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METHOD AND APPARATUS FOR PROVIDING IMPROVED COMBUSTION IN JET ENGINES

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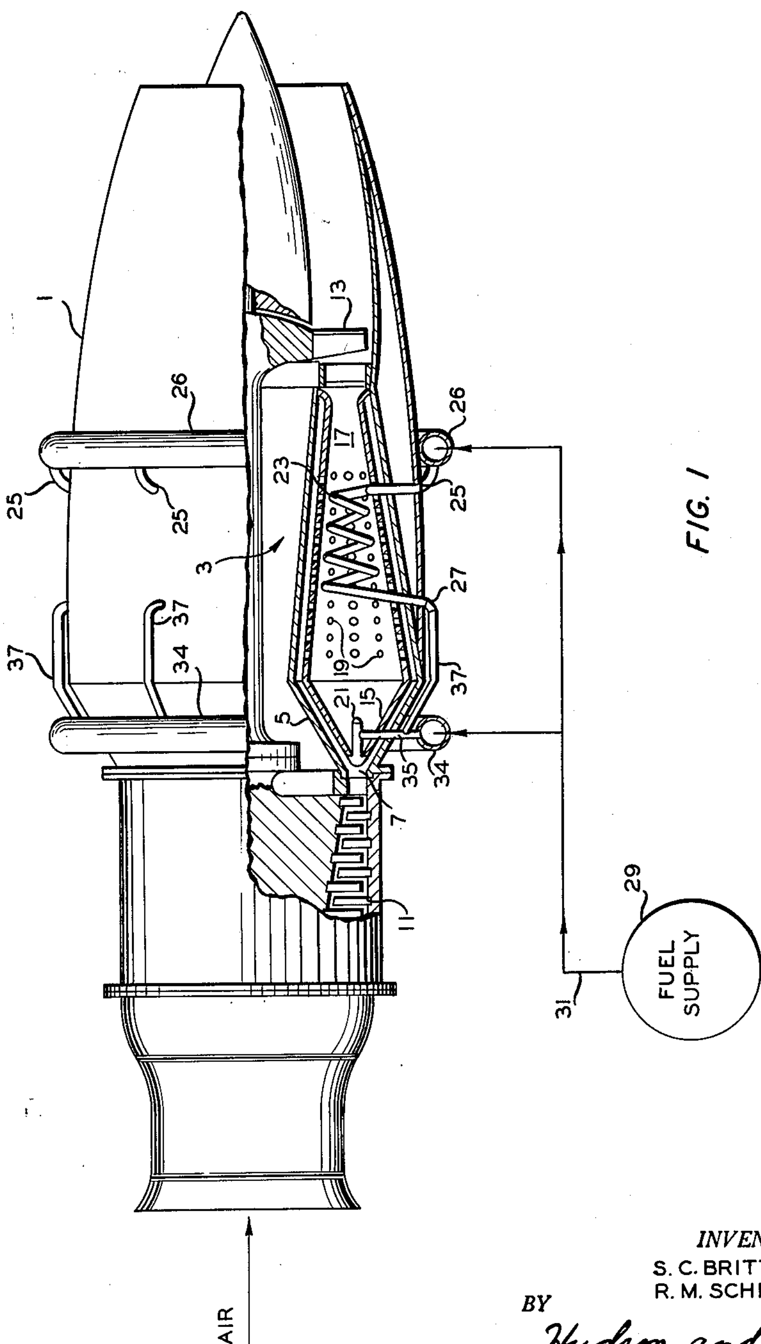

