May 26, 1964 R. H. JOHNSON 3,134,229

COMBUSTION CHAMBER

Filed Oct. 2, 1961 2 Sheets-Sheet 1

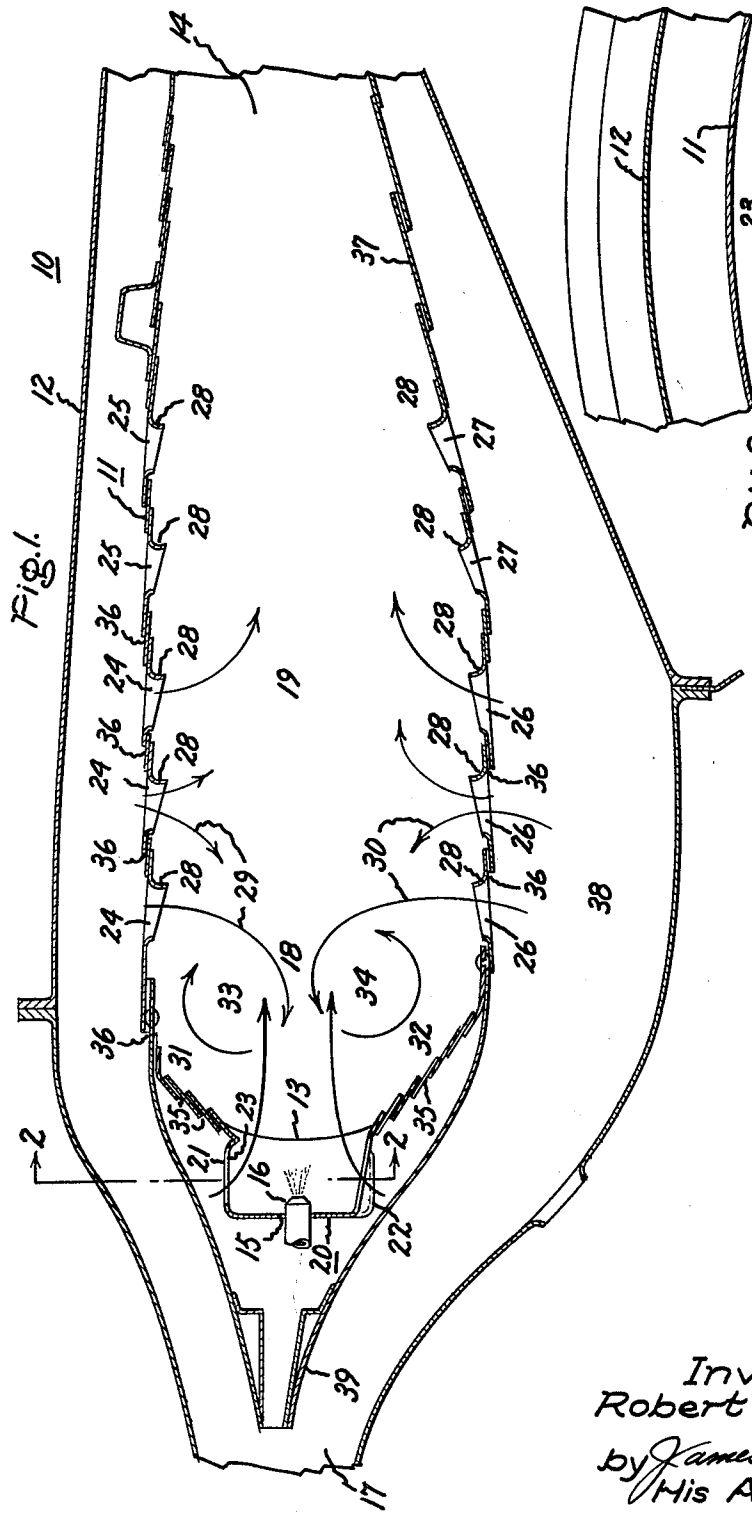


Fig. 1.

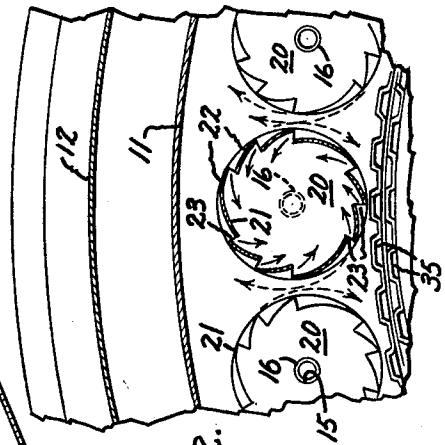


Fig. 2.

