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REVERSE VORTEX COMBUSTION CHAMBER

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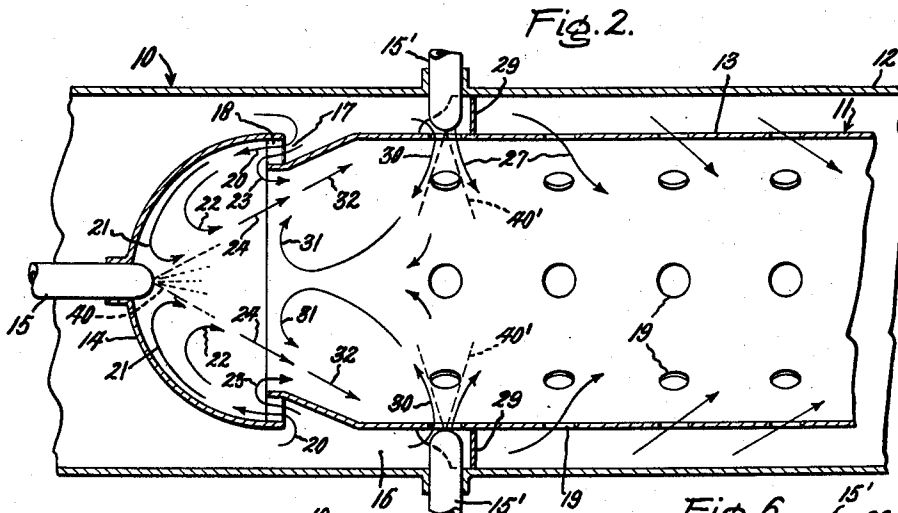
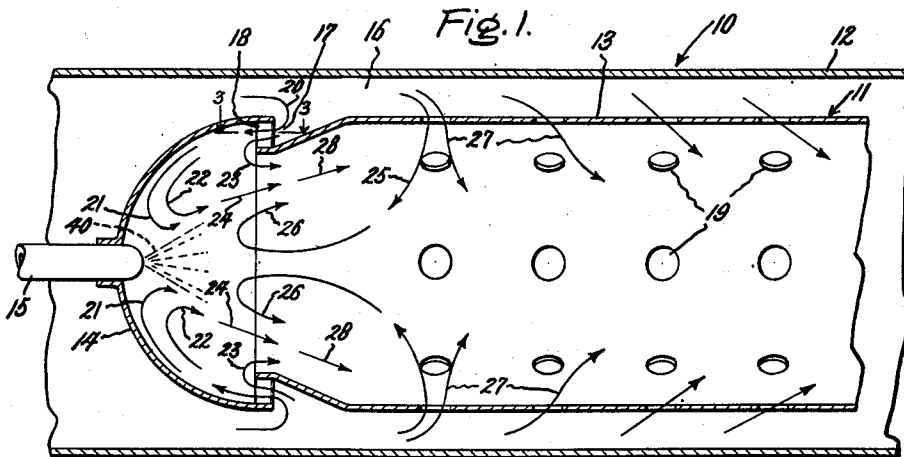


Fig. 3.

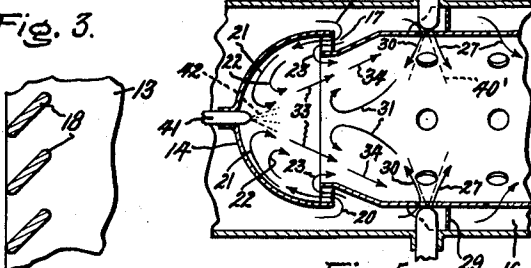
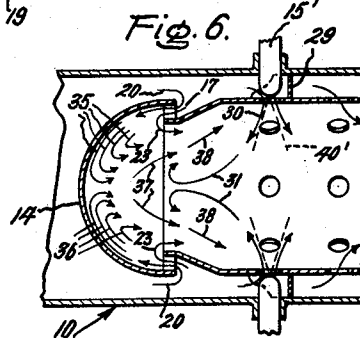


Fig. 4.



