

Feb. 20, 1951

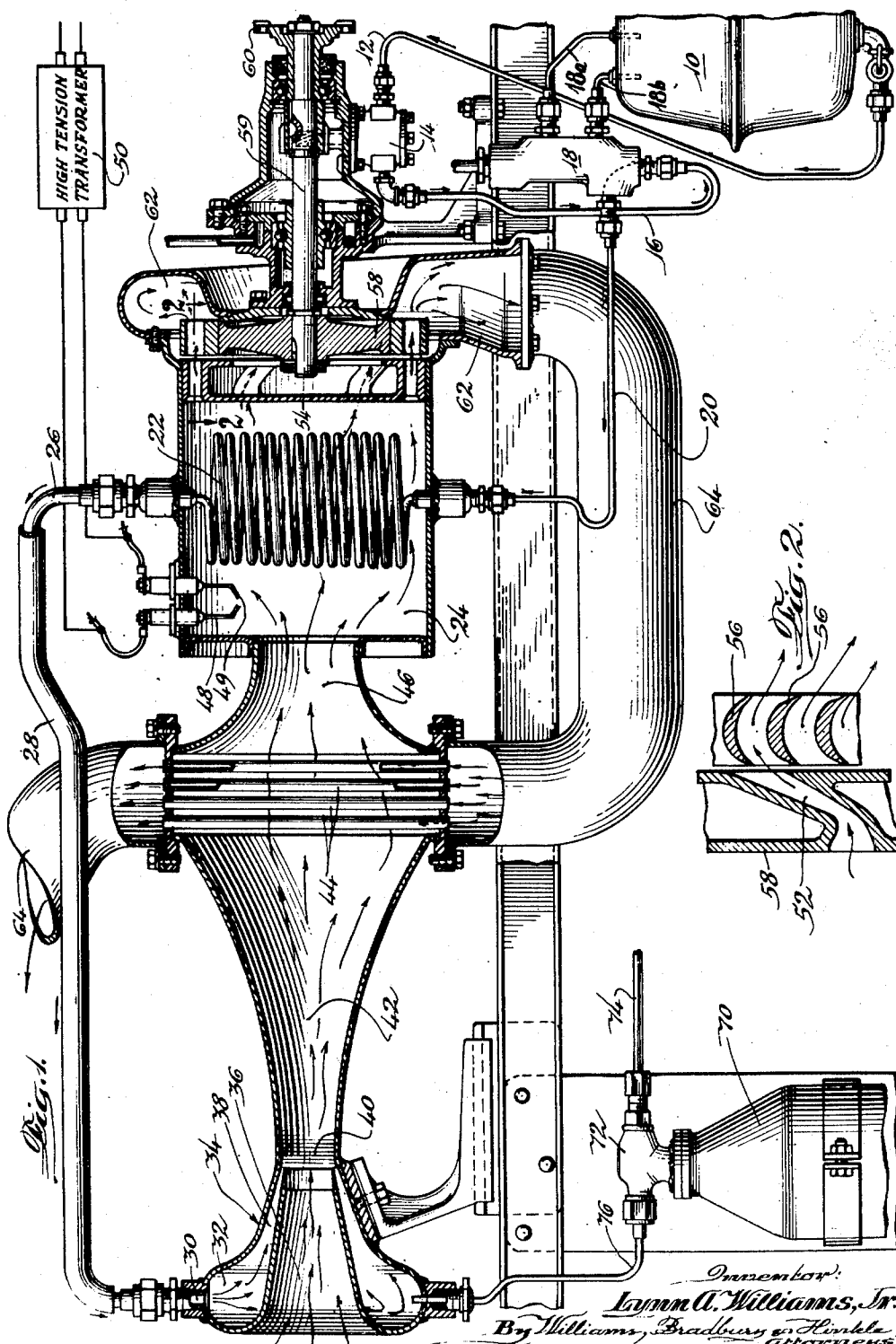
L. A. WILLIAMS, JR

2,542,953

COMBUSTION TURBINE HAVING MIXING TUBE TO ASPIRATE,
COMPRESS, AND PREHEAT THE AIR-FUEL MIXTURE