FIG. 1

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FIG. 3

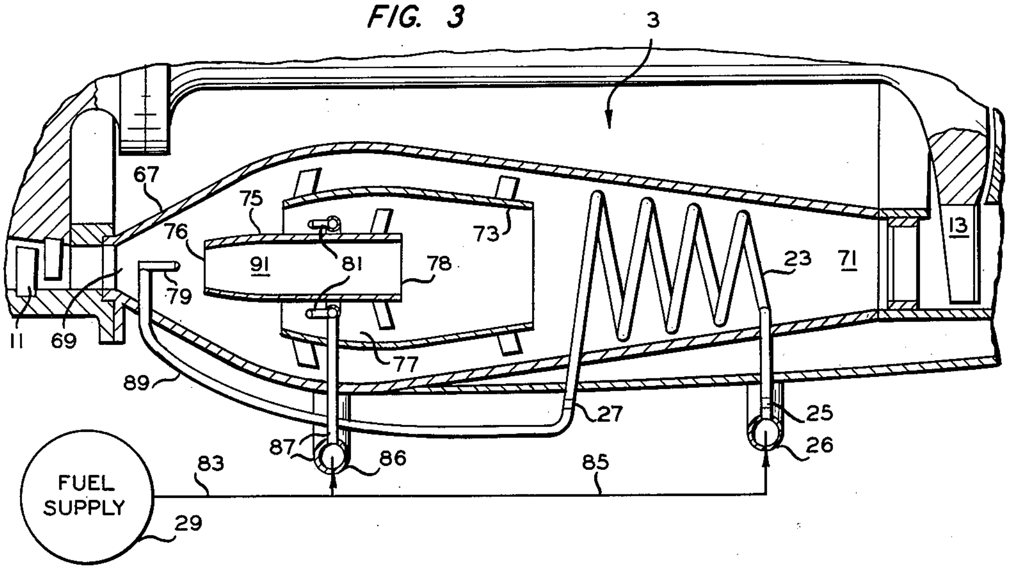
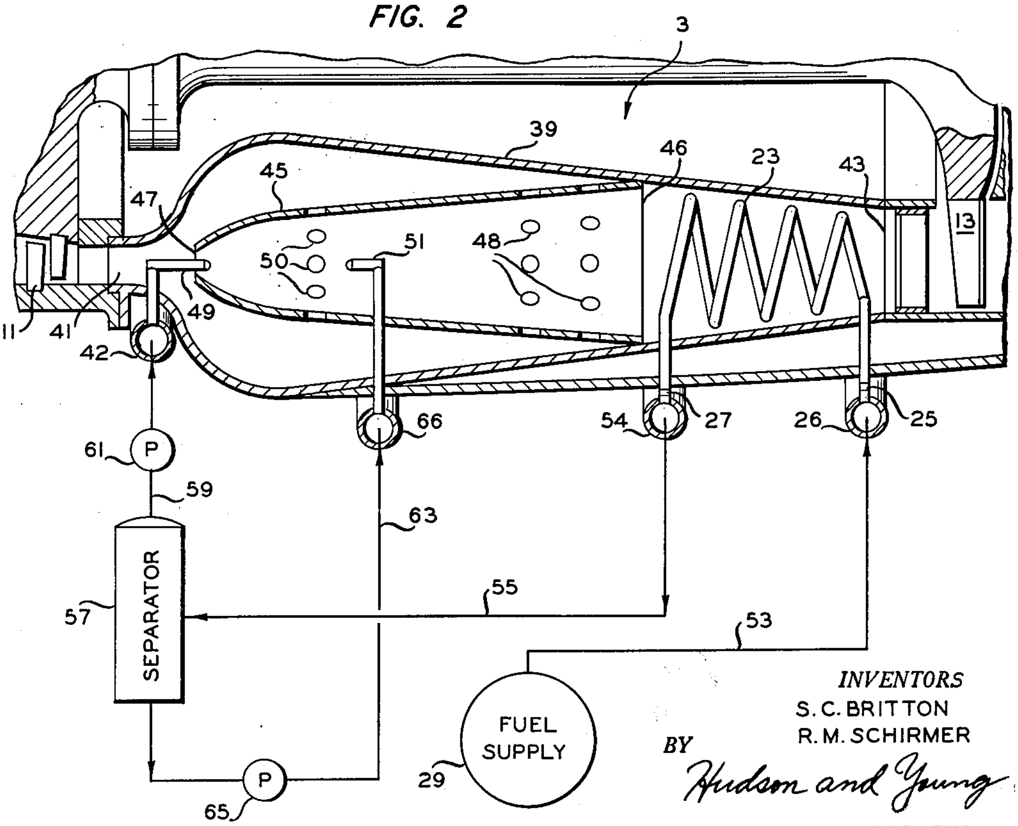


FIG. 2



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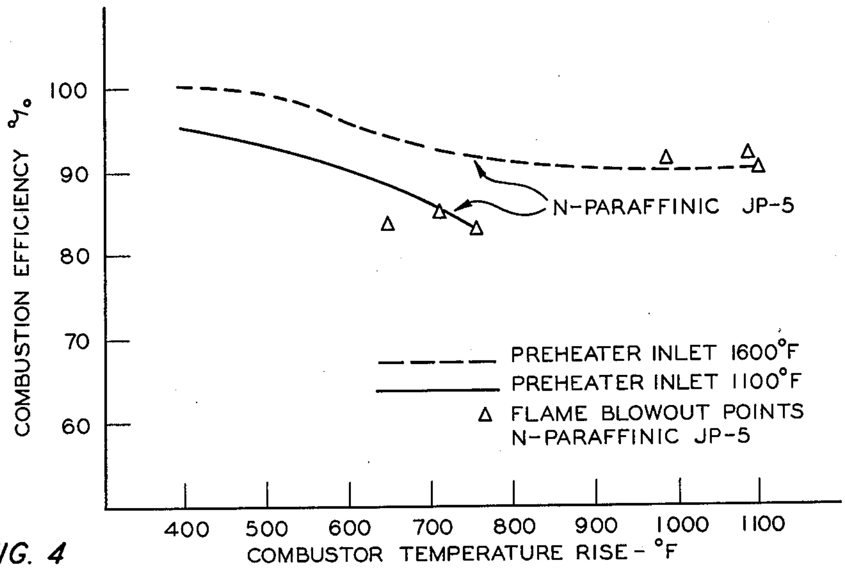

