Oct. 18, 1960 R. R. KASSNER ET AL 2,956,404

FUEL VAPORIZER

Filed Oct. 2, 1956 4 Sheets-Sheet 1

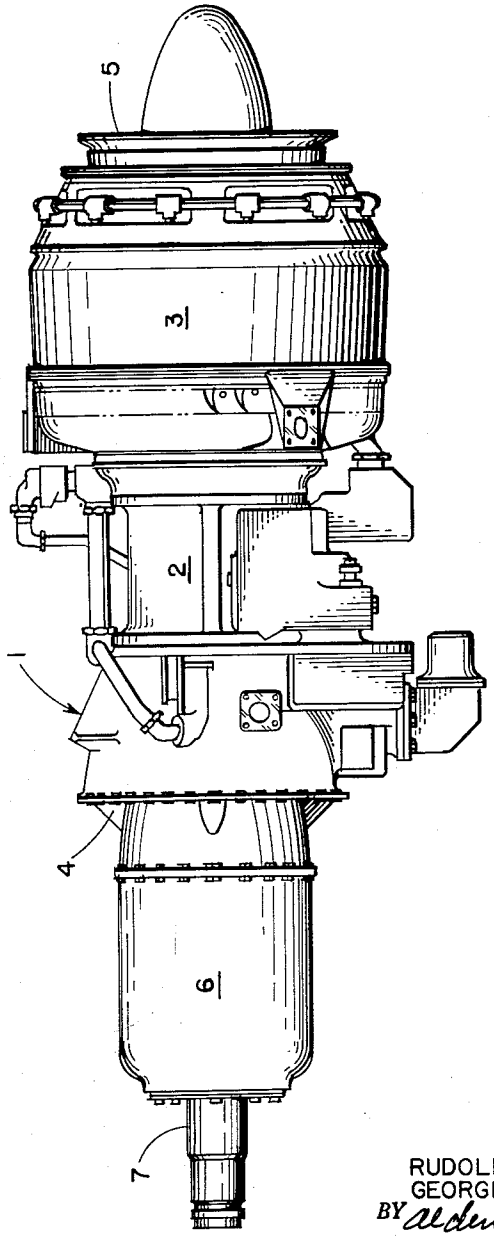

Fig 1

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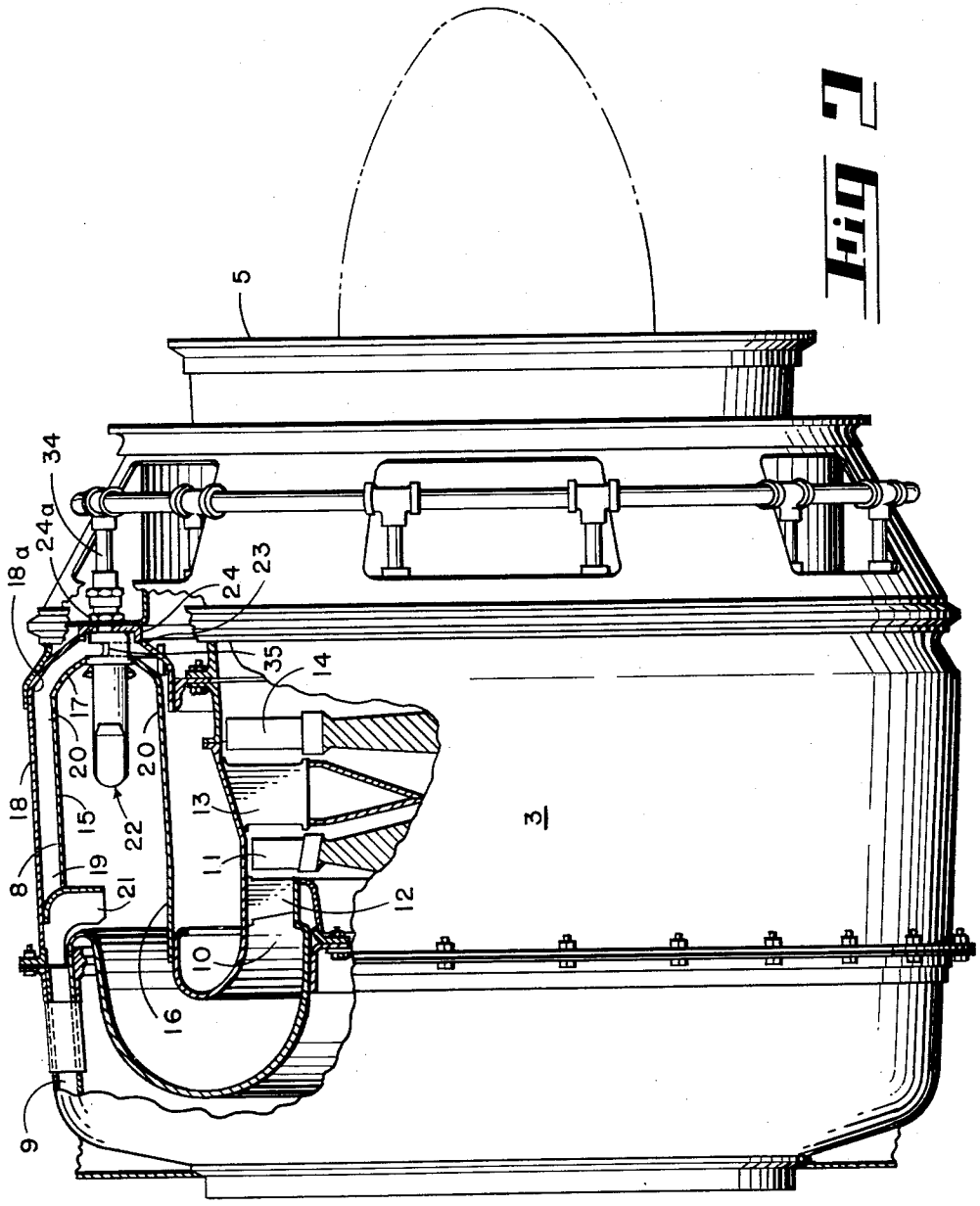
Filed Oct. 2, 1956 4 Sheets-Sheet 2

