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COMBUSTION CHAMBER

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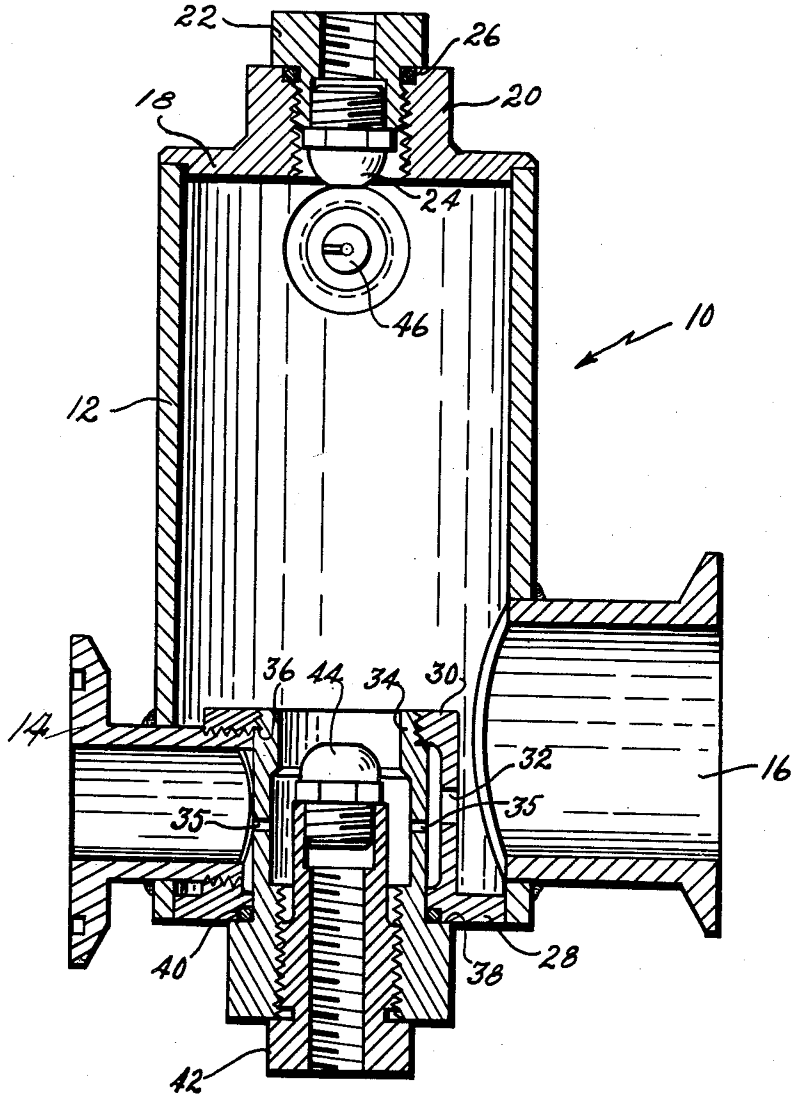

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COMBUSTION CHAMBER

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This invention relates to combustion chambers and is more particularly concerned with a combustion chamber for use in a fluid-operable starter motor for a prime mover such as a gas turbine engine or the like.

The propagation of a flame through a combustible mixture depends upon the transport of combustion products from the burned mixture into the unburned mixture of fuel and oxidizer. This mixing can and usually does occur by two processes—thermal diffusion and eddy diffusion. In mixtures of air and hydrocarbon fuels, however, the thermal diffusion (that diffusion that occurs due to random molecular motion) is not sufficient to produce useful combustion velocities. Consequently, eddy diffusion is required to transport combustion products into the unburned mixture at a rate high enough to produce combustion velocities that are useful.

In most combustion chambers, burning a liquid hydrocarbon fuel in air, the eddy diffusion necessary for combustion is produced by a device that has come to be known as a "flame holder." In ram-jets and aircraft gas turbine afterburners, the flame holder is usually a set of plates, discs, cups, cones or rods. In the main combustion chamber of a gas turbine, it usually comprises a can-type liner with holes or slots punched therein.

These combustion systems having been developed to meet certain requirements of low pressure drop, high inlet velocity and minimum cross-sectional area have a limitation which is a serious one for starter application—they use more volume than that needed for complete combustion. They require this volume because the combustion process, after being initiated in a low velocity, high vorticity region, is completed in a high velocity, low vorticity region downstream of the flame holder. To burn fuel and air in as small a volume as possible, it is necessary that the entire combustion process take place in a region where the eddy diffusivity is a maximum. In order to produce the smallest combustion chamber possible, the eddy should fill the entire volume.

