Sept. 20, 1971 T. L. DU BELL 3,605,405

CARBON ELIMINATION AND COOLING IMPROVEMENT TO SCROLL TYPE COMBUSTORS

Filed April 9, 1970 2 Sheets-Sheet 1

Fig 1

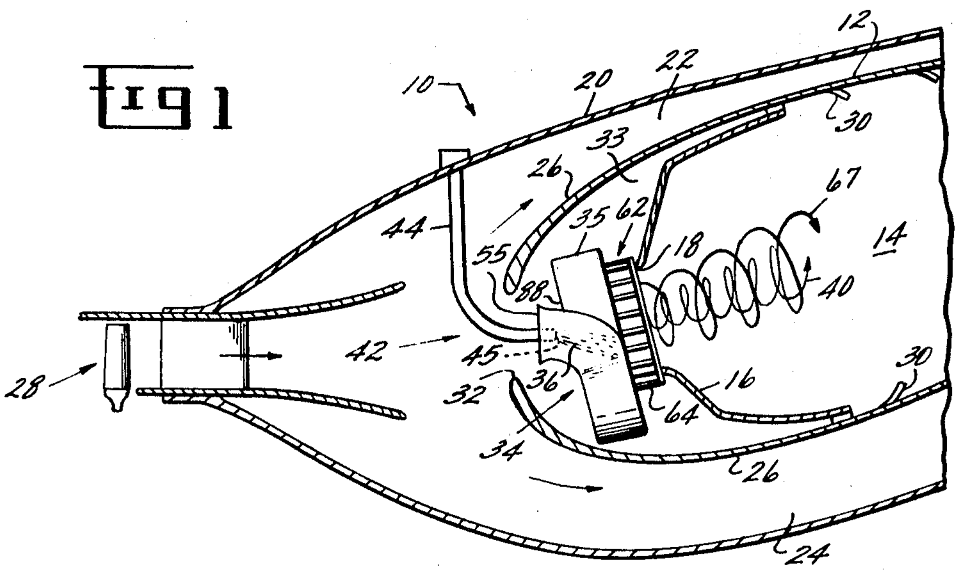
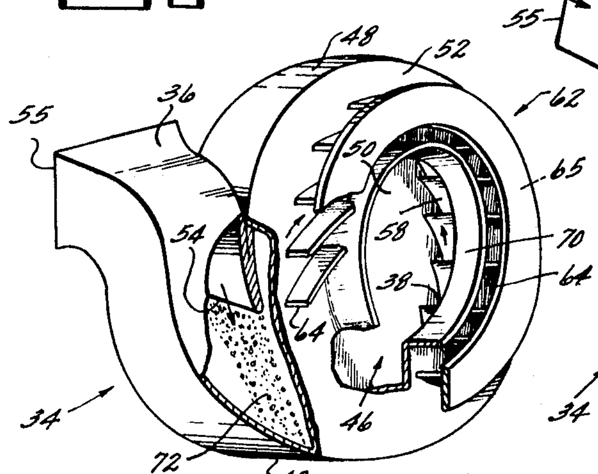