Fig 2



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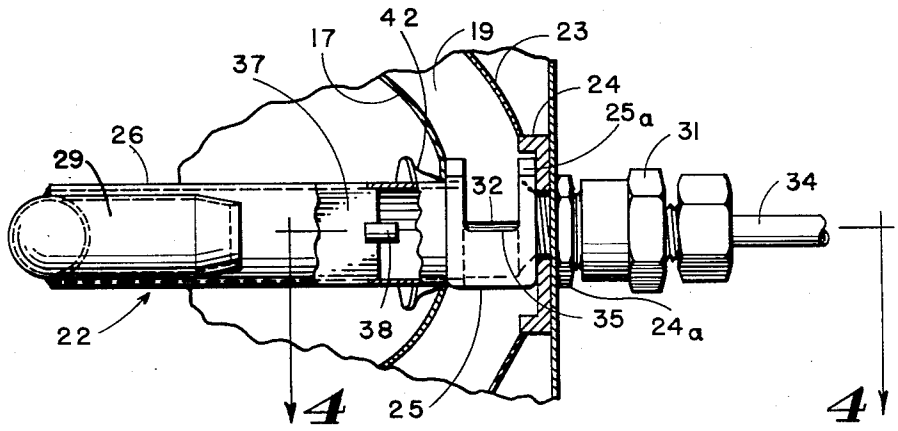

