Aug. 19, 1952 L. E. BERGGREN ET AL 2,607,193

ANNULAR COMBUSTION CHAMBER WITH MULTIPLE NOTCHED FUEL NOZZLES

Filed Oct. 25, 1947 2 SHEETS—SHEET 1

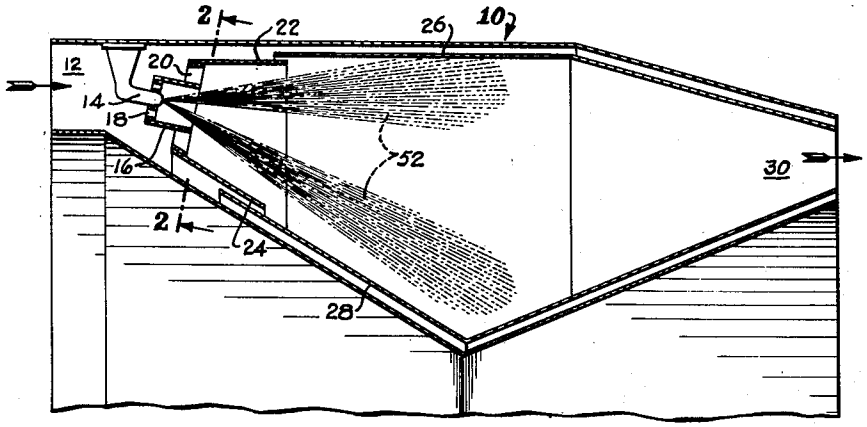


FIG. 1

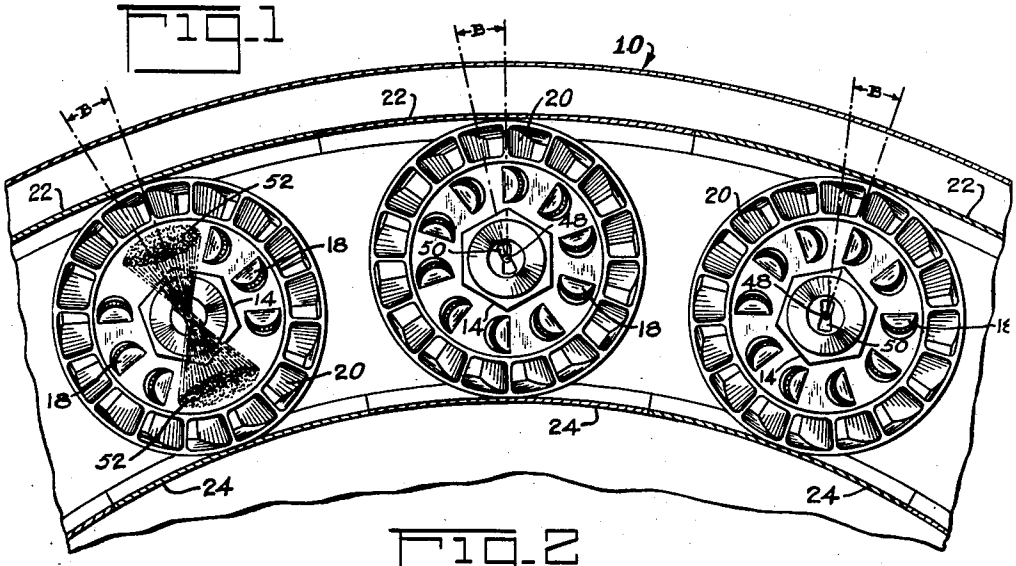


FIG. 2

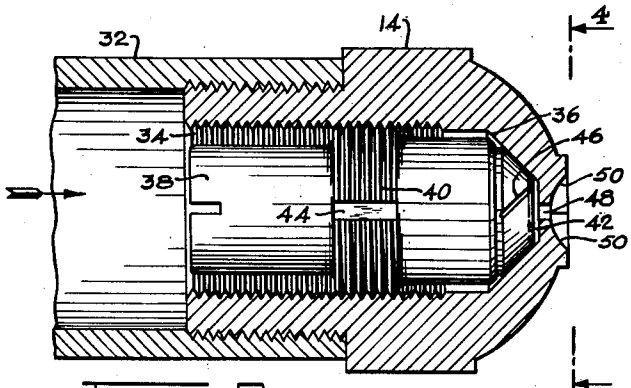


FIG. 3

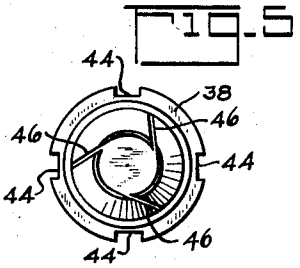


FIG. 5

INVENTORS
LLOYD E. BERGGREN.
DAVID MILLER.
BY Victor A. Bela
ATTORNEY

Aug. 19, 1952 L. E. BERGGREN ET AL 2,607,193

ANNULAR COMBUSTION CHAMBER WITH MULTIPLE NOTCHED FUEL NOZZLES

Filed Oct. 25, 1947 2 SHEETS—SHEET 2

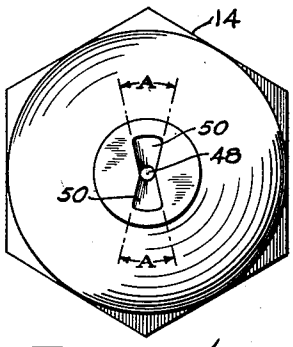


FIG. 4

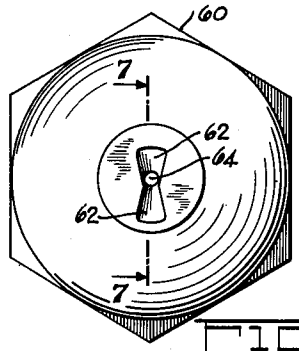


FIG. 6

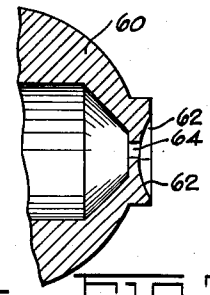


FIG. 7

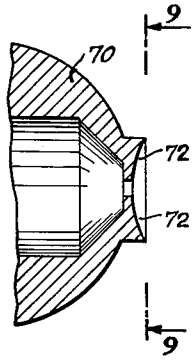


FIG. 8

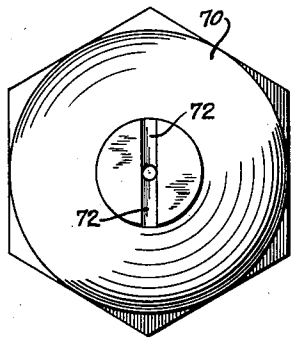


