Oct. 20, 1964 J. R. HAMM 3,153,323

INTERNAL COMBUSTION APPARATUS

Filed March 31, 1954

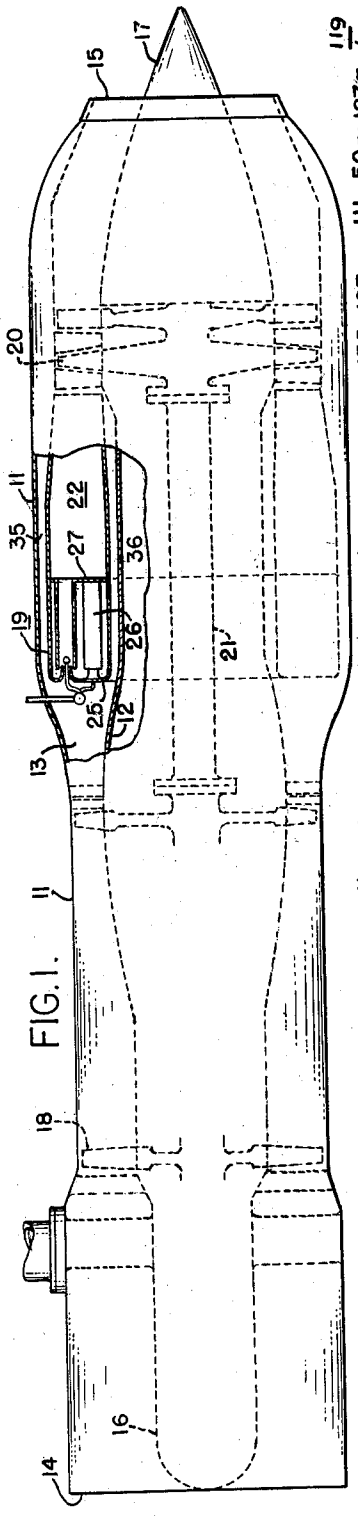


FIG. 1.

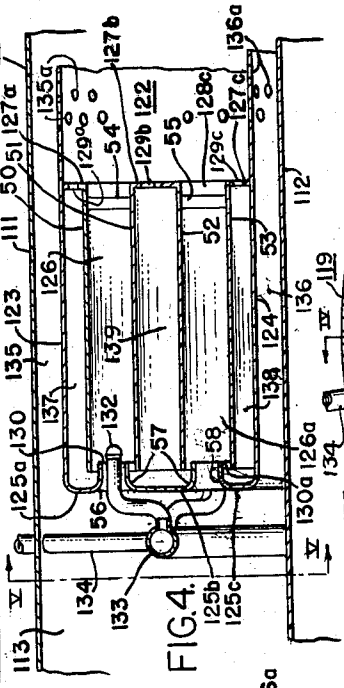


FIG. 4.

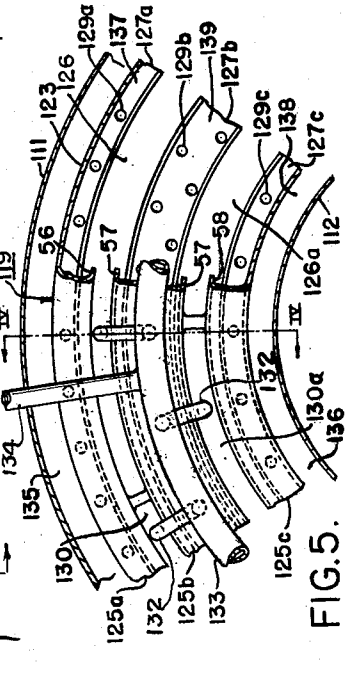


FIG. 5.

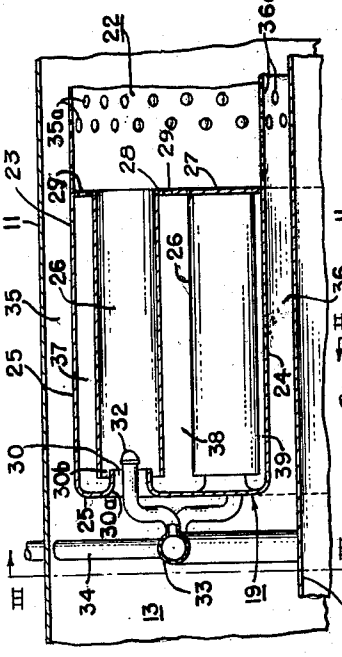


FIG. 2.