Fig 3

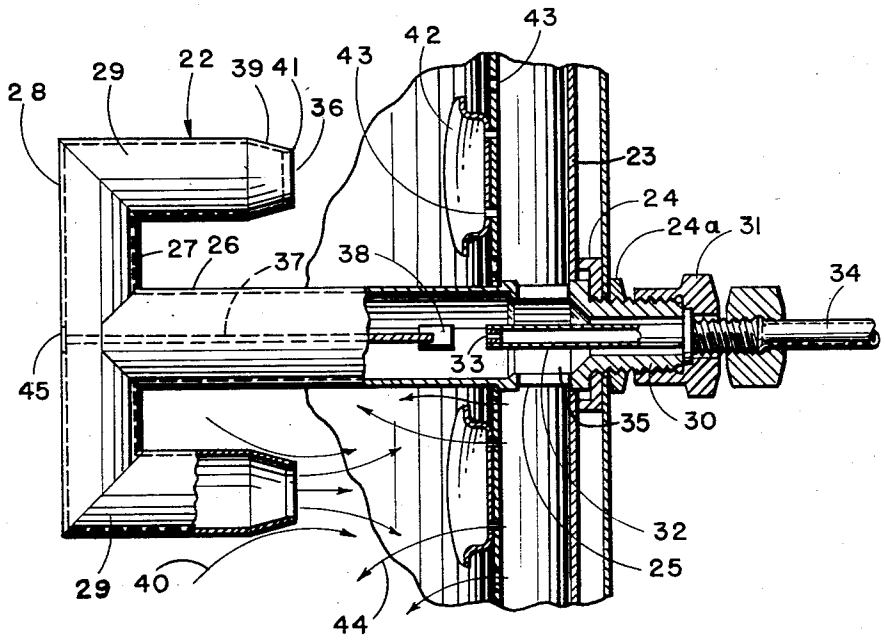

Fig 4

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FUEL VAPORIZER

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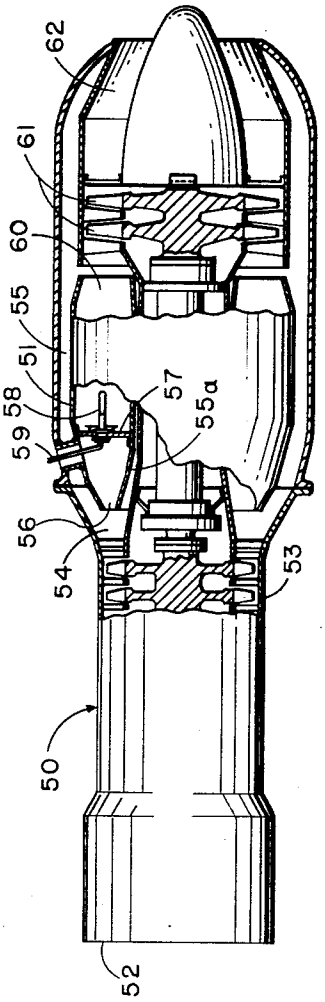

Fig. 5

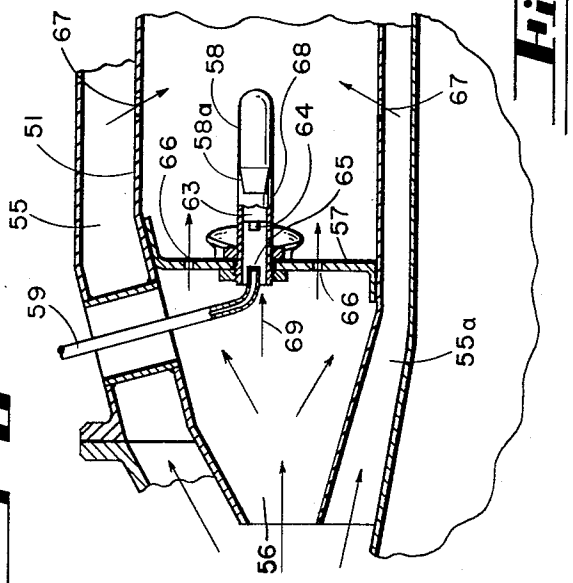

Fig. 6

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FUEL VAPORIZER

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7 Claims. (Cl. 60—39.71)

The present invention relates to an improvement in a gas turbine engine and more particularly to an improvement in the fuel delivery means for the combustion chamber of such an engine.

It is well recognized that efficient combustion of fuel requires intimate association of the fuel and combustion-supporting air. Today two principal methods are used for attaining such intimate association: The one method involves dispersion of the fuel in the air by high pressure discharge of fuel through an atomizing nozzle; the other method involves vaporization of the fuel inside of a chamber which is heated by subsequent combustion of the vaporized fuel. It is to this latter category of fuel handling equipment that the present invention relates.

Briefly stated, the invention comprises an improved, hollow T shaped fuel vaporizing tube. Although such tubes are generally known in the art, the present invention concerns specific improvements which render them more effective in operation. According to one such improvement, a partition is provided dividing the T tube symmetrically in halves to assure equal division of fuel and air which are introduced into the shank of the T. Another improvement concerns the provision of a central target against which incoming fuel impinges, resulting in uniform dispersion of the fuel throughout the cross section of the T tube. A further improvement concerns tapering the outlet ends of the T tube to increase the discharge velocity of the fuel-air mixture therefrom in order to promote efficient mixing of the combustion-supporting air and the fuel-rich mixture discharging from the T tube. The resulting high degree of turbulence favors complete combustion and minimum carbon formation.

