

# United States Patent

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## [54] SPONTANEOUS IGNITION OF FUEL IN A COMBUSTION CHAMBER

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60/39.82 R

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H, 60/39.82 R, 39.14, 39.74 R, 39.48, 39.46;  
137/542; 431/1, 2

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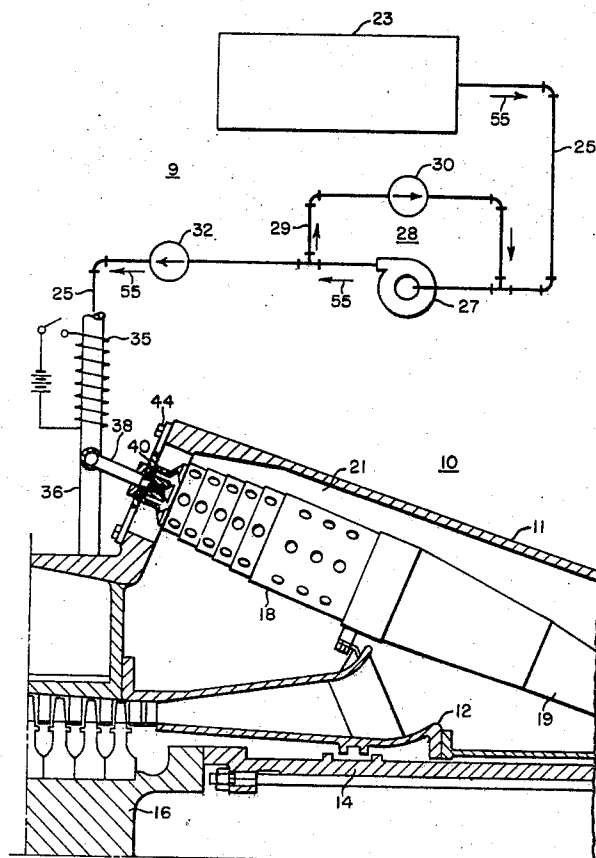
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## [57] ABSTRACT

An arrangement and method to heat fuel under constant volume to a temperature at which it will flash at the ambient pressure in the combustion chamber and then admit the fuel through a valve to the combustion chamber where the fuel mixes with air and spontaneously flashes into flame.

