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VAPORIZER TUBE SYSTEM

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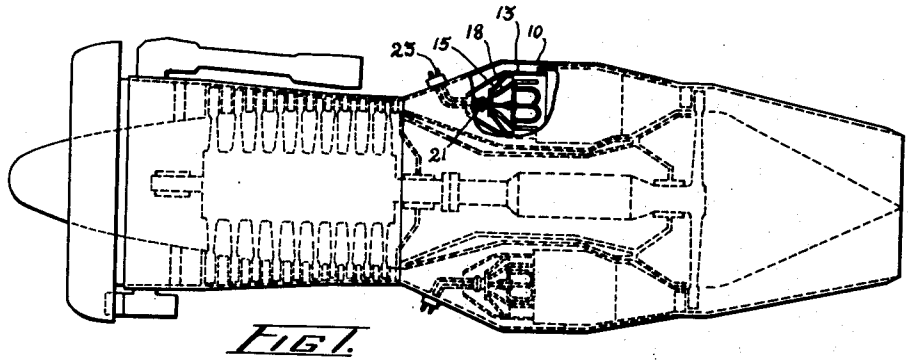


FIG. 1.

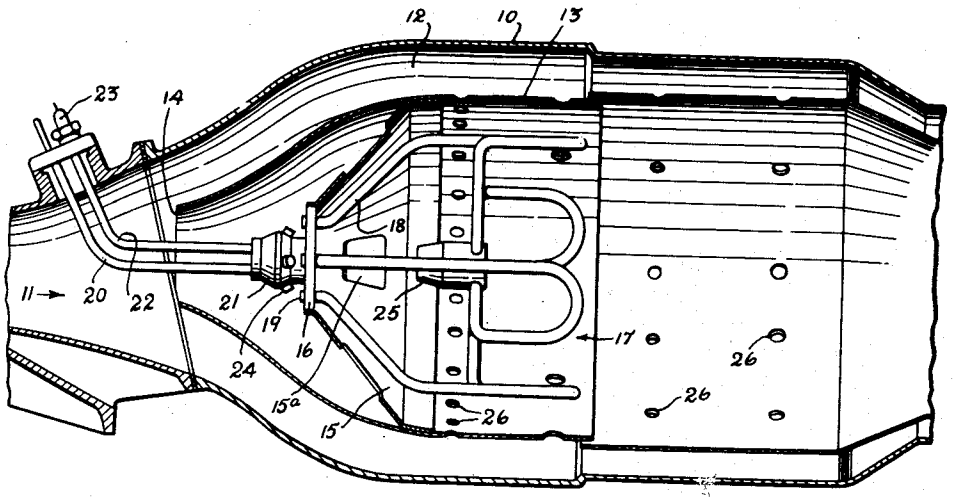


FIG 2.

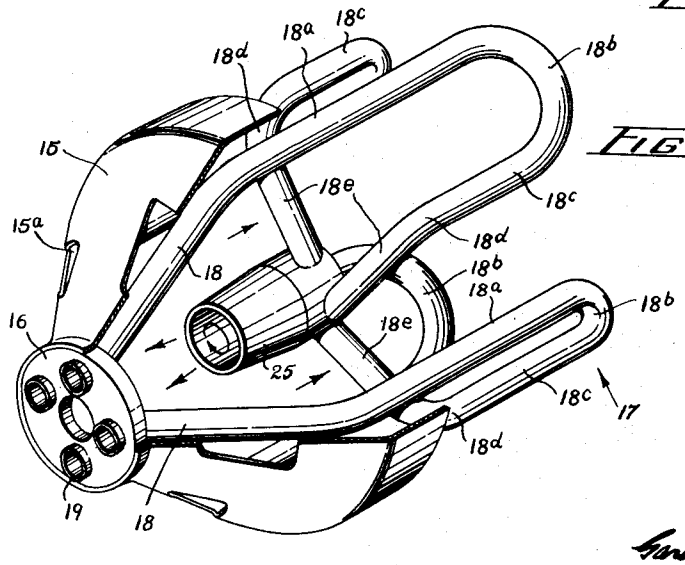


FIG 3.

