

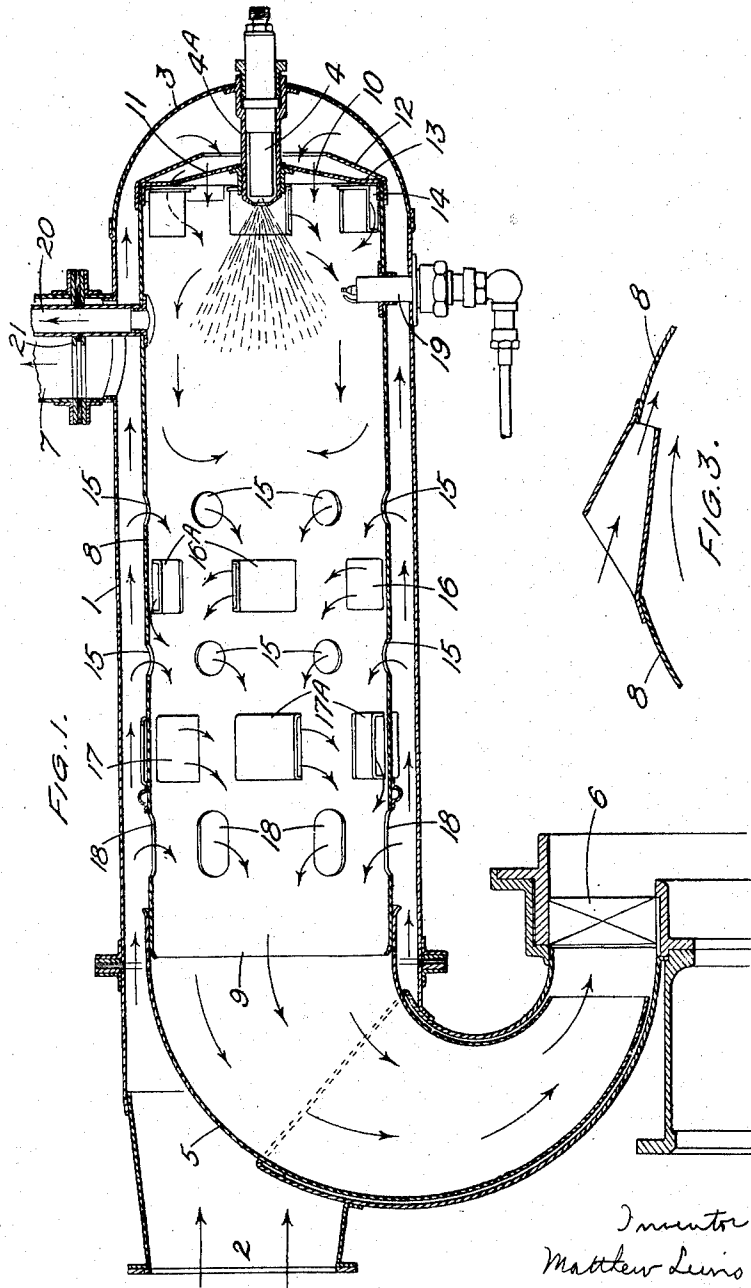
May 19, 1953

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INLETS FOR PRIMARY AND SECONDARY AIR