Fig. 5.



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REVERSE VORTEX COMBUSTION CHAMBER

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3 Claims. (Cl. 60—39.65)

This invention relates to combustion chambers and specifically to those utilizable as prime movers in gas turbine power plants, for the jet propulsion of aircraft, and in commercial oil and gas burners.

Combustion chambers capable of releasing large amounts of energy per unit volume are desirable in the gas turbine cycle and for small compact fuel burners. The high velocities and temperatures of combustion over wide ranges of operating conditions raise the problems of stability and completeness of reaction within the combustion chamber and the cooling of combustion wall surfaces. The latter to some extent may be overcome at least partially by air cooling. In those cases where the combustion reaction is unstable or incomplete, extinguishment of the flame in the combustion chamber may take place.

Accordingly, it is an object of my invention to provide a new and improved structure for use as a combustion chamber.

It is another object of the invention to provide an improved combustion chamber capable of very rapid changes in the rate of heat release without serious disturbance to the combustion process.

It is another object of the invention to obtain a higher space rate of combustion while maintaining the combustion chamber wall surfaces relatively cool.

It is a further object of the invention to provide a combustion chamber capable of effecting ready ignition and efficient combustion over a very wide range of combustion space pressures and fuel flows, as is required, for example, in thermal power plants for high altitude aircraft.

In carrying out my invention in one form, the flow set up in the reverse vortex primary combustion complements the back flow inside the liner whereby a stronger flame core is provided which results in a more stable combustion.

These and various other objects, features and advantages of the invention will be better understood from the following description taken in connection with the accompanying drawing in which

Fig. 1 is a longitudinal cross section of a preferred embodiment of my invention applied to a combustion chamber structure;

Fig. 2 is a longitudinal cross section of a modified combustion chamber structure;

Fig. 3 is a partial transverse section taken along line 3—3 of Fig. 1;

Fig. 4 is a perspective view of the deflecting member shown in Fig. 2;

Fig. 5 is a longitudinal cross section of a modified combustion chamber structure; and

Fig. 6 is a longitudinal cross section of another form of a modified combustion chamber structure.

Referring to Figs. 1 and 3 in the drawing, a combustion chamber, which can be used in gas turbine construction or where large quantities of heated air are re-

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quired to be obtained from the burning of fuel, is indicated generally at 10, comprising two coaxial walls, an inner wall or liner 11 and an outer wall 12 held in spaced relation to each other by suitable attaching means, for example, such as by a number of circumferentially spaced axially extending fins (not shown) which may be welded or otherwise fixed to either one or both of walls 11 and 12. The liner 11 may take the form of a substantially cylindrical body portion 13 open at the downstream or exhaust end and extending toward an enlarged dome or closed head portion 14. The fuel inlet 15 projects through the center of the closed head portion 14 in the form of a spray nozzle to give a finely divided spray of fuel from a fuel supplying means such as a fuel pump (not shown). The space between walls 11 and 12 forms a passage 16 to which air is supplied by appropriate means, not shown, at the left end of the combustion chamber as viewed in Fig. 1, at whatever pressure is found desirable.

A series of angularly directed apertures 17 are located about the enlarged end of the closed head portion 14 and form passageways through which primary air is admitted into the head portion 14. The apertures 17 may comprise a circular row of turning vanes 18, the angle of the vanes being arranged to direct the incoming primary air along a path which is nearly tangential to produce a swirling motion of a vortex into which the fuel is injected. In the body portion 13 of the liner 11 are a plurality of circumferentially spaced axially extending rows of holes 19 through which supplementary combustion air and diluting air passes from the passage 16 to the axially elongated space defined by inner wall 11. In the present instance, four longitudinal rows of holes are illustrated and shown as equally spaced circumferentially. It will be seen that the axial rows of holes 19 are arranged so that corresponding holes in the respective rows are in a common plane normal to the axis of the chamber.