Fig 3

Fig 2



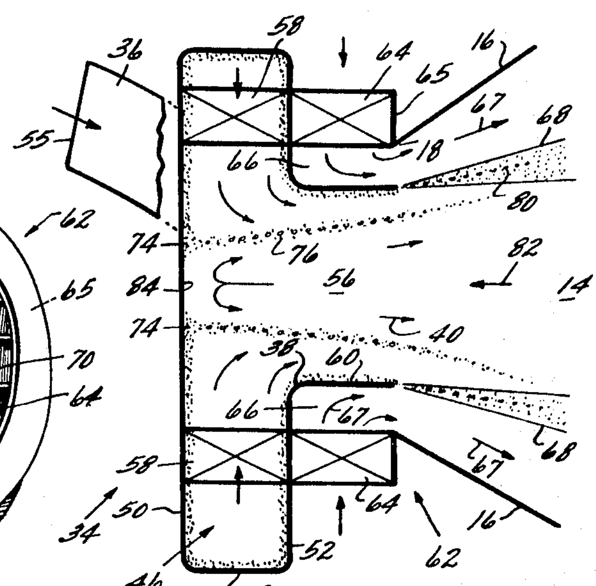




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Fig 4

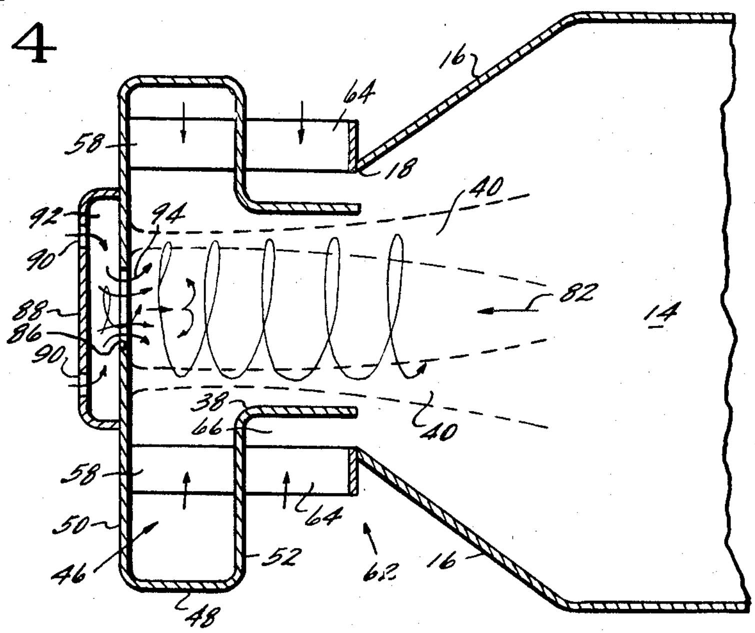
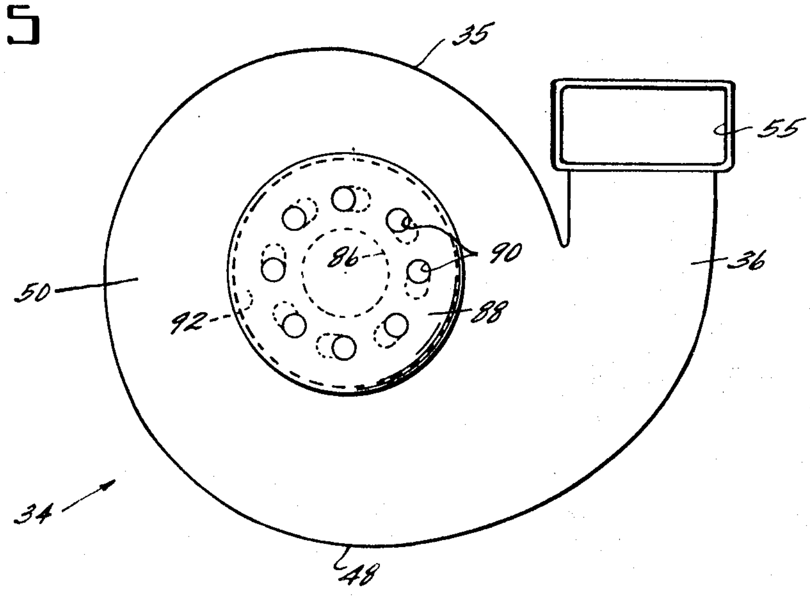



Fig 5

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# CARBON ELIMINATION AND COOLING IMPROVEMENT TO SCROLL TYPE COMBUSTORS

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U.S. Cl. 60—39.65 11 Claims

## ABSTRACT OF THE DISCLOSURE

An improvement for apparatus of the type adapted to premix air and fuel or carburet air prior to introduction thereof as a vortical flow into a primary zone of a combustor; the improvement comprises a purge air opening positioned within an upstream wall of a spin chamber and covered by a cap having a plurality of small openings located therein. Purge air flows from the compressor through the small openings into a chamber formed by the cap and thereafter into the spin chamber in such a manner as to prevent impingement of high temperature gases on the upstream wall of the spin chamber without detrimentally affecting generation of the primary vortical flow.

## BACKGROUND OF THE INVENTION

This invention relates generally to combustion apparatus for supplying fuel to a combustion chamber. More particularly, this invention relates to improvements in the above type apparatus which eliminate carbon accumulation and overtemperature problems presently associated therewith.