INVENTOR
F. H. KEAST
F. D. M. WILLIAMS
PER
ATTORNEY

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VAPORIZER TUBE SYSTEM

Francis Henry Keast, Toronto, Ontario, and Frederick Denison Morgan Williams, Weston, Ontario, Canada, assignors to A. V. Roe Canada Limited, Malton, Ontario, Canada, a corporation

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11 Claims. (Cl. 60—39.71)

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This invention relates to fuel vapourizing systems for combustion chambers and particularly to combustion chambers of gas turbine engines.

In order to introduce fuel into the flame tube of a combustion chamber in the form of a vapour which can be readily ignited, a well established practice of the art is to provide vapourizer tubes mounted at their forward or upstream ends in a tube plate and extending downstream into the flame zone. These tubes extend from the front face of the tube plate; the remainder of the tube plate forms a closure across the upstream end of the flame tube so that air flowing into the upstream end or inlet of the flame tube is directed into the vapourizer tubes and flows through them into the flame zone. The downstream ends of the vapourizer tubes are curved through 180° or, as shown in co-pending application Serial Number 139,843, dated January 21, 1950, now Patent No. 2,548,087, by F. D. M. Williams, they converge upon a common outlet nozzle, to discharge the air upstream into the flame zone. Liquid fuel is introduced to the upstream ends of the vapourizer tubes through suitable jets and is carried down the tubes by the flow of air. Since the greater part of the outer surfaces of the vapourizer tubes is exposed to the combustion in the flame zone the tubes become very hot and the liquid fuel flowing through them is vapourized so that a mixture of air and fuel vapour is discharged as a combustible gas. In the process of vapourization of the fuel the tubes are cooled against overheating.

It has been established by measurement that gas temperatures are very high near the centre of the flame zone and on the axis of the group of vapourizer tubes, and that in the outer regions of the flame zone, beyond a certain radius, they are progressively lower. In the prior art constructions the 180° bends or the portions of the tubes converging upon the common nozzle are situated in the hottest part of the flame zone, yet by centrifugal action the liquid fuel tends to be thrown to the outside of the bends, that is to the downstream walls, resulting in uneven and inadequate internal scrubbing by unvapourized fuel of the portions of the tubes exposed to the most severe external conditions. From this cause, frequent tube failures have occurred due to burning of the tubes on the upstream sides of the bends.

The object of this invention is to insure adequate scrubbing of the upstream walls of the vapourizer tubes situated in the hottest part of the flame zone. Other objects and advantages of

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the invention will be apparent from the following description of a preferred example.

In the following drawing forming a part of this specification and in which like reference characters designate like parts throughout the same:

Figure 1 is a side elevation, partly broken away, of a typical gas turbine engine embodying a vapourizer tube system according to the invention;

Figure 2 is a longitudinal section through a typical gas turbine engine combustion chamber embodying the invention, and showing the vapourizer tube system partly in elevation and partly in section; and

Figure 3 is an enlarged perspective view of the vapourizer tube assembly shown in Fig. 1, including a cut-away portion of the baffle.

Referring to the drawing, air from the compressor of the engine enters the combustion chamber 10 in the direction of the arrow 11. The combustion chamber 10 is insulated by the annular space 12 from the flame tube 13, the upstream end 14 of which is open to admit a portion of the air entering the chamber. A transverse baffle 15, having four radially disposed, substantially triangular openings or slots 15a, supports the tube plate 16 to which the vapourizer tube assembly 17 is coaxially secured. The four individual vapourizer tubes 18 are disposed on the same radii as the slots 15a and extend through the tube plate 16, protruding a slight distance in an upstream direction therethrough, and their open inlet ends 19 face the air stream flowing from the compressor through the combustion chamber.

Liquid fuel may be introduced to the vapourizer tube system through the pipeline 20 leading into the burner 21; the burner shown in the drawing is of the torch igniter type requiring an ignition lead which is carried in the tube 22 from the external terminal 23. Jets 24 are provided in the burner 21 to inject fuel into the upstream ends 19 of the vapourizer tubes and since the jets are slightly offset from the axes of their respective vapourizer tubes they present relatively little obstruction to the free entry of the air.

