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COMBUSTION APPARATUS HAVING VALVE CONTROLLED PASSAGES FOR PREHEATING THE FUEL-AIR MIXTURE

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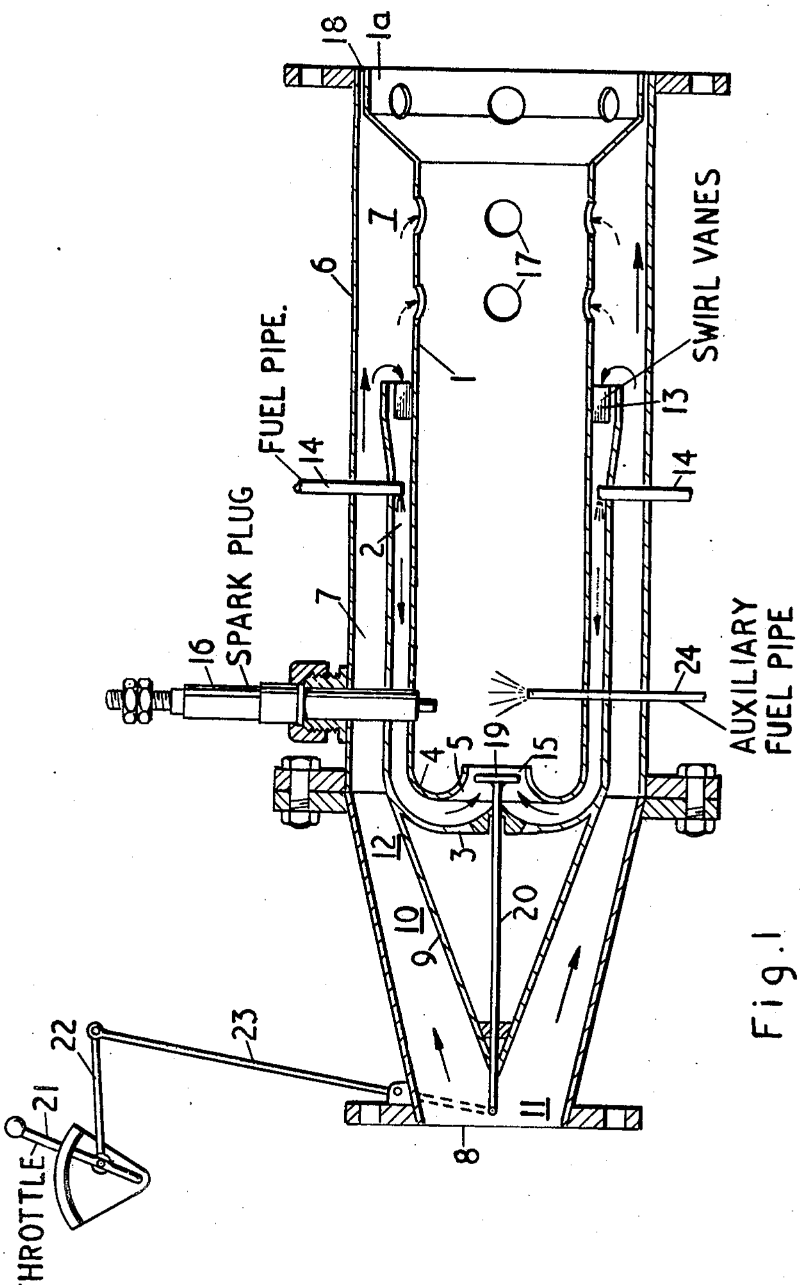

Fig. 1

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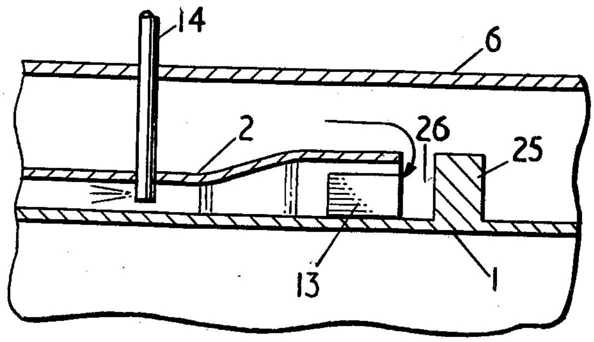