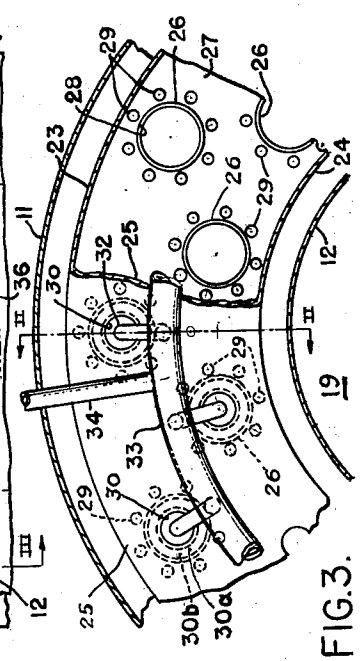


FIG. 3.

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INTERNAL COMBUSTION APPARATUS

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This invention relates to combustion apparatus, and more particularly to liquid fuel combustion apparatus for a gas power plant or the like.

In operation of combustion apparatus in a gas power plant, it is desirable to effect mixture of the finely divided fuel with air and to rapidly preheat the mixture immediately before combustion thereof, to insure greater combustion efficiency and flame stability.

It is an object of the invention to provide improved combustion apparatus for a gas power plant, or the like, constructed and arranged to effect rapid vaporizing and preheating of the fuel and air mixture.

Another object of the invention is to provide combustion apparatus of the above type constructed and arranged to provide recirculation of a part of the hot products of combustion through the fuel vaporizing means.

A more specific object is to provide combustion apparatus in an annular passage, which apparatus is arranged to provide recirculation of air and part of the hot products of combustion through the fuel vaporizing means.

These and other objects are effected by the invention as will be apparent from the following description taken in connection with the accompanying drawings, forming a part of this application, in which:

FIG. 1 is a diagrammatic view, partly in section, of a gas turbine power plant having combustion apparatus made in accordance with one form of the invention;

FIG. 2 is an enlarged detail, sectional view of a portion of the combustion apparatus shown in FIG. 1;

FIG. 3 is a fragmentary sectional view taken on line III—III of FIG. 2, and indicating the section line II—II along which the latter is taken;

FIG. 4 is an enlarged detail, sectional view similar to FIG. 2, but showing another form of the invention and;

FIG. 5 is a fragmentary sectional view taken on line V—V of FIG. 4, and indicating the section line IV—IV along which the latter is taken.

Referring to the drawings in detail, a typical aviation gas turbine power plant is illustrated diagrammatically in FIG. 1, the essential elements of which comprise an outer casing structure **11**, which may be made of a number of cylindrical sections and which has mounted therein an inner core structure **12** cooperating with the outer casing structure **11** to form an annular flow passageway **13** which extends longitudinally through the power plant from an air intake opening **14** to a discharge nozzle **15**. The core structure **12** may include an axially disposed, forwardly directed fairing cone **16** mounted adjacent the intake opening **14** and adapted to house fuel and oil pumps, ignition apparatus, etc., and a rearwardly directed fairing cone **17** mounted along the longitudinal axis of the casing adjacent the exhaust nozzle **15**. It will be understood that the casing structure **11** is adapted to be mounted in or on the fuselage or wing of an air ship, with the inlet opening **14** pointed forwardly.

The operating elements of the gas turbine plant are arranged in axial alignment and include an axial-flow compressor **18**, combustion apparatus **19** and a turbine **20** which is operably connected to the rotor of the compressor **18** by means of an axially disposed shaft **21**.

The operation of the gas turbine plane illustrated in FIG. 1 is well known and briefly is as follows: Air entering the annular intake opening **14** flows to the compressor

18, which pressurizes the air and delivers it along the annular passage **13**, to the combustion apparatus **19** where it supports combustion of fuel, which may be admitted thereto in a manner which will hereinafter be described. The products of combustion thus generated, together with heated air, form a hot motive fluid which is expanded through the turbine **20** for driving the compressor **18**, and is then exhausted to the atmosphere through the nozzle **15**, usually in the form of a jet establishing a propulsive thrust.