This has been accomplished in the design of the combustion chamber hereinafter described for aircraft gas turbine starters and the like. It is essentially a cylinder closed at one end with the mixture of fuel and air introduced at the opposite end. The fuel-air mixture directed into the closed end of the cylinder reverses on itself thereby producing the eddy required for combustion.

The effectiveness of this simple configuration can be measured by comparing its space rate of combustion with that of one of the main combustion chambers of a gas turbine burning the same fuel. The space rate of the starter combustion chamber at an average condition (1.5 lb./sec. flow at 345 p.s.i. and 2700° F. rise) is 17×10^6 B.t.u./hr. ft.^{3} atmos., a rate more than ten times higher than the 1.5×10^6 B.t.u./hr. ft.^{3} atmos. obtained in one of the main chambers of a gas turbine, despite the fact that a comparison on a "per atmosphere" basis penalizes the starter combustion chamber because it is operating at a much higher pressure (about six times as high). It is an established fact that the velocity of propagation in a given configuration decreases with an increase in pressure.

In accordance with the above, it is a primary object of this invention to provide a new and improved combustion chamber for starter motors and the like.

More specifically, it is an object of our invention to provide a combustion chamber wherein the space rate of combustion is vastly increased over presently used chambers.

A further object of the invention is to provide such a chamber wherein a reversal of inlet flow results in a greater eddy diffusion.

These and other objects of our invention will become apparent upon consideration of the following detailed description of one embodiment thereof, especially when taken in conjunction with the accompanying drawing, in which:

The single figure represents a vertical section taken through a combustion chamber constructed in accordance with the invention.

The combustion chamber of our invention is generally indicated at **10**. The chamber **10** comprises a cylindrical casing **12**. An inlet duct **14** and an exhaust duct **16** provide communication through the cylinder walls. The upper end of the casing **12** is closed by a plate **18**. A hollow boss **20** extends out from said plate, and internal threads on said boss receive a coupling member **22**. The coupling member is provided with a stepped, threaded bore therethrough. One portion of said threaded bore receives a nozzle **24** which faces inwardly towards the casing **12**. The other end of said bore is adapted to receive a fuel supply line. An O-ring seal **26** is placed in a recess formed between the boss **20** and the member **22**.

The other end of the casing **12** has a cover **28** fitted therein. An extended section **30** of said cover enters the casing **12** and is apertured to receive the inlet duct **14**. An exhaust opening **32**, aligned with the duct **16**, is also formed in said section. A mixing sleeve **34** is threaded centrally into the extension **30**, and a series of radial ports **35** is formed therein. Near the inner end of said sleeve, a shoulder **36** engages a flange on the end of the extension **30**. A second shoulder **38** on said sleeve engages the cover **28**, and an O-ring seal **40** insures against leakage at this point. The sleeve **34** is also centrally threaded and receives a coupling **42** similar to the coupling **22**. Another nozzle **44** is mounted in said coupling facing the nozzle **24**. The opposite end of the coupling **42** is adapted for connection to a fuel supply. An aperture through the wall of the casing **12** receives a spark plug **46** which serves to ignite the fuel-air mixture.

In operation the air supply from a control unit (not shown) enters the chamber **10** through the duct **14**. Slightly more than half of the supply passes through the radial ports **35** in the mixing sleeve **34**, and the remainder passes through the exhaust opening **32** into the duct **16**. The air which enters the sleeve **34** is directed into the casing **12** where it mixes with fuel sprayed in through the nozzle **24**, hereinafter also called the first step fuel nozzle. The spark plug **46** ignites the mixture which, as it burns, reverses direction producing the vorticity necessary for stable combustion. The combustion products pass into the duct **16** where they mix with the diluent air from opening **32**. When at the end of the first step, the air flow is increased to a full steady-state value, additional fuel is introduced through the second step nozzle **44**.

The air-fuel mixing area comprises the region inclosed by the sleeve **34**. This structure is one of the most important parts of the combustion chamber for it has a dominant effect on both ignition and combustion stability. Particularly important in the design are (*a*) the direction, size and number of air holes, (*b*) the diameter of the mixing region, (*c*) the distance between the air holes and the end of the sleeve, and (*d*) the distance between the air holes and the end of the second step fuel nozzle.

As a result of tests made with a variety of configurations, the following facts about the design of the air-fuel mixing area have been determined. Radial air holes are better than tangential holes. The whirl produced by tangential holes centrifuges some of the atomized fuel out of the stream onto the inner surface of the mixing area where it forms a liquid sheet. The fuel is then swept toward the end of the mixing area by the air where it breaks up into large droplets as it is carried into the combustion chamber. These large droplets cause roughness and instability and have, in a few instances, caused popping so severe that mixtures of air and fuel have been forced upstream of the mixing nozzle and ignited there causing explosions that have destroyed the control unit. The use of radial holes eliminated this trouble.