FIG. 9

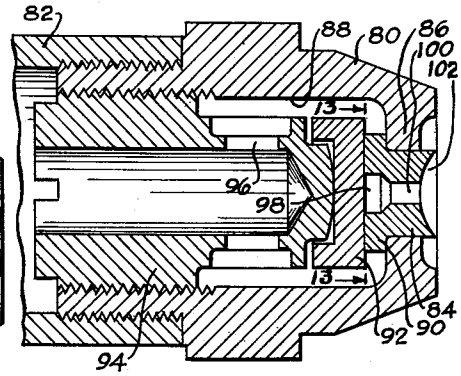


FIG. 12

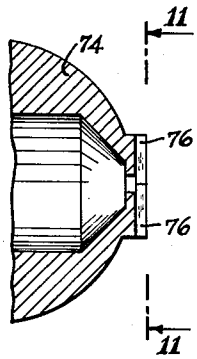


FIG. 10

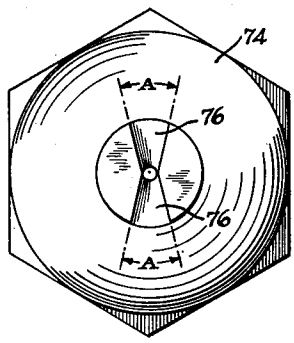


FIG. 11

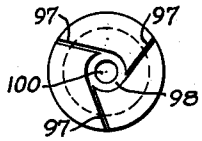


FIG. 13

INVENTORS
LLOYD E. BERGGREN
DAVID MILLER.
BY Victor D. Behn
ATTORNEY

Patented Aug. 19, 1952 2,607,193

UNITED STATES PATENT OFFICE

2,607,193

ANNULAR COMBUSTION CHAMBER WITH MULTIPLE NOTCHED FUEL NOZZLES

Lloyd E. Berggren, Roseland, N. J., and David Miller, Lynchburg, Va., assignors to Curtiss-Wright Corporation, a corporation of Delaware

Application October 25, 1947, Serial No. 782,163

4 Claims. (Cl. 60—39.74)

1

This invention relates to liquid spray nozzles and is particularly directed to a liquid fuel nozzle structure for combustion apparatus.