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COMBUSTION CHAMBER

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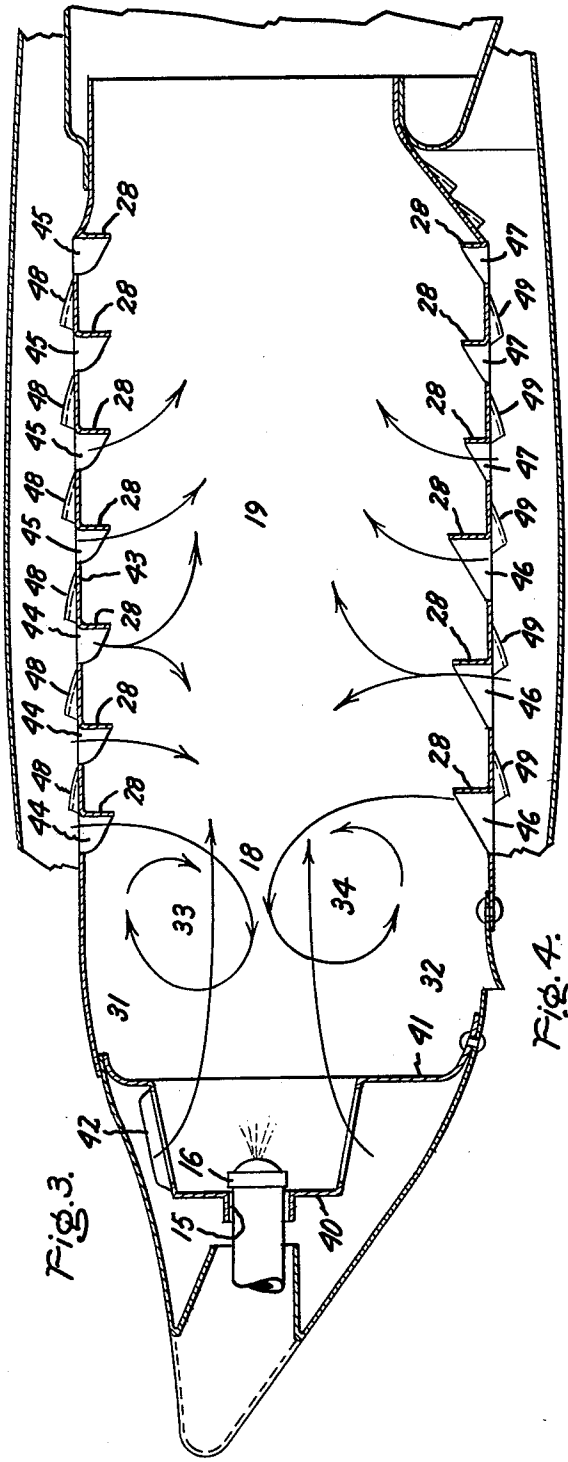


Fig. 3.

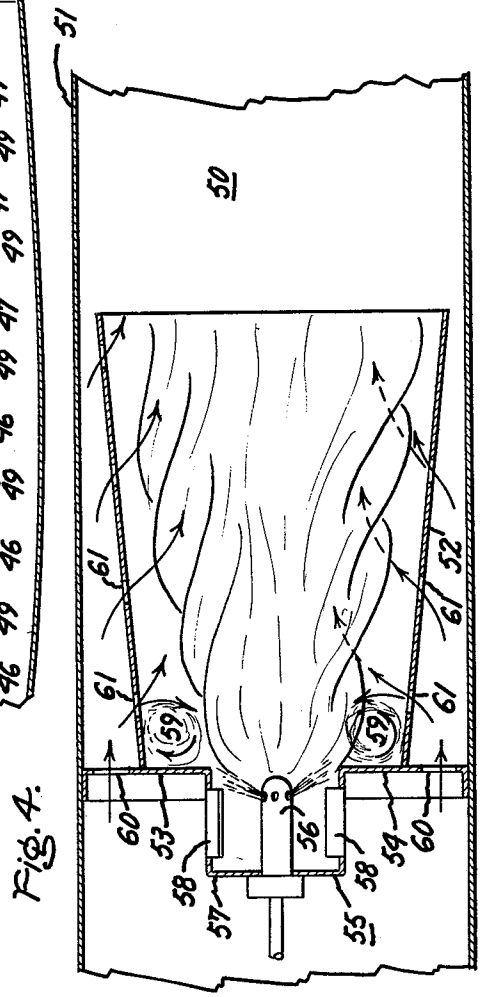


Fig. 4.

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United States Patent Office

3,134,229
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3,134,229

COMBUSTION CHAMBER

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Filed Oct. 2, 1961, Ser. No. 142,183
9 Claims. (Cl. 60—39.65)

This invention relates to combustion chambers and more particularly to an annular combustion chamber including a plurality of vortex air admission generators. More specifically, this invention relates to an improved method and apparatus for burning of fuel in a jet engine combustion chamber which utilizes, in conjunction with a vortex generator, discrete air flow patterns and controlled combustion in these patterns.

This application is a continuation-in-part application of copending application Serial No. 788,399, Johnson, filed January 22, 1959, now U.S. Patent 3,030,773 and assigned to the same assignee as the present invention. The aforementioned copending application is, in turn, a continuation-in-part application of copending application Serial No. 310,186, Johnson, filed September 18, 1952, now abandoned, and assigned to the same assignee as the present invention.