1 Claim, 3 Drawing Figures



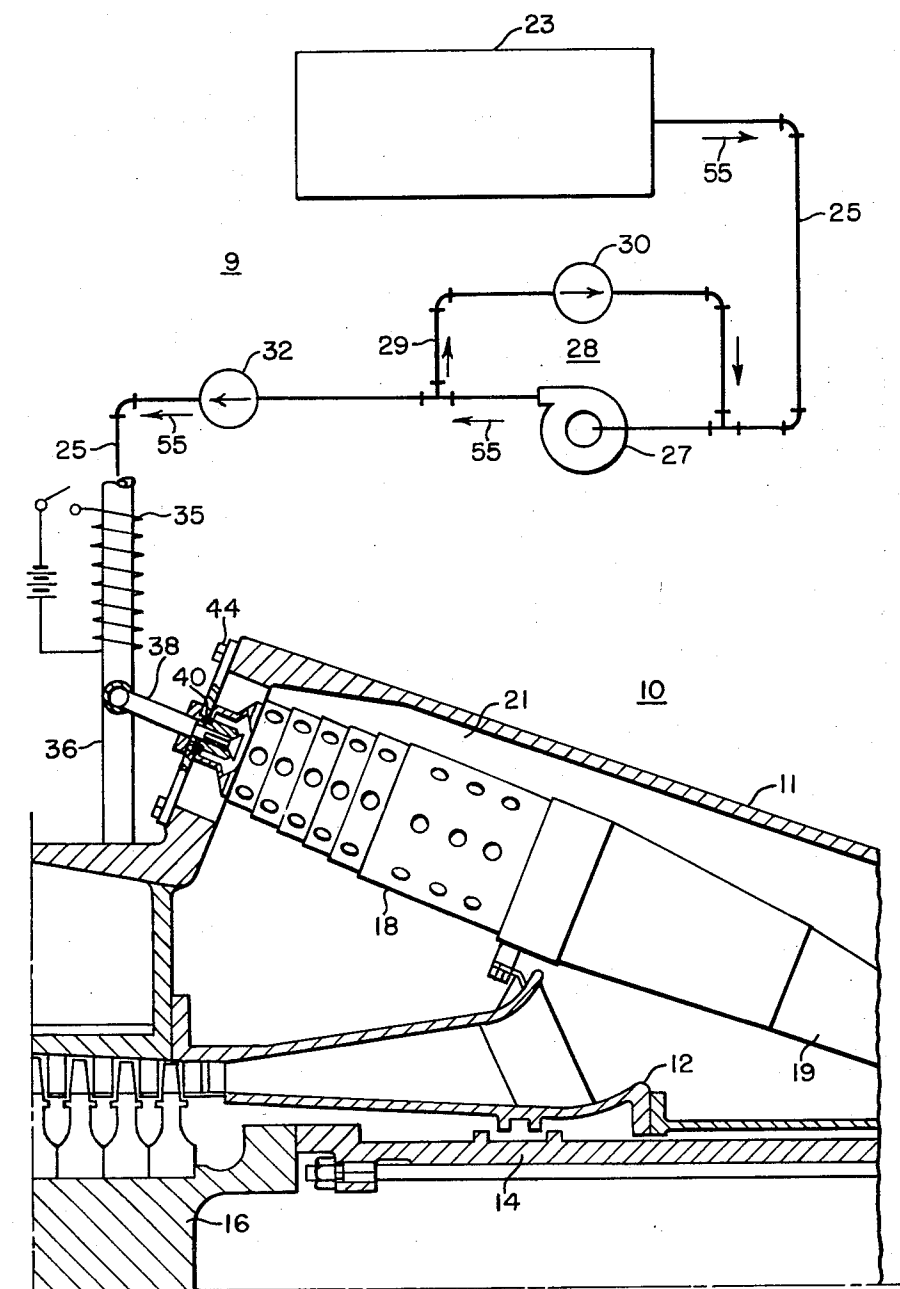


FIG. 1

WITNESSES

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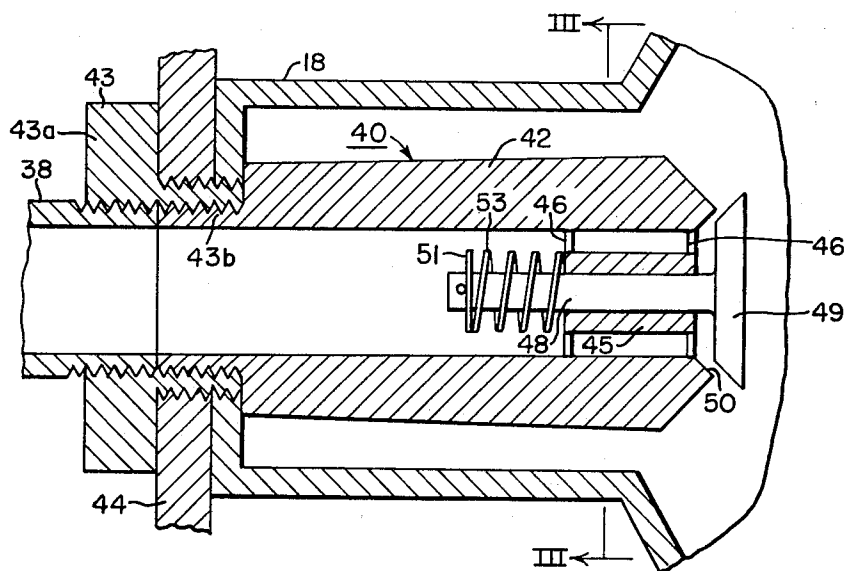


FIG. 2

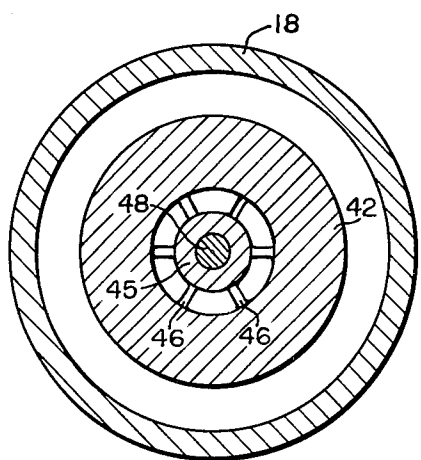


FIG. 3

## SPONTANEOUS IGNITION OF FUEL IN A COMBUSTION CHAMBER

### BACKGROUND OF THE INVENTION

This invention relates generally to the spontaneous ignition of pre-heated fuel in a combustion chamber and is well adapted for use in connection with gas turbine power plants.