The invention herein described was made in the course of or under a contract, or a subcontract thereunder, with the United States Department of the Air Force.

Delivery of fuel into a continuous burning combustion apparatus, as for example in gas turbine engine combustors, in a highly dispersed manner so as to achieve complete and efficient combustion of the fuel and, at the same time, minimize the occurrence of fuel-rich pockets, which upon combustion produce carbon or smoke, has posed a continuing problem to gas turbine engine manufacturers. Solutions to this problem are further complicated in applications such as gas turbine engines by the high temperature environment of the combustion chamber as well as by overall length and weight limitations for such combustion apparatus.

Present day emphasis on the elimination of air pollution has resulted in a great deal of work and effort by gas turbine engine manufacturers in an attempt to eliminate visible smoke emission from gas turbine engines. One proposed solution to the foregoing problems involves the use of a device for carbureting the inlet air or mixing the air and fuel and for delivering the combustible fuel/air mixture into the primary zone of a combustor as a vortical flow. Such an apparatus is shown and claimed in a copending application of Thomas L. Du Bell, Ser. No. 817,075, entitled "Fuel Delivery Apparatus," and assigned to the same assignee as the present application. The apparatus comprises a housing defining an air vortex generator or spin chamber therein about a centrally disposed core outlet. The housing is adapted to receive fuel and air, circulate the fuel and air through an array of swirl vanes in the spin chamber and generate a vortical discharge flow of air and highly dispersed fuel. The apparatus may include a collection surface provided at the core outlet for collection of non-vaporized or atomized fuel that may be expelled from the apparatus. A secondary array of swirl vanes surrounds the collection surface in such a manner as to generate and deliver a secondary vortical flow into the combustion chamber, about the primary

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vortex, which is generally coaxial with and counterrotating relative to the primary vortex.

Such an apparatus has been found to produce an extremely well vaporized fuel/air mixture with a resultant high efficiency and a reduction in smoke emission from the combustion apparatus. Certain applications of such an apparatus, however, have been found to result in carbon accumulation and metal overtemperatures such that normal operation, as described above, could be detrimentally affected.

Previous attempts to solve similar problems in such apparatus have been to ventilate the affected area by perforating the metal, thereby allowing copious amounts of air to flow through at very high velocities. Such an approach, however, frequently destroys the basic aerodynamics of the apparatus by upsetting the vortex previously generated. The net result is a worsening of ignition capability and poorer fuel distribution, which, in turn, results in poorer exit temperature distributions.

Accordingly, a primary object of this invention is to provide an improved scroll cup type fuel vaporizer which prevents carbon accumulation and metal overtemperature without affecting the vortex flow thereof.

Another object of this invention is to provide an improved apparatus as described above which controls the recirculation of gases into the center of the primary vortex.

## SUMMARY OF THE INVENTION

Briefly stated, the above and other objects are achieved in the present invention by providing a basic scroll housing with an opening in a generally planar upstream wall which forms one end of a spin chamber adapted to receive and circulate pressurized air and fuel around a central or core outlet in flow communication with the combustion chamber. A pan-shaped member is attached to the upstream wall of the scroll cup in such a manner as to surround the opening therein. The pan-shaped member is provided with a plurality of small openings in one face thereof, which openings may be normal to or inclined with respect to the surface of the pan-shaped member. The openings are positioned to prevent direct axial flow through the opening in the upstream wall of the scroll cup and they are sized so as to provide a low velocity flow of purge air through the opening in the upstream wall member to the spin chamber of the scroll cup. In this manner, recirculating hot gases within the vortex are prevented from impinging upon the interior walls of the scroll cup.

## DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of this invention, it is believed that the invention will be better understood upon reading the following description of a preferred embodiment in conjunction with the accompanying drawings wherein:

FIG. 1 is a fragmentary axial cross-sectional view of an exemplary gas turbine engine combustion apparatus embodying the improved scroll cup apparatus of this invention;

FIG. 2 is a perspective view, with portions removed, of the improved apparatus of FIG. 1;

FIG. 3 is a diagrammatical axial cross-sectional view of a scroll cup apparatus without the present improvement showing the air and fuel flow patterns generated thereby;

FIG. 4 is a diagrammatical axial cross-sectional view of the apparatus of FIG. 2 showing the improved air and fuel flow patterns generated thereby; and