A combustion chamber, especially for jet engine application or other high speed flight applications, is subjected to different environmental conditions and must overcome various disadvantageous problems associated with these conditions. For example, such a combustion chamber is generally positioned within a fast-moving gas stream and must provide not only ignition of fuel in such a fast-moving gas stream, but also continuation of the combustion process and full combustion in a relatively short period of transit time.

With the advent of still higher jet flight speeds, more power output per unit volume of combustion chamber, and more economy, substantial efforts are being expended to provide corresponding combustion chambers. However, the basic features of air delivery and fuel combustion become more complicated because of the necessity of providing more air in the combustion chamber at higher velocities while still attempting to provide optimum ignition, combustion and cooling characteristics. This in turn requires control over the incoming air for regulated air patterns and areas of low air velocities. In a can or tube combustion chamber, air control is better achieved because its entry is provided over 360° or the entire periphery of the tube. A jet engine, for example, generally employs a plurality of such tubes arranged circumferentially about and concentric and parallel to a common axis of the engine. For various reasons including economy, compactness, general space limitations, and efficiency, an annular type combustion chamber is desirable. An annular combustion chamber will provide far more combustion volume than the equivalent plural can arrangement, but air admission and general combustion control is more difficult because there is less area to provide air admission, and far more interference to discrete air flow patterns and combustion processes.

Accordingly, it is an object of this invention to provide an improved combustion chamber.

It is another object of this invention to provide an improved annular combustion chamber.

It is another object of this invention to provide improved air admission means for annular combustion chambers.

It is another object of this invention to provide improved combustion characteristics in an annular combustion chamber.

It is yet another object of this invention to provide a combination of controlled air flow patterns and combustion process within a combustion chamber.

It is another object of this invention to provide vortical generators in an annular combustion chamber to provide better mixing, burning, and combustion control.

It is another object of this invention to provide vortical generators in a can-type combustion chamber to provide better mixing, burning, and combustion control.

These and other objects of this invention will be better understood when taken in connection with the following description and the drawings in which:

FIG. 1 is a cross sectional view, partial, of a preferred embodiment of an annular combustion chamber utilizing a vortical generator therein;

FIG. 2 is a partial elevational and cross sectional view of the combustion chamber of FIG. 1 taken on the line 2—2;

FIG. 3 is a modification of the embodiment of FIG. 1; and

FIG. 4 is another modification of the embodiment of FIG. 1.

Briefly described, this invention comprises a combustion chamber utilizing an air vortex generator in conjunction therewith and more particularly an annular combustion chamber having a circumferential row of vortex air generators in the closed end thereof. Fuel is introduced into the vortices developed with a limited amount of air to commence ignition, and the remaining air necessary for combustion is introduced through perforations in the chamber. The arrangement provides an air flow and combustion pattern which includes a film of cooling air adjacent the walls of the annular combustion chamber, and a toroidal pattern of a burning fuel-air mixture about a central low pressure core developed by the vortex generator. A substantial portion of the fuel is burned in the toroidal configuration and less than the total amount of air necessary for combustion is injected through the vortex air generators. The remainder of the air necessary for combustion is introduced into the liner portion of the chamber through openings therein.

Referring now to FIG. 1, there is illustrated an annular combustion chamber **10** which generally includes a perforated annular liner **11** positioned concentrically within an annular casing **12**. Annular liner **11** includes a closed head end **13** and open exhaust end **14** and is positioned so that air flow through casing **12** moves from the head end **13** of liner **11** to exhaust end **14**. Head end **13** includes a circumferential row of fuel injection nozzle openings **15** to receive fuel nozzles **16** to supply fuel to the liner. Passageway **17**, in jet engine applications, receives air from a compressor which passes into the perforated liner for fuel air mixing and combustion. One of the most desirable aspects of such a combustion chamber is that it have a high heat release per unit volume so that the amount of fuel injected may be minimized, and all of the fuel entering the burner is effectively burned for maximum combustion efficiency.

Commensurate with the combustion efficiency of such a burner, is the air flow pattern developed within a burner during the combustion process. The problem of igniting and sustaining combustion has generally been overcome in jet engine combustors by providing a restricted portion of the chamber **18** where the introduced air and fuel may be properly mixed for combustion purposes, and to thereafter provide a portion **19** of the burner with conditions which favor maximum combustion, such conditions including, additional air delivery into the combustion process or temperature regulation and chamber wall cooling. Therefore, air delivery into a combustion chamber has been generally described as primary air and secondary air, the primary air being the major amount of air which is initially mixed with the fuel for the combustion process, and the secondary air being a minor amount of air introduced at other portions of the combustion chamber in order to provide proper cooling of the chamber walls and the additional air necessary to regulate the combustion process. In this invention a preferred form of air delivery is for the primary or major portion of air to enter the liner and the smaller amount or secondary air enter the head end or restrictively in other portions of the liner. This arrangement provides a reverse flow effect.

