United States Patent

[11] 3,589,127

[72] Inventors **Milton J. Kenworthy; Clifford C. Gleason; Michael M. Bluestone, all of Cincinnati, Ohio**

[21] Appl. No. **796,391**
[22] Filed **Feb. 4, 1969**
[45] Patented **June 29, 1971**
[73] Assignee **General Electric Company**

[54] **COMBUSTION APPARATUS**
2 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **60/39.37,** 60/39.65, 60/39.74, 431/352
[51] **Int. Cl.** **F02c 3/00**
[50] **Field of Search** 431/183, 352, 39.37; 60/39.65, 39.74

[56] **References Cited**

UNITED STATES PATENTS

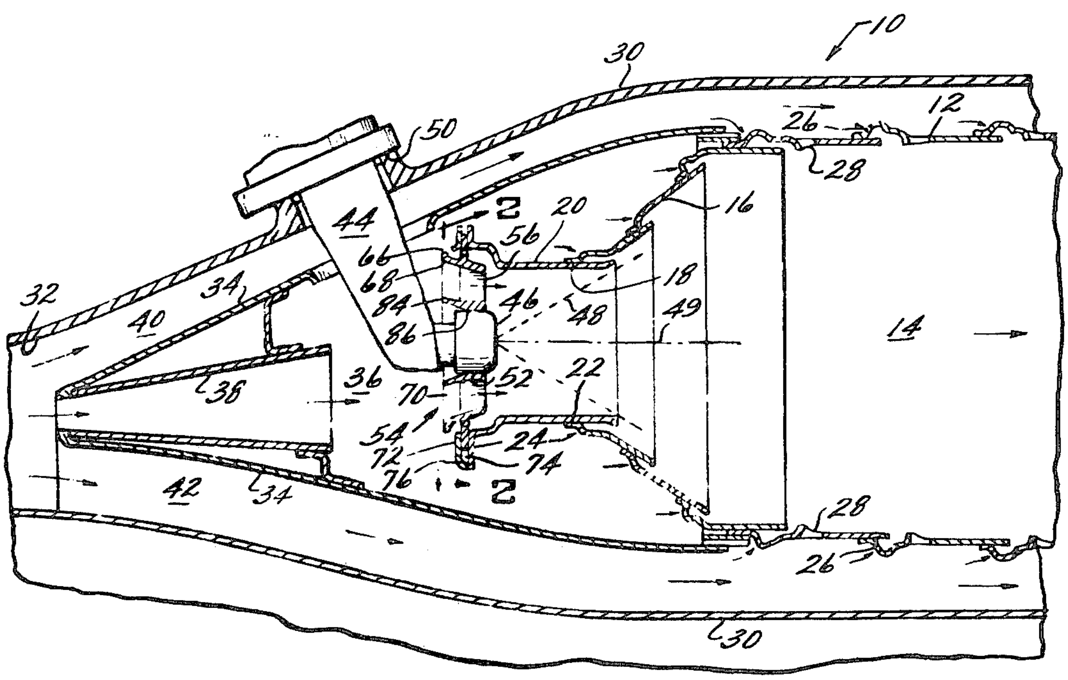
3,031,012	4/1962	Brola	431/183
2,398,654	4/1946	Lubbock et al.	60/39.65
2,560,223	7/1951	Hanzalek	60/39.65
3,283,502	11/1966	Lefebvre	60/39.74
3,447,317	6/1969	Dakin	431/183 X

FOREIGN PATENTS

894,470	4/1962	Great Britain	60/39.74
464,055	8/1928	Germany	431/183

Primary Examiner—Carroll B. Dority, Jr.
Attorneys—Derek P. Lawrence, Erwin F. Berrier, Jr., Lee Sachs, Oscar B. Waddell and Frank L. Neuhauser

ABSTRACT: A combustion apparatus is disclosed having a closure member disposed about a fuel nozzle and formed with a plurality of radially elongated and mutually spaced slots for delivery of air into a combustion chamber as a plurality of discrete streams about and generally along the fuel spray axis so as to mix the air and fuel in a manner producing low smoke combustion.