Filed Sept. 13, 1945

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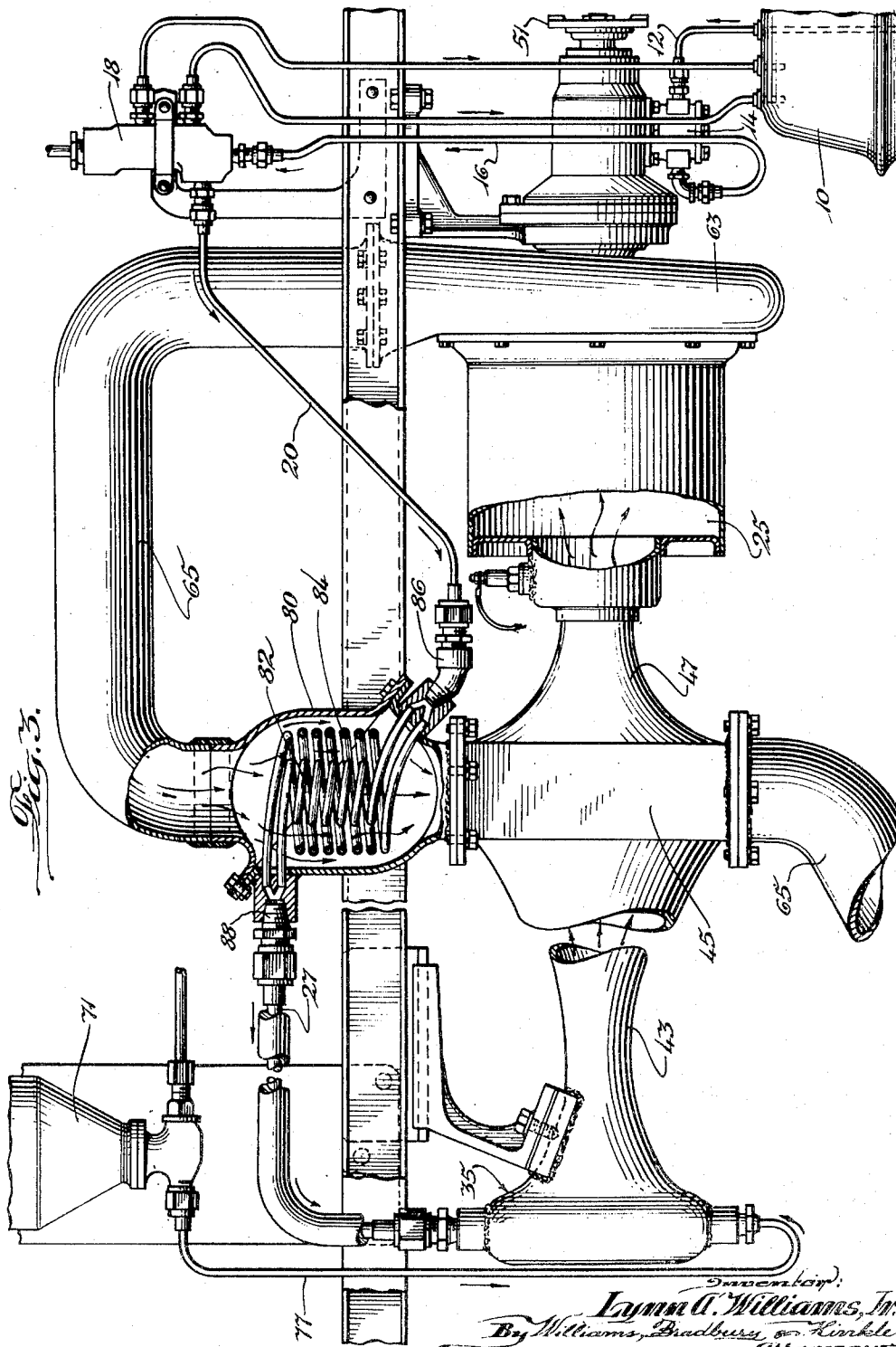
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UNITED STATES PATENT OFFICE