FIG. 4

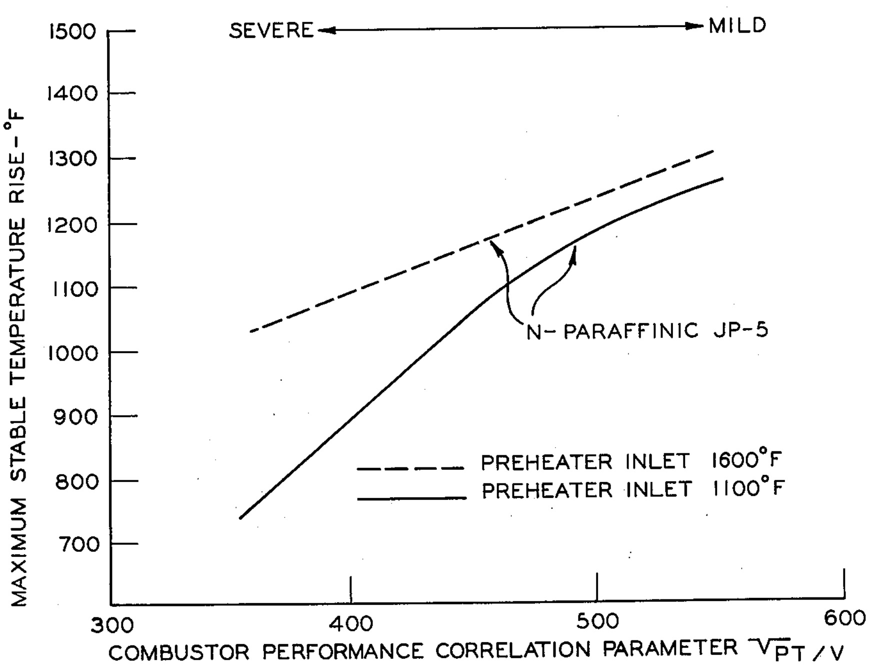

FIG. 5

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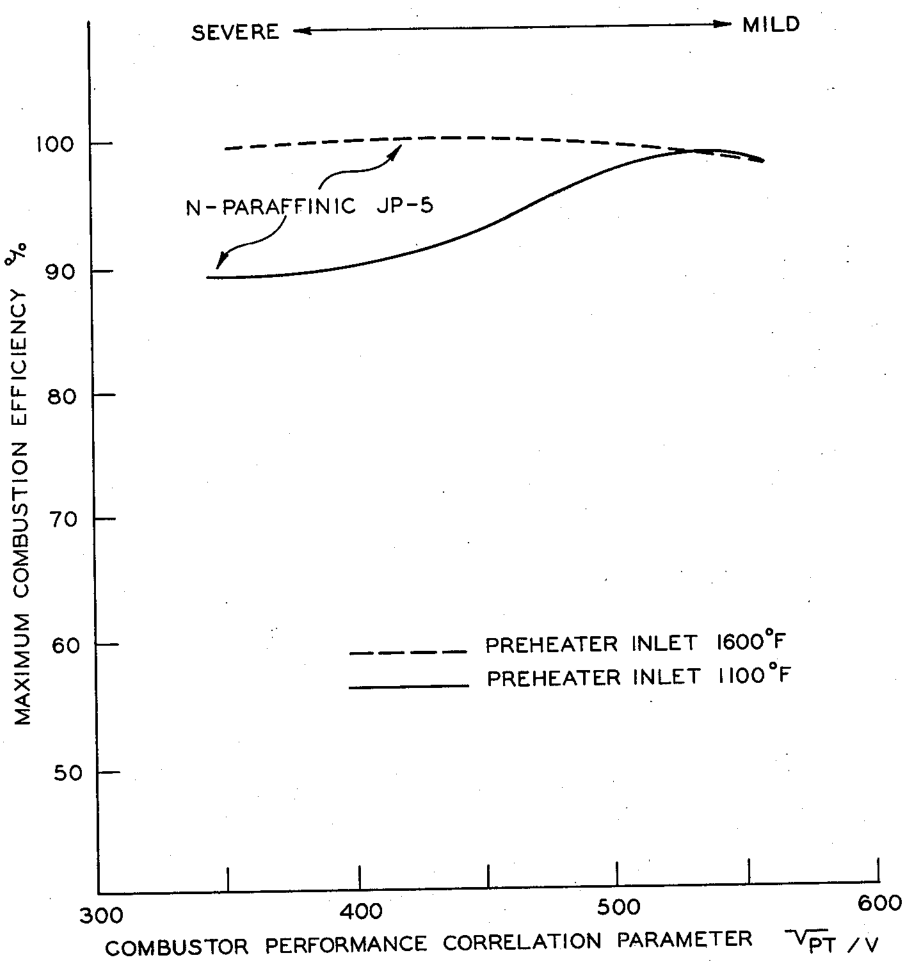

FIG. 6

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METHOD AND APPARATUS FOR PROVIDING IMPROVED COMBUSTION IN JET ENGINES

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Original application May 31, 1955, Ser. No. 511,978, now Patent No. 2,958,189, dated Nov. 1, 1960. Divided and this application July 27, 1960, Ser. No. 45,622
5 Claims. (Cl. 60—39.71)

This invention relates to jet engines. In one aspect, this invention relates to a method for improving the combustion of fuel in a jet engine. In a more specific aspect, this invention relates to an improved jet engine which comprises a system for transforming fuel supplied to the jet engine into a fuel having more desirable combustion characteristics.

This application is a division of our copending application Serial No. 511,978 filed May 31, 1955, now U.S. 2,958,189, patented November 1, 1960.

The most important element of a jet engine aircraft is the power plant, and this, in turn, is only as good as its combustion system. The study of the combustion chamber and the mechanics of combustion is of prime concern.

The purpose of the combustion chamber is to convert the chemical energy of hydrocarbon fuels into thermal energy. This energy is absorbed by the air flowing through the engine to provide the high-velocity exhaust jet necessary for propulsion.