The conventional fuel nozzle for liquid fuels is provided with means for imparting a whirling or rotary motion to the fuel before it discharges axially from the nozzle. As a result of this whirling and axial motion of the fuel relative to the nozzle, said fuel discharges from the nozzle in a hollow conical spray. When a plurality of such fuel nozzles are disposed in side-by-side relation in a combusion chamber—as in an annular combustion chamber of a gas turbine—it has been found that the temperature of the combustion gases is not uniform across the discharge end of the combusion chamber. In an actual installation with said conventional fuel nozzles, it has been found that the temperature of the combustion gases, at the annular discharge end of the combustion chamber, is a maximum at the mean radius of said annular discharge end and is a minimum at the inner and outer radii of said annular discharge end. However, since in general the efficiency of a gas turbine increases with increase in the average temperature of the turbine motive fluid, this non-uniform temperature distribution results in a corresponding decrease in turbine efficiency. Accordingly it is an object of this invention to provide a fuel nozzle having a fuel spray pattern such that when a plurality of such nozzles are used in an annular combustion chamber of a gas turbine, the combustion gases have a more uniform or a more desirable temperature distribution at the discharge end of the combustion chamber.

A still further object of the invention resides in the provision of a fuel nozzle having a fuel spray comprising two diverging diametrically spaced streams. With a plurality of such fuel nozzles in an annular combustion chamber, the one fuel stream of each nozzle can be directed toward the inner wall of the combustion chamber with the other fuel stream of said nozzle directed toward the outer wall of said combustion chamber whereby the temperature pattern of the combustion gases can be improved.

In conventional gas turbine, the combustion gases are directed from the combustion chamber against blades extending radially from a turbine rotor. During operation, the turbine rotor blades are subjected to centrifugal forces and to the pressure of the combustion gases acting thereon. In this conventional turbine construction, the stress in the turbine rotor blades, during turbine operation, is a maximum adjacent the root ends

2

of the blades and said stress progressively decreases toward the radially outer ends of the blades. Therefore the maximum safe temperature at which the turbine rotor blades can be operated progressively increases from a point adjacent the root ends of the blades to their radially outer ends. With this in mind, a still further object of the invention comprises the provision of a fuel nozzle having a spray pattern such that when a plurality of such nozzles are used in an annular combustion chamber, the temperature of the combustion gases, at the annular discharge end of said chamber, is a maximum at the maximum radius of said chamber and decreases radially inwardly therefrom.

A still further object of the invention comprises the provision of an annular combustion chamber having a plurality of circumferentially spaced fuel nozzles at the inlet end of said chamber with each fuel nozzle designed to provide a spray pattern comprising one fuel stream inclined to the nozzle axis and directed toward the inner wall of said combustion chamber and a second stream inclined to the nozzle axis and directed toward the outer wall of said combustion chamber.

Other objects of the invention will become apparent upon reading the annexed detailed description in connection with the drawing, in which:

Figure 1 is an axial sectional view of a gas turbine combustion chamber having fuel nozzles embodying the invention;

Figure 2 is an enlarged sectional view taken along line 2—2 of Figure 1;

Figure 3 is a further enlarged sectional view of a fuel nozzle incorporated in Figures 1 and 2;

Figure 4 is an end view of a fuel nozzle taken along line 4—4 of Figure 3;

Figure 5 is an end view of the swirl piece of the fuel nozzle of Figures 3 and 4;

Figure 6 is an end view of a nozzle generally similar to that of Figures 3, 4 and 5;

Figure 7 is a partial sectional view taken along line 7—7 of Figure 6;

Figure 8 is a partial sectional view of a nozzle similar to that of Figure 3 but providing a slightly different spray pattern;

Figure 9 is an end view taken along line 9—9 of Figure 8;

Figure 10 is a partial sectional view of a nozzle similar to that of Figure 3 but providing another slightly different spray pattern;

Figure 11 is an end view taken along line 11—11 of Figure 10;

Figure 12 is a sectional view through a different form of fuel nozzle embodying the invention; and

Figure 13 is a view taken along line 13—13 of Figure 12.