In view of the foregoing, it will be apparent that it is an object of this invention to provide an improved fuel vaporizer.

Further objects are as follows:

(*a*) To provide in a fuel vaporizer means for evenly dividing the fuel into two equal portions. This favors complete vaporization of the fuel and equalizes temperatures adjacent the vaporizer resulting from subsequent combustion of the fuel.

(*b*) To provide in a fuel vaporizer a target against which a stream of fuel impinges, resulting in complete and uniform dispersion of the fuel.

(*c*) To provide in a fuel vaporizer restricted outlets to increase discharge velocities in order to promote efficient mixing of combustion-supporting air and the fuel-air mixture discharging from the vaporizer.

(*d*) To improve the operation of T type fuel vaporizers to favor efficient use in an annular combustion chamber having a minimum number of fuel inlet connections.

(*e*) To provide a fuel vaporizer well adapted for use in an annular combustion chamber and characterized by uniform distribution of fuel within the chamber, favoring temperature uniformity throughout the combustion region.

The novel features that we consider characteristic of our invention are set forth in the appended claims; the invention itself, however, both as to its organization and mehod of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in conjunction with the accompanying drawings, in which:

Figure 1 is a side elevational view of a gas turbine engine in which the present invention may be used to advantage;

Figure 2 is an enlarged fragmentary sectional view of the rear half of the engine with parts broken away to disclose the construction of the combustion chamber;

Figure 3 is a side view of a fuel vaporizing tube used in the combustion chamber, the figure being drawn to an enlarged scale for greater clarity;

Figure 4 is a top plan view of the fuel vaporizer taken on plane 4—4 of Figure 3, with certain parts shown in cross section to illustrate the interior construction thereof;

Figure 5 is a schematic illustration of another type of gas turbine engine in which the present invention may be used to advantage; and

Figure 6 is an enlarged fragmentary longitudinal sectional view of the combustion chamber of the engine shown in Figure 5.

Although not so limited, the present invention may be used to particular advantage in gas turbine engines having annular combustion chambers such as shown in Figures 1 and 5. Referring first to Figure 1, there is shown an engine, generally designated **1**, which includes a compressor section **2** and a combustion chamber and turbine section **3**. Ambient air enters the engine through inlet **4** and is compressed in the compressor section before entering the combustion chamber of section **3**. Here, the temperature of the air is greatly increased before being directed to the turbine, as will be described in greater detail shortly. Spent combustion products exhaust from the engine through discharge opening **5**. The net power output of the engine is delivered through gear box **6** to a power output shaft **7**. An engine of the type shown constitutes a dependable power source of low specific weight.

Attention should now be directed to Figure 2 which shows the interior construction of the combustion chamber and turbine section **3**. The combustion chamber, shown in cross section at **8**, is annular in form and designed to effect two flow reversals in the gas path. Air from the compressor section enters the combustion chamber section through an annular diffuser **9** and is introduced into the combustion chamber proper through a plurality of primary and secondary air inlets, as will be described in greater detail subsequently. Hot combustion products leave the combustion chamber through discharge annulus **10** and are directed to the first stage turbine **11** by stationary guide vanes **12**. The first turbine stage is directly coupled to and drives the compressor. After leaving this turbine stage, the hot gases are directed by stationary vanes **13** to a second stage turbine **14**. It is this turbine which powers output shaft **7**.

Concentrating more specifically on the combustion chamber proper, it will be noted that it is defined by an outer annular wall **15** and an inner annular wall **16** which are interconnected at **17** by a toroidal shaped end wall. Surrounding the entire combustion chamber is an outer casing **18** which aids in defining annular air flow passage **19** through which the air is conveyed to primary air inlet openings **20** formed in the side walls of the combustion chamber. Secondary air and diluent air are introduced into the combustion chamber through curved scoops **21** which are provided at intervals circumferentially around

the combustion chamber. It will be noted that these scoops are adapted to receive a portion of the air directly from the diffuser **9** and to convey it to the interior of the combustion chamber.