Fig. 2

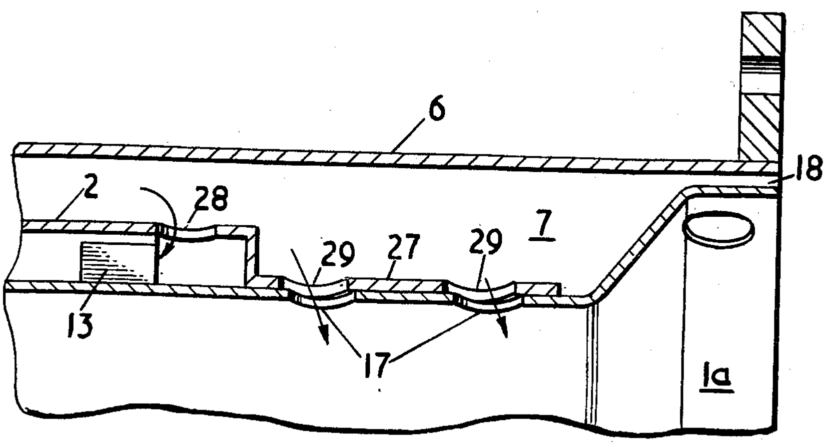

Fig. 3

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COMBUSTION APPARATUS HAVING VALVE CONTROLLED PASSAGES FOR PREHEATING THE FUEL-AIR MIXTURE

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8 Claims. (Cl. 60—39.23)

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This invention relates to improvements in combustion systems, and is intended in particular for use in cases in which combustion has to be supported by a fast-moving stream of fluid (hereinafter considered as being air). The description "fast moving" as applied to a combustion-supporting air stream is used herein to indicate that the mean speed of the air stream in its general direction of flow past a combustion zone, calculated from the ratio air volume passing in unit time/cross sectional area of the flow path, is sufficiently high in relation to the speed of flame propagation in the fuel/air mixture concerned to have flame extinguishing properties. For hydrocarbon fuels burning in air the speed of flame propagation is considered as being of the order of one foot per second at atmospheric temperature; the invention, on the other hand, is especially applicable to combustion apparatus for gas turbine or/and jet propulsion power units in which the speed of the air stream in its general direction of flow past a combustion zone, calculated on the basis indicated, might be from 10 to 300 feet per second or even more, depending on the design. The invention is further of particular interest in relation to installations which, in common with such power units, require stabilised burning to be supported not only by a fast moving airstream but also with high air/fuel ratios. Combustion apparatus for these purposes is also required to maintain stable burning at high rates of fuel injection with a minimum of pressure loss.

A further object of the present invention is to improve the combustion performance under conditions of very low pressure such as is experienced, for example, in the case of gas turbine aero engines operating at high altitudes. Hitherto combustion under such circumstances has presented considerable difficulties owing to the fact that in such cases the simple atomising burner operates at reduced efficiency and an object of the present invention is to overcome this disadvantage.

Accordingly the invention provides a combustion apparatus comprising an air casing having an air inlet, a flame tube within said air casing, a tubular sheath member enclosing and radially spaced from an upstream part of the flame tube to form therewith an annular passage, the upstream end of said member (in relation to the flow of working fluid through the flame tube) being closed and the downstream end being open and forming with the flame tube an annular entry for a stream of primary air from the air

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casing to said annular passage, means for injecting fuel into said annular passage to mix with the primary air, entry means connecting the annular passage to an upstream part of the interior of the flame tube, further entry means in the wall of the flame tube downstream of said sheath member for a stream of secondary air, and a valve located in and controlling the flow of one of said streams to vary the proportions of primary and secondary air.

The valve may be located at the entry to said annular passage or at the entry connecting the passage to the interior of the flame tube, thus controlling the flow of primary air. Alternatively the valve may control the flow of secondary air into the flame tube.

In order to maintain an approximately chemically correct mixture strength in the primary zone of the combustion system under all operating conditions, it is advantageous to vary the primary air flow for different rates of fuel supply corresponding to different positions of the engine throttle.

The invention is more particularly described by way of example with reference to the accompanying drawings of which:

Figure 1 is a diagrammatic axial cross-section of one embodiment of the invention;

Figures 2 and 3 are fragmentary views of two modifications of the embodiment shown in Figure 1.

The apparatus shown in Figure 1 comprises a substantially cylindrical flame tube 1 provided towards its upstream region (relative to the direction of flow of gases in the tube) with an annular envelope or jacket 2 co-axial with the tube 1 and having at its upstream end, incurved walls 3 which together with corresponding incurved walls 4 of the upstream end of the flame tube form arcuate passages 5 whereby the flow of fluid passing upstream through the annular envelope 2 can be reversed efficiently and led downstream through an axial entry into the flame tube 1.

Surrounding the whole of the flame tube 1 and the annulus 2 is an outer casing 6 which is also co-axial with the flame tube 1 and in combination with the latter forms a second annular space 7 around the above-mentioned annular envelope 2 and around the downstream portion of the flame tube 1.

