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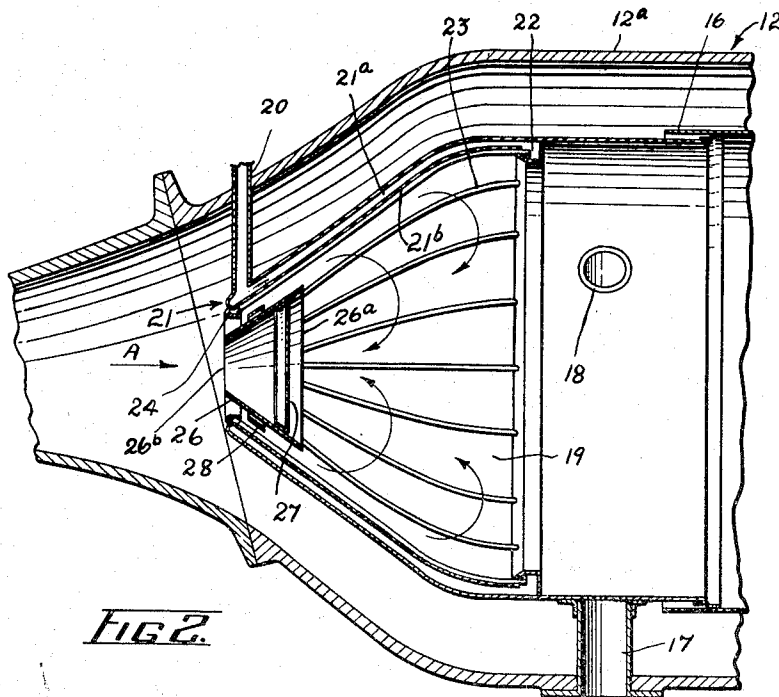
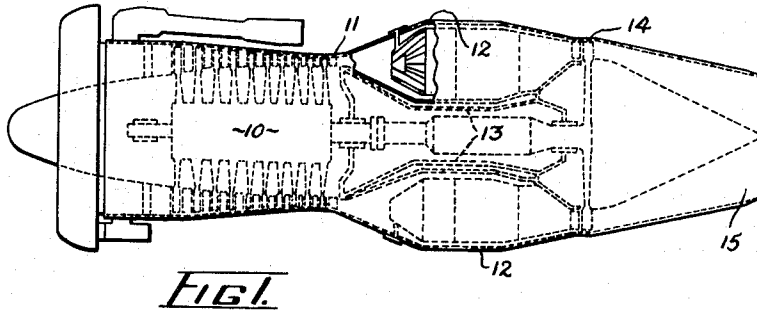
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2,664,703

