems or it can be biased to present a higher level of cooling flows to those stems or fuel tip assemblies requiring increased cooling by means of a simple trimming device or orifice in the fuel stems. The cooling flow is then circulated through cooling supply and return flow passages **198** and **200**, respectively, back to valve body **244**.

Once in the valve body **244**, the active fuel circulated through the active cooling circuit is collected and routed either to staging valve **246** or pilot injector supply tube **254** depending on the position of staging valve **246**. It will be appreciated from the '510 patent application that the staging valve position is controlled by setting the staging servo manifold pressure relative to the main manifold pressure by the main engine control. In this way, active fuel is supplied (or not) to tip assemblies **190** through tip fuel flow passages **202** and injected into mixing tubes **166** through injection passages **218** and insulated tubes **222**. In the cases where no main fuel flow is required (e.g., at engine idle), it will be appreciated that the active fuel flow through the active cooling circuit is provided by the pilot injector flow alone. Thus, cooling flow is provided to fuel stems **186** and **188**, as well as tip assemblies **190**, at all stages of combustor operation.

One benefit of having multiple injection sites (i.e., a plurality of fuel injection tubes **222** from a common source) is the facilitation of natural or self purging of fuel in the passages of such tubes **222**. It will be understood that when a given tip assembly **190** is staged or shutdown during engine operation, natural static pressure variations, which may be enhanced by strategic orientation of fuel injection tubes **222** relative to fuel stem wake regions, cause air to flow from high to low pressure regions. Thus, any stagnant fuel in fuel injection tubes **222**, and to a lesser extent tip fuel flow passage **202**, is evacuated. Fuel which remains in tip fuel flow passage **202** is of course still thermally protected by the active cooling feature of fuel injection assembly **174**. This self purging action eliminates the need for active inert gas purging of tip fuel flow passage **202** to avoid coking formation in stagnant fuel lines.

Having shown and described the preferred embodiment of the present invention, further adaptations of the fuel injection assembly can be accomplished by appropriate modifications by one of ordinary skill in the art without departing from the scope of the invention.

What is claimed is:

1. A fuel injection assembly for a gas turbine engine combustor, comprising:

(a) a pair of fuel stems positioned in spaced adjacent manner;

(b) a plurality of fuel tip assemblies connected to each said fuel stem;

(c) a bundle of concentrically disposed tubes positioned in each said fuel stem to define an independent cooling supply flow passage, cooling return flow passage, and tip fuel flow passage in flow communication with each said fuel tip assembly; and

(d) at least one cross brace member coupling said fuel stems.

2. A fuel injection assembly for a gas turbine engine combustor, comprising:

(a) at least one fuel stem;

(b) a plurality of fuel tip assemblies connected to each said fuel stem;

(c) a bundle of concentrically disposed tubes positioned in each said fuel stem to define an independent cooling supply flow passage, cooling return flow passage, and tip fuel flow passage in flow communication with each said fuel tip assembly;

(d) a valve body connected to each said fuel stem for housing a staging valve which controls the amount of active fuel circulated through said tubes, said valve body including a first inlet connection in flow communication with a main manifold, a second inlet connection in flow communication with a staging manifold, and a third connection in flow communication with a pilot supply tube.

3. The fuel injection assembly of claim **2**, further comprising a flange portion integrated with said valve body for coupling said fuel injection assembly to a casing for said combustor.

4. A fuel injection assembly for a gas turbine engine combustor, comprising:

(a) at least one fuel stem;

(b) a plurality of fuel tip assemblies connected to each said fuel stem; and

(c) a bundle of concentrically disposed tubes positioned in each said fuel stem to define an independent cooling supply flow passage, cooling return flow passage, and tip fuel flow passage in flow communication with each said fuel tip assembly;

wherein said fuel tip flow passage is an inner passage through said concentrically disposed tubes.

5. The fuel injection assembly of claim **4**, wherein said cooling supply flow passage is a middle annular passage through said concentrically disposed tubes located between said fuel tip flow passage and said cooling return flow passage.

6. The fuel injection assembly of claim **5**, wherein said cooling return flow passage is an outer annular passage through said concentrically disposed tubes.

7. The fuel injection assembly of claim **4**, further comprising a heat shield positioned around said bundle of concentrically disposed tubes.

8. The fuel injection assembly of claim **4**, said fuel stem including at least one non-linear portion, wherein a spacer is provided between each set of said concentrically disposed tubes in said non-linear fuel stem portions.

9. The fuel injection assembly of claim **7**, further comprising a lugged spacer member positioned between said concentrically disposed tube set and said heat shield.

10. A fuel injection assembly for a gas turbine engine combustor, comprising:

(a) at least one fuel stem;

(b) a bundle of concentrically disposed tubes positioned in each said fuel stem to define an independent cooling supply flow passage, cooling return flow passage, and tip fuel flow passage; and

(c) a plurality of fuel tip assemblies connected to each said fuel stem in flow communication with said passages, each said fuel tip assembly further comprising a fuel injector tip body having a plurality of injection passages in flow communication with said tip fuel flow passage, wherein said injection passages are oriented substantially radially to an axis through said tip fuel flow passage, said tip body further comprising:

(1) a first end connected to said fuel stem so as to provide flow communication between said cooling supply and cooling return flow passages; and

(2) a second end having said fuel injection passages formed therein, said second tip body end including a plurality of extensions extending radially outward therefrom, each said extension including a cavity therein so as to permit said injection tubes to extend therethrough.

11. The fuel injection assembly of claim **10**, further comprising a fuel injection tube positioned in each said injection passage.

12. The fuel injection assembly of claim **10**, further comprising a heat shield positioned around said fuel injector tip body.

13. The fuel injection assembly of claim **12**, wherein said heat shield is substantially conical in shape.

14. The fuel injection assembly of claim **12**, further comprising a lug positioned between said fuel injector tip body and said heat shield so as to control an air gap therebetween.

15. The fuel injection assembly of claim **2**, wherein the amount of active fuel provided to said cooling supply passages by said valve body is dependent upon a controlled amount of fuel to be injected into said combustor.

16. The fuel injection assembly of claim **2**, wherein the active fuel flowing through each said cooling return flow passage is collected by said valve body so that a predetermined portion thereof is provided to each said tip fuel flow passage for injection by each said tip fuel assembly.

17. The fuel injection assembly of claim **15**, wherein said valve body provides at least a predetermined amount of said active fuel to said cooling supply passages during combustor operation.

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