Referring first to Figures 1 and 2, reference numerals 10 indicate an annular combustion chamber of a gas turbine engine. Applicant's copending application Serial Number 782,162, filed October 25, 1947, schematically illustrates such a gas turbine engine Air is supplied under pressure to the annular inlet opening 12 of said chamber. A plurality of fuel nozzles 14 are circumferentially spaced about the combustion chamber inlet opening 12 from which fuel under pressure is sprayed into said chamber.

A short duct 16 is co-axially disposed about each nozzle 14 and, at the inlet end of the duct 16, vanes 18 are disposed so as to impart a whirling motion to the air entering said duct. An additional set of vanes 20 are disposed about each of said first set of vanes 18. The vanes 20 are positioned so as to impart a whirling motion to the air flowing therebetween opposite to that imparted by the first set of vanes 18. This whirling motion of the air about each fuel nozzle 14 helps to provide a thorough mixing of the air and fuel. The outer walls of the combustion chamber 10 are shielded by suitable flame and heat shields. Thus, a member 22 is supported radially outwardly by each nozzle 14 and its duct 16, in abutting engagement with the adjacent members 22, to form an annular shield thereabout. Similarly abutting shields are disposed radially inwardly of each nozzle 14 and its duct 16 to form a second annular shield. The annular shields 22 and 24 are spaced from their adjacent combustion chamber walls and they overlap annular shields 26 and 28 a short distance down-stream from the fuel nozzles 14. The shields 22, 24, 26, and 28, are spaced from the adjacent combustion chamber walls to permit air flow therebetween, thereby maintaining the outer combustion chamber walls relatively cool. The combustion chamber is also provided with conventional igniter means (not shown)—as for example electric spark gaps—in order to ignite the combustion mixture.

The structure of the combustion chamber so far described forms no part of the present invention. With the usual fuel nozzles, each nozzle atomizes or sprays fuel into its combustion chamber in a conical hollow spray pattern. It has been found that with such conventional nozzles, the temperature of the combustion gases at the annular discharge end of the combustion chamber, is a maximum at the mean radius of said discharge end and is a minimum at the inner and outer radii of said end. This temperature distribution probably results from overlapping of the hollow conical fuel spray patterns of the nozzles along the mean radius of the combustion chamber as well as from the relatively cool air flowing along the inside walls of the shields 26 and 28.

In accordance with the present invention each nozzle 14 is designed so that its spray pattern comprises two diverging diametrically opposed fuel jets or streams with each particle of fuel in said spray pattern having radial and axial components of velocity relative to the axis of its nozzle. In addition each nozzle is disposed in the annular combustion chamber 10 so that its two fuel streams are substantially symmetrically disposed relative to a plane including the axis of the combustion chamber 10 and the axis of the associated nozzle 14.

The nozzles 14 are all the same so that it is only necessary to describe one of the nozzles. Referring to Figures 3 to 5, the nozzle 14 is threaded on the end of a fuel conduit 32 from which fuel is supplied under pressure to a central bore 34 in said nozzle. The bottom of the nozzle bore 34 is conical as indicated at 36. A swirl piece 38 is threadedly secured within the nozzle bore 34 by its threads 40. The downstream end of said swirl piece is formed as a frustrum of a cone which is fitted to and is held against the conical bottom 36 of the bore 34 thereby forming a chamber 42 at the bottom of said bore.

The swirl piece threads 40 are provided with one or more axial grooves 44 through which fuel flows to the bottom of the bore 34. In addition the conical end of the swirl piece 38 is provided with a plurality of circumferentially spaced grooves 46. Each of the grooves 46 extends from the outer edge of the conical end of the swirl piece 38 and terminates substantially tangent to the outer periphery of the chamber 42. In this way fuel enters tangentially into the chamber 42 from the fuel passages formed by the grooves 46. Each of the grooves 46 is directed in the same direction about the axis of the chamber 42 whereby fuel tends to whirl in the chamber 42 about the axis of said chamber. The nozzle end wall adjacent the chamber 42 is provided with a small discharge orifice 48 co-axial with the chamber 42. If the outer surface of the nozzle 14 about the orifice 48 is symmetrical, in all directions, the whirling motion of the fuel discharging through each discharge orifice 48 causes each nozzle to have a hollow conical spray pattern.