Referring to FIGS. 2 and 3, in which one embodiment of the invention is shown, the combustion apparatus **19** is of annular form and is disposed in the annular passage **13** between the outlet of the compressor **18** and the inlet of the turbine **20** and comprises a combustion chamber **22** provided by an outer tubular wall **23** and an inner tubular wall **24** disposed in spaced coaxial relation with each other, the outer casing **11** and the inner core structure **12**. The outer and inner combustor walls **23** and **24** are connected to each other at their upstream ends (to the left as shown in the figures) by an annular plate **25**, hereinafter referred to as the upstream plate. A plurality of axially extending vaporizing tubes or chambers **26** are mounted within the inner and outer combustion walls **24** and **23**, preferably in two circular rows and in staggered relation with each other, as best shown in FIG. 3. An annular partition **27** joined to the inner and outer combustor walls **24** and **23**, respectively, may be provided for supporting the tubular vaporizing chambers **26**. The partition **27** is provided with a series of large openings **28** disposed in registry with the vaporizing chambers **26** and is further provided with a plurality of smaller openings **29** which may be arranged in any pattern, for example, in circular rows encompassing the openings **28**.

The upstream plate **25** is provided with a plurality of openings **30** for admitting primary air from the passage **13** into the vaporizing chambers **26**. Each of the openings **30** is defined by curved surface portions **30***a* of the upstream plate **25**, which curved portions extend into the vaporizing chambers a short distance and are spaced from the walls of the vaporizing chambers by an annular space **30***b*, thereby forming an air ejector structure.

Fuel may be admitted to the vaporizing chambers **26** by a plurality of fuel nozzles **32** which preferably extend through the openings **30** and which may be connected to a source of fuel supply (not shown) by a common manifold **33** connected to a fuel supply line **34**.

It will be noted that the outer and inner combustor walls **23** and **24** form annular air passageways **35** and **36** for flow of diluent air for cooling the casing **11**, the core structure **12** and the hot products of combustion prior to admission of the latter to the turbine.

Part of this air may be diverted to the combustion chamber **22** through a plurality of openings **35***a*, **36***a* provided in the outer and inner combustor walls **23** and **24** respectively. It will be noted that the openings **35***a* and **36***a* are provided in those portions of the walls **23** and **24** which lie downstream of the vaporizing chambers **26**.

The vaporizing chambers **26** are spaced from the outer and inner combustor walls **23** and **24** respectively, thereby forming recirculation passages **37**, **38** and **39** connecting the combustion chamber **22** with the upstream end of the vaporizing chambers. It will be noted that in the arrangement shown, the recirculating passages **37**, **38** and **39** are in communication with each other.

In operation, with pressurized air from the compressor flowing through the annular passageway **13**, primary air is delivered to the vaporizing chambers **26** by means of the openings **30** in the upstream plate. Fuel supplied by the nozzles **32** into the vaporizing chambers **26** is mixed with the primary air passing through the vaporizing chambers and flows downstream through the openings **28** into

the combustion chamber. By suitable ignition means (not shown) the fuel mixture is ignited and the resulting hot motive gases flow downstream to the turbine **20** where they are expanded, creating a resultant rotation of the shaft **21** and the rotor of the compressor **18**. They are then discharged through the exhaust nozzle **15** in the form of a propulsive jet. Some of the air flows from the diluent air passages **35** and **36** through the apertures **35***a* and **36***a* into the combustion chamber **22** where it serves to cool the hot motive gases to a temperature which can safely be accommodated by the turbine.

Part of the hot motive gases are drawn through the apertures **29** in the partition **27**, through the recirculation passages **37**, **38** and **39**, through the annular spaces **30***b* into the vaporizing chambers by ejector action of the curved surface portions **30***a* in the upstream plate. These hot motive gases are at a sufficiently high temperature to promote vaporization of the fuel and air mixture within the vaporizing chambers **26**, thereby preparing such vaporized mixture for more thorough combustion prior to delivery to the combustion chamber.

The air ejector action is attained in the following manner. As air flows through the openings **30** into the vaporizing chambers **26**, it creates a reduced pressure at the spaces **30***b* and in the recirculation passages **37**, **38** and **39** in communication therewith. Obviously, with a reduced pressure existing in the recirculation passages, the hot motive gases generated in the combustion chamber at a pressure higher than that in the recirculation passages create the flow described above. The hot motive gases recirculating through the recirculation passages **37**, **38** and **39** serve additional functions. They heat the walls of the vaporizing chambers **26** prior to admission thereto and further serve to heat the outer and inner combustor walls **23** and **24** to impart some heat to the diluent air passing through the diluent air passages **35** and **36**.

Referring to FIGS. 4 and 5, there is shown a second embodiment of the invention incorporated in combustion apparatus **119** of annular shape disposed within an annular air passageway **113** formed by outer casing structure **111** and inner core structure **112**, in a manner similar to that shown in conjunction with the first embodiment shown in FIGS. 1 through 3, inclusive.