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Filed Nov. 7, 1945

3 Sheets-Sheet 1



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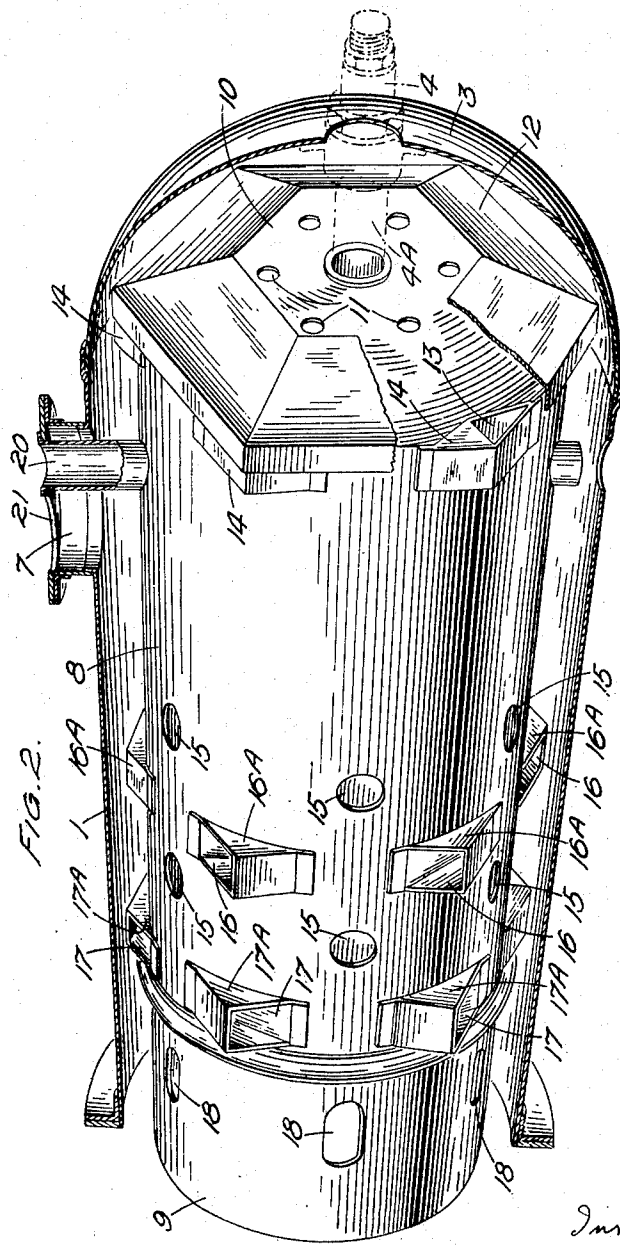
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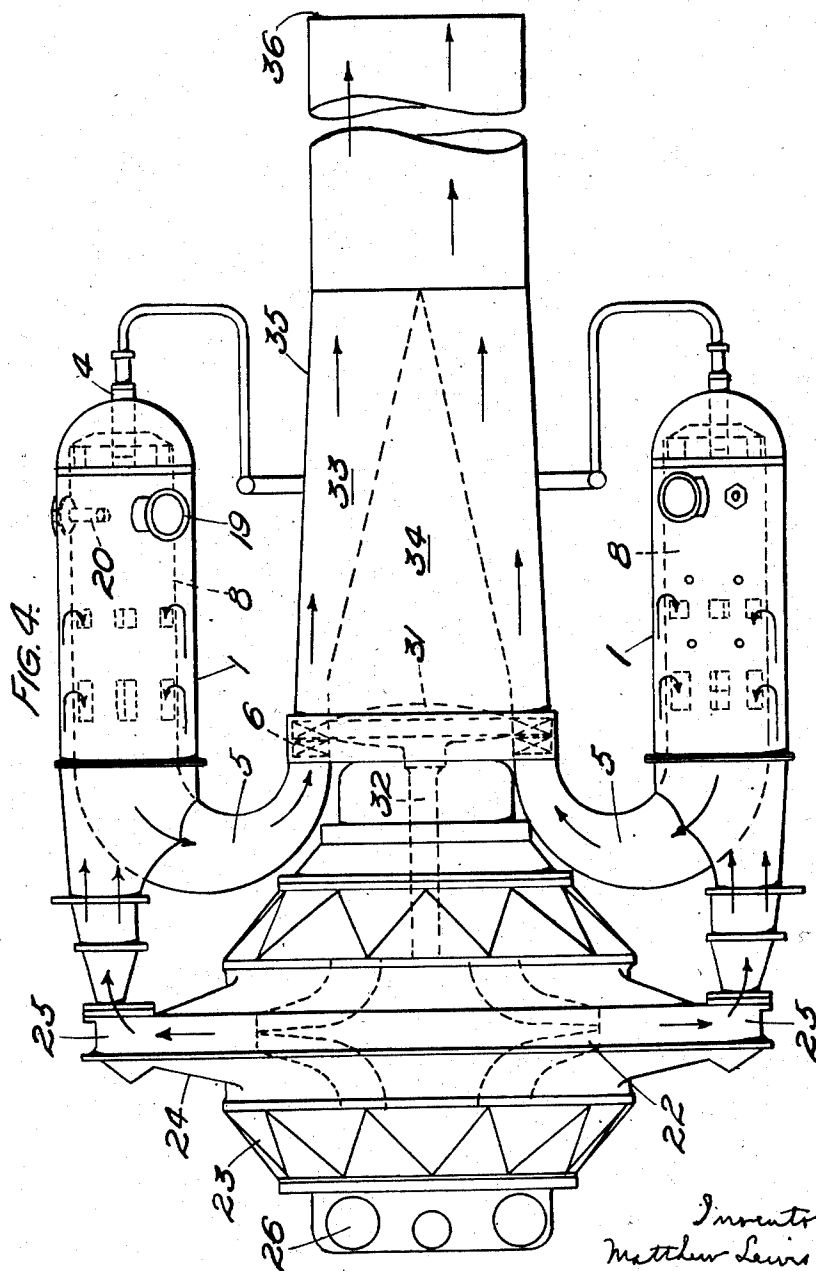
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UNITED STATES PATENT OFFICE

