Dec. 13, 1960 R. A. GROSS 2,963,864

FLAME STABILIZATION BY CORONA DISCHARGE

Filed June 26, 1957 2 Sheets-Sheet 1

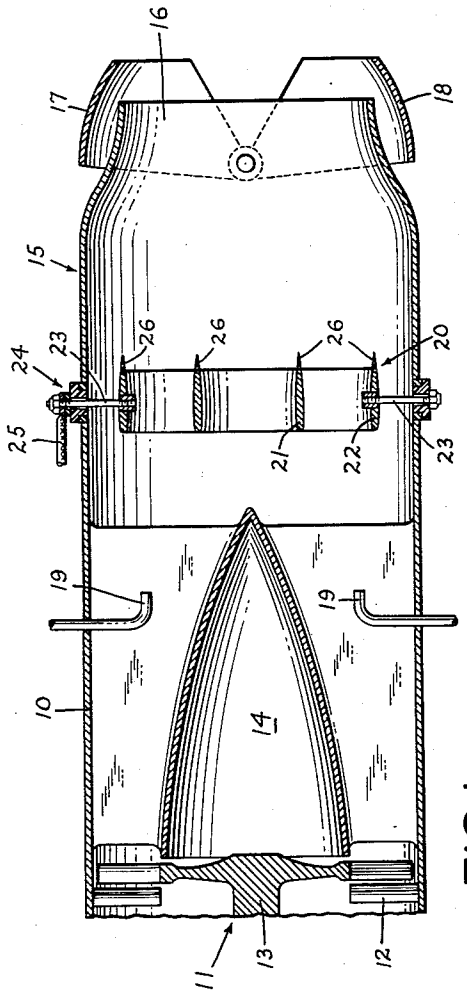


FIG. 1.

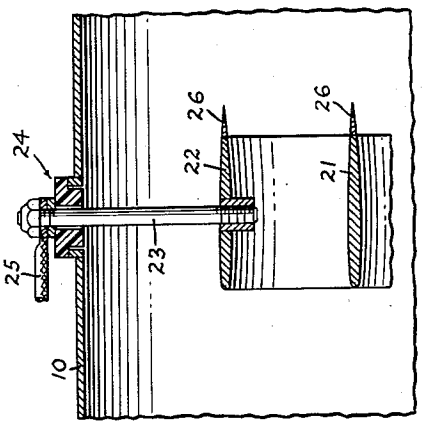


FIG. 2.

INVENTOR
ROBERT A. GROSS
BY
Brumbaugh, Free, Graves & Donohue
HIS ATTORNEYS

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FIG.3.

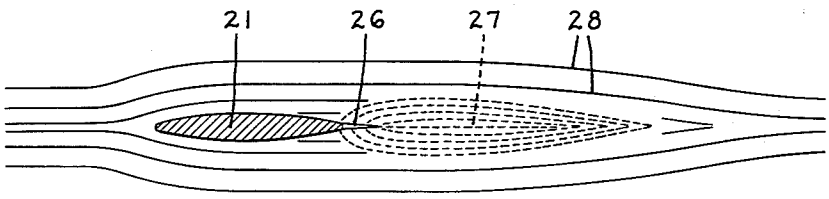
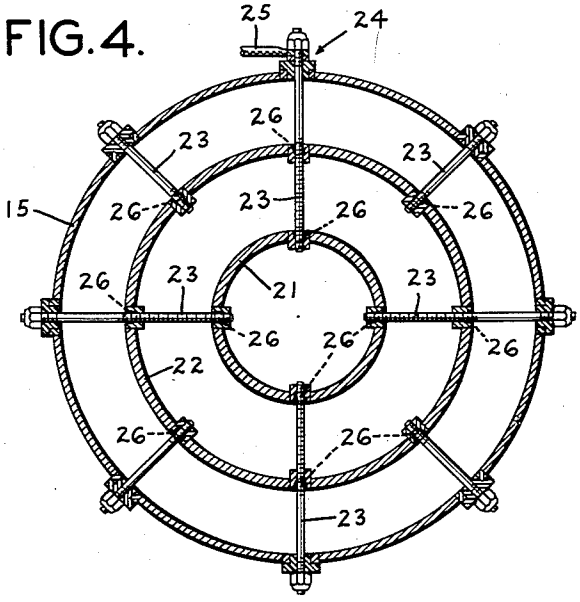


FIG.4.