Primary air is forced upstream towards the closed end of the head portion 14 through the angularly directed apertures 17 and nozzle vanes 18 causing a high velocity vortex flow into the head 14 as indicated generally by the arrows 20. The vortical flow of primary air within the closed head portion 14 reverses its direction of flow as indicated by the arrows 21 and 22. The portion of the air flow indicated by arrows 21 provides air for cooling the dome 14 through the conservation of angular momentum. As the air 21 is heated along its path of flow, the velocity rises and a constant heat transfer is provided. Cooling air is also provided for a portion of the inner wall of the body portion 13 of the liner 11 by a portion of the primary air flow as indicated by arrows 23 which is a result of the natural outflow of the vortex. In a first form of fuel air mixing, fuel 40 is sprayed into the liner 11 at the closed end thereof where most of it is entrained by the primary swirling air after the vortex has reversed its direction of flow as indicated by the arrows 24. This vortical air flow and reverse vortex flow of the fuel-air mixture leads to complete and stable combustion. The air that mixes with the fuel first has been preheated during its vortical flow out from the nozzle vanes 18, the helical flow path results in a longer heating period for the air, and it is in the zone of reversed fuel-air mixture as indicated by arrows 24 that ignition is started by conventional means, none being shown here.

The vortical flow of air through the angularly directed apertures 17 causes a low pressure in the center of the flow. This induces an inflow of supplementary air indicated by the arrows 25 into the core of the flame. This flow is important for stability of the flame and for

increasing the space rate of combustion. The inflow is provided by the upstream flow of air resulting from the air jets entering the liner 11 through the first ring of liner holes. The air entering through the first ring of liner holes 19 will be preheated by the combustion products it passes through and entrains. The air reverses its direction of flow as indicated by arrows 26 and starts to flow back out along the inner wall of the liner 11. The reverse fuel-air and air mixtures indicated by the arrows 24 and 26, respectively, combine and flow back out along the inner wall of the liner 11 as indicated by the arrows 28 between the rows of air jets shown by arrows 27.

Additional supplementary air necessary for combustion and for dilution of the product to the desired temperature, as indicated by the arrows 27, is provided by the holes 19 in the liner 11 in the conventional manner. Cooling off the outer wall 12 and the liner 11 is also provided by the air flow from the air source as it flows through passage 16.

The fuel injection system need not be as critical as is necessary in most combustion systems because the air vortex assists in atomizing the injected fuel and its mixing with the air and by keeping the reactants in contact with one another for a maximum length of time.

Fig. 2 is a modification of a combustion chamber used to provide additional or second form of fuel-air mixture comprising a series of fuel inlet nozzles mounted coaxially about the body portion 13 of the liner 11 in axial alignment with the first ring of liner holes 19. The construction and operation of both the preferred embodiment of Fig. 1 and the modification of Fig. 2 are similar with the exception of the additional fuel inlet means and air direction means mounted therearound whose operation is more fully set forth hereinbelow.

As in Fig. 1, a combustion chamber is shown generally at 10, comprising a liner 11 mounted coaxially within an outer wall 12. The liner 11 is shown as a substantially cylindrical tube having a body portion 13 open at the downstream or exhaust end and extends toward a dome or closed head portion 14. A fuel inlet nozzle 15 is centrally mounted in the closed head portion 14 for admission of fuel from a fuel source such as a fuel pump (not shown). Angularly directed apertures 17 having turning vanes 18 are mounted around the base of the dome or closed head portion 14 for vortical admission of combustion and cooling air. A series of circular rows of openings 19 are provided in the liner 11 for the admission of supplementary combustion air and diluting air. Air is admitted from an air source such as a compressor (not shown) through passage 16 provided between the liner 11 and outer wall 12 to the apertures 17 and the liner openings 19.