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GAS TURBINE COMBUSTOR HAVING TANGENTIAL AIR INLETS FOR PRIMARY AND SECONDARY AIR

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4 Claims. (Cl. 60—39.65)

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This invention relates to combustion arrangements for burning fluid fuel in an air stream. It is applicable more particularly (though not exclusively) to an arrangement for combustion of liquid pressure-fed fuel in a compressor and gas-turbine power unit. The particular use of the invention at present envisaged is as a flame-tube in an aircraft propulsion power unit comprising an air compressor, a plurality of combustion chambers supplied thereby, and a gas turbine driving the compressor by power derived from the combustion products on a continuous basis. In such units it may be assumed that each combustion chamber comprises a cylindrical outer chamber into which air enters at one end and an inner flame tube of less diameter, into which the air passes from the annular space between the chamber and flame tube; the latter discharges from one end, substantially axially.

The achievement of efficient combustion over a wide range of mixture strengths and in various operating conditions is in itself a difficult technical problem when limitations of volume, high air velocities, and the necessity for avoiding carbon deposition and excessive local heating are taken into account. It is also deemed to be desirable that stratification of gases in the outlet (i.e. wide variations of temperature across a section of the flow) is to be minimised.

It is usual to regard the flow of air into a flame tube as being of two or even three kinds; "primary" air is that proportion of the whole throughput which is required to sustain combustion in all operative conditions, "secondary" air is the remainder or that proportion which is required to effect complete combustion and as a diluent, and "tertiary" air if provided for, is mainly air which is a diluent. Diluent air is, of course, air over and above that which is required for combustion but which is required to be heated for the operation of the power unit or other purposes.

The present invention comprises in effect a form of flame tube which has shown itself in practice to meet actual requirements, has a reasonably long life, is simple to make and is light in weight. A functional object of the invention is to obtain a correct balance between primary, secondary and tertiary air flow and to so control these that the distribution of the flow is favourable for combustion; in particular it appears from experiment that the arrangement permits the injected fuel to vaporize thoroughly without being chilled.

