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[54] FUEL SPRAY NOZZLE

[72] Inventors: **Gregory E. McEneny; Edward E. Ekstedt,** both of Cincinnati, Ohio

[73] Assignee: **General Electric Company**

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[51] **Int. Cl.** **B05b 7/06**

[58] **Field of Search** 239/404, 416.5, 417.5, 418, 239/422, 423, 424, 426, 427.3, 427.5, 428, 433, 434, 434.5, 403

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Primary Examiner—Allen N. Knowles
Assistant Examiner—Edwin D. Grant
Attorney—Derek P. Lawrence, Erwin F. Berrier, Jr., Lee H. Sachs, Frank L. Neuhauser, Oscar B. Waddell and Joseph B. Forman

[57] **ABSTRACT**

A fuel spray nozzle for delivery of a conical spray of fuel droplets into a gas turbine engine combustion apparatus includes a shrouded and shielded discharge head arranged to establish a stable fuel spray angle, maintain low-operating temperatures and prevent accumulations of deleterious matter on the surfaces of the nozzle which are exposed to the combustion process.

5 Claims, 2 Drawing Figures

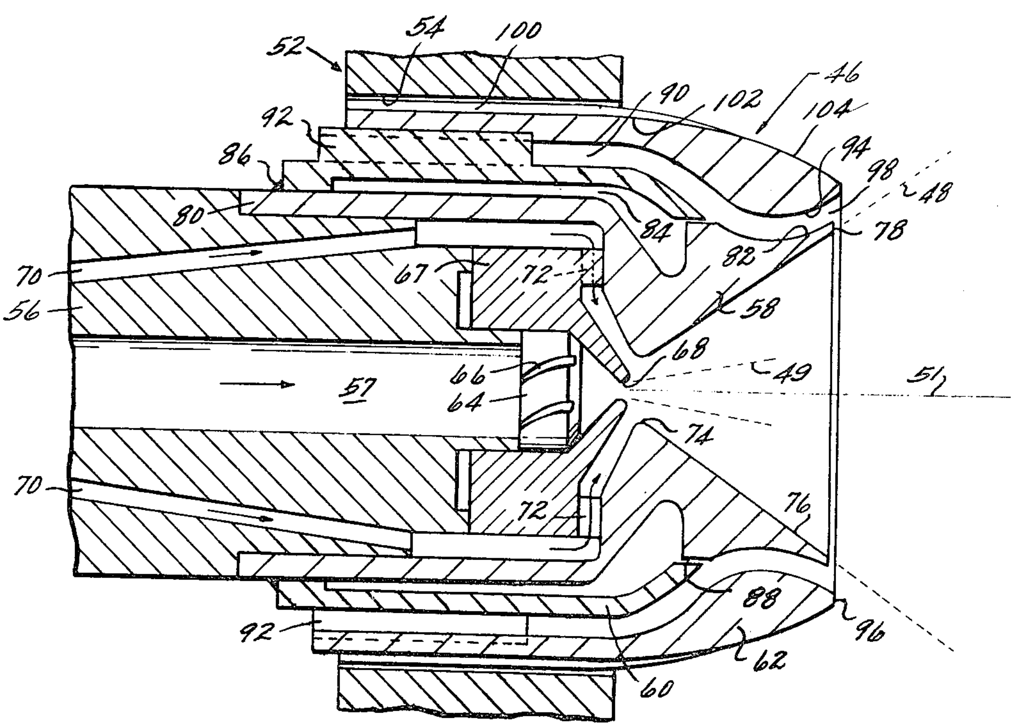


Fig 1

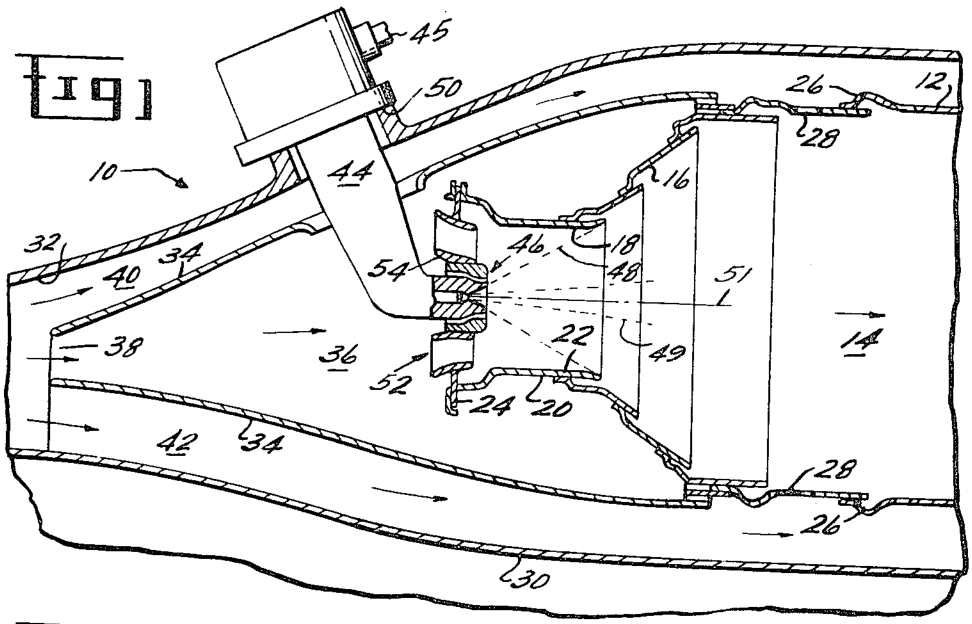
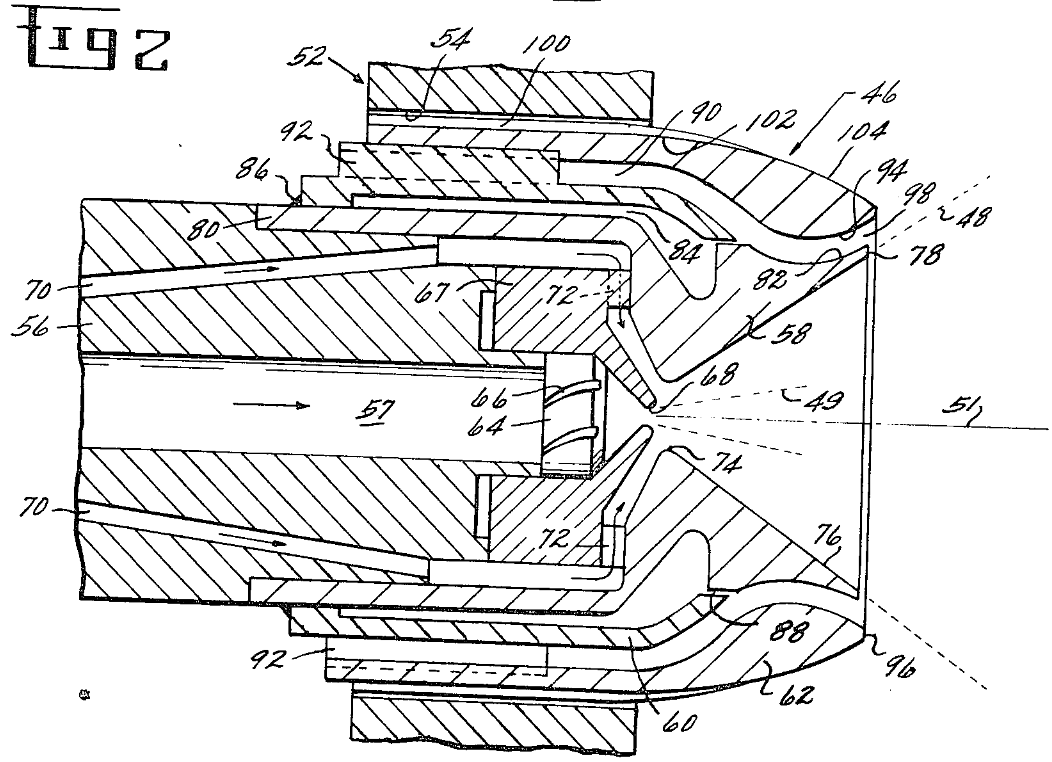


Fig 2



INVENTORS:
GREGORY E. McENENY
EDWARD E. EKSTEDT

Erwin F Berrier Jr.