Presently, fuel for gas turbines is ignited in combustion chambers by spark-plugs, flame throwers, or glow plugs. Generally, spark-plugs are very fragile because of the brittle characteristic of their ceramic insulating portions. In gas turbine applications, the combustion chambers are disposed within an annular outer casing, partially defining a plenum chamber, which is pressurized by air from a compressor. The igniting devices, which are generally a separate assembly from the fuel nozzle system, penetrate and project through both the outer casing and the combustion chambers, requiring complicated and costly sealing mechanisms to prevent leakage of compressor air to the atmosphere or into the combustion chambers, thereby having an adverse effect on combustion. The various igniting devices are also subject to damage from the flame itself, once ignition begins. Finally, another major disadvantage of the igniting devices is that they are internal devices and are not easily accessible without turbine shutdown, so that service on them is costly.

It would be desirable then, to design an ignition system that is not fragile, that is external to the turbine, that is more reliable than present igniters, and that is inexpensive to manufacture and service.

### SUMMARY OF THE INVENTION

This invention provides an arrangement and method of initiating fuel combustion in combustion chambers by heating the fuel under constant volume to a temperature at which it will flash at the ambient pressure in the combustion chambers and then allowing it to enter the combustion chambers where it mixes with air and spontaneously flashes into flame.

Fuel is pumped from a fuel source through a fuel conduit to the combustion chambers. The fuel is heated in the fuel conduit before it reaches the combustion chambers to a temperature value at least as great as its flash point temperature at the ambient pressure in the combustion chambers, under constant volume and increasing pressure. Valves, which are spring activated, are located at the combustion chamber end of the fuel line, one valve corresponding to each combustion chamber. When the pressure in the fuel line reaches a preset pressure value to overcome the spring force, each valve opens. The force in the fuel line pushes the pre-heated fuel into the lower pressure combustion chambers, which have an abundance of air, mixes with the air and spontaneously flashes into flame.

What is shown then, is an ignition system which only requires penetration of the outer turbine casing and the combustion chambers with fuel nozzles, is less fragile than the common igniting devices, is not subject to damage from the flame, is more reliable than standard igniting devices, is economical to build and is more accessible to service.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a spontaneous ignition system formed in accordance with the present invention, associated with the upper half of a gas turbine, which is shown in longitudinal section;

FIG. 2 is a sectional view of a fuel valve shown in FIG. 1 but enlarged for purposes of clarity; and

FIG. 3 is a view taken along line III—III of FIG. 2.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings in detail and particularly to FIG. 1, there is shown a diagrammatic representation of an ignition system 9 and a portion of an axial flow gas turbine 10. The turbine 10 comprises an outer casing 11 of generally annular shape, a tubular fairing member 12 of annular shape encompassed by the outer casing 11, and a spindle structure 14 surrounded by the fairing member 12, only portions of which are shown. The spindle structure 14 is rotatably supported within the outer and inner casings in any suitable manner (not shown) and comprises a turbine portion (not shown) and a compressor portion 16 (partially shown). The turbine portion of the spindle structure 14 is drivingly connected to the compressor portion 16 so that the compressor and turbine rotors rotate together, the turbine driving the compressor, as well known in the art.

Hot motive fluid, such as pressurized combustion gases, is, generated in combustion apparatus including a plurality of combustion chambers 18 (only one being shown). The combustion chambers 18 are disposed in an annular array about the rotational axis of the turbine 10. The combustion chambers 18, which are generally tubular in shape, have corresponding transition members 19, where the downstream ends of the members form arcuate outlets (not shown) which cooperatively direct the motive gases to the turbine to rotate the rotor structure (not shown) around its longitudinal axis.

The combustion chambers 18 are disposed in an annular plenum chamber 21, which is defined by the outer casing 11 and the fairing member 12, and is pressurized by air directed from the compressor portion 16 into the plenum chamber. The air is directed into the combustion chambers 18 to mix with the fuel to form a combustible mixture which is burned to provide the hot motive fluid. Only the upper half of the gas turbine 10 and combustion apparatus 18 is shown since the lower half may be substantially identical about the axis of rotation of the turbine.