PREHEATER AND VAPORIZER FOR GAS TURBINE ENGINES

Filed June 24, 1950

2 Sheets-Sheet 1



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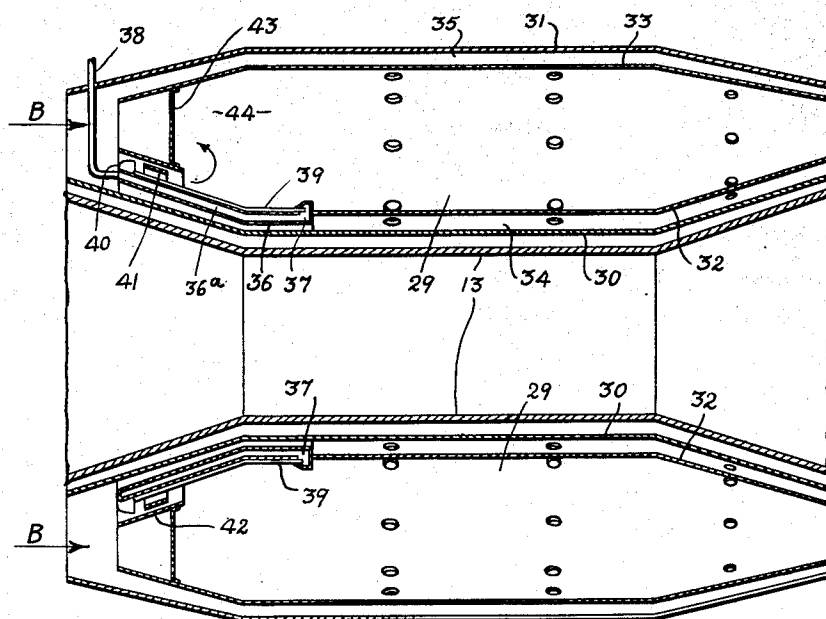
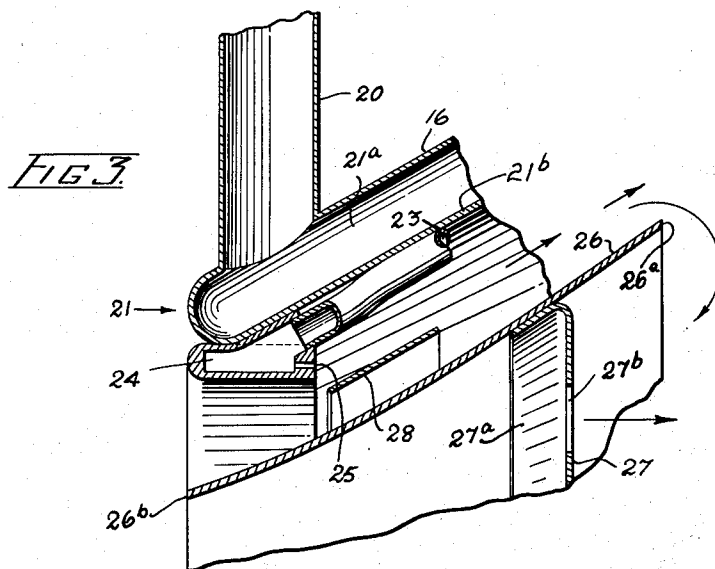
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PREHEATER AND VAPORIZER FOR GAS TURBINE ENGINES

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PREHEATER AND VAPORIZER FOR GAS
TURBINE ENGINESWalter B. Whitelaw, Toronto, Ontario, Canada,
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9 Claims. (Cl. 60—39.71)

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This invention pertains to combustion chambers for gas turbine engines and particularly to combustion chambers of the fuel preheating and vapourizing type.

In such engines, a high pressure and high velocity air stream is forced by a compressor into an elongated combustion chamber, in which a liner or flame tube is mounted in spaced relationship to the casing of the combustion chamber. Part of the air flows over the outside of the flame tube between the flame tube and the casing of the combustion chamber and the remainder flows longitudinally through it. Combustion occurs primarily in a region known as the flame zone contained within the flame tube and it extends downstream, the combustion mixture being progressively diluted by air introduced from the outside of the flame tube to provide a working medium for a turbine.

Fuel may be introduced into the flame tubes of combustion chambers of gas turbine engines by means of an atomizing spray, or in the form of a vapour, or by a combination of atomization and vapourization.

In known constructions vapourization is effected by preheating the liquid fuel, either alone or in the presence of a limited supply of air, before admission into the flame zone, and this is achieved by means of vapourizing tubes through which the fuel is passed and which extend directly into the flame zone in a downstream direction; the tubes, after traversing the upper portion of the flame zone, are bent back upon themselves to direct the vapourized fuel or a mixture of air and vapourized fuel upstream into the flame zone. Such vapourizing tubes are entirely dependent for their support on their mounting in a tube plate at the upstream end of the flame tube, an arrangement which is structurally undesirable. Furthermore, particularly in instances where air is introduced into the vapourizing tubes, it has been found difficult to distribute the fuel evenly over the internal surface of the tubes, especially at the bends therein; when there is uneven distribution of the fuel the normal cooling effect derived from the vapourization of the fuel is inadequate. The local overheating which results from this condition has caused many tube failures. It will be understood that failure of the tubes from any cause may result in pieces of the tubes being carried downstream seriously to damage the turbine.