FIG. 5 is a front end view of the improved apparatus of FIG. 1.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawings wherein like numerals correspond to like elements throughout, attention is drawn to FIG. 1 wherein a continuous burning combustion apparatus of a 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** includes a domed upstream closure member **16**, having an opening **18** located centrally thereof for receiving a fuel/air mixture. The domed closure member **16** defines the upstream end of the combustion chamber **14** and may be suitably secured to or formed integrally with the hollow body **12**. As will be understood by those skilled in the art, the combustion chamber **14** may be of the annular type, the cannular type, or the can type, with the domed closure member **16** having a plurality of circumferentially spaced openings **18**.

An outer shell **20** may be provided to enclose the hollow body **12** and to cooperate therewith to form passageways **22** and **24** surrounding the hollow body **12**. An upstream extension **26** of the hollow body **12** cooperates with the outer shell **20** to form the inlets of the passageways **22** and **24**. As will be understood, the passageways **22** and **24** are adapted to deliver a flow of pressurized air from a suitable source, such as a compressor **28**, into the combustion chamber **14** through suitable apertures or louvers **30**. In this manner, the passageways **22** and **24** act to both cool the hollow body **12** and to provide dilution air to the gaseous products of combustion formed within the combustion chamber **14**.

The upstream extension **26** of hollow body **12** is adapted to function as a flow splitter to divide the pressurized air delivered from the compressor **28** between the passageways **22** and **24** and an upstream end opening **32** centrally formed within the extension **26**. As clearly shown in FIG. 1, the opening **32** communicates with a chamber **33**, which is defined by the internal wall of the extension **26** and the external wall of the domed member **16**.

Located within the chamber **33** and attached to the domed member **16** in any suitable manner known in the art is an improved fuel injection apparatus **34** constructed in accordance with this invention. The fuel injection apparatus **34** has been shown as comprising a housing **35** having inlet passage means **36** for receiving pressurized air from the compressor **28** by means of the opening **32**, a first or core outlet **38** (FIG. 2) in flow communication with the hollow body opening **18** for delivery of an air/fuel mixture into the combustion chamber **14** as a primary vortical flow **40**. Suitable fuel delivery means **42** are provided to deliver fuel to the interior of the housing **35** as will presently be explained. The fuel delivery means **42** may comprise a conduit **44**, having a discharge end **45**, which extends through the outer shell **20** and communicates with a source of pressurized fuel (not shown). While the improved fuel delivery apparatus **34** is particularly adapted for use with liquid fuel and will hereinafter be described in connection with liquid fuel, it should be understood that fuel in the liquid state, gaseous state, solid state or a combination thereof may be effectively used.

Referring now to FIGS. 2–4, the housing **35** has been shown to comprise an involute outer wall **48** and generally planar, spaced upstream and downstream end walls **50** and **52**, respectively, which are peripherally joined to the outer wall **48**. As best shown in FIG. 3, the housing **35** defines an air vortex generator or spin chamber **46** outwardly of the outlet **38**. The outer wall **48** is of spiral shape with a progressively decreasing radius from the inlet passage **36** to a terminal edge or lip **54** (FIG. 2) which defines, in part, the inlet opening from passage **36** to the spin chamber **46**. The inlet passage **36** is formed with a generally axially facing upstream end opening **55** for receiving a flow of pressurized air from compressor **28** and has one wall formed as a streamline continuation of the involute outer wall **48** so as to deliver the inlet air in a generally streamline manner into the spin chamber **46**. In this manner, the pressurized inlet air is directed from inlet **36** in a circular motion of ever decreasing radius so as to generate the primary vortical flow **40** as shown in FIG. 1. As schematically shown in FIG. 3, the vortex has a substantially hollow core portion **56**.



To further provide the swirling motion of the primary vortical flow **40** as well as to accurately position the vortical flow **40** relative to the opening **38**, a plurality of primary swirl vanes **58**, each of which extends between the upstream and downstream walls **50** and **52**, may be provided in a peripheral array about the outlet **38** as shown in FIG. 2. Such an array of swirl vanes **58** may also be adapted to throttle the air passing therethrough so as to increase the rotational velocity of the primary vortical flow **40**. In order to maintain a generaly uniform rotational velocity of the inlet air within the spin chamber **46**, outwardly of the vanes **58**, the outlet **38** and the swirl vanes **58** are preferably positioned with respect to the outer wall **48** so that the cross-sectional flow area progressively decreases from the inlet **55** to the lip **54**.