The ignition system 9 comprises a reservoir or fuel source 23 which is external to the turbine 10. A fuel conduit 25 extends from the source 23 and a fuel pump 27 is connected to the conduit 25. Downstream of the pump 27, is a pump recirculation circuit 28. The circuit 28 comprises a bypass conduit 29 to which is connected a pneumatically controlled bypass valve 30 and the conduit 29 exits back into the main fuel conduit 25, upstream of the pump 27. Downstream of the bypass circuit 28 is a pneumatically controlled cutoff valve 32. Downstream of the cutoff valve 32, the fuel conduit 25 is encompassed by a heating apparatus 35, which as shown, comprises an electrical heating coil. The heating coil 35 surrounds the main portion of the fuel conduit 25 before the line divides to go to the combustion

chambers 18. Further downstream of the heating apparatus 35 is an annular manifold portion or flow dividing structure 36 of the fuel conduit 25 (only partly shown). The manifold portion 36 has exit portions 38 which are in fluid communication with the combustion chambers 18. There are a corresponding number of exit portions 38 and combustion chambers 18.

At the combustion chamber end of each exit portion 38 and in fluid communication therewith, is a pressure regulated valve 40, as best seen in FIG. 2, one valve corresponding to each combustion chamber 18.

Since all the valves 40 are similar, only one will be described. The valve 40 projects into the upstream end of the combustion chamber 18. As best seen in FIG. 2, each valve 40 has a tubular outer casing 42 and is secured by any suitable means to the exit portion 38, which as shown is a tubular locking member 43. The locking member 43 has an annular flanged portion 43a and a reduced central portion 43b. The flanged portion 43a is threaded on its inner diameter and the central portion 43b is threaded on its inner and outer diameter. A disc-shaped sealing plate 44 is secured to the turbine outer casing 11 (FIG. 1) to seal the plenum chamber 21 and is screw threaded to the outside diameter of the central portion 43b of the locking member 43 (FIG. 2), between the shoulder 43a and the combustion chamber 18.

A tubular sleeve 45 is concentrically disposed within the valve outer casing 42. The sleeve 45 is supported within the casing 42 by a plurality of radially extending ribs 46 (FIGS. 2 and 3). There is one set of ribs on each end of the sleeve 45. A shaft 48 is slidably disposed within the sleeve 45 (FIG. 2). At the downstream end of the shaft 48, and integral therewith, is a tapered valve seating member 49, which corresponds in shape to a tapered downstream seating portion 50 of the valve outer casing 42. A disc-shaped support member 51 is secured to the upstream end of the shaft 48. A helical spring 53 encompasses the shaft 48 and is secured between the support member and the sleeve 45.

In operation (FIG. 1), the spindle structure 14 of the turbine 10 must be cranked to a predetermined speed by an external power supply (not shown) before the fuel ignition is initiated, so that the cranking effort is augmented by the motive gases produced to render the turbine capable of attaining a self-sustaining speed. As an example, if the normal running speed of the turbine 10 is 3,600 r.p.m., a predetermined speed of about 25 percent of normal speed or 900 r.p.m. is required before fuel ignition is required. This is well known in the art and is more fully disclosed in P.D. Evans U.S. Pat. No. 3,485,041, issued Dec. 23, 1969 and assigned to the same assignee as the present invention.

During operation, the pump 27 pumps the fuel from the fuel source 23 in a direction indicated by the arrows 55. The fuel normally flows through the fuel conduit 25 past the recirculation circuit 28 and through the cutoff valve 32. The fuel fills the manifold portion 36 but is prevented from entering into the combustion chambers 18 by the valves 40. When the fuel conduit 25 and the manifold portion 36 are filled with fuel, the heating apparatus 35 heats the fuel under constant volume. The fuel is heated and the pressure in the fuel conduit 25 and the manifold 36, correspondingly, increases, since there is a direct relation between the pressure and tem-

perature when the volume remains constant. The preheated fuel spontaneously flashes into flame when admitted into the combustion chamber 18 so the pressure in the combustion chamber is determinative of the corresponding flash point temperature. The fuel is heated to a temperature according to the equation:

$$T = T_f + T_L$$

where  $T$  is the temperature the fuel is heated to in the fuel line,  $T_f$  is the flash point temperature of the fuel in the combustion chamber and determined by the pressure therein, and  $T_L$  is the temperature due to the heat transfer losses as the fuel flows from the fuel conduit to the combustion chamber. The pressure in the combustion chamber is known and the corresponding flash point temperature  $T_f$  in the chamber is calculable.