The desired properties of jet engines include low frontal area for minimum drag, low weight, and operational flexibility. In some respects, frontal area and weight are inversely related to the heat release rate of the combustor employed. Thus, for a given thrust rating a combustion process yielding a high heat release rate (expressed as B.t.u./hr./cu. ft.) will generally permit the use of an engine design having lower frontal area and weight than will a combustion process having a lower heat release rate. In other words, higher heat release rates will generally permit the design of engines having higher thrust per unit of engine weight and per unit of engine frontal area. Heat release rates depend, in turn, on the stability and efficiency of the combustion process, as well as on the heating value of the fuel.

It is known that fuels having high flame speeds, e.g., hydrogen, acetylene and ethylene, possess high combustion stability and efficiency. Additionally, the fuel must be in the gaseous or vaporous state before combustion can occur. Consequently, a gaseous or vaporized fuel requires a shorter overall residence time in the combustor for complete combustion than does a fuel injected in the liquid state since the latter must first be vaporized. The net result is that low molecular weight fuels, such as hydrogen, acetylene and ethylene provide higher thrust per unit of engine weight and of frontal area than does a high molecular weight, liquid fuel. As used herein the term "flame speed" is intended to mean rate of flame propogation.

The ability of a jet engine to operate over a wide range of conditions is also enhanced by the use of low molecular weight, high flame speed fuels. As the temperature and pressure of the inlet air to the combustor are decreased, e.g., as by an increase in altitude, it becomes more difficult to maintain stable and efficient combustion. The use of the more stably burning, gaseous, high flame speed fuels permits stable and efficient combustion at lower inlet air temperature and pressure, and thus increases the altitude operational range of the engine.

Since these low molecular weight fuels are gases under normal conditions of temperature and pressure, they have

not been used as jet aircraft fuels owing to the obvious difficulties fostered by their gaseous state. Thus, a method and means of increasing the combustion stability and efficiency of the usual liquid jet engine fuels are grealy desired. Such a method and means would not only increase the operational range of the engine and permit the decrease of its weight and frontal area, but would also increase the availability (and concomitantly decrease the cost) of jet fuels by permitting the inclusion of fuel components of lower volatility, lower combustion stability, and lower combustion efficiency. Also, the performance increase provided by such a method and means can be taken as an increase in thrust per unit of engine weight and unit of engine frontal area.

An object of this invention, therefore, is to provide an improved jet engine.

A further object is to provide a jet engine comprising a system for transforming its fuel into a fuel having desirable combustion characteristics under severe operating conditions.

A still further object is to provide a method and means for utilizing a high heating value fuel in a jet engine under severe operating conditions.

We have discovered a system for attaining the foregoing objects and other objects and advantages which comprises preheating the fuel to a temperature above that necessary for vaporization alone so as to at least partially decompose at least a portion of the fuel supplied to the combustion zone of the jet engine.. The preheating or decomposition zone may comprise thermal and/or catalytic means and is arranged so as to utilize the heat generated in the combustion zone to furnish the energy for the decomposition reaction. The products from the decomposition zone are supplied to the combustion zone to be burned in air inducted into the engine.

The decomposition reactions to which reference has been made ordinarily involve predominantly cracking and depolymerization reactions although other reactions which influence the formation of hydrogen and low molecular weight unsaturated hydrocarbons also take place. The reaction products formed in the decomposition zone contain a substantial amount of high flame speed gaseous components, such as hydrogen, acetylene, propylene and the like, admixed with a portion which is normally liquid at atmospheric temperature and pressure. The improved combustion performance obtained by using the fuel mixtures formed by the method and means of this invention is believed to be the result of superior piloting action of the high flame speed components in the combustion chamber at the flame holding areas.

The present invention provides a method of operating jet propulsion type engines with a single fuel whereby higher combustion efficiency and combustion stability are obtained than was previously possible in conventional jet propulsion engines burning the same fuel. This invention is particularly effective in producing improved combustion stability and combustion efficiency in combustion systems operated under rich mixture conditions. The present invention also permits certain fuels, which heretofore have not been considered to be completely suitable fuels for jet propulsion engines because of low volatilities and excessive carbon deposition, to be effectively utilized in jet propulsion engines.

The fact that jet fuels of relatively low volatility are rendered useful by this invention is of importance because the newest high altitude, high Mach number aircraft and missiles place severe requirements on their fuels because of aerodynamic heating and decreased ambient pressures. These effects dictate the use of fuels of low volatility if excessive vapor losses from conventional vented fuel tanks are to be avoided. Also, such aircraft are limited in their performance by the volume of fuel which they can carry and, therefore, the higher volumetric heating value of heavier petroleum fractions is a desirable feature. However, this invention is applicable to combustion processes in general, such as stationary gas turbine power plants, and is not restricted to aircraft jet engines such as turbojet, turboprop, pulse jet and ram jet engines.

The decomposition reactions to which reference has been made may be performed under partial vacuum or at approximately atmospheric or superatmospheric pressure. The liquid fuel is heated to a temperature above the temperature at which the fuel is vaporized, i.e., to a temperature sufficiently high to crack at least a portion of the fuel, and usually a temperature of at least about 900° F. is used. The specific temperature employed can be varied over a wide range, depending upon the susceptibility of the fuel to decomposition as determined by the type of hydrocarbons present in the fuel and the molecular weight of the particular hydrocarbons of each type, the flow rate of the fuel into the decomposition zone and the degree of decomposition desired. Allowing for the variations in types of fuels and combustor design, the preferred temperature to which the fuel is heated in accordance with this invention is in the range from 1000 to 2000° F.