PATENTED JUN 29 1971

3,589,127

Fig 1

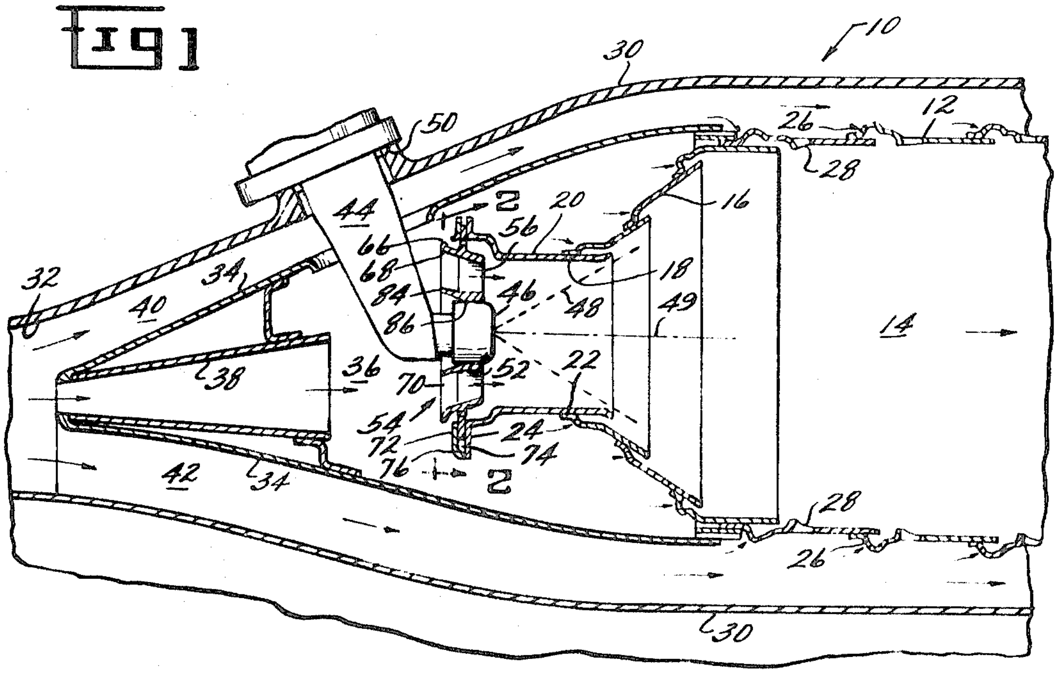
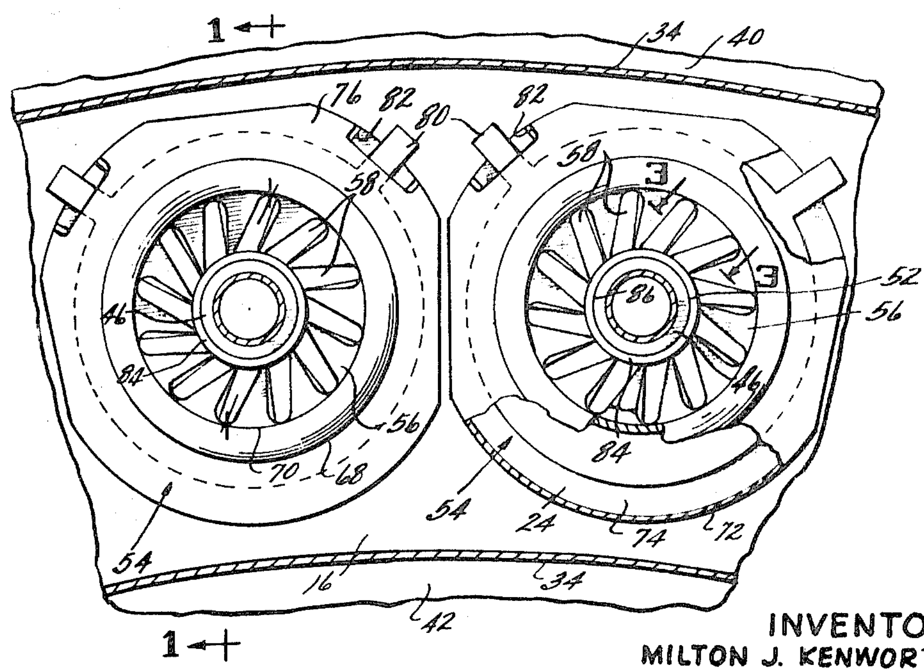