2,542,953

COMBUSTION TURBINE HAVING MIXING
TUBE TO ASPIRATE, COMPRESS, AND
PREHEAT THE AIR-FUEL MIXTURELynn A. Williams, Jr., Northfield, Ill., assignor to
Stewart-Warner Corporation, Chicago, Ill., a
corporation of Delaware

Application September 13, 1945, Serial No. 616,015

9 Claims. (Cl. 60—41)

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This invention relates to combustion turbines of the type employing liquid fuel, and one object of the invention is to provide a new and improved turbine in which the air supplied for combustion of the liquid fuel is compressed and forced into the combustion chamber under pressure without the use of a mechanical compressor, but by entrainment in a stream of vaporized fuel moving at high velocity toward the combustion chamber.

Another object is to provide a combustion turbine of the type indicated in which the mixture of air and fuel is pre-heated before it enters the combustion chamber in out-of-contact heat exchange relation with the exhaust gas from the turbine.

A further object of the invention is to provide a combustion turbine employing liquid fuel mixed with air in which the fuel is injected in vapor form and at high velocity and operates to aspirate the air for combustion and to compress it and deliver it under pressure to the combustion chamber, and in which the efficiency of the apparatus is increased by pre-heating said compressed air in out-of-contact heat exchange relation with the exhaust gases discharged by the turbine.

It is also an object of the invention to provide a new and improved gas combustion turbine in which the liquid fuel for the injection at high velocity is vaporized and expanded by a portion of the heat derived from combustion in the apparatus, and specifically by heat supplied by a heat exchanger located in the exhaust passage.

An additional object of the invention is to provide a new and improved gas turbine in which vaporized liquid fuel is supplied to the combustion chamber at high velocity through an air injecting and compressing nozzle of improved efficiency as compared with prior structures.

Other objects and advantages of the invention will appear from the following description taken in connection with the drawings, in which:

Fig. 1 is a somewhat diagrammatic illustration of apparatus embodying this invention, the view being partly in elevation but showing the combustion chamber, the turbine wheel, and the fuel injecting nozzle with a heat exchanger therein, in section;

Fig. 2 is a fragmentary detail section taken as indicated at line 2—2 on Fig. 1 and on a larger scale;

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Fig. 3 is a diagrammatic view of a modified structure embodying this invention, showing most of the parts in elevation but with a portion of the exhaust passage shown in section to reveal a heat exchanger located therein.

This invention is concerned with the same general type of gas turbine as that disclosed in an application Serial No. 587,927, filed April 12, 1945, now abandoned, directed to an invention of Henry J. DeN. McCollum, and it is designed to provide energy for driving a turbine wheel by burning a mixture of liquid fuel and compressed air and discharging it through suitable nozzles directed toward the reaction blades of the wheel. In most prior turbines, it has been customary to provide mechanical means for compressing the air prior to its induction into the combustion chamber, and a considerable portion of the power delivered by the turbine wheel was absorbed by the air compressor, leaving only the excess of power available for useful work outside the turbine circuit. But in the McCollum apparatus shown in the application above mentioned, the liquid fuel is vaporized and expanded in a boiler or heat exchanger which is heated by the combustion of the fuel, and the vaporized fuel then is discharged at high velocity through a nozzle designed to aspirate and compress the necessary air for combustion, thus dispensing with the use of a mechanical compressor. Incidentally, the pre-heating and vaporizing of the liquid fuel absorbs some of the heat from the products of combustion fed against the turbine wheel and tends to hold the temperature of these gases to a safe limit at which the turbine blades will not be injured.

The present invention also provides for vaporizing the liquid fuel and feeding it at high velocity to the combustion chamber through an aspirating nozzle which entrains and compresses the air for combustion and it aims further to increase the efficiency of the apparatus by pre-heating and expanding the combustible mixture just before it enters the combustion chamber by exposing it to the heat of the exhaust gases.