Another shortcoming of known fuel systems is the limitation which they impose upon the choice of fuel. Although gas turbine engines

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are well adapted for operation using a wide variety of fuels, the choice of fuel is usually restricted by the capabilities of the burners, vapourizers and the like which, when designed to produce satisfactory vapourization of one type of fuel, e. g. kerosene, are often quite unsuited for use with fuels of widely different characteristics.

The principal object of the present invention is to provide an improved construction of combustion chamber for a gas turbine engine which will be free from failure of the fuel vapourizing means due to fatigue, excessive local heating, or like causes. Another object of the invention is to provide a fuel system which is suitable for use with a wide variety of liquid fuels ranging from gasoline to heavy fuel oils.

According to the present invention these objects are achieved by a construction in which fuel before admixture with the combustion air is passed through a preheating element having a wall exposed to the flame zone and a wall remote from the flame zone. Such a preheating element may extend over the entire surface of the flame tube containing the flame zone and thereby possesses the advantage of a much larger heat exchanging area than that furnished by the aforementioned prior art bent vapourizing tubes, permitting operation at lower overall temperatures to heat the fuel to the same extent. This in turn permits the use of heavier and less costly fuels.

For the heavier fuels, means may also be provided in accordance with the invention for superheating the fuel. For this purpose, after passage through the preheating element, the fuel is passed through superheating tubes disposed in the flame zone adjacent to the exposed wall of the preheating element. Unlike the known vapourizer tubes, the preheating tubes in accordance with the present invention may be adequately supported throughout their length, do not include any 180° bends, and do not require to be disposed centrally in the hottest part of the flame zone.

To facilitate further the combustion of heavier fuels, in accordance with a further feature of the invention, the fuel on emergence into a flame tube may be forcibly sprayed upon an impingement or "splash" member disposed in the high velocity airstream entering the flame tube from the compressor.

Thus a construction in accordance with the invention eliminates the need for the aforementioned bent vapourizer tubes extending substantially as unsupported cantilevers into the flame

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zone, thereby obviating the dangers of tube failure due to fatigue or overheating, and it provides instead a robust vapourizing device operating at relatively low temperatures.

In order that the invention may be more readily understood and carried into effect, some embodiments thereof will now be described with reference to the accompanying drawings, in which like reference characters refer to like parts in the several views and in which

Figure 1 is an elevation, partly in section, of a gas turbine engine embodying a plurality of tubular combustion chambers constructed in accordance with the present invention;

Figure 2 is an enlarged section of the front portion of one of the tubular combustion chambers;

Figure 3 is a further enlarged section of a detail of Figure 2; and

Figure 4 is a section of an annular combustion chamber constructed in accordance with the invention.

In the operation of the engine illustrated in Figure 1, air is compressed in a compressor 10 and fed through a diffuser 11 into a plurality of tubular combustion chambers 12, arranged in spaced relationship around a backbone member 13 of the engine. Fuel is injected into the combustion chambers 12 and burnt in a portion of the available air, and the products of combustion and heated air are discharged at high velocity into a turbine 14, which drives the said compressor 10 and, according to the construction of the turbine 14, otherwise generates power from the energy contained in the hot gases. The final discharge of the gases from an exhaust 15 may be employed for jet propulsion of the unit. (The relative location of the various parts is herein referred to as "upstream" or "downstream" with respect to the sense of the air flow through the engine.)

As shown more clearly in Figure 2, each tubular combustion chamber 12 has an outer casing 12^a and a flame tube 16 secured coaxially therein by means of a support 17 and also by suitable mountings for interconnectors 18, which constitute ports for the connection of neighbouring combustion chambers.

The upstream or inlet portions of the combustion chamber casing 12^a and of the flame tube 16, surrounding the flame zone 19, decrease in diameter toward the air inlet, being substantially conical in shape. Air from the compressor 10 is forced into the upstream end of the combustion chamber 12 in the direction of the arrow A (see Figure 2). A portion of the air enters the flame tube 16 and the remainder passes between the flame tube 16 and the combustion chamber casing 12^a cooling the flame tube and in part being introduced into the flame tube downstream of the flame zone through apertures (not shown) in the flame tube, to provide the working fluid for the turbine 14 to which the combustion chamber discharges.