Fig 2



INVENTORS.
MILTON J. KENWORTHY
CLIFFORD C. GLEASON
MICHAEL M. BLUESTONE

Erwin F. Berrier Jr.
ATTORNEY—

FIG 3

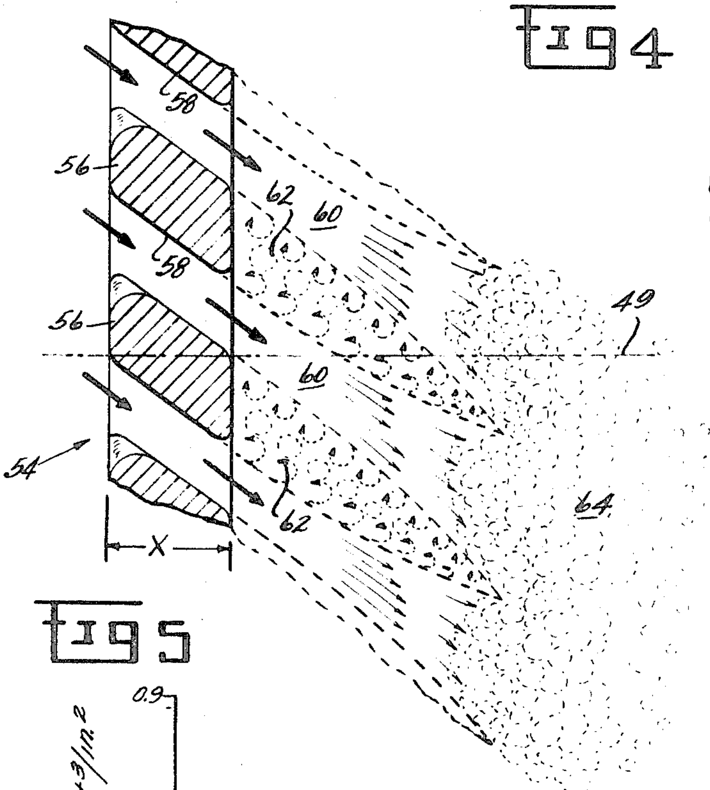
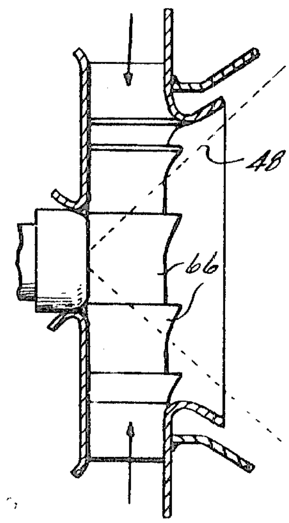
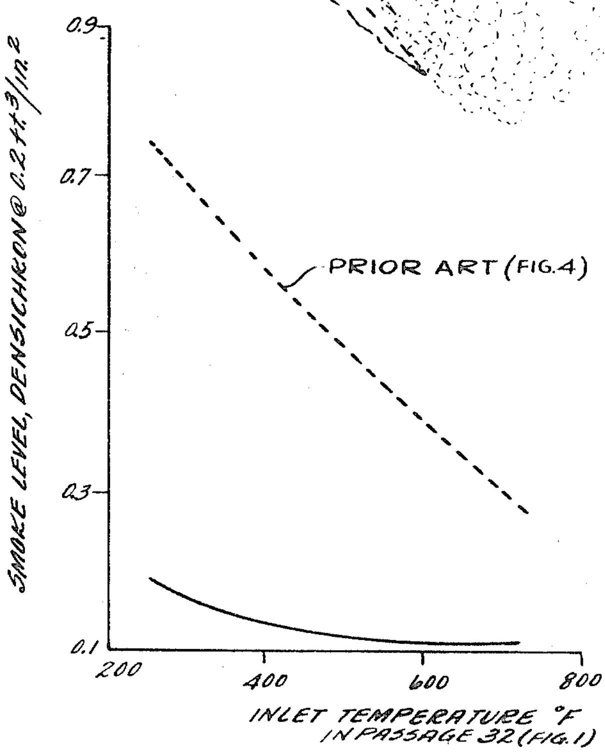


FIG 4



PRIOR ART

FIG 5



INVENTORS.
MILTON J. KENWORTHY
CLIFFORD C. GLEASON
MICHAEL M. BLUESTONE

Erwin F Berrier Jr.