As shown in Fig. 1, the apparatus includes a fuel tank 10 for liquid fuel connected by a pipe 12 with a mechanically-driven pump 14 from which the fuel is fed through a pipe 16 into a pressure regulating valve device 18. This device has a pressure relief return pipe 18a and a leakage return pipe 18b, both leading back to the

tank 10. The internal structure of the valve is shown and described in detail in the McCollum application mentioned above. From the regulating valve 18 a feed pipe 20 leads to a heat exchanging coil 22 located in the combustion chamber 24 and of sufficient length to insure vaporization of the liquid fuel as it is fed through the coil 22. A pipe 26 leading from the coil 22 is preferably enclosed in a heat insulating jacket 28 and discharges at 30 into the annular receiving chamber 32 of the nozzle, indicated generally by the numeral 34.

The nozzle 34 includes an inwardly tapering and axially disposed air intake passage 36 and a fuel injection passage of annular cross section at 38 which leads from the receiving chamber 32 toward the constricted portion 40 of the mixing passage 42. The passage 38 narrows in cross section toward the constriction 40 so that the vaporized fuel is discharged from it at high velocity and aspirates or entrains air for combustion which is supplied to the intake 36. The mixture of fuel and air proceeds through the flaring mixing passage 42 and at the widest portion thereof the mixture flows between the tubes 44 grouped to form a heat exchanger and connected to convey the products of combustion in out-of-contact heat exchange relation to the incoming mixture. Just beyond this heat exchanger the mixing tube or passage narrows rapidly to a throat 46 opening into the combustion chamber 24. Here the mixture is ignited by a high tension spark between electrodes 48 and 49 connected to a high tension transformer 50.

Further expansion in the combustion chamber 24 drives the products of combustion through the jet nozzles 52 arranged in an annular series in the end wall 54 of the combustion chamber, and these nozzles deliver the gases obliquely and against the reaction vanes or blades 56 of the turbine wheel 58. Passing through the openings between the vanes 56, the gases escape into an exhaust manifold 62 and the exhaust pipe 64. The heat exchanger consisting of the device 44 is interposed in the exhaust pipe 64 so that the hot gases are forced to flow through the group of tubes 44 which constitute the heat exchanger.

With the arrangement just described, the liquid fuel which is vaporized and greatly expanded in the coil 22 by means of heat absorbed from the combustion occurring in chamber 24, is fed through the pipe 26 and from the nozzle 34 at extremely high velocity which enables it to entrain or aspirate a sufficient quantity of air at the intake 36 to produce a combustible mixture. The flaring form of the passage 42 somewhat reduces the velocity and raises the pressure of the gases, but the heat added to them by the heat exchanger 44 produces a rapid expansion of the mixture, and its velocity as it passes through the outlet 46 into the combustion chamber is above the rate of flame propagation and thus prevents flash-back. Here again the gas is further expanded by combustion and its energy is released to the turbine wheel 58, and transmitted by its shaft 59 and coupling 60 to perform useful work; but the temperature of the products of combustion is lowered considerably by reason of the heat absorbed therefrom and transferred to the liquid fuel in the coil 22. This tends to hold the temperature below the point at which the metal of the turbine wheel 58 would be damaged by the hot gases; and a considerable portion of the heat which would otherwise escape by way

of the exhaust is recovered and put to work by means of the heat exchanger 44.

Since the liquid fuel must be vaporized by heat absorbed from combustion in the chamber 24, it will be evident that the fuel supplied from the tank 10 will be available only after combustion is well under way in the chamber 24. Accordingly, to initiate the operation of the apparatus, there is provided a supplemental fuel tank 70 which contains a hydrocarbon fuel under pressure, such as propane, which has a high vapor pressure at ordinary temperatures and therefore volatilized instantly upon its release from the tank 70. An outlet valve fitting is shown at 72 provided with an operating rod or stem 74 by which the propane or similar fuel may be released at will for discharge through a tube 76 to the annular chamber 32 of the main fuel nozzle 34 so that the propane thus is discharged into the mixing tube 42. Being discharged at high velocity from the nozzle 34, the gaseous fuel aspirates air for combustion as it enters the mixing tube 42 and the mixture is ignited readily by the spark of electrodes 48, 49, thus starting and maintaining combustion until the heating of the fuel supplied from the tank 10 is well under way. Thereafter, the auxiliary fuel supply may be shut off at the valve 72.