A particular example of a combustion chamber incorporating these concepts is that disclosed and claimed in U.S. Patent 2,601,000, Nerad. The Nerad combustion chamber describes a basic type of air flow or pattern in a combustion chamber. More particularly, the can or tube chamber comprises a tubular structure having one closed end through which a fuel nozzle projects to admit fuel axially into the chamber. The chamber is of the perforate type having a plurality of particularly positioned and sized circumferential rows of openings therein. The combustion chamber is positioned concentrically within a casing, and air from the annular plenum defined thereby is introduced through opposed holes in the liner which are directed towards the center line thereof. Opposite flows of incoming air impinge at the center line to thereafter reverse, i.e., to have a portion flow towards the head end of the combustion chamber. The flow pattern thus obtained is extremely favorable to proper fuel air mixing and zones of reduced air velocities are provided which favor the combustion process. Increasing requirements of jet engine combustors include higher efficiencies, higher heat release per unit volume commensurate with economical operation with respect to fuel and reduced costs and space requirements. The above requirements are favored by an improved combustion chamber in accordance with this invention which involves utilizing the principles of air delivery of the Nerad patent together with complementary vortical air generators. This arrangement is adapted to annular combustion chambers particularly. Accordingly, the disclosure of the U.S. Patent 2,601,000, Nerad, is incorporated by reference herewith.

It is obvious that in order to achieve the Nerad flow pattern together with maximum combustion, maximum heat release, and maximum fuel economy, not only must sufficient air be admitted into such a liner but the air must be admitted in such a manner as to commence and sustain proper combustion throughout the combustion chamber while not deterring the Nerad flow pattern. It has been discovered that an improved combustion chamber is obtained by maintaining the Nerad effect and complementing it with a vortical air generator and discrete air flows.

Air admission is a critical feature. Comparing the annular combustion chamber, FIG. 1, with a can-type combustion chamber, for example, a can-type as illustrated in FIG. 1 of the Nerad patent, each can or tube is provided with a plurality of circumferential rows of openings extending a full 360° about the periphery of each can to provide the required amount of air. In

the annular type combustion chamber, it is obvious that the same number of circumferential rows of openings about the annulus does not provide equivalent amount of air through the combustion chamber. Merely making larger or more openings does not equate the difference since as described in the Nerad patent these openings must be predicated on the amount of pressure delivered to the combustion chamber by the compressor and the amount of air flow so that the holes can be properly sized to provide optimum jets of air entering the combustion chamber to impinge upon themselves and to provide the reverse flow air as described. In the same respect, providing large openings in the head on closed end **13** would only defeat the reverse air pattern since these openings would provide large quantities of air at high velocity directly into the reverse pattern and prevent its formulation. It has been discovered that the use of vortical air generators **20** in the head end **13** of the annular combustion chamber **10** will provide a sufficient quantity of air in the combustion chamber, while at the same time sustaining and complementing the reverse flow and also providing a discrete flow pattern in which large amounts of fuel may be burned.

A vortical generator **20** is best described with respect to FIGS. 1 and 2. In FIG. 1, vortical generator **20** comprises a cup-shaped body or shell **21** having vanes **22** extending therefrom. Generally, these vanes **22** are struck from the body **21** so that the vanes define air openings **23** into the body. As air passes axially across body **21**, it is caused to pass by through vanes **22** and into openings **23** in a tangential manner to provide a swirling motion or vortical movement of the air proceeding out of the generator and into liner **11**. The word "tangential" is employed to describe the direction given the air entering or passing through vanes **22** of generator **20**. Since the outer circumference of generator **20** defines an assumed circle from which vanes **22** extend, the entering air is given a whirling motion, the direction of which may be said to be nearly tangential to this assumed circle. Broadly speaking, vortex generators are known in the art and may take various forms, such as the body **21** being conical, frustoconical, hemispherical, etc., and plane, curved or dished vanes depending into the body or extending externally thereof. Furthermore, openings **23** may be in the form of slots or circles, for example. The importance given to the vortical generator is directed to its location and the use rather than to its specific structure.

Referring to FIG. 2, there is shown a sectional and elevation view of the annular combustion chamber **10** of FIG. 1. In FIG. 2, a plurality of vortex generators **20** are positioned in the head end of liner **11** in equidistant relationship about the periphery thereof. In one operative embodiment of this invention, 32 vortical generators **20** are employed. A preferred fuel delivery in this arrangement is by means of a fuel nozzle **16** in each opening **15** for each generator **20**. The fuel nozzles **16** may be of various types well known in the art to deliver a conical spray of fuel axially into the combustion chamber. The conical fuel spray should not be diverging to the extent that it interferes or impinges on the vortex generator nor be in a thin stream. Generally, a 90° or less cone angle provides good results. In a high air velocity burner where transit time is reduced, rapid fuel air mixing must take place together with a high rate of combustion near the head end of the combustion chamber. Fuel injection into the vortical movement of the air from the vortex generators causes fuel particles to be taken up by the vortical movement of air for good mixing and distribution throughout the turbulent whorling air mass. Ignition of the fuel is commenced by well known ignition devices such as sparking devices placed generally in the vicinity of closed end **13**.