ATTORNEY

COMBUSTION APPARATUS

This invention relates to combustion apparatus and, more particularly, to means for mixing fuel and air in a continuous burning combustion apparatus in a manner producing low visible smoke in the products of combustion.

With the increasing concern over air pollution, visible smoke has become of great concern in the operation of gas turbine engines in commercial aircraft as well as gas turbines used in power plant operations.

While numerous combustion chamber structures and combustion chamber air baffling means have been proposed heretofore, such proposals have generally been concerned with enhancing thermodynamic combustion efficiency, controlling temperature variations within the combustion chamber, or eliminating hot spots or streaks on the liner or chamber wall which might result in premature burnout. Furthermore, such prior structures tend to be highly configuration dependent. That is, their characteristics, particularly smoke level, tend to vary widely with the temperature, pressure and flow rate of the air supplied to support combustion, the fuel spray angle and delivery pressure, and the location of dilution and cooling holes.

A primary object of this invention is to provide means for delivering air into a combustion chamber and mixing said air with the fuel in a manner which results in efficient and low smoke combustion of the fuel.

Another object of this invention is to provide a combustion apparatus wherein low smoke combustion may be achieved over a wide range of air and fuel delivery conditions.

The above and other objects are achieved by the present invention by providing means for delivering air into the combustion chamber as a plurality of discrete streams about the fuel spray which are direction generally with the fuel spray. In this manner, low-pressure wake regions are established between adjacent airstreams followed by a region of interaction and turbulent dissipation of the discrete streams whereby mixing of the combustion air and fuel is promoted in a manner producing low smoke combustion.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of this invention, it is believed the invention will be better understood from the following description of the preferred embodiment when taken in connection it the accompanying drawings wherein:

FIG. 1 is an axial cross-sectional view of an exemplary gas turbine combustion apparatus embodying the present invention, said view taken along lines 1–1 of FIG. 2;

FIG. 2 is a partial cross-sectional view taken along lines 2–2 of FIG. 1 and drawn to an enlarged scale;

FIG. 3 is a partial cross-Sectional view taken along lines 3–3 of FIG. 2 and drawn to an enlarged scale, said view diagrammatically showing the manner in which a portion of the air is delivered into the combustion apparatus of FIG. 1;

FIG. 4 is a partial cross section view drawn to an enlarged scale and showing the fuel delivery portion of a prior art combustion apparatus; and

FIG. 5 is a graph depicting the smoke levels obtained at various air temperatures for the combustion apparatus of this invention and the prior art combustion apparatus of FIG. 4.

Referring now to the drawings and particularly to FIG. 1, a continuous burning combustion apparatus of the type suitable for use in a gas turbine engine has been shown generally at 10 as comprising a hollow body 12 defining a combustion chamber 14 therein. The hollow body 12 is formed with a domed end 16 and, as shown in FIG. 2, is generally annular. It should be understood, howe... hat this invention is not limited to such an annular config... ...tion and may be employed with equal effectiveness in combustion apparatus of the well-known cylindrical can or cannular type.

The domed end 16 of the hollow body 12 is formed with a plurality of spaced openings 18, each respectively communicating with a suitable conduit 20 adapt to deliver at least a portion of the air required to burn the fuel and dilute the gaseous products of combustion into the chamber 14. The conduit 20 is secured to the hollow body 12 at 22 as by welding or other suitable means and extends upstream of the opening 22 where it terminates in a radial flange 24.

The hollow body 12 may be formed with a plurality of cooling air passages 26 adapted to deliver a protective boundary layer of cooling air along the inner wall surfaces of the hollow body and a plurality of dilution holes 28 for delivery of the remaining portion of the required combustion air. As used herein, the term "combustion air" includes both the air required chemically to completely burn the fuel or for stoichiometric combustion plus any excess or dilution air which may be required to effect combustion and lower the temperature of the gaseous products of combustion to a temperature sufficiently low to enable their effective use, for example, in driving turbomachinery.

The hollow body 12 may be enclosed by a suitable shell 30 having an upstream end passage 32 communicating with a source of compressed air, as for example the discharge end of a gas turbine engine compressor.

An annular snout assembly 34 may be employed to direct the compressed air from passage 32 to the opening 18, the cooling air passages 26 and the dilution air passages 28. As best shown in FIG. 1, the snout assembly 34 is secured to the hollow body 12 and extends upstream thereof, defining a chamber 36 upstream the hollow body domed end 16 and a passage 38 for delivery of the compressed air to the chamber 36.