Projecting through end wall **17** are a plurality of fuel vaporizers, generally designated **22**. Each vaporizer is T shaped in appearance and for convenience is referred to as a "T tube," one of which is illustrated in greater detail in Figures 3 and 4. At this point it is well to note that the T tubes are secured to a toroidal end wall **23** which is secured to the outer casing **18**, as at **18***a*. Welded at equal circumferential intervals around this end wall are sockets **24** that receive and position the T tubes which are locked in position by means of lock nuts **24***a*.

Attention is now directed to Figures 3 and 4 which show a T tube and an adjacent portion of the combustion chamber. It will be noted that the socket **24** receives base **25** of the T tube. To the base is integrally secured a tubular shank **26** which is in axial alignment with the generally cylindrical shaped base. To the opposite end of the shank is secured the head **27** of the T tube which comprises a transverse tubular portion **28** to the opposite ends of which are integrally secured parallel tubular portions **29**. These latter tubular portions are parallel to each other and to shank **26**. It will be recognized that all the tubular portions comprise an interconnected hollow structure.

The base of the T tube includes a projection **25***a* which serves as a key engaging a complementary recess in socket **24**. This orients the T tube within the combustion chamber with the head extending circumferentially of the chamber.

To threaded end **30** of base **25**, which protrudes outside the combustion chamber, there is secured nut **31** which clamps a fuel injector **32** to the T tube. A small orifice **33** is provided at the end of the fuel injector so that the fuel from manifold **34** enters the T tube in a small, well defined stream. This fuel is vaporized within the T tube by the heat of combustion of fuel within the combustion chamber. While passing through the T tube, the incoming fuel is not only vaporized but is intimately mixed with the air required for combustion so that the mixture which emerges from the T tube is in condition to enter immediately into the combustion process.

Attention is now directed to air inlet **35** which is formed in one side wall of base **25**. This air inlet is positioned to receive air flowing through passage **19** and directs the air into the T tube closely adjacent the discharge orifice of the fuel injector.

A T tube is a particularly desirable form of fuel vaporizer for an annular combustion chamber. This will be fully appreciated when it is understood that a combustion chamber of this type has a significant circumferential extent over which it is desirable to maintain temperature uniformity. This is best done by introducing the vaporized fuel at a relatively large number of points rather than at a few points of relative high fuel concentration and high temperature. With this in mind it will be understood that each T tube provides two separate outlets **36** for vaporized fuel. While it is desirable to provide a relatively large number of vaporized fuel outlets, it is also desirable to introduce liquid fuel to the combustion chamber at a relatively few points, so that the fuel injectors may have metering orifices and flow passages as large as possible to provide the greatest insensitivity to clogging by dirt or foreign particles in the fuel stream. The T tube meets these requirements very well since it has only one liquid fuel inlet for two vaporized fuel outlets.

An inherent problem of using a T tube, however, is distribution of fuel equally to the two sides of the vaporizer. In accordance with the present invention, equal distribution of the fuel is assured by the provision of a central divider **37** which symmetrically partitions the interior of the T tube and extends from a region near the fuel injector, through the length of shank **36**, and across transverse tubular portion **28**. A small target **38** is secured to the free end of the divider closely adjacent the outlet of the fuel injector. Fuel from the injector impinges against the target and is dispersed into a relatively fine mist which readily mixes with the incoming primary air entering through inlet **35**. The mixture of air and fuel readily divides equally on either side of the divider **37** and flows in equal concentrations through the symmetrical halves of the T tube. This is of basic importance since in this way uniform distribution of fuel in the combustion chamber is assured. This in turn assures even temperature distribution within the combustion chamber and minimum warpage, distortion and carbon formation within the combustion chamber. These are all fundamental to efficient combustion.

It has also been found highly desirable to taper the free ends of the parallel tubular portions **29**, as indicated at **39**. These tapered ends restrict the outlets **36** from the T tube and increase velocity of the fuel-air mixture as it emerges from the tube. This induces a flow of gases along the exterior of each tapered portion **39**, as indicated by arrows **40**. This gas flow, coupled with the increased velocity of the mixture issuing from the T tubes, assures that the highest possible level of turbulence will be present in the primary combustion zone to provide the intimate mixing necessary to highly efficient combustion and minimum carbon formation. To further deter carbon formation edges **41** may be sharpened, although this is considered optional.