Downstream of the tube plate 16 the vapourizer tubes are arranged to diverge arcuately from the axis of their annular mounting in the tube plate, each tube extending in an oblique direction, along a downstream projection of its corresponding slot 15a in the baffle 15; after traversing the slot the tube enters another arcuate bend to assume a position adjacent and substantially parallel to the wall of the flame tube 13 to

provide a longitudinally directed portion 18a; the portion 18a of each tube terminates in an arcuate bend 18b through approximately 180° around an axis of curvature which represents a radius of the flame tube, whereby each tube turns in a substantially circumferential direction, in the same sense as the other tubes, and is continued through the bend 18b in an upstream direction to provide a longitudinally directed intermediate portion 18c, also adjacent and parallel to the wall of the flame tube. Thus the longitudinally directed portions 18a and 18c are annularly disposed in the outer region of the flame zone where the combustion temperatures are relatively low. The portion 18c of each tube extending in an upstream direction terminates in an arcuate bend 18d, from which bends the tubes converge obliquely upon a common nozzle 25 to provide outlet terminal portions 18e lying cross-stream in a plane substantially transverse to the axis of the combustion chamber. The nozzle 25 consists of a substantially tubular hollow body, which may be substantially cylindrical or slightly frusto-conical in form, closed at its downstream end and open at its upstream end which faces in an upstream sense; the outlet terminal portions 18e of the vapourizer tubes enter the nozzle substantially tangentially to induce swirl and thereby to promote thorough mixing and to ensure that any residual unvapourized fuel which may enter the nozzle will scrub its internal cylindrical surfaces and be vapourized before the fuel-air mixture emerges as a vortex into the flame zone. The dimensions of the nozzle and of the variously directed portions of the vapourizer tubes are so chosen that the outlet terminal portions 18e of the tubes are of significant length, at least three times the diameter of the vapourizer tubes.

In operation, the greater portion of the air entering the combustion chamber flows into the annular space 12 between the combustion chamber 10 and the flame tube 13 and thence, through the various stages of the orifices 26, into the flame tube opposite or downstream of the vaporizer tube assembly 17; the remainder enters the upstream end 14 of the flame tube 13 and, while a part of this air flows through the slots 15a, a part enters the vaporizer tubes 18 through the open inlet ends 19. Liquid fuel is injected by the jets 24 into the same inlet ends, so that a mixture of fuel and air flows through the vapourizer system, finally emerging from the outlet nozzle 25. Combustion is initiated by means of the torch igniter, and thereafter continues in a self-propagating manner in accordance with normal gas turbine practice.

Since the tubes 18 are exposed to the flame zone they become very hot and the liquid fuel flowing through them is vapourized in the course of its passage from the inlet ends 19 to the outlet nozzle 25. However, because the tubes diverge from their mounting in the tube plate 16 and extend through a relatively cool region of the flame zone, adjacent the flame tube wall, a fairly large proportion of the liquid fuel arrives at the bends 18b in liquid form; the liquid fuel is carried to the outside of the bends under centrifugal action, but these bends are not situated in a high temperature region and the ineffective vapourization cooling of their upstream walls resulting from the uneven distribution of the liquid fuel is not important. After passing the bends 18c, the mixture of air and fuel vapor and liquid fuel is projected in an upstream direction through the intermediate portions 18c before entering the outlet terminal portions 18e of the vapourizer tubes, which lie in the region of highest temperature. The liquid fuel is completely vapourized in the terminal portions 18e and the mixture enters the nozzle 25, whence it is discharged into the flame zone.

The radially disposed slots 15a, being on the same radii as the diverging portions of the vapourizer tubes 18, serve the double purpose of admitting primary air to the flame zone (the effect of the baffle 15 being to form a region of low pressure in the air stream, in which stable combustion can take place) and to direct a flow of air upon the diverging portions of the vapourizer tubes, to effect some cooling of the tubes in this region and to prevent the formation of carbon deposits thereupon.

It will be understood that the upstream outer surfaces of the outlet terminal portions 18e of the vapourizer tubes are exposed to the region of most intense flame in the flame zone. By this construction the direction of flow of the mixture of air and fuel entering these portions of the vapourizer tubes is so altered by the arcuate bends 18d that any liquid fuel is projected by centrifugal action against the upstream inner surfaces to provide a thorough scrubbing action on the most severely heated walls. The radii of the bends 18d may vary considerably in order to produce the desired result but they are normally made as small as possible, approaching the minimum bend radii of the tube sections concerned. The portions 18e are made as long as conveniently possible in order to produce a large heat transfer in this high temperature region of the flame zone, thereby promoting vapourization of the liquid fuel. It has been found that the length of the outlet terminal portion of each tube should be at least three times the diameter of the tube to give the most satisfactory results. The essence of the invention lies in the conformation of the tubes or similar vapourizing ducts by which the fuel-air mixture contained therein is directed against the upstream sides of the main vapourizing portions of the tubes thereby subjecting the vapourizing surfaces to an effective scrubbing action by the liquid fuel during vapourization; and in the situation of the main vapourizing portion in the hottest regions of the flame zone, while the remainder of the vapourizing system is so situated that it is not exposed to unduly high temperatures. By this means burning and corrosion of the vapourizer tubes may be avoided and more complete vapourization of the liquid fuel achieved.