A large number of air holes should be used to give as uniform a flow as possible out of the mixing region. It must be kept in mind, however, that trouble from clogging may result if so many holes are used that the hole size is too small.

The total area of the air holes in the mixing nozzle will depend on the pressure drop desired and the fraction of the total air flow that is to be admitted to the combustion chamber (the remainder being by-passed through the diluent air holes). The quantity of air into the combustion chamber should be kept low in order to keep the velocities in the combustion chamber at a minimum, but not so low as to produce a fuel-rich mixture in the combustion zone that would result in the formation of carbon. A stoichiometric mixture is the ideal, combustion-wise, because the high temperatures and minimum inlet velocities produce the greatest combustion stability. However, there is another factor to be considered here and that is the heating up of the walls of the combustion chamber. If the time duration of a run is high, the walls may get too hot in which case the fuel-air mixture in the chamber will have to be reduced below the stoichiometric value unless the chamber wall can be externally cooled.

The diameter of the mixing region should be as large as possible (although it is felt it should not exceed 50% of the inner diameter of the combustion chamber) in order to make the velocity of the air-fuel mixture entering the combustion zone as low as possible. Enough fundamental work has not been done to fully determine the exact quantitative effect of the diameter of the mixing region on ignition and combustion, but when the diameter of the mixing region was increased from 0.531 in. to 0.733 in. (20% to 28% of the chamber diameter) the ignition and combustion range increased by a factor of more than 2 to 1. Increasing the diameter to 1.0 in. (38% of the chamber diameter) increased the ignition and combustion range at normal temperatures to the point where other factors were limiting. Increasing the mixing region diameter to 1.0 in. made it possible to ignite the fuel-air mixture over a range of chamber pressure from 5 p.s.i. (where the fuel valve opened) to over 150 p.s.i. (where spark plug reliability became the limiting factor).

The distance between the air holes and the end of the mixing area should be as great as possible to minimize the turbulence and velocity variations in the air stream as it enters the combustion chamber. The second step fuel nozzle should be located in the air-fuel mixing region in a manner which will allow the atomized fuel to be picked up by the air before any of it reaches the inclosing surface of the mixing region. The location of this fuel nozzle will also effect ignition at low temperatures because of its effect on the pattern of air flow from the mixing area.

It is to be understood that the above-described arrangement is merely illustrative of the applications of the principles of our invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A device for providing working fluid for use in a fluid-operated starter motor comprising a cylindrical housing, a spark plug in said housing, a first step fuel nozzle in one end of said housing, an air supply duct entering said housing adjacent the other end thereof, an exhaust duct leading from said housing adjacent said other end, closure means for said other end having a sleeve passing therethrough into said housing, a series of radial ports in said sleeve, said supply duct abutting said sleeve whereby air passes through said ports and into said housing, and a second step fuel nozzle positioned centrally within said sleeve and opposite said first step nozzle.

2. A device as set forth in claim 1 in which the closure means includes means for passing air from the supply duct to said exhaust duct for dilution of combustion products.

3. A device as defined in claim 1 wherein said sleeve extends into said housing beyond said second step fuel nozzle whereby the interior of said sleeve forms a mixing region for air passing through said ports and fuel from the last-named nozzle.

4. A device for providing working fluid for use in a fluid-operated starter motor comprising a cylindrical housing, an igniter means in said housing, a first fuel nozzle in one end on said housing, an air supply duct entering said housing adjacent the other end thereof, an exhaust duct leading from said housing adjacent said other end, a closure for said other end having a sleeve passing therethrough into said housing, a series of ports in said sleeve, said closure including an extension portion in said housing and surrounding said sleeve, said portion being cut away on one side and receiving said supply duct therethrough, port means in said extension adjacent said exhaust duct, and a second fuel nozzle positioned centrally within said sleeve whereby fuel from said second nozzle and air from the supply duct are mixed within said sleeve before passing into said housing.

5. A device as defined in claim 4 wherein said series of ports are radial and at least a portion of said supply duct abuts said sleeve.

References Cited in the file of this patent

UNITED STATES PATENTS

2,438,858	Lindsey	Mar. 30, 1948
2,574,495	Parker	Nov. 13, 1951
2,576,046	Scarth	Nov. 20, 1951
2,638,745	Nathan	May 19, 1953
2,648,950	Miller	Aug. 18, 1953