The outer shell 30 is sized in relation to the snout assembly 34 and hollow body 12 so as to define annular passages 40 and 42 therebetween which function in part, to deliver compressed air from passage 32 to cooling air passages 26 and dilution air passages 28.

A fuel nozzle assembly 44 having a discharge end 46 adapted to deliver at least one generally conical spray of fuel (indicated generally at 48) about axis 49 is provided for each hollow body opening 18. Each nozzle 44 is secured to the shell 30 as at 50 and extends inwardly through the outer shell 30 and snout assembly 34 and terminates at discharge end 46. The nozzle discharge end 46 may include a shroud of the well-known type and is formed with a suitable external surface 52 which is preferably cylindrical.

Means for directing at least a portion of the combustion air into the chamber 14 about the nozzle discharge end 46 has been shown at 54 as comprising a closure member 56 which extends between the nozzle discharge end 46 and the conduit 20.

The closure member 56, as best shown in FIGS. 2 and 3, is formed with a plurality of spaced, elongated slots are respectively defined, in part, be generally parallel sidewalls 58 which extend generally radially with respect to the fuel spray axis 49.

As has been diagrammatically shown in FIG. 3, the slots 58 are sufficiently spaced relative to one another and have sufficient axial length "X" so that the combustion air passing therethrough enters the chamber 14 as a plurality of discrete streams of air 60. By spacing the streams 60, low-pressure wake regions 62 are established intermediate adjacent streams due to the aspirator effect of the discrete streams. Downstream of the closure member 56, as diagrammatically shown at 64, the discrete streams 60 interact and dissipate in a region of high turbulence. In addition to the above, the slots 58 are preferably sized in relation to the cooling passages 26 and the dilution passages 28 so that the amount of air delivered to the chamber 14 by each means 54 is a substantial portion of the air required for stoichiometric combustion of the fuel delivered by its respective nozzle 44. For example, satisfactory results from the standpoint of smoke in the gaseous products of combustion have been obtained with the slots 58 sized to deliver from 25 percent to 100 percent of the air required for stoichiometric combustion of the fuel. In operation, the low pressure within the regions 62 operates to pull minute fuel droplets from the fuel spray 48 into that region for initial mixing with the air. Final mixing of the air and fuel then occurs in the region **64** of turbulent interaction and dissipation of the airstreams. By introducing air in this manner about the fuel spray, it has been found that thorough mixing of the air and fuel is accomplished and the occurrence of local overrich pockets of fuel is greatly reduced with the result that low smoke combustion is achieved.

For comparison purposes, the nozzle portion of an exemplary prior art combustion apparatus has been shown in FIG. 4 wherein air is introduced about the fuel spray **48** in a swirl pattern by vanes **66**. A comparison of the smoke level in the gaseous products of combustion of the prior art structure of FIG. 4 and the apparatus of this invention has been graphically shown in FIG. 5 as a function of the temperature of the air in passage **32**. It will be noted that markedly lower smoke levels were observed in the combustion apparatus of this invention than were observed for the prior art structure of FIG. 4. It will also be noted that the apparatus of this invention exhibited less sensitivity to changes in the air temperature. Although smoke levels will vary with factors such as the overall fuel-to-air ratio, the included angle of the fuel spray cone **48**, the fuel delivery pressure and the pressure of the air, it has been found that the combustion apparatus of this invention exhibits relatively low sensitivity insofar as smoke level output is concerned to variations in these parameters.

Referring again to FIGS. 1 and 3, the axial extent of slots **58** may be formed at an angle relative to the fuel spray axis **49** so as to impart a swirling or spiral motion to the air to minimize the occurrence of hot spots or streaks along the inner surface of the hollow body **12**. Additionally, to promote a sweeping action of the air over the nozzle discharge end **46** to prevent carbon accumulations thereon, the slots **58** may be formed so as to direct the streams of air **60** with a slight radially inwardly component relative to the fuel spray axis **49**. It has been found also that lower smoke content in the products of combustion is achieved when the slots **58** or discrete airstreams **60** are closely spaced relative to the fuel spray axis **49**, as is shown in FIG. 1, and such is the preferable form. By so locating or forming the slots **58**, the discrete streams **60** intersect the fuel cone **48** upstream of the turbulent interaction and dissipation region **64** which is believed to enhance the fuel-air mixing action.