The minimum pressure needed in the fuel line is determinable according to the equation:

$$P = P_c + P_L$$

where  $P$  is the minimum required pressure of the fuel in the fuel conduit,  $P_c$  is the pressure in the combustion chambers and  $P_L$  is the pressure loss due to the opening of each valve 40.

The spring 53 on each valve 40 is selected with a proper spring constant, so that when the predetermined pressure is reached in the fuel conduit, which is equal to or greater than  $P$ , the force will be sufficient to overcome the spring force and open the valve. The fuel, upon entering the lower pressure combustion chambers, has a temperature at least as great as the flash point temperature and pressure of the fuel at the ambient pressure in the combustion chambers at ignition conditions. Because of the absence of air in the manifold 36 and the fuel conduit 25 when filled and pressurized with fuel, the fuel will not flash in the manifold 36.

As well known in the art, various schemes are used to alleviate the starting problems in a turbine such as the high pressure buildup, which restricts spindle rotation. One such scheme is the bleeding off of compressor air before discharge (not shown). Referring to the previously stated example, when the spindle is turning at 900 r.p.m., the air in the combustion section will only be slightly greater than atmospheric pressure, although at full running speed the pressure can reach 10 atmospheres or even more.

By way of example, number 2 distillate fuel has a flash point temperature,  $T_f$ , of approximately 600° F at atmospheric pressure. If the pressure in the combustion chambers  $P_c$  is about 1 or 2 psig at an ignition speed of 900 r.p.m., then the temperature of the fuel in the fuel conduit,  $T$ , must be greater than 600° F and the corresponding pressure  $P$ , in the conduit, must be greater than atmospheric for spontaneous ignition to occur in the combustion chambers.

Once there is combustion, the heating apparatus 35 is interrupted or shut off since the fuel is being sprayed into the burning combustion chamber which self-sustains combustion.

If air leaks into the fuel conduit 25 or there is an accumulation of combustible mixture during shutdown, valve 32 is activated by an external signal (not shown) resulting in a pressure drop in the conduit and the spring 53 shuts the tapered valve seating member 49 against the seating portion 50 of the valve 40 (FIG. 2).

As the ambient pressure in the turbine increases after ignition, with the increase in turbine speed, the pump 27 increases the fuel pressure in the conduit 25 to maintain the valve 40 in an open position and supply the required accelerated fuel flow. The recirculation circuit 28 relieves the pressure in the conduit 25 by pneumatically opening the valve 30 in response to an external signal (not shown) and correspondingly increases the pressure by closing the valve 30.

Furthermore, if the pressure in the manifold 36 builds up to a value greater than that necessary to overcome the spring force in the valves 40, before the preheated fuel reaches its flash point temperature, fuel can be diverted to the recirculation circuit 28 and through the bypass valve 30 to control and regulate the pressure buildup.

What is shown then is an arrangement and method of initiating fuel combustion in a combustion chamber without the necessity for an independent lighting source such as a spark plug, which arrangement is easily serviceable, is not subjected to damage from the flame, and does not require complicated and costly sealing structures which are presently used.

What is claimed is:

1. An ignition system for a gas turbine having a combustion chamber, means for delivering pressurized fuel

to said combustion chamber and means for supplying air to said combustion chamber to support combustion of the fuel, said ignition system comprising means for heating all of the fuel before it enters said combustion chamber to a temperature at least as great as its flash point temperature at the ambient pressure in said combustion chamber, means for admitting the fuel of said combustion chamber, means for preventing the back flow of fuel through said fuel delivering means, said air supply means and said means for admitting the fuel being cooperatively associated to produce spontaneous and generally complete combustion of all of the fuel as the fuel admixes with the air in the combustion chamber, and means for shutting off the heating means after combustion of the fuel has commenced, said means for admitting fuel comprises a tubular outer casing, a tubular sleeve concentrically disposed within said casing, a shaft slidably supported within said sleeve, a valve seating member secured to the downstream end of said shaft, a support portion secured to the upstream end of said shaft, and a spring disposed between said support portion and said sleeve encompassing said shaft, which activates said seating member to admit the fuel to the combustion chamber, when the fuel reaches a predetermined pressure.

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