According to the invention a flame tube for use in a combustion system comprises a tubular body

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with one end open for emission of combustion products and the other end closed except for minor perforations, provision being made for the introduction of fuel into the tube in the region of the closed end, the wall of the tube in this region (within which primary combustion takes place) having openings associated with means which direct primary air into the tube in a tangential sense, whilst other openings are provided in the tube wall further towards the open end likewise associated with air directing means for secondary air to enter the tube in a tangential sense. The fuel is preferably liquid fuel injected in the region of the closed end; the air directing means are mainly external to the bore of the tube and their purpose is to cause the entering air to swirl in the bore in vortex manner. The openings and associated air directing means in any one axially defined region of the tube are provided as a ring or circumferential series and evenly spaced in the circumferential sense. Beside the openings which have air directing means other openings are preferably provided which are plain and these are distributed mainly towards the open end of the tube. The air directing means in one axially located region may be oppositely handed in rotational sense to those of an adjacent region, i. e. one further up or down stream. The air directing means may comprise chutes of rectangular cross-section which are convergent in the direction of air flow and this lends itself to their construction from sheet metal. The extent to which air directing means project into the bore of the tube is small and the nature of any such projection is such that it does not substantially interfere with the air flow within the tube so that serious local turbulence caused thereby is avoided and also the susceptibility of the means to damage by the impingement of flame or hot gas is minimized.

A flame tube according to the invention and its arrangement within a combustion chamber are illustrated in the accompanying drawings in which

Fig. 1 is a sectional view showing a flame tube and associated parts together with the method of mounting and locating.

Fig. 2 is a partly sectioned illustration showing the external appearance of a flame tube.

Fig. 3 is a sectional fragmentary view of one air directing means.

Fig. 4 is a representation of a power unit for jet propulsion intended for use on an aircraft and is an example of one case in which the invention may be applied.

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Referring first to Fig. 4, a compressor rotor 22 of a double sided centrifugal compressor draws in air through double air intakes 23 and the compressed air is delivered from the compressor casing 24 through outlets 25 to a plurality of interconnected combustion chambers or air casings 1 arranged symmetrically in a circular series around the axis of the compressor 22. Each chamber 1 comprises a flame tube 8 provided with suitable apertures through which the air enters and by means of a fuel injector 4 fuel under pressure from a supply source and pump 26 is sprayed into the flame tube 8 and the gaseous mixture ignited, for example by means of an electric spark plug. The gaseous products are then delivered through elbow ducts 5 to the nozzle assembly 6 of a turbine 31 mounted on the same shaft 32 as the compressor rotor 22. The hot gases thus drive turbine 31 which in turn drives the rotor 22, and the gases after passing through the turbine 31 flow into an annular duct 33 formed between a conical fairing 34 and a jet pipe 35, being finally ejected to atmosphere through the outlet 36 of jet pipe 35 and forming in this way a main propulsive jet stream.

The flame tube 8 is illustrated on a larger scale in Fig. 1. Each combustion chamber consists of a cylindrical wall 1, with an air entry 2 and with one end closed by a hemispherical end 3 through which extends axially a fuel injector 4 the purpose of which is to inject liquid fuel in at atomised state. From the interior of the combustion chamber 1 there leads an elbowed receiving duct 5 to lead combustion products laterally out of the chamber 1 to the nozzles 6 of the gas turbine 31 (Fig. 4). The lateral air duct 7 leads from the combustion chamber 1 to an identical neighbouring chamber.

Coaxially within the chamber 1 is mounted the flame tube. This consists of a sheet metal body 8 made in the form of a tubular cylinder with an open end at 9 which fits spigot-wise into the corresponding open end of the receiving duct 5, and is a sliding fit therein. The other end of the flame tube 8 is virtually closed by a dished end closure 10 which has minor perforations through it arranged as a ring at 11. The closure 10 also has an axial central hole provided with an inwardly extending mounting sleeve, through which the fuel injector 4 extends. Out side the closure 10 there is also provided a frusto conical screen 12 with a comparatively large central aperture. The space between the elements 10 and 12 serves as a distributing duct to lead primary air to the entrance 13 of air directing chutes 14 which are arranged as a ring or circumferential series equally spaced around the flame tube and terminating in openings in the wall of the flame tube, the direction of the chutes being tangential. The air entering chutes 14 when it reaches the interior or bore of the flame tube 8 constitutes a flow of vortex nature and it will be appreciated that this air mixing with the injected fuel burns in the region of the closed end of the flame tube; this combustion being relatively rich mixture combustion which is self-sustaining in all intended operational conditions is the primary combustion. The fact that it is self-sustaining appears to be due largely to the fact that the vorticity produces a reversal of flow or reversed core whereby a certain amount of flame is always sustained in the region of fuel injection. Beyond the region of primary combustion openings are provided in the flame tube wall for the introduction of sec-