Referring again to FIG. 1, the burning or combustion characteristics are dependent on the establishment of discrete air flow patterns developed by the combination of

air vortex generators and the Nerad liner 11. Liner 11 includes a plurality of circumferential rows of openings 24 and 25 about the outer periphery and 26 and 27 about the inner periphery. As a modification of the Nerad liner, the mentioned openings are provided with lip or channel surfaces 28 which provide directional stability to air passing therethrough.

As heretofore described, the vortex generators 20 provide a vortical movement of fuel and air into the liner. At the same time, air entering the liner from the first and second row of holes 24 and 26, enters as discrete streams which impinge at the center line. The vortical movement of air from generator 20 contains a low pressure core into which the flow of air from the impinging streams proceeds as indicated by arrows 29 and 30. As pressure is rising in the vortex, the fuel air mixture is being thrown outwardly into the annular spaces 31 and 32 surrounding the vortical movement of air of all generators. This provides forced rotating bands or toroids 33 and 34 of a burning fuel air mixture which are maintained in position and wherein a large amount of fuel is burned. Toroids 33 and 34 are an important combustion feature which locks the combustion process in the head end of liner 11, provides a high rate of turbulence, heat transfer, fuel air mixing, and combustion, in a relatively short period of time. Toroids 33 and 34 become a single toroid encircling or concentric with the vortical mass of air emanating from a vortex generator in a can-type burner. In the annular combustion chamber, two segmental toroids or bands are developed. For example, toroid 33 extends circumferentially about the annular chamber adjacent the outer wall. Toroid 34 therefor also extends circumferentially about the annular chamber adjacent the inner wall. The two toroids 33 and 34 are concentric with each other framing the row of vortex generators therebetween. A circumferential row of small slot openings 35 are employed to provide a film of cool air adjacent the wall of liner 11 for cooling purposes. These slots 35 also add air to the toroid feature. Such film cooling is prevalent in the art and is further illustrated by slots 36 which provide film cooling of the liner as is well known in the art.

Certain overall requirements are necessary to provide the combustion characteristics as described. Insofar as generators 20 are concerned, the air passing therethrough must, of course, be limited so that no air escapes through the first row of openings 24 and 26 in liner 11. In this invention even more drastic limitations are imposed. For example, considering stoichiometric combustion, less than half the air necessary passes through generators 20. By the same token, more than half the air necessary for combustion passes through liner openings 24, 25, 26 and 27. More specifically, a preferred operation limits the air passing through generators 20 to from about 10 to 20% of that necessary for combustion; otherwise, the toroidal burning and reverse flow are limited or so severely diminished that the overall efficiency of the burner is substantially less than optimum. By the same token, this limitation applies to the head end or portion 13 of the liner 11.

No other openings are provided adjacent or near the vortex generators because of the resultant effect on the described flow patterns. The minor exceptions are the small circumferential slots 35 which are employed primarily to provide a film of cooling air along the liner 11 walls without interfering with the established patterns.

The combustion thus described is with respect to an annular combustion chamber although from this description, its application to can-type combustion chambers is self-evident. In the annular combustion chamber the teachings of this invention provide the addition of a large amount of air in the head end of a combustion chamber in an effective manner for increased performance. At the same time, the requirements of rapid fuel air mixing and burning are more fulfilled.

Fuel air mixing is further benefited by the placing of generators 20 adjacent each other as illustrated in FIG. 2. The air streams emanating from adjacent generators are caused to impinge on each other with great degree of shearing action and consequent good fuel air mixing characteristics.

FIGS. 1 and 2 relate to a practical embodiment of this invention as utilized to provide propulsive power in turbojet engines. An exemplary combustion chamber follows the general proportions illustrated in FIGS. 1 and 2 with more salient features as set forth in the following table:

Table I

Type fuel nozzle	dual-cone.
Spray angle at S.L.S.[1]	90°/80°.
Type spray	hollow cone.
lb./hr. per nozzle @ S.L.S	666.
ηb [2] @ S.L.S	98.5%.
Heat release B.t.u./hr. @ S.L.S	389×10^6.
Liner volume (in.^{3})	13276.
Liner O.D	38.36".
Liner I.D	25.66".
Liner length from fuel nozzle	23.75".
# nozzles	32.
Pressure loss	5½–6%.
Space rate (B.t.u./hr.ft.^{3}/atm.)	6×10^6.

[1] S.L.S Sea level static

[2] ηb combustion efficiency.