As has been shown in FIG. 1, the nozzle discharge end **46** and the air-directing means **54** are preferably spaced upstream of the chamber opening **18** so that the region of turbulent interaction and dissipation **64** of the discrete streams **60** is initiated within the conduit **20**.

The closure member **56** may include an upstream portion **66** having a bell mouth or outwardly flared upstream end **68** and adapted to define an annular passage **70** intermediate the chamber **36** and the slots **58** to efficiently direct air in a generally streamline manner from the chamber **36** to the slots **58**.

With reference now to FIGS. 1 and 2, the closure member **56** is preferably secured to conduit **20** in a manner permitting relative movement between the nozzle **44**, the closure member **56** and the conduit **20** during periods of relative thermal expansion and contraction. To this end, the closure member **56** may include a peripheral flange **72** which is housed and floats within a peripheral groove **74** cooperatively formed by a retaining ring **76** and the conduit flange **24**. Rotation of the closure member **56** relative to the nozzle **46** and the conduit **20** may be prevented by providing ears **80** which extend outwardly from the flange **74** through slots **82** formed in the retaining ring **76**.

As shown in FIG. 1, the closure member **56** may include a centrally disposed wear sleeve or collar **84** formed with a central opening **86** sized to slidingly receive the external surface **52** of the nozzle discharge end **46** in close fitting relationship. The wear sleeve **84** may extend upstream of the slots **58** so as to define the inner boundry of passage **70** and may be outwardly flared as at **88** to facilitate insertion of the nozzle into opening **86**.

Although the closure member **56** has been show disposed at the upstream end of the conduit **20**, it should be understood that it may be disposed intermediate the ends of the conduit, the conduit may be eliminated and the closure member **56** disposed at the hollow body upstream end opening **18**, or the air-directing means **56** may be integrally with the hollow body **12**.

Although the present invention has been depicted and described in connection with a combustion apparatus of the annular-type, it will be appreciated by those skilled in the art that this invention may be employed with equal effectiveness in other combustor configurations such as the well-known cannular or cylindrical can-type. Further, although one embodiment of the invention has been depicted and described, it will be appreciated that many additions, modifications and changes may be made thereto without departing from the invention's fundamental theme.

What I claim is:

1. A combustion apparatus including, in combination:
   a hollow body defining a combustion chamber therein, said hollow body formed with an opening at one end thereof;
   conduit means carried by said hollow body and communicating with said opening for delivery of air into said chamber;
   a fuel nozzle having a discharge end generally centrally disposed in said conduit means for delivery of a fuel spray to said conduit means and hence into said chamber, the discharge end of said nozzle being disposed upstream of the junction of said conduit and said hollow body;
   a closure member for restricting the flow of air through said conduit, said closure member extending between said nozzle discharge end and said conduit and formed with a plurality of generally radially elongated slots for passage of air therethrough;
   said closure member being formed with a peripheral flange and a central opening adapted to slidingly receive the discharge end of said fuel nozzle, said peripheral flange floatingly received within a peripheral groove defined, at least in part, by said conduit whereby said closure member is accurately located relative to said fuel spray and unrestricted relative movement may occur between said fuel nozzle, said closure member and said conduit during periods of thermal expansion an contraction.

2. A combustion apparatus including, in combination:
   a hollow body having a generally closed upstream end and defining an annular combustion chamber therein, said hollow body upstream end formed with a plurality of angularly spaced openings;
   a generally cylindrical conduit for each said opening, each said conduit connected, in flow communication with its respective opening, to said upstream end of said hollow body and extending upstream thereof;
   a fuel nozzle for each said conduit, each fuel nozzle having a discharge end generally centrally disposed in its respective conduit, in axial spaced relationship to said opening, for delivery of a fuel spray into said conduit; and
   a closure member extending between said discharge end of said fuel nozzle and the upstream end of said conduit and formed with an annular array of generally axially extending slots sized to deliver at least 25 percent of the air required for stoichiometric combustion of its respective fuel spray, each said slot defined, in part, by generally parallel, radially extending sidewalls, whereby said air is delivered as a plurality of radially elongated discrete streams about said fuel spray which dissipate in a region of turbulent interaction to thereby promote mixing of the air and fuel in a manner producing low smoke combustion.