A suitable catalyst which is known to be effective in promoting cracking reactions can be used in the decomposition zone and, when such a catalyst is used, somewhat lower temperatures can be employed. Examples of the catalyst, which can be used are the silica-alumina or silica-magnesia types derived from natural clays or prepared synthetically.

The fuels which can be employed in this invention include the conventional jet engine fuels, such as gas oils, kerosene, and aviation gasoline, as well as heavier hydrocarbon fractions which are not usually burned in jet propulsion engines. Fuels containing a predominant proportion of paraffinic type hydrocarbons are particularly well adapted to this invention because such fuels decompose at lower temperatures than do aromatic fuels.

Several embodiments of our invention are shown in the accompanying drawings to illustrate our invention and not necessarily to limit it, and wherein:

FIGURE 1 is a diagrammatic view, partially in section, of a jet engine wherein the combustion chamber thereof is constructed in accordance with this invention so that a portion of the fuel is decomposed and then admixed with the remaining portion of the original fuel;

FIGURE 2 is a diagrammatic view, partially in section, of a combustion chamber in a jet engine wherein all of the fuel is subjected to decomposition and the resulting fuel is separated into liquid and gaseous phases before being introduced into the combustion zone as separate streams in specific localities;

FIGURE 3 is a diagrammatic view, partially in section, of a combustion chamber in a jet engine wherein a portion of the fuel is decomposed and the decomposed fuel and the remaining portion of the original fuel are supplied to the combustion chamber as separate streams to be burned in specific localities therein;

FIGURE 4 shows the improved maximum stable combustor temperature rise in relation to combustion efficiency for a JP–5 jet fuel at the most severe operating condition,

$$\frac{T\sqrt{P}}{V}=362$$

as defined by the combustor performance correlation parameter,

$$\frac{T\sqrt{P}}{V}$$

wherein T is the inlet air temperature in degrees Rankine, wherein P is the combustor inlet pressure in pounds per square foot and V is the linear velocity of the inlet air in feed per second, when the JP–5 fuel is treated in accordance with this invention;

FIGURE 5 shows the improved maximum stable temperature rise for the JP–5 fuel when treated in accordance with this invention upon a reduction in the severity of conditions within the combustor; and

FIGURE 6 shows the improved maximum combustion efficiency when a JP–5 fuel, treated in accordance with this invention, is subjected to increasingly severe conditions

$$\left(\frac{T\sqrt{P}}{V}\text{ decreases}\right)$$

in comparison to a JP–5 fuel which was heated insufficiently to at least partially decompose the fuel.

Those skilled in the art will readily appreciate that other specific embodiments of this invention can be devised whereby the fuel to a combustion chamber in a jet engine is decomposed to provide high flame speed components to improve the combustion performance of a jet propulsion engine.

Referring now to FIGURE 1, a jet engine 1 is shown which comprises a plurality of combustors indicated generally as 3 which are constructed in accordance with this invention, and particularly as the invention is illustrated in FIGURES 1, 2 and 3. Combustor 3 comprises a streamlined combustion chamber 5 having an air inlet 7 and an exhaust gas outlet 9. Combustion air is supplied to the combustion chamber by a compressor 11 and the exhaust gases removed from outlet 9 drive a turbine 13 in a manner well known to the art. A flame tube 15 having a streamlined shape similar to that of combustor 5 is axially positioned within and spaced from combustor 5. The end of flame tube 15 adjacent to the air inlet of combustion chamber 5 is closed and the opposite end of flame tube 15 is open to form a flame tube exhaust gas outlet 17. Outlet 17 is attached securely within exhaust gas outlet 9. Flame tube 15 also comprises a plurality of perforations 19 which are disposed around the surface of flame tube 15. A fuel nozzle 21 is attached to the interior of flame tube 15 at the end thereof adjacent to the air inlet to the combustion chamber 5. Fuel nozzle 21 is positioned so as to direct the flow of fuel therethrough toward the exhaust gas outlet 17 of flame tube 15. In the operation of our invention, the total amount of air and fuel used is substantially the same as that normally used.

In accordance with this invention, an elongated, tubular fuel decomposition means 23 is positioned within flame tube 15 so that fuel which is passed through fuel decomposition means 23 is in indirect heat exchange relationship with the combustion taking place within flame tube 15. Fuel decomposition means 23 also comprises fuel inlets 25 and decomposed fuel outlets 27. At least a portion of liquid fuel from a fuel supply 29 is passed via a conduit 31 and manifold 26 to the inlets 25 of fuel decomposition means 23, through the fuel decomposition means 23 in indirect heat exchange relationship with the combustion taking place within flame tube 15, and out the outlets 27 of fuel decomposition means 23. The remainder of the liquid fuel is passed via conduit 31, manifold 34 and conduits 35 to fuel nozzle 21. The portion of fuel passed through fuel decomposition means 23 is passed from outlets 27 via conduits 37 to conduits 35 and fuel nozzle 21. The fuel which is burned in combustor 3, therefore, comprises the reaction products from the decomposition of the liquid fuel in fuel decomposition means 23 and which comprises gaseous, high flame speed components. Thus, the total fuel burned has increased combustion stability characteristics due to the presence of such high flame speed components. The combustion products of heated air and burned fuel are discharged to the atmosphere through exhaust outlets 9 and 17 and turbine 13.