ATTORNEY

FUEL SPRAY NOZZLE

This invention relates to fuel spray nozzles and, more particularly, to improvements therein which are particularly applicable to spray nozzles used in gas turbine engines. The invention herein described was made in the course of or under a contract, or a subcontract thereunder, with the U.S. Department of the Air Force.

Gas turbine engines commonly employ fuel spray nozzles for delivery of a single cone or dual concentric cones of fuel droplets into the engine combustion apparatus. Each fuel spray nozzle generally includes an axially extending discharge head which is formed with a single orifice or dual concentric orifices and projects through an upstream wall of the apparatus and into the combustion chamber. In such applications, the fuel nozzle discharge head is exposed to the extremely high temperatures, pressure variations and recirculation flows of the combustion apparatus, the combination of which may result in the deposition of fuel particles and the formation of carbon or coke on the exposed surfaces of the discharge head. To the end of preventing such deposition or accumulation, it has been the practice to provide an air shroud for directing a sweeping flow of compressor pressurized air over the exposed surfaces of the discharge head. In high pressure ratio engines, however, the air available for such purposes may be at high temperature, making it desirable that the discharge head be insulated therefrom. Additionally, such prior shroud arrangements, while in most cases effectively preventing accumulations in the immediate vicinity of the discharge orifice or orifices, tend to accumulate carbon or coke on the exposed surfaces of the shroud itself.

A further problem in shroud arrangements used heretofore is found in the fragile nature of the fuel spray cone and its susceptibility to being closed down or narrowed by the shroud airflow. When this occurs, overrich fuel pockets may develop and cause visible smoke in the products of combustion.

A primary object of this invention is a fuel spray nozzle discharge head which overcomes the foregoing problems.

A further object of the present invention is a fuel spray nozzle discharge head having low operating temperature characteristics.

Another object of this invention is a low temperature fuel nozzle discharge head which includes means for sweeping all surfaces exposed to the combustion process so as to prevent coke or carbon accumulation thereon.

A still further object is a heat shield arrangement for the discharge head of a fuel spray nozzle which permits unrestrained relative thermal growth between the shield and the discharge head.

Yet another object of this invention is an insulated fuel nozzle discharge head which is adapted to deliver a conical fuel spray, of stable and predictable apex angle, and wash all surfaces exposed to the combustion process with either fuel or air.

Briefly stated, the above and other objects and advantages of the present invention are achieved by forming an annular, axially extending support surface on the outer periphery of the discharge head, adjacent its downstream end. An annular shield is telescoped over the head and defines an annular insulating airspace therebetween and intermediate the ends of the shield. The upstream end of the shield is rigidly connected to the head while the downstream end extends into close fitting engagement with the head support surface so as to close the downstream end of the airspace and permit unrestrained relative axial movement between the head and the shield so as to accommodate differential thermal growth or shrinkage during engine operation. An annular shroud is connected at its upstream end in telescoping relationship to the shield and the head and defines, in cooperation with the shield and the head, an annular, generally axially extending air passage. The discharge head is formed with an annular orifice of small axial extent which terminates in a downstream opening, frustoconical guide surface which extends to the downstream end of the head. The outer peripheral surface of the head is flared to its downstream end to define a relatively sharp downstream edge in cooperation with the guide surface. The inner surface of the shroud is flared to its downstream end and defines a divergent outlet for the shroud air passage for delivery of shroud air as a hollow cone about the fuel spray in close parallel proximity thereto. A plurality of peripherally spaced, axially extending ribs project radially from the outer peripheral surface of the shroud to space the shroud from the combustion apparatus wall member through which it projects so as to provide means for establishing a film flow along such surface. The shroud outer peripheral surface converges to its downstream end, preferably in a streamline arcuate manner, and defines, in cooperation with the flared inner surface, a downstream edge of small radial extent whereby the film flow is efficiently directed to the downstream shroud edge without separation. The exposed external surfaces of the shroud are minimized and the downstream end of the head is protected by terminating the shroud in a plane downstream of and closely spaced to that of the downstream end of the head. The radial extent of the ribs is small relative to the radial extent of the shroud air passage so that the air efflux from the latter will turn the film at the downstream edge of the shroud and prevent the film from closing down the fuel spray angle.