The main air-stream is led downstream into this second annular space 7 through a connecting duct 8 which is of frusto-conical form having its narrow end upstream and its wider end downstream and arranged co-axially with the flame tube 1. Within the duct 8 is arranged a co-axial hollow cone 9 having its apex pointing upstream and its base abutting against the upstream end of the flame tube 1 thereby forming in combination with the frusto-conical duct an annular passage 10 which leads into the above-mentioned second annular space 7 and which may constitute either a diffusing passage or an accelerating passage according to the relationship between the cross sectional area of the upstream and downstream ends 11, 12 of the annular passage.

The downstream end of the annular envelope 2 is open and the arrangement is such that the main air stream flows in a downstream direction through the above-mentioned second annular space 7 and at the downstream open end of the annular envelope 2 a part of the main air stream reverses its flow path through 180° to enter the said envelope, and flow through it in an upstream direction.

Within the envelope 2 are provided a circular series of radially directed swirl vanes 13 by means of which the incoming air is given a swirling movement around the axis of the flame tube 1.

One or more liquid fuel supply pipes 14, are arranged so that their delivery ends protrude into the annular envelope 2 and when liquid fuel is discharged from these ends, it impinges against the wall of the flame tube 1 so as to form a spray which, if this wall is hot, immediately vaporizes, the fuel vapour then mixing with the air within the envelope 2.

The mixture of air and fuel vapour flows upstream while at the same time swirling around the axis of the tube 1 and at the upstream end of the envelope 2 its path is again reversed through 180° by the incurved walls 3, 4, whereby the mixture is led through an axial entry 15 into the flame tube 1 in a downstream direction.

Within the flame tube 1 and a short distance downstream of the said entry is arranged a spark plug 16 by means of which the mixture may be ignited.

In the wall of the flame tube 1 and downstream of the annular envelope 2 are provided a number of apertures 17 through which a part of the main air stream enters the flame tube to constitute mixing air.

In the region of its downstream outlet, the flame tube 1 is preferably provided with a portion 1*a* of short axial length but enlarged diameter relative to the main portion of the flame tube, which enlarged portion together with the outer casing 6 forms an annular space 18 of very small radial dimensions relative to the annular space 7. The dimensions are arranged so that through the space 18 there flows a small part (conveniently approximately 10 per cent) of the main air stream to constitute cooling air.

At its axial entry into the flame tube 1 the mixture of primary air and fuel vapour is throttled by means of a disc valve 19 located immediately upstream of this entry, the valve being supported by a stem 20 which is arranged within the cone 9 and is co-axial with the flame tube 1. Suitable means are provided for varying the distance between the disc 19 and the entry 15 so as to obtain a variable throttle effect.

The disc 19 causes turbulence near the entry 15 whereby the air-fuel mixture fills the space formed by the walls 4 and thus promotes heating of the flame tube wall and vaporization of the fuel.

The disc valve 19 is operated from the engine

throttle 21 through linkage 22, 23, so that if the fuel supply is increased the distance between the valve 19 and the entry 15 is also increased so as to maintain an approximately chemically correct mixture strength in the primary combustion zone.

In order to initiate the combustion process it is necessary to provide auxiliary means for injecting fuel within the flame tube 1 and for this purpose use may be made of a pilot fuel jet or gas delivery pipe 24 which may deliver to a region in the vicinity of the spark plug 16. The auxiliary fuel supply is, of course, cut off once combustion has begun and the flame tube wall has become sufficiently hot to vaporize the fuel.

As an alternative to the above-mentioned disc valve 19 a variable throttling effect may also be obtained by making use of differential expansion between the tube 1 and the outer casing 6 to open or close one or more restricting orifices through which the mixture of air and fuel passes into the flame tube 1.

This arrangement is shown in Figure 2. In this case the flame tube 1 is formed with an outwardly directed annular projection which forms with the end of the envelope 2 an annular passage 26 through which primary air flows to the flame tube. It will be appreciated that the flame tube 1 will expand to a greater extent than the envelope 2 in operation and consequently as the flame tube temperature increases due to an increased fuel supply, the passage 26 will also increase in size so that a greater quantity of air is admitted to the flame tube to maintain a substantially constant air/fuel ratio.

As a further alternative throttling means, the proportion of air entering as mixing air through the apertures 17 in the flame tube wall may be varied by making some or all of said apertures, for example by means of a sleeve slidable over the flame tube.