In addition, the first three rows of holes 24 each comprise 32 equally spaced holes of 1 inch diameter, the rows being about 2 inches apart on centers. The last two rows of holes 25 each comprise 32 equally spaced holes of 0.86 inch diameter with the same axial spacing. The rows of openings 26 are similar to those of 24 and the openings 27 are similar to those of 25. Openings 25 of liner 11 have their center lines together with their channels or lips 28 tilted at a slight angle to the center line of liner 11 towards the closed end of liner 11 to further complement the reverse flow characteristics of liner 11. Liner 11 includes an upwardly curving lower surface 37 so that the openings 25 therein are even more angled or tilted. In the embodiment as described air from a compressor, for example, enters passage 17 to flow into the defined plenum 38 and then into liner 11 through openings 24, 25, 26 and 27, primarily. Air flow into generators 20 is controlled by a duct member 39.

Air flow through generators 20 comprise about 11% of W, i.e., the total flow from the compressor. Flow through the head end including slots 35 is about 5% of W. Flow from the first row of holes which recirculates is about 3½% of W.

FIG. 3 relates to a further operative embodiment of this invention. Referring to FIG. 3, the basic features follow those of FIG. 1 with the exception of the more salient features as given in Table II.

Table II

Type fuel nozzle	dual-cone.
Spray angle at S.L.S.	90°.
Type spray	hollow cone.
lb/hr. per nozzle @ S.L.S.	225.
ηb @ S.L.S.	97.0%.
Heat release B.t.u./hr. @ S.L.S.	49×10^6.
Liner volume (in.^{3})	1013.
Liner O.D.	15.48".
Liner I.D.	9.06".
Liner length from fuel nozzle	9.16".
# nozzles	12.
Pressure loss	6–7%.
Space rate (B.t.u./hr./ft.^{3}/atm.)	12×10^6.

Vortical air generators 40 are each about 1.65 inches O.D. and about 0.9 inch wide and are circumferentially equally spaced in closed end 41. The circumference of each generator 40 includes 10 equally spaced louvers 42 struck from the circumference and providing tangential openings of about ¾ inch in length and 0.08 inch in

thickness. Liner 43 openings on the outer periphery include three rows of openings 44 and four rows of openings 45. Openings 44 have a diameter of about 0.530 inch and the center line of the first row of openings is about 3 inches from the back vortex generators 20. Openings 45 are about 0.580 inch in diameter and the center line of the last row is about 7.56 inches from the back of vortex generators 20. All openings are spaced equidistant axially on center. Liner 43 openings on the inner periphery include three rows of openings 46 and three rows of openings 47. Center lines are the same as the outer rows. Openings 46 are about 0.75 inch in diameter and openings 47 about 0.530 inch in diameter. Louver openings 48 are positioned at the intersection of diagonals between any four adjacent openings and provide rectangular openings. Louver openings 49 are positioned like louver openings 48 and also provide rectangular openings.

A further embodiment of this invention is illustrated in FIG. 4. Referring to FIG. 4, there is shown a can-type or cannular type combustion chamber 50 comprising an outer casing 51, an inner perforated tapered Nerad type liner 52 and a radial wall structure 53 which closes one end of casing 51. Wall structure 53 includes a wall member 54 having a vortex generator 55 centrally disposed therein and a fuel nozzle 56 in said generator 55. Vortex generator 55 is similar to those generators 20 of FIGS. 1 and 2, having minor modifications in vane or louver design. Generator 55 comprises a cup-shaped housing 57 from which vanes 58 depend. About the internal periphery of housing 57 the vanes 58 depend inwardly and are adjusted to a converging angle to thus define passageways through which primary air is admitted into generator 55. The angle of the vanes 58 is arranged to direct the incoming air along a path which is nearly tangential to produce the swirling motion of a vortex into which the fuel is injected as described with relation to FIG. 1. Vanes 58 have been described as being adjusted to a converging angle. Such a converging angle is inclusive in a preferred form of this invention of a pair of angles. For example, good results have been obtained with a generator 55 in accordance with the teachings of this invention where each vane 58 is inclined at an angle from about 10 to 25° from the tangential direction of the assembled circle which is the periphery of housing 57. In addition, a preferred form of this modification includes the feature that individual adjacent pairs of vanes 58 define a converging nozzle or passage. Vanes spacing, i.e., the closest distance between adjacent vanes at the converging portion has been varied over a wide range of up to 1/16 of an inch or greater. In one form of this invention a generator 55 has a circle diameter of approximately 2¾ inches from which vanes 58 have been bent inwardly from the circle, each of said vanes being along its radial length approximately ¾ of an inch and inclined at an angle of 25°, together with an end spacing between adjacent blades of 1/16 of an inch. By this means, the sharp velocity gradient of the rotating mass of air breaks up the streams of fuel into fine particles which migrate outwardly due to centrifugal forces. This mixture of fuel and primary air is readily ignitible and is carried forward by the axial component of the motion of the air in a substantially vortical manner into the combustion chamber.