In addition to the primary flow generating apparatus just described, a control or collector surface **60** is provided at the outlet **38** to collect downstream wall fuel flow as will be described. The collector surface **60** cooperates with means **62** for introducing a secondary flow of air into said combustion chamber **14** about and along the collector surface **60** in a manner which carries such collected fuel as an atomized spray into the combustion chamber **14**. In the depicted embodiment, the control or collection surface **60** takes the form of an annular sleeve extending around the outlet **38** and defining a downstream extension thereof. The collection surface **60** may be suitably joined to the downstream wall **52** or formed integrally therewith. The secondary air flow means **62** has been shown as comprising a plurality of swirl vanes **64**, spaced radially outwardly of and in a circular array around, sleeve **60**. The swirl vanes **64** are suitably secured between the downstream wall **52** and an annular rim **65** spaced axially downstream thereof. The array of swirl vanes **64** and the annular rim **65** are spaced radially outwardly of the sleeve **60** so as to form an axially extending annular passage **66** therebetween which is generally coaxial with the outlet **38** and with vortical flow **40**.

As best shown in FIG. 1, the fuel injection apparatus **34** is positioned with the annular rim closely spaced or joined to the rim of enclosure member opening **18** so as to establish a flow of pressurized air from chamber **33**, radially inwardly through the swirl vanes **64**, and hence axially into the combustion chamber **14**. The swirl vanes **64** are adapted to swirl such air flow and generate a secondary vortical flow **67** which is preferably counterrotating relative to the primary vortex flow **40**, although it may be otherwise. In this manner, a region of high shear stress **68** is created downstream of the sleeve **60** at the outer boundary of the vortex **40** due to the interaction of the primary and secondary flows.

In operation, liquid fuel is delivered to inlet passage **36** through the conduit **44**. Some of this fuel may be immediately picked up by or entrained within the high velocity inlet air entering through the inlet **55** and carried into the combustion chamber **14**. The remaining fuel lands on the interior surface of the inlet passage **36** and is driven or pushed by the high velocity air to the spin chamber **46** and centrifugally along outer wall **48**. During such flow, a portion of the fuel may be vaporized and/or atomized and entrained within the inlet air flow. A portion of the outer wall fuel flow which is not so evaporated is then sheared off the lip **54**, as at **72** (FIG. 2), and again passes through the inlet air flow path which results in more fuel being entrained within the inlet air. In addition to the above and with reference to FIG. 3, the liquid fuel circulating within spin chamber **46** is carried by the air in a swirling flow along the inner surface of upstream wall **50** by the swirling air flow. Such upstream wall fuel flow is carried through the vanes **58** and forms a ring of fuel **74** where the fuel velocity forces are balanced by the centrifugal forces. While flowing along the inner surface of upstream wall **50** to the ring **74**, some of the fuel may be evaporated from the surface by the inlet air and by radiant heat from the flame within the combustion chamber **14**. The liquid fuel within the ring of fuel **74** is spun off and atomized into extremely small fuel droplets by the high velocity vortical flow of air **40** and directed or carried toward the combustion chamber **14** as a conical spray **76**. Since these atomized fuel droplets are extremely small, they quickly vaporize and mix with the air vortex **40**.

Any fuel flow along the downstream wall **52** is carried or pushed to the downstream end of the sleeve **60** in a swirling flow by the vortex **40**. The fuel is then spun or sheared off the downstream end of the sleeve **60** by the primary and secondary flows **40** and **67** and carried into the region **68** of high shear stress where it is sheared to small droplets **80** which quickly vaporize. Accordingly, by providing the control surface or sleeve **60** and the secondary flow generating means **62**, positive and controlled introduction of all liquid fuel effluxing from the apparatus **34** is achieved over a wide range of operating conditions in a gas turbine engine.