INVENTOR
ROBERT A. GROSS
BY Brumbaugh, Free
Graves + Donohue
HIS ATTORNEYS

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FLAME STABILIZATION BY CORONA DISCHARGE

Robert A. Gross, Huntington, N.Y., assignor to Fairchild Engine and Airplane Corporation, Hagerstown, Md., a corporation of Maryland

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5 Claims. (Cl. 60—39.82)

This invention relates to improvements in jet engines and it relates particularly to improvements in afterburners for jet engines of the ram jet, gas turbine and turbo-prop types.

Afterburners are used in jet type engines to obtain an increase in the thrust of such engines. An afterburner injects fuel into the high velocity exhaust gas stream of the engine so that the additional fuel will be burned in the gas stream thereby increasing its heat content and volume and increasing the thrust of the engine. Although it appears that the fuel should be ignited and consumed immediately upon being injected or sprayed into the hot gas, as a practical matter this does not occur. The high velocity of the gas stream causes the fuel to travel a considerable distance from the nozzle before burning of the fuel is completed. To avoid waste of fuel it has been customary either to increase the overall length of the engine to permit substantially complete combustion of the fuel or a flameholder is placed in the discharge duct to slow down the gas issuing from the combustion chamber or the turbine and to some extent at least recirculate the gas behind the flameholder. Usually the flameholder consists of a V or gutter-shape channel or a group of such channels having their open ends facing in the direction of gas flow.

While the burning of the fuel in the afterburner ocurrs in a shorter distance when such a flameholder is present, the distance still is undesirably long and other difficulties are caused by the flameholder. Inasmuch as the flameholder is of substantial cross-sectional area, it blocks off as much as 35% of the duct area so that the size of the discharge nozzle of the engine must be proportionally increased to maintain a desired flow area. An increase in the duct area increases the weight of the engine and also the overall size of the engine.

The function of the flameholder is to provide a region of slow moving combustible gas within which the flame can stabilize. This region can either be a fluid boundary layer or an eddy. A flameholder ceases to function for rapid gas flows and this action has resulted in a concept referred to as the "quenching distance." In accordance with this concept, it is believed that the chemical reaction between the fuel and the gas cannot take place close to the flameholder. The distance within which reaction cannot take place is called the quenching distance. Not all of the factors which determine the quenching distance are known. Evidently a part of the explanation for the concept involves the heat transfer conditions between the flame and the flameholder or possibly a catalytic effect of the flameholder on the distribution of the molecules which are known to be important in the combustion reactions. In any event the quenching distance for a conventional flameholder is relatively great thereby reducing the overall efficiency of the engines provided with such flameholders.

In accordance with the present invention, I have provided an improved form of afterburner for engines of the type described above which enables the fuel to be

ignited and burned in a much shorter distance than heretofore. Due to the shortened combustion zone in the afterburner, the length of the engine and its weight can be materially reduced so that the performance of air craft or the like equipped with such engines is enhanced considerably.

More particularly, the present invention involves the provision of an element in the afterburner combustion chamber which modifies the conventional relation between a flameholder and the gas stream so as to promote the combustion of fuel in the afterburner combustion chamber.

The present invention involves a means for altering the quenching distance and consequently the blow-off characteristics of a form of flameholder or grid in which the natural ion distribution in the immediate neighborhood of the flameholder is disrupted and the environment for combustion is made more favorable.