Wall structure 53 as illustrated has been effectively employed in a combustion chamber. Under adverse conditions, burning was effective and a forced rotating toroid 59 of burning fuel air mixture was definitely established adjacent wall 54 which effectively locked or maintained the combustion process in position. The aforementioned and illustrated particular flow pattern of a rotating toroid surrounding a vortical moving air mass is definitely established, because unless a fluid is directed or forced it will flow as a free vortex. Thus, the air expanding out of generator 55 forms vortices which take on a free vortex velocity distribution whereby the velocities at the inner boundaries of the vortices will be higher than at the outer boundaries. The corresponding pressures which are inversely proportional to the velocities squared will be lower at the inner boundaries of the vortices than at the outer boundaries of the vortices.

The juncture of liner 52 with wall 54 provides a sheltered area. Wall 54 also includes openings 60 so proportioned as to provide the desired division of air entering the liner through generator 55 and openings 61 of liner 52. During burner operation, the combustion provides a toroid 59 of a burning fuel air mixture in which a large percentage of fuel is burned, and which constitutes an important feature of the whole combustion process.

Accordingly, it is understood that by means of this invention, the optimum features of a Nerad combustion chamber are utilized, but at the same time, improved and complemented by vortex generator air delivery. The combination provides optimum and controlled combustion in discrete air fuel patterns. It is important to note that the toroid patterns developed are fully developed for fuel burning and that these patterns are not just eddies but forced rotating masses, rotating in the opposite sense as applied to fluid eddies. It is further important to note that this combination not only provides for a substantial amount of fuel to be burned in the toroid mass but also serves hold or maintains the complete combustion process closer to the head end. Thus, where transit time is very short, more time is given to the combustion process for more complete combustion. The toroidal pattern in all modifications is provided for by predetermined sheltered and defined areas, by predetermined air flow patterns.

While a specific method and apparatus in accordance with this invention has been shown and described, it is not desired that the invention be limited to the particular description nor to the particular configurations illustrated, and it is intended by the appended claims to cover all modifications within the spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a closed head end and open exhaust end reverse flow perforated combustion chamber liner wherein a portion of the entering air from the perforations flows in an upstream direction towards the closed end, the improvement comprising, an air vortex generator in said closed end adapted to provide a vortical movement of air in said chamber liner flowing in opposition to said portion of air flowing towards said closed end so that the low pressure core of said vortical air movement receives said upstream flow, vaned opening means in said air vortex generator providing less than one-half the amount of air necessary for stoichiometric combustion, a fuel injector in said air vortex generator to spray fuel axially into said vortical air movement, and a sheltered area in said closed end of said combustion chamber in cooperative relationship to said air movements to provide a band of a fuel-air mixture adjacent said closed end where a substantial portion of the fuel in said combustion chamber is burned.

2. A combustion chamber comprising in combination, a casing, a perforated liner spaced within said casing, said liner having a closed end and an open end and adapted to provide for the combustion of a fuel-air mixture therein to be discharged from said open end, said liner having a plurality of predetermined circumferential rows of predetermined openings therein spaced from said closed end, means to pass combustion air through said openings to provide impinging streams of air into said liner for an axial flow of air towards said closed end, an air vortex generator in said closed end, said vortex generator having vaned opening means therein adapted to direct a vortical mass of air into said liner so that the low pressure core of said vortical mass of air encompasses

said axial flow of air flowing towards said closed end, a fuel nozzle concentrically positioned within said vortical air generator to inject fuel axially into said liner so that fuel is taken up by said vortical air mass and said axial flow to form a band of a fuel-air mixture surrounding said vortical air movement and adjacent said closed end wherein a substantial portion of the fuel in said chamber is burned, said air vortex generator supplying less than one-half the air necessary for stoichiometric combustion.

3. A combustion chamber comprising in combination, a tubular liner having an open and closed end, said liner adapted for the combustion of a fuel-air mixture therein the products of which exhaust through said open end, said liner having a plurality of predetermined circumferential rows of predetermined openings therein spaced from said closed end so that combustion air enters said openings in impinging streams for an axial flow of air towards the closed end of said liner, an air vortex generator in said closed end of said liner to provide a vortical movement of air into said liner to encompass in its low pressure core said axial air flow, a fuel nozzle positioned coaxially within said air vortex generator to inject fuel into said vortical movement of air so that the fuel is entrained by said vortical movement of air, vane opening means on said air vortex generator providing a radial component of air delivery into said generator limiting the amount of air through said generator to less than about one-half the amount of air necessary for stoichiometric combustion, said air vortex generator and said liner combining to provide a band of a fuel-air mixture surrounding said air vortex generator and adjacent said closed end wherein a substantial portion of fuel is burned.