Referring again to FIG. 3, the reduced pressure of the vortex core **56** causes a reverse or recirculation flow to be established from the combustion chamber **14**, as generally shown at **82**. This recirculation of high temperature gas from the combustion chamber **14** into the central or core portion of the spin chamber **46** further enhances vaporization of the liquid fuel from the spin chamber surfaces as well as vaporization of any atomized fuel droplets carried by the air intake or expelled from the fuel ring **74**. This recirculation of high temperature gas, however, can have detrimental effects if it is permitted to impinge upon the upstream wall **50** of the spin chamber **46**. That is, the impingement of the high temperature air can cause an overtemperature of the wall **50** with resultant damage thereto. Additionally, the impingement can result in the accumulation of carbon deposits on the wall **50**, as shown schematically by the numeral **84**. Such accumulation interferes with the normal operation of the apparatus **34** thereby causing unpredictable burning conditions in the combustion chamber **14**. An additional problem results when the carbon accumulation **84** breaks loose from the upstream wall **50** and travels downstream through the combustion chamber **14**. Therefore, some means is necessary to prevent the impingement of the recirculating high temperature gases **82** upon the upstream wall **50** to prevent the overtemperature and carbon accumulation problems.

One possible approach to this problem might be to perforate the upstream wall **50** and to pass copious amounts of high velocity air therethrough, thus preventing impingement by the hot recirculating gases **82**. Such an approach, however, frequently destroys the basic aerodynamics of the system by upsetting the primary vortex **40**. The net result of such a system is a worsening of ignition capability and poorer fuel distribution, thereby causing poorer temperature distribution with resultant turbine damage.

To eliminate this problem, as shown in FIG. 4, the upstream wall **50** is provided with an opening **86** centrally thereof. A pan-shaped cover **88** is placed over the opening **86** and is attached to the upstream wall **50** by any appropriate means such as by welding. The cover **88** is provided with a plurality of small holes **90** appropriately spaced circumferentially around the flat plate portion of the cover **88**. The holes **90** may be inclined with respect to the flat plate portion of the cover **88** as shown in FIG. 5. As shown in FIG. 1, the cover **88** is located within the chamber **33** such that high velocity air entering the chamber **33** through the opening **32** is capable of flowing through the holes **90** to an interior chamber **92** (FIG. 4) formed between the cover **88** and the wall **50**. The chamber **92** lies in fluidic flow cooperation with the spin chamber **46** by means of the opening **86**. Air entering the holes **90** thus flows through the chamber **92** into the spin chamber **46** as purge air schematically shown by the arrows **94**. As shown in FIGS. 4 and 5, however, the holes **90** are positioned to prevent direct axial flow between the holes **90** and the central opening **86** of the forward wall **50**. Additionally, the holes **90** are inclined as shown in FIG. 5 so that the purge air swirls within the chamber **92** prior to exiting through the opening **86**. The holes **90** are preferably inclined in a direction to provide swirling motion in the same direction as the primary vortex flow **40**.

The holes **90** are appropriately spaced and sized to regulate the amount and the pressure of the purge air **94** flowing into the chamber **46** in order to prevent high velocity air flow from destroying the primary vortex **40**. As shown in FIG. 4, the purge air **94** entering the opening **86** is made to turn over the forward wall **50** along the interior surface thereof by the pumping action of the vortex **40**, aided by its own swirling motion as described above. This air flow exits at a low enough velocity such that the aerodynamics of the spin chamber **46** are not destroyed, but it enters at a high enough velocity such that the recirculating hot gases **82** never impinge upon the upstream wall **50** of the spin chamber **46**. Thus, carbon is prevented from depositing upon the upstream wall **50**, the upstream wall **50** is maintained cool, and the overall performance of the combustion apparatus **34** is not sacrificed.

From the foregoing, it will be appreciated that the present invention provides an improved combustion apparatus of simplified and economical construction for efficiently and satisfactorily introducing fuel into a combustion chamber in a positive and controlled manner over a wide range of operating conditions while preventing carbon accumulation and metal overtemperature of such apparatus. While the purge air inlet means have been shown and described as comprising a pan-shaped member including a plurality of small holes located therein, it should be understood that other arrangements may be employed and that such means may be formed integrally with the apparatus **34**. Additionally, while a plurality of small purge holes have been shown, one larger hole could be utilized if appropriately positioned within the cover **88**. Accordingly, while a preferred embodiment of the present invention has been depicted and described, it will be appreciated by those skilled in the art that many modifications, substitutions, and changes may be made thereto without departing from the invention's fundamental scheme.