While the specification concludes with claims particularly pointing out the novel aspects of the present invention, it is believed the invention will be better understood upon reading the following description of the preferred embodiment in conjunction with the accompanying drawings, wherein:

FIG. **1** is a partial cross-sectional view of a gas turbine engine employing the improved fuel spray nozzle of this invention; and

FIG. **2** is an enlarged partial cross-sectional view of the discharge end of the fuel nozzle of FIG. **1**.

With reference now to FIG. **1** of the drawings, 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 upstream end **16** and may be annular, cylindrical or a combination thereof.

In the annular configuration, the domed end **16** is formed with a plurality of circumferentially spaced openings **18**, each respectively communicating with a suitable conduit **20** adapted to deliver into chamber **14** at least a portion of the air required to burn the fuel and dilute the gaseous products of combustion. 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 **18** and 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 surfaces of the hollow body and a plurality of dilution holes **28** for delivery of the remaining portion of the required combustion and dilution air.

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**, to the cooling air passages **26** and to the dilution air passages **28**. The snout assembly **34** is secured to the hollow body **12** and extends upstream thereof, defining a chamber **36** and a passage **38** for delivery of compressed air thereto.

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 and dilution air passages **26** and **28**.

A fuel spray nozzle **44** is provided for each hollow body opening **18** and includes an inlet **45** for connection with a source of pressurized fuel and a discharge end **46** for delivery of dual concentric, generally hollow conical sprays of fuel droplets, as at **48** and **49**, about fuel spray axis **51**. Each spray nozzle **44** is suitably secured to shell **30**, as at **50**, and extends inwardly through the shell **30** and the snout assembly **34**, terminating at discharge end **46**. A suitable member **52** is connected to the flange **24** to close the upstream end of conduit **20** and combustion chamber **14**. The discharge end **46** extends into the combustion chamber **14** through an opening **54** formed in the combustion apparatus closure member **52**.

Referring now to FIG. **2**, the discharge end **46** of fuel spray nozzle **44** has been shown as comprising a main body portion **56**, a discharge head **58**, a shield **60**, a shroud **62**, and primary and secondary plugs **64** and **67**.

The main body **56** is formed with a primary passage **57** for delivery of pressurized fuel from inlet **45** to plug **64**, which includes a plurality of peripherally spaced, axial swirl slots **66** for imparting a swirling motion to the fuel prior to discharge through a primary orifice **68** which generates the primary fuel spray cone **49**. In a like manner, the main body **56** is formed with a secondary passage **70** for delivery of pressurized fuel to a plurality of spaced, radial swirl slots **72** which are defined by the secondary plug **67** in cooperation with the discharge head **58**. The swirling fuel from slots **72** is directed to a secondary orifice **74** which is formed in the discharge head **58** and is of relatively small axial extent. The orifice **74** terminates in a downstream opening, frustoconical guide surface **76** which extends to the downstream end **78** of the discharge head and directs the swirling fuel effluxing from orifice **74** to end **78** as an attached conical fuel film having an apex angle generally equal to the desired spray or apex angle of spray **48**.

The head includes an upstream tubular portion **80** which telescopes over the main body portion **56** and is connected thereto, preferably at a location outside the chamber **14** and upstream of the closure member **52**, as by welding, threaded engagement or other suitable means.

The outer peripheral surface of the discharge head **58** is flared, as at **82**, to its downstream end **78** so as to define a downstream edge which is relatively sharp or of small radial extent to thereby minimize the possibility of collecting carbon or coke thereon. By way of example, it has been found that a radial height of between 0.015 and 0.025 inches on an inner diameter of approximately one-half inch provides satisfactory operation.

The shield **60** has been shown as being generally annular and telescoped over the head **58** so as to define an annular airspace **84** which extends axially along a substantial portion of the outer boundary of the head to insulate the head from the high temperature fluid passing therearound. The shield is connected to the head at its upstream end by welding, as at **86**, by brazing or by other suitable means.