In the embodiment of the present invention illustrated in Figures 1 to 3, fuel is introduced to the combustion chamber 12 at the forward end by a conduit 20, one end of which communicates with a source of fuel under pressure and the other end of which communicates with an annular preheating element 21, providing a chamber 21^a which extends along the surface of the upstream portion of the flame tube 16; the wall of the flame tube 16 itself provides the outer or remote wall of the said annular preheating ele-

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ment, and the inner or exposed wall 21^b of the preheating element 21 constitutes an annular liner which is exposed to the flame zone and in direct contact with the hot gases therein. The preheating chamber 21^a is closed at its upstream end and terminates at its downstream end in a somewhat enlarged portion providing a hollow rear distributing ring 22. Extending upstream from the distributing ring 22 is a plurality of spaced, symmetrically disposed, superheating tubes 23 which lie in the flame zone adjacent to and supported by the exposed wall 21^b of the preheating element. The superheating tubes terminate in a hollow front distributing ring 24 located concentrically to and adjacent the upstream end of the preheating element in the flame tube. In the front distributing ring 24 is provided a series of spaced apertures 25 directed downstream and designed to operate as spray nozzles (see Figure 3).

Inside the upstream end of the flame tube 16 and spaced from the front distributing ring 24 and the superheating tubes 23 in an air deflector 26, comprising a hollow truncated conical member terminating downstream in a sharp circular edge 26^a and a plate 27 extending transversely across the deflector 26; a peripheral flange 27^a on the plate 27 is secured to the inside of the conical member. The conical surface of the air deflector 26 is arranged substantially parallel to the conical upstream portion of the wall of the flame tube 16, and the front edge 26^b of the air deflector is substantially flush with the upstream end of the flame tube, while its rear edge extends downstream to a hypothetical plane located approximately one-quarter to one-third of the distance from the front distributing ring 24 to the rear distributing ring 22. The plate 27 lies in a radial plane situated a short distance upstream of the rear edge of the deflector 26. The flame zone 19 is situated immediately downstream of the air deflector 26 and the plate 27 may advantageously have one or more apertures 27^b to admit additional air through the plate into the flame zone.

Surrounding the central portion of the conical air deflector 26 and supported in parallel spaced relationship to the deflector is impingement member 28 which in effect is a second truncated cone of slightly larger diameter.

In operation, fuel in liquid form and under pressure enters the preheating chamber 21^a, as previously described, and flows through it to the rear distributing ring 22. As the fuel flows downstream through the preheating chamber 21^a, it receives a considerable amount of heat since one wall of the surrounding preheating element is exposed to radiation from the flame zone 19. From the rear distributing ring 22 the heated fuel travels upstream again through the series of superheating tubes 23 and in so doing it absorbs more heat, becoming very hot by the time it reaches the front distributing ring 24.

Air from the compressor 10 enters the combustion chamber 12 at the upstream end in the direction of the arrow A and a portion of the air enters the flame tube 16 while the remainder passes between the flame tube 16 and the combustion chamber casing 12^a. The portion of air entering the flame tube 16 is guided by the air deflector 26 so that it passes between the deflector and the flame tube. The area of low pressure in the airstream created immediately downstream of the plate 27 establishes a region of relative stability in the flame zone 19, into

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which some air may be admitted directly, if desired, by providing the previously mentioned optional apertures 27^b in the plate 27.

The very hot fuel emerging at high velocity from the nozzle 25 strikes the conical impingement member 28 and breaks into a fine spray or vapour due to the combined effect of its high temperature and the mixing action of the high velocity air passing on both sides of the impingement member. Any fuel which is not vapourized upon leaving the impingement member 28 strikes the outer surface of the air deflector 26 and is finally swept off the sharp rear edge of the air deflector 26 in the form of a vapour or a fine spray. The mixture of air, fuel vapour and, in lesser amount, fine droplets of fuel, enters the flame zone 19 immediately downstream of the air deflector 26.