It will be noted that a pair of deflectors **42** are secured to wall **17** opposite outlets **36** of the T tubes. A plurality of primary air openings **43** are provided adjacent and through these deflectors and provide streams of air indicated by arrows **44** which unite with and aid in supporting the combustion of the fuel-air mixture emerging from the T tube. Since movement of air, indicated at **44**, is contrary to movement of the fuel-air mixture, thorough mixing is assured but there may be a tendency to carry the fuel mixture back over the surface of tubular portions **29** if the ends **39** are not tapered to increase the discharge velocity of the fuel-air mixture.

Although only indicated with respect to one outlet **36**, it will be understood that similar movement of gases occurs with respect to the other outlet.

The T tube may be conveniently fabricated by welding together sections of stainless steel tubing. The exact material is a matter of choice but must be able to withstand the relatively high temperatures developed in the combustion chamber. The divider **37** is made of similar material. The shank **26** and tubular portions **28** and **29** are first welded together after which a longitudinal saw cut is made in assembly to receive divider **37**. The divider is separately formed, and target **38** is welded to the divider prior to installation in the tubular assembly. A hole is provided at **45** to accommodate target **38** as the target and divider assembly is slid through the saw cut into the tubular assembly. Thereafter the divider and tubular assembly are welded together along exterior surfaces. The target **38** is then machined to assure concentricity with the base **25**. This may be most readily done by the use of a hollow milling cutter which may be inserted through the opening of base **25**. In this way it is certain that fuel from the fuel nozzle will strike the target centrally.

Attention should now be directed to Figure 5. An axial flow gas turbine engine, generally designated **50**, has been shown to illustrate application of the present invention to an annular combustion chamber **51** of the straight through type. In other words, no reversal of gas flow occurs as in the combustion chamber shown in Figure 2.

In the engine illustrated in Figure 5, ambient air enters at **52** and is compressed in axial flow compressor

53 before entering the combustion chamber at 54. A portion of the compressed air flows through annular channels 55 and 55*a* surrounding combustion chamber 51 and a portion of the air directly enters the combustion chamber through annulus 56. A transverse annular wall 57 is provided near the up-stream end of the combustion chamber for supporting a plurality of T tubes 58 which are secured to the wall. Fuel under pressure is introduced into the T tubes through a plurality of incoming fuel lines 59. Hot compressed gases leave the combustion chamber at 60 before entering turbine stages 61. The exhaust from the last turbine stage leaves the engine at 62 forming, in the engine shown, a jet of power gases providing forward thrust.

Attention should now be directed to Figure 6 showing to an enlarged scale the up-stream end of a portion of the combustion chamber 51. It will be noted that the T tube 58 has the same interior construction as that previously described, including partition 63, central target 64, and restricted outlets 58*a*. The end of fuel line 59 serves as a fuel injector having an orifice 65 that directs fuel against the target by which it is uniformly dispersed throughout the cross section of the T tube. Combustion-supporting air is introduced through a plurality of holes 66 and 67 formed in transverse wall 57 and the annular walls of the combustion chamber, respectively.

The operation of the T tube is substantially the same as in the annular combustion chamber shown in Figure 2. It should be noted, however, that combustion supporting air enters the T tube of Figure 6 directly through the end of the shank 68, as indicated by arrow 69. This is in contrast to side entry of combustion supporting air through the side air inlet 35 shown in Figures 3 and 4.

Here again, the T tube is particularly well adapted to introduciton of fuel uniformly throughout the combustion region, favoring uniform fuel and temperature distribution which minimizes warpage and carbon formation in the combustion chamber.

Having described a preferred embodiment of our invention, we claim:

1. In combination, an annular combustion chamber including a toroidal end wall, an annular casing spaced from and surrounding said combustion chamber and including a toroidal wall spaced from said toroidal wall of said combustion chamber, a T tube vaporizer secured to said toroidal wall of said casing, said vaporizer comprising a base portion having a side air inlet receiving air from the space between said casing and said combustion chamber, a shank secured to said base and extending longitudinally within said combustion chamber, a head secured to said shank remote from said base, said head comprising a transverse tubular portion and parallel portions secured integrally to the opposite ends of said transverse portion, said parallel portions being parallel to each other and to said shank, a divider symmetrically dividing said head and said shank, a target secured to the end of said divider adjacent said base, and a fuel injector secure to said base and projecting towards said target for injecting fuel against said target which serves to disperse it and distribute it equally on both sides of said divider, said fuel mixing intimately with air entering said base through the side air inlet opening.