The downstream end of the shield **60** extends into close-fitting sliding relationship with an axially extending, annular support surface **88** which is formed on the outer peripheral surface of the head **58**, adjacent its downstream end **78**. In this manner, a closure is provided for the downstream end of the insulating airspace **84** and unrestrained relative thermal growth and contraction between the head and the shield is accommodated.

The shroud **62** is telescoped over the head **58** and shield **60** and radially spaced therefrom so as to define a generally axially extending, annular air passage **90** therebetween for receiving compressor pressurized air from chamber **36** and directing same into the chamber **14**. The shroud is connected to the shield adjacent its upstream end, through a plurality of circumferentially spaced ribs **92** which may be carried by either the shield or the shroud.

The inner surface of the shroud is flared, as at **94**, to its downstream end **96** and defines, in cooperation with the flared portion **82** of the head, a divergent outlet **98** for effluxing shroud airflow in the form of a hollow conical stream about and along the fuel spray **48**. The apex angle of the conical shroud efflux is approximately equal to the desired spray angle of fuel cone **48** so as to stabilize the fuel cone in the vicinity of the fuel nozzle and effectively shield it from any disruptive pressure variations and reverse flows in the chamber **14**.

The shroud **62** includes a plurality of peripherally spaced, axially extending ribs **100**, of small radial extent relative to the radial height of shroud air passage **90**, which maintain the outer surface **102** of the shroud centrally spaced from the closure member opening **54** and establish a flow, in the form of a thin film, from chamber **36** along the exposed outer surface **102** of the shroud. The shroud outer surface **102** is tapered as at **104**, preferably in a streamline arcuate manner, to its downstream end **96** to minimize the radial extent of the downstream edge **96** and, at the same time, efficiently direct the film flow to the downstream end of the shroud.

By making the ribs **100** of small radial extent relative to the radial height of shroud air passage **90**, the film flow is sufficient to sweep surface **102** and prevent any carbon and coke accumulations thereon, but is weak enough to merge with and be turned by the relatively stronger shroud airflow at downstream end of the shroud without affecting the spray angle of the fuel cone **48**. By way of example, a shroud rib radial height of about 0.015 inches, from an outer shroud surface diameter of about 0.75 inches, with a shroud air passage radial height of approximately 0.045 inches has been found to provide satisfactory sweeping without adverse affect to the fuel spray angle.

As shown in FIG. **2**, the downstream shroud edge **96** resides in a plane parallel to and closely spaced downstream (for example, 0.005 to 0.015 inch) of the plane of the head downstream end **78**. In this manner, the surface area of the shroud which is exposed to the combustion process is minimized and protection to the edge **78** during handling is provided.

By interconnecting the head **58**, the shield **60** and the shroud **62** only at their upstream ends and at a location spaced from the high temperatures of the combustion chamber **14**, unrestrained relative thermal growth or contraction between such components is accommodated and high stresses in the connecting joints are prevented.

Since the fuel from passage **57** is at a relatively low temperature compared to the temperature of the air within chamber **36** and the combustion temperatures within chamber **14**, relatively low operating temperatures are maintained in the head **58** by the fuel flow therethrough and along guide surface **76**, coupled with the thermal resistance of insulating airspace **84**.

From the foregoing, it will be noted that the present invention provides a fuel spray nozzle discharge head, having a stable and predictable fuel spray angle, in which all surfaces exposed to the combustion process are washed with either air or fuel to thereby prevent accumulation of coke and carbon and maintain low operating temperatures in the discharge head.

While the invention has been depicted and described in connection with a so-called dual spray nozzle, it will be understood that the primary orifice **68** and plug **64** may be eliminated. Additionally, while a particular arrangement for swirling the primary and secondary fuel flows, using the primary and secondary plugs **64** and **67**, has been shown, numerous other arrangements which are well known in the art may be used to generate such swirl.

While one embodiment has been depicted and described, such embodiment is intended to be exemplary only and not definitive and it will be appreciated that many substitutions, modifications and variations may be made thereto without departing from the fundamental theme of the invention.