It will be undersood that the form of the invention herewith shown and described is to be taken as a preferred example of the same, applied to a tube type combustion chamber and that it may be similarly applied to an annular combustion chamber; furthermore the convergence of the tubes to a common nozzle is not an essential feature of the invention and various other changes in the shape, size and arrangement of the parts may be resorted to without departing from the spirit of the invention or the scope of the claims.

What we claim as our invention is:

1. A vapourizer system for a combustion chamber into which liquid fuel is introduced and burned as a vapour in an air stream flowing in the combustion chamber comprising, a plurality of vapourizer tubes each having an inlet at one end and being secured within the combustion chamber with the inlet facing the air stream, and

a nozzle having an outlet facing upstream, the tubes having terminal portions converging substantially transversely of the air stream into the nozzle and having intermediate portions adjoining the terminal portions, the senses toward the terminal portions of the longitudinal axes of the intermediate portions each having a component directed upstream.

2. A vapourizer system for a combustion chamber into which liquid fuel is introduced and burned as a vapour in an air stream flowing in the combustion chamber comprising, a plurality of vapourizer tubes having open inlet ends and secured within the combustion chamber with the inlet ends facing the air stream, and a tubular nozzle within the combustion chamber and having an outlet facing upstream, the tubes having terminal portions converging non-radially and substantially transversely of the air stream into the circumferential walls of the nozzle and having intermediate portions adjoining the terminal portions and extending in an upstream sense toward the terminal portions.

3. A vapourizer system for a combustion chamber in which fuel is burned in a stream of air flowing longitudinally through the combustion chamber, comprising a baffle disposed within the combustion chamber substantially transversely thereof and having annularly spaced openings for the admission of a part of the air stream, vapourizer tubes having open inlet ends mounted in the baffle and having a common outlet facing upstream, each tube having a terminal portion adjoining the outlet and an intermediate portion adjoining the terminal portion and extending in an upstream sense toward the terminal portion, the inlet ends of the tubes being annularly spaced in the baffle and facing the air stream, each inlet end being radially spaced towards the longitudinal axis of the combustion chamber from an associated one of the openings in the baffle, the tubes diverging radially downstream of the baffle and each extending across one of said openings to provide portions directly downstream of the associated openings in the baffle and then extending downstream to provide longitudinally directed portions of the tubes, the tubes then extending from the longitudinally directed portions successively to the intermediate portions and to the terminal portions.

4. A vapourizer system for a combustion chamber in which fuel is burned in an air stream flowing longitudinally through the combustion chamber and in which the combustion chamber has a flame zone in which the fuel is burned as a vapour, the flame zone having a central region of maximum temperature and outer regions surrounding the central region, the vapourizer system comprising vapourizer tubes having open inlet ends and secured within the combustion chamber with the inlet ends facing the air stream, and a nozzle within the combustion chamber and having an outlet facing upstream, the nozzle being in longitudinal alignment with the flame zone, the tubes having terminal portions disposed across a portion of the central region of the flame zone and extending into the nozzle and having intermediate portions adjoining the terminal portions and extending in an upstream sense toward the terminal portions, the major portions of the vapourizer tubes not including the terminal portions being annularly spaced in the outer regions of the flame zone.

5. A vapourizer system for a combustion chamber into which liquid fuel is introduced and burned as a vapour in an air stream flowing in

the combustion chamber comprising, a plurality of vapourizer tubes having open inlet ends and secured within the combustion chamber with the inlet ends facing the air stream so as to admit a portion of the air stream, means for introducing liquid fuel to the inlet ends, and a nozzle within the combustion chamber and having an outlet facing upstream, the tubes having terminal portions converging substantially transversely of the air stream into the nozzle and having intermediate portions adjoining the terminal portions and extending in an upstream sense toward the terminal portions so that the fuel and air flowing therein are directed by centrifugal force upon the upstream sides of the terminal portions of the tubes before being introduced into the nozzle, the length of each of the terminal portions of the tubes being at least three times the diameter of the tubes.