Fig. 3 illustrates a modification of the apparatus which differs from that shown in Fig. 1 in that the liquid fuel from the tank 10 is pre-heated and vaporized in a heat exchanger located in the exhaust passage instead of in the combustion chamber. The tank 10 is shown with an outlet pipe 12 leading to a mechanically driven pump 14 from which a delivery pipe 16 is connected into the pressure regulating valve 18. The feed pipe 20 leads from the valve 18 into the heat exchanger section 80 of the exhaust passage 65 which is shown extending from the exhaust manifold 63.

In the particular form shown, the heat exchanger 80 is provided with a double coil for the liquid fuel, comprising an inner coil 82 and an outer coil 84, said coils being connected in parallel between the inlet fitting 86 and the outlet fitting 88, and being mounted in the path of the exhaust gases flowing through the passage 65. This passage includes a portion 45 which may be understood as containing heat exchanger tubes similar to the tubes 44 of Fig. 1 for transferring heat to the combustible mixture as it flows to the combustion chamber 25 through the mixing tube 43 and its outlet 47.

The heated and vaporized fuel flowing from the heat exchanger 80 is conducted by an insulated pipe 27 to the nozzle 35 which may be similar in all respects to the nozzle 34 of Fig. 1 and which is shown provided with a feed pipe 77 for supplying auxiliary starting fuel, such as propane, from a tank 71. A turbine wheel similar to wheel 58 may be understood as housed adjacent the combustion chamber 25 and provided with a shaft which terminates in a coupling 61 for transmitting the mechanical power developed by the apparatus.

While there is shown and described herein certain structure embodying the invention, it is to be understood that the invention is not limited thereto or thereby, but may assume numerous other forms and includes all modifications and equivalents coming within the scope of the following claims:

I claim:

1. In a gas turbine, in combination, a mixing tube having an air intake opening, a fuel feed-

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ing nozzle discharging into said tube in a direction to aspirate and compress air from said intake, a combustion chamber into which the mixing tube leads, a turbine wheel, nozzle means directing the gaseous products of combustion from said combustion chamber against the turbine wheel, an exhaust passage for said gases, a heat exchanger in the combustion chamber, means feeding liquid fuel into said heat exchanger to be vaporized therein, means delivering the vaporized fuel to said nozzle, and a heat exchanger in the mixing tube forming a part of said exhaust passage for transferring heat from the exhaust gases to the mixture of air and fuel vapor therein to pre-heat and expand said mixture on its way to the combustion chamber.

2. In a gas turbine, in combination, an elongated mixing tube of Venturi form including a nozzle having an axially disposed air intake passage and a feed passage of annular cross section for vaporized fuel, said annular passage narrowing toward and terminating near the constricted portion of the venturi for aspirating air from the intake passage, a combustion chamber adjoining the mixing tube, a turbine wheel to which the gaseous products of combustion are fed from the combustion chamber, an exhaust passage for said gases, a heat exchanger in the mixing tube forming a part of said exhaust passage for transferring heat from the exhaust gases to the mixture of air and fuel vapor therein, and means for supplying fuel to said nozzle in vaporized form and at relatively high pressure.

3. In a gas turbine, in combination, an elongated mixing tube of Venturi form including a nozzle having an axially disposed air intake passage and a feed passage of annular cross section for vaporized fuel, said annular passage narrowing toward and terminating near the constricted portion of the venturi for aspirating air from the intake passage, a combustion chamber adjoining the mixing tube, a turbine wheel to which the gaseous products of combustion are fed from the combustion chamber, an exhaust passage for said gases, and a heat exchanger in the mixing tube forming a part of said exhaust passage for transferring heat from the exhaust gases to the mixture of air and fuel vapor therein, said mixing tube flaring from said constricted portion to a portion of maximum cross section which contains said heat exchanger.