Moreover, the present invention contemplates the provision of elements which can be energized with an electrical potential of a nature such that a cold electron discharge or a corona discharge takes place. The electrodes in the afterburner may be so distributed that they are effective to ignite substantially a uniform cross-sectional area of gas flowing therearound and may be appropriately formed so as to provide a corona flame extending along with the gas stream towards the discharge nozzle. The corona discharge terminates in free space. Under these circumstances in the presence of such corona discharge, the quenching distance is greatly decreased and combustion of the fuel in the afterburner is accomplished within a much shorter distance so that the overall length of the afterburner and nozzle structure of the engine can be greatly decreased and the diameter of the nozzle maintained at a size small enough to greatly improve the operating characteristics of aircraft provided with engines having the new afterburner structure.

For a better understanding of the present invention reference may be had to the accompanying drawings in which:

Figure 1 is a cross-sectional and schematic representation of a portion of a gas turbine engine with the compressors and combustion chamber for supplying gases to the turbine omitted;

Figure 2 is an enlarged cross-sectional view of a portion of the grid in the afterburner chamber by means of which cold electron emission or corona discharge is effected in the gas stream;

Figure 3 is a schematic representation illustrating the corona discharge from one of the electrodes of this invention;

Figure 4 is a sectional view of Figure 1 showing the manner in which the rings of the grid are secured to each other and to the chamber.

The invention will be described with respect to its use in turbo-jet engines, but it will be understood that it is not restricted to this use and can be applied to ram jet and other jet types of engines. A portion of a turbo-jet engine is illustrated in the drawings and includes a casing 10 having in one end portion thereof a turbine 11 including the usual stator vanes 12 and the turbine rotor 13 which is rotated at high speed by discharge of the gases to operate a compressor (not shown) for supplying air under pressure to the combustion chamber of the engine. Downstream of the turbine is a bullet-nosed shield portion 14 around which the gas flows into the afterburner section 15 of the engine. Downstream of the afterburner section is the discharge nozzle 16 of the engine which is provided with the adjustable nozzle sections 17 and 18 for controlling the size of the nozzle and producing reverse braking if desired.

In accordance with the present invention, the engine

is provided with one or more fuel injecting nozzles **19** which introduce fuel into the high temperature gas discharged from the turbine **11** into the afterburner chamber **15**. Mounted within the afterburner **15** is a grid **20** which may correspond in some respects to a flameholder although, as illustrated, it is made up of a plurality of elements such as, for example, concentric rings **21** and **22** of thin streamlined cross-section so as to produce as little obstruction of gas flow through the chamber as possible. The rings **21** and **22** may be formed of an electrically conductive metal or other material having a high melting point and are supported in spaced relation to the shell **10** by means of inwardly extending rods **23** as shown in Figures 1 and 4 which serve as spacers and which insulate the rings from the casing. The rings may be provided with ceramic covers or coatings to protect them from the hot exhaust gases.

At least one of the spacers, for example, a spacer and supporting element **24** may be an electrically conductive rod which is attached to the grid **20** and supplies electrical energy to the rings **21** and **22** through a cable **25** connected with a suitable source of electrical potential.

Inasmuch as the grid is intended to provide a cold electron emission or a corona discharge, the source of electrical potential (not shown), may be of a high voltage and high frequency type of generator of known type. The generator supplies a circuit having a frequency of 50 kc. to 1 mc. and a high voltage or potential, for example, between about 10 and 50 kilovolts. The power supplied may be as much as 2 kilowatts.

Corona discharge is facilitated by providing the rings **21, 22** with sharp pointed electrodes **26** spaced at intervals around the electrodes and pointing generally toward the discharge nozzle of the engine. The electrodes **26** are distributed most advantageously so that each will be surrounded by a flowing column of gas of about the same cross-sectional area. When the high potential is supplied to the grid and the electrodes **26** thereon, a corona discharge of flame-like form will extend from the electrodes into the gas stream and terminates in free space. This is shown in Figure 3 wherein the corona discharge is represented by the dotted lines **27**, and the flowing column of gas about the ring **21** is shown by lines **28**. The fuel injected into the gas stream is thereby readily ignited and burns quickly in the afterburner combustion chamber and the nozzle **16** to greatly increase the thrust of the engine. The electron or corona discharge from the electrodes **26** greatly shortens the quenching distance around the grid so that combustion is completed within a much shorter space and with higher gas velocities than is possible with prior gas turbine engines with or without conventional flameholders.