In a preferred embodiment of our invention, the elongated, tubular fuel decomposition means 23, shown in FIGURE 1, is a helical tube which is axially positioned within and spaced from flame tube 15. The helical tube 23 can be lined with a catalyst for the decomposition reaction if desired and can be positioned in various places in flame tube 15; however, the position which is preferred is that shown wherein tube 23 is positioned in that portion of flame tube 15 which is adjacent to the exhaust gas outlet 17. Obviously, tube 23 can be formed in other shapes, such as a spiral or a plurality of loops. The helical shape shown is preferred since it conveniently affords adequate heat exchange between the fuel and combustion gases and minimizes plugging difficulties where the fuel is excessively decomposed to form carbon. Tube 23 is preferably made of stainless steel, such as the well known 310 or 314 types of stainless steels. Other materials which stand the elevated temperatures sufficiently to offer a reasonable length of useful life can also be used, such as Ascoloy, an alloy of 24 to 30 percent chromium and 75 to 69 percent iron.

Referring now to FIGURE 2 a partial, sectional view of combustor 3 is shown wherein another embodiment of my invention is used. Combustor 3 comprises a generally frusto-conical chamber 39, the large end of which is tapered in a streamlined fashion to form an air inlet 41 at the forward end of chamber 39. The opposite, downstream end of chamber 39 is open so as to form an exhaust gas outlet 43. A flame shield 45, having a generally frusto-conical shape, is positioned within combustion chamber 39. The large downstream end 46 of flame shield 45 is positioned generally intermediate to the ends of chamber 39 and is securely attached to the interior wall of chamber 39. The outside cross sectional area of the large end of flame shield 45 is equal to the inside cross sectional area of chamber 39 at the place where said large end of flame shield 45 is attached to the interior of chamber 39. The small end of flame shield 45 is slightly curved inwardly to form an air inlet 47 for flame shield 45. Flame shield 45 also comprises a plurality of perforations 48 disposed around the wall of flame shield 45 adjacent to the downstream end 46 thereof, and a plurality of perforations 50 disposed around the wall of flame shield 45 intermediate to air inlet 47 of flame tube 45 and nozzle 51. The air inlet 47 of flame shield 45 is positioned directly downstream of the air inlet 41 of combustion chamber 39. A fuel nozzle 49 is axially positioned within an inlet 41 of chamber 39 and extends longitudinally so that its discharge end, through which the fuel flows, is positioned within air inlet 47 of flame shield 45. Fuel nozzle 49 is positioned so as to direct the flow of fuel toward exhaust gas outlet 43. A second fuel nozzle 51 is axially positioned within flame shield 45 and is positioned so as to direct the flow of fuel therethrough toward air inlet 47 of flame shield 45. Fuel nozzle 51 is positioned generally intermediate the air inlet 47 and downstream end 46 of flame shield 45.

In accordance with this invention, the elongated tubular decomposition means 23 is positioned within combustion chamber 39 intermediate the downstream end 46 of flame shield 45 and the exhaust gas outlet 43 of combustion chamber 39. However, in the embodiment shown in FIGURE 2, all of the liquid fuel from fuel supply 29 is passed via a conduit 53 and manifold 26 to the inlets 25 of fuel decomposition means 23, through fuel decomposition means 23 and out the outlets 27 thereof. The fuel which has thus been at least partially decomposed and which comprises liquid and gaseous products of the decomposition reaction is passed via manifold 54 and a conduit 55 to a liquid-gas separator 57. The decomposed fuel in separator 57 is separated into a gaseous fuel which is passed via a conduit 59 having a pump 61 connected therein to the first fuel nozzle 49 and a liquid fuel which is passed via a conduit and manifold 66, having a pump 65 connected therein and a manifold 42, to the second fuel nozzle 51. Thus, the forward portion of flame shield 45, in which the gaseous products of the fuel decomposition reaction are burned, functions as a pilot flame zone. The high flame speed components which are produced by the fuel decomposition reaction are utilized to stabilize combustion throughout the combustor 3 and to provide a pilot flame zone for fuel passed into combustion chamber 39 via nozzle 51. It will be readily appreciated that the embodiment of our invention, shown in FIGURE 2, provides a very efficient way and means for producing and utilizing high flame speed components in a liquid fuel supplied to a combustion section of a jet engine.

Referring now to FIGURE 3, a further embodiment of combustor 3 is shown comprising a streamlined combustion chamber 67. Chamber 67 is open at its upstream end to form an air inlet 69 and is open at its downstream end to form an exhaust gas outlet 71. A first, generally cylindrical and slightly streamlined flow shield 73 is axially positioned within and spaced from combustion chamber 67. Flow shield 73 is open at each end thereof and is positioned, generally, in the upstream portion of combustion chamber 67 which is adjacent to the air inlet 69 thereof. A second generally cylindrical and slightly streamlined flow shield 75 is axially positioned within and spaced from the first flow shield 73 thereby forming an annular space 77 between first flow shield 73 and second flow shield 75. The ends of the second flow shield 75 are open and the upstream end 76 of shield 75 is positioned generally intermediate to air inlet 69 of combustion chamber 67 and the upstream end of the first flow shield 73. The downstream end 78 of shield 75 is positioned generally intermediate the ends of the first flow shield 73. A first fuel nozzle 79 is axially positioned within combustion chamber 67 immediately downstream of air inlet 69 thereof and is positioned so as to direct the flow of fuel therethrough toward exhaust gas outlet 71. A plurality of fuel nozzles 81, preferably 3 or more, are positioned within annular space 77 adjacent to the upstream end of flame shield 73 and are positioned so as to direct the flow of fuel therethrough toward air inlet 69.