6. A combustion chamber as claimed in claim 5 wherein the nozzle is tubular and the terminal portions of the vapourizer tubes converge non-radially upon the side walls of the nozzle to introduce the fuel therein thereby inducing a swirling action of the fuel within the nozzle.

7. A vapourizer system for a combustion chamber in which fuel is burned in an air stream flowing longitudinally through the combustion chamber and which has a flame zone extending longitudinally through the said chamber in which the fuel is burned as a vapour, the vapourizer system comprising a vapourizer tube having an open inlet end facing the air stream, an intermediate portion, a vapourizing terminal portion of a length substantially exceeding its diameter, an outlet facing upstream and located near the longitudinal axis of the flame tube and producing in the flame zone downstream of the outlet a radially central region of maximum temperature annularly surrounded by a radially outer cooler region, and means for introducing liquid fuel into the inlet end, substantially all the vapourizer tube not including the terminal portion being at a materially greater radial distance from the said axis than the outlet so as to be disposed in the said outer region of the flame zone, the terminal portion extending from the intermediate portion to the outlet whereby the terminal portion extends for a substantial distance transversely across a portion of the central region of the flame zone to provide vapourization of the liquid fuel by the heat of the said central region, the intermediate portion extending in an upstream sense toward the terminal portion so that the fuel and air flowing therein are directed by centrifugal force upon the upstream side of the terminal portion before reaching the outlet.

8. A vapourizer system as claimed in claim 7 in which the length of the terminal portion of the tube is at least three times the diameter of the tube.

9. A vapourizer system for a combustion chamber in which fuel is burned in an air stream flowing longitudinally through the combustion chamber and in which the combustion chamber has a flame zone in which the fuel is burned as a vapour, the flame zone having a central region of maximum temperature and an outer region surrounding the central region, the vapourizing system comprising a baffle disposed within the combustion chamber substantially transversely thereof and having annular spaced openings for the admission of a part of the air stream, vapourizer tubes each having an open in-

let end mounted in the baffle and each having an intermediate portion, a terminal portion, and an outlet disposed in the said central region of the flame zone and facing upstream, and means for introducing liquid fuel into the inlet ends, the inlet ends of the tubes being annularly spaced in the baffle and facing the air stream, each inlet end being radially spaced towards the longitudi- introducing liquid fuel into the inlet ends, the nal axis of the combustion chamber from an associated one of the openings in the baffle, the tubes diverging radially downstream of the baffle and each extending across one of the said openings to dispose portions directly downstream of the associated openings in the baffle and then extending downstream to provide longitudinally directed portions of the tubes, the tubes then extending from the longitudinally directed portions successively to the intermediate portions and to the terminal portions, the intermediate portions extending in an upstream sense toward the terminal portions so that the fuel and air flowing therein are directed by centrifugal force upon the upstream sides of the terminal portions before reaching the outlets.

10. A vapourizer system for a combustion chamber in which fuel is burned in an air stream flowing longitudinally through the combustion chamber and which has a flame zone extending longitudinally through the said chamber in which the fuel is burned as a vapour, the vapourizing system comprising a vapourizer tube having an open inlet end facing the air stream and extending to an outlet disposed relatively near the central longitudinal axis of the flame zone, thus producing in the flame zone a radially central region of maximum temperature extending longitudinally downstream from the location of the outlet end and annularly surrounded by a radially outer cooler region, and means for introducing liquid fuel into the inlet end, the vapourizer tube extending downstream from the inlet end and including a bend of approximately 180° located at a materially greater distance from the said axis than the outlet so as to be wholly disposed in the said outer region of the flame zone, an intermediate portion, and a terminal portion of a length substantially exceeding its diameter, the intermediate portion extending upstream from the bend also within the said outer region of the flame zone and leading into the terminal portion, the latter extending from the intermediate portion to the outlet transversely across a portion of the central region of the flame zone to provide vapourization of the liquid fuel by the heat of the said central region.

11. A vapourizing system as claimed in claim 10 in which a length of the terminal portion of the tube is at least three times the diameter of the tube.

FRANCIS HENRY KEAST.
FREDERICK DENISON MORGAN WILLIAMS.

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