2. Apparatus as defined in claim 1 in which said parallel portions of said head have restricted outlets.

3. A fuel vaporizer for a gas turbine engine having a source of fuel under pressure comprising a cylindrical base defining a bore and inlet means for introducing air to the bore, a tubular shank integrally secured to said base in axial alignment with the bore, a tubular head symmetrically mounted on and integrally secured to the end of said shank remote from said base, said head comprising a transverse tubular portion and parallel tubular portions integrally secured to the opposite ends of said transverse portion and having free ends extending

in the direction of said base, said parallel portions being disposed parallel to said shank and having their free ends tapered to define restricted outlets, a divider within said shank extending longitudinally thereof from the region adjacent said base through said shank and across said transverse tubular portion, said divider dividing said shank and said head symmetrically and being substantially planar and disposed perpendicularly to the transverse axis of said transverse tubular portion, a cylindrical target secured to the end of said divider adjacent said base, said target being concentric with said shank and the bore of said base, and a fuel injector projecting towards said target for injecting fuel against said target which serves to disperse it and distribute it equally on both sides of said divider, said fuel mixing intimately with air entering said base through the air inlet means.

4. A fuel vaporizer for a gas turbine engine comprising a cylindrical base having an air inlet opening, a tubular shank integrally secured to said base in axial alignment therewith, a tubular head symmetrically mounted on and integrally secured to the end of said shank remoted from said base, said head comprising a transverse tubular portion and parallel tubular portions integrally secured to the opposite ends of said transverse portion and having free ends extending in the direction of said base, said parallel portions being disposed parallel to said shank and having their free ends tapered to define restricted outlets, a divider within said shank extending longitudinally thereof from the region adjacent said base through said shank and across said transverse tubular portion, said divider being substantially planar and disposed perpendicularly to the transverse axis of said transverse tubular portion, and a target secured to the end of said divider adjacent said base and located centrally of said shank.

5. A T tube vaporizer for a gas turbine engine having a source of fuel under pressure comprising a cylindrical base defining a central bore and an air inlet opening through one side thereof, a tubular shank integrally secured to said base in alignment therewith, a head secured to said shank remote from said base, said head comprising a transverse tubular portion and parallel portions secured integrally to the opposite ends of said transverse portion, said parallel portions being parallel to each other and to said shank, a divider symmetrically dividing said head and said shank, a target secured to the end of said divider adjacent said base, and a fuel injector secured to said base and projecting towards said target for injecting fuel against said target which serves to disperse it and distribute it equally on both sides of said divider, said fuel mixing intimately with air entering said base through the air inlet opening.

6. In a gas turbine engine, a fuel injection means, a T tube vaporizer for vaporizing fuel and intimately mixing it with air for combustion, said vaporizer comprising a base supporting said fuel injection means and through which fuel and air may be introduced, a tubular shank secured to said base for receiving fuel and air therefrom, a transverse tubular head secured to said shank remote from said base, said head comprising a transverse tubular portion, two outlet ends from said transverse tubular portion one on each side of said shank, and means comprising a divider extending longitudinally of said shank and inside said shank and into said head across said tubular portion from a point adjacent said fuel injection means for internally dividing said shank and said transverse tubular portion symmetrically so that fuel and air passing through said shank and said tubular portion are equally divided in flow into the thus divided transverse tubular portion.

7. In a gas turbine engine, a fuel injection means, a T tube vaporizer for fuel discharged from said fuel injection means, said vaporizer comprising a base supporting said fuel injection means and through which

fuel and air may be introduced, a tubular shank secured to said base for receiving fuel and air therefrom, a head secured to said shank at the outer end thereof, said head comprising a transverse tubular portion and parallel portions secured integrally to the opposite ends of said transverse portion, said parallel portions being parallel to each other and to said shank, a divider symmetrically dividing said head and said shank, and a target secured to the end of said divider remote from said head and adjacent said fuel injection means.

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