In connection with the first ring of holes 19 in the liner 11, there are provided additional fuel inlet nozzles 15' through which fuel may be discharged into closed head portion 14. In the present instance, two additional fuel inlet nozzles 15' are illustrated, the same being arranged diametrically opposite each other. This modification allows an unlimited fuel flow that will not quench the primary combustion flame; provides vaporization and gasification of the fuel, and very rapid combustion reaction. A flow deflecting member 29, as best shown in Fig. 4, is mounted around each of the holes in the first ring of openings 19 about which a fuel inlet nozzle 15 is coaxially mounted for purposes to be hereinafter described.

In the above arrangement, part of the air flow entering the passage 16 is deflected by the deflecting member 29 and enters the apertures in the first ring of openings 19 of the liner 11 about which the fuel inlet nozzles 15 are mounted. The atomized fuel 40' is injected with the air entering through the first ring of combustion air holes 19. The fuel-air mixture indicated by the arrows 30 enters the hollow core of the vortex flow created by the angularly directed apertures 17 thereby raising the tempera-

ture of the fuel-air mixture up to a high value. The fuel-air mixture 30 reverses its direction of flow as shown by the arrows 31 and combines as a third mixing form with the reversed directional fuel-air mixture indicated by the arrows 24 to flow back out along the inner wall of the liner 11 as indicated by the arrows 32. The fuel flow into the closed head portion 14 can, if desired, be constant, with all of the fuel metering occurring at the multiplicity of fuel nozzles at the first ring of liner holes 19. The use of a multiplicity of fuel nozzles would eliminate the need for a complex fuel nozzle such as the duplex type having more than one set of fuel slots. The limited range of pressure drops giving good atomization to the swirl type nozzle will be overcome by shutting off one nozzle at a time as the fuel demand is decreased. Thus the atomization of the remaining nozzles will remain good.

The mixing and flow pattern of primary air admitted through apertures 17 with the fuel admitted through the centrally mounted fuel nozzle 15 is identical with the operation of the combustion chamber shown in Fig. 1 and described above. Accordingly, the detailed description is not again repeated for Fig. 2.

The modified combustion chamber shown in Fig. 2 may be considered as a vaporizing type of burner. That is, the heat released in the closed head portion is used for heating and vaporizing the major part of the combustion air and fuel, respectively. This modified combustion chamber, unlike most types of fuel vaporizers, does not use a hot metal plate or heat exchanger to achieve the vaporizing process. Rather by properly injecting and mixing the fuel and air, conditions are set up in the air streams themselves that allow the hot products from the combustion taking place in the reversed vortex at the closed head portion 14 of the liner 11 to vaporize and gasify the greater part of the fuel entering inside of the first ring of combustion air holes 19. The remainder of the combustion and diluting air is brought in through the remaining liner holes 19 in the conventional manner for obtaining the desired temperature.

Figs. 5 and 6 are further modifications of combustion chambers. The construction and operation of the embodiment of Fig. 2 and the further modifications of Figs. 5 and 6 are similar with the exception of a pilot burner being substituted in the combustion chamber shown in Fig. 5, and of a closed head portion substituted in the structure shown in Fig. 6, for the centrally mounted fuel inlet nozzle shown in Fig. 2. Accordingly, the above detailed description of the construction and operation of the combustion chamber will not be restated since similar parts have the same reference numerals throughout the description and in the drawing.

In connection with the head portion 14 of the liner 11 as shown in Fig. 5, a pilot burner 41 having a flame 42 issuing therefrom is centrally mounted in a head portion 14. The pilot burner 41 prevents extinguishment of the flame tore within the liner 11 thereby providing a combustion chamber which may be used over a very wide range of combustion space pressures and fuel flows. The injection of air 30 and fuel 40' through the first row of openings in the body portion 13 of the liner 11 is accomplished in the same manner as described above in the operation of the chamber shown in Fig. 2. Primary air is forced upstream toward the closed end of the head portion 14 through the angularly directed apertures 17 and nozzle vanes 18 causing a high velocity vortex flow into the head 14 as indicated generally by the arrows 20. The vortical flow of primary air within the closed head portion 14 reverses its direction of flow as indicated by the arrows 21, 22 and 23. The portion of the air flow indicated by the arrows 21 provides air for cooling the wall of the dome 14. Cooling air is also provided for part of the inner wall of the body portion 13 of the liner 11 by a portion of the primary air flow as indicated by arrows 23. The vortical primary air flow reverses its