What is claimed is:

1. A fuel spray nozzle comprising a main body having an inlet for receiving pressurized fuel and a discharge head formed with an orifice and adapted to discharge at least one generally hollow conical spray of fuel droplets at a predetermined spray angle into a gas turbine engine combustion apparatus, an annular, axially extending support surface formed on the outer periphery of said head adjacent its downstream end, an annular shield having an upstream end and a downstream end, said shield telescoped over said head and defining, in cooperation therewith, an annular, axially extending insulating airspace therebetween, with the upstream end of said shield connected to said head and the downstream end of said shield extending into close-fitting engagement with said head support surface to close said airspace at its downstream end and to permit unrestrained relative axial movement between said head and said shield, an annular shroud telescoped over said head and secured to said shield in radial spaced relationship thereto and defining, in cooperation with said shield and said head, an annular, generally axially extending air passage for directing fluid flow along the exposed outer surfaces of said shield and said head, said shroud includes a plurality of peripherally spaced, generally axially extending ribs projecting radially outwardly from the outer peripheral surface of said shroud, said ribs adapted to be slidingly received within an opening of said combustion apparatus and define, between said outer surface and said opening, a space for directing a film of fluid along said outer surface to prevent accumulation of deleterious matter thereon, said outer shroud surface being tapered to its downstream end.

2. The fuel spray nozzle of claim **1** further characterized in that said orifice terminates in a downstream opening, frustoconical guide surface having an apex angle approximately equal to said predetermined spray angle, said guide surface being of substantial axial length relative to the axial length of said orifice and extending to the downstream end of said discharge head, said discharge head formed with a divergently flared outer surface which defines, in cooperation with said guide surface, a sharp downstream edge for said discharge head, the inner surface of said shroud being flared at its downstream end so as to define, in cooperation with the flared outer surface of said discharge head, a divergent annular outlet for effluxing air from said air passage in close parallel proximity to the desired course of fuel droplets from said nozzle, the outer peripheral surface of said shroud converging to its downstream end so as to define, in cooperation with said flared inner surface, a generally downstream edge for said shroud.

3. The fuel spray nozzle of claim **2** further characterized in that the downstream end of said shroud and the downstream end of said head reside in closely spaced planes normal to said spray axis.

4. The fuel spray nozzle of claim **2** further characterized in that said convergent shroud surface is arcuate so as to establish a generally streamline flow of said fluid film therealong, the radial height of said ribs being substantially

less than the radial depth of said shroud air passage, whereby said film merges with the conical flow from said divergent outlet without affecting the fuel spray angle.

5. In a gas turbine engine combustion apparatus of the type including a hollow body defining a combustion chamber therein, an upstream closure for said combustion chamber, and a fuel spray nozzle having a discharge head projecting into said combustion chamber through an opening in said upstream closure, said fuel spray nozzle including a main body having an inlet for receiving pressurized fuel, the improvement comprising:

said discharge head formed with an orifice terminating in a downstream opening, frustoconical guide surface which extends to the downstream end of said discharge head for delivery of a generally hollow conical spray of fuel droplets into said combustion chamber, the outer peripheral surface of said discharge head being divergently flared to its downstream end, to define a sharp edge at the downstream end of the head and including an axially extending, annular guide surface, an annular shield having an upstream end fixedly connected to said discharge head, upstream of said combustion chamber, and a downstream end extending into close-fitting, sliding engagement with said guide surface, said shield defining an annular airspace intermediate its ends and about said discharge head, an annular shroud telescoped over said discharge head and said shield and defining an annular, generally axially extending air passage therebetween, said shroud having an upstream end fixedly connected upstream of said combustion chamber, to said shield, and a downstream end residing in a plane closely spaced downstream of said discharge head downstream end, said shroud including a plurality of peripherally spaced radial ribs slidably received in said closure opening and defining a small passage between the outer periphery of said shroud and said closure opening, with the inner surface of said shroud being divergently flared to its downstream end and the outer peripheral surface of said shroud being convergently tapered to its downstream end, whereby all surfaces of said fuel nozzle exposed to the combustion chamber are washed with either fuel or air without adverse effect to the fuel spray angle and low operating temperatures are maintained in said discharge head.

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