4. An annular combustion chamber comprising in combination an elongated casing defining an air passage, a reverse flow closed head end and open exhaust end perforated liner positioned in said casing with said closed end in the upstream position so that a flow of air entering the perforations of said liner meet in impinging streams in said liner to cause a portion thereof to flow in the upstream direction towards said head end, an air vortex generator in the head end of said casing to provide a low pressure core of vortical air movement into said liner to receive said reverse flow of air in said liner into said low pressure core, means to inject fuel into the vortical movement of air from said vortex generator, means to ignite said fuel, said air vortex generator, closed end, and liner, providing a sheltered area in said head end whereby the flow of fuel and air into said liner is directed to provide a burning toroid of fuel-air mixture adjacent said closed end and surrounding said vortical air movement.

5. An annular combustion chamber liner comprising in combination an annular closed head portion and an annular perforate open end body portion extending therefrom, said perforate body portion including a series of circumferential predetermined rows of predetermined openings so that when said liner is positioned axially in an air stream flowing from the said closed end to the said open end air enters said openings in impinging streams to provide an axial flow of air towards said closed end, a circumferential row of equally spaced cup-shaped air vortex generators positioned in said closed head end portion in axial relationship to the said liner, axially extending vane means defining radially openings in said air vortex generators to provide low pressure core vortical movements of air into said liner so that said axial flow of air proceeds into said low pressure cores, means to inject fuel from said air vortex generator axially into said low pressure cores, means to ignite said fuel, said air vortex generators, said closed end and said liner cooperating to provide rotating forced toroidal patterns of a fuel-air mixture around said low pressure core, said vane means limiting the air flowing therethrough to less than about one-half that necessary for stoichiometric combustion.

6. In a combination chamber positioned in a fast-moving air stream, the combination comprising, an elongated perforated reverse flow annular liner having a closed head end and an open exhaust end, said liner positioned in said fast-moving air stream so that air enters said liner through the perforations so that a portion thereof flows axially towards said head end, a circumferential row of vortex generators in the head end of said liner and positioned in axial relationship to said liner to provide vortical movements of air into said liner with low pressure cores so that the reverse air flow in said liner enters said low pressure cores, said cup shaped air vortex generators including axially extending vaned openings in the peripheral wall thereof, said vaned openings providing for a radial and tangential inlet for the entering air into said generators, each of said generators being spaced sufficiently close to an adjacent generator so that the air vortices emanating from one of said generators radially overlaps with the air vortex emanating from an adjacent generator and shearing action between the air flows takes place in said liner closely adjacent said row of generators, means to inject fuel axially through each generator into said liner, means to ignite said fuel, said air vortex generators, closed head end, and liner, cooperating to provide a sheltered area in the head end thereof whereby the air flow into said liner provides a pair of concentric toroidal patterns of a burning fuel-air mixture in said sheltered area framing said generators, said vane opening means in said air vortex generator admitting between about 20 to 50 percent of the air necessary to provide stoichiometric combustion in said combustion chamber.

7. A combustion chamber comprising in combination, a substantially cylindrical open end casing defining an air flow passage, a radial inlet wall structure closing one end of said casing, a cup shaped air vortex generator having a closed upstream wall and a peripheral wall having vaned openings defining tangential air inlets, said generator positioned in said wall structure to provide a rotating vortical pattern of air into said casing substantially less than that necessary for complete combustion, a fuel nozzle coaxial with said inlet wall structure and projecting through said closed upstream wall of said air vortex generator to inject fuel axially into said rotating vortical air pattern, a perforated tubular liner spaced within and coaxial with said casing and joining said radial wall structure, said liner having spaced circumferential rows of openings longitudinal thereof to provide impinging streams of air entering said liner a portion of which flows in the upstream direction, said liner entrance surrounding said air vortex generator, said radial wall structure having openings therein between the said liner juncture and said casing, said radial inlet wall structure and said perforated liner combining their respective air flows to generate a forced toroidal burning fuel-air mixture at said juncture about said vortical air pattern from said air vortex generator, said openings in said radial wall and the first row of openings in said liner being of a predetermined size to admit combustion air to said toroid to strengthen and maintain said toroid in its operative relationship.

8. The invention as described in claim 6 wherein said liner tapers from a smaller entrance into a larger exit end.

9. In a jet engine combustion chamber including an axial casing and an axial liner therein a method of combining a plurality of fuel air patterns to provide a high space heat release combustion chamber which consists of generating an axially moving rotating vortical air mass with a low pressure core and passing through said liner, introducing fuel centrally and axially of said rotating vortical air mass, maintaining the quantity of

air in said air mass at less than about one-half the amount of air necessary for stoichiometric combustion of said fuel, introducing additional air into said vortical rotating air mass radially thereof to supply the remainder of air necessary for the combustion of said fuel, correlating the air in said vortical air mass and the said additional air so that reverse flow characteristics are provided in said liner and a portion of said additional air flows upstream into said low pressure core, said correlation providing a forced toroid of a fuel-air mixture about said vortical rotating air mass at the originating end thereof,

maintaining the individual fuel air patterns distinct throughout the combustion process, and burning a substantial amount of the introduced fuel in said toroidal pattern.

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