In accordance with this invention, the fuel decomposition means 23 is axially positioned within and spaced from combustion chamber 67 at a place intermediate the downstream end of the first flow shield 73 and exhaust gas outlet 71. In the embodiment shown in FIGURE 3, at least a portion of liquid fuel is passed from the fuel supply 29 via a conduit 83 and a conduit 85 through fuel decomposition means 23. The remainder of the liquid fuel is passed via the conduit 83, manifold 86 and a conduit 87 to the second fuel nozzle 81. The decomposed fuel leaving outlet 27 of fuel decomposition means 23 is passed via a conduit 89 to the first fuel nozzle 79.

It will be seen that the embodiment of our invention in FIGURE 3 provides a pilot flame zone 91 within the second flow shield 75. The high flame speed components produced by cracking the fuel in cracking means 23 are burned in pilot flame zone 91 since the fuel containing these components is introduced thereto by fuel nozzles 79. The primary combustion within combustor 3 is provided by the fuel passed through nozzle 81 and the combination of the two combustion zones, one of which is provided by burning high flame speed components, provides a highly stable combustion reaction.

The following examples and data are supplied in order to illustrate the improved jet engine fuel which is obtained in accordance with our invention. These examples and data are not intended, however, to unduly restrict the invention.

EXAMPLE

The effect of at least partially decomposing a normal-paraffinic JP–5 jet fuel on combustion of this fuel was determined in a laboratory test in which hot combustion gases otbained from a primary burner were employed in a fuel pre-heater to at least partially decompose the test fuel. The properties of this test fuel are presented below in Table I.

Table I

PROPERTIES OF NORMAL-PARAFFINIC JP-5 JET FUEL USED IN TEST

Specific gravity		0.810
Reid vapor pressure		——
Distillation:		
IBP	° F.	414
5%	° F.	434
10	° F.	443
50	° F.	483
90	° F.	525
95	° F.	538
DP	° F.	540
Freezing point	° F.	3.2
Lower heating value unit weight		18,700 B.t.u./lb.[1]
Lower heating value unit volume		126,000 B.t.u./gal.

[1] Calculated using Hougen and Watson characterization factor. Hougen & Watson, "Industrial Chemical Calculations," John Wiley & Sons, 2nd ed. (1936), p. 214.

The JP-5 fuel discharged from the preheater was burned in test burner to determine the effect of decomposition of the fuel in the preheater on combustion performance. Samples of the fuel discharged from the preheater were analyzed to determine the composition of the decomposed fuel. The decomposition of the fuel was carried out at two temperature levels. A run was carried out wherein the temperature of the hot combustion gases obtained from the primary burner was 1100° F. A second run was carried out wherein the temperature of the combustion gases obtained from the primary burner was 1600° F. The latter temperature was adequate to assure at least partial decomposition of the JP-5 fuel. The residence time of the fuel within the preheater in the runs was very short and was of a magnitude of about 0.1 second.

The chemical composition of the JP-5 test fuel leaving the preheater after having been subjected to a temperature of approximately 1600° F. is presented below in Table II.

Table II

CHEMICAL COMPOSITION OF JP-5 FUEL LEAVING FUEL PREHEATER AT 1600° F. PREHEATER GAS INLET TEMPERATURE

Products	Normal Paraffinic JP-5 Blend	
	Weight percent	Volume percent
Hydrogen	0.1	2.9
Methane	1.4	9.6
Ethane	1.6	5.7
Ethylene	4.6	17.4
Propane	----------	----------
Propylene	2.7	6.8
Butylenes	0.9	1.6
Pentanes	----------	----------
Hexanes	----------	----------
Miscellaneous Liquid Hydrocarbons	[1] 88.7	[1] 56.1

[1] Distillation range 140–550° F.

These data show that substantial quantities of high flame speed components were formed in the decomposition reaction. Furthermore, these data show that an important advantage is obtained in the system of our invention, namely, that the relatively high boiling, normal paraffinic type JP-5 jet fuel was decomposed so that the front end of its distillation curve was dropped considerably and the fuel leaving the preheater was actually more like a JP-4 jet fuel than a JP-5 fuel. It is well known that normal paraffinic type JP-5 jet fuels are often difficult to burn in some jet engines because of the low volatility of this fuel. However, when the combustor of our invention is used, the problem of low volatility in the JP-5 jet fuel is lessened and the high heating value of the heavier fuel is still taken advantage of.

The results of heating the JP-5 test fuel above the temperature at which it is vaporized and, therefore, to a temperature at which the fuel is at least partially decomposed is illustrated in FIGURES 4, 5 and 6. FIGURE 4 shows the relationship between combustor temperature rise in degrees F. and the combustion efficiency in percent for the JP-5 test fuel at the most severe operating condition, corresponding to a value of 362 for combustor performance correlating parameter

$$\frac{(T\sqrt{P})}{V}$$

It should be noted that both combustion efficiency, particularly at the higher combustor temperature rise values (richer mixtures), and maximum stable temperature rise (denoted by the flame blowout points) were increased at the higher temperature (1600° F.) for the heating gases admitted to the preheater.