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direction of flow as indicated by the arrows 33. The fuel-air mixture also reverses its direction of flow as shown by the arrows 31 and combines with a reversed directional air flow indicated by the arrows 33 to flow back out along the inner wall of the liner 11 as indicated by the arrows 34 between the rows of air jets shown by the arrows 27. The pilot burner 41 provides for the further burning of any excess fuel contained in the fuel-air mixture injected through the openings of the first rows of holes 19 in the liner 11.

In connection with the combustion chamber structure shown in Fig. 6, the dome or head portion 14 is completely closed. There is no centrally mounted fuel inlet nozzle or pilot burner provided in the dome 14. The injection of the fuel-air mixture through the first row of openings 19 in the liner 11 is accomplished in the same manner as disclosed hereinabove in the combustion chamber structures shown in Figs. 2 and 5. Air is forced upstream toward the closed end of the dome or closed head portion 14 through the angularly directed apertures 17 and nozzle vanes 18 causing a high velocity vortex flow into the head portion 14 as indicated generally by the arrows 29. The vortical flow of air within the closed head portion 14 reverses its direction of flow as indicated by the arrows 35 and 36. The air flow indicated by the arrows 35 and 36 provides air for cooling the wall of the dome 14. Cooling air is also provided for the inner wall of the body portion 13 of the liner 11 by a portion of the primary air flow as indicated by the arrows 23. Some of the fuel-air mixture also reverses its direction of flow as shown by the arrows 31 and combines with the reversed directional air flow indicated by the arrows 37 to flow back out along the inner wall of the liner 11 as indicated by the arrows 38 between the rows of air jets shown by the arrows 27.

In both the preferred embodiment of Fig. 1 and the modifications of Figs. 2, 5, and 6, a standard means of ignition such as a spark plug may be used, although none is disclosed herein.

As will be apparent to those skilled in the art, the objects of my invention are attained by the use of concentric strong vortex formations of primary and secondary air which produce a low pressure area adjacent the center of the flow inducing intimate atomizing and mixing of combustion air and fuel so that not as fine an atomization is required to achieve atomization of injected fuel. The flow set up in the reversed vortex supplements the back flow inside the liner 13 as described in U.S. Patent No. 2,601,000, issued in the name of Anthony J. Nerad, and having the same assignee as the present application. That is, the low pressure resulting from the vortex flow in the head 14 allows more of the back flow from the air coming in the first ring of holes. A stronger torque will result in a more stable combustion since the resulting thermal regeneration is necessary for high rates of combustion reaction over a wide range of pressures, fuel rates, and air fuel ratios.

While other modifications of this invention and variations of apparatus which may be employed within the scope of the invention have not been described, the invention is intended to include all such as may be embraced within the following claims.

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

1. In a combustion chamber for gas turbines and the like, the combination comprising an outer casing adapted for the flow of air therethrough, a liner having a series of circumferential rows of openings therein positioned axially in and spaced from said casing, a domed closed head portion axially enclosing, spaced from, and overlying one end of said liner to provide a circumferential air inlet between the dome and the liner, a fuel nozzle centrally positioned in said dome to spray fuel axially into said liner, vanes in said circumferential inlet to provide a vortical movement of air into said dome toward

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said fuel nozzle, means including the curvature of said dome and the position of said circumferential air inlet to reverse the said vortical movement of air to flow vortically into said liner and to entrain fuel from said fuel nozzle, a pair of additional fuel nozzles positioned in said casing without said liner and adjacent a pair of holes in the first circumferential row on said liner to provide impinging streams of fuel-air mixture, whereby there is provided a vortical movement of a fuel air mixture from the said dome into the said liner, and a portion of the fuel air mixture from said impinging streams is caused to move towards said dome to mix with the fuel air mixture moving from said dome.