The aforementioned embodiment of the invention is particularly adapted for operation with heavier fuels. If lighter fuels only are to be used in the combustion chamber then the superheating tubes 23 may be dispensed with and the rear distributing ring serves as an inlet channel for the preheating chamber 21^a. In this instance the conduit 20 is connected to the preheating chamber 21^a at the downstream end of the latter to introduce the fuel directly in the rear distributing ring 22; the fuel flows upstream through the preheater chamber 21^a, which is arranged to communicate at the upstream end with a front distributing ring similar to the aforescribed ring 24, from which the fuel is then ejected into the flame zone 19 by nozzles similar to the nozzle apertures 25. Furthermore, when using some of the lighter fuels efficient combustion may be obtained without incorporating an impingement member 28. However it should be understood that an installation embodying both the superheating tubes and the impingement member may be used satisfactorily with lighter fuels and the provision of these features imparts some degree of flexibility in the choice of fuel.

The preheating element containing the chamber 21^a has been described and illustrated as being provided by a wall spaced from the flame tube and exposed to the flame zone, but it will be appreciated that alternatively the element could be provided by a wall spaced from the flame tube and remote from the flame zone. In the latter case, the flame tube itself would provide the exposed wall of the preheater element.

In the application of the invention to a combustion chamber 29 of annular form, as illustrated in Figure 4, it is to be understood that the annular combustion chamber 29 simply takes the place of the plurality of combustion chambers 12 illustrated in Figure 1, the arrangement being otherwise similar. The annular combustion chamber 29 is mounted coaxially with the backbone member 13 of the engine and is supplied with compressed air from the diffuser 11, the hot gases being discharged into the turbine 14.

By reference to Figure 4, it will be seen that the combustion chamber 29 comprises an annular chamber bounded by an inner casing 30 and an outer casing 31 mounted coaxially with the backbone member 13 of the engine. Between the casings 30 and 31 is the flame tube provided by the inner wall 32 and the outer wall 33; these walls 32 and 33 are supported in spaced relationship to the casings 30 and 31 of the combustion chamber so that annular spaces 34 and 35 are provided between the inner wall of the flame tube

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and the inner casing of the combustion chamber and between the outer wall of the flame tube and the outer casing of the combustion chamber respectively.

In this construction, according to the invention a hollow annular casing 36 forming the upstream portion of the wall 32 of the flame tube contains an annular preheating chamber 36^a. The casing 36 has at its downstream end an enlarged portion constituting a rear distributing ring 37 located where the casing 36 abuts the flame tube wall 32. Liquid fuel is supplied under pressure to the upstream end of the preheating chamber 36 by means of conduit 38, the construction being such as to favour an even distribution of fuel in the preheating chamber 36. The fuel flows to the rear distributing ring 37 at the downstream end of the preheating chamber, and from the ring the fuel passes through a series of superheating tubes 39 to a front distributing ring 40 provided with a series of spaced spray nozzles similar to the nozzles 25 (see Figure 3); the general features of construction are similar to those described in connection with the application of the invention to one of a plurality of tubular combustion chambers.

An impingement member 41 comprising a narrow ring of truncated conical form and a larger diameter than the inner wall 32 of the flame tube is provided; the impingement member is disposed adjacent the spray nozzles and parallel with and spaced from the said wall of the flame tube so as to present an oblique surface to fuel ejected from the nozzles. An air deflector 42 is also mounted within the forward portion of the flame tube and comprises a truncated conical member coaxially encircling and spaced from the impingement member 41 and disposed in a plane parallel to the surfaces of the impingement member and of the inner wall 32 of the flame tube. An annular plate 43 lying substantially in a radial plane of the engine is situated a short distance upstream of the downstream edge of the deflector 42 and extends between the air deflector at its inner radius and the outer wall of the flame tube at its outer radius. The plate 43 may be provided with a number of apertures to permit the entry of some air through the plate into the flame zone 44 which is situated immediately downstream, as described with respect to the application of the invention to a tubular combustion chamber.

The airstream from the compressor 10 enters the combustion chamber 29 in the direction of the arrows B in Figure 4. Part of this air passes over the inner and outer surfaces, respectively, of the inner and outer walls 32 and 33 of the flame tube to cool the said flame tube and to provide diluent air, and the other portion of the air passes through the flame tube to support combustion. The main air for combustion flows through the annular space provided between the conical surface of the air deflector 42 and the inner wall 32 of the flame tube, passing on both sides of the impingement member 41. The functioning of this combustion chamber is similar to that previously described in relation to the tubular combustion chamber and should be clear without further explanation.