FIGURE 5 shows the relationship between combustor performance correlation parameter

$$\frac{(T\sqrt{P})}{V}$$

and maximum stable temperature rise in degrees F., and shows, particularly, the effect of a decrease in severity of conditions within the combustor on maximum stable temperature rise and on the rich mixture flame blowout points. Thus, FIGURE 5 shows clearly the improvement in combustion stability performance resulting from at least partially decomposing the JP-5 test fuel in accordance with this invention.

For a given severity of inlet air conditions, as expressed by

$$\frac{T\sqrt{P}}{V}$$

as the fuel-air mixture is changed from lean through stoichiometric to rich, in many cases the combustion efficiency increases to a maximum at or near stoichiometric and then decerases until the blowout point is reached. Furthermore, for conventional combustors, this maximum efficiency tends to decrease as the severity of inlet air conditions increases. When operating according to the present invention, this decrease in maximum combustion efficiency with increasing severity of inlet air conditions is minimized. The effect of treating a fuel in accordance with this invention is illustrated in FIGURE 6 where the effect of heating the fuel to at least partially crack the fuel on the variation in maximum efficiency with severity of inlet air conditions is shown.

It will be obvious to those skilled in the art that many substitutions, changes, and modifications are apparent and suggest themselves in light of the foregoing disclosure without departing from the spirit or scope of our invention.

We claim:

1. A method of preparing high flame speed components in a fluid, predominantly *n*-paraffinic, fuel and of supplying said fuel to the combustion zone of a jet engine comprising a pilot flame zone and a primary combustion zone, which comprises, passing all of said fuel through said combustion zone under pyrolytic conditions, separating the resulting pyrolyzed fuel into a gaseous fuel and a liquid fuel, continuously passing said gaseous fuel to said pilot flame zone as fuel therefor, and passing said liquid fuel to said primary combustion zone as fuel therefor.

2. A jet engine which comprises, in combination, a combustion chamber having an air inlet in one end thereof and an exhaust gas outlet in the other end thereof, a flow shield axially positioned within said combustion chamber, said flow shield having a generally frusto-conical shape and being open at the large end thereof to form a flow shield exhaust gas outlet and being open at the small end to form a flow shield air inlet, said flow shield

having a plurality of perforations disposed around the surface of said shield, said flow shield exhaust gas outlet being attached to the inner wall of said combustion chamber at a point generally intermediate the air inlet and exhaust gas outlet of said combustion chamber, a first fuel nozzle axially-positioned within said combustion chamber adjacent to said combustion chamber air inlet and positioned so as to direct fuel towards said exhaust gas outlet and so as to be within said air inlet to the combustion chamber and to extend partially through the flow shield air inlet, a second fuel nozzle axially-positioned within said flow shield, said second fuel nozzle being positioned so as to direct fuel towards said flow shield air inlet and positioned generally intermediate the air inlet and exhaust gas outlet of said flow shield, an elongated, tubular fuel cracking means having an inlet and an outlet positioned within said combustion chamber, said cracking means being positioned between said flow shield exhaust gas outlet and said combustion chamber exhaust gas outlet, a liquid-gas separator, a first conduit means for supplying liquid fuel to said cracking means inlet, a second conduit connecting said cracking means outlet to said separator, a third conduit means for supplying liquid fuel from said separator to said second fuel nozzle, and a fourth conduit means for supplying gaseous fuel from said separator to said first fuel nozzle.

3. A jet engine in accordance with claim 2 wherein said elongated, tubular fuel cracking means is a helical tubing axially-positioned within and spaced from said combustion chamber.

4. A continuous combustion burner assembly comprising, in combination, a combustion chamber having an open inlet and an open outlet, a vapor burner in said open inlet, an atomizing burner for burning liquid fuel intermediate said inlet and said outlet, an opening in the wall of said combustion chamber adjacent said atomizing burner for inlet of combustion air, a heat exchange means on the side of the outlet of said combustion chamber opposite the inlet thereof, a first vessel for storage of liquid fuel, a first conduit communicating said storage vessel with one end of said heat exchange means, a second vessel for separation of liquid and vapor, a second conduit communicating the other end of said heat exchange means with said second vessel, a third conduit communicating the normally liquid containing space in said second vessel with said atomizing burner for passage of liquid fuel, a fourth conduit communicating the normally vapor containing space of said second vessel with said vapor burner for passage of fuel vapor, and a housing open at opposite ends surrounding said combustion chamber and said heat exchange means.

5. A method of preparing high flame speed components in a hydrocarbon fuel and of supplying said fuel to the combustion zone of a jet engine comprising a pilot flame zone and a primary combustion zone, which comprises, passing said fuel in indirect heat exchange with said combustion zone under pyrolytic conditions, passing the resulting stream containing pyrolyzed fuel into a separation zone, separating said stream into a gaseous fuel and a liquid fuel, continuously passing said gaseous fuel to said pilot flame zone as fuel therefor, and passing said liquid fuel to said primary combustion zone as fuel therefor.

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