2. A high space heat release combustion chamber comprising in combination, a plurality of discrete coacting fuel-air mixing means, said combustion chamber including an outer casing for the flow of air therethrough, a sleeve having a series of circumferential rows of openings therein and positioned coaxially within said casing, an imperforate dome-shaped end cap enclosing one end of said liner, one of said fuel-air mixing means comprising a plurality of primary air apertures between said dome and the end of said liner, a fuel nozzle positioned centrally in said end cap to direct a fuel stream axially through said liner, vanes in said air apertures directing a rotating flow of air surrounding said fuel stream and oppositely thereto, means including the curvature of said dome to reverse the in-flow of air from the said vanned air openings to flow parallel to said fuel stream and entrain fuel therein, a second fuel-air mixing means comprising a plurality of oppositely positioned first row of secondary air openings circumferentially in said liners and spaced from said end dome, a plurality of fuel nozzles spaced from and positioned coaxially with said air openings and in opposition with each other, said nozzles and said openings providing impinging fuel-air streams centrally into said liner, a third mixing means comprising means including the position of said oppositely directed fuel nozzles and the position of the central fuel nozzle and air openings in said end cap to provide a flow of a fuel-air mixture from the impinging fuel-air stream to flow into the fuel-air mixture envelope emanating from said end dome.

3. In a high space heat release combustion chamber including a casing for a flow of air therethrough, a sleeve positioned coaxially within said casing, and a domed closed end on said sleeve, means providing plural forms of fuel-air mixing and flow patterns comprising a first fuel-air mixing form, said form including a circumferential row of primary air openings adjacent the closed end to direct air into said closed end in an upstream direction, a fuel nozzle centrally located in said closed end to spray fuel axially into said sleeve, said fuel and air nozzles coacting with the curvature of said dome to provide a reversal of the air entry into said dome to flow in the same direction as the fuel from the said fuel nozzle and to entrain portions of said fuel, a second fuel-air mixing form comprising a first row of secondary air of openings circumferential of the said sleeve and spaced from said air nozzles, a plurality of fuel nozzles positioned coaxially with said openings and spaced therefrom to provide a plurality of impinging fuel air streams centrally into said sleeve, and a third fuel-air mixing form comprising said first and second fuel-air mixing means positioned in relation to each other to provide centrally impinging fuel air streams perpendicular to the axis of the liner to provide opposite flow axially thereof, means to provide a blending of said fuel-air mixing forms, said means including the first fuel-air mixing form providing a rotating envelope of a fuel-air mixture flowing into said liner, and the third fuel-air mixing form adjacent to said first but spaced therefrom providing a portion of the impinging fuel-air stream to flow towards said rotat-

ing envelope of the fuel-air mixture for blending of both fuel-air mixtures.

References Cited in the file of this patent

UNITED STATES PATENTS

2,510,645	McMahan	June 6, 1950	2,635,426
2,552,492	Nathan	May 8, 1951	2,637,974
2,552,851	Gist	May 15, 1951	2,646,664
2,555,965	Garber	June 5, 1951	2,657,531
2,579,614	Ray	Dec. 25, 1951	2,679,295
2,581,999	Blatz	Jan. 8, 1952	2,734,560
2,601,390	Hague	June 24, 1952	2,745,250
2,602,292	Buckland et al.	July 8, 1952	2,752,753
2,603,064	Williams	July 15, 1952	2,768,497

5

10

Meschino	Apr. 21, 1953
Nathan	May 12, 1953
Meschino	July 28, 1953
Pierce	Nov. 3, 1953
Parsons	May 25, 1954
Harris et al.	Feb. 14, 1956
Johnson et al.	May 15, 1956
Dooley	July 3, 1956
Hayes	Oct. 30, 1956

FOREIGN PATENTS

Germany	May 30, 1923
Great Britain	Feb. 24, 1947
Great Britain	May 14, 1952

376,570
585,763
671,937