In accordance with the present invention the outer surface of each nozzle 14 is provided with a pair of notches 50 extending in diametrically opposite directions from its discharge orifice 48. As illustrated in Figure 4, the notches 50 are similar and the width of each notch 50, adjacent its orifice 48, is approximately equal to the diameter of said orifice 48. The side walls of each notch 50 diverge in a radially outward direction from its orifice 48 so that the width of each notch 50 is a maximum at its radially outer end. The angle A, included between the side walls of each notch 50, is approximately 30° as illustrated in Figure 4. The depth of each notch 50 is a maximum at its orifice 48 and said depth progressively decreases in a radially outward direction from said hole. Such diametrically opposed notches 50 may readily be machined in the outer surface of a nozzle 14 by means of a cylinder cutting tool.

Because of the whirling action of the fuel about the axis of its nozzle discharge orifice 48, the fuel discharging therethrough is subjected to centrifugal forces so that on leaving its nozzle, each particle of fuel has a radial as well as an axial component of velocity. The notches 50 split the fuel discharging from their discharge orifice 48 into two similar diametrically spaced diverging streams as indicated at 52 (Figures 1 and 2). For clarity, the fuel streams 52 have only been indicated for one nozzle in Figure 2. As a result of the whirling action of the fuel, a plane, including the axes of the two fuel streams 52 discharging from each nozzle, is inclined by an angle B (Figure 2) to the direction at which said notches 50 extend from the axis of its discharge orifice 48. The rotative displacement of this plane

of a pair of fuel streams 52, from the direction of their notches 50 is the same as the direction of the whirling action of the fuel discharging through its nozzle orifice 48. Each nozzle is disposed in the combustion chamber so that a plane including its axis and the axis of said combustion chamber passes symmetrically through its two fuel streams 52. This means that each nozzle is disposed in the combustion chamber so that the direction at which its notches 50 extend from its orifice 48 is inclined by said angle B to a radial line passing through the axis of said combustion chamber and the axis of said orifice.

In an actual installation, with the angle A equal to 30° it was found that the angle B was roughly 10 to 15°. Therefore, as illustrated in Figure 2, each nozzle 14 is disposed in the combustion chamber 10 so that its notches 50 extend from its nozzle discharge orifice 48 along a line making an angle B, equal to approximately 10 to 15°, with a line radial to the axis of the combustion chamber and passing through said discharge orifice 48. With this construction, each pair of fuel streams 52 discharging from a nozzle 14 is symmetrically disposed relative to a plane including the axis of the annular combustion chamber 10 and the axis of its fuel nozzle 14. That is, the one fuel stream or flame 52, emanating from the orifice 48 of a nozzle 14, is directed axially and radially from the nozzle toward the outer wall of the combustion chamber 14 while the other fuel stream or flame 52, emanating from said nozzle orifice, is directed axially and radially from the nozzle toward the inner wall of the combustion chamber 14. With this arrangement, a more uniform temperature of the combustion gases is produced at the discharge end of the combustion chamber.

The specific form of the nozzle notches 50 depends on the particular spray pattern desired which, in the case of a fuel nozzle, depends on the dimensions of the combustion chamber to which fuel is supplied by the associated nozzle.

In a conventional gas turbine, the turbine rotor blades extend radially from the turbine rotor across the annular discharge end of the turbine combustion chamber. In this conventional structure, the stress in each turbine blade, during turbine operation, is a minimum at the radially outer end or tip of the blades and said stress increases toward the root ends of the blades. Therefore the maximum safe operating temperature of the turbine rotor blades is higher at the radially outer ends of the blades and decreases radially inwardly therefrom with increase in the stress in the blades. Accordingly, in the case of a gas turbine, the temperature of the combustion gases at the discharge end of the turbine preferably is a maximum at the maximum radius of said discharge end and decreases toward the minimum radius of said discharge end. This temperature distribution may be produced by making the fuel stream directed toward the outer wall of the combustion chamber larger than the fuel stream directed toward the radially inner wall of the combustion chamber. Figures 6 and 7 illustrate a nozzle 60 having a spray pattern comprising two such non-equal fuel streams.