What is new and desired to be secured by Letters Patent of the United States is:

**1**. In a combustion apparatus of the type including a hollow body defining a combustion chamber therein, means disposed outwardly of said combustion chamber for defining a spin chamber including upstream and downstream end walls, said spin chamber including means adapted to receive pressurized air and liquid fuel and to circulate said air and said fuel about a centrally disposed outlet in said downstream wall of said spin chamber and to generate a primary vortical discharge flow of said air and said fuel from said outlet into said combustion chamber, and means for igniting said discharge flow to form a high temperature gas stream, the improvement which comprises:

an opening formed in said upstream end wall of said spin chamber, means forming a purge air chamber adjacent said opening, and means for generating a flow of purge air through said opening into said spin chamber, along said upstream end wall, to prevent impingement of the high temperature gas stream upon said upstream end wall.

2. The improved apparatus of claim 1 further characterized in that said opening is located centrally of said upstream end wall, said chamber forming means comprises a pan-shaped member, and said pan-shaped member covers said opening and includes at least one purge air hole formed therein.

3. The improved apparatus of claim 2 further characterized in that said pan-shaped member includes a plurality of purge air holes formed therein, said purge air holes being located radially outwardly of said central opening, thereby preventing direct axial flow of purge air into said spin chamber.

4. The improved apparatus recited in claim 3 further characterized in that said purge air holes are inclined with respect to said pan-shaped member, whereby said purge air is provided with a swirling motion within said purge air chamber.

5. The improved apparatus of claim 2 further comprising means forming a control surface around said outlet for collecting liquid fuel flowing along said downstream wall to said outlet, and means for generating a secondary flow of air into said combustion chamber, about said fuel collection means, to form a region of high shear stress at the outer boundary of said primary vortical flow, whereby said collected fuel is introduced into said combustion chamber in a controlled and highly dispersed manner.

6. The improved apparatus of claim 5 further characterized in that said fuel collection means comprises an annular sleeve generally coaxially disposed relative to said primary vortical flow, said sleeve being secured to said downstream end wall about said outlet.

7. The improved apparatus of claim 6 further characterized in that said secondary flow generating means includes a plurality of swirl vanes disposed in a radially outwardly spaced circular array about said annular sleeve, said swirl vanes being adapted to deliver said secondary flow as a vortex about, and counterrotating relative to, said primary vortical discharge flow.

8. Apparatus for introducing fuel into a combustion chamber to be ignited to form a high temperature gas stream, said apparatus comprising:

a housing having upstream and downstream end walls, said downstream end wall including a core outlet therein, said housing defining a spin chamber around said core outlet, said core outlet including means to establish flow communication between said spin chamber and said combustion chamber;

means for receiving and directing pressurized air and fuel into said spin chamber;

said spin chamber including means to utilize the energy



of said pressurized air to circulate said air and said fuel about said core outlet and to generate a primary vortical discharge flow of said air from said core outlet, whereby fuel is entrained within said primary vortical flow and discharged from said outlet in a highly dispersed manner;

an opening formed in said upstream end wall;

means carried by said upstream end wall for forming a purge air chamber, said purge air chamber lying in flow communication with said spin chamber; and

means for generating a flow of purge air through said opening, said purge air flowing along said upstream end wall and preventing the impingement of the high temperature gas stream thereon.

9. Apparatus as described in claim 8 further characterized in that said purge air chamber forming means comprises a pan-shaped member, said pan-shaped member covering said opening and including a plurality of purge air inlet holes forced therein.

10. The apparatus recited in claim 9 further characterized in that said purge air inlet holes are disposed radially outwardly of said opening, thereby preventing direct axial flow of purge air into said spin chamber, and are inclined with respect to said pan-shaped member, whereby purge air flowing within said purge air chamber is given a swirling motion.

11. The apparatus recited in claim 9 further comprising means carried by said downstream end wall for defining an axially downstream extending fuel collection surface, said collection surface defining said core outlet at its junction with said downstream end wall; and means for directing a secondary flow of pressurized air into said combustion chamber, about said collection surface, so as to form a region of high shear stress at the outer boundary of said primary vortical flow, whereby fuel collected on said collection surface is discharged in a controlled and highly dispersed manner.


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