This is shown in Figure 3 in which the envelope 2 is extended downstream to form a sleeve 27 closely fitting over the downstream portion of the flame tube 1. A circular series of apertures 28 are provided for the admission of primary combustion air to the space between the envelope 2 and the flame tube 1, and further apertures 29 are provided in the sleeve corresponding to the apertures 17 in the flame tube. It will be seen that due to differential thermal expansion between the sleeve 27 and the flame tube 1, the apertures 17 will be progressively blanked off as the temperature increases. The secondary air supply is thus restricted and a greater quantity of air is constrained to enter the primary combustion zone.

The proportions of the air stream entering the annular envelope 2, mixing air and coolant air are of course adjusted to suit the combustion requirements of the particular case under consideration.

We claim:

1. Combustion apparatus comprising an air casing having an air inlet, a flame tube within said air casing, a tubular sheath member enclosing and radially spaced from an upstream part of the flame tube to form therewith an annular passage, the upstream end of said member (in relation to the flow of working fluid through the flame tube) being closed and the downstream end being open and forming with the flame tube an annular entry for a stream of primary air from the air casing to said annular passage, means for injecting fuel into said annu-

lar passage to mix with the primary air, entry means connecting the annular passage to an upstream part of the interior of the flame tube, further entry means in the wall of the flame tube downstream of said sheath member for a stream of secondary air, and a valve located in and controlling the flow of one of said streams to vary the proportions of primary and secondary air.

2. Combustion apparatus according to claim 1 wherein said valve is operable, when the rate of delivery of fuel is varied, in a sense to maintain a substantially constant ratio between the quantities of primary air and fuel.

3. Combustion apparatus according to claim 2 wherein said valve is operatively linked to an engine throttle.

4. Combustion apparatus comprising an outer air casing, a flame tube within said air casing, a tubular sheath member closed at its upstream end (in relation to the flow of working fluid through the flame tube) and annularly enclosing the upstream part of the said flame tube, said sheath and flame tube together defining an annular jacket surrounding the latter, fuel injecting means introducing fuel into said jacket, means for leading air into said air casing, further means for dividing said air and delivering part thereof into said jacket as primary air to mix with the fuel therein and entry means connecting said jacket and flame tube whereby the fuel/air mixture is led into the latter, said entry comprising valve means controlling the flow of fuel/air mixture therethrough, and further entry means in the wall of the flame tube downstream of said jacket whereby a further part of the air is led into the flame tube as secondary air.

5. Combustion apparatus comprising an outer air casing, a flame tube within said air casing, a tubular sheath member closed at its upstream end (in relation to the flow of working fluid through the flame tube) and annularly enclosing the upstream part of the said flame tube, said sheath and flame tube together defining an annular jacket surrounding the latter, fuel injecting means introducing fuel into said jacket, means for leading air into said air casing, further means for dividing said air and delivering part thereof into said jacket as primary air to mix with the fuel therein and entry means connecting said jacket and flame tube whereby the fuel/air mixture is led into the latter, and further entry means in the wall of the flame tube downstream of said jacket whereby a further part of the air is led into the flame tube as secondary air, and valve means controlling the flow of air/fuel mixture through the jacket, said valve means being actuated by differential thermal expansion between the flame tube and the enclosing structure.

6. Combustion apparatus comprising an outer air casing, a flame tube within said air casing, a tubular sheath member closed at its upstream end (in relation to the flow of working fluid through the flame tube) and annularly enclosing the upstream part of the said flame tube, said sheath and flame tube together defining an annular jacket surrounding the latter, fuel injecting means introducing fuel into said jacket, means for leading air into said air casing, further means for dividing said air and delivering part thereof into said jacket as primary air to mix with the fuel therein and entry means connecting said jacket and flame tube whereby the fuel/air mixture is led into the latter, and further entry means including a valve in the wall of the flame tube downstream of said jacket whereby a further part of the air is led into the flame tube as secondary air.

7. Combustion apparatus according to claim 6 wherein said valve is actuated by differential thermal expansion between the flame tube and the enclosing structure.

8. Combustion apparatus comprising an outer air casing, a flame tube within said air casing, a tubular sheath member closed at its upstream end (in relation to the flow of working fluid through the flame tube) and annularly enclosing the upstream part of the said flame tube, said sheath and flame tube together defining an annular jacket surrounding the latter, fuel injecting means introducing fuel into said jacket, means for leading air into said air casing, further means for dividing said air and delivering part thereof into said jacket as primary air to mix with the fuel therein, entry means connecting said jacket and flame tube whereby the fuel/air mixture is led into the latter, further entry means in the wall of the flame tube downstream of said jacket whereby a further part of the air is led into the flame tube as secondary air, and valve means controlling the flow through the jacket.

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