The nozzle 60 is similar to the nozzle 14 except its notches 62, on the outer surface of said nozzle 60, in effect are displaced relative to the axis of the nozzle discharge orifice 64. Thus the notches 62 are generally similar to the notches 50 except their minimum width portion is displaced slightly from the axis of the nozzle discharge orifice 64.

With the nozzle 60 disposed in the position illustrated in Figures 6 and 7, the notches 62 extend in a vertical direction and the minimum width portion of said notches is disposed below the axis of its discharge orifice 64 and, with said nozzle in this position, its upper fuel stream is larger or contains more fuel than its lower fuel stream. Accordingly in a gas turbine installation, each nozzle 60 is disposed in the turbine combustion chamber with its notches 62 making an angle with a radial line passing through the combustion chamber axis and the axis of its nozzle (as illustrated in Figure 2) and with the minimum diameter portion of the notches 62 disposed closer to the axis of the combustion chamber than is the axis of its nozzle. With this arrangement the temperature of the combustion gases at the discharge end of the combustion chamber may be made a maximum at the maximum radius of said discharge end.

Figures 8 and 9 illustrate a fuel nozzle 70 similar to that of Figures 3 to 5 except the angle A, between the sides of each of the diammetrically opposed notches 72, is made equal to zero. The remaining parts of the nozzle 70 are similar to those of the nozzle 14 of Figures 3 to 5.

Figures 10 and 11 illustrate a fuel nozzle 74 which comprises a further modification of the fuel nozzle 14 of Figures 3 to 5. In Figures 10 and 11 the sides of the diammetrically opposed notches 76, like the sides of the notches 50, diverge in a radially outward direction by an angle A but the depth of each of the notches 50'' is constant. The remaining parts of the fuel nozzle 74 are similar to those of the fuel nozzle 14.

The fuel nozzles 70 and 74 both provide spray patterns generally similar to that provided by the nozzle 14 in that each of these nozzles provide a spray pattern similar to that schematically illustrated in Figure 1. The spray pattern of the nozzle 70 differs from that of the nozzle 14 in that the pattern is narrower in a direction transverse to the notches 72, while the spray pattern of the nozzle 74 diverges considerably more than the spray pattern of the nozzle 14. Figures 3 to 5 illustrate the preferred fuel nozzle notch construction for a nozzle having a fuel spray pattern comprising two diverging fuel streams of equal strength while Figures 6 and 7 illustrate a modified construction in which the fuel spray pattern comprises two diverging fuel streams of unequal strength.

The invention is not limited to the specific type of nozzle illustrated in detail in Figures 3 to 5. For example, Figures 12 and 13 illustrate the invention applied to another form of nozzle 80 threaded on the end of a fuel conduit 82. A nozzle orifice member 84 extends through the end wall 86 formed by a counterbore 88 in the nozzle. The orifice member 84 has an external annular flange 90 which is held against the end wall 86 by an intermediate member 92 and a member 94 threadedly secured within the bore 88. The member 94 is hollow and is provided with a plurality of radially disposed holes 96 through which fuel is supplied to the bottom of the bore 88 from the conduit 82. The engaged surfaces of the members 84 and 92 are flat. The surface of the member 64 engaged by the member 92 is provided with a plurality of circumferentially spaced grooves 97 extending inwardly from the outer periphery of said surface to a chamber 98. These grooves terminate substantially tangential relative to the outer periphery of the chamber 98.

With this construction of Figures 12 and 13,

fuel enters the chamber 98 in a tangential direction and therefore said fuel tends to whirl about the axis of said chamber and the nozzle orifice 100 through which the fuel discharges. In addition the outer surface of the nozzle orifice member 84 is provided with a pair of notches 102 extending in diametrically opposed directions from the nozzle orifice 100, said notches preferably being similar to the notches 50 of Figures 3 to 5 or the notches 62 of Figures 6 and 7. Accordingly it should be clear that the nozzle of Figures 12 and 13 will provide substantially the same form of spray pattern as that provided by the nozzle of Figures 3 to 5 or the nozzle of Figures 6 and 7. In the structure of Figures 12 and 13, the discharge end of each groove 97 is directed along a line which does not intersect the axis of its nozzle orifice 100 and which is inclined at right angles to said axis instead of obliquely as in the structure of Figures 3 to 5.