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ondary air. Some of these simply constitute rings of plain holes 15 but other openings 16 and 17 are associated with air directing chutes 16A, 17A. The openings 16 are arranged in a ring and it has been found successful to arrange these with an opposite rotational direction to the chutes 14. The chutes 17A again arranged as a ring and axially spaced from the chutes 16A are again oppositely handed, that is to say they are of the same hand as the chutes 14. The last openings in the downstream direction are somewhat elongated holes 18 this shape having been found most suitable for the introduction of tertiary air in this region.

The flame tube of which the open end 9 is supported against all movement except axial by its sliding fit, is supported towards its closed end by various means which may be used together or alternatively. In some cases it may be supported by and located with respect to the fuel injection 4 or any tubular fuel injector mounting such as 4A. Again it may be supported by an igniter plug exemplified at 19 or in the case of a combustion chamber not having such a plug a dummy plug occupying the place of an igniter plug, and further it may be supported by a tubular element 20 which constitutes a branch connection between the interior of the flame tube 8 and a like adjacent flame tube in an adjacent combustion chamber. As is apparent the branch connection 20 lies within the branch duct 7 and may be supported therein by a perforated plate 21 interposed in an assembly joint of the duct 7.

The general form of the chutes is illustrated by Fig. 3 in which it can be seen that the air passage of a chute is convergent in the direction of flow and that the structure of the chute lies mainly external to the bore of the flame tube the only internal projection being so inclined to the direction of whirl of the gases within the flame tube and so adequately cooled by the air flow in the chute that the structure is not susceptible to damage due to the combustion nor is it such as to promote any substantial amount of turbulence within the bore. The chutes at 14 only differ from the form represented in Fig. 3 by having the air entrance to the chute somewhat differently disposed as can be seen most clearly at 13 in Fig. 2.

In the construction described it can be seen that the flame tube as a whole can be mounted within the combustion chamber 1 prior to final assembly and sufficiently supported therein for the combustion chamber with flame tube complete to be assembled to the other parts. In general so far as the flame tube itself is concerned the closed end is regarded as the upstream end and the open end 9 the downstream end.

I claim:

1. In combustion apparatus for the combustion of fuel in a combustion supporting gas supplied as a high velocity stream, and of the kind comprising a flame tube which is open at its downstream end for emission of combustion products and is provided with swirl inlets at its upstream end constituting main primary combustion supporting gas entries from said stream and with additional inlets downstream of said primary entries constituting secondary combustion supporting gas entries, in combination with a fuel injector which enters the upstream end of said flame tube along the axis of the tube, and which accordingly directs the fuel into the core of reverse flow which will be formed by the primary combustion supporting gas entering by said swirl inlets and swirling around the axis of the tube, the improve-

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ment that said flame tube is made up of a peripheral wall and an upstream end closure wall and said swirl inlets are ports formed in said peripheral wall, adjacent to said end closure wall and around said fuel injector, and are shaped to direct the air into the flame tube substantially tangentially on to the inner surface of the said peripheral wall.

2. Combustion apparatus according to claim 1 wherein said inlets for secondary combustion supporting gas are also located to direct the combustion supporting gas inward substantially tangentially to the periphery of said tube.

3. Combustion apparatus according to claim 2 wherein the said inlets for primary combustion supporting gas are located to direct said primary combustion supporting gas to swirl around the axis of the tube in one sense and the inlets for secondary combustion supporting gas are located to direct said secondary combustion supporting gas to swirl in the opposite sense around the axis of said tube.

4. Combustion apparatus according to claim 3 in which there are inlets downstream of the inlets for secondary combustion supporting gas, said

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downstream inlets being located to direct additional secondary combustion supporting gas to swirl in the same sense as the primary air.

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