It is to be understood that the details of the construction of the aforescribed embodiments of the invention may be modified without exceeding the scope of the invention. For example in the case of the annular combustion chamber, it will be realized that the preheating chamber

could alternatively be provided in the outer wall 33 of the flame tube, a corresponding rearrangement of the impingement member and the air deflector being made, when such parts are used. Furthermore the preheating element containing the chamber 36 may be provided by a wall spaced from the flame tube and either exposed to the flame zone or alternatively remote from the flame zone; in the latter construction the flame tube itself constitutes the exposed wall of the preheating element. Furthermore in either construction the preheating chamber may extend over the surface of the flame tube to a greater or lesser degree than that shown in the drawings or a configuration of the air deflector may be adopted which would render the radially disposed plate unnecessary in creating the stabilizing depression in the flame zone; and the proportions and arrangements of the various other elements may be modified to suit the construction of the engine.

The term "remote" as used herein and in the subjoined claims in reference to a wall of the preheating element is not to be read as meaning that the said wall is situated at a great distance from the flame zone; actually the element itself is of relatively narrow cross-section. The term is used to signify that the wall is not exposed to the flame zone, as distinct from the other wall of the element which is so exposed.

What I claim as my invention is:

1. A vapourizing system for a gas turbine engine comprising, a flame tube having an open end for the admission of air and containing a flame zone of primary combustion, a preheating element having a wall facing the interior of the flame tube and being exposed to the flame zone and having another wall spaced from the said exposed wall and being remote from the flame zone, a fuel conduit communicating with the preheating element for introducing liquid fuel between the walls of the preheating element to preheat the fuel, superheating tubes situated in the flame zone and disposed adjacent the exposed wall of the preheating element, the superheating tubes communicating with the preheating element to receive the preheated fuel, discharging means communicating with the superheating tubes for discharging the superheated fuel into the flame tube, and means defectively interposed in the path of discharge of the discharging means and exposed to the stream of air to scatter the superheated fuel in the air stream.

2. A vapourizing system for a gas turbine engine comprising, a flame tube having an open end for the admission of a stream of air and containing a flame zone of primary combustion, a preheating element having a wall facing the interior of the flame tube and being exposed to the flame zone and having another wall spaced from the said exposed wall and being remote from the flame zone, a fuel conduit communicating with the preheating element for introducing liquid fuel between the walls of the preheating element to preheat the fuel, superheating tubes situated in the flame zone and disposed adjacent the exposed wall of the preheating element, the superheating tubes being supported by the exposed wall of the preheating element and communicating with the preheating element to receive the preheated fuel, discharging means communicating with the superheating tubes for discharging the superheated fuel into the flame tube, and means defectively interposed in the path of discharge of the discharging means and

exposed to the stream of air to scatter the superheated fuel in the air stream.

3. A vapourizing system for a gas turbine engine comprising, a flame tube having an open end for the admission of a stream of air and containing a flame zone of primary combustion, a preheating element having a wall facing the interior of the flame tube and being exposed to the flame zone and having another wall remote from the flame zone, the preheating element having an upstream end adjacent the open end of the flame tube and a downstream end, a fuel conduit communicating with the upstream end of the preheating element for introducing liquid fuel between the walls of the preheating element to preheat the fuel, superheating tubes situated in the flame zone and disposed adjacent the exposed wall of the preheating element, the superheating tubes communicating with the downstream end of the preheating element, discharging means communicating with the superheating tubes for discharging the preheated and superheated fuel into the flame tube, and a spray-producing member defectively interposed in the path of discharge of the discharging means and exposed to the stream of air and the discharged fuel to scatter the preheated and superheated fuel in the air stream.