While we have described our invention in detail in its present preferred embodiments, it will be obvious to those skilled in the art, after understanding our invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. We aim in the appended claims to cover all such modifications.

We claim as our invention:

1. In combination: an annular combustion chamber; a plurality of fuel nozzles disposed in said chamber and circumferentially spaced about the axis of said chamber, each of said nozzles having an end wall with a discharge opening through which fuel discharges into said combustion chamber and at least the discharge end of the discharge opening of each nozzle being elongated diametrically across the nozzle axis, each of said nozzles being oriented so that the plane defined by its nozzle axis and said diametrical direction of its elongated discharge opening is approximately radial relative to the axis of said combustion chamber.

2. In combination: an annular combustion chamber; a plurality of fuel nozzles disposed in said chamber and circumferentially spaced about the axis of said chamber; each of said nozzles having an end wall with a discharge opening through which fuel discharges into said combustion chamber and at least the discharge end of the discharge opening of each nozzle being elongated diametrically across the nozzle axis; and means within each nozzle for causing fuel discharging through its discharge opening to whirl about the nozzle axis whereby said elongated discharge opening is effective to produce a fuel spray pattern having a maximum divergence in a plane including the nozzle axis but rotatively displaced about said nozzle axis by an acute angle B in the direction of said whirl from a plane including said nozzles axis and the diametrical direction of its elongated discharge opening, each of said nozzles being oriented so that said plane of its elongated opening is rotatively displaced about the nozzle axis in a direction opposite to said whirling motion by said acute angle B from a radial plane including said nozzle and combustion chamber axes so that said fuel stream plane of maximum divergence is substantially radial relative to the axis of the combustion chamber.

3. In combination: an annular combustion chamber; a plurality of fuel nozzles disposed in said chamber and circumferentially spaced about the axis of said chamber; each of said nozzles having an end wall with a discharge orifice through which fuel discharges into said combustion chamber, the outer surface of each said nozzle end wall having a pair of notches extending in substantially diametrically opposite directions from the associated nozzle discharge orifice; and means within each nozzle for causing fuel discharging through its discharge orifice to whirl about the axis of said orifice whereby each pair of nozzle notches are effective to cause fuel to discharge from the associated nozzle orifice in a pair of substantially co-planar streams diverging from each other with the plane of the axes of each pair of fuel streams being rotatively displaced about the axis of nozzle discharge orifice from a plane including said nozzle axis and said diametrical direction of its associated pair of notches, said rotative displacement of the plane of the pair of fuel streams of each nozzle being equal to an acute angle B and being in the direction of said fuel whirling motion about the axis of said nozzle, each of said nozzles being oriented so that said plane of its notches is rotatively displaced about the nozzle axis by said acute angle B from a radial plane including said nozzle and combustion chamber axes and in a direction opposite to said whirling motion so that said fuel stream plane is substantially radial relative to the axis of said combustion chamber.

4. In combination: an annular combustion chamber; a plurality of fuel nozzles disposed in said chamber and circumferentially spaced about the axis of said chamber; each of said nozzles having an end wall with a discharge orifice through which fuel discharges into said combustion chamber, the outer surface of each nozzle end wall having a pair of notches extending in substantially diametrically opposite directions from the associated nozzle discharge orifice and each of said nozzles being oriented so that the plane defined by its nozzle axis and the diametrical direction of its said notches is approximately radial relative to the axis of said combustion chamber.

LLOYD E. BERGGREN.
DAVID MILLER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,150,940	Irish	Aug. 24, 1915
1,508,281	Kelley	Sept. 9, 1924
1,581,223	Moore	Apr. 20, 1926
1,813,733	Freeman	July 7, 1931
2,110,409	Veach	Mar. 8, 1938
2,422,214	Meyer	June 17, 1947

FOREIGN PATENTS

Number	Country	Date
9,382	Great Britain	June 26, 1915