4. In a gas turbine, in combination, an elongated mixing tube of Venturi form including a nozzle having an axially disposed air intake passage and a feed passage of annular cross section for vaporized fuel, said annular passage narrowing toward and terminating near the constricted portion of the venturi for aspirating air from the intake passage, a combustion chamber adjoining the mixing tube, a turbine wheel to which the gaseous products of combustion are fed from the combustion chamber, an exhaust passage for said gases, and a heat exchanger in the mixing tube forming a part of said exhaust passage for transferring heat from the exhaust gases to the mixture of air and fuel vapor therein, said mixing tube flaring from said constricted portion to a portion of maximum cross section which contains said heat exchanger and being tapered therefrom to an outlet of smaller cross section discharging into the combustion chamber, together with means for supplying fuel to said nozzle in vaporized form and at relatively high pressure.

5. In a gas turbine, in combination, an elongated

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gated mixing tube of Venturi form including a nozzle having an axially disposed air intake passage and a feed passage of annular cross section for vaporized fuel, said annular passage narrowing toward and terminating near the constricted portion of the venturi for aspirating air from the intake passage, a combustion chamber adjoining the mixing tube, a turbine wheel to which the gaseous products of combustion are fed from the combustion chamber, an exhaust passage for said gases, and a heat exchanger in the mixing tube forming a part of said exhaust passage for transferring heat from the exhaust gases to the mixture of air and fuel vapor therein, together with a heat exchanger in the combustion chamber, pump means supplying liquid fuel to said heat exchanger under pressure, and a conduit conveying the vaporized fuel from said heat exchanger to said nozzle from which it is discharged at high velocity into said mixing tube.

6. In a gas turbine, in combination, an elongated mixing tube of Venturi form including a nozzle having an axially disposed air intake passage and a feed passage of annular cross section for vaporized fuel, said annular passage narrowing toward and terminating near the constricted portion of the venturi for aspirating air from the intake passage, a combustion chamber adjoining the mixing tube, a turbine wheel to which the gaseous products of combustion are fed from the combustion chamber, an exhaust passage for said gases, and a heat exchanger in the mixing tube forming a part of said exhaust passage for transferring heat from the exhaust gases to the mixture of air and fuel vapor therein, together with a heat exchanger in the exhaust passage, pump means supplying liquid fuel to said heat exchanger under pressure, and a conduit conveying vaporized fuel from said heat exchanger to said nozzle from which it is discharged at high velocity into said mixing tube.

7. In a gas turbine, in combination, an elongated mixing tube of Venturi form including a nozzle having an axially disposed air intake passage and a feed passage of annular cross section for vaporized fuel, said annular passage narrowing toward and terminating near the constricted portion of the venturi for aspirating air from the intake passage, a combustion chamber adjoining the mixing tube, a turbine wheel to which the gaseous products of combustion are fed from the combustion chamber, an exhaust passage for said gases, and heat exchange means heated by the combustion and operated to vaporize liquid fuel to be supplied to said nozzle and to pre-heat and expand the air and fuel mixture in the mixing tube, together with means for supplying liquid fuel to said heat exchange means at relatively high pressure.

8. In a gas turbine, in combination, an elongated mixing tube of Venturi form including a nozzle having an axially disposed air intake passage and a feed passage of annular cross section for vaporized fuel, said annular passage narrowing toward and terminating near the constricted portion of the venturi for aspirating air from the intake passage, a combustion chamber adjoining the mixing tube, a turbine wheel to which the gaseous products of combustion are fed from the combustion chamber, an exhaust passage for said gases, heat exchange means heated by the combustion and operated to vaporize liquid fuel, means supplying liquid fuel to said heat exchange means at relatively high pressure, and means conveying the vaporized fuel to said nozzle.

9. In a gas turbine, in combination, a mixing tube having an air intake opening, a fuel feeding nozzle discharging into said tube in a direction to aspirate and compress air from said intake, a combustion chamber into which the mixing tube leads, a turbine wheel, nozzle means directing the gaseous products of combustion from said combustion chamber against the turbine wheel, an exhaust passage for said gases, means for supplying fuel to said fuel feeding nozzle in gaseous form and at relatively high pressure, and a heat exchanger in the mixing tube forming a part of said exhaust passage for transferring heat from the exhaust gases to the mixture of air and fuel vapor therein to preheat and expand said mixture on its way to the combustion chamber.

LYNN A. WILLIAMS, JR.

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