It will be understood that the afterburner embodying the present invention is susceptible to considerable modification and that the grid **20** may be modified as to shape and location and that the electrodes themselves may be in the form of needle or chisel pointed elements or other shapes depending upon the conditions under which they are to be used.

It will be understood that the electrical connection to the grid is insulated from the shell and that appropriate insulation may also be provided between the grid and the shelf to avoid arcing under operation. It will also be understood that the corona discharge from the sharp-pointed electrodes terminates in free space. Therefore, the form of the invention described herein should be considered as illustrative and not as limiting the scope of the following claims.

I claim:

1. An ignition system for a jet engine in which gas is discharged from a discharge nozzle comprising a chamber upstream of said nozzle, means for introducing fuel into said chamber for combustion therein, at least one small sharp-pointed electrode in said chamber downstream of said fuel introducing means and means for applying an electrical potential to said electrode to produce only a corona discharge therefrom, the corona discharge extending into the gas and terminating in free space to aid in igniting and burning said fuel in said chamber and discharge nozzle.

2. An ignition system for a jet engine in which gas is discharged from a discharge nozzle comprising a chamber upstream of said nozzle, at least one nozzle for injecting fuel into said chamber, a grid of electrically conductive material in said chamber downstream of said fuel injecting nozzle, said grid being composed of elements of streamlined cross section to minimize turbulence of gas in and obstruction to flow of gas through said chamber, substantially equally spaced small sharp-pointed electrodes supported by said grid and extending downstream therefrom and means for applying an electrical potential to said electrodes to produce only a corona discharge therefrom, the corona discharge extending into the gas and terminating in free space to aid in igniting and burning said fuel in said chamber and discharge nozzle.

3. An ignition system for a jet engine in which gas is discharged from a discharge nozzle comprising a chamber upstream of said nozzle, at least one nozzle for injecting fuel into said chamber, a grid formed of a plurality of streamlined, concentric, electrically conductive ring elements of thin cross-sectional area in said chamber downstream of said fuel injecting nozzle, said grid occupying a minimum of the cross-sectional area of said chamber to minimize creation of turbulence in the gas in said chamber and substantial obstruction to its flow, substantially equally spaced small sharp-pointed electrodes supported by said grid and extending downstream therefrom and means for applying an electrical potential to said electrodes to produce only a corona discharge therefrom, the corona discharge extending into the gas and terminating in free space to aid in igniting and burning said fuel in said chamber and discharge nozzle.

4. An ignition system for a jet engine in which gas is discharged from a discharge nozzle comprising a chamber upstream of said nozzle, means for introducing fuel into said chamber for combustion therein, a grid of streamlined elements of small cross-sectional area in said chamber downstream of said fuel introducing means, a plurality of substantially equally spaced small sharp-pointed electrodes supported by said grid, and means for applying an electrical potential to said electrodes to produce only a corona discharge therefrom, the corona discharge extending into the gas and terminating in free space to aid in igniting and burning said fuel in said chamber and discharge nozzle.

5. An ignition system for a jet engine in which gas is discharged from a discharge nozzle comprising a chamber upstream from said nozzle, means for introducing fuel into said chamber for combustion therein, a grid of streamlined elements of small cross-sectional area in said chamber downstream of said fuel introducing means, a plurality of substantially equally spaced small sharp-pointed electrodes supported by said grid, and means for applying an electrical potential of from about 10 to about 50 kilovolts with a frequency of from about 50 kilocycles to about one megacycle to said electrodes to produce only a corona discharge therefrom, the corona discharge extending into the gas and terminating in free space to aid in igniting and burning said fuel in said chamber and discharge nozzle.

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