The combustor apparatus **119** is provided by a pair of inner and outer tubular walls **124** and **123**, respectively, disposed in coaxial relation with each other and spaced from the outer casing **111** and the inner core **112**, thereby providing diluent air passages **135** and **136**. The inner and outer walls **124** and **123** define a combustion chamber **122** in the downstream portion somewhat similar to that shown in the first embodiment.

A plurality of tubular walls **50**, **51**, **52** and **53**, disposed in coaxial relation with each other, provide vaporizing chambers **126** and **126***a* of annular shape. The vaporizing chamber walls **50** and **53** are mounted in spaced relation with the walls **123** and **124** and together therewith form recirculation passages **137** and **138** of annular shape. An intermediate recirculation passage **139** is defined by the walls **51** and **52**. The vaporizing chamber walls may be fastened to the combustor walls **123** and **124** in any desired manner, for example, by partition plates **127***a*, **127***b* and **127***c* which in turn may be joined to each other by struts **54** and **55**. The partitions **127***a*, **127***b* and **127***c* are of annular shape and are provided with a series of apertures **129***a*, **129***b* and **129***c*, respectively, which apertures serve to connect the recirculation passages **137**, **138** and **139** to the combustion chamber **122**.

The upstream ends of the combustor walls **123** and **124** are closed by upstream plate structure including annular plates **125***a*, **125***b* and **125***c* spaced from each other and forming annular primary air openings **130** and **130***a* which are disposed in registry with the annular vaporizing chambers **126** and **126***a*, respectively. The air admission openings **130** and **130***a* are defined by curved portions **56**, **57**, **57** and **58** which extend into the vaporizing chambers **126** and **126***a*, respectively, for a short distance. As described in connection with the first embodiment, the curved surface **56** and the adjacent curved surface **57** cooperate with each other to form ejector structure for the vaporizing structure **126**, while the curved surface **58** and the adjacent curved surface **57** cooperate with each other to form ejector structure for the vaporizing chamber **126***a*.

Fuel may be injected into the vaporizing chambers **126** and **126***a* by means of a series of fuel nozzles **132** connected to a common manifold **133** which in turn is connected to a fuel supply pipe **134**. Here again, the fuel nozzles **132** are preferably, though not essentially, extended through the openings **130** and **130***a*.

The operation of the combustion apparatus **119** is somewhat similar to that of the apparatus **19** previously shown and described. Specifically, as pressurized air is delivered through the annular passageway **113**, primary air enters through the openings **130** and **130***a* into the vaporizing chambers **126** and **126***a* respectively. Simultaneously therewith, fuel is injected into the vaporizing chambers by means of the fuel nozzles **132**, whereupon the fuel and air form a mixture which is sent downstream through the vaporizing chambers into the combustion chamber. The fuel and air mixture is ignited in the combustion chamber (by means not shown) and the resultant hot motive gases flow downstream thereof to drive the turbine (shown in FIG. 1). Diluent air flowing through the passageways **135** and **136** is admitted into the combustion chamber through the apertures **135***a* and **136***a*, serving to cool the hot motive gases for the same reasons and in the same manner given in connection with the first embodiment.

The primary air flow through the annular openings **130** and **130***a* of the air ejector structures formed by the curved surfaces in the upstream plate structure provides a reduced pressure in the recirculation passages **137**, **138** and **139**, thereby causing some of the hot motive gases and some of the diluent air to be recirculated therethrough in upstream direction and through the vaporizing chambers **126** and **126***a*, thereby heating the gas and fuel mixture and providing improved fuel vaporization thereof prior to ignition of the fuel and air vapors in the combustion chamber **122**.

It will be noted that in this embodiment the recirculating hot motive gases also serve to heat the diluent air as it passes downstream over the walls **123** and **124** and further serves to heat the vaporizing chamber walls **50**, **51**, **52** and **53** prior to entry into the vaporizing chambers.

It will now be seen that there is provided combustion apparatus for a gas turbine which promotes vaporization of the fuel and air mixture for more thorough and uniform combustion thereof. Also, it will be noted that the objects of the invention are attained by simple, lightweight structure which is especially adapted for aviation gas turbine power plants requiring light but sturdy and long lived apparatus.

It will further be noted that the invention lends itself to various configurations and arrangements for efficiently and simply providing recirculation of hot motive gases into the vaporizing chambers of combustion apparatus.

It should be pointed out that the partition **27** and the partitions **127***a*, **127***b* and **127***c* shown in the first and second embodiments, respectively, primarily serve to support the vaporizing chambers in the apparatus and may, if desired, be dispensed with provided that other means for supporting the vaporizing chambers is provided.