4. A vapourizing system for a gas turbine engine comprising, a flame tube having an open end for the admission of a stream of air and containing a flame zone of primary combustion, a preheating element having a wall facing the interior of the flame tube and being exposed to the flame zone and having another wall spaced from the said exposed wall and being remote from the flame zone, the preheating element having an upstream end adjacent the open end of the flame tube and a downstream end, a fuel conduit communicating with the upstream end of the preheating element for introducing the liquid fuel between the walls of the preheating element to preheat the fuel, superheating tubes situated in the flame zone and disposed adjacent to the exposed wall of the preheating element, the superheating tubes communicating with the downstream end of the preheating element and extending toward the upstream end thereof, a distributor communicating with the upstream ends of the superheating tubes and being provided with nozzles adjacent the open end of the flame tube for discharging the preheated and superheated fuel into the flame tube, and means defectively interposed in the path of discharge of the nozzle and exposed to the stream of air to scatter the preheated and superheated fuel in the air stream.

5. A vapourizing system for a gas turbine engine comprising, a flame tube having an open end for the admission of a stream of air and containing a flame zone of primary combustion, a preheating element having a wall facing the interior of the flame tube and being exposed to the flame zone and having another wall spaced from the said exposed wall and being remote from the flame zone, the preheating element having an upstream end adjacent the open end of the flame tube and a downstream end, a fuel conduit communicating with the upstream end of the preheating element for introducing liquid fuel between the walls of the preheating element to preheat the fuel before admixture with air, superheating tubes communicating with the downstream end of the preheating element and disposed adjacent the exposed wall of the preheating

ing element, an impingement member situated in the open end of the flame tube and in spaced relationship with the flame tube, the impingement member being exposed to the stream of air, and a distributor communicating with the superheating tubes and provided with nozzles directed toward the impingement member for spraying the preheated and superheated fuel forcibly against the impingement member to scatter the preheated and superheated fuel in the air stream.

6. A vapouring system for a gas turbine engine comprising, a flame tube having an opening for the admission of a stream of air, an impingement member having a frusto-conical outer surface disposed in the opening with its base end directed downstream with respect to the air stream, a source of fuel, and a ring of discharge outlets each connected to the source of fuel, the surface of the impingement member intersecting the axis of flow of each of the outlets whereby fuel discharged from the outlets may be scattered in the air stream on contact with the impingement member.

7. A vapourizing system or a gas turbine engine comprising, a flame tube having an opening for the admission of a stream of air, a fuel atomizer including a deflector disposed in the opening and having a frusto-conical outer surface the base end of which is directed downstream with respect to the air stream, and an impingement member encircling and spaced from the said surface, a source of fuel, and a ring of discharge nozzles each connected to the source of fuel and being so positioned in relation to the position of the impingement member that the paths of discharge of the nozzles is intersected by the outer surface of the impingement member for spraying the fuel forcibly against the impingement member to scatter the fuel in the air stream.

8. A vapourizing system for a gas turbine engine comprising, a flame tube having an opening for the admission of a stream of air, a fuel atomizer including a hollow open-ended deflector dis-

posed in the opening having a frusto-conical outer wall surface the base end of which is directed downstream with respect to the air stream, the fuel atomizer also including a baffle disposed transversely in the deflector to create a low pressure space in the flame tube downstream of the baffle and an impingement member having a frusto-conical outer wall surface coaxially encircling and spaced from the said surface in substantially parallel relationship thereto, a source of fuel, and a ring of discharge nozzles each connected to the source of fuel and being so positioned in relation to the position of the impingement member that the paths of discharge of the nozzles is intersected by the outer surface of the impingement member for spraying the fuel forcibly against the impingement member to scatter the fuel in the air stream.

9. A vapourizing system for a gas turbine engine comprising, a flame tube wall encircling a flame zone and providing an opening for admitting a stream of air to the flame zone, an outer wall spaced from the first wall and providing between the walls an annular liquid fuel preheating space of appreciable axial length, a conduit leading to one end of the said space for introducing liquid fuel, fuel discharge nozzles communicating with the other end of the said space, and a baffle disposed in the opening and deflector interposed in the path of discharge of the nozzles to scatter the fuel in the air stream.

WALTER B. WHITE LAW.

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