While the invention has been shown in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof.

What is claimed is:

1. Combustion apparatus comprising coaxially spaced

casing and core structure forming an annular air supply passage, first wall structure mounted within said annular passage and providing a combustion chamber, second wall structure disposed within said first wall structure and providing a plurality of fuel vaporizing chambers, said vaporizing chambers being disposed upstream of said combustion chamber and in communication therewith, means for admitting fuel to said vaporizing chambers, means including an opening for admitting primary air to each of said vaporizing chambers, said second wall structure further defining, at least partially, a recirculation passage extending from said combustion chamber to said primary air admitting means, said primary air admitting means further including an air ejector structure adjacent at least one said opening, whereby a reduced pressure is adapted to be created in said recirculation passage for drawing hot products of combustion therethrough and into said vaporizing chambers.

2. The structure recited in claim 1 in which said primary air admitting means are provided by an upstream plate connected to said first wall structure and said air ejector structure comprises a curved surface portion of said upstream plate defining said opening.

3. Combustion apparatus comprising substantially cylindrical casing and core structure forming an annular air supply passage, inner and outer tubular combustor walls mounted in spaced coaxial relation in said passage for providing an annular combustion chamber, upstream plate structure of annular shape connected to said inner and outer combustor walls, said upstream plate structure having a plurality of ejector structures, each of said ejector structures having an aperture adapted to receive a fuel admission nozzle, wall structure disposed within said combustor walls extending in upstream direction toward said upstream plate structure and providing a plurality of axially elongated fuel vaporizing passages, apertured downstream plate structure disposed between said inner and outer combustor walls, said vaporizing passages having communication with the apertures in said ejector structures and at least some of the apertures in said downstream plate, whereby fuel from said nozzles forms a mixture with air admitted to said vaporizing chamber through the apertures in said ejector structures and draws hot products of combustion through the other apertures in said downstream plate by ejector action.

4. The structure recited in claim 3 in which said upstream plate structure is provided with curved surface portions, said curved surface portions encompassing the apertures in said ejector structures and extending toward said vaporizing passages.

5. The structure recited in claim 3 in which said inner and outer combustor walls are disposed in spaced relation with said casing and core structure and define secondary annular air passages therewith for diluent air, said inner and outer combustor walls having a plurality of apertures providing communication between said secondary air passage and said combustion chamber.

6. Combustion apparatus comprising substantially cylindrical casing and core structure forming an annular air supply passage, a first pair of tubular walls mounted in spaced coaxial relation in said supply passage for providing an annular combustion chamber, a second pair of tubular walls mounted in spaced coaxial relation between said first pair of walls and providing an annular fuel vaporizing chamber, means for admitting fuel to said vaporizing chamber, annular upstream plate structure connected to said first pair of walls, said upstream plate structure having means including an opening for admitting primary air to said vaporizing chamber, one wall of said second pair of walls cooperating with one wall of said first pair of walls to provide a recirculation passage, said air admitting means further including air ejector structure for providing a reduced fluid pressure in said recirculation passage, whereby hot products of combustion from said combustion chamber are drawn through said recirculation passage and into said vaporizing chamber.

7. The structure recited in claim 6 in which at least one wall of said first pair of walls is provided with an aperture for admitting diluent air into said combustion chamber, whereby part of the diluent air is entrained with the combustion products drawn through said recirculation passage, and said upstream plate structure has a curved surface portion adjacent said primary air admitting opening, said air ejector structure comprising said curved surface portion.

8. Combustion apparatus comprising substantially cylindrical casing and core structure forming an annular air supply passage, a pair of tubular walls mounted in spaced coaxial relation in said supply passage for providing an annular combustion chamber, a plurality of axially elongated tubular fuel vaporizing chambers disposed between said pair of walls, means for admitting fuel to said vaporizing chambers, an annular upstream plate connected to said pair of walls, said upstream plate having means including an opening for admitting primary air to each of said vaporizing chambers, said pair of walls defining at least in part a plurality of recirculation passages, said air admitting means further including an air ejector structure adjacent each said opening for providing a reduced fluid pressure in said recirculation passages, whereby hot products of combustion from said combustion chamber are drawn through said recirculation passages and into said vaporizing chambers.

9. The structure recited in claim 8 in which at least one wall of said pair of walls is provided with an aperture for admitting diluent air into said combustion chamber, whereby part of the diluent air is entrained with the combustion products drawn through said recirculation passages, and said upstream plate has a curved surface portion encompassing each said primary air admitting opening, each said air ejector structure comprising one said curved surface portion.

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